

**UNIT-I**  
**PARTIAL DIFFERENTIAL EQUATIONS**  
**PART A**

**1. Form the partial differential equation by eliminating the arbitrary constants a and b from**

$$z = (x + a)^2 (y + b)^2 \quad \text{(AU - N/D - 2018)}$$

$$p = 2x(y + b)^2 \Rightarrow p/2x = (y + b)^2 \quad \text{----- (1)}$$

$$q = (x + a)^2 2y \Rightarrow q/2y = (x + a)^2 \quad \text{----- (2)}$$

From (1) and (2), eliminate a and b

$$z = pq/4xy \Rightarrow 4xyz = pq.$$

**2. Form a PDE by eliminating the arbitrary constants 'a' and 'b' from  $z = ax^2 + by^2$ .**

Given  $z = ax^2 + by^2$  (AU - A/M - 2017)

$$p = 2ax \Rightarrow \frac{p}{2} = ax \quad \text{----- (1)}$$

$$q = 2by \Rightarrow \frac{q}{2} = by \quad \text{----- (2)}$$

From (1) and (2), eliminate a and b

$$z = \frac{px}{2} + \frac{qy}{2}$$

$$2z = px + qy.$$

**3. Form the partial differential equation from  $(x-a)^2 + (y-b)^2 + z = 1$ , by eliminating a and b.**

Partial differentiation w.r.to x and y gives

(AU - M/J - 2013)-2

$$2(x-a) + 2zp = 0 ; (x-a) = -pz$$

$$2(y-b) + 2zq = 0 ; (y-b) = -qz$$

Using these in the given equation we get,

$$p^2z^2 + q^2z^2 + z = 1.$$

**4. Form the p.d.e from  $z = ax^3 + by^3$**

(AU - M/J - 2014)-2

$$z = ax^3 + by^3 \quad \text{.....(1)}$$

$$\frac{\partial z}{\partial x} = 3ax^2 ; \quad \frac{\partial z}{\partial y} = 3ay^2 \quad \text{ie) } p = 3ax^2 \quad q = 3ay^2$$

$$\text{ie) } \frac{p}{3x^2} = a \quad \frac{q}{3y^2} = b$$

$$(1) \Rightarrow z = \frac{px}{3} + \frac{qy}{3} \quad \text{ie) } 3z = px + qy.$$

**5. Find the PDE of all spheres whose centre lie on  $x=y=z$ .**

(AU - N/D - 2016)-3

General equation of the sphere is

$$(x - a)^2 + (y - b)^2 + (z - c)^2 = r^2$$

Here centre is (a, b, c) and radius r. Centre lies on  $x = y = z$ . i.e  $a = b = c$ .

$$\text{Equation of the sphere is } (x - a)^2 + (y - b)^2 + (z - c)^2 = r^2 \quad \text{-----(1)}$$

$$\text{Diff. w.r.to x partially, } 2(x-a) + 2(z-a) \frac{\partial z}{\partial x} = 0 ; (x-a) + (z-a) p = 0 \quad \text{----(2)}$$

$$\text{Diff. w.r.to y partially, } 2(y-a) + 2(z-a) \frac{\partial z}{\partial y} = 0 ; (y-a) + (z-a) q = 0 \quad \text{----(3)}$$

$$(2) \Rightarrow x - a + zp - ap = 0 ; x + zp = a + ap ; x + zp = a(1+p) \quad \text{----- (4)}$$

$$(3) \Rightarrow y - a + zq - aq = 0 ; y + zq = a + aq ; y + zq = a(1+q) \quad \text{----- (5)}$$

$$(4) / (5) \Rightarrow x + xq + zp + zpq = y + yp + zq + zpq$$

$$x + xq + zp - y - yp - zq = 0 ; x - y + (x - z)q + (z - y)p = 0$$

$$x - y = (z - x)q + (y - z)p ; (z - x)q + (y - z)p = x - y.$$

**6. Form the partial differential equation by eliminating the arbitrary constants a and b from**

$$\log(az-1) = x+ay+b$$

(AU - A/M - 2015)

$$\text{Given } \log(az-1) = x+ay+b \text{ -----(1)}$$

$$\text{Differentiating w.r.t } x : \frac{1}{az-1} ap = 1 \text{ -----(2)}$$

$$\text{Differentiating w.r.t } y : \frac{1}{az-1} aq = a \text{ -----(3)}$$

$$\text{From (2) : } a = \frac{1}{z-p} \text{ -----(4)}$$

$$\text{From (3) : } q = az-1 \text{ ----- (5)}$$

Solving (4) and (5) and eliminate 'a'.

$$p(q+1) = zq$$

This is the required PDE.

**7. Form a PDE by eliminating the arbitrary function f from  $z = e^{ay} f(x+by)$**  (AU - A/M - 2017)

$$z = e^{ay} f(x+by)$$

$$p = \frac{\partial z}{\partial x} = e^{ay} f'(x+by) \cdot 1$$

$$q = \frac{\partial z}{\partial y} = e^{ay} f'(x+by) \cdot b + f(x+by) e^{ay} \cdot a = e^{ay} \frac{p}{e^{ay}} b + f(x+by) e^{ay} \cdot a$$

$$q = pb + f(x+by) e^{ay} \cdot a.$$

$$\frac{q - pb}{ae^{ay}} = f(x+by) = \frac{z}{e^{ay}}$$

$q - pb = a$  is the required PDE.

**8. Form the p.d.e by eliminating the arbitrary function f from  $z = f(y/x)$ .** (AU - N/D - 2012)-2

$$\text{Given: } z = f\left(\frac{y}{x}\right) \text{ ----- (1)}$$

$$\text{Diff. (1) p.w.r.to } x \text{ we get } \frac{\partial z}{\partial x} = p = f'\left(\frac{y}{x}\right) \left(-\frac{y}{x^2}\right) \text{ ----- (2)}$$

$$\text{Diff. (1) p.w.r.to } y \text{ we get } \frac{\partial z}{\partial y} = q = f'\left(\frac{y}{x}\right) \left(\frac{1}{x}\right) \text{ ----- (3)}$$

$$\frac{p}{q} = \left(-\frac{y}{x^2}\right) \left(\frac{1}{x}\right) = \left(-\frac{y}{x}\right) ; xp + yq = 0 \text{ is the required p.d.e.}$$

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**9. Form the p.d.e by eliminating the function f from  $z = f(x^2 - y^2)$**  (AU - N/D - 2017)

$$\text{Given } z = f(x^2 - y^2)$$

$$\text{Differentiation w.r.to } x : p = f'(x^2 - y^2) \cdot 2x \text{ -----(1)}$$

$$\text{Differentiation w.r.to } y : q = f'(x^2 - y^2) \cdot -2y \text{ -----(2)}$$

Eliminating f from (1) and (2)

$$\frac{(1)}{(2)} \Rightarrow \frac{p}{q} = \frac{-x}{y}$$

$px - qy = 0$ . This is the required p.d.e.

**10. Form the p.d.e by eliminating the arbitrary function  $f(x^2 - y^2, z) = 0$ .** (AU - N/D - 2014)

$$\text{Given } x^2 - y^2 = f(z)$$

$$\text{Partially differentiating w.r.to } x, 2x = f'(z)p \text{ -----(1)}$$

$$\text{Partially differentiating w.r.to } y, -2y = f'(z)q \text{ -----(2)}$$

(1)/(2) implies that  $p/q = -x/y$

$$py = -qx$$

$qx + py = 0$ . This is the required p.d.e.

**11. Form the p.d.e by eliminating the arbitrary function from  $f(x^2 + y^2, z - xy) = 0$ .**

$$\text{Given } x^2 + y^2 = f(z - xy)$$

(AU - M/J - 2016)

Partially differentiating w.r.to x,  $2x = f'(z-xy)(p-y)$ -----(1)

Partially differentiating w.r.to y,  $2y = f'(z-xy)(q-x)$ -----(2)

(1)/(2) implies that  $x/y = (p-y)/(q-x)$

$qx-x^2 = py-y^2$  This implies that  $x^2+y^2 = qx- py$ . This is the required p.d.e.

**12. Find the complete integral of  $p+q = 1$ .**

**(AU - N/D - 2014)**

Given  $p+q = 1$ -----(1)

Let  $z = ax+by+c$ -----(2)

$$\frac{\partial z}{\partial x} = p = a \text{ and } \frac{\partial z}{\partial y} = q = b \quad \text{-----(3)}$$

Substitute equation (3) in equation (1), we get  $a+b = 1$

That is  $b = 1 - a$  -----(4)

Substitute equation (4) in equation (2), we get  $z = ax + (1-a)y + c$  is the complete integral.

**13. Find the complete solution of the partial differential equation  $p^3-q^3 = 0$ .** (AU - A/M - 2016)

This equation is of the form  $F(p, q) = 0$

Hence the trial solution is  $z = ax+by+c$

$p = a$  and  $q = b$

Therefore  $a^3 - b^3 = 0$ .

**14. Find the complete integral of  $\sqrt{p} + \sqrt{q} = 1$**

**(AU - N/D - 2017)**

$$\sqrt{p} + \sqrt{q} = 1 \quad \text{--- (1)}$$

This is of the type  $F(p, q) = 0$

The trial solution is  $z = ax+by+c$

Sub.  $p = a$  and  $q = b$  in (1)

Therefore (1) implies  $b = (1 - \sqrt{a})^2$

Then,  $z = ax + (1 - \sqrt{a})^2 y + c$  which is Complete Integral.

**15. Find the complete integral of the PDE:  $z = px + qy + \sqrt{pq}$**

**(AU - A/M - 2018)**

This is of the form  $z = px + qy + f(p, q)$

Hence the complete integral is  $z = ax + by + \sqrt{ab}$

**16. Find the complete integral of  $\frac{z}{pq} = \frac{x}{q} + \frac{y}{p} + \sqrt{pq}$**

**(AU - N/D - 2016)**

This is of the form  $z = px + qy + f(p, q)$

Given  $z = px+qy+(pq)^{3/2}$

Hence the complete integral is  $z = ax+by+(ab)^{3/2}$ .

**17. Find the complete integral of  $p+q = x+y$**

**(AU - N/D - 2018)-3**

Let  $p+q = x+y = k$

$p-x = k, \quad y-q = k$

$p = k+x, \quad q = y-k$

$$z = \int p dx + \int q dy = \int (k+x) dx + \int (y-k) dy = kx + \frac{x^2}{2} + \frac{y^2}{2} - ky + c.$$

**18. Find the complete solution of  $q = 2px$ .**

**(AU - A/M - 2015)**

$q = 2px = a$  (say)

$q = a; \quad p = a/2x$

$dz = (a/2x) dx + a dy$

Integrating,  $z = (a/2) \log x + ay + b$

This is the complete solution.

**19. Find the general solution of the Lagrange linear equation given by  $pyz+qzx = xy$ .**

**(AU - N/D - 2013)**

This is of the form :  $Pp+Qq= R$

$$\text{Auxiliary equation is : } \frac{dx}{P} = \frac{dy}{Q} = \frac{dz}{R} \Rightarrow \frac{dx}{yz} = \frac{dy}{zx} = \frac{dz}{xy}$$

Group 1:  $\frac{dx}{yz} = \frac{dy}{zx}$

$xdx = ydy$

Integrating,  $x^2/2 = y^2/2 + c_1^2/2$

$x^2 - y^2 = u$

Group 2:  $\frac{dx}{yz} = \frac{dz}{xy}$

$xdx = zdz$

Integrating,  $x^2 - z^2 = v$

Therefore the solution is  $\varphi(u, v) = 0$

$\Phi(x^2 - y^2, x^2 - z^2) = 0.$

**20. Solve  $(D^4 - D'^4)z = 0.$**

**(AU - M/J - 2014)**

A.E is  $m^4 - 1^4 = 0$

$(m^2)^2 - (1^2)^2 = 0$  implies that  $(m^2 + 1)(m^2 - 1) = 0$

$m = 1, -1$  and  $m = i, -i$

$z = f_1(y+x) + f_2(y-x) + f_3(y+ix) + f_4(y-ix).$

**21. Solve  $(D^3 - 3DD'^2 + 2D'^3)z = 0.$**

**(AU - A/M - 2018)-3**

A.E is  $m^3 - 3m + 2 = 0$

$m = 1, 1, -2$

The solution is  $z = f_1(y-2x) + f_2(y+x) + xf_3(y+x)$

**22. Solve  $(D^3 - D^2D' - 8DD'^2 + 12D'^3)z = 0$**

The A.E is  $m^3 - m^2 - 8m + 12 = 0$

$m = 2, 2, -3$

The Solution is,  $z = f_1(y + 2x) + xf_2(y + 2x) - f_3(y - 3x)$

**23. Solve  $(D^2 - DD' + D' - 1)z = 0$**

**(AU - N/D - 2018)**

The given equation can be written as

$(D-1)(D-D'+1)z = 0$

Here  $m_1 = 0, m_2 = 1, c_1 = 1, c_2 = -1$

$z = C.F = e^x f_1(y) + e^{-x} f_2(y+x)$

**24. Solve  $\frac{\partial^2 z}{\partial x^2} - \frac{\partial^2 z}{\partial x \partial y} + \frac{\partial z}{\partial x} = 0$**

**(AU - N/D -**

**2013)**

$(D^2 - DD' + D)z = 0$

$D(D-D'+1)z = 0$  that implies  $(D - m_1 D' - c_1)(D - D' + 1)z = 0$

$m_1 = 0, c_1 = 0, m_2 = 1, c_2 = -1$

The solution is  $z = e^{0x} f_1(y) + e^{-x} f_2(y+x)$

**25. Solve  $(D + D' - 1)(D - 2D' + 3)z = 0$**

**(AU - N/D - 2015)**

Here  $c_1 = 1, c_2 = -3, m_1 = -1, m_2 = 2$

C.F =  $e^x f_1(y-x) + e^{-3x} f_2(y+2x)$

**PART - B**

1. a. Form the PDE by eliminating the arbitrary function  $\varphi$  from the relation

$\Phi(x^2 + y^2 + z^2, xyz) = 0.$

**(AU - M/J - 2016)-2-(8)**

b. Find the partial differential equations of all planes which are at a constant distance 'k' units from the origin.

**(AU - A/M - 2016)(8)**

2. a. Form the PDE by eliminating the arbitrary function 'f' and 'g' from  $z = f(x^3 + 2y) + g(x^3 - 2y).$

**(AU - N/D - 2018)(8)**

b. Form the PDE by eliminating the arbitrary functions 'f' and 'φ' from the relation

$z = x f(y/x) + y \phi(x).$

**(AU - A/M - 2016)(8)**

3. a. Form the partial differential equation by eliminating arbitrary functions from

$z = y^2 + 2f(1/x + \log y).$

**(AU - M/J - 2014)(8)**

b. Find the complete solution of  $9(p^2 z + q^2) = 4.$

**(AU - N/D - 2014)-2-(8)**

4. a. Find the singular solution of the p.d.e.  $z = px + qy + \sqrt{1 + p^2 + q^2}$

**(AU - N/D - 2015)-4(8)**

b. Solve:  $z = px + qy + p^2 q^2.$

**(AU - N/D - 2018)(8)**

5. a. Find the general solution of  $z = px+qy+p^2+pq+q^2$ . (AU - A/M - 2018)-3-(8)  
 b. Find the singular solution of  $z = px+qy+p^2-q^2$ . (AU - A/M - 2017)-4-(8)
6. a. Solve  $p^2x^2+q^2y^2 = z^2$ . (AU - N/D - 2014)-2-(8)  
 b. Obtain the complete solution of  $p^2+x^2y^2q^2 = x^2z^2$ . (AU - M/J - 2015)(8)
7. a. Find the complete solution of  $z^2(p^2+q^2) = x^2+y^2$ . (AU - A/M - 2015)(8)  
 b. Solve  $x(z^2-y^2)p + y(x^2-z^2)q = z(y^2-x^2)$ . (AU - M/J - 2018)-4-(8)
8. a. Find the general solution of  $(z^2-2yz-y^2)p+(xy+zx)q = xy-zx$ . (AU - A/M - 2017)(8)  
 b. Solve  $x(y^2+z)p-y(x^2+z)q = z(x^2-y^2)$ . (AU - N/D - 2018)(8)
9. a. Solve  $(x^2-yz)p + (y^2-zx)q = (z^2-xy)$ . (AU - A/M - 2016)-3-(8)  
 b. Solve  $(x-2z)p + (2z - y)q = y-x$ . (AU - A/M - 2017)(8)
10. a. Solve  $x(y-z)p+y(z-x)q = z(x-y)$ . (AU - A/M - 2018)-3-(8)  
 b. Find the general solution of  $(D^2-6DD'+5D'^2)z = e^x\sin hy+xy$ . (AU - N/D - 2018)(8)
11. a. Solve  $(D^3-2D^2D')z = 2e^{2x}+3x^2y$ . (AU - A/M - 2016)(8)  
 b. Solve  $(D^2-5DD'+6D'^2)z = y\sin x$ . (AU - N/D - 2017)(8)
12. a. Solve  $(D^2+DD'-6D'^2)z = y\cos x$ . (OR)  $(r+s-6t) = y \cos x$ . (AU - A/M - 2018)-3-(8)  
 b. Find the general solution of  $(D^2+2DD'+D'^2)z = xy+e^{x-y}$ . (AU - N/D - 2017)(8)
13. a. Find the general solution of  $(D^2+2DD'+D'^2)z = 2(y-x) + \sin(x-y)$ . (AU - N/D - 2018)(8)  
 b. Find the general solution of  $(D^2+2DD'+D'^2)z = x^2y+e^{x-y}$ . (AU - A/M - 2017)(8)
14. a. Solve:  $(D^2-3DD'+2D'^2)z = (2+4x)e^{x+2y}$ . (AU - N/D - 2015)-2-(8)  
 b. Find the general solution of  $(D^2-3DD'+2D'^2+2D-2D')z = \sin(2x+y)$ . (AU - A/M - 2017)(8)
15. a. Solve  $(D^2+2DD'+D'^2-2D-2D')z = \sin(x+2y)$ . (AU - N/D - 2015)(8)  
 b. Solve  $(D^2+4DD'-5D'^2)z = \sin(x-2y)+e^{2x-y}$ . (AU - N/D - 2017)(8)

**UNIT - II**  
**FOURIER SERIES**  
**PART A**

**1. State Dirichlet's conditions for a given function to expand in Fourier series.**

(AU - N/D - 2017)-8

Let  $f(x)$  be defined in the interval  $c < x < c+2\pi$  with period  $2\pi$  and satisfy the following conditions:

- (1)  $f(x)$  is single valued.
- (2) It has a finite number of discontinuities in a period of  $2\pi$ .
- (3) It has a finite number of maxima and minima in a given period.

$$(4) \int_c^{c+2\pi} |f(x)| dx \text{ is convergent.}$$

These conditions are Dirichlet's conditions.

**2. State the sufficient conditions for existence of Fourier series.**

(AU - A/M - 2017)-2

The sufficient conditions for existence of Fourier series is given by

- (i)  $f(x)$  is defined and single valued except possibly at a finite number of points in  $(-\pi, \pi)$ .
- (ii)  $f(x)$  is periodic with period  $2\pi$ .
- (iii)  $f(x)$  and  $f'(x)$  are piecewise continuous in  $(-\pi, \pi)$ , then the Fourier series of  $f(x)$  converges to
  - (a)  $f(x)$  if  $x$  is a point of continuity
  - (b)  $\frac{f(x+0) + f(x-0)}{2}$  if  $x$  is a point of discontinuity.

**3. Find the value of the Fourier series of  $f(x) = 0$  in  $(-c, 0)$   
 $= 1$  in  $(0, c)$ ,**

**at the point of discontinuity  $x = 0$ .**

(AU - M/J - 2016)

The value of the Fourier series is  $f(x) = \frac{f(0+) + f(0-)}{2} = \frac{0+1}{2} = \frac{1}{2}$ .

**4. If  $f(x)$  is discontinuous at a point  $x=a$ , then what does its Fourier series represent at that point.**

(AU - N/D - 2017)

If  $f(x)$  is discontinuous at a point  $x = a$ , then at that point  $f(x)$  cannot be expanded as Fourier series.

**5. Find the constant term in the Fourier series corresponding to  $f(x) = \cos^2 x$  expressed in the interval  $(-\pi, \pi)$ .**

(AU - M/J - 2012)

$$\text{Given } f(x) = \cos^2 x = \frac{1 + \cos 2x}{2}$$

$$\text{We know that } f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos nx + \sum_{n=1}^{\infty} b_n \sin nx$$

$$a_0 = \frac{1}{\pi} \int_{-\pi}^{\pi} \cos^2 x dx = \frac{2}{\pi} \int_0^{\pi} \cos^2 x dx = \frac{2}{\pi} \int_0^{\pi} \frac{1 + \cos 2x}{2} dx = \frac{1}{\pi} \int_0^{\pi} (1 + \cos 2x) dx = 1$$

$$\text{Therefore the Constant term} = \frac{a_0}{2} = \frac{1}{2}.$$

**6. Write down the form of the Fourier series of an odd function in  $(-l, l)$  and associated Euler's formulas for Fourier coefficients.** (AU - N/D - 2013)

$$f(x) = \sum_{n=1}^{\infty} b_n \sin \frac{n\pi x}{l}$$

$$b_n = \frac{1}{l} \int_l f(x) \sin \frac{n\pi x}{l} dx.$$

**7. Find the co-efficient  $b_n$  of the Fourier series for the function  $f(x) = x \sin x$  in  $(-2, 2)$ .** (AU - N/D - 2012)

$$f(x) = x \sin x$$

$$f(-x) = -x \sin(-x) = x \sin x = f(x)$$

Therefore  $f(x)$  is an even function.

Therefore  $b_n = 0$ .

**8. Find  $a_0$  in the expansion of  $f(x) = e^x$  as a Fourier series in  $0 < x < 2\pi$**  (AU - N/D - 2013)

$$a_0 = \frac{1}{\pi} \int_0^{2\pi} f(x) dx = \frac{1}{\pi} \int_0^{2\pi} e^x dx = \frac{1}{\pi} [e^x]_0^{2\pi} = \frac{1}{\pi} [e^{2\pi} - 1].$$

**9. Determine the Fourier series for the function  $f(x) = x$  in  $-\pi \leq x \leq \pi$ .** (AU - N/D - 2015)

$$f(x) = x$$

$$f(-x) = -x = -f(x)$$

Therefore  $f(x)$  is an odd function. Therefore  $a_0 = a_n = 0$ .

$$b_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin nx dx = \frac{1}{\pi} \int_{-\pi}^{\pi} x \sin nx dx$$

$$u = x \quad v = \sin nx$$

$$u' = 1 \quad v_1 = -\cos nx / n$$

$$u'' = 0 \quad v_2 = -\sin nx / n^2$$

$$b_n = \frac{1}{\pi} \left[ \frac{-x \cos nx}{n} + \frac{\sin nx}{n^2} \right]_{-\pi}^{\pi} = \frac{1}{\pi} \left[ \frac{-2\pi(-1)^n}{n} \right] = \frac{-2(-1)^n}{n}.$$

$$f(x) = \sum_{n=1}^{\infty} \frac{-2(-1)^n}{n} \sin nx.$$

**10. Find the value of  $b_n$  in the Fourier series expansion of  $f(x) = x + \pi$  in  $(-\pi, 0)$   
 $= -x + \pi$  in  $(0, \pi)$**  (AU - M/J - 2016)

$$\text{Let } f(x) = \phi_1(x), (-\pi, 0)$$

$$= \phi_2(x), (0, \pi)$$

$$\phi_1(x) = x + \pi, \quad \phi_2(x) = -x + \pi \quad \text{and} \quad \phi_1(-x) = -x + \pi = \phi_2(x)$$

$f(x)$  is an even function.

Therefore  $b_n = 0$ .

**11. Find  $b_n$  in the expansion of  $f(x) = x^2$  as a Fourier series in  $-\pi < x < \pi$ .** (AU - N/D - 2017)

$$f(-x) = (-x)^2 = x^2 = f(x).$$

Therefore  $f(x)$  is an even function.

$$\therefore b_n = 0.$$

**12. Find the sum of the Fourier series for  $f(x) = x + x^2$  in  $-\pi < x < \pi$  at  $x = \pi$ .** (AU - A/M - 2017)

$$x = \pi \text{ is an end point. Sum of Fourier series} = \frac{f(\pi) + f(-\pi)}{2} = \frac{\pi + \pi^2 - \pi + \pi^2}{2} = \frac{2\pi^2}{2} = \pi^2.$$

13. If  $(\pi - x)^2 = \frac{\pi^2}{3} + 4 \sum_{n=1}^{\infty} \frac{\cos nx}{n^2}$  in  $0 < x < 2\pi$ , then deduce that the value of  $\sum_{n=1}^{\infty} \frac{1}{n^2}$ . (AU - N/D - 2014)

$$\text{Put } x = 0, \pi^2 - \frac{\pi^2}{3} = 4 \sum_{n=1}^{\infty} \frac{1}{n^2} \Rightarrow \frac{2\pi^2}{3} = \sum_{n=1}^{\infty} \frac{1}{n^2} \Rightarrow \frac{\pi^2}{6} = \sum_{n=1}^{\infty} \frac{1}{n^2}$$

14. Expand  $f(x) = 1$  as a half range sine series in the interval  $(0, \pi)$  (or) Find the sine series of function  $f(x) = 1, 0 \leq x \leq \pi$  (AU - A/M - 2015)-3

The half range sine series formula is  $f(x) = \sum_{n=1}^{\infty} b_n \sin nx$

$$\text{Where } b_n = \frac{2}{\pi} \int_0^{\pi} f(x) \sin nx dx = \frac{2}{\pi} \int_0^{\pi} \sin nx dx = \frac{2}{\pi} \left[ \frac{-\cos nx}{n} \right]_0^{\pi} = \frac{2}{\pi} \left[ \frac{-(-1)^n - 1}{n} \right]$$

$$= \frac{2}{n\pi} [1 - (-1)^n] = \frac{4}{n\pi} \text{ if } n \text{ is odd,}$$

$$f(x) = \sum_{n \text{ is odd}} \frac{4}{n\pi} \sin nx$$

15. Write the complex form of the Fourier series in the interval  $c < x < c+2l$  (AU - N/D - 2018)

The series for  $f(x)$  defined in the interval  $(C, C+2l)$  satisfying the Dirichlet's Conditions can be put in the complex term as

$$f(x) = \sum_{-\infty}^{\infty} C_n e^{\frac{in\pi x}{l}} \text{ where } C_n = \frac{1}{2l} \int_c^{c+2l} f(x) e^{-\frac{in\pi x}{l}} dx$$

16. Write the complex form of the Fourier series of  $f(x)$ . (AU - N/D - 2017)-3

The series for  $f(x)$  defined in the interval  $(C, C+2\pi)$  satisfying the Dirichlet's Conditions can be put in the complex term as

$$f(x) = \sum_{-\infty}^{\infty} C_n e^{inx} \text{ where } C_n = \frac{1}{2\pi} \int_C^{C+2\pi} f(x) e^{-inx} dx$$

17. Find the complex form of Fourier series for  $f(x) = e^x$ ;  $-\pi < x < \pi$  and  $f(x+2\pi) = f(x)$

(AU - N/D - 2017)

$$\text{We know that } f(x) = \sum_{n=-\infty}^{\infty} C_n e^{inx}$$

$$\text{Where } C_n = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^x e^{-inx} dx = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{-(in-1)x} dx = \frac{1}{2\pi} \left[ \frac{e^{-(in-1)x}}{-(in-1)} \right]_{-\pi}^{\pi} = \frac{(-1)^n (in+1)}{\pi^2 (n^2+1)} \sinh \pi.$$

18. Write the complex form of the Fourier series of  $f(x)$  defined in  $-l < x < l$  (AU - N/D - 2017)-3

The series for  $f(x)$  defined in the interval  $(-l, l)$  satisfying the Dirichlet's Conditions can be put in the complex term as

$$f(x) = \sum_{n=-\infty}^{\infty} c_n e^{\frac{in\pi x}{l}} \text{ where } c_n = \frac{1}{2l} \int_{-l}^l f(x) e^{-\frac{in\pi x}{l}} dx.$$

19. State Parseval's Theorem on Fourier series. (AU - A/M - 2017)-3

If  $f(x)$  is expressed as a Fourier series in the interval  $(a, b)$ , then

$$\bar{y}^2 = \frac{a_0^2}{4} + \frac{1}{2} \sum_1^{\infty} (a_n^2 + b_n^2) \text{ Where } a_0, a_n, b_n \text{ are the Fourier constants and } \bar{y} \text{ is the R.M.S. value.}$$

20. Define root mean square value of a function  $f(x)$  in  $a < x < b$ . (AU - A/M - 2018)-4

Let  $f(x)$  be a function defined in an interval  $(a, b)$  then,

$$\text{R.M.S} = \sqrt{\frac{\int_a^b [f(x)]^2 dx}{b-a}} \text{ is called the root mean square.}$$

**21. Find the root mean square value of  $f(x) = x^2$  in the interval  $(0, \pi)$ . (AU - A/M - 2017)**

$$\text{RMS value} = \sqrt{\frac{\int_0^\pi x^4 dx}{\sqrt{\pi}}} = \frac{\pi^2}{\sqrt{5}}.$$

**22. Find the root mean square value of  $f(x) = x^2$  in the interval  $(-\pi, \pi)$ . (AU - N/D - 2018)**

$$\text{R.M.S} = \sqrt{\frac{\int_a^b [f(x)]^2 dx}{b-a}} = \frac{2\pi^2}{\sqrt{5}}.$$

**23. Find the root mean square value of the function  $f(x) = x$  in the interval  $(0, l)$ . (AU - N/D - 2017)-3**

$$\text{R.M.S} = \sqrt{\frac{\int_a^b [f(x)]^2 dx}{b-a}} \text{ in the interval } (a, b) = \sqrt{\frac{\int_0^l x^2 dx}{l-0}}$$

$$\text{Here } a = 0 ; b = l \text{ implies that } \sqrt{\frac{l^2}{3}} = \frac{l}{\sqrt{3}}$$

**24. Find the R.M.S value of  $f(x) = x(l-x)$  in  $0 \leq x \leq l$ . (AU - N/D - 2015)**

RMS value in  $(0, l)$  is

$$\frac{1}{l} \int_0^l [f(x)]^2 dx \quad \text{Here } l = 1$$

$$\frac{1}{l} \int_0^l x^2 (l-x)^2 dx = \frac{2}{l} \left[ \frac{l^2 x^3}{3} + \frac{x^5}{5} - \frac{2lx^4}{4} \right]_0^l = \frac{2}{l} \left[ \frac{l^5}{3} + \frac{l^5}{5} - \frac{l^5}{4} \right] = \frac{17l^4}{30}.$$

**25. What do you mean by Harmonic Analysis? (AU - M/J - 2013)-2**

When a function  $f(x)$  is given by its numerical values at  $q$  equally spaced points, the Process of determining the co-efficient of Fourier series representing  $f(x)$  using numerical integration is known as Harmonic Analysis.

### **PART-B**

1. a. Determine the Fourier series for the function  $f(x) = x \cos x$  in  $(0, 2\pi)$ . (AU - A/M - 2017)(8)

b. Find the Fourier series expansion of  $f(x) = x \sin x$  in  $0 < x < 2\pi$ . (AU - N/D - 2018)(8)

2. a. Find the Fourier series expansion of  $f(x) = 1$  for  $0 < x < \pi$   
 $= 2$  for  $\pi < x < 2\pi$ . (AU - N/D - 2013)(8)

b. Find the Fourier series expansion of the periodic function  $f(x)$  of the period  $2$  defined by  
 $f(x) = l-x, 0 < x \leq l$   
 $= 0, l < x \leq 2l$ , in  $(0, 2l)$ . (AU - N/D - 2017)(8)

3. a. Find the Fourier series of  $f(x) = x$  in  $-l < x < l$  and Hence deduce the value of  $\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \dots$   
(AU - N/D - 2018)-2-(8)

b. Find the Fourier series for the function  $f(x) = |\cos x|$  in  $-\pi < x < \pi$ . (AU - A/M - 2016)(8)

4. a. Determine the Fourier series for the function  $f(x) = x^2$  of period  $2\pi$  in  $-\pi < x < \pi$ . Hence deduce the value of  $\sum_{n=1}^{\infty} \frac{1}{n^2}$  (AU - A/M - 2018)-2-

(8)  
b. Find the Fourier series expansion of  $f(x) = 1+x+x^2$  in the interval  $(-\pi, \pi)$  and hence deduce the

value of  $\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \dots$

(AU - N/D - 2018)

(8)

5. a. Find the Fourier series expansion the following periodic function of period 4

$f(x) = 2+x, -2 \leq x \leq 0$

$= 2-x, 0 < x \leq 2.$  Hence deduce that  $\frac{1}{1^2} + \frac{1}{3^2} + \frac{1}{5^2} + \dots \infty = \frac{\pi^2}{8}.$

(AU - A/M -

2015)(8)

b. Find the Fourier series for the function  $f(x) = |\sin x|$  over the interval  $(-\pi, \pi).$

(AU - A/M - 2015)(8)

6. a. Obtain the Fourier series for the function given by  $f(x) = \begin{cases} 1 + \frac{2x}{l} & \text{in } -l \leq x \leq 0 \\ 1 - \frac{2x}{l} & \text{in } 0 \leq x \leq l \end{cases}$

Hence deduce that  $\frac{1}{1^2} + \frac{1}{3^2} + \frac{1}{5^2} + \dots = \frac{\pi^2}{8}.$

(AU - N/D - 2014)-2-(8)

b. Expand  $f(x) = x+x^2$  as a Fourier series in  $(-\pi, \pi)$  and hence deduce the value of  $\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \dots$

(AU - N/D - 2017)(8)

7. a. Find the half range sine series of  $f(x) = x \cos \pi x$  in  $(0, 1).$

(AU - N/D - 2016)(8)

b. Find the half range sine series of  $f(x) = 4x-x^2$  in the interval  $(0, 4).$  Hence deduce the value of

the series  $\frac{1}{1^3} - \frac{1}{3^3} + \frac{1}{5^3} - \frac{1}{7^3} + \dots \infty$

(AU - N/D - 2014)

(8)

8. a. Find the half range sine series of  $f(x) = x, 0 < x < \pi/2$   
 $= \pi -x, \pi/2 < x < \pi.$

Hence deduce the sum of the series  $\sum_{n=1}^{\infty} \frac{1}{(2n-1)^2}.$

(AU - A/M - 2017)(8)

b. Find the half range cosine series for  $f(x) = x(\pi - x)$  in  $(0, \pi).$

(AU - A/M -

2018)(8)

9. a. Find the half range cosine series of  $f(x) = x$  in  $0 < x < \pi.$  Hence deduce the value of

$\frac{1}{1^2} + \frac{1}{3^2} + \frac{1}{5^2} + \dots \infty.$

(AU - N/D - 2017)-2-

(8)

b. Find the half range cosine series expansion of  $(x-1)^2$  in  $0 < x < 1.$

(AU - N/D - 2014)(8)

10. a. Find the Half range cosine series of  $f(x) = \sin x$  in  $(0, \pi)$

(AU - N/D - 2015)(8)

b. Expand  $f(x) = x, 0 < x < 1$

$= 2-x, 1 < x < 2$  as a series of cosine in the interval  $(0, 2).$

(AU - A/M - 2017)(8)

11. a. Find the complex form of the Fourier series  $f(x) = e^{-ax}$  in  $-\pi < x < \pi.$

(AU - A/M - 2017)-2-(8)

b. Find the complex form of Fourier series of the function  $f(x) = e^x$  in  $-\pi < x < \pi.$

(AU - M/J - 2016)(8)

12. a. Find the complex form of Fourier series of  $f(x) = \sin x$  in  $-\pi < x < \pi.$

(AU - A/M - 2014)-2-(8)

b. Find the complex form of Fourier series of the function  $f(x) = e^{-x}$  in  $(-1, 1).$

(AU - M/J - 2016)-2-(8)

13. a. Find the complex form of the Fourier series  $f(x) = e^{ax}$  in the interval  $-\pi < x < \pi,$  where 'a' is a

real constant. Hence deduce that  $\sum_{n=-\infty}^{\infty} \frac{(-1)^n}{a^2 + n^2} = \frac{\pi}{a \sinh a\pi}.$

(AU - N/D - 2015)(8)

b. Calculate the first three harmonic of Fourier series from the following data

x	0	$\frac{\pi}{3}$	$\frac{2\pi}{3}$	$\pi$	$\frac{4\pi}{3}$	$\frac{5\pi}{3}$	$2\pi$
y	1.0	1.4	1.9	1.7	1.5	1.2	1.0

(AU - A/M - 2018)-7-(8)

14. a. Obtain the constant term and the coefficient of the first sine and cosine terms in the Fourier

expansion of y as given in the following table:

(AU - A/M - 2017)-5-(8)

x	0	1	2	3	4	5
y	9	18	24	28	26	20

b. Compute of the Fourier series for f(x) from the table below

first two harmonic

x:	0	60°	120°	180°	240°	300°
y:	1.98	1.30	1.05	1.30	-0.88	-0.25

(AU - A/M - 2010)(8)

15. a. Compute the first four coefficients in the Fourier sine series of f(x) from the table

(AU - N/D - 2018)(8)

x	0°	30°	60°	90°	120°	150°	180°
y	0	5224	8097	7850	5499	2626	0

b. Find the Fourier cosine series up to third harmonic to represent the function given by the following table

(AU - N/D - 2015)-2-(8)

x	0	1	2	3	4	5
y	4	8	15	7	6	2

**UNIT -**

**III**

**APPLICATIONS OF PARTIAL DIFFERENTIAL EQUATIONS**

**PART-A**

1. Classify the differential equation  $3\frac{\partial^2 u}{\partial x^2} + 4\frac{\partial^2 u}{\partial x \partial y} + 6\frac{\partial^2 u}{\partial y^2} - 2\frac{\partial u}{\partial y} - u = 0$ . (AU - N/D - 2013)

A = 3, B = 4, C = 6

$B^2 - 4AC = 16 - 72 < 0$

Therefore, elliptic equation.

2. Classify the partial differential equation  $u_{xx} + u_{yy} = f(x, y)$ . (AU - M/J - 2016)

A = 1, B = 0, C = 1

$B^2 - 4AC = -4 < 0$

Elliptic equation.

3. Classify the PDE of  $u_{xy} = u_x u_y + xy$ . (AU - N/D - 2017)

Here B = 1, A = 0, C = 0

$B^2 - 4AC = 1 > 0$

∴ Given PDE is Hyperbolic equation.

4. Classify the partial differential equation  $(1-x^2)z_{xx} - 2xy z_{xy} + (1-y^2)z_{yy} + x z_x + 3x^2 y z_y - 2z = 0$ . (AU - A/M - 2015)-2

A = (1-x<sup>2</sup>), B = -2xy, C = (1-y<sup>2</sup>)

$B^2 - 4AC = 4x^2 y^2 - 4(1-x^2)(1-y^2) = 4x^2 y^2 - 4 + 4x^2 + 4y^2 - 4x^2 y^2 = 4x^2 + 4y^2 - 4$

x = y = 0,  $B^2 - 4AC = -4 < 0$ , Elliptic equation

x = y = positive,  $B^2 - 4AC = 4 > 0$ , Hyperbolic equation

x = y = negative,  $B^2 - 4AC = 4 > 0$ , Hyperbolic equation.

5. Find the nature of the p.d.e  $4u_{xx} + 4u_{xy} + u_{yy} + 2u_x - u_y = 0$

A = 4, B = 4, C = 1

$B^2 - 4AC = 0$

Therefore, Parabolic equation.

6. Use method of separation of variables, Solve  $\frac{\partial u}{\partial x} = 2\frac{\partial u}{\partial t} + u$ , where  $u(x, 0) = 6e^{-3x}$  (AU - A/M - 2017)

$$u = abe^{kx} e^{\frac{1}{2}(k-t)}$$

$$u(x, 0) = abe^{kx}$$

$$u(x, 0) = 6e^{-3x}$$

$$ab = 6, k = -3$$

$$\therefore u = 6e^{-(3x+2t)}$$

**7. Write down the three mathematically possible solutions of one dimensional wave equation. (AU - A/M - 2015)-5**

$$y(x, t) = (c_1 e^{px} + c_2 e^{-px})(c_3 e^{pat} + c_4 e^{-pat})$$

$$y(x, t) = (c_1 \cos kpx + c_2 \sin kpx)(c_3 \cos pat + c_4 \sin pat)$$

$$y(x, t) = (c_1 x + c_2)(c_3 t + c_4)$$

**8. What is the constant  $c^2$  in the wave equation  $u_{tt} = c^2 u_{xx}$ ? (AU - N/D - 2018)**

$$c^2 = \frac{T}{m} = \frac{\text{Tension}}{\text{mass / unit length of the string}}$$

**9. What is the basic difference between the solutions of one dimensional wave equation and one dimensional heat equation with respect to the time? (AU - N/D - 2017)-2**

Solution of the one dimensional wave equation is of periodic in nature. But solution of the One dimensional heat equation is not of periodic in nature.

**10. State the assumptions in deriving one-dimensional wave equation. (AU - N/D - 2017)-3**

(i) The motion takes place entirely in one plane i.e., xy plane.

(ii) Only transverse vibrations are considered. The horizontal displacement of the particles of the string is negligible.

(iii) The tension T is constant at all times and at all points of the deflected string.

(iv) T is considered to be so large compared with the weight of the string and hence the force of gravity is negligible.

(v) The effect of friction is negligible.

(vi) The string is perfectly flexible, i.e., it can transmit tension but not bending or shearing forces.

(vii) The slope of the deflection curve at all points and at all instants is so small that  $\sin \alpha$  can be replaced by  $\alpha$ , where  $\alpha$  is the inclination of the tangent to the deflection curve.

**11. Write down the diffusion problem in one-dimensional as a boundary value problem in two different forms. (AU - M/J - 2013)**

$$\frac{\partial u}{\partial t} = a^2 \frac{\partial^2 u}{\partial x^2} \text{ one dimensional heat flow}$$

Where  $a^2 = \frac{K}{s\rho}$  is known as diffusivity of the material of the bar.

$$\text{In the steady state } \frac{d^2 u}{dx^2} = 0.$$

**12. Write down one-dimensional heat equation and all possible solution for the same. (AU - A/M - 2018)-10**

$$u_t = \alpha^2 u_{xx}$$

$$u(x, t) = (A_1 e^{\lambda x} + B_1 e^{-\lambda x}) C_1 e^{\alpha^2 \lambda^2 t}$$

$$u(x, t) = (A_2 \cos \lambda x + B_2 \sin \lambda x) C_2 e^{-\alpha^2 \lambda^2 t}$$

$$u(x, t) = (A_3 x + B_3) C_3$$

**13. How many conditions are needed to solve the one dimensional heat equation? Totally three conditions needed. (AU - M/J - 2009)**

**14. State the suitable solution of the one dimensional heat equation  $\frac{\partial u}{\partial t} = a^2 \frac{\partial^2 u}{\partial x^2}$**

The suitable solution of the given equation is  $u(x, t) = (A \cos px + B \sin px) e^{-c^2 p^2 t}$  (AU - A/M - 2017)

**15. State the governing equation for one dimensional heat equation and necessary conditions to solve the problem.**

The one dimensional heat equation is  $\frac{\partial u}{\partial t} = a^2 \frac{\partial^2 u}{\partial x^2}$  where  $u(x,t)$  is the temperature at time  $t$  at a point distant  $x$  from the left end of the rod. The boundary conditions are

- a)  $u(0, t) = k_1^\circ\text{C}$  for all  $t \geq 0$
- b)  $u(l, t) = k_2^\circ\text{C}$  for all  $t \geq 0$
- c)  $u(x, 0) = f(x)$ ,  $0 < x < l$

**16. A rod of 30cm long has its ends A and B kept at  $20^\circ\text{C}$  and  $80^\circ\text{C}$  respectively until steady state conditions prevail. Find the steady state temperature in the rod. (AU - A/M - 2015)-2**

The steady state equation of the one dimensional heat flow is  $\frac{d^2u}{dx^2} = 0$  .....(1)

The general Solution of (1) is  $u(x) = ax+b$  .....(2)

The boundary conditions are  $u(0) = 30$ , and  $u(30) = 80$

Put  $x = 0$  in (2),  $u(0) = b = 20$

Put  $x = 30$  in (2),  $u(30) = 30a+b = 80$

$30a+b = 80$  that implies  $30a = 60$  implies that  $a = 2$  and equation (2) implies  $u(x) = 2x+20$ .

**17. A rod of length 20cm whose one end is kept at  $30^\circ\text{C}$  and the other end is kept at  $70^\circ\text{C}$  is maintained so until steady state prevails. Find the steady state temperature.**

The steady state equation of one dimensional heat flow is  $\frac{d^2u}{dx^2} = 0$  .....(1) (AU - N/D - 2014)-2

The general Solution of (1) is  $u(x) = ax+b$  .....(2)

The boundary conditions are  $u(0) = 30$ , and  $u(l) = 70$

Put  $x = 0$  in (2),  $u(0) = b = 30$

Put  $x = l$  in (2),  $u(l) = al+b = 70$

$al = 40$  that implies  $a = 40/l$

(2) implies  $u(x) = \frac{40}{l}x + 30$  Here  $l = 20$ .

Therefore  $u(x) = 2x+30$ .

**18. An insulated rod of length  $l$  cm has its ends A and B maintained at  $0^\circ\text{C}$  and  $80^\circ\text{C}$  respectively. Find the steady state solution of the rod (AU - N/D - 2013)**

The steady state equation of the one dimensional heat flow is  $\frac{d^2u}{dx^2} = 0$  .....(1)

The general Solution of (1) is  $u(x) = ax+b$  .....(2)

The boundary conditions are  $u(0) = 0$ , and  $u(l) = 80$

Put  $x = 0$  in (2),  $u(0) = b = 0$

Put  $x = l$  in (2),  $u(l) = la+b = 80$

$la+b = 80$  that implies  $la = 80$  implies that  $a = 80/l$  and equation (2) implies  $u(x) = (80/l)x$ .

**19. A bar of length 50cm has its ends kept at  $20^\circ\text{C}$  and  $100^\circ\text{C}$  until steady state conditions prevail. Find the temperature at any point of the bar. (AU - A/M - 2014)**

The steady state equation of one dimensional heat flow is  $\frac{d^2u}{dx^2} = 0$  .....(1)

The general solution of (1) is  $u(x) = ax+b$  .....(2)

Put  $x = 0$  in (2),  $u(0) = b = 20$

Put  $x = l$  in (2),  $u(l) = al+b = 100$

$al = 80$

$a = 80/l$

$a = 80/50$  that is  $a = 8/5$ . Equation (2) implies  $u(x) = \frac{8}{5}x + 20$

**20. A rod of 60cm long has its ends A and B kept at  $20^\circ\text{C}$  and  $80^\circ\text{C}$  respectively until steady state conditions prevail. Find the steady state temperature in the rod. (AU - N/D - 2012)**

The steady state equation of the one dimensional heat flow is  $\frac{d^2u}{dx^2} = 0$  .....(1)

The general Solution of (1) is  $u(x) = ax+b$  .....(2)

The boundary conditions are  $u(0) = 20$ , and  $u(60) = 80$

Put  $x = 0$  in (2),  $u(0) = b = 20$

Put  $x = 60$  in (2),  $u(60) = 20a + b = 80$

$20a + 20 = 80$  that implies  $20a = 60$  implies that  $a = 3$  and equation (2) implies  $u(x) = 3x + 20$ .

**21. In 2D heat equation or Laplace equation, what is the basic assumption?**

When the heat flow is along the curves instead of straight lines, the curves lying in parallel planes the flow is called two dimensional.

**22. Write all possible solutions of two dimensional heat equations  $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$ .**

(AU - N/D - 2018)-7

$$u(x, y) = (A_1 e^{px} + A_2 e^{-px})(A_3 \cos py + A_4 \sin py)$$

$$u(x, y) = (A_5 \cos px + A_6 \sin px)(A_7 e^{py} + A_8 e^{-py})$$

$$u(x, y) = (A_9 x + A_{10})(A_{11} y + A_{12}).$$

**23. State two-dimensional Laplace equation.**

The two-dimensional Laplace equation is given by  $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$  i.e.,  $\nabla^2 u = 0$ ,

**24. An infinitely long rectangular plate with insulated surface is 10 cm wide. The two long edges and one short edge are kept at zero temperature while the other short edge  $x = 0$  is kept at temperature given by  $u = 20y$ ,  $0 \leq y \leq 5$   
 $= 20(10-y)$ ,  $5 \leq y \leq 10$ . Give the boundary conditions.**

The equation to be solved is  $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$ . The boundary conditions are

(i)  $u(x, 0) = 0$  for all  $x$

(ii)  $u(x, 10) = 0$  for all  $x$

(iii)  $u(\infty, y) = 0$  (ie) when  $x \rightarrow \infty$ ,  $u \rightarrow 0$

(iv)  $u(0, y) = 20y$ ,  $0 \leq y \leq 5$   
 $= 20(10-y)$ ,  $5 \leq y \leq 10$ .

**25. A square plate has its faces and the edge  $y = 0$  insulated. Its edges  $x = 0$  and  $x = \pi$  are kept at zero temperature and its fourth edge  $y = \pi$  is kept at temperature  $\pi x - x^2$ . Write the boundary conditions alone.**

The equation to be solved is  $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$ . The boundary conditions are

a)  $u(0, y) = 0$   $0 \leq y \leq \pi$

b)  $u(\pi, y) = 0$   $0 \leq y \leq \pi$

c)  $\left(\frac{\partial u}{\partial y}\right)_{y=0} = 0$   $0 \leq x \leq \pi$

d)  $u(x, \pi) = \pi x - x^2$   $0 < x < \pi$

**PART-B**

1. A string is stretched and fastened to 2 points  $x = 0$  and  $x = l$ . Motion is started by displacing the string into the form  $y = kx(l-x)$  from which it is released at time  $t = 0$ . Find the displacement at any point on the string at a distance of  $x$  from one end at time  $t$ . (AU - A/M - 2018)-7-(16)
2. A string of length  $2l$  is fastened at both ends. The midpoint of the string is taken to a height  $b$  and then released from rest in that position. Find the displacement. (AU - N/D - 2018)-4-(16)
3. A string is stretched and fastened to points at a distance  $l$  apart. Motion is started by displacing the string in the form  $y = a \sin(\pi x/l)$ ,  $0 < x < l$ , from which it is released at time  $t = 0$ . Find the displacement at any time  $t$ . (AU - M/J - 2014)(16)
4. A tightly stretched string of length 'l' with fixed end points is initially at rest in its equilibrium

position. If it is set vibrating by giving each point a velocity  $y_t(x,0) = v_0 \sin\left(\frac{3\pi x}{l}\right) \cos\left(\frac{\pi x}{l}\right)$ , where  $0 < x < l$ . Find the displacement of the string at a point, at a distance  $x$  from one end at any instant  $t$ .  
(AU - N/D - 2012)(16)

5. A tightly stretched string with fixed end points  $x = 0$  and  $x = l$  is initially at rest in its equilibrium position. If it is set vibrating giving each point a velocity  $\lambda x(l-x)$ , show that

$$y(x,t) = \frac{8\lambda^3}{a\pi^4} \sum_{n=1}^{\infty} \frac{1}{(2n-1)^4} \sin \frac{(2n-1)\pi x}{l} \sin \frac{(2n-1)\pi at}{l} \quad (\text{AU - N/D - 2014})$$

(16)

6. Find the displacement of a string stretched between two fixed points at a distance of  $2l$  apart when the string is initially at rest in equilibrium position and points of the string are given initial velocities  $v = \frac{x}{l}$  in  $(0, l)$   
 $= \frac{2l-x}{l}$  in  $(l, 2l)$ ,  $x$  being the distance measured from one end. (AU - M/J - 2016)

(16)

7. If a string of length  $l$  is initially at rest in its equilibrium position and each of its points is given a velocity  $v$  such that

$$V = 2kx/l \text{ for } 0 < x < l/2 \\ = 2k(l-x)/l \text{ for } l/2 < x < l \quad (\text{AU - N/D - 2015})(16)$$

8. A bar, 10cm long with insulated sides, has its ends A and B kept at  $20^\circ\text{C}$  and  $40^\circ\text{C}$  respectively until steady state conditions prevail. The temperature at A is then suddenly raised to  $50^\circ\text{C}$  and at the same instant that at B is lowered to  $10^\circ\text{C}$ . Find the subsequent temperature at any point of the bar at any time.  
(AU - N/D - 2018)-2-(16)

9. A rod of length  $l$  has its end A and B kept at  $0^\circ\text{C}$  and  $100^\circ\text{C}$  respectively until steady state conditions prevail. If the temperature at B is reduced suddenly to  $75^\circ\text{C}$  and at the same time the temperature at A raised to  $25^\circ\text{C}$  find the temperature  $u(x, t)$  at a distance  $x$  from A and at time  $t$ .  
(AU - N/D - 2017)-2-(16)

10. An insulated rod of length  $l$  its ends A and B are maintained at  $0^\circ\text{C}$  and  $100^\circ\text{C}$  respectively until steady state conditions prevail. If B is suddenly reduced to  $0^\circ\text{C}$  and maintained so, find the temperature at a distance  $x$  from A at time  $t$ .  
(AU - N/D - 2017)-2-(16)

11. A square plate is bounded by the lines  $x = 0, y = 0, x = 20, y = 20$ . Its faces are insulated. The temperature along the upper horizontal edge is given  $u(x, 20) = x(20-x)$  while the other three edges are kept at  $0^\circ\text{C}$ . Find the steady state temperature in the plate. (AU - N/D - 2014)-2-(16)

12. A square plate is bounded by the lines  $x = 0, y = 0, x = l$  and  $y = l$ , its faces are insulated. The temperature along the upper horizontal edge is given by  $u(x, l) = x(l-x)$  when  $0 < x < l$  while the other three edges are kept at  $0^\circ\text{C}$ . Find the steady state temperature in the plate.  
(AU - N/D - 2013)(16)

13. A long rectangular plate with insulated surface is  $l$  cm wide. If the temperature along one short edge is  $u(x, 0) = k(l-x^2)$  for  $0 < x < l$ , while the other two long edges  $x = 0$  and  $x = l$  as well as the other short edge are kept at  $0^\circ\text{C}$ , find the steady state temperature function  $u(x, y)$ .  
(AU - N/D - 2016)(16)

14. A rectangular plate with insulated surface is 20cm wide and so long compared to its width that it may be considered infinite in the length without introducing an appreciable error. If the temperature along one short edge  $x = 0$  is given by  $u = \begin{cases} 10y, 0 \leq y \leq 5 \\ 10(20-y), 5 \leq y \leq 20 \end{cases}$  and the two long edges as well as the other short edge are kept at  $0^\circ\text{C}$ , find the steady state temperature distribution  $u(x, y)$  in the plate.  
(AU - A/M - 2017)(16)

15. An infinitely long rectangular plate with insulated surface is 10 cm wide. The two long edges and on short edge are kept at zero temperature, while the other short edge  $y = 0$  is kept at temperature given by  $u = \begin{cases} 20x, 0 \leq x \leq 5 \\ 20(10-x), 5 \leq x \leq 10 \end{cases}$ . Find the steady state temperature distribution in the plate.  
(AU - M/J - 2014)-2-(16)

**UNIT - IV**  
**FOURIER TRANSFORMS**  
**PART-A**

1. State Fourier integral theorem

(AU - N/D - 2018)-8

If  $f(x)$  is piece-wise continuously differentiable and absolutely integrable in  $(-\infty, \infty)$ , then

$$f(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(t) e^{is(x-t)} dt ds$$

$$\text{or equivalently } f(x) = \frac{1}{\pi} \int_0^{\infty} \int_{-\infty}^{\infty} f(t) \cos \lambda(t-x) dt d\lambda$$

This is known as Fourier integral theorem or Fourier integral formula.

**2. Show that  $f(x)=1, 0 < x < \infty$  cannot be represented by a Fourier integral.**

$$\int_{-\infty}^{\infty} |f(x)| dx = \int_0^{\infty} 1 \cdot dx = [x]_0^{\infty} = \infty$$

Therefore the given function cannot be represented as Fourier integral.

**3. Write the Fourier transforms pair.**

**(AU - M/J - 2011)-2**

If  $f(x)$  is a given function then  $F[f(x)]$  and  $F^{-1}[f(x)]$  are called Fourier transform pair

$$F(s) = F[f(x)] = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{isx} dx ; \text{ The inverse } f(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} F(s) e^{-isx} ds.$$

**4. Prove that  $F[\overline{f(x)}] = \overline{F(-s)}$**

**(AU - N/D - 2012)**

$$F(s) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{isx} dx$$

$$F(-s) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{-isx} dx$$

Taking complex conjugate on both sides we get

$$\overline{F(-s)} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \overline{f(x)} e^{isx} dx = F[\overline{f(x)}].$$

**5. Find the Fourier transform of  $f(x)$  if**

**(AU - N/D - 2014)-3**

$$f(x) = \begin{cases} 1 ; |x| < 1 \\ 0 ; |x| > 1 \end{cases}$$

$$\text{We know that } F[f(x)] = \int_{-\infty}^{\infty} f(x) e^{isx} dx = \int_{-1}^1 e^{isx} dx = \left[ \frac{e^{isx}}{is} \right]_{-1}^1 = \frac{e^{is} - e^{-is}}{is} = \frac{2}{s} \left[ \frac{e^{is} - e^{-is}}{2i} \right] = \frac{2}{s} \sin s.$$

**6. Find the (complex) Fourier transform of  $f(x) = \begin{cases} e^{ikx}, a < x < b \\ 0, x < a < x > b \end{cases}$**

**(AU - A/M - 2010)**

$$\begin{aligned} F(s) = F[f(x)] &= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{isx} dx = \frac{1}{\sqrt{2\pi}} \int_a^b e^{ikx} e^{isx} dx = \frac{1}{\sqrt{2\pi}} \int_a^b e^{i(k+s)x} dx \\ &= \frac{1}{\sqrt{2\pi}} \left[ \frac{e^{i(k+s)x}}{i(k+s)} \right]_a^b = \frac{-i}{\sqrt{2\pi}(k+s)} [e^{i(k+s)b} - e^{i(k+s)a}] = \frac{i}{\sqrt{2\pi}(k+s)} [e^{i(k+s)a} - e^{i(k+s)b}]. \end{aligned}$$

**7. State and prove modulation theorem on Fourier transform.**

**(AU - A/M - 2014)-2**

**Statement:** If  $F(s)$  is the Fourier transform of  $f(x)$ , then  $F[f(x) \cos ax] = \frac{1}{2} [F(s+a) + F(s-a)]$ .

$$F[f(x)] = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{isx} dx$$

**Proof:**

$$\begin{aligned} F[f(x) \cos ax] &= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) \cos ax e^{isx} dx = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) \left[ \frac{e^{iax} + e^{-iax}}{2} \right] e^{isx} dx \\ &= \frac{1}{2} \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) [e^{i(s+a)x} + e^{i(s-a)x}] dx = \frac{1}{2} [F(s+a) + F(s-a)]. \end{aligned}$$

**8. If  $F(s)$  is the Fourier transform of  $f(x)$ , then show that the Fourier transform of**

**$e^{iax} f(x)$  is  $F(s+a)$ .**

**(AU - A/M - 2015)-4**

$$F[e^{iax}f(x)] = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{iax} f(x) e^{isx} dx = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{i(s+a)x} f(x) dx = F(s+a).$$

**9. State and prove first shifting theorem. (or) P.T  $F[f(x-a)] = e^{ias}F(s)$ .** (AU - N/D - 2018)-4  
First shifting theorem is given by  $F[f(x-a)] = e^{ias}F(s)$

**Proof:**  $F[f(x-a)] = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x-a) e^{isx} dx$

Put  $x-a = y$  when  $x = -\infty, y = -\infty$   
 $dx = dy$  when  $x = \infty, y = \infty$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(y) e^{is(y+a)} dy = \frac{e^{ias}}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(y) e^{isy} dy = \frac{e^{ias}}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{isx} dx = e^{ias} F(s)$$

**10. State change of scale property of Fourier transforms.** (AU - N/D - 2017)-3  
Change of scale property of Fourier transforms is given by

If  $F\{f(x)\} = F(s)$  then  $F\{f(ax)\} = \frac{1}{a} F_c\left[\frac{s}{a}\right]$  where  $a \neq 0$ .

**Proof:**  $F(f(ax)) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{isx} f(ax) dx$

Put  $t = ax, dt = adx \Rightarrow dx = dt/a$

$F(f(ax)) = \frac{1}{a\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{it(s/a)} f(t) dt$  By definition,  $F(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(t) e^{ist} dt$

$F(f(ax)) = \frac{1}{a} F(s/a)$  for  $a > 0$

$= -\frac{1}{a} F(s/a)$  for  $a < 0$

$F\{f(ax)\} = \frac{1}{a} F_c\left[\frac{s}{a}\right]$  where  $a \neq 0$ .

**11. Find Fourier sine transform of  $\frac{1}{x}$**  (AU - A/M - 2017)-5

We know that

$$F_s[f(x)] = \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \sin sx dx = \sqrt{\frac{2}{\pi}} \int_0^{\infty} \frac{1}{x} \sin sx dx = \sqrt{\frac{2}{\pi}} \frac{\pi}{2} = \sqrt{\frac{\pi}{2}}$$

$$\therefore \int_0^{\infty} \frac{\sin ax}{x} dx = \frac{\pi}{2}, a > 0.$$

**12. Find the Fourier sine transform of  $e^{-ax}$**

We know that  $F_s[f(x)] = \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \sin sx dx$

$$F_s[e^{-ax}] = \sqrt{\frac{2}{\pi}} \int_0^{\infty} e^{-ax} \sin sxdx = \sqrt{\frac{2}{\pi}} \frac{s}{a^2 + s^2}$$

**13. If  $F_s(s)$  is the Fourier sine transform of  $f(x)$ , show that**

$$F_s(f(x) \sin ax) = \frac{1}{2} [F_s(s+a) + F_s(s-a)]$$
 (AU - N/D - 2017)-3

$$F_s(f(x) \sin ax) = \frac{1}{2} [F_c(s-a) - F_c(s+a)]$$

$$= \sqrt{\frac{2}{\pi}} \left[ \int_0^{\infty} f(x) \frac{1}{2} [\cos(s-a)x - \cos(s+a)x] dx \right]$$

$$= \frac{1}{2} \sqrt{\frac{2}{\pi}} \left[ \int_0^{\infty} f(x) \cos(s-a)x dx - \int_0^{\infty} f(x) \cos(s+a)x dx \right] = \frac{1}{2} [F_c(s-a) - F_c(s+a)]$$

**14. Define Fourier cosine transform and its inversion formula.**

The infinite Fourier cosine transform of  $f(x)$  is defined as

$$F_c[f(x)] = F_c(s) = \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \cos sx \, dx$$

The inversion formula is  $f(x) = \sqrt{\frac{2}{\pi}} \int_0^{\infty} F_c(s) \cos sx \, ds$ .

**15. Find the Fourier cosine transform of**

**(AU-N/D-2011)-3**

$$f(x) = \begin{cases} \cos x; & \text{if } 0 < x < a \\ 0; & \text{if } x \geq a \end{cases}$$

$$\begin{aligned} F_c(s) &= \sqrt{\frac{2}{\pi}} \int_0^{\infty} \cos x \cos sx \, dx = \sqrt{\frac{2}{\pi}} \int_0^a \cos x \cos sx \, dx \\ &= \sqrt{\frac{2}{\pi}} \frac{1}{2} \int_0^a [\cos(s+1)x + \cos(s-1)x] \, dx \\ &= \frac{1}{\sqrt{2\pi}} \left[ \frac{\sin(s+1)x}{s+1} + \frac{\sin(s-1)x}{s-1} \right]_0^a = \frac{1}{\sqrt{2\pi}} \left[ \frac{\sin(s+1)a}{s+1} + \frac{\sin(s-1)a}{s-1} \right] \text{ provided } s \neq 1; s \neq -1. \end{aligned}$$

**16. Find Fourier cosine transform of  $e^{-ax}$ ,  $a > 0$ .**

**(AU - N/D - 2015)-3**

We know that  $F_c[f(x)] = \frac{2}{\pi} \int_0^{\infty} f(x) \cos sx \, dx$

$$F_c[e^{-ax}] = \frac{2}{\pi} \int_0^{\infty} e^{-ax} \cos sx \, dx = \frac{2}{\pi} \left[ \frac{a}{s^2 + a^2} \right] \text{ since } \int_0^{\infty} e^{-ax} \cos bx \, dx = \frac{a}{a^2 + b^2}$$

**17. Find Fourier cosine transform of  $e^{-x}$ ,  $a > 0$ .**

**(AU-N/D-2015)-3**

We know that,  $F_c(f(x)) = \sqrt{\frac{2}{\pi}} \left[ \int_0^{\infty} f(x) \cos sx \, dx \right] = \sqrt{\frac{2}{\pi}} \left[ \int_0^{\infty} e^{-x} \cos sx \, dx \right] = \sqrt{\frac{2}{\pi}} \left[ \frac{1}{s^2 + 1} \right]$

**18. Prove that  $F_c[f(x) \cos ax] = \frac{1}{2} [F_c(s+a) + F_c(s-a)]$  where  $F_c$  denotes the Fourier cosine transform  $f(x)$ .**

**(AU - M/J - 2011)-3**

$$\begin{aligned} F_c[f(x) \cos ax] &= \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \cos ax \cos(sx) \, dx = \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \left[ \frac{\cos(s+a)x + \cos(s-a)x}{2} \right] \, dx \\ &= \frac{1}{2} \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \cos(s+a)x \, dx + \frac{1}{2} \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \cos(s-a)x \, dx = \frac{1}{2} [F_c(s+a) + F_c(s-a)] \end{aligned}$$

**19. If  $F_c(s)$  is the Fourier cosine transform of  $f(x)$ . Prove that the Fourier cosine transform of  $f(ax)$  is  $\frac{1}{a} F_c \left[ \frac{s}{a} \right]$**

**(AU - N/D - 2015)**

To prove:  $F_c(f(ax))$  is  $\frac{1}{a} F_c \left[ \frac{s}{a} \right]$  We know that  $F_c[f(ax)] = \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(at) \cos st \, dt$

Put  $at=u$  when  $t \rightarrow 0 \Rightarrow u \rightarrow 0, t \rightarrow \infty \Rightarrow u \rightarrow \infty, a dt = du$

$$= \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(u) \cos \left( \frac{su}{a} \right) \frac{du}{a} = \frac{1}{a} \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(t) \cos \frac{s}{a} t \, dt = \frac{1}{a} F_c \left[ \frac{s}{a} \right]$$

**20. Find the Fourier sine transform of  $e^{-3x}$ .**

**(AU - M/J - 2013)**

We know that  $F_s[f(x)] = \sqrt{\frac{2}{\pi}} \int_0^{\infty} f(x) \sin sx \, dx = \sqrt{\frac{2}{\pi}} \int_0^{\infty} e^{-3x} \sin sx \, dx = \sqrt{\frac{2}{\pi}} (s/s^2+9)$

**21. Given that of  $e^{-x^2/2}$  is self reciprocal under Fourier cosine transform, find Fourier sine transform of  $xe^{-x^2/2}$**

**(AU - A/M - 2015)**

WKT,  $F_c [e^{-x^2/2}] = e^{-s^2/2}$ ,  $F_s [xe^{-x^2/2}] = -d/ds F_c [xe^{-x^2/2}] = -d/ds [e^{-s^2/2}] = -e^{-s^2/2} (-s) = s e^{-s^2/2}$

**22. Define the Convolution of two functions.**

The Convolution of two functions is given by  $(f * g)(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(t)g(x-t)dt.$

**23. State the convolution theorem for Fourier transforms. (AU - A/M - 2018)-3**

If F(s) and G(s) are the Fourier transform of f(x) and g(x) respectively, then the Fourier transform of the convolution of f(x) and g(x) is the product of their Fourier transform.

$F[f(x)g(x)] = F(S)G(S) = F[f(x)]F[g(x)]$  and  $F^{-1}[F(S)G(S)] = F^{-1}[F(S)] * F^{-1}[G(S)]$

**24. State Parseval's identity of Fourier transforms. (AU - M/J - 2011)-2**

Let F(s) be the Fourier transform of f(x) , then

$\int_{-\infty}^{\infty} |f(x)|^2 dx = \int_{-\infty}^{\infty} |F(s)|^2 ds$

**25. State Parseval's identity of Fourier cosine transform.**

$\int_0^{\infty} |f(x)|^2 dx = \int_0^{\infty} |F_c(s)|^2 ds$

**PART-B**

1. a. Express the function  $f(x) = \begin{cases} 1-|x| & -1 \leq x \leq 1 \\ 0 & |x| > 1 \end{cases}$  as a Fourier Integral. Hence evaluate

$\int_0^{\infty} \frac{\sin \lambda \cos \lambda x}{\lambda} d\lambda$  &  $\int_0^{\infty} \frac{\sin \lambda}{\lambda} d\lambda$  (AU - N/D -

**2015)-2-(8)**

b. Solve for f(x) from the integral equation  $\int_0^{\infty} f(x) \cos cx dx = e^{-x}$  (AU - A/M - 2014)(8)

2. a. Solve for f(x) from the integral equation (AU - N/D - 2015)(8)

$\int_0^{\infty} f(x) \sin sx dx = 1, 0 \leq s \leq 1$   
 $= 2, 1 \leq s \leq 2$   
 $= 0, s \geq 2$

b. Find the Fourier transform of,  $f(x) = \begin{cases} 1 & \text{for } |x| < a \\ 0 & \text{otherwise.} \end{cases}$  Hence prove that

$\int_0^{\infty} \frac{\sin x}{x} dx = \int_0^{\infty} \frac{\sin^2 x}{x^2} dx = \frac{\pi}{2}$  (AU - N/D - 2018)-2-

**(8)**

3. a. Find the Fourier transform of  $e^{-a|x|}$ . Hence Deduce that

(i)  $F[xe^{-a|x|}] = i\sqrt{\frac{2}{\pi}} \frac{2as}{(s^2 + a^2)}$  (ii)  $\int_0^{\infty} \frac{\cos xt}{a^2 + t^2} dt = \frac{\pi}{2a} e^{-a|x|}$  (AU - N/D - 2014)-4-

**(8)**

b. Show that the Fourier transform of  $e^{-x^2/2}$  is  $e^{-s^2/2}$  (AU - A/M - 2018)-3-

**(8)** 4. Find the Fourier transform of f(x) given by  $f(x) = \begin{cases} 1-x^2 & \text{for } |x| \leq 1 \\ 0 & \text{for } |x| \geq 1. \end{cases}$  Hence evaluate

$\int_0^{\infty} \frac{\sin s - s \cos s}{s^3} \cos\left(\frac{s}{2}\right) ds = \frac{3\pi}{16}$ . also show that  $\int_0^{\infty} \frac{(x \cos x - \sin x)^2}{x^6} dx = \frac{\pi}{15}$ . (AU - A/M - 2018)-6- (16)

5. a. Find the Fourier transform of f(x) if (AU - N/D - 2017)-3-(8)

$f(x) = \begin{cases} 1-|x| & \text{for } |x| < 1 \\ 0 & \text{for } |x| > 1. \end{cases}$  Hence deduce that  $\int_0^{\infty} \left(\frac{\sin t}{t}\right)^2 dt = \frac{\pi}{2}$  and  $\int_0^{\infty} \left(\frac{\sin t}{t}\right)^4 dt = \frac{\pi}{3}$ .

b. Find the Fourier transform  $f(x) = e^{-\frac{x^2}{2}}$  and hence find  $Fc[e^{-\frac{x^2}{2}}]$ . **(AU - N/D - 2018)(8)**

6. a. Find Fourier transform of  $e^{-a^2x^2}$ ,  $a > 0$  and hence find  $e^{-\frac{x^2}{2}}$  is self reciprocal under the Fourier transform. **(AU - A/M - 2016)-3-(8)**

b. Find the Fourier sine transform of  $e^{-|x|}$ . Hence show that  $\int_0^{\infty} \frac{x \sin x}{(1+x)^3} dx = \frac{\pi}{2} e^{-a}$ ,  $m > 0$ .

7. a. Find the Fourier Sine transform of the function  $f(x) = \frac{e^{-ax}}{x}$  hence deduce the infinite Fourier sine transform of  $1/x$ . **(AU - N/D - 2016)-2-(8)**

b. Find the Fourier Sine transform of  $f(x) = \begin{cases} \sin x, & 0 < x < a \\ 0 & x > a \end{cases}$  **(AU - N/D - 2018)-2-(8)**

8. a. Find the Fourier sine transform of  $e^{-ax}$ ,  $a > 0$  and hence deduce the inversion formula. **(AU - A/M - 2016)-3-(8)**

b. Find the Fourier sine transform of  $xe^{-x^2/2}$ . **(AU - A/M - 2015)(8)**

9. a. Find the Fourier cosine transform of  $f(x) = \begin{cases} 1-x, & 0 \leq x \leq 1 \\ 0, & \text{otherwise} \end{cases}$ , Hence show that

$$\int_0^{\infty} \frac{\sin x}{x} dx = \int_0^{\infty} \frac{\sin^2 x}{x^2} dx = \frac{\pi}{2} \quad \text{(AU - N/D - 2015)(8)}$$

b. Find the Fourier sine and cosine transform of  $x^{n-1}$ ,  $0 < n < 1$ . Hence Show that  $\frac{1}{\sqrt{x}}$  is self reciprocal under both the transformation **(AU - A/M - 2015)-2-(8)**

10. a. Solve the integral equation  $\int_0^{\infty} f(x) \cos \lambda x dx = e^{-\lambda}$  and also show that  $\int_0^{\infty} \frac{\cos \lambda x}{1+x^2} dx = \frac{\pi}{2} e^{-\lambda}$  **(AU - A/M - 2016)-2-(8)**

b. Prove that  $e^{-\frac{x^2}{2}}$  is self reciprocal under Fourier Cosine transform. **(AU - A/M - 2014)(8)**

11. a. Find Fourier Cosine transform of  $e^{-a^2x^2}$  and hence find Fourier sine transform of  $xe^{-a^2x^2}$  **(AU - A/M - 2018)-5-(8)**

b. Find the Fourier Cosine transform of  $f(x) = \frac{e^{-ax} - e^{-bx}}{x}$ ,  $x > 0$  **(AU - N/D - 2015)(8)**

12. Find the Fourier cosine transform of  $f(x) = e^{-4x}$  for  $x > 0$ ,  $a > 0$ . Hence deduce that

$$\int_0^{\infty} \frac{\cos 2x}{x^2 + 16} = \frac{\pi}{8} e^{-8} \text{ and } \int_0^{\infty} \frac{\sin 2x}{x^2 + 16} dx = \frac{\pi}{2} e^{-8} \quad \text{(AU - M/J - 2016)(16)}$$

13. a. Verify the convolution theorem for Fourier transform if  $f(x) = g(x) = e^{-x^2}$  **(AU - M/J - 2015)(8)**

b. State and prove convolution theorem for Fourier transforms. **(AU - N/D - 2018)(8)**

14. a. Use transform method to evaluate  $\int_0^{\infty} \frac{dx}{(x^2 + 1)(x^2 + 4)}$  **(AU - A/M - 2017)-2-**

**(8)**

b. Using Parseval's identity evaluate the following integrals

$$(i) \int_0^{\infty} \frac{dx}{(a^2 + x^2)^2} \quad (ii) \int_0^{\infty} \frac{x^2 dx}{(a^2 + x^2)^2}, \text{ where } a > 0. \quad \text{(AU - N/D - 2017)-2-(8)}$$

15. a. Evaluate  $\int_0^{\infty} \frac{\lambda^2 d\lambda}{(\lambda^2 + a^2)(\lambda^2 + b^2)}$  using transforms.

b. Evaluate  $\int_0^{\infty} \frac{dx}{(x^2 + a^2)(x^2 + b^2)}$  using transforms. **(AU - M/J - 2018)(8)**

**UNIT - V**  
**Z- TRANSFORM**  
**PART-A**

**1. Define Z- Transforms**

Let  $\{x(n)\}$  be a sequence defined for all integers then its Z-transform is defined to be

$$Z\{x(n)\} = X(Z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} \text{ where } z \text{ is an arbitrary complex number.}$$

**2. Prove that  $Z\{a^n\} = \frac{z}{z-a}$**

**(AU - A/M - 2017)-5**

We know that  $Z\{x(n)\} = X(Z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n}$

$$\begin{aligned} Z\{a^n\} &= \sum_{n=0}^{\infty} a^n z^{-n} = \sum_{n=0}^{\infty} \left[\frac{a}{z}\right]^n \\ &= 1 + \frac{a}{z} + \left(\frac{a}{z}\right)^2 + \dots \\ &= \left[1 - \frac{a}{z}\right]^{-1} \\ &= \frac{z}{z-a}, |z| > |a| \end{aligned}$$

**3. Find the Z  $\left[\frac{1}{n(n+1)}\right]$**

**(AU - N/D - 2016)-3**

$$\frac{1}{n(n+1)} = \frac{A}{n} + \frac{B}{n+1} \dots\dots\dots(1)$$

$$1 = A(n+1) + B(n)$$

Put  $n=0$  we get

$$1 = A$$

Put  $n=-1$  we get

$$1 = -B$$

$$B = -1$$

(1) implies  $\frac{1}{n(n+1)} = \frac{1}{n} - \frac{1}{n+1}$

We know that  $Z\left(\frac{1}{n}\right) = \log \frac{z}{z-1}$

$$Z\left(\frac{1}{n+1}\right) = z \log \frac{z}{z-1}$$

$$Z\left(\frac{1}{n(n+1)}\right) = Z\left(\frac{1}{n}\right) - Z\left(\frac{1}{n+1}\right)$$

$$= \log \frac{z}{z-1} - z \log \frac{z}{z-1} = (1-z) \log \frac{z}{z-1}$$

**4. Find  $Z\{(\cos \theta + i \sin \theta)^n\}$**

**(AU - M/J - 2016)**

Let  $a = e^{i\theta}$

$$a^n = (e^{i\theta})^n = e^{in\theta} = \cos n\theta + i \sin n\theta$$

$$Z[a^n] = \frac{z}{z-a}$$

$$Z[(e^{i\theta})^n] = \frac{z}{z-e^{i\theta}}$$

$$Z[e^{in\theta}] = \frac{z}{z-(\cos\theta + i\sin\theta)}$$

$$Z[\cos n\theta + i\sin n\theta] = \frac{z}{(z-\cos\theta) - i\sin\theta}$$

$$\begin{aligned} Z[\cos n\theta] + iZ[\sin n\theta] &= \left[ \frac{z}{(z-\cos\theta) - i\sin\theta} \right] \left[ \frac{(z-\cos\theta) + i\sin\theta}{(z-\cos\theta) + i\sin\theta} \right] \\ &= \frac{z(z-\cos\theta) + iz\sin\theta}{(z-\cos\theta)^2 + \sin^2\theta} = \frac{z(z-\cos\theta) + iz\sin\theta}{z^2 - 2z\cos\theta + \cos^2\theta + \sin^2\theta} \\ &= \frac{z(z-\cos\theta) + iz\sin\theta}{z^2 - 2z\cos\theta + 1} = \frac{z(z-\cos\theta)}{z^2 - 2z\cos\theta + 1} + i \frac{z\sin\theta}{z^2 - 2z\cos\theta + 1} \end{aligned}$$

**5. Find**  $Z\left[\sin^2 \frac{n\pi}{4}\right]$  **(AU - N/D - 2018)**

$$Z\left[\sin^2 \frac{n\pi}{4}\right] = Z\left[\frac{1 - \cos \frac{n\pi}{2}}{2}\right] = \frac{1}{2} \left\{ Z(1) - Z\left(\cos \frac{n\pi}{2}\right) \right\} = \frac{1}{2} \left\{ \frac{z}{z-1} - \frac{z^2}{z^2+1} \right\}$$

**6. Find**  $Z\left[\frac{1}{n!}\right]$  **(AU - M/J - 2016)**

$$Z[x(n)] = \sum_{n=0}^{\infty} x(n)z^{-n}$$

$$\begin{aligned} Z\left[\frac{1}{n!}\right] &= \sum_{n=0}^{\infty} \frac{1}{n!} z^{-n} = \sum_{n=0}^{\infty} \frac{1}{n!} \left(\frac{1}{z}\right)^n \\ &= 1 + \frac{1}{1!} \left(\frac{1}{z}\right) + \frac{1}{2!} \left(\frac{1}{z}\right)^2 + \dots \\ &= e^{\frac{1}{z}} \end{aligned}$$

**7. Prove that**  $Z(n) = \frac{z}{(z-1)^2}$  **(AU - A/M - 2018)-2**

$$\text{We know that } Z\{x(n)\} = \sum_{n=0}^{\infty} x(n)z^{-n}$$

$$Z[n] = \sum_{n=0}^{\infty} \frac{n}{z^n} = 0 + \frac{1}{z} + \frac{2}{z^2} + \frac{3}{z^3} + \dots = \frac{1}{z} \left[ 1 + 2\left(\frac{1}{z}\right) + 3\left(\frac{1}{z}\right)^2 + \dots \right] = \frac{1}{z} \left[ \left(\frac{z-1}{z}\right)^{-2} \right] = \frac{1}{z} \left[ \frac{z}{z-1} \right]^2 = \frac{z}{(z-1)^2}$$

**8. Find**  $Z[na^n]$  **(AU - N/D - 2018)**

$$Z[na^n] = \left\{ \frac{z}{(z-1)^2} \right\}_{z \rightarrow \frac{z}{a}} = \frac{\frac{z}{a}}{\left(\frac{z}{a}-1\right)^2} = \frac{az}{(z-a)^2}$$

**9. Find**  $Z(n^2)$  **(AU - M/J - 2014)**

$$\text{We know that } Z[nf(n)] = -z \frac{dF(z)}{dz}$$

$$Z(n^2) = Z[nn] = -z \frac{d}{dz} [Z(n)] = -z \frac{d}{dz} \left[ \frac{z}{(z-1)^2} \right] = -z \left[ \frac{(z-1)^2(1) - z[2(z-1)]}{(z-1)^4} \right]$$

$$= -z \left[ \frac{z-1-2z}{(z-1)^3} \right] = -z \left[ \frac{-1-z}{(z-1)^3} \right] = z \frac{z+1}{(z-1)^3} = \frac{z^2+z}{(z-1)^3}$$

10. Find Z-transform of  $nC_2$

(AU - A/M - 2017)

$$Z[nC_2] = Z\left[\frac{n(n-1)}{2}\right] = Z\left[\frac{n^2-n}{2}\right] = \frac{1}{2}[Z(n^2) - Z(n)] = \frac{1}{2}\left[\frac{z^2+z}{(z-1)^3} - \frac{z}{(z-1)^2}\right]$$

11. Find  $Z\left(\frac{1}{n}\right)$

(AU - N/D - 2017)-2

We know that  $Z\{x(n)\} = \sum_{n=0}^{\infty} x(n)z^{-n}$

$$\begin{aligned} Z\left[\frac{1}{n}\right] &= \sum_{n=1}^{\infty} \frac{1}{n} z^{-n} = \sum_{n=1}^{\infty} \frac{1}{nz^n} = \frac{1}{z} + \frac{1}{2z^2} + \frac{1}{3z^3} + \dots \\ &= -\log\left[1 - \frac{1}{z}\right] = -\log\left[\frac{z-1}{z}\right] = \log\left[\frac{z}{z-1}\right] \quad [\because \log a^p = p \log a] \end{aligned}$$

12. Find  $Z[e^t \sin 2t]$

(AU - N/D - 2015)

$$\begin{aligned} \text{We know that } Z[e^{at} \sin 2t] &= Z[f(t)]_{z \rightarrow ze^{-aT}} \\ &= [Z[\sin 2t]]_{z \rightarrow ze^{-T}} \quad (a = 1) \\ &= \left[ \frac{z \sin 2T}{z^2 - 2z \cos 2T + 1} \right]_{z \rightarrow ze^{-T}} = \left[ \frac{ze^{-T} \sin 2T}{z^2 e^{-2T} - 2ze^{-T} \cos 2T + 1} \right] \end{aligned}$$

$$Z[\sin at] = \left[ \frac{z \sin aT}{z^2 - 2z \cos aT + 1} \right]$$

13. Find  $Z(t)$

We know that  $Z\{f(t)\} = \sum_{n=0}^{\infty} f(nT)z^{-n}$

$$Z(t) = \sum_{n=0}^{\infty} nTz^{-n} = T \sum_{n=0}^{\infty} nz^{-n} = T z[n] = \frac{Tz}{(z-1)^2}$$

2

14. Find  $Z[\cos t]$

$$Z[\cos^2 t] = Z\left[\frac{1 + \cos 2t}{2}\right] = \frac{1}{2}\left[\frac{z}{z-1} + \frac{z(z - \cos 2T)}{z^2 - 2z \cos 2T + 1}\right]$$

15. Find the Z-transform of  $(nC_k)$

$$Z[nC_k] = \sum_{n=0}^{\infty} nC_k z^{-k} = 1 + nC_1 z^{-1} + nC_2 z^{-2} + \dots + nC_n z^{-n}$$

This is expansion of binomial theorem =  $(1+z^{-1})^n$

16. Evaluate  $Z^{-1}\left(\frac{z}{z^2 + 7z + 10}\right)$

(AU - M/J - 2010)-2

$$X(z) = \frac{1}{(z+5)(z+2)}$$

$$X(z)z^{n-1} = \frac{1}{(z+5)(z+2)} z^{n-1} = \frac{1}{(z+5)(z+2)} z^n \dots \dots \dots (1)$$

Here  $z = -2, -5$  are simple poles.

$$\begin{aligned} \text{Res } X(z)z^{n-1} &= \lim_{z \rightarrow -2} (z+2) \frac{z^n}{(z+2)(z+5)} \\ &= \frac{(-2)^n}{3} \end{aligned}$$

$$\text{Res}_{z=-5} X(z)z^{n-1} = \lim_{z \rightarrow -5} (z+5) \frac{z^n}{(z+2)(z+5)} = \frac{(-5)^n}{3}$$

$$X(n) = \text{sum of residues} = \frac{(-2)^n}{3} + \frac{(-5)^n}{3} = \frac{1}{3}[(-2)^n + (-5)^n]$$

**17. Evaluate**  $Z^{-1} \left( \frac{z^2}{(z-a)(z-b)} \right)$

(AU - N/D - 2015)

$$X(Z) = \frac{z^2}{(z-a)(z-b)}$$

$$X(Z)z^{n-1} = \frac{z^2}{(z-a)(z-b)} z^{n-1} = \frac{z^{n+1}}{(z-a)(z-b)}$$

$z=a$  and  $z=b$  are simple poles

$$\text{Res}_{z=a} X(z)z^{n-1} = \lim_{z \rightarrow a} (z-a) \frac{z^{n+1}}{(z-a)(z-b)} = \lim_{z \rightarrow a} \frac{z^{n+1}}{(z-b)} = \frac{a^{n+1}}{a-b}$$

$$\text{Res}_{z=b} X(z)z^{n-1} = \lim_{z \rightarrow b} (z-b) \frac{z^{n+1}}{(z-a)(z-b)} = \lim_{z \rightarrow b} \frac{z^{n+1}}{(z-a)} = \frac{b^{n+1}}{b-a}$$

$X(n) = \text{Sum of the residues}$

$$= \frac{a^{n+1}}{a-b} + \frac{b^{n+1}}{b-a} = \frac{1}{a-b} [a^{n+1} - b^{n+1}]$$

**18. Prove that  $Z[f(t+T)] = [ \bar{f}(z) - f(0) ]$ , where  $\bar{f}(z) = Z[f(t)]$**

$$Z[f(n+1)] = \sum_{n=0}^{\infty} f(n+1)z^{-n} = z \sum_{n=0}^{\infty} f(n+1)z^{-(n+1)} = z \sum_{m=0}^{\infty} f(m)z^{-m} \text{ where } m = n+1$$

$$= zF(z) - zf(0)$$

**19. Find the value of  $z[f(n)]$  when  $f(n) = na^n$**

(AU - N/D - 2014)

$$z[na^n] = -z \frac{d}{dz} [z(a^n)] = -z \frac{d}{dz} \left[ \frac{z}{z-a} \right] = \frac{az}{(z-a)^2}$$

**20. Prove that  $Z[nf(n)] = -z \frac{dF(z)}{dz}$**

(AU - A/M - 2018)-2

$$\text{Given: } F(Z) = Z[f(n)] \quad \frac{d}{dz} [F(Z)] = \sum_{n=0}^{\infty} (-n) f(n) z^{-n-1}$$

$$F(Z) = \sum_{n=0}^{\infty} a^n z^{-n} = - \sum_{n=0}^{\infty} n f(n) \frac{z^{-n}}{z}$$

$$z \frac{d}{dz} [F(Z)] = - \sum_{n=0}^{\infty} n f(n) z^{-n} = -Z[nf(n)]$$

$$Z[nf(n)] = -z \frac{dF(z)}{dz}$$

**21. State and prove initial value theorem in Z-transforms.**

(AU - A/M - 2017)-2

Initial value theorem in Z-transforms is given by

$$\text{If } Z[f(t)] = F(z), \text{ then } f(0) = \lim_{z \rightarrow \infty} F(z)$$

**Proof:**  $F[z] = Z[f(t)] = \sum_{n=0}^{\infty} f(nT)z^{-n}$

$$= f(0.T) + \frac{f(1.T)}{z} + \frac{f(2.T)}{z^2} + \dots$$

$$= f(0) + \frac{f(T)}{z} + \frac{f(2T)}{z^2} + \dots$$

$$\lim_{z \rightarrow \infty} F(z) = \lim_{z \rightarrow \infty} \left[ f(0) + \frac{f(T)}{z} + \frac{f(2T)}{z^2} + \dots \right]$$

$$= f(0).$$

**22. State final value theorem on Z-transform**

(AU - A/M - 2017)

If  $Z[f(t)] = F(z)$ , then

$$\lim_{t \rightarrow \infty} f(t) = \lim_{z \rightarrow 1} (z - 1)F(z)$$

**23. State convolution theorem on Z-transform.**

(AU - N/D - 2016)-3

The convolution theorem on Z-transform is given by

If  $Z[x(n)] = X(z)$  and  $Z[y(n)] = Y(z)$  then  $Z[x(n) * y(n)] = X(z) \cdot Y(z)$ .

**24. Form the difference equation by eliminating arbitrary constants from**

$$U_n = \alpha 2^{n+1}$$

(AU - N/D - 2017)-2

Given

$$U_n = a \cdot 2^{n+1} \dots \dots \dots (1)$$

$$U_{n+1} = a \cdot 2^{n+2}$$

$$U_{n+1} = a \cdot 2^{n+1} \cdot 2 \dots \dots \dots (2)$$

$$U_{n+1} = 2U_n \quad [\text{Using (1)}]$$

**25. Solve  $y_{n+1} - 2y_n = 0$ , given that  $y(0) = 2$**

(AU - N/D - 2012)

$$Z[y_{n+1}] - 2Z[y_n] = 0$$

$$zY(z) - zy(0) - 2Y(z) = 0 \text{ that implies } Y(z)(z-2) - 2z = 0$$

$$Y(z) = \frac{2z}{z-2}$$

$$y(n) = 2(2)^n = 2^{n+1}$$

**PART-B**

1. a. Find  $Z[n^3]$  and  $Z[e^{-t}t^2]$ .

(AU - N/D - 2016)-(8)

b. Find Z-transform of  $\left[ \frac{2n+3}{(n+1)(n+2)} \right]$  by using method of partial fraction. (AU - N/D - 2017)-2-(8)

2. a. Find  $Z[a^n r^n \cos n\theta]$  and  $Z[a^n r^n \sin n\theta]$ .

(AU - N/D - 2015)-2-(8)

b. Find the Z transform of  $\cos \frac{n\pi}{2}$  and  $\frac{1}{n(n+1)}$

(AU - A/M - 2016)

**(8)**

3. a. State and Prove initial value and Final value theorems.

(AU - A/M - 2010)(8)

b. Find  $Z\left[\frac{1}{(n+1)}\right]$  and  $Z[n]$

(AU - A/M - 2018)

**(8)**

4. a. Find  $Z^{-1}\left[\frac{2z}{(z-1)(z^2+1)}\right]$  by using integral method.

(AU - N/D - 2018)(8)

b. Find  $Z^{-1}\left[\frac{z^2-3z}{(z+2)(z-5)}\right]$  by residue method.

(AU - A/M - 2018)(8)

5. a. Find  $Z^{-1}\left[\frac{2z^2-10z+13}{(z-3)^2(z-2)}\right]$  when  $2 < |z| < 3$

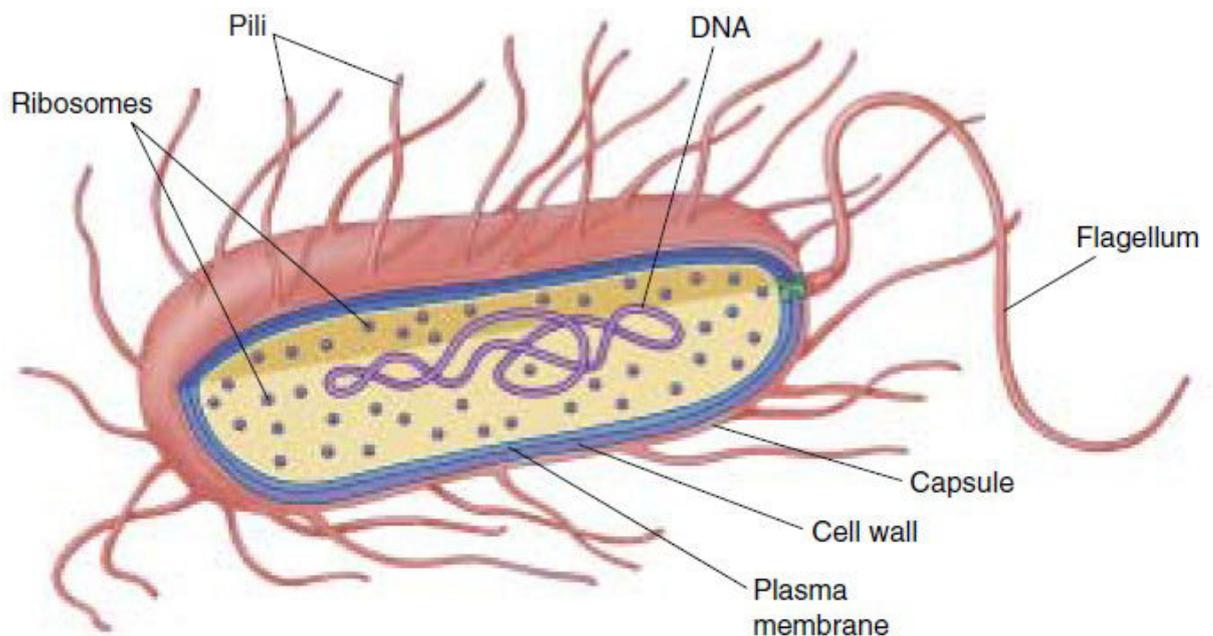
(AU - A/M - 2015)(8)

- b. Find  $Z^{-1} \left[ \frac{9z^3}{(3z-1)^2(z-2)} \right]$  by using residue method. **(AU - A/M - 2015)(8)**
6. a. Find  $Z^{-1} \frac{4z^3}{(2z-1)^2(z-1)}$  by using method of partial fraction. **(AU - A/M - 2017)(8)**
- b. Find the inverse z-transform of  $\frac{z}{z^2 - 2z + 2}$  by residue method. **(AU - A/M - 2015)(8)**
7. a. Find  $Z^{-1} \frac{z^3}{(z-1)^2(z-2)}$  by using method of partial fraction. **(AU - A/M - 2017)(8)**
- b. Using the inversion integral method, find the inverse Z-transform of
- $$U(Z) = \frac{z^2}{(z+2)(z^2+4)}$$
- (AU - A/M - 2015)(8)**
8. a. If  $U(Z) = \frac{2z^2 + 5z + 14}{(z-1)^4}$ , find  $u_2$  and  $u_3$ . **(AU - N/D - 2018)(8)**
- b. Derive the difference equation from  $y_n = (A+Bn)(-3)^n$
9. a. Using Convolution theorem evaluate  $Z^{-1} \left[ \frac{z^2}{(z-1)(z-3)} \right]$  **(AU - N/D - 2018)**
- (8)**
- b. Using Convolution theorem evaluate  $Z^{-1} \left[ \frac{z^2}{(z-a)^2} \right]$  **(AU - M/J - 2016)**
- (8)**
10. a. Find  $Z^{-1} \left[ \frac{z^2}{\left(z - \frac{1}{2}\right)\left(z - \frac{1}{4}\right)} \right]$  by using Convolution theorem. **(AU - N/D - 2017)(8)**
- b. Using Convolution theorem evaluate  $Z^{-1} \left[ \frac{z^2}{(z-3)(z-4)} \right]$  **(AU - A/M - 2015)**
- (8)**
11. a. Find  $Z^{-1} \left[ \frac{z^2}{(z-a)(z-b)} \right]$  by using Convolution theorem. **(AU - M/J - 2014)-3-(8)**
- b. Using Convolution theorem evaluate  $Z^{-1} \left[ \frac{8z^2}{(2z-1)(4z+1)} \right]$  **(AU - A/M - 2018)-3-(8)**
12. a. Solve  $y_{n+2} - 4y_{n+1} + 4y_n = 0$  given  $y_0 = 1$  and  $y_1 = 0$ . **(AU - A/M - 2018)-3-(8)**
- b. Using Z- Transform solve the equation  $u_{n+2} + 3u_{n+1} + 2u_n = 0$  given  $u(0) = 1$  and  $u(1) = 1$  **(AU - A/M - 2015)-(8)**
13. a. Using Z- Transform solve the equation  $u_{n+2} - 5u_{n+1} + 6u_n = 4^n$  given  $u(0) = 0$  and  $u(1) = 1$ . **(AU - M/J - 2014)-2-(8)**
- b. Using Z-Transform solve the equation  $y_{n+2} - 5y_{n+1} + 6y_n = 1$  given  $y(0) = 0$  and  $y(1) = 1$ . **(AU - N/D - 2018)(8)**
14. a. Solve  $y_{n+2} + y_n = 2$  given  $y_0 = 0$  and  $y_1 = 0$  by using Z-transforms. **(AU - M/J - 2016)(8)**
- b. Solve using z-transform,  $y_{n+2} - 7y_{n+1} + 12y_n = 2^n$  given  $y_0 = 1$  and  $y_1 = 0$  **(AU - N/D - 2017)-3-(8)**
15. a. Solve  $y_{n+2} + 6y_{n+1} + 9y_n = 2^n$ , given  $y_0 = y_1 = 0$ . **(AU - M/J - 2016)(8)**
- b. Solve using z-transform,  $y_{n+2} - 3y_{n+1} - 10y_n = 0$  given  $y_0 = 1$  and  $y_1 = 0$ . **(AU - M/J - 2014)(8)**

**UNIT I**  
**CELL STRUCTURE AND FUNCTION OF THE ORGANELLES**  
**PART – A**  
**TWO MARKS QUESTION AND ANSWERS**

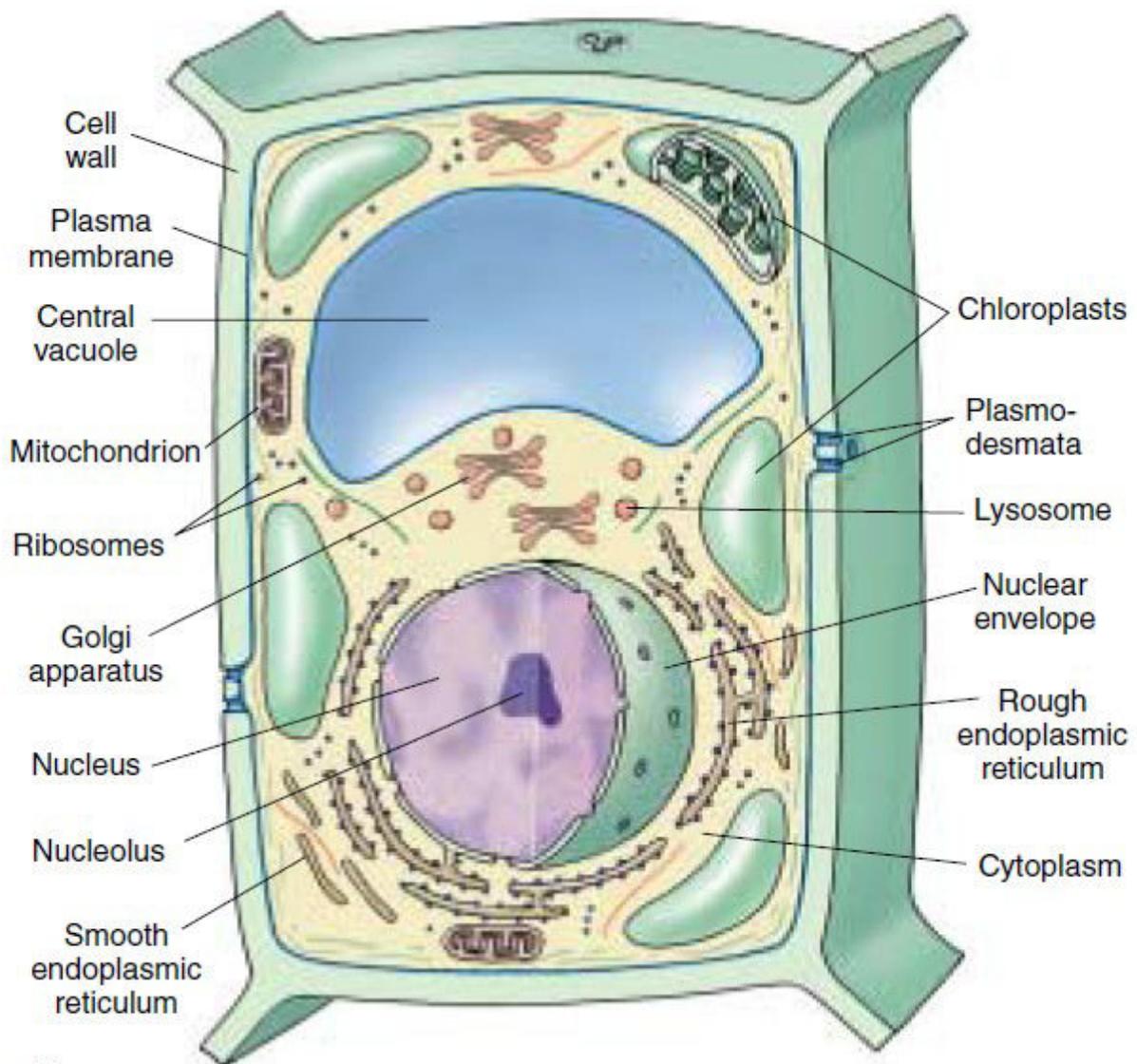
**1. Define prokaryotic cell and draw the structure of bacterial cell.**

Prokaryotic cell is the single closed compartment that is surrounded by plasma membrane. It lacks a defined nucleus and it lack histones. It has simple internal organization. Example: Bacteria.



**2. Define eukaryotic cell and draw the structure of plant cell.**

Single membrane (plasma membrane) surrounds the cell. But interior contains many membrane-limited compartments/organelles. It is the defining characteristics and segregation of cellular DNA within a defined nucleus which is bounded by double membrane. Example: fungi, yeast, plants and animals.



**3. What is the main role of lysosomes and peroxisomes?**

Lysosome is the acidic organelle and contains degradative enzymes. It is a single membrane vesicle containing hydrolytic enzyme which function for intracellular and extracellular digestion; digest materials taken in by endocytosis and pinocytosis.

Peroxisome is spherical form rich in oxidative enzyme and other such as catalase, peroxidase and D-amino acid oxidase common in plant cell carry our oxidative reactions. It degrades fatty acids and toxic components.

**4. Define cisternae. Write the types of endoplasmic reticulum.**

It is a network of closed, flattened membrane bound sac called cisternae. The types are smooth endoplasmic reticulum and rough endoplasmic reticulum. Smooth endoplasmic reticulum is smooth because of lack of ribosomes. The fatty acid and phospholipid synthesis takes place. The cytosolic face of rough endoplasmic reticulum has ribosomes. It synthesize certain membrane and organelle protein and virtually all protein to be secreted from cell.

**5. Define chloroplasts, thylakoid and grana.**

Chloroplast is spheroid/ovoid structures in plant cell and it contains complex system of thylakoid membrane in their interiors. These membranes contain pigments and enzymes that absorb light and produce ATP during photosynthesis.

Thylakoid is an extensive internal system of inter-connected membrane limited sac called thylakoid which are flattened to form disks. Thylakoid often form stack called grana and are embedded in matrix, the stroma.

6. **Write the properties of lipid bilayer.**

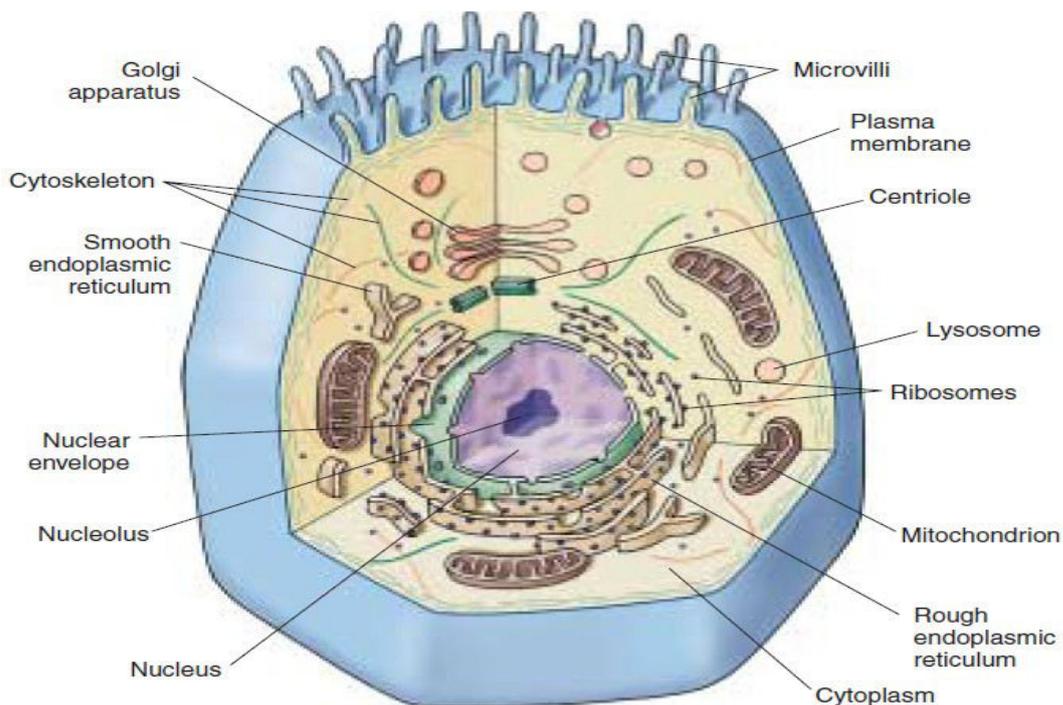
Hydrophobic core is an impermeable barrier that prevents the diffusion of water-soluble (hydrophilic) solutes across the membrane. The second property of bilayer is stability. It is maintained by hydrophobic and van der Waal interaction between lipid chains. Even though the exterior aqueous environment can vary ionic strength and pH, the bilayer has retained its strength and stability.

7. **What are the classes of lipids and proteins found in biomembrane?**

Phosphoglycerides, Spingholipids and steroids are the three classes of lipids found in biomembrane. All are amphipathic molecules having polar (hydrophilic head) and non-polar (hrdrophobic tail). Integral protein, Lipid-anchored protein and Peripheral protein can be classified into three based on the nature of membrane-protein interaction.

8. **What is FRAP? Draw the structure of animal cell.**

The lateral movement of specific plasma membrane protein and lipid can be quantified by a technique called Fluorescence Recovery after Photo bleaching (FRAP). In this method, rate at which membrane lipid/protein molecules moved and their diffusion coefficient can be determined as well as proportion of molecules are laterally mobile.



9. **Define lipid-anchored membrane protein.**

Lipid-anchored membrane proteins are bound covalently to one/more lipid molecules. The hydrophobic carbon chain of attached lipid is embedded in one leaflet of membrane and anchors the protein to the membrane. The polypeptide chain itself does not enter the phospholipid bilayer.

10. What is osmosis?

Osmosis is defined as water move across such a semi-permeable membrane from a solution of low solute (high water) concentration to one of high solute (low water) concentration until total solute concentration and this water concentration on both sides are equal.

11. Define the term isotonic, hypertonic and hypotonic solution.

When most cells animal cells are placed in isotonic medium (one with total concentration of solute equal to that of cell interior) there is no net movement of water in/out of the cells.

- a. In hypertonic solution (one with higher solute concentration than that of cell interior), water flows out of the cell and causing them to shrink.
- b. In hypotonic solution (one with lower solute concentration than that cell interior), water flows into the cell and causing them to swell.

12. Define the term plasmodesmata and desmosome.

Adjacent plant cell are held together by a thin layer of cementing material called middle lamella. Such cells are further interconnected by fine channels passing through the cell wall and the middle lamella. These are called plasmodesmata.

Desmosome are composed of fine tonofilament that run across two parallel thickenings of cell in some regions, separated by intercellular spaces. It provide anchorage to the adjacent cells by strong point of attachments.

13. Define tight junction and explain the function of gap junction.

Tight junction is formed through fusion of plasma membrane of adjacent cells at the point of contact, without leaving an intercellular space. They may be belt-like/band-like in form, completely sealing off the area of contact.

The main role of gap junction/nexus is to form cellular adhesion and also to form intercellular communication by metabolic coupling and electrical coupling.

14. What is ECM? (Nov/Dec 2015) Explain the functions.(Nov/Dec 2014)

Cells frequently need to protect themselves from environment by developing extra cellular matrix (ECM) around a gap of cells. It is a complex structural entity that surrounds and supports cells. It often refers as connective tissue. The extracellular materials secreted from cell themselves perform a variety of functions:

They help in adhesion of cell layers.

They allow movement of cells to different locations.

They form sieve-like structures for flow of macromolecules.

They help in the formation of different layers of cells and

They provide extraneous structures.

15. What is CAM and SAM?

- a. Cell Adhesion Molecules (CAM) is family of proteins which have very high content of sialic acid responsible for cell aggregation. They may be seen from projecting from bilipid layer of plasma membrane.
- b. Substrate Adhesion Molecules (SAM) is a cell attaches to an artificial substrate, it starts secreting an extracellular material/microexudate. This microexudate/SAM contains fibronectin, heparin sulphate ,glycosaminoglycans and trace amounts of collagen.

16. What is collagen?

- a. Collagen is fibrous protein of high tensile strength. It is characteristic of connective tissue present in all animals abundant in skin, bone, tendons and cartilage. It is secreted in extracellular space from which it can be extracted. The collagen fibers are polymers composed of three polypeptide chains twisted around each other and bonded by hydrogen bonds and hence called trimers.

17. Define glysoaminoglycans.

Glycosaminoglycans are sugar polymers which are different from other glucose polymers (starch, glycogen etc.). These are amorphous in appearance, extremely viscous and occupy huge space. The carbohydrate chain of glycosaminoglycans exists as repeating disaccharide as wells in which one of the sugar is always an aminosugar, either N-acetylglucosamine or N-acetylgalactosamine.

18. What is cytoskeletal protein?

The interior of the cell matrix is well-organized and consists of reticulum of protein fibers responsible for its shape and organization. This has been named as cytoskeletal protein. It is composed of three well-defined fibrous components. They are Microfilament, Microtubule and Intermediate filament.

19. Explain the function of microfilament.

Muscle contraction, cell movement, nerve outgrowth, tubular gland formation, movement of intestinal microvilli, gastrulation and cytoplasmic streaming. In animal cells, cytokinesis and cell division are brought by microtubule of spindle.

20. Define tubulin and micelle.

Microtubule is a hollow cylindrical cell organelles of each microtubule made up of globular protein subunits called tubulin. The tubulin subunits are spirally arranged and it is formed in pair is called heterodimer.

21. Micelle is the amphipathic substances were found to emulsify mixtures of immiscible polar and non-polar liquids in the form of spherical droplets coated with monolayers; in aqueous solution spherical micelles (i.e., bilayer envelopes) could be formed under certain conditions.

22. Write the importance of carbon and water to the cells. (Apr/May 2018)

Cells are composed of water, inorganic ions, and carbon-containing (organic) molecules. Water is the most abundant molecule in cells, accounting for 70% or more of total cell mass. The interactions of polar and nonpolar molecules with water and with each other play crucial roles in the formation of biological structures, such as cell membranes. Carbon is the basis of many of the complex organic compounds vital to life, such as the glucose ring (along with a single oxygen molecule), and the backbone of the polypeptide chains that form the different proteins in the bodies of living things.

23. Differentiate prokaryotic cell and eukaryotic cell with example. (Apr/May 2018)

Prokaryotic cell is the single closed compartment that is surrounded by plasma membrane. It lacks a defined nucleus and it lack histones. It has simple internal organization. Example: Bacteria.

Eukaryotic cell is the Single membrane (plasma membrane) surrounds the cell. But interior contains many membrane-limited compartments/organelles. It is the defining characteristics and segregation of cellular DNA within a defined nucleus which is bounded by double membrane. Example: fungi, yeast, plants and animals.

24. What are desmosomes? (Apr/May 2018) & (May/June 2016)

Desmosome are composed of fine tonofilament that run across two parallel thickenings of cell in some regions, separated by intercellular spaces. It provide anchorage to the adjacent cells by strong point of attachments.

25. What is the basic difference in the organization of DNA in prokaryotic and Eukaryotic cell? (May/June 2016)

Prokaryotic DNA:

Is found freely in the cytoplasm (within a region called the nucleoid)

Is naked (i.e. not bound with proteins and therefore doesn't form chromatin)

Genomes are compact (contain little repetitive DNA and no introns)

Eukaryotic DNA:

Is contained within a nucleus

Is bound to histone proteins

Genomes contain large amounts of non-coding and repetitive DNA (including introns)

26. What is the function of peroxisomes? (May/June 2016)

Peroxisome is spherical form rich in oxidative enzyme and other such as catalase, peroxidase and D-amino acid oxidase common in plant cell carry our oxidative reactions. It degrades fatty acids and toxic components.

27. Describe the function cell adhesion molecules. (May/June 2016)

The adhesion of cells to one another to provide organised tissue structure  
the transmission of extracellular cues and signals across the cell membrane  
the migration of cells through the regulation of CAM assisted adhesions

28. What are the functions of membrane bound proteins? (Nov/Dec 2014)

The functions of membrane bound proteins are Signal transduction, Cell-cell recognition, Intercellular joining, Enzymatic activity, Cell-cell recognition and Attachment to the cytoskeleton and extracellular matrix (ECM).

29. What is the significance of motor protein? (Nov/Dec 2014)

Motor proteins are enzymes that convert chemical energy into motion. Chemical energy is obtained from the hydrolysis of ATP and the motion is generated by the conformational changes depending on the bound nucleotide such as myosin, kinesin and dynein. Motor proteins play an important role in muscle contraction, cell migration, chromosome segregation, morphogenesis and beating of sperms and cilia.

30. What are the three types of endocytosis? (Nov/Dec 2014)

The three types are Phagocytosis, Pinocytosis and Receptor-Mediated Endocytosis.

31. What are functions of flagella and pili? (Nov/Dec 2015)

The function of flagella is to assist in locomotion, act as sensory organ and adhesion. The primary function of pili is to attach a bacterial cell to specific surfaces or to other cells. Pili can also aid in attachment between bacterial cells. Some bacteria are able to produce conjugation pili that allow for the transfer of DNA from one bacterial cell to another.

32. What is the importance of cytoskeleton protein? (Nov/Dec 2015)

The interior of the cell matrix is well-organized and consists of reticulum of protein fibers responsible for its shape and organization. This has been named as cytoskeletal protein. The cytoskeleton provides structure like our skeleton, but it also acts like a highway to transport materials around the cell, allows cells to move, and aids in cell division.

#### **PART-B (16 MARKS QUESTIONS)**

33. Draw neatly the structure of prokaryotic and eukaryotic cell and differentiate between them.

34. Explain the location and functions of mitochondria, chloroplasts and nucleus.

35. Define clathrin. Elaborate the endoplasmic reticulum, golgi vesicles and endosome.

36. Describe in detail about the eukaryotic structure and its organelles.

37. Explain in detail about the lipid composition and structural organization of biomembrane.

38. Write elaborately about the bio membrane of protein.

39. Explain in detail about CAM and CJM.

40. Define ECM. Elaborate your answer.

41. Explain in detail about the cytoskeletal protein.

42. Describe the process of peroxisome, lysosome, ribosome and vacuole.

43. Explain about microtubule and microfilament.

44. How the lipid composition influences the physical properties of membrane? Explain FRAP.

45. Describe elaborately cell-cell junction.

46. Define the term: Desmosome, gap junction, plasmodesmata and draw the structure of lipid bilayer.

47. Describe in detail about intermediate filament, integral membrane protein and peripheral membrane protein.

48. What are cytoskeletal proteins? Explain their types, structure and functions? (Apr/May 2018)

49. Describe the structure and function of cell membrane and Give a detailed account on

tight junctions. (Apr/May 2018)

50. Draw a neat diagram explain the characteristic feature of eukaryotic cell and describe the function of their organelles. (May/June 2016)
51. Explain the structure and function of microfilament, (May/June 2016)
52. Explain about gap junctions and connexins. (May/June 2016)
53. Describe the structure and functions of mitochondria and golgi apparatus. (Nov/Dec 2014)
54. Elaborate the structural organization of cell membrane. (Nov/Dec 2014) & (Nov/Dec 2015)
55. Describe the structure of prokaryotes. (Nov/Dec 2014) & (Nov/Dec 2015)
56. Explain the structural organization of three types of cytoskeleton proteins. (Nov/Dec 2014)
57. Describe cell-cell junction and cell-cell matrix junction. (Nov/Dec 2014)
58. Describe the structure and functions of nucleus and mitochondria. (Nov/Dec 2015)
59. Elaborate microtubule structure and function. (Nov/Dec 2015)
60. Discuss about various types of cell junctions. (Nov/Dec 2015)

**UNIT II**  
**CELL DIVISION, CANCER, APOPTOSIS AND IMMORTALIZATION OF CELLS**  
**PART – A**  
**TWO MARKS QUESTION AND ANSWERS**

1. What is cell cycle?

In eukaryotic cells, the cells are divided by a complex process of mitosis. Eukaryotic cell division takes place through a series of orderly events known as cell cycle.

2. What are the different phases of cell cycle?

The different phases of cell cycle are Gap1 (G1 phase), S phase, Gap 2 (G2 phase), Mitosis (M phase).

3. Define mitosis.(Apr/May 2018)

Mitosis is defined as the “division of a cell into two identical daughter cells each with a nucleus having the same amount of DNA, the same number of chromosome and the same amount of genes as the parent cell”.

4. What are types of mitosis occurs in organisms?

The types are intranuclear mitosis, extranuclear mitosis, anastral mitosis, astral mitosis, endomitosis, symmetrical mitosis and asymmetrical mitosis.

5. Define karyokinesis and cytokinesis.

The division of nuclei into two daughter nuclei is called karyokinesis. The division of cytoplasm into two daughter cells is called cytokinesis.

6. What are the phases of karyokinesis? Define cell plate.

It consists of four phases are prophase, metaphase, anaphase and telophase. The phragmoplasts are fuse together to form a flat disc like structure called cell plate.

7. Define phragmoplasts.

8. After the completion of karyokinesis in plant cell, a cell plate develops between the two daughter nuclei. Many small vesicles developed from golgi complex and endoplasmic reticulum get

accumulated at the equatorial plane across the spindle fiber. These vesicles are called phragmoplasts.

9. Define meiosis. (Apr/May 2018)

Meiosis is also called reduction division because the chromosome number is reduced to haploid from diploid. It takes place only in reproductive cells during the formation of gametes. The cells in which meiosis takes place are termed meiocyte. Meiosis produces four daughter cell from parent cell.

10. What is meant by heterotypic and homotypic division?

It is the first meiotic division during which the diploid cell is divided into two haploid cells. The daughter cell resulting from the divisions are different from the parent cell in chromosome number. Hence the first meiotic division is called heterotypic division.

It is the second meiotic division. During this division the two haploid cells are formed during the first meiotic division divide into four diploid cells. The daughter cells are similar to parent cells in the chromosome number. Hence this division is called homotypic division.

11. Define the term bivalent, diad, synapsis and boquetsatge.

Two homologous chromosomes approach each other and begin to pair. The pairing is called synapsis. Each pair consists of a maternal chromosome (the chromosome of the mother) and a paternal chromosome (the chromosome of the father). The pairs so termed are bivalents.

The pairing usually starts from ends, and proceed towards the centromere. This peculiar state of orientation, polarization and association is described as boquet stage.

12. When separated in each chromosome the sister chromatids are connected by a centromere. This stage of the chromosome is called diad.

13. Define chiasmata.

The homologous chromosomes of each pair begin to separate because of the gradual disappearance of force of attraction between them. However, the two homologous chromosomes don not completely separate but remain attached together at one/more points as indicated by X arrangements known as chiasmata.

14. Define crossing over.

The two homologous chromosomes don not completely separate but remain attached together at one/more points as indicated by X arrangements known as chiasmata. The chromatids break at these points. The broken segments are interchanged. As a result a genetic recombination takes place. The interchange of chromatin material is described as crossing over.

15. Define tetrad.

Each individual chromosome of each bivalent begins to split longitudinally into two similar chromatids. As a result each bivalent now contains four chromatids. This is described as tetrad stage.

16. Write the significance of meiosis.

Gametes are produced by meiosis

If there is no meiosis, the chromosome number is doubled/quadrupled. This would result in formation of monostrositis (abnormal forms).

The constant number of chromosome in a given species is maintained by meiosis.

Owing to crossing over, the hereditary factors(gene) from male and female parents get mixed. This causes genetic variation among species variations are the raw materials for evolution.

17. What are the types of tumour?

There are two types of tumour. They are Benign and malignant tumour. Benign tumour are always localized and consists of well differentiated cell similar to tissue of origin. Such tumours never

establish growth in other parts of the body. Malignant tumors are usually invasive type of tumour derived from single cell, thus monoclonal in character. Clusters/ group of malignant cells are detached from malignant neoplastic growth and get distributed to other location in the body through circulation where they establish secondary tumours. It can be called as metastasis.

18. Define the term carcinoma and sarcoma. Expand MAP and ERK.

Tumours originating from ectoderm/endoderm give rise to carcinoma. Tumours originating from mesoderm is called sarcoma. MAP- Mitogen-activated protein kinase and ERK-Extracellular signal regulated kinase.

19. Define ras.

20. Ras protein are prototype of large family of approximately 50 related proteins frequently called small GTP-binding protein because Ras and its relatives are about half the size of G-protein alpha subunit. While Ras protein regulate cell growth and differentiation. Activation of ERK is mediated by two upstream protein kinase which are coupled to growth factor receptor by a GTP-binding protein called Ras.

21. Differentiate apoptosis Vs necrosis.

Apoptosis ( Programmed Cell Death- PCD) is a well-defined process and regulated series of events and is an active process distinct from death in response to tissue damage; in which cells die in a process called necrosis. In apoptosis, content of the cell are not released in extracellular but in necrosis, contents are released leads to damage surrounding cells called inflammation.

22. Define stem cell.

Stem cells are undifferentiated biological cell give rise to renewing cell population of body through well directed pathway of differentiation. In mammals, stem cells are broadly divided as Embryonic stem cell (ESC) and Adult stem cell (ASC).

23. What are the sources of stem cell? Explain totipotent, pluripotent and multipotent stem cell.

Bone marrow, adipose tissue and Umbilical cord blood are the main sources of stem cell.

Totipotent stem cell also called omnipotent cell can differentiate into any type i.e., embryonic and extra-embryonic types to produce a complete viable organism. Pluripotent stem cell are descendants of totipotent cell and can differentiate into all kinds of cells in body since these cells are derived from any of three germ layers. Multipotent stem cell can differentiate into limited number of types which form closely related family of cells.

24. What is the feature of crossing over in meiosis? (Nov/Dec 2014)

Occurs at two levels, at gross chromosomal level (chromosomal recombination) and at DNA level (genetic recombination).

Occurs between non-sister chromatids of homologous chromosomes.

Exchange is normally reciprocal but sometimes unequal.

Frequency of crossing over is closely related to physical distance between genes located on chromosomes.

### **PART-B (16 MARKS QUESTIONS)**

25. What is cell cycle? Explain the phase of cell cycle with a neat diagram.

26. Describe in detail about mitosis and the significance of mitosis with a neat diagram.

27. Describe in detail about meiosis and the significance of meiosis with a neat diagram.

28. Explain the heterotypic division of meiosis with a neat diagram.

29. Explain in detail about the control of cell cycle with a neat diagrammatic representation.

30. How cell become cancerous? Explain the characteristics and types of cancer cells.

31. Describe in detail about the activation of Ras and Raf in oncogenesis.

32. Differentiate the morphological difference occur in apoptosis and necrosis with a neat diagram. How to activate caspase and its role?

33. Classify stem cell and explain it in detail. Write the applications of stem cell.

34. Explain in detail about cytokinesis in plant cell with a neat diagram and the significance of mitosis.
35. Describe in detail about the karyokinesis with a neat diagram and the significance of meiosis.
36. Classify the types of malignancies. What are the physiological properties of cancer cells?
37. How to activate and regulate Ras protein? Explain in detail.
38. Describe in detail about growth of cultured cells and maintenance of cell subpopulation.
39. Discuss the available cancer treatments and their side effects. Write the significance of
40. mitosis and meiosis.

#### PART B

41. Define cell cycle. Explain in detail of regulation of cell cycle. (Apr/May 2018),  
(Nov/Dec 2014) & (Nov/Dec 2015)
42. Explain the different phases of mitosis with a neat diagram. (Apr/May 2018) & (May/June 2016)
43. Explain the stages of meiosis. (Nov/Dec 2015)

**UNIT III**  
**TRANSPORT ACROSS CELL MEMBRANE**  
**PART – A**  
**TWO MARKS QUESTION AND ANSWERS**

1. What is passive transport?
2. In passive transport, the transported species always moves down its electrochemical gradient and is not accumulated above the equilibrium point.
3. Define active transport?
4. In active transport, the accumulation of solute above the equilibrium point. It is thermodynamically unfavorable (endergonic) and occurs only when coupled (directly/indirectly) to an exergonic process such as absorption of sunlight, an oxidation reaction, the breakdown of ATP/concomitant flow of some other chemical species down its electrochemical gradient.
5. What are the types of active transport?
6. The types are primary active transport and secondary active transport.

Primary active transport, solute accumulation is coupled directly to an exergonic chemical reaction such as conversion of ATP to ADP and inorganic phosphate.

Secondary active transport, occurs when endergonic transport of one solute is coupled to exergonic flow of different solute that was originally pumped by primary active transport.

7. Write a short note on permeases?

All members of very large and diverse ABC superfamily of transport proteins contain two transmembrane domain and two cytosolic ATP-binding domain. The plasma membrane of many bacteria contain numerous permeases belong to ABC superfamily. These proteins use the energy released by ATP hydrolysis to transport specific aminoacid, sugar, vitamins/even peptides into the cell. Example: Bacterial permeases, In *E.coli* histidine permeases.

8. Write a note on ion channels?

The plasma membrane contains channel proteins that allow the principal cellular ions ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Cl}^-$ ) to move through them at different rates down their concentration gradient. Ion concentration gradient generated by pumps and selective movement of ions through channels constitute the mechanism by which difference in voltage/electric potential is generated across plasma membrane.

9. Define ATP pumps and classify its classes.

ATP powered pump transport ions and small molecules against their concentration gradient. It is a transmembrane protein. It is located in cytosolic face of membrane (ATP) these proteins are called ATPases. Unless ions/other molecules are transported they cannot be hydrolysed (ATP) into ADP and  $\text{P}_i$ .

ATP Pumps are classified as P class, F class, V class and ABC superfamily. P, F and V transport ions only. ABC superfamily transport primarily small molecules.

10. Which drug is used to inhibit ATPase activity?

Drug Ouabain, which binds to specific region on exoplasmic surface of protein and specifically inhibits its ATPase activity, also prevent cells from maintaining their  $\text{Na}^+/\text{K}^+$  balance.

11. Define electrochemical gradient.

If a transported substance carries a net charge, its movement is influenced by both its concentration gradient and membrane potential, the electrical potential (voltage) across the membrane. The combination of these two forces called electrochemical gradient, determines energetically favorable direction of transport of charged molecule across the membrane.

12. Define facilitated diffusion.

Channel proteins transport water/specific types of ions and hydrophilic small molecules down their concentration gradient or electrical potential gradient. Such protein-assisted transport is referred as facilitated diffusion.

13. Differentiate between gated and non-gated channel.

Channel proteins form a hydrophilic passage way across the membrane through which multiple water molecules or ions move simultaneously at very rapid rate. Some ion channels are open much of time; these are referred as non-gated channel.

Most ion channels are open only in response to specific chemical/electric signal; these are referred as gated channel.

14. What are transporter and its types?

Transporters (also called carriers) move wide variety of ions and molecules across cell membranes. There are three types of transporters. They are Uniport, Symport and Antiport.

15. Define Uniport with an example.

16. Uniport transport a single type of molecule down its concentration gradient via facilitated diffusion. Example: Glucose and amino acid cross plasma membrane into most mammalian cells with the aid of uniporters.

17. Define cotransporter.

Antiport and symport couple the movement of one type of ion/molecule against its concentration gradient with the movement of one/more different ions down its concentration gradient. The proteins often called cotransporter refer ability to transport two different solute.

18. What is voltage – gated channel with an example?

Action potential is sudden membrane depolarization followed by rapid repolarization. An action potential resulting from sequential opening and closing of voltage gated  $\text{Na}^+$  and  $\text{K}^+$  channel in plasma membrane of neuron and muscle cells.

19. What is the ligand gated ion channel with an example?

The ligands for ion channels are synaptic neurotransmitters, the binding of which results in either opening/closing of channel. In either case, the ion gradient is altered, which changes the electrical potential across the membrane. Example: Acetylcholine.

20. Define agonist.

Drugs targeted to membrane receptors can have a variety of effects. They may elicit same biological effects as natural ligands. If so they are called agonists. Agonist which mimic the function of normal hormone by binding to its receptor and inducing normal response.

21. Define antagonist.

Antagonists inhibit the effect of natural ligand (hormone, neurotransmitter), agonist, partial agonist and even inverse agonist. Antagonist which bind to the receptor but induce no response.

22. Define partial agonist and inverse agonist.

Partial agonist, binds at same binding site and leads in absence of natural ligand to either a full/partial response. Inverse agonist, when applied to the receptor that has a basal or constitutive activity in absence of a bound ligand.

23. What are the types of antagonists?

The types of antagonists are competitive antagonists, non-competitive antagonists and irreversible antagonists.

24. Define allosteric antagonists.

Allosteric antagonists bind to an allosteric site on the receptor, inducing a conformational change in receptor so the ligand, agonist, partial agonist could not bind.

### **PART-B (16 MARKS QUESTIONS)**

25. Describe antagonist and its types with a neat picture.

26. Describe in detail about agonist with an example.

27. Describe ligand gated channel and explain with an example.

28. How the voltage gated ion channel works? Explain the operational mode of voltage gated ion Channel with a neat diagram.

29. Explain in detail about the depolarization, repolarization an resting state in voltage gate channel with an example.

30. Explain in detail about the different types of transporters with an example.

31. Describe the mechanism of action of  $\text{Na}^+/\text{K}^+$  ATPase.

32. Describe the mechanism of action of  $\text{Ca}^{2+}$  ATPase.

33. Explain in detail about muscle  $\text{Ca}^{2+}$  ATPase pump.

34. Define ATP pumps. Classify its types in detail with a neat diagram

35. Discuss the various ion channels and permeases.

36. Differentiate between passive and active transport with a neat diagram. Write a note on permeases.

37. Give a detail introduction about transporters and its types.
38. Explain about uniport and symport with a neat diagram.
39. Explain in detail about the ligand and voltage gated ion channel.

## University Question Bank

### PART A

40. Give a brief note on Agonist. (Apr/May 2018)

Drugs targeted to membrane receptors can have a variety of effects. They may elicit same biological effects as natural ligands. If so they are called agonists. Agonist which mimic the function of normal hormone by binding to its receptor and inducing normal response.

41. What is the need for membrane transport? (Apr/May 2018)

Membrane transport is essential for cellular life. Transport may involve the incorporation of biological molecules and the discharge of waste products that are necessary for normal function. Membrane transport refers to the movement of particles (solute) across or through a membranous barrier. example, phospholipid bilayer. Membrane transport is dependent upon the permeability of the membrane, transmembrane solute concentration, and the size and charge of the solute.

42. What are the three types of endocytosis? (Nov/Dec 2014)

The three types of endocytosis are Phagocytosis, Pinocytosis and Receptor-mediated endocytosis.

43. What is lactose permease? (Nov/Dec 2014)

Lactose permease (LacY) is an integral protein that facilitate the passage of lactose. The active transport uses the energy of the electrochemical proton gradient, i.e. one  $H^+$  is transported in with each sugar (co-transport). The proteins play a critical role in transmembrane traffic. Malfunction of these transporters is associated with various pathophysiological conditions, such as diabetes and depression.

44. What are the roles of cyclin and cyclin dependent kinase? (Nov/Dec 2015)

Cyclin-dependent kinase, or CDK, is a type of enzymatic protein that resides in eukaryotic cells and plays a key role in cellular metabolism and renewal, a series of biological processes collectively referred to as the cell cycle. The mechanism of CDK activity is based on phosphorylation, or the process of contributing phosphate groups to substrate proteins. However, in order for a protein to be modified by phosphorylation, it must form a complex with another kind of protein known as cyclin. This is why this particular specialized protein is termed cyclin-dependent kinase.

45. Define facilitated diffusion. Give an example. (Nov/Dec 2015)

Facilitated diffusion is a form of facilitated transport involving the passive movement of molecules along their concentration gradient, guided by the presence of another molecule – usually an integral membrane protein forming a pore or channel. It does not directly involve ATP or GTP since the molecules are moving along their concentration gradient. Example: Glucose transporter, Ion channels.

46. Give the differences between symporter and antiporter with examples. (Nov/Dec 2015)

**Symport:** When the transported molecule and cotransported ion move in the same direction, the process is called symport. Example: Na<sup>+</sup> linked symporter

**Antiport:** When the transported molecule and cotransported ion move in the opposite direction, the process is called antiport. Example: Glycerol-3-phosphate

47. What are the processes included in co-transport? (May/June 2016)

Cotransporters are proteins that transport two different solutes such as glucose and amino acids simultaneously across the cell membrane against a concentration gradient. It mediates coupled reactions in which an energetically unfavorable reaction (uphill movement of molecules) is coupled to an energetically favorable reaction. Cotransporters can be divided as Symport and Antiport.

48. What are the function of permeases? (May/June 2016)

Like the cell membrane, membranes of some organelles contain transport proteins, or [permeases](#), that allow chemical communication between organelles. Permeases in the lysosomal membrane, for example, allow [amino acids](#) generated inside the lysosome to cross into the [cytoplasm](#), where they can be used for the synthesis of new proteins. Communication between organelles is also achieved by the membrane budding processes of endocytosis and exocytosis, which are essentially the same as in the cell membrane.

#### **PART B**

49. Explain in detail about K<sup>+</sup> pump and its transport mechanism with a neat sketch. (Apr/May 2018)

50. Explain in detail about calcium pump and its transport system. (Apr/May 2018)

51. Describe the various types of active transport and ion channels. (Nov/Dec 2014)

52. i) Discuss simple diffusion and facilitated diffusion. (Nov/Dec 2014)

ii) Describe the types of agonist and antagonist with examples. (Nov/Dec 2014)

53. Describe various types of active transports with appropriate examples. (Nov/Dec 2015)

54. i) Explain agonist, antagonist and its types with examples. (Nov/Dec 2015)

ii) Explain ion channels and its role in cells. (Nov/Dec 2015)

55. Explain the co-transport of Na<sup>+</sup> and K<sup>+</sup> by ATPase mechanism. (May/June 2016)

56. Describe co-transport and uniport systems. (May/June 2016)

## **UNIT IV SIGNAL TRANSDUCTION PART – A TWO MARKS QUESTION AND ANSWERS**

1. Define signal transduction.

2. The overall process of converting signals into cellular responses as well as individual steps in this process is termed as signal transduction.

3. What are the types of signaling?

Signaling by soluble extracellular molecules can be classified into three types. They are endocrine, paracrine and autocrine signaling based on the distance over which signal acts. Certain membrane-bound protein act as signals.

4. Define endocrine signaling.

The signaling molecules called hormones, act on target cells distant from their site of synthesis by cells of various endocrine organs. In animals, an endocrine hormone usually carried by blood/by other extracellular fluids from its site of release to its target.

5. Define paracrine signaling.

The signaling molecules released by a cell affect target cell only in close proximity. The conduction by a neurotransmitter of a signal from one nerve cell to another or from nerve cell to muscle cell occurs via paracrine signaling.

6. Define autocrine signaling.

Autocrine signaling, cell responds to substances that they themselves release. Some growth factors act and cultured cells often secrete growth factors that stimulate their own growth and proliferation.

7. How the external signals induce cellular responses?

Changes in activity/function of specific preexisting protein.

Changes in amounts of specific proteins produced by a cell, most commonly as the result of modification of transcription factor leading to activation/repression of gene transcription.

8. What are the classes of cell surface receptors?

G-protein coupled receptor, cytokine receptor, receptor tyrosine kinase, TGF- $\beta$  receptor, Hedgehog receptor, Wnt receptor and Notch receptor.

9. Write a short note on cytokine and Hedgehog receptor.

Cytokine receptor:

Associated with cytosolic JAK kinases

Activate cytosolic STAT transcription factor by phosphorylation.

Hedgehog receptor:

Hh ligand tethered to membrane of signaling cell by cholesterol anchor.

Control processing of transcription factor by Hh binding causes release from cytosolic complex.

10. Write the functions of cell surface receptors.

The largest family of cell surface receptor is G-protein coupled receptor, includes the receptor for many hormones, neurotransmitters, transmit signals to intracellular targets via intermediary action of G-proteins.

The receptor for most growth factor is protein tyrosine kinase.

The receptors for many cytokines act in association with non-receptor protein tyrosine kinases.

Other kinds of cell surface receptors include protein tyrosine phosphatase, protein-serine/threonine kinases and guanylylcyclase.

11. Write the function of G-protein coupled receptor.

It regulates the activity of a variety of intracellular targets in response to extracellular signals.

They regulate ion channels.

They have distinct effect on nerve and skeletal muscle.

12. It has also effect on slowing heart muscle contraction.

13. What are the second messengers molecules?

The second messenger molecules are cyclic Adenosine Mono Phosphate, Phospholipids and  $Ca^{2+}$ , Phosphatidylinositol – 2-phosphate and cyclic Guanosine Mono Phosphate.

14. Write the functions of cAMP.

Most effects of cAMP are mediated by protein kinase A. cAMP can also directly regulate ion channels, independent of protein phosphorylation.

cAMP functions in this way as second messenger involved in sensing smells.

15. Define extracellular signaling.

Extracellular signaling molecules are synthesized and released by signaling cells and produce a specific response only in target cells that have receptor for signaling molecules.

16. How the signaling molecule induces cellular responses?

The signaling molecules act as ligand, which bind to structurally complementary site on extracellular/membrane-spanning domain of receptor. Binding of a ligand to its receptor causes a conformational change in cytosolic domain/domain of receptor that ultimately induces specific cellular responses.

17. What are G-protein coupled receptor and receptor tyrosine kinase?

G-protein coupled receptor:

Linked to a trimeric G protein that controls the activity of an effector protein (adenylyl cyclase)

Activate cytosolic/nuclear transcription factor via several pathways (protein kinase A)

Receptor tyrosine kinase:

Cytosolic domain with tyrosine kinase activity.

Activate cytosolic kinases (MAP Kinase) that translocate to nucleus and activate nuclear transcription factor by phosphorylation.

18. Write a note on Notch and Wnt receptor.

Notch receptor:

Ligand, delta is a transmembrane protein on signaling cell.

Cytosolic domain of notch released by proteolysis acts in association with nuclear transcription factor.

Wnt receptor:

Palmitoylated Wnt ligand binds seven transmembrane protein receptor complex.

Release on activated transcription factor from a multiprotein complex in the cytosol.

19. Write the mode of action of cytokine receptor.

Ligand induced receptor dimerization and cross phosphorylation of associated non-receptor protein tyrosine kinases. Then, the activated kinases then phosphorylate the receptor, providing phosphotyrosine, binding sites for the recruitment of downstream signaling molecules that contain SH2 domain.

20. Write the mode of action of Re-linked to enzymatic activities.

Protein tyrosine phosphatase remove phosphate group from phosphotyrosine residues these acting to counterbalance the effects of protein tyrosine kinases.

21. Write the example of autocrine and endocrine signaling.

The example of endocrine signaling - Steroid hormone and steroid receptor superfamily. The example of autocrine signaling – lymphocytes & immune system.

22. Write the example of paracrine signaling. Expand GABA.

The example of paracrine signaling - nitric oxide, carbon monoxide and neurotransmitter. GABA- $\gamma$ -amino butyric acid.

## PART-B (16 MARKS QUESTIONS)

23. Write a brief note on extracellular signaling.
24. Briefly describe the cell surface receptor and its functions with a neat diagram.
25. Explain in detail about the different classes of receptor with a neat diagram.
26. Describe endocrine signaling with a diagram.
27. Briefly describe paracrine signaling.
28. Explain about autocrine signaling with an example.
29. Explain in detail about cAMP pathway with a neat diagram.
30. Write a brief note on cGMP pathway.
31. Write a brief note on calmodulin and phorbol esters.
32. How phospholipase C activated by protein tyrosine kinase? Write a role of cGMP in photoreception.
33. Explain in detail about PIP<sub>2</sub> – a second messenger.
34. Explain in detail about phospholipids and Ca<sup>2+</sup> with a neat diagram
35. Describe in detail about second messenger with a neat diagram.
36. Write a short note on G-protein coupled receptor and Re-protein tyrosine kinase with a neat diagram
37. What are the steps involved in communication by extracellular signals? Write a brief note on direct cell-cell signaling.

### University Question Bank PART A

38. Define autocrine signaling. (Apr/May 2018)  
Autocrine signaling, cell responds to substances that they themselves release. Some growth factors act and cultured cells often secrete growth factors that stimulate their own growth and proliferation.
39. What is extracellular signaling? (Apr/May 2018)  
Extracellular signaling molecules are synthesized and released by signaling cells and produce a specific response only in target cells that have receptor for signaling molecules.
40. Define hormone response element. ? (Nov/Dec 2014)  
An HRE is a cis-regulatory DNA sequence for a hormone that acts by binding to a receptor that can act as a transcription factor, that is a binding site for the hormone-receptor complex.
- 42.
45. Give an example for a hormone which is soluble in Lipid and classified as Amine. (Nov/Dec 2014)  
Estrogen and testosterone are lipid-soluble hormone and amino acid derived hormone is Epinephrine and Norepinephrine.
46. What is the role of hormone response elements? (Nov/Dec 2015)  
An HRE is a cis-regulatory DNA sequence for a hormone that acts by binding to a receptor that can act as a transcription factor, that is a binding site for the hormone-receptor complex. Activated receptors bind to "hormone response elements", which are short specific sequences of DNA which are located in promoters of hormone-responsive genes.  
  
For Example in the absence of hormone, some intracellular receptors do not bind their hormone response elements and silence transcription, but, when complexed to hormone, become activated and strongly stimulate transcription.
47. Write the biological significance of cGMP. (Nov/Dec 2015)

cGMP is an important molecule of the cell that takes part in various activities in cellular system. When guanylyl cyclase stimulation leads to elevated levels of cGMP, it then mediates biological responses, such as blood vessel dilation which increases blood flow.

48. The action of cGMP is regularly facilitated by stimulation of cGMP dependent protein kinases, although cGMP is a common regulator of ion channel conductance, glycogenolysis, cellular apoptosis and phosphodiesterases.

49. Give examples of secondary messengers.(May/June 2016)

The second messenger molecules are cyclic Adenosine Mono Phosphate, Phospholipids and  $Ca^{2+}$ , Phosphotidyl inositol – 2-phosphate and cyclic Guanosine Mono Phosphate.

50. What is meant by paracrine action ? Give examples of paracrine factors. (May/June 2016)

The signaling molecules released by a cell affect target cell only in close proximity. The conduction by a neurotransmitter of a signal from one nerve cell to another or from nerve cell to muscle cell occurs via paracrine signaling.

The example of paracrine signaling - nitric oxide, carbon monoxide and neurotransmitter.

## **PART B**

51. Explain about endocrine signaling with two examples. (Apr/May 2018)

52. Write about secondary messengers in detail. (Apr/May 2018)

53. Explain with examples signal transduction by (Apr/May 2018)

i) Cell Surface receptors

ii) Cytosolic receptors.

54. Explain the general signal transduction through G protein-coupled

a. receptor with an example .(Nov/Dec 2014)

55. i) Elaborate signal transduction via insulin receptor and (Nov/Dec 2014)

a. ii) Explain second messengers. (Nov/Dec 2014)

56. Explain the signal transduction through G protein-coupled receptor by

a. epinephrine and its regulation (Nov/Dec 2015)

57. i) Describe the general signal transduction of steroid hormones.(May/June 2016)

58. (ii) Elaborate signal transduction via receptor tyrosine kinases. (May/June 2016)

59. Explain in detail how do cAMP act as secondary messenger Kinases.(May/June 2016)

60. Discuss in detail the G-Protein coupled receptor system.(May/June 2016)

## **UNIT V**

### **TECHNIQUES USED TO STUDY CELLS**

#### **PART – A**

#### **TWO MARKS QUESTION AND ANSWERS**

1. Define immunofluorescence microscopy.

When a flurochrome-antibody complex is added to a permeabilized cell or tissue section, the complex will bind to the corresponding antigen, which then light up when illuminated by the exciting wavelength, a technique called immunofluorescence microscopy.

2. Define flow cytometry.

A flow cytometry identifies different cells by measuring the light that they scatter and the fluorescence that they emit as they flow through a laser beam; thus it can sort out cells of particular type from a mixture. It separates different cell types. Some special cell types differ sufficiently in density that they can be separated on basis of this physical property.

3. Expand FACS.

FACS- Fluorescent Activated Cell Sorter, an instrument based on flow cytometry can select one cell from thousands of other cells.

4. Write the uses of flow cytometry.

Measurement of cell's DNA & RNA content and determination of its general shape and size.

FACS can make simultaneous measurements of size of cell and the amount of DNA.

5. Which technique is used to separate WBC and RBC?

Both WBC and RBC have very different densities because erythrocytes have no nucleus; thus these cells can be separated by equilibrium density centrifugation.

6. What is centrifugation?

The centrifugation is used to separate protein and nucleic acids. Separating and purifying the various organelles which differ in both size and density and thus undergo sedimentation at different rates.

7. Which technique is used to purify the impure organelle?

An impure organelle fraction obtained by differential centrifugation can be purified by equilibrium density-gradient centrifugation, which separate cellular components according to their density.

8. Define SEM.

Scanning Electron Microscope of metal coated unsectioned cells/tissues produces images that appear to be three-dimensional.

9. Define TEM.

In Transmission Electron Microscopy, the specimen is illuminated by a beam of electrons and electromagnetic lenses are used to focus the transmitted electrons to produce an image on the photographic film.

10. Define Electron Microscope.

In Electron Microscopy, live material cannot be observed and the light source is a beam of electrons that pass through a vacuum. The material has to be suitably prepared and inserted into the electron microscope after evacuating air with the help of vacuum pump.

11. Define fluorescence Microscope.

Fluorescence Microscope is like an ordinary compound microscope which is modified by incorporation of special filters that allow specific wavelength of light to pass through the specimen and cause fluorescence.

12. Which type of microscope is commonly used and what are the factors to determine the

Quality?

The most common microscopic technique in use today is the bright-field microscopy which uses a compound microscope. Two factors determine the quality of a microscope: magnification and resolution.

13. Define Refractive index.

Refractive index is the ratio of phase velocity of light in a vacuum to that in a specified medium. An image is produced in which the degree of brightness or darkness of a portion of the specimen depends on the refractive index of that region.

14. Define cell fractionation.

Cell fractionation is a technique by which a cell is broken open by homogenization and separating cell organelles as well as macromolecules by centrifugation.

15. Define Magnifying Power.

The Magnifying power of a microscope is determined by multiplying the magnification of the objective and the magnification of the ocular lens.

16. Define Resolution.

Resolution is dependent on the wavelength of the beam used for illumination and the optical quality of the lens.

17. Write the formula of resolving power.

$$RP = \lambda / 2 \times NA$$

Where,

- i. RP is the resolution power
- ii.  $\lambda$  is the wavelength of the light used
- iii. NA is the numerical aperture of the objective of the microscope

18. What is direct immunostaining?

In direct immunostaining, an antibody that recognizes an antigen is coupled directly to an indicator (a fluorescent dye/an enzyme).

19. What is indirect immunostaining?

In Indirect immunostaining, is more sensitive method because a second antibody is coupled to the indicator. The second antibody recognizes a common epitope on the antigen-specific antibody. Multiple second antibodies can bind to first antibody, leading to an increased signal from the indicator compared to direct immunostaining.

20. What are the limitations of SEM?

The specimen cannot be observed in live condition

The thin specimen preparation is difficult.

Morphological alteration of cells occurs during thin specimen preparation.

Due to its high cost, it is not used in ordinary laboratories.

### **PART-B (16 MARKS QUESTIONS)**

21. Describe in detail about flow cytometry with a neat diagram.

22. Explain in detail about the working principle and limitations of SEM.

23. Explain in detail about the working principle of TEM with a neat diagram.

24. Describe about cell fractionation.

25. Define principle of SEM and draw a diagram. How the 3D models constructed from microscopy images of SEM?

26. Discuss the working principle of TEM. How metal shadowing is prepared?

27. Explain in detail about confocal microscopy.
28. Differentiate between the working principle of SEM and TEM.
29. Explain in detail about the immunostaining.
30. By which technique is used to locate protein in cells? Explain in detail.
31. What are the types of immunostaining? Write the limitations of conventional fluorescence microscope and uses of immunostaining.
32. By which technique is used to broken the cell and purify the contents? Explain in detail.
33. Draw a neat labeled diagram of flow cytometry. Expand FACS and its uses.
34. Which technique is used to separate mixed organelle? Describe the principle of bright-field light microscopy.
35. Explain in detail about Electron Microscopy with a neat diagram.

### **University Question Bank**

#### **PART A**

36. Write the principle of confocal microscopy? (Apr/May 2018)

The confocal microscope uses fluorescence optics. Instead of illuminating the whole sample at once, laser light is focused onto a defined spot at a specific depth within the sample. This leads to the emission of fluorescent light at exactly this point. A pinhole inside the optical pathway cuts off signals that are out of focus, thus allowing only the fluorescence signals from the illuminated spot to enter the light detector.

37. What do you mean by immunostaining? (Apr/May 2018)

The staining of a specific substance by using an antibody against it which is complexed with a staining medium (as horseradish peroxidase). The types are direct and indirect immunostaining.

38. What is the working principle of SEM? (Nov/Dec 2014)

In SEM, there are several electromagnetic lenses, including condenser lenses and one objective lens. Electromagnetic lenses are for electron probe formation. Two condenser lenses reduce the crossover diameter of the electron beam. The objective lens further reduces the cross-section of the electron beam and focuses the electron beam as probe on the specimen surface. Objective lens thus functions like a condenser.

Electron probe or beam is scanned across the specimen and the procedure is known as Raster scanning. Raster scanning causes the beam to sequentially cover a rectangular area on the specimen. The signal electrons emitted from the specimen are collected by the detector, amplified and used to reconstruct the image according to one-to-one correlation between scanning points on the specimen and picture points on the screen of cathode ray tube (CRT). CRT converts the electronic signals to a visual display.

39. List out the techniques used to localize proteins in the cell. (Nov/Dec 2014)

Immunostaining, Confocal laser scanning Microscopy and Fluorescence Microscopy based techniques are used to localize protein in cells.

40. Write the principle of confocal microscopy. (Nov/Dec 2015)

The confocal microscope uses fluorescence optics. Instead of illuminating the whole sample at once, laser light is focused onto a defined spot at a specific depth within the sample. This leads to the emission of fluorescent light at exactly this point. A pinhole inside the optical pathway cuts off signals that are out of focus, thus allowing only the fluorescence signals from the illuminated spot to enter the light detector.

41. What are the general applications of microscopic techniques in cell biology? (Nov/Dec 2015)

Counting of cells using a hemocytometer utilizes light microscopy.

Microscopic analysis of blood samples is routinely used to determine the blood cell count, to detect the microbial infection, and to identify any changes in the cellular structures.

*Live cell imaging:* Inverted microscopes allow direct microscopy of the cultured cells.

*Cell biology:* Owing to its ability to operate on liquid samples, AFM has been used to study the real-time biological processes. Migrating epithelial cells, dynamics of membrane invaginations, conformational changes in membrane proteins, and assembly/disassembly of structural proteins have been studied in real time using Atomic Force Microscopy.

42. What are fixatives? (May/June 2016)

A chemical substance used to preserve or stabilize biological material prior to microscopy or other examination.

Fixative: A medium such as a solution or spray that preserves specimens of tissues or cells. Most biopsies and specimens removed at surgery are fixed in a solution such as formalin (dilute formaldehyde) before further processing takes place. Other common ingredients used in fixatives are alcohol, mercuric chloride, potassium dichromate and sodium sulfate.

43. What forms the basis of electron microscopy techniques? (May/June 2016)

In Electron Microscopy, live material cannot be observed and the light source is a beam of electrons that pass through a vacuum. The material has to be suitably prepared and inserted into the electron microscope after evacuating air with the help of vacuum pump. The types are TEM and SEM.

## **PART B**

44. Explain the principle, instrumentation and applications of flow cytometer. (Apr/May 2018)

45. Explain the protocol for the localization of cellular proteins. (Apr/May 2018)

46. Discuss cell fractionation method and cell sorting by flow cytometry. (Nov/Dec 2014)

47. i) Describe the studies on the cell using TEM and confocal microscopy. (Nov/Dec 2014)

(ii) Write a short note on immunostaining. (Nov/Dec 2014)

48. i) Discuss about cell sorting by flow cytometry

ii) Describe immunostaining with an example. (Nov/Dec 2015)

49. i) Describe the working principle and advantages of TEM and STEM in cell biology (Nov/Dec 2015)

ii) Discuss cell fractionation method and its applications (Nov/Dec 2015)

50. Explain in detail the principle, operation and application of SEM. (May/June 2016)

51. Explain in detail the principle, operation and application of Confocal

a. Microscopy.(May/June 2016)

## QUESTION BANK

### UNIT I - BASIC CHEMICAL CALCULATIONS

#### [REGULATION 2017]

#### 1. Give notes on units & dimensions?

Dimension: They are the basic concepts of measurements of quantities such as temperature, time

Units: They are the means of exposing dimensions such as centimetre or meter for length.

#### 2. Give notes of base units & derives units?

Base units: They are the building blocks of quantities and all other units of measure can be derived from the base units.

Length-m, Time-s

Derived units: They are derived from base units.

Eg pressure=force/area  $N/m^2$

#### 3. Define molality, normality, and molarity?

**Molality** is defined as the number of gram moles of solute dissolved in 1kg of solvent.

Molality= gm. moles of solute / mass of solvent in kg

**Molarity** is defined as the number of gram moles of solute dissolved in 1lit of solution.

Molarity=gm. moles of solute/volume of solvent in lit

**Normality** is defined as the number of gram equivalents of solute dissolved in 1 lit of solution

Normality=gm. equivalent of solution/volume of solution in 1 lit

#### 4. What is mole fraction?

It is the ratio of moles of individual components to the total moles of a system

$X_A = \text{moles of A} / \text{total moles of a system}$

### **5. What is weight fraction?**

It is the ratio of individual weight of a component to the total weight of a system

Weight fraction = individual weight of a component / total weight of the system.

### **6. Define specific gravity?**

It is defined as the ratio of density of a substance to that of standard substance at same condition.

For gases standard substance is Air and for liquids standard substance is water.

### **7. Define Average molecular weight?**

It is defined as the weight of unit mole of the mixture which is also equal to total weight of gas mixture divided by total number of moles.

### **8. Define equivalent weight?**

It is defined as the ratio of atomic or molecular weight to its valence

### **9. State conservation of mass?**

Mass can be neither created nor destroyed. Is called the conservation of mass

### **10. Give notes on process and system?**

**Process:** A process refers to any operation or number of operation in series which causes physical or chemical changes on substance or group of substance.

**System:** The substance or group of substance under considerations is called system. eg: storage tank

### **11. What is an isolated system?**

In an isolated system the mass of a system remains constant regardless of the changes taking place within the system.

**12. What is intensive & extensive property?**

**Extensive property:**

It is the state of system which depends on the mass under consideration. Eg volume, density

**Intensive property:**

It is the state of system which depends on the mass. Eg Temperature

**13. Define atomic weight?**

An atomic weight is the ratio of average mass per atom of the element to  $1/12^{\text{th}}$  mass of an atom carbon 12

**14. What is molecular weight?**

It is calculated as the sum off mass each atom multiplied by no. of atoms of that element in the molecular formula.

**15. Define gram-atom.**

It is used to specify amount of chemical elements

Gm. atom= weight in gms of element /atomic weight of element

**16. Define gram-mole.**

It is used to specify amount of chemical compounds Gm. mole= weight in gms of compound /molecular weight of compound

**17. State conservation of energy?**

Energy can be neither be created nor destroyed

**18. State the law of conservation of mass. (NOV/DEC 2009) (NOV/DEC 2007)**

**Conservation of mass:**

The total mass of various compounds remain unchanged during an unit operation or a chemical reaction.

**19. Explain the law of conservation of energy for unsteady system.  
(APR/MAY 2010)**

**Law of conservation of energy:**

Energy can neither be created nor be destroyed. It can only be converted from one form to another form.

**20. What is Avogadro's principle?**

One gram mole of any substance at NTP occupies 22.414 litre or 22414 cc

One kilo mole of any substance at NTP occupies 22.414 m<sup>3</sup> One pound mole of any substance at NTP occupies 359 ft<sup>3</sup>

**21. What is called valence of a compound?**

It is the no. Of H<sup>+</sup> accepted or oh<sup>-</sup> ions donated for each atomic weight or molecular weight

**22. What is volume fraction?**

It is the ratio of volume of individual components to the total volume of a system  
Volume fraction = volume of individual component / total volume of a system.

**23. Define Average molecular weight.**

The average molecular weight (or molecular weight distribution) describes the relationship between the number of moles of each component (N<sub>i</sub>) and the molar mass (M<sub>i</sub>) of that component

**24. What is 'Nondecimal Unit'? (NOV/DEC 2011)**

Measurements in non-metric (non-base 10) measurements, e.g. feet, inches and pre-decimal (pre-1971) UK currency.

Non-base 10 units difficult to work with for statistical analysis unless, either convert to metric or convert the overall measurement into a single unit (e.g. convert pounds, shilling and pence to just pence or feet and inches to just inches. If comparing a dataset with metric measurements with a dataset with imperial measurements it is preferable to convert to metric for comparisons.

**25. Give the S.I. units and dimensions of mass velocity. (NOV/DEC 2012)**

**Mass velocity:**

S.I. unit of mass velocity (G) = kg/m<sup>2</sup>.s

Dimension = ML<sup>-2</sup>T<sup>-1</sup>

**26. Give the S.I. units and dimensions of pressure. (NOV/DEC 2012)**

**Pressure:**

S.I. unit of Pressure (P) = N/m<sup>2</sup> (or) Pa

Dimension = ML<sup>-1</sup>T<sup>-2</sup>

**27. Write down the value of gas constant in SI and CGS units. (NOV/DEC 2010) Value of gas constant in SI units:**

**R = 0.083 bar m<sup>3</sup> / kmole K**

Value of gas constant in CGS units:

**R = 0.085 kgf m<sup>3</sup> / kmole K**

**28. State the SI units of pressure and Energy. (NOV/DEC 2009)**

**SI units of pressure:** The unit of pressure

is N/ m<sup>2</sup> 1 Pa = 1 N/ m<sup>2</sup>

1 atm = 760 mm Hg

1 atm = 1.01325 bar

1 bar = 10<sup>5</sup> Pa

**SI units of Energy:** 1 Joule = 1 N.m

1 Joule = 1 kg.m<sup>2</sup>/s<sup>2</sup>

1 Joule = 10<sup>7</sup> erg

**29. Convert 50°F to °R (NOV/DEC 2009)**

50°F to °R:

$$^{\circ}\text{R} = 459.63 + ^{\circ}\text{F} = 459.63 + 50 = 509.63$$

$$50^{\circ}\text{F} = 509.63^{\circ}\text{R}$$

**30. Convert 50°F to Kelvin scale. (NOV/DEC 2009)**

$$^{\circ}\text{K} = ^{\circ}\text{C} + 273 = 10 + 273 = 283\text{K}$$

$$50^{\circ}\text{F} = 283\text{K}$$

**31. Define the term 'Celsius Temperature'. (NOV/DEC 2011)**

It is the unit of measurement of temperature. It corresponds to the Kelvin temperature minus

273.15. it defines the freezing point as 0°C (273.15K) and the boiling point as 373.15 K (100°C)

$$^{\circ}\text{C} + 273.15 = ^{\circ}\text{K}$$

**32. What are the basic quantities used in SI system? (NOV/DEC 2008)**

**Basic quantities used in SI system**

- Mass (kg)
- Length (m)
- Time (s)
- Temperature (K)

**33. Give some examples for derived quantities. (NOV/DEC 2008)**

**Examples of derived quantities**

- Force (F)
- Pressure (P)
- Density ( $\rho$ )
- Viscosity ( $\mu$ )

**34. Name various systems of units.**

There are three system of units.

- ✓ System international (SI)

- ✓ English Engineering units (FPS)
- ✓ Metric Engineering units (CGS/MKS)

**35. What are the basic quantities used in the SI system and CGS system of units?**

**SI system**

<i>Quantities</i>	<i>Unit</i>	<i>Symbol</i>
Length	metre	m
Mass	kilogram	kg
Time	second	s
<i>Derived unit</i>		
<i>force</i>	Newton	N

**CGS system**

<i>Quantities</i>	<i>Unit</i>	<i>Symbol</i>
Length	centimetre	cm
Mass	gram	g
Time	second	s
<i>Derived unit</i>		
<i>force</i>	dyne	dyne

**36. Give the dimensions and units for pressure and force in S.I.system.**

**Pressure:**

S.I.unit of pressure (P) = N/m<sup>2</sup> (or) Pa

Dimension = ML<sup>-1</sup>T<sup>-2</sup>

**Force:**

S.I.unit of force (F) = Newton (N)

Dimension = MLT<sup>-2</sup>

**37. Give notes on °Be scale for finding specific gravity of a solution., (°Be)**

**Baume for liquids lighter than water**

°Be=(140/G)-130

Baume (Be<sup>o</sup>) for heavier lighter than

water °Be=145-(145/G)

**38. Give notes on °API and Twaddell scale for finding specific gravity of a solution.**

$$^{\circ}\text{API scale} = (141.5/G) - 131.5$$

This is mostly used for expressing specific gravity of petroleum products.

Twaddell scale: this scale is mostly used for liquids heavier than water  $^{\circ}\text{Tw} = 200(G-1)$

**39. Give notes on Brix scale for finding specific gravity of a solution**  
For the sugar industry, an arbitrary scale of Brix is developed.  
 $^{\circ}\text{Brix} = (400/G) - 400$ .

## PART B

### UNIT I -BASIC CHEMICAL CALCULATIONS

1. Convert 150  $\frac{lb}{ft^3}$  into  $\frac{g}{cm^3}$
  
2. (i) The available nitrogen in the urea sample is found to be 45% by weight. Calculate the actual urea content in the sample. **(NOV/DEC 2016)**  
**(Stoichiometry by Bhatt & Vora, Pg.No.23)**  
(ii) A natural gas has the following composition by volume Methane -83.5%, Ethane – 12.5% and Nitrogen – 4%. Calculate the composition in (1) Mole% (2) Weight % (3) Average molecular weight. **(NOV/DEC 2016) (Class notes)**
  
3. Describe in detail various system of units and explain how it is being derived. **[NOV/DEC 2013] [NOV/DEC 2010]**  
**(Stoichiometry by Bhatt & Vora, Pg.No.15-18)**

4. Find the equivalent weight of HCl, NaOH, Na<sub>2</sub>CO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>PO<sub>4</sub>, CaCl<sub>2</sub>, FeCl<sub>3</sub>, KMnO<sub>4</sub>. [NOV/DEC 2015]  
(Stoichiometry by Bhatt & Vora, Pg.No.20-21)
5. A chemist is interested in preparing 500 ml of 1 normal, 1 molar and 1 molal solution of H<sub>2</sub>SO<sub>4</sub>. Assuming the density of H<sub>2</sub>SO<sub>4</sub> solution to be 1.075 g/cm<sup>3</sup>, calculate the quantities of H<sub>2</sub>SO<sub>4</sub> to be taken to prepare these solutions. [NOV/DEC 2015]  
(Stoichiometry by Bhatt & Vora, Pg.No.28)
6. Convert 1000 W in hp and  $kgf^m_s$  Convert volumetric flow rate of 5  $\frac{m^3}{s}$  to  $\frac{l}{s}$
7. In a double effect evaporator plant, the second effect is maintained under vacuum of 455 torr. Find the absolute pressure in kPa.
8. A force equal to 25kgf is applied on the piston with a diameter of 2cm. Find the pressure exerted on a piston in kPa.
9. Convert -40°C and 50°C to °F
10. Prove that  $1 \frac{kcal}{h} \circ 1.163 N. m_s$
11. Iron metal weighs 500 lb and occupies a volume of 29.25 liters. Find the density in  $m^3$  \_\_\_\_\_
12. Convert 25 psig to psia
13. Air is flowing through a duct under a draft of 4.0cm of H<sub>2</sub>O. The barometer indicates that the atmospheric pressure is 730 mm Hg. What is the absolute pressure of the gas in inches of mercury?

## UNIT II – IDEAL AND ACTUAL GAS EQUATIONS

### PART A

**1. What is psychrometry?**

It is the subject that deals with properties of gas vapour mixture. In this type of operation, the gas is brought into contact with a pure liquid in which the gas is essentially insoluble, the liquid can evaporate and the gas becomes saturated with respect to the liquid.

**2. What is dry bulb temperature?**

The temperature of the vapour gas mixture recorded by the immersion of a thermometer is called dry bulb temperature(DBT)

**3. What is wet bulb temperature(WBT)?**

The temperature measured by thermometer or thermocouple with a wet wick covering the bulb under equilibrium condition is called wet bulb temperature.

**4. Wet bulb temperature is always lower than dry bulb temperature.**

At 100% saturation, dry bulb temperature = wet bulb temperature=dew point

**5. What is absolute humidity?**

The weight of water vapour present in a unit weight of dry air is called absolute humidity. Its unit is Kg of water vapour/kg of dry air.  $H = H_m \times 0.622$

**6. What is molal humidity?**

Moles of water vapour present in a unit mole of dry air are called molal humidity or absolute molal humidity.

Its unit is Kmol of water vapour/kmol of dry air.  $H_m = p_A / (P - p_A)$

**7. What is saturated humidity?**

The absolute humidity at 100% saturation is called saturation humidity. If  $P_s$  is the vapour pressure of water at dry bulb temperature and when partial pressure  $P_A$  is equal to  $P_s$  then

$$H_s = 0.622 * P_s / (P - P_s)$$

**8. What is dew point?**

It is the temperature at which the air, water vapour mixture becomes saturated when the mixture is cooled at constant total temperature in the absence of liquid water

This means that partial pressure of water vapour in the mixture equals the vapour pressure of water at dew point. Dew point is always lower than or equal to dry bulb temperature. At the moment, the temperature is reduced below dew point; vapour will condense as liquid dew.

**9. What is humid heat?**

It is defined as the heat capacity of 1 kg of dry air and the moisture contain in it

$$C_s = 1.006 + 1.84H \text{ KJ/Kg of dry air K}$$

**10. What is humid volume?**

It is the volume of a mixture of air and water vapour per Kg of dry air. This is also known as psychrometry volume.

**11. What is %humidity or absolute % humidity or %saturation?**

%Humidity is defined as the ratio of actual absolute humidity to the saturation humidity.

$$\% \text{Humidity} = (H/H_s) * 100$$

**12. What is Relative humidity or %Relative humidity or Relative saturation?**

It is defined as the ratio of partial pressure of water vapour in air to the vapour pressure of water at dry bulb temperature.  $RH = (p_A/p_s) \times 100$

**13. What is adiabatic saturation temperature?**

When a definite quantity of water is allowed to evaporate in a stream of air adiabatically dry bulb temperature of air drops and the humidity of air increases. The final temperature of the intimately mixed stream is termed as adiabatic saturation temperature.

**14. Define vapour pressure?**

It is defined as the absolute pressure at which the liquid and its vapour are in equilibrium at a given temperature

Pure water exert vapour pressure of 101.325kpa at 373.15 K

Normal boiling point of a liquid is the temperature at which the vapour pressure equals to the existing atmospheric pressure. A substance with a high vapour pressure at normal temperature is referred as volatile.

**15. State Dalton's law?**

The total pressure exerted by a gaseous mixture in a definite volume is equal to the sum of all the partial pressures.  $P = P_A + P_B + P_C$

Where  $P_A, P_B, P_C$  are partial pressures of each component

**16. State Amagats law or Leduc's Law?**

The total volume  $v$  occupied by a gaseous mixture is equal to the sum of the pure component volume

$V_a + V_b + V_c = V$  where  $V_a, V_b, V_c$  pure component volume of a, b, c

**17. Define partial pressure?**

Partial pressure of a gas is present in a mixture of gases is the pressure that would be occupied by that component gas if it alone were present in same volume and at the same temperature in same condition

**18. What is meant by pure component volume?**

The pure component volume of a gas that is present in the mixture of gases is the volume that would be occupied by that component gas if it alone present in same temperature and pressure

**19. Give notes on equation of state?**

It is the combination of three laws Boyle's law, Charles law, and Gay lussacs law. It shows the relationship between the pressure, volume and temperature for mixed mass of gas

$$PV/T = \text{constant}$$

$$PV = CT$$

$$PV = nRT$$

P-pressure of gas, V-volume of gas, n=no of moles of gas, R-gas constant

**20. State Raoult's law**

Raoult's law states that equilibrium of partial pressure of component is equal to the product of vapour pressure and mole fraction of liquid base.

$$P_i = P_i^o x_i$$

Partial pressure of I component = vapour pressure of 'i' x mole fraction of 'i' in liquid phase.

**21. State Henry's law**

It states partial pressure of a solute gas is proportional to the mole fraction of the solute in the solution.

$$P_i = H_i x_i$$
  $H_i$  is Hendry's law constant and  $x_i$  is solute mole fraction

**22. What is meant by combustion process?**

Combustion refers to the rapid oxidation of the fuels accompanied by the production of heat and light .complete combustion of a fuel is possible only in the presence of adequate supply of oxygen.

**23. What is meant by heating value?**

The amount of heat released during combustion per unit weight of fuel is called heating value. Its unit is kcal/kg

**24. What is flue gas?**

Flue gas is the gas exiting to the atmosphere through the pipe or channel after combustion.

Its composition depends upon what is being burnt but it usually consists of nitrogen, carbon di oxide, water vapour, carbon monoxide, sulphur di oxide.

**25. What is orsat analysis?**

It means only dry flue gas i.e. Water vapour is not considered in this analysis.

**26. Explain Dalton's law. (NOV/DEC 2005)**

Dalton's Law states that the total pressure of a mixture of gases is equal to the sum of the partial pressures of the constituent gases. The partial pressure is the pressure each gas would exert if it alone occupied the volume of the mixture.

Dalton's Law for moist air can be expressed as  $p = p_a + p_w$ , where  $p$  = total pressure of air

(Pa, N/m<sup>2</sup>),  $p_a$  = partial pressure dry air (Pa, N/m<sup>2</sup>),  $p_w$  = partial pressure water vapor (Pa, N/m<sup>2</sup>)

**27. State Raoult's law. (NOV/DEC 2016)**

It states that the vapor pressure of the solvent in the solution is directly proportional to the mole fraction of the solvent.

(Vapor pressure of the solvent in the solution) = (vapor pressure of pure solvent) x (mole fraction of the solvent)

**28. Define relative humidity (APR/MAY 2015) (NOV/DEC 2012,2007)**

Relative humidity is defined as the ratio of the partial pressure of water vapour in air to the vapour pressure of water.

**29. Define percentage humidity. (APR/MAY 2015) (NOV/DEC 2012,2007)**

Percentage humidity is defined as the ratio of humidity under given condition to the humidity under the saturated condition.

H- humidity,  $H_s$  –humidity under saturated condition

$H_m$ -molal humidity,  $H_{ms}$  – molal humidity at saturation

**Write the numerical quantity of Universal Gas Constant, R in: L Torr k<sup>-1</sup> mol<sup>-1</sup> (APR/MAY 2015)**

Universal gas constant  $R = 0.08215 \text{ atm.m}^3 / \text{kg.mol.K}$

**30. If molal humidity is 0.5 what is absolute humidity? (NOV/DEC 2014)**

Molal humidity ( $H_m$ ) – 0.5

i.  $H_m = 1.611 \times H$

ii.  $H = H_m / 1.611 = 0.5 / 1.611$

iii.  **$H = 0.3103 \text{ kg water} / \text{kg of dry air}$**

**31. State ideal gas law. (NOV/DEC 2013)**

For a given mass of an ideal gas the product of pressure and volume is constant at the constant temperature.

$$PV = nRT$$

P- Absolute pressure

V-volume of 1 kgmol gas

R- Gas constant

T – Absolute temperature

**32. Define absolute humidity. (NOV/DEC 2013) (NOV/DEC 2009)**

It is defined as the weight of water vapor per unit weight of dry air in the mixture.

$$\circ \frac{WA}{WB}$$

**33. State Boyle's Law:**

This law states that at constant temperature, the product of the volume and pressure of a given amount of gas is a constant.

$$a. P \times V = \text{constant}$$

The value of the constant depends on how much gas is in the volume.

**34. State Charles's Law:**

This law states that at constant pressure, the volume of a given quantity of gas is proportional to absolute temperature ( $^{\circ}\text{K}$ ).

$$V = q \times T$$

Where

q is a proportionality constant that depends on the quantity of gas.

Charles's law can be stated in another form: at constant volume, the pressure of a given quantity of gas is proportional to absolute temperature.

$$1. P = j \times T$$

Where

j is a proportionality constant that depends on the particular sample of gas and its volume

Note: to convert temperature in  $^{\circ}\text{C}$  into absolute temperature in  $^{\circ}\text{K}$ , add the constant 273.15.

**35. State Raoult's law. (NOV/DEC 2016)**

It states that the vapor pressure of the solvent in the solution is directly proportional to the mole fraction of the solvent.

$$(\text{Vapor pressure of the solvent in the solution}) = (\text{vapor pressure of pure solvent}) \times (\text{mole fraction of the solvent})$$

**36. Define of Humidity**

Vapor Concentration (Absolute Humidity)

The vapor concentration or absolute humidity of a mixture of water vapor and dry air is defined as the ratio of the mass of water vapor  $M_w$  to the volume  $V$  occupied by the mixture.

$$D_v = M_w / V, \text{ expressed in grams/m}^3 \text{ or in grains/cu ft}$$

The value of  $D_v$  can be derived as follows from the equation  $PV = Nrt$

**37. Define relative humidity (APR/MAY 2015) (NOV/DEC 2012,2007)**

Relative humidity is defined as the ratio of the partial pressure of water vapour in air to the vapour pressure of water.

$$\%RH = 100 \times p/ps$$

Where

p is the actual partial pressure of the water vapor present in the ambient and

ps the saturation pressure of water at the temperature of the ambient.

Relative Humidity, Pressure and Temperature  $M_w = n_w \times m_w$ ,

where :

$n_w$  = number of moles of water vapor present in the volume V

$m_w$  = molecular mass of water

### **38. Define SPECIFIC HUMIDITY**

Specific humidity is the ratio of the mass  $M_w$  of water vapor to the mass ( $M_w + M_a$ ) of Moist Air.

$$Q = M_w / (M_w + M_a)$$

### **39. Define Mixing Ratio**

The mixing ratio r of moist air is the ratio of the mass  $M_w$  of water vapor to the mass  $M_a$  of dry air with which the water vapor is associated:

$$r = M_w / M_a$$

### **40. Define percentage humidity. (APR/MAY 2015) (NOV/DEC 2012,2007)**

Percentage humidity is defined as the ratio of humidity under given condition to the humidity under the saturated condition.

H- humidity , HS –humidity under saturated condition

Hm-molal humidity , Hms – molal humidity at saturation

### **41. What is DEW POINT? NOVEMBER/DECEMBER 20 18**

It is defined as the temperature at which air attains saturation and a further addition of water vapour leads to dew formation because of condensation of water vapour. It is rarely used to indicate the moisture content of the air/atmosphere.

### **42. DEGREE OF SATURATION**

It is stated as the ratio of weight of water vapour in air at given conditions to the weight of the water vapour in air at saturation, keeping temperature constant. It is also called saturation ratio or percentage humidity. Mathematically, it can be expressed as

Where,

e = Vapour pressure or Partial pressure due to water vapour (kPa)

Pb = Barometric pressure (kPa )

esd = Saturation vapour pressure at wet bulb temperature (kPa)

### **43. Write the numerical quantity of Universal Gas Constant, R in: APRIL/MAY 2015**

L Torr kmol-l

ft<sup>3</sup> psi °R-lb-mol-l.

### **PART B**

## UNIT-2- IDEAL AND ACTUAL GAS EQUATIONS

1. Define 'Absolute humidity, Relative humidity and Saturation humidity. (NOV/DEC 2016)

(Stoichiometry by Bhatt & Vora, Pg.No.340-342)

2. A gas mixture containing 12% CO<sub>2</sub>, 8% O<sub>2</sub> and 80% N<sub>2</sub> by volume leaves from the fermenter at 1.5 atm (abs) pressure and 40°C and 1 m<sup>3</sup>/hr. Calculate how many kg/hr of the gas mixture is coming out. [NOV/DEC 2014]

(Stoichiometry by Bhatt & Vora, Pg.No.52-53)

3. A mixture of acetone vapor and nitrogen contains 15.8% acetone by volume. Calculate the relative and percent saturation of mixture at a temperature of 293 K and pressure of 101.323 kPa.

Data: Vapor pressure of acetone at 293 K = 24.638 kPa. (NOV/DEC 2016)

(Class notes)

4. A mixture of gases has the following composition by weight Cl<sub>2</sub> = 65% Br<sub>2</sub> = 25% and O<sub>2</sub> = 5%. Using ideal gas law calculate
- Composition of the gas mixture by volume %
  - Density of the gas mixture in kg/m<sup>3</sup> at 25°C & 740 mm Hg.
  - Specific gravity of the gas mixture. [NOV/DEC 2013]

(Stoichiometry by Bhatt & Vora, Pg.No.51)

5. If the wet bulb temperature is 25°C and the dry bulb temperature is 30°C, find the following
- Absolute humidity
  - Relative humidity
  - Molal humidity
  - Humid heat
  - Humid volume
  - Dew point temperature (Stoichiometry by Bhatt & Vora, Pg.No.349-351)

6. What is the volume of 25kg of chlorine at standard condition?

7. What is the weight of one liter of methane (CH<sub>4</sub>) at standard conditions?

8. A compound whose molecular weight is 103 analyses Carbon = 81.5%,

Hydrogen = 4.9% and N<sub>2</sub>=13.6%, by weight. Find its formula? (May/June-2009/QC.D0052)

9. Chimney gas has the following composition: CO<sub>2</sub> – 9.5%: CO-0.2%: O<sub>2</sub>-9.6% and N<sub>2</sub>-80.7%. Using ideal gas law, calculate  
Its weight percentage

Volume occupied by 0.5kg of gas at 30°C and 760 mmHg

Density of the gas in kg/m<sup>3</sup> at condition of (ii)

Specific gravity of the gas mixture

(Density of air may be taken as 1.3 g/cc) (May/June-2009/QC.D0052)

10. A gas mixture contains 0.274 kmol of HCl, 0.337 kmol of N<sub>2</sub> and 0.089 kmol of O<sub>2</sub>. Calculate i. Average molecular weight of gas and ii. Volume occupied by this mixture at 405.3kPa and 303K. (May/June-2009/QC.D0052)
11. A gas has the following composition by volume. CO<sub>2</sub>=9.5%, CO=0.2%, O<sub>2</sub>=9.6% and N<sub>2</sub>=80.7%. using ideal gas law, calculate Composition by wt % (4)  
Volume occupied by 1 kg of the gas at 40 °C and 740 mm Hg(6)  
Density of the gas in kg/m<sup>3</sup> at 40 °C and 740 mm Hg. (May/June -2012/QC:10240)
12. Derive from ideal gas law volume % =mole% =Pressure %
13. 1000 litres of mixture of H<sub>2</sub>, N<sub>2</sub> and CO<sub>2</sub> at 150°C was found to have the following ratio for the partial pressure of the gases: P<sub>H<sub>2</sub></sub>:P<sub>N<sub>2</sub></sub>:P<sub>CO<sub>2</sub></sub> is 1:4:3. If the total pressure is 2 atm absolute, calculate  
Mole fraction of each of these gases Weight per cent of each of these gases , Average molecular weight Weight of CO<sub>2</sub> in kg (May/June-2013/QC:21246)
14. Estimate the density of chlorine gas at temperature 503K(230°C) and 15.2MPa pressure using  
The ideal gas law and The Van der waals equation  
A=            B=
10. Convert 5000 ppm into weight %?
11. The strength of phosphoric acid usually represented as weight % of P<sub>2</sub>O<sub>5</sub>. A sample of phosphoric acid analyzed 40% P<sub>2</sub>O<sub>5</sub>. What is the % by weight of H<sub>3</sub>PO<sub>4</sub> in the sample? (Nov/Dec-2010/QC:G0465)
12. An aqueous solution contains 40% of Na<sub>2</sub>CO<sub>3</sub> by weight. Express the composition in mole percent?

### UNIT III – MATERIAL BALANCE

#### PART A

**1. What is steady state? Explain. (NOV/DEC 2006)**

The condition does not change with time is known as steady state operation.

**2. Classify various types of Unit operations. (NOV/DEC 2005)**

It deals mainly with the transfer and change of energy & transfer and change of materials primarily by physical means but also by physical – chemicals means.

Eg: Filtration, Drying, Distillation etc

**2 What are the objectives of Unit Processes? (NOV/DEC 2005)**

It deals mainly with process involving chemical reactions. Eg: Nitration, Chlorination

**3 Define the following for a binary mixture. (a) mol fraction (b) vol%**

Mole Fraction is defined as the ratio moles of one component to the total number of moles.

$$\text{Volume \%} = \frac{\text{Volume of one component}}{\text{Total Volume}} \times 100$$

Total Volume

**4 What is the purpose of recycle and bypass? (NOV/DEC 2009)**

**Purpose of recycle:**

To improve the conversion whenever the conversion is low and to have energy economy in operations

To improve the performance of equipment.

To improve the selectivity of a product.

To control the operating variable in a reaction like pressure, temperature.

To minimize waste generation.

**5 Purpose of bypass:**

The purpose of bypass is to control the concentration of the downstream (product stream)

**6 What is recycle? Explain. (NOV/DEC 2008, 2007,2005)**

**Recycle:**

A part of the main product stream or the intermediate product stream comprising both reactants and products or the intermediate product is sent back along with feed to the system or somewhere in the middle of the system. Such stream is called recycle stream.

**7 Define recycle?**

It refers to the process stream that conducts material existing or downstream from a unit back to the inlet or upstream of the same unit.

The objective being either

To control process parameter or to increase the yield

Conversion with respect to a particular reactant

**8. What is bypass? Explain. (NOV/DEC 2008, 2007,2005)**

**Bypass:**

Bypassing of a fluid stream is dividing it into two streams, and is often used in industries to have a closer control in operation. This is done if there is a sudden change in the property of a fluid stream like excessive heating (or cooling) as it passes through a preheater (cooler) before entering another unit. In such cases this conditional stream is mixed with a portion stream at its original condition and then used in the process. This is called bypassing operation.

**9 Define reflux ratio.**

Reflux ratio is defined as the ratio of refluxed quantity to the actual product.

**10 Define crystallization.**

Crystallization is a process in which the solid particles are formed from a homogeneous phase.

During crystallization, the crystals form when a saturated solution gets cooled. The solution left behind after the separation of crystals is known as mother liquor or saturated solution. The mixture of crystals and mother liquor is known as magma.

**11 What is a bypass?**

It is a stream that skips one or more stages of the process and gives directly to another stage with the purpose of controlling the composition of final or downstream.

**12 What is purging?**

A stream bleed off to remove an accumulation of certain inerts or unwanted materials that might otherwise build up in the recycle stream is called purge stream. It is generally associated with the recycle stream.

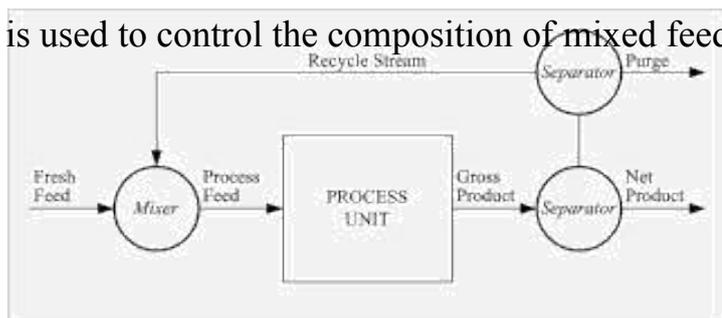
**13 Define adsorption process. (NOV/DEC 2016)**

Adsorption involves contact of solid with either a liquid or a gaseous mixture in which a specific substance from the mixture concentrates on the

solid surface. For example, (i) removal of color from solutions using activated carbon, (ii) removal of moisture from air by silica gel.

**14 What is purge and write its necessity for a process? (APR/MAY 2015)**

Purge is a stream which is discarded from the recycled stream to prevent the accumulation of certain unwanted impurities or inert materials. It is necessary for maintaining low salt concentration in the mixed feed during recycling. It is used to control the composition of mixed feed.



**15 Explain the difference between the recycle and bypass stream. (NOV/DEC 2011)**

**Recycle:**

It is a stream that conducts materials leaving or downstream a process back to the inlet or upstream a process is called as recycle.

**Bypass:**

It is a stream which skips one or more steps of process and goes directly to another process. The purpose is to control the concentration of downstream or product stream.

**16 Name any four separation processes. (APR/MAY 2010)**

Absorption

Distillation

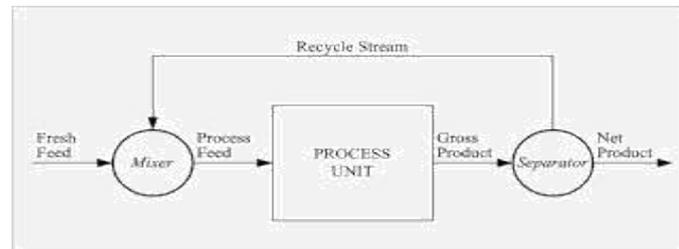
Extraction

Crystallization

**17 Give the recycle and bypass operations in chemical industries with one example. (NOV/DEC 2010)(APR/MAY 2010)**

### Recycle operations in chemical industries:

Recycle process improves the performance of equipment as in the case of absorption of sulphur trioxide using sulphuric acid rather than water, as the solubility is low in pure water.



### 18 Bypass operations in chemical industries:

Bypassing of a fluid stream is dividing it into two streams, and is often used in industries to have a closer control in operation. This is done if there is a sudden change in the property of a fluid stream like excessive heating (or cooling) as it passes through a preheater (cooler) before entering another unit.

## PART B

### UNIT-3 - MATERIAL BALANCE

1. Define Absorption, Distillation and Extraction operations.(Nov/Dec2016) (Stoichiometry by Bhatt & Vora, Pg.No.321,333,325)
2. 1000 Kg/hr of solution containing 20% methanol is continuously fed to a distillation column. Distillate is found to contain 98% methanol and waste solution from the column contains 1% methanol. Calculate: (1) Mass flow rate of Distillate and Bottom product.  
(2) The percent loss of methanol. . (NOV/DEC 2016) (Class notes)
3. Pure CO<sub>2</sub> is produced by treating limestone containing CaCO<sub>3</sub>, MgCO<sub>3</sub> and Inerts, with sulphuric acid. The residue from the process contains Ca SO<sub>4</sub> – 8.56%, MgSO<sub>4</sub>-5.23%, H<sub>2</sub>SO<sub>4</sub>-1.05%, Inerts-0.53%, CO<sub>2</sub>-0.12% and H<sub>2</sub>O – 84.51%. Calculate the amount of CaCO<sub>3</sub>, MgCO<sub>3</sub> and Inerts in limestone. (NOV/DEC 2016) (Class notes)

4. The waste acid from nitrating process contains 23%  $\text{HNO}_3$ , 57%  $\text{H}_2\text{SO}_4$  and 20%  $\text{H}_2\text{O}$ . This has to be concentrated to contain 27%  $\text{HNO}_3$  and 60%  $\text{H}_2\text{SO}_4$  by the addition of 93% conc.  $\text{H}_2\text{SO}_4$  and 90% conc.  $\text{HNO}_3$ . Calculate the weight of waste and conc. acid that must be combined to obtain 1000 Kg of the desired mixture. [NOV/DEC 2013]

**(Stoichiometry by Bhatt & Vora, Pg.No.70-71)**

5. 1000 kg of  $\text{Na}_2\text{CO}_3$  solution containing 25%  $\text{Na}_2\text{CO}_3$  is subjected to evaporative cooling. During its process 15% of  $\text{H}_2\text{O}$  present in the solution is evaporated. From the concentrated solution  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  crystallizes out. Calculate how much crystals would be produced if the solubility of  $\text{Na}_2\text{CO}_3$  is 21.5 g per 100 g of  $\text{H}_2\text{O}$ . [NOV/DEC 2011]

**(Stoichiometry by Bhatt & Vora, Pg.No.333)**

6. A solution containing 53.8 g  $\text{MgSO}_4/100\text{g}$  of water is cooled from 353 K to 323 K. during the process, 6% of water evaporates. How many kg of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  crystals obtained per 100 kg of the original solution? at 323 K the solution contains only 0.3 mass fraction of  $\text{MgSO}_4$ . [NOV/DEC 2015]

**(Stoichiometry by Bhatt & Vora, Pg.No.334-335)**

7. It is required to make 1000 kg mixed acid containing 60%  $\text{H}_2\text{SO}_4$ , 32%  $\text{HNO}_3$  and 8% water by blending
- The spent acid containing 11.3%  $\text{HNO}_3$ , 44.4%  $\text{H}_2\text{SO}_4$  and 44.3%  $\text{H}_2\text{O}$
  - Aqueous 90%  $\text{HNO}_3$ , and
  - Aqueous 98%  $\text{H}_2\text{SO}_4$ . All percentages are by mass. Calculate the quantities of each of three acids required for blending.

**(Stoichiometry by Bhatt & Vora, Pg.No.70-71)**

### **Distillation**

8. The feed to a fractionating column analyses by weight 28% benzene and 72% toluene. The analyses of the distillate shows 52 weight % benzene and 5% product. Calculate the amount of distillate and bottom product per 1000 kg of feed per hour. Also calculate the percent recovery of benzene.(8) (May/June-2009/QC.D0052)

9. 10000kg/hr of solution containing 20% methanol is continuously fed to a distillation column. Distillate is found to contain 98% methanol and waste solution from the column carries 1% methanol. All percentages are by weight. Calculate

- a. The mass flow rates of distillate and bottom product.
- b. The percentage loss of methanol.

10. The feed to a fractionating system is 45000kg/hr of 49% benzene, 30% toluene and remaining xylene. This system consists of two towers. The overhead and the bottom product from the first tower contains 95% benzene, 2% xylene with toluene and 4% toluene, 95% xylene with benzene. The bottom product from the tower-I is sent to the second tower as feed. The composition of the benzene, toluene and xylene in the overhead and bottom of the tower-II is 3%, 95%, 2% and 1%, 4%, 95% respectively. Find the amount of overhead product of tower I and II and the bottom product of the tower II. (Nov./Dec-2013/QC53048)

**Evaporation:**

11. A multiple effect evaporator handles 100 tonnes per day of pure cane sugar. The feed to the evaporator contains 30% solids. While the concentrate is leaving with 75% solids concentration, calculate the amount of water evaporated per day.

12. An evaporator system concentrating weak liquor from 10% to 50% solids, handles 200kg of solids per hour. If the same system is to concentrate a weak liquor from 5% to 40%. Find the capacity of the system in terms of solids that can be handled to be the same assuming water evaporating capacity to be the same in both cases.

**Crystallization:**

13. A crystallizer is fed with 150000kg/hr of a solution containing 10% NaCl, 15% NaOH and rest water. In the operation, water is evaporated and NaCl is precipitated as crystals. The thick liquor leaving the evaporator contains 45% NaOH, 2% NaCl and rest water. Calculate

- i. Kg/hr water evaporated
- ii. Kg/hr salt precipitated
- iii. Kg/hr thick liquor

14. A solution containing 53.8 g  $\text{MgSO}_4$ /100 g water is cooled from 353K to 323K. During process 6% of the water evaporates. How many kg of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  crystals obtained per 100 kg of the original solution? At 323K the solution contains only 0.3 mass fraction of  $\text{MgSO}_4$ .

a. (May/June-2009/QC.D0052)

15. A crystallizer is charged with 6400 kgs of an aqueous solution containing 29.6% anhydrous  $\text{Na}_2\text{SO}_4$ . The solution is cooled and 10% of the initial  $\text{H}_2\text{O}$  is lost by evaporation. The crystals obtained are  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ . If the mother liquor is found to contain 18.3%  $\text{Na}_2\text{SO}_4$ , Calculate the weight of the mother liquor and crystals. (16). (May/June -2012/QC:10240)

16. After crystallization operation, the solution of calcium chloride in water contains 60 gram of  $\text{CaCl}_2$  per 100 gram of water. Calculate the amount of this solution necessary to dissolve 200kg of  $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$  crystals at a temperature of 298K (25°C) The solubility of  $\text{CaCl}_2$  at 298K is 819.2 gram of  $\text{CaCl}_2$  per 1000 gram of water.

### Drying:

17. A water soaked fabric is dried from 44% moisture to final moisture of 9%. Calculate the weight of water removed per 200 kg of dried fabric.

18. A cotton mill dries a water soaked fabric in a drier from 54% to 9% moisture. How many kg of water are removed by drying operation per 1200 kg of feed.

### Absorption:

19. Gas mixture containing 15mole% A and 85mole% inerts is fed to an absorption tower where it is contacted with liquid solvent B which absorbs A. The mole ratio of solvent to gas entering tower is 2:1. The gas leaving the absorber contains 2.5% A, 1.5%B and rest inerts on mole basis. Calculate.

The percentage recovery of solute "A"

ii. The fraction of solvent „B“ fed to column lost in gas leaving the tower.

iii. During the process, some solvent evaporates and gets added in gas leaving the tower.

**20.** Ammonia and air mixture contains 5.1% ammonia at 28°C and 735 mm of Hg. The gas is passed through an absorption tower to recover ammonia at the rate of 40 kg/m<sup>3</sup>. The gases leaving the tower at 725 mm of Hg and 20°C. having 0.08% ammonia absorbed.

Calculate: i. The rate of flow of gas leaving the tower Weight of ammonia absorbed (Nov./Dec-2013/QC53048)

i.

**Acid mixing problem:**

21. Waste acid from a nitrating process contains 25%  $\text{HNO}_3$ , 55%  $\text{H}_2\text{SO}_4$  and 20%  $\text{H}_2\text{O}$  by weight. This is to be concentrated to get fortified acid containing 27%  $\text{HNO}_3$ , 60%  $\text{H}_2\text{SO}_4$  and 13%  $\text{H}_2\text{O}$ . This is done by adding concentrated  $\text{H}_2\text{SO}_4$  of strength 93%

22.  $\text{H}_2\text{SO}_4$  and concentrated  $\text{HNO}_3$  of strength 90%  $\text{HNO}_3$  in suitable quantities to the waste acid. If 1500 kg of fortified acid is to be produced calculate the kg of various solutions mixed. (16) 2010/QC:G0465)

23. It is required to make 1000kg mixed acid containing 60%  $\text{H}_2\text{SO}_4$ , 32%  $\text{HNO}_3$  and 8% water by blending

a. i. Spent acid containing 11.3%  $\text{HNO}_3$ , 44.4%  $\text{H}_2\text{SO}_4$  and 44.3%  $\text{H}_2\text{O}$ ,

b. ii. Aqueous 90%  $\text{HNO}_3$  and

c. iii. Aqueous 98%  $\text{H}_2\text{SO}_4$

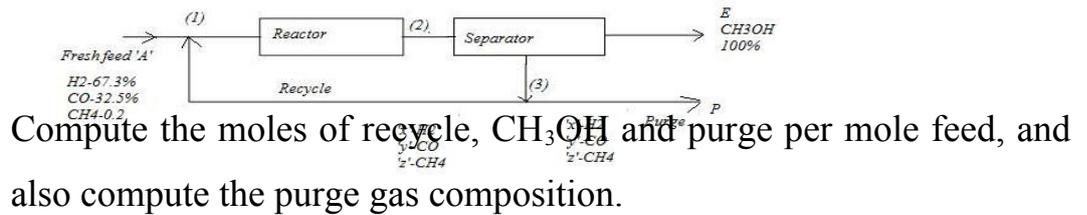
d. All percentages are by mass. Calculate the quantities of each of three acids required for blending.

(16)(May/June-2013/QC:21246)

24. **Recycle without chemical reaction:** A distillation column separates 10,000kg/hr of a 50% benzene, 50% toluene mixture. The product D recovered from the condenser at the top of the column contains 95% benzene, and the bottom W for the column contains 96% toluene. The vapor stream V entering the condenser from the top of the column is 8,000kg/hr. A portion of the product from the condenser is returned to the column as reflux, and the rest is withdrawn for use elsewhere. Assume that the compositions of the streams at the top of the column (V), the product withdrawn (D), and the reflux (R) are identical because the V stream is condensed completely. Find the ratio of the amount refluxed R to the product withdrawn D.

**25. Purge:** Hydrogen and CO gases can be combined to yield methanol according to the following equation

$CO + 2H_2 \rightleftharpoons CH_3OH$  Figure illustrates a steady-state process. All compositions are in the mole fraction. The stream flows are in moles.  $CH_4$  enters the process, but the  $CH_4$  does not participate in the reaction. A purge stream is used to maintain the  $CH_4$  concentration in the exit to the separator at no more than 3.2 mole%. The once through conversion of the CO in the reactor is 81%.



**26. Unsteady state operation:** A storage tank contains 5,000kg of a solution containing 6% acetic acid by wt%. A fresh feed of pure water is entering the tank at a rate of 450 kg/min and dilutes the solution in the tank. The mixture is stirred well and the product leaves the tank at a rate of 450 kg/min. At what instant of the time the acid concentration in the tank will drop to 0.9% acetic acid by wt%. After one hour operation what will be the concentration in the tank? (Nov./Dec-2013/QC53048)

**27.** A tank contains 10 kg of a salt solution at a concentration of 2% by weight. Fresh solution enters the tank at a rate of 2 kg/min at a salt concentration of 3% by weight. The contents are stirred well and the mixture leaves the tank at a rate of 1.5kg/min.

- i. Express the salt concentration as a function of time and
- ii. At what instant of time the salt concentration in the tank will reach 2.5% by weight?

### PART C

1. A tank contains 100 litres of salt solution in which 5 kg of salt is dissolved. Water flows into the tank at the rate of 5 litres/min and salt solution leaves the tank from the top at the same rate. Due to complete mixing, the concentration of

salt in the tank is uniform at all times. Find the amount of salt in the tank at the end of 50 min. Take the density of the salt solution as 1 kg/litre. (NOV/DEC 2106)

(Class notes)

3. Fresh juice contains 15% solids and 85% water by weight and is to be concentrated to contain 40% solids by weight. In order to overcome these problems parts of the fresh juice bypass the evaporator. Calculate
- (i) The fraction of juice that bypass the evaporator.
  - (ii) The concentrated juice produced (containing 40% solids) per 100 kg of fresh juice fed to the process. [NOV/DEC 2013]

(Stoichiometry by Bhatt & Vora, Pg.No.142)

## UNIT IV – ENERGY BALANCE

### PART A

#### 1. What is conversion? (NOV/DEC 2016)

Conversion is defined as the ratio of the reacting amount of a component to its initial amount. The amounts can be expressed as mole%, mass % or volume %. The conversion is also expressed as mole%, mass % or volume %.

#### 2. State Hess's law. (NOV/DEC 2016)

The heat evolved or absorbed in a chemical reaction is the same whether the reaction takes place in single step or in a series of step, this is known as Hess's law.

#### 3. Brief the difference between sensible and latent heat with an example.(APR/MAY 2015,2011)(NOV/DEC 2009)

**Sensible heat:**

The heat which can be measured by a measuring device. It occurs within the same phase.

**Latent heat:**

The heat which cannot be measured by a measuring device and which accompanies the phase change.

#### 4. What is heat capacity?-

Heat capacity of a system is the amount of heat required to rise the systems temperature by 1°C or K. It is expressed in units of thermal energy per °C

#### 5. What is specific heat capacity?

Heat capacity of a system is the amount of heat required to increase the temperature of unit weight of a substance by 1° temperature. It is expressed by J/Kg K.

#### 6. What is Molar heat capacity of a system?

Molar heat capacity of a system is the amount of heat required to increase the temperature of 1 mole of substance by 1°C. It is expressed in J/mol K or J/Kmol K.

#### 7. What is Latent heat?

The heat required to change the phase of a substance at constant temperature is called Latent heat

For eg water remains at 100°C while boiling, at the same time, the further heat is used to change the phase from water to vapour.

$$Q=m\lambda$$

$\lambda$  – Latent heat of the substance

#### 8. What is sensible heat?

The heat required to increase the temperature of a substance is called sensible heat.

$$Q=mC_p dT$$

m=Mass in kg ,

$C_p$  specific heat in KJ/KgK and T = temperature in K

**9. State Kopp's rule?**

It states that at room temperature the sum of the heat capacity of the individual elements is equal to the heat capacity of solid compound.

**10. What is Cox chart?**

It is graphical representation of Antoine equation in graphical form.

By using Antoine equation a graph can be plotted having  $\ln P$  on Y-axis and  $1/T$  on X-axis. The resulting chart is called Cox chart.

**11. What is Thermo chemistry?**

Enthalpy changes accompanied with chemical reaction. Whenever a chemical reaction takes place, heat may either be evolved or absorbed and this plays a major role in the economics of chemical process.

**12. What is Heat of chemical reaction?**

Heat of Reaction is the Enthalpy change resulting due to reaction where in the reactants are fed in stoichiometric amounts and reaction proceeds to complete and reactants & products having same temperature and pressure.

**13. What is standard heat of reaction?**

Standard heat of reaction is the heat of a reaction that is Enthalpy resulting from the procedure of reaction when both reactants & products in there standard state at temperature of  $25^{\circ}\text{C}$  with pressure of 1 bar absolute. It is represented by  $\Delta_B^0$

If the heat of reaction is positive, the reaction is said to be endothermic and if is negative, the reaction is called exothermic.

**14. What is Heat of formation?**

It is enthalpy change accompanying the formation of 1 mole of a compound from its element at a given temperature and pressure.

**15. What is standard heat of formation?**

It is heat of formation of 1 mole of a compound from its element in a reaction, beginning and ending at 298 K temperature and pressure of 1bar or 1Mpa. It is represented by  $\Delta_f^0$ . If the heat of formation is positive, the reaction is said to be endothermic and if it is negative, the reaction is called exothermic. Heat of formation is zero in standard at 32°C in 1bar for each element.

**16. Define Heat of combustion?**

It is the heat of reaction 1 mole substance with molecular oxygen, the combustion reaction proceeds with a reduction in enthalpy of system. Hence, Heat of combustion is always assigned negative. It is represented by  $\Delta_c$ .

**17. Define standard heat of combustion?**

Standard heat of combustion of substance is the heat of the substance with molecular oxygen to yield specified products with both reactants and products in the standard state i.e at 25°C (298K) and 1bar absolute. It is represented by  $\Delta_c^0$

**18. Explain about Antoine equation?**

The variation of the latent heat of vapourization with respect to pressure or temperature is to play a vital role in the process industries. For solving this problem Antoine equation correlates the pressure and corresponding saturation temperature.

P- Vapour pressure in KPa

T- Temperature in Kelvin

A, B, C- Constants

### **19. State Trouton's rule?**

Trouton's rule which relates the enthalpy of vapourization to the temperature of phase change.

### **20. Define Entropy of vapourization?**

The Entropy of vapourization is defined as the enthalpy of vapourization and the boiling temperature.

The enthalpy of liquids may be estimated using Trouton's rule.

### **21. State Hess law of heat summation?**

Hess law states that for a chemical equation that can be written as the sum of two or more steps, the enthalpy change for the overall equation is the sum of the enthalpy change for the individual steps

### **22. What is Heat of a solution?**

When a solute solid, liquid or gas is dissolved in a solvent to make its solution, enthalpy change when the solid or gas is dissolved in the solvent or liquid is called Heat of a solution.

When two liquids are mixed, the heat effect is called Heat of mixing. It is also the excess enthalpy. These heat changes are measured at constant temperature usually at 1 bar and expressed as kJ/Kmol or kJ/kg of the solution.

When the solids dissolve in a solvent, the exothermic heat of solution is given as positive sign and endothermic heat is given as negative sign

### **23. What is Effect of Temperature on heat of reaction?**

Standard heat of reaction is the enthalpy change associated with a reaction where in reactance and products are at a temperature of 25°C. The heat of a reaction at any temperature may be calculated from a known data of heat of reaction provided heat capacity are available up to the temperature for reactance and products of a reaction.

### **24. What are the enthalpy changes in reaction in different temperatures?**

The enthalpy change accompanying a chemical reaction can be expressed in terms of an overall energy balance. Hence for constant pressures or flow process where in kinetic, potential and surface energy changes are negligible and no works performed.

$$\Delta H = \sum H_R + \sum H^\circ - \sum H_p$$

$H^\circ$ —standard heat of reactions involved

$\sum H_p$ - sum of the enthalpy of all products relative to standard state of bar in 25°C

### **25. What is Effect of Pressure on heat of reaction?**

Effect of pressure of reaction on solids, ideal gases up to moderate pressure is very negligible for solid gas or liquid reactants. At high pressure of operation, pressure does have significant effect on heat of reaction and all terms of equation must be evaluated.

### **26. What is adiabatic process?**

A process in which the heat can leave or enter the system i.e the system surroundings or does the system receive heat from the surroundings

### **27. What is adiabatic reaction?**

It is the reaction which proceeds without loss or gain of heat. When the adiabatic reaction is exothermic, the temperature of product steam rises and when the adiabatic reaction is endothermic, the temperature of product steam decreases.

**28. What is adiabatic reaction temperature?**

It is the temperature of the products under adiabatic conditions of reactions.

**29. What is theoretical flame temperature or adiabatic flame temperature?**

The temperature attained when a fuel is burnt or oxygen without loss or gain of heat is called the theoretical flame temperature.

**30. Define entropy. (NOV/DEC 2012)**

**Entropy** is used to define the unavailable energy in a system. Entropy defines the relative ability of one system to act to another. As things moves toward a lower energy level, where one is less able to act upon the surroundings, the entropy is said to increase. The second law is concerned with entropy (S). Entropy is produced by all processes and associated with the entropy production is the loss of ability to do work. The second law says that the entropy of the universe increases.

**31. Define the terms: sensible heat and latent heat. (APR/MAY 2010) (NOV/DEC 2010,2008,2006,2005)**

**Sensible heat:** The heat which can be measured by a measuring device. It occurs within the same phase.

**Latent heat:** The heat which cannot be measured by a measuring device and which accompanies the phase change.

**32. What is the relation between vapor pressure and boiling point of liquids? (APR/MAY 2010)(NOV/DEC 2009)**

**Vapour pressure:** it is defined as the absolute pressure at which the liquid and its vapour are in equilibrium at a given temperature.

Boiling point of liquids:

**33. What is a state function? Give examples. (NOV/DEC 2010)**

It is a property which is independent of the path followed by the system. It is otherwise known as point function.

(eg) temperature, pressure, volume.

**34. What is vapor pressure? (NOV/DEC 2009)**

Vapour pressure is defined as the absolute pressure at which the liquid and its vapour are in equilibrium at a given temperature.

**35. State the second law of thermodynamics. (NOV/DEC 2008)**

The 2<sup>nd</sup> law is needed to determine the direction of processes. The second law is concerned with entropy, which is a measure of disorder. The second law says that the entropy of the universe increases. The second law is a generalization of experiments dealing with entropy--it is that the  $dS$  of the system plus the  $dS$  of the surroundings is equal to or greater than 0. Entropy is not conserved like energy.

**36. Define specific heat and molar heat capacity. (NOV/DEC 2007)**

Specific heat: Specific heat of a substance is the ratio of the heat capacity of a particular substance to that of water.

Molar heat capacity: Heat energy required to raise the temperature of 1 mole of substance by 1°C/1K.

**37. Write down the equation for the conservation of momentum. (APR/MAY 2005)**

The general momentum equation is also called the equation of motion or the Navier-Stoke's equation; in addition the equation of continuity is frequently used in conjunction with the momentum equation.

(Rate of momentum accumulation) = (rate of momentum in) – (rate of momentum out) + (sum of forces acting on the system)

**38. Define: heat of formation and heat of reaction..(APR/MAY 2005)**

**Heat of formation:** The thermal change involved in the formation of 1 mole of a substance from the elements is called the heat of formation of a substance. ( $\Delta H_f$ )

**Heat of reaction:** It is defined as the enthalpy of products minus the enthalpy of reactants. ( $\Delta H_R$ )

**39. What is Trouton's rule? (NOV/DEC 2011)**

The ratio of molal heat vaporization  $\lambda_b$  of a substance at its normal boiling point to the absolute temperature  $T_b$  is constant.

**40. Write the energy balance relation for a chemical reaction in an open system. .(APR/MAY 2015)**

**Energy Balances on Open Systems**

*First law of thermodynamics*

$$\oint dQ = \oint dW$$

$$Q = U_{Total} + W_{Total}$$

$$U_{Total} = Q + W_{Total}$$

$$\Delta u + \Delta E_{kinetic} + \Delta E_{potential} = Q - (W_{shaft} + W_{flow})$$

$$\Delta H = \Delta u + W_{flow}$$

$$(\Delta u + W_{flow}) + \Delta E_{kinetic} + \Delta E_{potential} = Q - (W_{shaft})$$

$$\Delta H + \Delta E_{kinetic} + \Delta E_{potential} = Q - W_{shaft}$$

**PART B**

**UNIT IV ENERGY BALANCE**

1. (i) A liquid ethanol fermentation medium at 45°C is pumped at the rate of 1000 kg/hr through enters at 75°C and leaves at 90°C, the average heat capacity of the medium and water is 3.986 and 5.21 kJ/kg K. respectively the medium stream and hot water stream are separated by a metal surface through which heat is transferred and do not physically with each other. Make the complete heat balance of the system and calculate the hot water flow and the amount of heat added to the fermentation medium assuming there is no heat loss in the system.

[ NOV/DEC 2013] (Stoichiometry by Bhatt & Vora, Pg.No.)

- (ii) Heat capacity of acetic acid is given by  $C_p = 155.48 - 326.595 \times 10^{-3}T + 744.199 \times 10^{-6} T^2$  based on this equation, calculate the mean capacity for acetic acid for temperature range of 25°C to 50°C

[ NOV/DEC 2013] (Refer class notes)

2. (i) Explain the concept of heat capacity and how it is being calculated for various substances. (Stoichiometry by Bhatt & Vora, Pg.No.181-184)
3. Explain the various thermodynamic processes like constant volume, constant pressure, isothermal & adiabatic process.

(Stoichiometry by Bhatt & Vora, Pg.No.265-271)

4. The heat capacity of CO<sub>2</sub> is given by the following relation  
 $C_p = 26.540 + 42.454 \times 10^{-3}T - 14.298 \times 10^{-6} T^2$  where  $C_p$  KJ/Kmol K and T is in Kelvin.

- (i) How much heat is required to heat 1 kg of CO<sub>2</sub> from 300 K to 1000K?
- (ii) Obtain the relation expressing the heat capacity in kcal/kmol°C and temperature in °C
- (iii) Obtain the relationship giving heat capacity in Btu/lb mol °F and temperature in °F [NOV/DEC 2015]

(Stoichiometry by Bhatt & Vora, Pg.No.184-193)

4. Estimate the heat of vapourization of methyl chloride at 30°C from the Clapeyron equation assuming ideal behavior for the vapour phase. The vapour pressure (kPa) is given by
5. The heat capacity of carbon dioxide is given by the following relation  $C_p = 26.540 + 42.454 \times 10^{-3} T - 14.298 \times 10^{-6} T^2$  where  $C_p$  is in  $\text{kJ/kmol K}$  and  $T$  is in K.
- How much heat is required to heat 1 kg of  $\text{CO}_2$  from 300 K to 1000 K?
  - Obtain the relation expressing the heat capacity in  $\text{kcal/kmol.}^\circ\text{C}$  and temperature in  $^\circ\text{C}$ .
  - Obtain the relationship giving heat capacity in  $\text{Btu/lb-mol}^\circ\text{F}$  & temperature in  $^\circ\text{F}$ .
6. The molal heat capacity of CO is given by  $C_p = 26.586 + 7.582 \times 10^{-3} T - 1.12 \times 10^{-6} T^2$  Where  $C_p$  is in  $\text{kJ/kmol K}$  and  $T$  is in K.
- Calculate the mean molal heat capacity in the temperature range of 500-1000 K.
  - CO enters a heat exchanger at a rate of  $500\text{m}^3$  per hour at STP. Calculate the heat to be supplied to the gas to raise its temperature from 500 to 1000 K.
  - CO is to be heated from 500 to 1500 K. What percent error is expected if the heat requirement is calculated using the mean heat capacity value determined in part (a)?
7. Combustion of solid wastes produces a flue gas of the following analysis:  $\text{CO}_2 = 9.0\%$ ,  $\text{CO} = 2.00\%$ ,  $\text{O}_2 = 7.00\%$  and  $\text{N}_2 = 82.0\%$ . Find the difference in enthalpies for this gas between the bottom and top of the stack if the temperature of the gas at the bottom is 600 K and that at the top is 375 K. The heat capacities of the gas are:

$$\text{CO}_2 : C_p = 26.540 + 42.454 \times 10^{-3} T - 14.298 \times 10^{-6} T^2$$

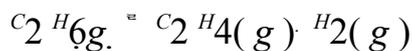
CO :  $C_p = 26.586 + 7.582 \times 10^{-3} T - 1.12 \times 10^{-6} T^2$   
 $O_2 : C_p = 25.74 + 12.987 \times 10^{-3} T - 3.864 \times 10^{-6} T^2$   
 $N_2 : C_p = 27.03 + 5.815 \times 10^{-3} T - 0.289 \times 10^{-6} T^2$   
 $C_p$  is in kJ/kmol K and  $T$  is in K.

8. Determine the heat capacity of  $Na_2SO_4 \cdot 10H_2O$  at room temperature using Kopp's rule. The atomic heat capacities of elements (J/g-atom K) are 26.04 for Na, 22.6 for S, 16.8 for O, and 9.6 for H. Compare the result with the experimental value of the heat capacity of 592.2 J/mol K
9. Enthalpy of steam at 75 kPa and 573 K is 3075 kJ/kg referred to liquid water at 273 K. If the mean heat capacity of liquid water and water vapour are 4.2 kJ/kg K and 1.97 kJ/kg K respectively, calculate the heat of vaporization of water at 75 kPa. The saturation temperature of water at 75 kPa is 365 K.
10. The gas having the following composition is at temperature of 750 K.  
 $SO_2 = 7\%$ ,  $O_2 = 11\%$ ,  $SO_3 = 1\%$  and  $N_2 = 81\%$ . Calculate the heat content of 2 kgmol of gas mixture over 300 K using heat capacity data given below

$$C_p^o = a + bT + cT^2$$

Component	a	$b \times 10^3$	$c \times 10^6$
$SO_2$	43.46	10.64	-5.95
$O_2$	26.01	11.76	-2.34
$SO_3$	22.03	121.63	-91.87
$N_2$	29.60	-5.15	-13.19

11. Calculate the standard heat of reaction of the following reaction



$\Delta H^\circ C$ (kJ/

Data: Component mole)

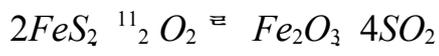
- a.  $C_2H_6(g)$  -1561  
 b.  $C_2H_4(g)$  -1411  
 c.  $H_2(g)$  -286

12. Calculate the heat of reaction at 25°C of the following reaction



Data: Component	$\Delta H^\circ C$ (kJ/mole)
d. C <sub>2</sub> H <sub>5</sub> OH(g)	1410
e. CH <sub>3</sub> CHO(g)	1193
f. H <sub>2</sub> (g)	-286

13. Calculate the standard heat of reaction of the following reaction at  $\Delta H_R^{298}$  for the reaction



The standard heat of formation of the compounds as

Data: Component	$\Delta H_f^{298}$ (kJ/mole)
g. FeS(g)	-178.03
h. O <sub>2</sub> (g)	0
i. Fe <sub>2</sub> O <sub>3</sub>	-822.75
j. SO <sub>2</sub>	-297.11

14. Calculate the heat of formation of liquid ethyl alcohol at 298K

using following data  $\Delta H_f^\circ$  (CO<sub>2</sub>) = -93.98kcal/mole

$\Delta H_f^\circ$  (H<sub>2</sub>O) = -68.26kcal/mole

$\Delta H_f^\circ$  (C<sub>2</sub>H<sub>5</sub>OH) = -336.79kcal/mole

15. SO<sub>2</sub> gas is oxidised in 100% excess air 70% conversion to SO<sub>3</sub>. The gases enter the converter at 400°C and leave 450°C. How many kcal are absorbed in the heat exchanger of the converter per kmole of SO<sub>2</sub> sent?

	SO <sub>3</sub>	SO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>

Cp, mean				
Cal/gmole°C	15.5	11	7.5	7.1

$$\Delta H_{\text{rxn}} = -23490 \text{ cal/gmole}$$

16. Calculate the theoretical flame temperature of a gas having 20% CO and 80% N<sub>2</sub> when burnt with 150% excess air. Both air and gas being at 25°C.

Data: Heat of formation of CO<sub>2</sub> = -94052 cal/gmole

CO = -26412 cal/gmole at 25°C

C<sub>p</sub>, CO<sub>2</sub>: 12.1, O<sub>2</sub>: 7.9, N<sub>2</sub>: 7.55 Cal/gmole K

17.E.1. 1000 m<sup>3</sup> of a gas containing 60% hydrogen and 40% ammonia is cooled from 773K to 313K at 1 atm pressure. Calculate the heat removed.

The C<sub>p</sub> values in kcal/kmole K and T in K are

For hydrogen C<sub>p</sub> = 6.9 - 0.2 × 10<sup>-3</sup>T + 0.48 × 10<sup>-6</sup>T<sup>2</sup>

For Ammonia C<sub>p</sub> = 6.08 + 8.81 × 10<sup>-3</sup>T - 1.5 × 10<sup>-6</sup>T<sup>2</sup>

(May/June-2009/QC.D0052)

17.E.2. Heat capacity data for gaseous SO<sub>2</sub> is given by the following equation:

$$C_p = 43.458 + 10.634 \times 10^{-3}T - 5.945 \times 10^{-5}T^2$$

Calculate the heat needed to raise the temperature of 1 kmole pure sulphur dioxide from 300K to

1000K (May/June-2009/QC.D0052)

17.E.3. A natural gas has the following composition on mole basis CH<sub>4</sub> = 84%, C<sub>2</sub>H<sub>6</sub> = 13%, N<sub>2</sub> = 3%. Calculate the amount of heat required to heat 10 kmol of natural gas from 298K (25°C) to 523K (250°C) using heat capacity data given below:

$$^{\circ}\text{Cp} = a + bT + cT^2 + dT^3 \text{ kJ}/(\text{kmol}\cdot\text{K})$$

Gas	a	b $\times 10^3$	c $\times 10^6$	d $\times 10^9$
	19.2494	52.1135		
CH <sub>4</sub>	11.973		-11.3173	
				8.714
C <sub>2</sub> H <sub>6</sub>	5.4129	178.0872	-67.3749	7
		13.1829		
	29.5909	-	-4.968(	
N <sub>2</sub>	5.141		C:11226)	

17.E.4. Coal is burnt to a gas of the following composition: CO<sub>2</sub>-9.2%, O<sub>2</sub>-7.4%, CO-2.9%. What is the enthalpy difference for this gas between the bottom and the top of the stack if the temperature at the bottom is 550°F at the top is 200°F.

$$\text{Cp of N}_2 = 6.895 + 0.7624 \times 10^{-3}T - 0.7 \times 10^{-7} T^2$$

$$\text{Cp of O}_2 = 7.104 + 0.7851 \times 10^{-3}T - 0.5528 \times 10^{-7} T^2$$

$$\text{Cp of CO}_2 = 8.448 + 5.757 \times 10^{-3}T - 21.59 \times 10^{-7} T^2 + 3 \times 10^{-10} T^3$$

$$C_p \text{ of CO} = 6.865 + 0.8024 \times 10^{-3} T - 0.736 \times 10^{-7} T^2 \quad (\text{Nov./Dec-2013/QC53048})$$

6.E.5. One kg of water is heated from 250 K to 400 K at one standard atmosphere pressure. How

much heat is required for this? The mean heat capacity of ice between 250 K and 273 K is 2.037

kJ/kg K, the mean heat capacity of water between 273 K and 373 K is 75.726 kJ/kmol K and the

heat capacity of water vapor (kJ/kmol K) is

$$C_p = 30.475 + 9.652 \times 10^{-3} T + 1.189 \times 10^{-6} T^2$$

where  $T$  is in K. The latent heat of fusion and vaporization of water are, respectively, 6012 kJ/kmol and 40608 kJ/kmol

### PART C

- (i) Define sensible heat and latent heat.  
(NOV/DEC 2016) (Stoichiometry by Bhatt & Vora, Pg.No.194-195 & 205-206)

(ii) Calculate the standard heat of reaction of the following reaction at 298 K and 101.32 kJ/mol for 4 kg mol of  $\text{NH}_3$  (NOV/DEC 2016) (Class notes)
- (i) How is calculated standard heat of reaction from heat of formation and heat of combustion data? (NOV/DEC 2016) (Stoichiometry by Bhatt & Vora, Pg.No.260-262)

(ii) 100 kg/hr of methanol liquid at a temperature of 303 K is obtained by removing heat from saturated methanol vapor. Find out the amount of heat to be removed.

Data: Boiling point of methanol = 337.8 K

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Latent heat of condensation of methanol = 1101.7 KJ/kg

Specific heat of methanol = 2.7235 (KJ/kg.K) (NOV/DEC 2016) (Class notes)

## UNIT – V

### CHEMICAL REACTION

**1. What is meant by limiting reactant?**

A reactant which decides the conversion in a reaction is called as limiting reactant.

**2. What is meant by excess reactant?**

A reactant which present in excess of stoichiometric in a reaction is called excess reactant.

**3. What is meant by conversion?**

Conversion means how much of a reactant has reacted or consumed.

**4. What is yield?**

Yield means how much of a desired product was formed.

**5. What is selectivity?**

Selectivity means how much desired product was formed in ratio to the undesired product.

**6. Explain weight percent. (NOV/DEC 2008)**

Weight percent:

It is defined as the ratio of weight of a particular component to the total weight of the system in every 100 part.

**7. Define selectivity**

The ratio of amount of limiting reactant that reacts to give the desired product to the amount that reacts to give undesirable products.

**8. Define conversion.**

Conversion is defined as the ratio of the reacting amount of a component to its initial amount. It is expressed as mole %, mass % (or) volume %.

**9. Define degrees of freedom. (NOV/DEC 2009,2006)**

Degree of freedom is defined as the number of independent variables required to define system completely.

Phase rule:  $F = C - P + 2$

F – Degree of freedom, C– Number of component and P– Number of phases

**10. What is limiting and excess reactant? (NOV/DEC 2016) (APR/MAY 2015,2005)**

Limiting reactant:

Limiting reactant is defined as the material that is not present in excess of that required to continue any of the other reacting materials and it is not present in the product.

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**11. Excess reactant:**

A reactant which is present in excess of the stoichiometric amount in a reaction and it is always present in the product.

**12. Define yield and excess component in chemical reaction. (NOV/DEC 2010)**

Yield:

yield is defined as the ratio of the moles of reactants converted to main product to its moles of reactants taking part in the reaction.

Excess component:

A component which is present in excess of the stoichiometric amount in a reaction and it is always present in the product.

**13. State Kopp's law.**

Kopp's law: The heat capacity of a solid compound is approximately equal to the sum of the heat capacities of the constituent elements.

**14. Define adiabatic reaction temperature.**

Adiabatic reaction temperature is the temperature attained by reaction products, if the reaction proceeds without loss or gain of heat and if all the products of the reaction remain together in a single mass or stream of materials.

**15. Explain theoretical flame temperature.**

The temperature attained when a fuel is burnt in air or oxygen without loss or gain of heat is called the theoretical flame temperature.

**16. Define heat of mixing.**

When two solutions are mixed, the heat evolved or absorbed during the mixing process is known as heat of mixing.

**17. What is state function and path function?**

State function: It is a property which is independent of the path followed by the system. It is otherwise known as point function.

(eg) Temperature, Pressure, Volume.

Path function: it is a property which is dependent of the path followed by the system. (eg) Heat, Work.

**18. Write notes on extensive property and intensive property.**

Extensive property: It is a state of system, which depends on the mass under consideration. (eg) Volume, Enthalpy.

Intensive property: This state of a system is independent of mass. An example of this property is temperature, density, viscosity, entropy, internal energy.

**19. Distinguish between heat and temperature?**

Heat                      Temperature

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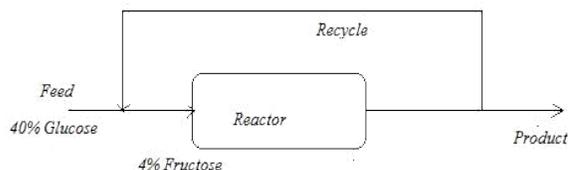
- |  |    |   |
|--|----|---|
| 20. It is a form of energy in transit (always flow). | 1  | It is a property used to measure heat energy. |
| 2. Heat is a path function.                          | 2. | Temperature is a state function.              |
| 3. Unit of heat is Joule.                            | 3. | Unit of temperature is K / °C / °F / °R       |
| 4. It is extensive property.                         |    |   |

It is intensive property.

## UNIT 5

### PART B

- Calculate the amount of heat given off when 1 m<sup>3</sup> of air at standard conditions cools from 500°C to -100°C at constant pressure.
- The Orsat analysis of the flue gases from a boiler house chimney gives CO<sub>2</sub>:11.4%, O<sub>2</sub>:4.2% and N<sub>2</sub>:84.4% (mole%). Assuming that complete combustion has taken place, (a) Calculate the % excess air, and (b) find the C:H ratio in the fuel. (Stoichiometry by Bhatt & Vora, Pg.No.416-417)
- Pure sulphur is burnt in a burner at the rate of 0.3 kg/s. fresh dry air is supplied at 30°C and 100 kPa. The gases from the burner contain 16.5%SO<sub>2</sub>, 3% O<sub>2</sub> and rest N<sub>2</sub> on SO<sub>3</sub> free volume basis. The gases leave the burner at 800°C and 101.325 kPa. Calculate the Fraction of sulphur burnt into SO<sub>3</sub>  
 The percentage excess air over the amount required to oxidize sulphur to SO<sub>2</sub>  
 The volume of dry air in m<sup>3</sup>/s  
 The volume of burner gases in m<sup>3</sup>/s. [NOV/DEC 2015]
- (Stoichiometry by Bhatt & Vora, Pg.No.125-126)



5. **Recycle with a reaction occurring:** Immobilized glucose isomerase is used as a catalyst in producing fructose from glucose in a fixed-bed reactor (water is the solvent). For the system shown in figure. What percent conversion of glucose results on one pass through reactor when the ratio of the exit stream to the recycle stream in mass units is equal to 8.33?
6. (i) Define yield and selectivity. (NOV/DEC 2016)
7. (Stoichiometry by Bhatt & Vora, Pg.No.112-114)
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## **BT8302 APPLIED THERMODYNAMICS FOR BIOTECHNOLOGISTS**

### **UNIT I -THERMODYNAMIC LAW AND PROPERTIES OF FLUIDS(9)**

First Law of thermodynamics, a generalized balance equation and conserved quantities, Volumetric properties of fluids exhibiting non ideal behavior; residual properties; estimation of thermodynamic properties using equations of state; calculations involving actual property exchanges; Maxwell's relations and applications.

### **UNIT II - SOLUTION THERMODYNAMICS (9)**

Partial molar properties; concepts of chemical potential and fugacity; ideal and non-ideal solutions; concepts and applications of excess properties of mixtures; activity coefficient; composition models; Gibbs Duhem equation.

### **UNIT III - PHASE EQUILIBRIA(9)**

Criteria for phase equilibria; VLE calculations for binary and multi component systems; liquid- liquid equilibria and solid-solid equilibria.

### **UNIT IV- CHEMICAL REACTION EQUILIBRIA (9)**

Equilibrium criteria for homogeneous chemical reactions; evaluation of equilibrium constant; effect of temperature and pressure on equilibrium constant; calculation of equilibrium conversion and yields for single and multiple reactions.

### **UNIT V -THERMODYNAMIC DESCRIPTION OF MICROBIALGROWTH AND PRODUCT FORMATION (9)**

Thermodynamics of microbial growth stoichiometry thermodynamics of maintenance, Calculation of the Operational Stoichiometry of a growth process at Different growth rates, Including Heat using the Herbert –Pirt Relation for Electron Donor, thermodynamics and stoichiometry of Product Formation.

#### **TEXT BOOKS:**

1. Smith J.M., Van Ness H.C., and Abbot M.M. "Introduction to Chemical Engineering Thermodynamics", 6th Edition. Tata McGraw-Hill, 2003.
2. Narayanan K.V. "A Text Book of Chemical Engineering Thermodynamics", PHI,2003.
3. Christiana D. Smolke, " The Metabolic Pathway Engineering Handbook Fundamentals",CRC Press Taylor & Francis Group, 2010.

#### **REFERENCE:**

1. Sandler S.I. "Chemical and Engineering Thermodynamics", John Wiley,1989.

## BT8302 APPLIED THERMODYNAMICS FOR BIOTECHNOLOGISTS

S. No.	Title	Reference Book	Page No.
<b>UNIT I - THERMODYNAMIC LAW AND PROPERTIES OF FLUIDS (9)</b>			
1.	First Law of thermodynamics	Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" (CET)	23-30
2.	A generalized balance equation and conserved quantities	Narayanan K.V (CET)	31-32
3.	Volumetric properties of fluids exhibiting non ideal behavior;	Narayanan K.V (CET)	188-191
4.	Residual properties	Narayanan K.V (CET)	237-240
5.	Estimation of thermodynamic properties using equations of state	Narayanan K.V (CET)	191-216
6.	Calculations involving actual property exchanges	Narayanan K.V (CET)	288-291
7.	Maxwell's relations and applications.	Narayanan K.V (CET)	192-195
<b>UNIT II - SOLUTION THERMODYNAMICS (9)</b>			
1.	Partial molar properties	Narayanan K.V (CET)	257-262
2.	Concepts of chemical potential and fugacity	Narayanan K.V (CET)	265-273
3.	Ideal and non-ideal solutions	Narayanan K.V (CET)	273-275
4.	Concepts and applications of excess properties of mixtures.	Narayanan K.V (CET)	298-300
5.	Activity coefficient	Narayanan K.V (CET)	278-282
6.	Composition models	Narayanan K.V (CET)	288-294
7.	Gibbs Duhem equation	Narayanan K.V (CET)	283-285
<b>UNIT III - PHASE EQUILIBRIA (9)</b>			
1.	Criteria for phase equilibria	Narayanan K.V (CET)	310-312
2.	VLE calculations for binary and multi component systems	Narayanan K.V (CET)	315-380
3.	Liquid- liquid equilibria and	Narayanan K.V (CET)	381-383
4.	Solid-solid equilibria.	Narayanan K.V (CET)	REF.PAPER
<b>UNIT IV- CHEMICAL REACTION EQUILIBRIA (9)</b>			
1.	Equilibrium criteria for homogeneous chemical reactions	Narayanan K.V (CET)	398-404
2.	Evaluation of equilibrium constant	Narayanan K.V (CET)	404-408
3.	Effect of temperature and pressure on equilibrium constant	Narayanan K.V (CET)	409-421
4.	Calculation of equilibrium conversion and yields for single and multiple reactions.	Narayanan K.V (CET)	422-439
<b>UNIT V - THERMODYNAMIC DESCRIPTION OF MICROBIAL GROWTH AND PRODUCT FORMATION (9)</b>			
1.	Thermodynamics of microbial growth stoichiometry thermodynamics of maintenance	Christiana D. Smolke, "The Metabolic Pathway Engineering Handbook Fundamentals"	11-2, 11-13
2.	Calculation of the Operational Stoichiometry of a growth process at Different growth rates, Including Heat using the Herbert -Pirt Relation for Electron Donor	Christiana D. Smolke	11-14
3.	Thermodynamics and stoichiometry of Product Formation.	Christiana D. Smolke	11-17

**BT8302 APPLIED THERMODYNAMICS FOR BIOTECHNOLOGISTS**  
**UNIT I -THERMODYNAMIC LAW AND PROPERTIES OF FLUIDS**  
**PART A**

1. What are the limitations of first law of thermodynamics? (Apr/May 2017)
  - (i) The first law of thermodynamics is a law of conservation of energy. It does not specify the direction of the process. All spontaneous processes processed in one direction only.
  - (ii) The first law of thermodynamics does not specify the feasibility of a process reversing itself.
  - (iii) This Law is silent about its % of conversion of energy from one form to another form. Work can be converted into equivalent amount of heat but heat cannot be converted into equivalent amount of work.
  - (iv) Mathematically first law of thermodynamics is  $dU = dQ - dW$ . Thus first law gives the term of internal energy 'U'.
  
2. What is 'equation of state'? (Apr/May 2017)

An equation of state is a functional relationship between state variables P, T and V.  
Ideal gas equation of state is  $PV = RT$ .  
This equation was established from the postulates of the kinetic theory of gases by [Maxwell](#) with the following assumptions:

  - (1) There is little or no attraction between the molecules of the gas
  - (2) Volume occupied by the molecules is negligibly small compared to the volume of gas

**Applicability:** Ideal gas equation of state is applicable to gas with very small pressure or very high temperature.
  
3. Discuss on volume expansivity. (May/June 2016)

It is a parameter that is used to measure the volume expansivity of pure substances and is defined at constant pressure, P. In the field of materials science, the property of linear coefficient of thermal expansion is an important consideration in materials selection and design of products. This property is used to account for the change in volume when the temperature of the material is changed.

$$\beta = \frac{1}{V} \left( \frac{\partial V}{\partial T} \right)_p$$
  
4. Define the principle of corresponding states. (May/June 2016)

All gases when compared at the same reduced temperature and reduced pressure, have approximately the

same compressibility factor and all deviate from the ideal behavior to the same extent.

$$Z = f(T_r, P_r)$$

5. Distinguish between internal energy, kinetic energy and potential energy of a system. (Apr/May 2015)

S.No.	Internal Energy	Kinetic Energy	Potential Energy
1	The system possesses by virtue of the molecular configuration and motion of molecules. Unit of energy is joule.	The energy possessed by the body by virtue of its motion is called its kinetic energy. (KE)	The energy possessed by the system due to its position above some arbitrary reference plane is referred to as its potential energy. (PE)
2	1J = 1 Nm = 1kg m <sup>2</sup> /s <sup>2</sup>	KE = ½ mv <sup>2</sup>	PE = mgz
3	Internal energy is a thermodynamic property of the system.	Kinetic Energy is not a thermodynamic property of the system. It doesn't change with change in the temperature or pressure of the body.	Potential Energy is not a thermodynamic property of the system. It doesn't change with change in the temperature or pressure of the body.

6. What are the Maxwell's equations and what is their importance in establishing relationships between thermodynamic properties? (Apr/May 2015)

Maxwell's equations are helpful in replacing unmeasurable quantities appearing in thermodynamic equations by measurable quantities. Using these relations, the partial derivatives of entropy with respect to pressure and volume are expressed as derivatives possessing easily identifiable physical meaning. Each of the four Maxwell's equations is derived from the exact differential equations of the four energy properties.

$$\left( \frac{\partial T}{\partial V} \right)_S = \left( \frac{\partial P}{\partial S} \right)_V \rightarrow 1$$

$$\left( \frac{\partial T}{\partial P} \right)_S = \left( \frac{\partial V}{\partial S} \right)_P \rightarrow 2$$

$$\left( \frac{\partial P}{\partial T} \right)_V = \left( \frac{\partial S}{\partial V} \right)_T \rightarrow 3$$

$$\left( \frac{\partial V}{\partial T} \right)_P = \left( \frac{\partial S}{\partial P} \right)_T \rightarrow 4$$

7. Distinguish between state and path function. (May/June 2014) (May/June 2007)

State Function	Path Function
Depends only on the state at the moment and independent of path taken to establish property or value.	Dependent on path taken to establish property or value.
Can integrate using final and initial values.	Need multiple integrals and limits of integration in order to integrate.
Multiple steps result in same value.	Multiple steps result in different value.
Based on established state of system (temperature, pressure, amount, and internal energy).	Based on how state of system was established. (heat and work)

8. Define  $C_p$  and  $C_v$ . (May/June 2014)

At constant volume (isometric),  $C_v$  = molar specific heat at constant V

At constant pressure (isobaric),  $Q_p = n C_p \Delta T$ ,  $C_p$  = molar specific heat at constant P

$C_p$  = Specific heat capacity at constant pressure, i.e.  $C_p = \left( \frac{\partial H}{\partial T} \right)_P$

$C_v$  = Specific heat capacity at constant volume, i.e.  $C_v = \left( \frac{\partial U}{\partial T} \right)_V$

It can be shown that for a perfect gas:  $C_p - C_v = R$ , where R is the gas constant.

The ratio,  $C_p/C_v = \gamma$

9. Give two examples of properties. (May/June 2013)

Temperature, volume, entropy – Examples of reference properties.  
Internal energy, enthalpy – Examples of energy properties.

10. Define Helmholtz energy. (May/June 2013,2012)

Helmholtz free energy ( $A$ ) of a system is defined as  $A = U - TS$

Where,  $U$  - Internal energy,  $T$ - Temperature,  $S$  –Entropy of the system. Since,  $U$ ,  $T$  and  $S$  are characteristic of the system and depend only on its thermodynamic state, Helmholtz free energy is a state function. Since  $U$  and  $S$  are both extensive,  $A$  also is an extensive property.

11. What are residual properties? (May/June 2012) (Apr/May 2010)

The residual properties are defined as the difference between the thermodynamic property at the specified temperature and pressure and the property that the substance would have exhibited at the same temperature and pressure (ideal gas condition).

Properties in the ideal state represented with the superscript *id*, the residual enthalpy ( $H^R$ ) and residual entropy ( $S^R$ ) are defined as

$$H^R = H - H^{id}$$

$$S^R = S - S^{id}$$

12. What are fundamental property relations? (May/June 2013) (Apr/May 2010)

The differentials of energy properties form the basis for the derivation of a large number of equations relating thermodynamic properties. These are developed for systems of constant mass and composition in which the only external force is the pressure and the process occurring is reversible.

### Fundamental property relations

i) **Internal Energy**,  $dU = dQ - dW = TdS - PdV$

$$dU = TdS - PdV \rightarrow (1)$$

ii) **Enthalpy**,  $H = U + PV$ ,  $dH = dU + d(PV)$ ,  $dH = (TdS - PdV) + PdV + VdP$

$$dH = TdS + VdP \rightarrow (2)$$

iii) **Helmholtz Free Energy**,  $A = U - TS$ ,  $dA = dU - d(TS) = dU - SdT - TdS$

$$dA = TdS - PdV - SdT - TdS$$

$$dA = -PdV - SdT \rightarrow (3)$$

iv) **Gibbs Free energy**,  $G = H - TS$ ,  $dG = dH - d(TS) = TdS + VdP - TdS - SdT$

$$dG = VdP - SdT \rightarrow (4)$$

13. What are three means by which the second virial coefficient can be determined? (Apr/May 2010)

The second virial coefficient can be determined by,

- (i) Kinetic theory
- (ii) Equations of state
- (iii) Physical interpretation.

14. Define-volume expansivity and isothermal compressibility. (Apr/May 2011)

The volume coefficient of expansion ( $\beta$ ) and coefficient of isothermal compressibility ( $\kappa$ ) are two other measurable quantities like heat capacities at constant pressure and constant volume. They are defined as

$$\beta = \frac{1}{V} \left( \frac{\partial V}{\partial T} \right)_P$$

$$\kappa = -\frac{1}{V} \left( \frac{\partial V}{\partial P} \right)_T$$

$$\beta = \frac{1}{k_B T} \left( \frac{\partial V}{\partial T} \right)_P, \quad \kappa = -\frac{1}{V} \left( \frac{\partial V}{\partial P} \right)_T$$

By introducing wherever possible, volume coefficient of expansion ( $\beta$ ) and coefficient of isothermal compressibility ( $\kappa$ ), the resulting relationships get fully expressed in terms of measurable quantities.

15. How do you relate the Van der Waals constants to the critical properties? (May/June 2009) (Apr/May 2011)

Van der Waals equation is used to explain the P-V-T behavior of real gases.

$$\left( P + \frac{a}{V^2} \right) (V - b) = RT$$

Where a and b are called van der Waals constants.

This equation is cubic in volume and below the critical temperature, there are three real roots. The largest is the vapour volume and the smallest the liquid volume. The intermediate root has no physical significance. When P is the saturation pressure, the smallest and the largest roots correspond to molar volumes of saturated liquid and saturated vapour respectively.

$$V_c = 3b ; T_c = \frac{8a}{27Rb} ; P_c = \frac{RT_c}{2b} - \frac{a}{9b^2}$$

Van der Waals constant is expressed in terms of critical properties

$$\frac{27R^2T_c^2}{RT_c}$$

$$a = \frac{bc}{64P_c}; \quad b = \frac{bc}{8P_c}$$

16. Define system.(Nov/Dec 2009)

A system is a region in which the process occurs. (eg) reaction vessel, distillation column.

17. Define system and surroundings. (Nov/Dec 2009)

The part of the universe outside the system and separated from the system by boundaries is called surroundings.

18. What is physical significance of virial coefficients? (Apr/May 2008)

- Virial coefficients are functions of temperature only (for a given gas).
- virial coefficients can be given physical interpretation.
- The virial coefficients account for the molecular interactions.

The two sets of virial coefficients are related as:

$$B' = \frac{B}{RT}, \quad C' = \frac{C - B^2}{RT^2}$$

19. What is compressibility factor? (Apr/May 2008)

Compressibility factor (Z) is defined as the ratio of the volume of a real gas (V) to the volume if the gas behaved ideally at the stated temperature and pressure (RT/P). Virial equations express the compressibility factor of a gas or vapor as a power series expansion in P or 1/V.

$$Z = \frac{PV}{RT} = 1 + B' P + C' P^2 + D' P^3 + \dots$$

$$Z = \frac{PV}{RT} = 1 + \frac{B}{V} + \frac{D}{V^3} + \dots$$

20. State the law of corresponding states and explain its significance. (Nov/Dec 2008)

**Law of corresponding states:** All gases when compared at the same reduced temperature and reduced pressure, have approximately the same compressibility factor and all deviate from the ideal behavior to

the same extent.  $Z = f(T_r, P_r)$

**Significance:** generalized compressibility charts are made correlating the P-V-T behavior of all fluids, based on the principle of corresponding states.

21. What is control volume? (Nov/Dec 2008)

For a control volume, the law of conservation of mass may be written as:

$$\left( \begin{array}{l} \text{Rate of accumulation of mass} \\ \text{Within the control volume} \end{array} \right) + \left( \begin{array}{l} \text{Net rate of mass out} \\ \text{by the flowing streams} \end{array} \right) = 0$$

$$\frac{dm}{dt} + \Delta(\rho u A) = 0$$

For steady-state flow process, there is no accumulation of mass within the control volume, hence  $dm/dt=0$  then above equation becomes,  $\Delta(\rho u A) = 0$

22. Show that the Joule-Thomson coefficient is zero for ideal gases. (May/June 2007)

For ideal gases:  $PV = RT \Rightarrow V = \frac{RT}{P}$ , Differentiate w.r.to temperature at constant pressure

$$\left( \frac{\partial V}{\partial T} \right)_P = \frac{R}{P}$$

Joule Thomson coefficient:  $\mu C_p = \left( \frac{\partial V}{\partial T} \right)_P - V$

Substitute  $\left( \frac{\partial V}{\partial T} \right)_P = \frac{R}{P}$  in above equation which gives

$$\mu C_p = T \left( \frac{R}{P} \right)$$

$$\mu C_p = \frac{TR}{P} - \frac{RT}{P} \Rightarrow 0$$

$$\mu = 0$$

Hence, Joule Thomson coefficient is zero for ideal gases.

23. State first law of thermodynamics. (May/June 2006)

The law states that change in internal energy (dU) in any system is equal to the heat added to the system (dQ) minus the work done by the system (dW).

$$dU = dQ - dW$$

24. State second law of thermodynamics. (May/June 2006)

The change in entropy (dS) during any change in a system is equal to the heat entering the system (when

the change is performed reversibly) divided by the absolute temperature, T.

$$dS = \frac{dQ_{rev}}{T}$$

Entropy of an isolated system always increases ( $dS > 0$ ).

The statements for the first and second laws of thermodynamics can be combined: *The energy of the universe is conserved whereas the entropy is increasing.*

25. Define a closed system with one example. (Nov/Dec 2003)

Systems that can exchange energy with the surroundings but which cannot transfer matter across the boundaries are known as closed systems. (eg) batch reactor, power and refrigeration cycles

26. Define an open system with one example. (Nov/Dec 2003)

Systems that can exchange both energy and matter with their environment. (eg) compressor, pump and heat exchanger.

27. Define Clausius inequality.

In a cyclic operation, the sum of the  $dQ/T$  terms around a complete cycle is less than or equal to zero depending on whether the process is irreversible or reversible.

$$\oint \frac{dQ}{T} \leq 0$$

28. Define the term: Intensive property.

An intensive property is independent of the size of the system. (eg) pressure, temperature and density are intensive properties.

29. Define the term: Extensive property.

Extensive properties depend on the quantity (or extent) of matter specified in the system. (eg) Mass and volume are extensive properties.

30. State the commonly used equation for equations of state.

- (i) Van der waals equation
- (ii) Redlich –Kwong equation
- (iii) Redlich-Kwong-Soave equation
- (iv) Peng-Robinson equation
- (v) Benedict –Webb-Rubin equation
- (vi) Virial equation

31. Define equilibrium state.

A system is said to be in a state of equilibrium if the properties are uniform throughout and they do not vary with time. A system is in

- (i) Thermal equilibrium: when no heat exchange occurs within the system & temperature is uniform throughout.
- (ii) Mechanical equilibrium: pressure is uniform.

32. Define triple point of water.

The temperature at which the solid, liquid and vapor phases of water coexist in equilibrium and it is assigned as value of 273.15 K.

33. State Avogadro's hypothesis.

Avogadro's hypothesis states that gases containing the same number of molecules occupy the same volume at same temperature. That is, the number of molecules in one mole of any substance is constant and it is called the Avogadro Number ( $N_A$ )

$$N_A = 6.022 \times 10^{23} \text{ per mole}$$

34. Mention the application of equation of state?

Equation of state is applicable to gas with very small pressure or very high temperature. With increase in pressure the intermolecular force of attraction and repulsion increases, and also the volume of the molecules becomes appreciable compared to the gas volume. Under such condition real gas equations are to be used.

35. State Hess's law.

The net heat evolved or absorbed in a chemical reaction is the same whether the reaction takes place in a single step or in a series of steps.

### PART B

1. Derive Maxwell equations and also mention the applications. (13)(APR/MAY 2017,2010,12,13,14) (Narayanan K.V“A Text Book of Chemical Engineering Thermodynamics” Page No. 192-194)
2. Derive the residual property equation for Gibbs energy, volume, enthalpy and entropy. (13) (MAY 2010,12,13) (Narayanan K.V“A Text Book of Chemical Engineering Thermodynamics” Page No. 237-240)
3. (i) Show that ideal gases  $C_p - C_v = R$  (4) (MAY 2007) (Narayanan K.V“A Text Book of Chemical Engineering Thermodynamics” Page No. 208)  
(ii) Prove that  $[dc_p/dp]_T = -T [d^2v / dT^2]_P$  (6) (MAY 2008,09) (Narayanan K.V“A Text Book of Chemical Engineering Thermodynamics” Page No. 210-211)
4. Calculate the pressure developed by 1 kmol of gaseous ammonia contained in a vessel of  $0.6\text{m}^3$  capacity at a constant temperature of 473 K by the following methods:
  - (i) Using the ideal gas equation
  - (ii) Using the vander Waals equation given  
that  $a = 0.4233 \text{ Nm}^4/\text{mol}^2$ ;  
 $b = 3.73 \times 10^{-5} \text{ m}^3/\text{mol}$
  - (iii) Using the Redlich – Kwong equation given that  $P_c = 112.8 \text{ bar}$ ;  $T_c = 405.5\text{K}$  (Apr/ May 2010) (Narayanan K.V“A Text Book of Chemical Engineering Thermodynamics” Page No.73 )
5. Show that

$$(i) \quad T \left( \frac{\partial P}{\partial T} \right)_V = \left( \frac{\partial U}{\partial V} \right)_T \quad (\text{May/June 2009})$$

$$(ii) \quad \left( \frac{\partial C}{\partial P} \right)_T = -T \left( \frac{\partial^2 V}{\partial T^2} \right)_P \quad (\text{Nov/Dec 2009,2008})(\text{Apr/May 2011})$$

$$(iii) \quad \left( \frac{\partial C}{\partial T} \right)_P = T \left( \frac{\partial^2 P}{\partial T^2} \right)_V \quad (\text{Nov/Dec 2008}) (\text{Apr/May 2011})$$

(Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.210-211)

6. How is Joule-Thomson coefficient evaluated from P-V-T information? And show that the Joule-Thomson coefficient is zero for ideal gases. (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.214-216)

### **PART-C**

1. Deduce from fundamentals, the first law of thermodynamics for flow process. (Apr/May 2017) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No. 30-32)
2. What are different types of thermodynamic diagrams? Explain the method of construction of any two thermodynamic diagrams. (May/June 2014) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No. 240-245)
3. Derive the relationship between entropy and heat capacity. (MAY 2009) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.197-199)
4. Develop equations for evaluating the change in internal energy and change in enthalpy for process involving ideal gases. (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.200-201)

## UNIT II - SOLUTION THERMODYNAMICS

### PART A

1. What is mass and molar concentration? (Apr/May 2017)

Mass concentration is defined as the mass of a constituent divided by the volume of the mixture. The mass concentration of a component in a mixture can be called the density of a component in a mixture. Molar concentration is defined as the amount of a constituent (usually measured in moles) divided by the volume of the mixture.

2. Define chemical potential. What is its physical significance? (Apr/May 2017, 2015) (May/June 2013,2012,2009,2007)(Nov/Dec 2010)

Chemical potential is used as an index of chemical equilibrium in the same manner as temperature and pressure are used as indices of thermal and mechanical equilibrium. The chemical potential  $\mu_i$  of component I in a solution is same as its partial molar free energy in the solution,  $G_i$ . That is, chemical potential of a component i in a solution can be defined as,

$$\mu_i = \left( \frac{\partial G}{\partial n_i} \right)_{T, P, n_j}$$

3. Differentiate between Clapeyron and Clausius-Clapeyron equations. (May/June 2016) (Apr/May 2011,2010)

**Clapeyron equation:** The Clapeyron equation predicts the dependence of equilibrium pressure on temperature when two phases of a given substance coexist. It is given by

\_\_\_\_\_

$$\frac{dP}{dT} = \frac{\Delta H}{T\Delta V}$$

Where  $\Delta H$  and  $\Delta V$  are the enthalpy and volume change accompanying a phase change.

**Clausius-Clapeyron equation:** If the temperature is not too near the critical point, the volume of the liquid is small in comparison with the volume of vapour. The volume change accompanying vapourization  $\Delta V = V_G - V_L$  is therefore approximately equal to  $V_G$ , the molar volume of vapour.

$$\frac{dP}{dT} = \frac{\Delta H}{TV_G}$$

The vapour pressure in regions well below the critical point is relatively small so that the vapor can be assumed to behave as an ideal gas. The molar volume,  $V_G$ , can now be replaced by  $RT/P^s$

So the above equation becomes

$$\frac{dP^s}{dT} = \frac{\Delta H}{P \frac{RT^2}}{\quad} \quad \text{or} \quad \frac{d \ln P^s}{dT} = \frac{\Delta H}{RT^2}$$

This equation is known as Clausius-Clapeyron equation.

4. What is meant by partial molar property?(May/June 2016) (Apr/May 2011,2008)(Nov/Dec 2010,2009)

Partial molar property of a particular component in a mixture measures the contribution of that component to the mixture property. The partial molar property  $\bar{M}_i$  of the component  $i$  in the solution is defined as

$$\bar{M}_i = \left( \frac{\partial nM}{\partial n_i} \right)_{T,P,n_{j \neq i}} = \left( \frac{\partial M^t}{\partial n_i} \right)_{T,P,n_{j \neq i}}$$

$M^t$  is the total value of any extensive thermodynamic property of a solution,  $n$  is the total number of moles and  $M$  is the molar property of the solution.  $n_i$  denotes the number of moles of component  $i$  in the solution.

5. Distinguish between molar volume and partial molar volume. Does the partial molar volume of a substance vary with concentration of the substance in the solution? (Apr/May 2015)

**Molar volume:** consider an open beaker containing a huge volume of water. Assume that one mole of water is added to it. The volume increases by  $18 \times 10^{-6} \text{ m}^3$ , which is the molar volume of pure water.

**Partial Molar volume:** if the same amount of water is added to a large amount of pure ethanol taken in a beaker, the increase in volume will be approximately  $14 \times 10^{-6} \text{ m}^3$ , which is the partial molar volume of water in pure ethanol.

The difference in the increase in volumes can be explained thus: the volume occupied by a given number of water molecules depends on the molecules surrounding them. When water is mixed with a large volume of alcohol, there is so much alcohol present that each water molecule is surrounded by pure ethanol.

Yes. The partial molar volume of a substance varies with concentration of the substance in the solution.

6. State Raoult's law, show that it is a simplified form of Lewis Randell rule. (May/June 2014)

**Raoult's law** states that the partial pressure of a component in vapor phase is equal to the product of liquid phase mole fraction and pure component vapor pressure.

$$\bar{p}_i = x_i P_i^s$$

**Lewis Randell rule** is applicable to ideal liquid solutions which states that fugacity ( $f_i$ ) of each constituent is directly proportional to the number of moles of the constituent in the solution.

$$f_i = x_i f_i^s$$

7. What are excess properties and give its significance? (May/June 2014)(Nov/Dec 2009)

For real liquid solutions, the molar excess property is the departure function which quantifies the deviation from ideal solution property.

The excess property,  $M^E$ , is defined as the difference between an actual property and the property that would be calculated for the same temperature, pressure and composition by the equations for an ideal solution.

$$M^E = M - M^{id}$$

$M$  - molar property of the solution

$M^{id}$  - property of an ideal solution under the same conditions.

$M^E$  - excess property

8. State Gibbs Duhem equation.(Nov/Dec 2013) (May/June 2006)

At constant temperature and pressure, the property  $M^t$  of the solution is the sum of the partial molar properties of the constituents, each weighted according to the number of moles of the respective constituents.

$$M^t = \sum_i n_i M_i$$

9. How is the activity coefficient related to the excess free energy? (May/June 2012,2007) (Apr/May 2011)

The most useful excess property is the partial molar excess Gibbs free energy ( $G^E$ ) which can be directly related to the activity coefficients.

$$G^E = RT \sum_i x_i \ln \gamma_i$$

$$\ln \gamma_i = \left[ \frac{\partial (nG^E/RT)}{\partial n_i} \right]_{T,P,n_j}$$

10. What do you mean by acentric factor? (Apr/May 2011)

For simple fluids, temperature equal to 7/10 of the critical temperature, the reduced vapor pressure closely follows the following empirical result:

$$\frac{P^S}{P_C} = 1 - 10^{\omega} \left( \frac{T}{T_C} \right)^6 = 0.7$$

Where  $P^S$  is the vapor pressure. Pitzer defined the acentric factor in terms of the reduced vapour pressure at a reduced temperature of 0.7 as

$$\omega = -1.00 - \log \left( \frac{P^S}{P_C} \right)_{T_R=0.7}$$

For simple fluids, the acentric factor = 0; for more complex fluids, the acentric factor > 0.

11. What are the characteristics of an ideal solution? (Apr/May 2011,2008)

- (i) There is no volume change when the components are mixed together to form an ideal solution.
- (ii) If a mixture of two liquids is to behave ideally, theoretical considerations reveal that the two types of molecules must be similar.

12. State Gibb's theorem. (Apr/May 2010)

Except for volume all other partial molar property of a species in an ideal gas mixture is equal to the corresponding molar property of the species as a pure ideal gas at a temperature same as that of the mixture, but at a pressure equal to its partial pressure in the mixture.

13. Define fugacity coefficient. (Apr/May 2010)

The ratio of fugacity to pressure is referred to as fugacity coefficient and is denoted by  $\phi$ . It is dimensionless and depends on nature of the gas, the pressure, and the temperature.

$$\phi = \frac{f}{P}$$

14. How is entropy change in an irreversible process determined? (Apr/May 2010)

The entropy change in an irreversible process occurring between any two states would be the same as the entropy change in a reversible process occurring between them. Thus, the entropy change in any irreversible process can be evaluated by devising an imaginary reversible process for accomplishing the same change and calculating the entropy change in the latter.

15. Define the term activity coefficient. (Apr/May 2011) (May/June 2006)

Activity coefficients measure the extent to which the real solution departs from ideality. Activity coefficient of the component i in the solution is denoted by  $\gamma_i$  and is defined by the following relationship.

$$\bar{f}_i = \gamma_i x_i f_i^0$$

Where  $f_i^0$  is the fugacity in the standard state. For ideal solutions  $\gamma=1$ .

16. What is the effect of temperature on the activity coefficient of a component in a solution? (May/June 2009)

Effect of temperature on activity coefficient is given by

$$\left( \frac{\partial \ln \gamma_i}{\partial P} \right)_T = \frac{H_i - H_i^*}{RT^2}$$

The term  $(H_i - H_i^*)$  is the partial heat of mixing of component  $i$  from its pure state to the solution of given composition both in the same state of aggregation and pressure. For gaseous mixtures, this term is negligible at low pressures.

17. What is the effect of pressure on the activity coefficient of a component in a solution? (May/June 2009)

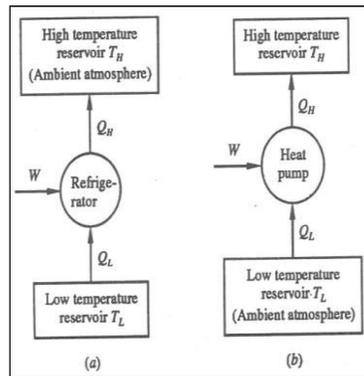
Effect of pressure on activity coefficient is given by

$$\left( \frac{\partial \ln \gamma_i}{\partial P} \right)_T = \frac{V_i^* - V_i}{RT}$$

The molar volumes  $\bar{V}_i$  and  $V_i$  correspond to the particular phase under consideration. For liquid solutions, the effect of pressure on activity coefficients is negligible at pressures below atmospheric. For gaseous mixtures, activity coefficients are nearly unity at reduced pressures below 0.8.

18. What is a heat pump? (Nov/Dec 2009)

A heat pump is a thermodynamic system operating in a cycle that removes heat from a low temperature body and delivers it to a high temperature body. External energy in the form of work is necessary to accomplish this.



19. Define fugacity for a real gas. (Apr/May 2008)(Nov/Dec 2008)

Fugacity is used in the study of phase and chemical reaction equilibria involving gases at high pressures. For real gas, pressure is replaced by an 'effective pressure' or fugacity  $f$  of the gas.

$$dG = RTd(\ln f)$$

20. Define fugacity coefficient for a real gas. (Apr/May 2008)(Nov/Dec 2008)

Fugacity coefficient for a real gas is given by the following relation,

$$G = G^0 + RT \ln \frac{P}{P^0} + RT \ln \phi$$

Free energy of a real gas = free energy of an ideal gas +  $RT \ln \phi$ . The quantity expresses the entire effect of intermolecular interaction.

$RT \ln \phi$ , therefore,

21. What is an inversion point? (Nov/Dec 2008)

At any given pressure, the joule-Thomson coefficient is positive only within a temperature range that is between the upper and lower inversion temperatures. Only within these temperatures a gas cools on throttling.

22. Define COP of refrigerator. (Nov/Dec 2008)

The coefficient of performance (COP) is defined as the ratio of heat transferred from low temperature reservoir ( $Q_2$ ) to the work-input ( $W$ ). For refrigerator,

$$\eta = \frac{Q_2}{W}$$

23. Define COP of pump. (Nov/Dec 2008)

The COP is defined as the ratio of heat rejected ( $Q_1$ ) to the work-input ( $W$ ).

For heat pump,

$$\eta = \frac{Q_1}{W}$$

24. Define the term activity.

Activity or relative fugacity is defined as the ratio of fugacity to fugacity in the standard state. It finds wide application in the study of homogeneous chemical reaction equilibria involving solids and liquids. Activity is denoted by 'a'.

$$a = \frac{f}{f^0}$$

25. What are ideal solutions?

A solution in which the partial molar volumes of the components are the same as their molar volumes in the pure state is called an ideal solution.

26. State Lewis fugacity rule. (Nov/Dec 2013)

It states that the fugacity of a component in an ideal solution is directly proportional to the mole fraction of the component in the solution.

$$\bar{f}_i = y_i f_i$$

Lewis fugacity rule is valid for systems where the intermolecular forces in the mixture are similar to those in the pure state.

27. State Henry's law.

Partial pressure or fugacity is directly proportional to the concentration in the liquid or its mole fraction, the proportionality constant.

$$\bar{p}_i = x_i k_i \text{ Or } \bar{f}_i = x_i k_i$$

$\bar{p}_i$  - Partial pressure of the solute

$x_i$  - Mole fraction in the solution

$k_i$  - Proportionality constant (or) Henry's law constant

28. Define non -ideal solution.

A solution, any of whose components does not obey Raoult's law is known as non-ideal solution. Even non –ideal solutions exhibit a common form of ideal behavior over a limited concentration range where the fugacity (or, the partial pressure) is directly proportional to the concentration in the liquid.

29. State lewis Randall rule.

Lewis Randall rule is applicable to ideal liquid solutions which states that fugacity (  $f_i$  ) of each constituent is directly proportional to the number of moles of the constituent in the solution.

$$f_i = x_i f_i^*$$

30. Define partial molar volume.

**Partial Molar volume:** if the same amount of water is added to a large amount of pure ethanol taken in a beaker, the increase in volume will be approximately  $14 \times 10^{-6} \text{ m}^3$ , which is the partial molar volume of water in pure ethanol.

The difference in the increase in volumes can be explained thus: the volume occupied by a given number of water molecules depends on the molecules surrounding them. When water is mixed with a large volume of alcohol, there is so much alcohol present that each water molecule is surrounded by pure ethanol.

31. Mention the application of Gibbs Duhem equation.

Gibbs-Duhem equation can be used for the calculation of

(i) a partial molar quantity of a binary mixture from measurements of the composition dependence of the corresponding total molar quantity,

(ii) the partial molar quantity of a component, say 1, of a binary mixture from measurements of the composition dependence of the corresponding partial molar quantity of component 2, and

(iii) the partial vapor pressures from measurements of the liquid-phase composition dependence of the total vapor pressure.

32. Define Clausius-Clapeyron equations.

**Clausius-Clapeyron equation:** If the temperature is not too near the critical point, the volume of the liquid is small in comparison with the volume of vapour. The volume change accompanying vapourization  $\Delta V = V_G - V_L$  is therefore approximately equal to  $V_G$ , the molar volume of vapour.

$$\frac{dP}{dT} = \frac{\Delta H}{TV_G}$$

The vapour pressure in regions well below the critical point is relatively small so that the vapor can be assumed to behave as an ideal gas. The molar volume,  $V_G$ , can now be replaced by  $RT/P^s$

So the above equation becomes

$$\frac{dP^S}{dT} = \frac{s \Delta H}{P RT^2} \quad \text{or} \quad \frac{d \ln P^S}{dT} = \frac{\Delta H}{RT^2}$$

This equation is known as Clausius-Clapeyron equation.

33. State the Characteristics of Entropy.

1. It increases when the heat is supplied irrespective of the fact whether temperature changes or not.
2. Whether temperature changes or not the entropy decreases when heat is rejected.
3. In all the adiabatic processes, the entropy remains constant.

34. State conditions of Lewis fugacity rule.

Lewis fugacity rule is valid

- (i) At low pressures when the gas phase behaves ideally
- (ii) At any pressure if the component is present in excess
- (iii) If the physical properties of the components are nearly the same
- (iv) At moderate and high pressures, the Lewis-Randall rule will give incorrect results if the molecular properties of the components are widely different and the component under consideration is not present in excess.

### PART B

1. Derive an expression for fugacity and fugacity coefficient of pure species.(APR/MAY 2017,2007) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.225 – 228)
2. Discuss the importance of Gibbs-Duhem equation and explain its various forms. Explain the applications of Gibbs-Duhem equation. (MAY 2017, 2010,12,13,14) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.283-285)
3. Derive the Lewis / Randell rule as applicable to ideal solutions. (MAY 2010) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.271-272)
4. At 300 K and 1 bar, the volumetric data for a liquid mixture of benzene and cyclohexane are represented by  $V = 109.4 \times 10^{-6} - 16.8 \times 10^{-6} x - 2.64 \times 10^{-6} x^2$ , where x is the mole fraction of benzene and V has the units of  $m^3 / mol$ . Find the expressions for the partial molar volumes of benzene and cyclohexane. (May/June 2014,2013) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.262-263)
5. Derive the expressions for the effect of temperature and pressure on activity coefficient. (Nov/Dec 2013) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.236 - 237)
6. The enthalpy of a binary liquid mixture containing components 1 and 2 at 298 K and 1.0 bar is given by

$$H = 400x_1 + 600x_2 + x_1x_2(40x_1 + x_2)$$

where H is in J/mol, Determine

- (i) Pure component enthalpies
- (ii) Partial molar enthalpies (Apr/May 2015,2011) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.263-264)

### PART-C

1. Explain the methods by which fugacity for a pure component is calculated. (MAY 2010,12) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” PageNo.228-234)
2. Derive the expressions for the effect of temperature and pressure on fugacity coefficient. (Nov/Dec 2013) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.227-228)
3. Find the van Laar constants for the binary system benzene (1) – ethanol (2) using the following data:

$x_1$	0.1	0.3	0.45	0.7	0.9
$P_1^S$ kPa	73.31	68.64	63.98	67.98	81.31
$P_2^S$ kPa	75.98	69.64	67.98	69.31	79.98

(May/June 2016)

(Narayanan K.V“ A Text Book of Chemical Engineering Thermodynamics” Page No.389)

4. Two substances A and B are known to form ideal liquid solutions. A vapour mixture containing 50% (mol) A and 50% (mol) B is at 311 K and 101.3 kPa. This mixture is compressed isothermally until condensation occurs. At what pressure, does condensation occur and what is the composition of the liquid that forms? The vapour pressures of A and B are 142 kPa and 122 kPa respectively. (May/June 2016) (Narayanan K.V“ A Text Book of Chemical Engineering Thermodynamics” Page No.386)

### UNIT III - PHASE EQUILIBRIA PART A

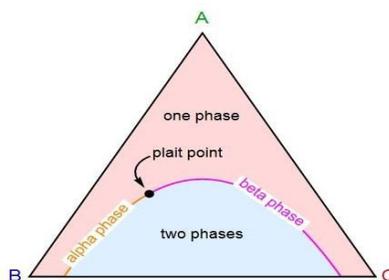
1. Define the term Phase equilibria. (Apr/May 2017)

The equilibrium state of a closed system is that state for which the total Gibbs energy is a minimum with respect to all possible changes at the given T and P.

$$\left[ dG^t \right]_{T,P} = 0$$

2. In liquid–liquid equilibrium curve, define plait point with neat sketch. (Apr/May 2017)

The Plait Point P is the intersection of the raffinate-phase and extract-phase boundary curves. At this **point**, the equilibrium phases become coincident and no separation can be made at that **point**.



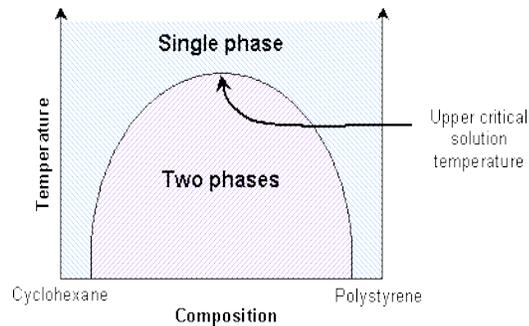
3. Distinguish between bubble point and dew point temperature. (May/June 2016, 2012) (Apr/May 2011,2008)

S.No	Bubble point temperature	Dew point temperature
1	The first bubble of vapour is produced from the liquid on heating at a constant pressure.	The first drop of condensate is formed on cooling a vapour at constant pressure.
2	At the bubble point the liquid has the same composition as the original mixture.	The vapour in equilibrium with the liquid at the dew point has the same composition as the original mixture.
3	At bubble point, $\sum y_i = \sum k_i x_i = 1$	At dew point, $\sum x_i = \sum y_i / k_i = 1$

4. What is an azeotrope? Under what conditions do azeotropes generally form? (May/June 2016, 2014)

An **azeotrope** is a mixture of two or more liquids whose proportions cannot be altered by simple distillation. This happens because, when an azeotrope is boiled, the vapor has the same proportions of constituents as the unboiled mixture. Because their composition is unchanged by distillation, **azeotropes** are also called **constant boiling mixtures**.

5. What is critical solution temperature? (Apr/May 2015) (May/June 2012)



The point P gives the critical solution temperature. This point represents the last of the tie lines where the A-rich and B-rich phases become identical.

6. Write down the equation for solving general VLE problem. (Apr/May 2015)(Nov/Dec 2008)

Vapour liquid equilibrium (VLE) data are essential for many engineering calculations, especially in the design and analysis of separation operations such as distillation, absorption, etc. The fundamental relationship in the study of vapor liquid equilibrium is given by,

$$y_i \bar{\phi}_i P = \gamma_i x_i f_i^o$$

7. What is Poynting correction? (May/June 2014)

For a pure fluid in vapor-liquid equilibrium, the vapor phase fugacity is equal to the liquid phase fugacity. The fundamental relationship in the study of vapour-liquid equilibrium is  $y_i \bar{\phi}_i P = \gamma_i x_i f_i^o$ . At pressures above the saturation pressure, the liquid phase fugacity is  $f_i^o = \phi_i^s P^s \exp \left[ \frac{V_i(P - P^s)}{RT} \right]$ . When

this equation is substituted in the first equation, we get,  $y_i \bar{\phi}_i^L = \gamma_i x_i \phi_i^S P^S \exp \left[ \frac{V_i(P - P^S)}{RT} \right]$ . The

exponential term represents the Poynting correction factor and is usually near 1.0 unless pressures are very high.

8. What is the general criteria for phase equilibrium for heterogeneous multicomponent system?(Nov/Dec 2013) (May/June 2013)

When a system consisting of several components distributed between various phases is in thermodynamic equilibrium at a definite temperature and pressure, the chemical potential of each component is the same in all the phases.

If they are different, the component for which such a difference exists will show a tendency to pass from the region of higher to the region of lower chemical potential.

Thus the equality of chemical potential along with the requirement of uniformity of temperature and pressure serves as the general criterion of thermodynamic equilibrium in a heterogeneous multicomponent system.

$T = \text{constant}; \quad P = \text{constant}$ $\mu_i^\alpha = \mu_i^\beta = \dots = \mu_i^\pi \quad \text{for } i = 1, 2, 3, \dots, C$
---

9. What are bubble point and dew point temperatures? (May/June 2013)

**Bubble point temperature:** Bubble point temperature is the one at which the first bubble of vapour is produced from the liquid on heating at a constant pressure.

**Dew point temperature:** Dew point temperature is one at which the first drop of condensate is formed on cooling a vapour at constant pressure.

10. What is the fugacity criterion for phase equilibrium? (Apr/May 2011) (Apr/May 2010)

General fugacity criterion for phase equilibrium is given by

$T = \text{constant};$	$P = \text{constant}$
$f_i$	$f_i$

$$\bar{f}_i^\alpha = \bar{f}_i^\beta = \dots = \pi \quad \text{for } i = 1, 2, 3, \dots, C$$

Fugacity is a more useful property than chemical potential for defining equilibrium since it can be expressed in absolute values, whereas chemical potential can be expressed only relative to some arbitrary reference state. This equation is widely used for the solution of phase equilibrium problems.

11. Brief on bubble point and dew point pressures. (Apr/May 2011) (Nov/Dec 2008)

To find the bubble point pressure, assume various values of pressure and get the  $k_i$  values at this pressure. Calculate  $y_i = k_i x_i$ . if the assumed pressure is correct then  $\sum y_i = \sum k_i x_i = 1$

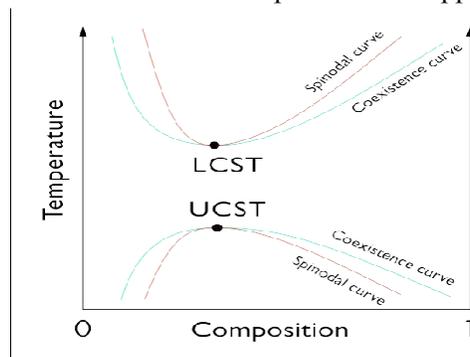
To find the dew point pressure, pressure is assumed arbitrarily and  $k_i$  is determined. Then,  $x_i = y_i / k_i$

At the dew point,  $\sum x_i = \sum y_i / k_i = 1$ .

12. What is the criterion for liquid-liquid equilibrium? (Apr/May 2010)

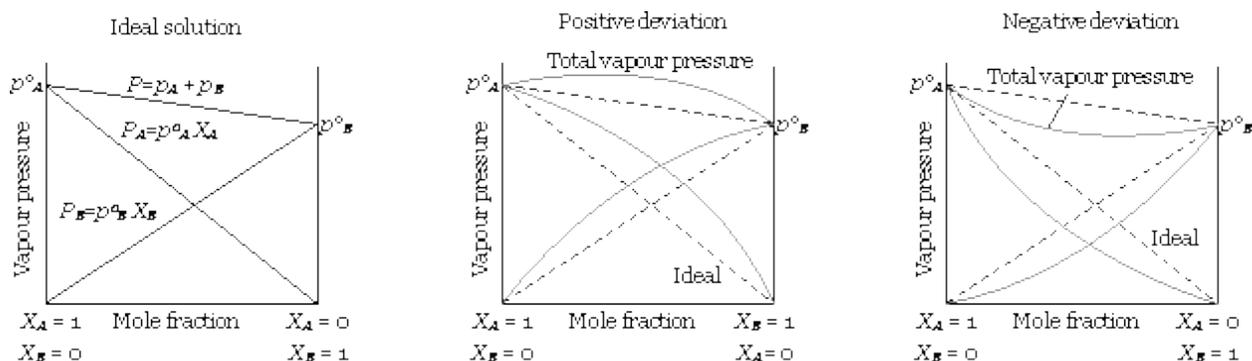
$\hat{f}_i^\alpha = \hat{f}_i^\beta$  for all  $i=1, 2, \dots, n$ ,  $\alpha$  and  $\beta$  are two liquid phases.

13. Define lower critical solution temperature and upper critical solution temperature. (Apr/May 2010)



The curves FC and GD eventually merge to a single point and the two liquid phases become identical. The temperature at which this occurs is known as the upper critical solution temperature (UCST). For pressures above this critical condition, the three phase equilibrium conditions do not exist.

14. What is meant by positive and negative deviations from Raoult's law? (Apr/May 2010)



**Positive deviation from ideality** results when the actual partial pressure of each constituent is greater than it should be if Raoult's law were obeyed. It is present in solutions in which intermolecular forces between like molecules are stronger than those between unlike molecules.

(eg) benzene-cyclohexane, water-ethanol,  $O_2-N_2$ .

**Negative deviation from ideality** results when the partial pressures are less than those given by Raoult's law. At molecular level, negative deviation reflects stronger intermolecular forces between unlike molecules than between like pairs of molecules.

(eg) chloroform-acetone, HCL-water, chloroform-benzene.

15. How does one mathematically express the molar change in enthalpy (dh) for a multicomponent system? (Apr/May 2010)

$$dh = T\Delta V \frac{dP}{dT}$$

Where

$\Delta V$  - volume change accompanying phase rule

dP- change in pressure

dT-change in temperature

16. State Gibb's phase rule. (Nov/Dec 2010)

$F = C - \pi + 2$ . This equation is known as Gibbs phase rule. F-Number of degrees of freedom

$\pi$  -The number of phases in equilibrium

C- Number of components constituting the system.

17. List the criteria for phase equilibrium. (Nov/Dec 2010)

The criteria of internal thermal and mechanical equilibrium are that the temperature and pressure be uniform throughout the system.

- (i) Constant U and V  $dS_{U,V} \geq 0$   
:  
(ii) Constant T and V:  $dA_{T,V} \leq 0$

(iii) Constant P and T:  $dG_{T,P} \leq 0$

18. How do you predict the low pressure VLE data for a binary system using the excess Gibbs free energy models? (May/June 2009)

Redlich-kister method is used to test the consistency of experimental data when the activity coefficient value over the entire concentration range is available. It is based on the excess free energy of mixing which is the difference between the free energy of mixing of a real solution and that of an ideal solution.

$$\Delta G^E = RT \sum_i x_i \ln \gamma_i$$

For a binary solution, it can be written as

$$\Delta G^E = RT \sum_i (x_i \ln \gamma_i + x_i \ln \gamma_i)$$

19. What is an azeotrope? (May/June 2009)

An **azeotrope** is a mixture of two or more liquids whose proportions cannot be altered by simple distillation. This happens because, when an azeotrope is boiled, the vapor has the same proportions of constituents as the unboiled mixture. Because their composition is unchanged by distillation, **azeotropes** are also called **constant boiling mixtures**.

20. How many types of azeotropes are there? (May/June 2009)

There are two types of azeotropes.

- (i) Minimum boiling azeotropes
- (ii) Maximum boiling azeotropes.

21. Define equilibrium in terms of chemical potential. (Nov/Dec 2009)

For the system to be in equilibrium with respect to mass transfer, the driving force for mass transfer –the chemical potential- must have uniform values for each component in all phases.

$$\sum \mu_i dn_i = 0 \text{ (At constant temperature and pressure)}$$

22. Define isochoric process. (Nov/Dec 2009)

The relationship between pressure and volume is assumed to be  $PV^n = \text{const}$ , where n is a constant. If  $n = \infty$ , the process is isochoric (constant volume).

23. Why does immiscibility occur in liquid solutions? (May/June 2009)

The equilibrium state of the system is two phases of a fixed composition corresponding to a temperature. The compositions of two such phases, however, change with temperature.

24. Define coexistence equation and its applications. (May/June 2009)

The coexistence equation can be used for testing the consistency of vapor-liquid equilibrium data.

$$\frac{dP}{dy_1} = \frac{P(y_1 - x_1)}{y_1(1 - y_1)}$$

The above equation is known as the coexistence equation.

25. Write the applications of coexistence equation. (May/June 2009)

Applications:

- (i) It can be used to calculate any one of the three variables P, x or y if experimentally measured values of the other two variables are available.
- (ii) If all the three variables are experimentally determined, then coexistence equation can be used to test the consistency of the measured data.

26. State Duhem's theorem.

For any closed system formed initially from the given masses prescribed chemical species, the equilibrium state is completely determined when any two independent variables are fixed.

27. Explain about consistency test.

Thermodynamic provides tests for consistency of experimental VLE data, as the VLE measurements are prone to accuracies.

All the tests are based on Gibbs-Duhem equation written in terms of activity coefficients.

$$\left( \frac{\partial \ln \gamma_1}{\partial \ln \gamma_2} \right)$$

$$x_1 \left( \frac{\partial x}{\partial x} \right)_{T,P} = x_2 \left( \frac{\partial x}{\partial x} \right)_{T,P}$$

28. Name the different types of consistency tests for VLE data.

- (i) Using slope of  $\ln \gamma$  curves
- (ii) Using data at the Mid-point
- (iii) Redlich-kister method (or) zero order method
- (iv) Using the coexistence equation
- (v) Using the partial pressure data.

29. Define criterion of stability.

At constant temperature and pressure, the free energy change on mixing  $\Delta G$ , its first and second derivatives are all continuous functions of the concentration  $x$  and

$$\frac{d^2 \Delta G}{dx_1^2} > 0 \text{ at constant } T \text{ \& } P.$$

30. Define system at equilibrium.

System at equilibrium is defined as one in which there are no driving forces for energy or mass transfer. That is for a system in a state of equilibrium, all forces are in exact balance.

31. What are the two types of phase equilibrium problems?

- (i) The determination of composition of phases which exist in equilibrium at a known temperature and pressure
- (ii) The determination of conditions of temperature and pressure required to obtain equilibrium between phases of specified compositions.

32. What are the advantages of NRTL equation?

NRTL equation is applicable to partially miscible as well as totally miscible systems. This equation is also applicable for non ideal solutions and especially partially miscible systems.

33. What is bubble point temperature?

Bubble point temperature is the one at which the first bubble of vapour is produced from the liquid on heating at a constant pressure.

34. What is dew point temperature?

Dew point temperature is one at which the first drop of condensate is formed on cooling a vapour at constant pressure.

35. Define zero order method.

This method is used to test the consistency of experimental data when the activity coefficient value over the entire concentration range is available. It is based on the excess free energy of mixing which is the difference between the free energy of mixing of a real solution and that of an ideal solution.

### **PART B**

1. Construct the P-x-y diagram for the cyclohexane(1)-benzene (2) system at 313 K the vapour

*P*

pressures are  $P_1^s = 24.62$  kPa and  $P_2^s = 24.41$  kPa. The liquid-phase activity coefficients are given by  $\ln \gamma_1 = 0.458x_2^2$ ,  $\ln \gamma_2 = 0.458x_1^2$ . (Apr/May 2017, 2015) (May/June 2012) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.356)

2. Explain the phase equilibria in single component systems. (May/June 2013) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.315-316)
3. (i) Describe the methods used for testing the thermodynamic consistency of experimentally determined vapor-liquid equilibrium data for binary systems. (MAY 2007,11) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.367-372)  
(ii) Compare Dew point and bubble point temperature. (4) (Apr/May 2007,11) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.328)
4. Explain the liquid/liquid solubility diagram for liquid liquid equilibrium (10) (MAY 2007,11) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.381-383)
5. A binary system, (i) benzene (ii) ethyl benzene obeys the Raoult's law and at vapour pressures are given by the Antoine equations

$$\ln P_1^s = 13.8858 - \frac{2788.51}{T - 60.00}$$

$$\ln P_2^s = 14.0045 - \frac{3276.47}{T - 60.00}$$

where P is in kPa and T is in K. Construct the p-x-y at 373K and T-x-y at 101.3 kPa. (May/June 2014) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.337)

6. Ethanol-water mixture forms an azeotrope boiling at 351.4K under a pressure of 101.3kPa and its composition is 89.4% (mol) ethanol. The vapour pressures of ethanol and water at 351.4K are 100 kPa and 44 kPa respectively. Using Van Laar method and assuming that the ratio of vapour pressures remains constant. Calculate the composition of the vapor in equilibrium with a liquid containing 80% ethanol. (May/June 2013) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.390)

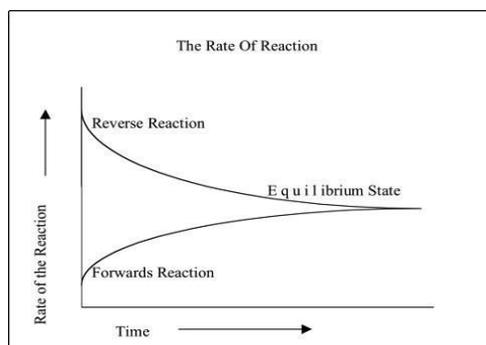
### PART C

1. At 750 mm Hg pressure, the A-B azeotrope boils at 65°C and contains 35 mole% of A. The vapor pressure of A and B are 1000 mm and 800 mm of Hg respectively at 65°C. Calculate the composition of vapour at this temperature in equilibrium with liquid analyzing 10 mole% of A. what is the total pressure at this condition? (Apr/May 2017) (class notes)
2. Discuss in detail about Vapour – Liquid Equilibria (VLE) at low pressures. (Narayanan K.V“ A Text Book of Chemical Engineering Thermodynamics” Page No.347-352)
3. Explain in detail about the methods available for calculation of Vapour Liquid Equilibria involving high pressures. (Narayanan K.V“ A Text Book of Chemical Engineering Thermodynamics” Page No.362-364)
4. A vapour mixture containing 18% ethane, 17% propane, 62% isobutene and the rest n-butane is subjected to partial condensation so that 75% of the vapour is condensed. If the condenser temperature is 300 K, determine the pressure.(May/June 2016) (Narayanan K.V“ A Text Book of Chemical Engineering Thermodynamics” Page No. 391)

## UNIT IV- CHEMICAL REACTION EQUILIBRIA PART A

1. When the chemical reaction attains equilibrium? (Apr/May 2017)

The chemical equilibrium state describes concentrations of reactants and products in a reaction taking place in a closed system, which no longer change with time. In other words, the rate of the forward reaction equals the rate of the reverse reaction, such that the concentrations of reactants and products remain fairly stable, in a chemical reaction. Equilibrium is denoted in a chemical equation by the  $\rightleftharpoons$  symbol.



2. For the gas phase reaction  $C_2H_4 + H_2O \rightarrow C_2H_5OH$  the equilibrium constant at  $145^\circ C$  and 1 bar is  $K = 6.8 \times 10^{-2}$ , how would you calculate the equilibrium constant at 10 atm pressure? (Apr/May 2017)

Solution:

Given data:  $T = 145^\circ C$ ,  $P = 1$  bar,  $K = 6.8 \times 10^{-2}$

Equilibrium constant  $k = ?$  At  $P = 10$  atm.

3. Define equilibrium constant  $K_e$  of a chemical reaction. How is it related to  $K_f$  and  $K_p$ ? (May/June 2016) (Apr/May 2011)(May/June 2007)

Consider the chemical reaction  $aA + bB \rightarrow lL + mM$

The equilibrium constant  $K_e$  for this reaction is defined in terms of the activities of the reactants and the products as

$$K_e = \frac{a_L^l a_M^m}{a_A^a a_B^b} = \prod a_i^{v_i}$$

Where  $a_i$  is the activity of component  $i$  in the reaction mixture and  $v_i$  is the stoichiometric number of  $i$ .

Equilibrium constant in terms of fugacity is given by

$$K_e = \prod (\bar{f}_i)^{v_i} = K_f$$

Equilibrium constant in terms of partial pressures is given by

$$K_e = \prod (p_i)^{v_i}$$

For gaseous systems, the relationship between equilibrium constants is given by  $K = K_f = K_p$ .

4. What is reaction coordinate? What is its significance in chemical reaction? (Apr/May 2015)

Reaction coordinate measures the progress of a reaction. It is defined as the degree to which a reaction has advanced. Reaction coordinate is otherwise known as extent of reaction.

The extent of reaction and number of moles taking part in the reaction are related as,

$$\frac{dn_i}{v_i} = d\varepsilon$$

For the initial state of the system, (ie) before the reaction, the value of  $\varepsilon$  is zero.

5. What is the effect of pressure on equilibrium conversion of a gas-phase chemical reaction? (Apr/May 2015) (Apr/May 2008)

In the case of reaction equilibrium for  $N_2 + 3H_2 \rightarrow 2NH_3$  formation of ammonia will be favored by an increase in pressure as there is a reduction in the number of moles due to this reaction. When the composition of the system changes in this manner in response to increase or decrease in pressure, it does so without changing the equilibrium constant.

6. What is the phase rule for reacting systems? (May/June 2014) (Nov/Dec 2013)

The number of degrees of freedom will be reduced by one for each independent chemical reaction. If  $r$  independent reactions occur in the system, then the phase rule becomes

$$F = C - \pi - r + 2$$

7. What is meant by extent of reaction? (May/June 2014)(May/June 2013)(Nov/Dec 2010)

The extent of the reaction measures the progress of the reaction and it is defined as the degree to which a reaction has advanced. It is denoted by  $\epsilon$ . It is also known as the reaction coordinate. It has the advantage that the change in the change in the extent of reaction  $d\epsilon$  is the same for each component, whereas the change in the number of moles is different for different species taking part in the reaction.

$$\frac{dn_i}{\nu_i} = d\epsilon$$

8. List the criterion for chemical reaction equilibria. (May/June 2013,2012)

At constant temperature and pressure, the transfer of materials from one phase to another under equilibrium is found to occur with no change in the free energy.

$$d_{T,P} =$$

The criterion of equilibrium for chemical reaction is given by

$$\sum \mu_i \nu_i = 0$$

9. How the equilibrium is constant related to the standard free energy change? (May/June 2012)

The standard free energy change  $\Delta G^0$ , accompanying the reaction when each of the reactants and the products is in its standard state.

$$\Delta G^0 = -RT \ln K$$

The equilibrium constant is determined by the standard free energy change and the temperature.

The standard free energy change depends on the temperature, the specification of standard state for each component and the number of moles involved in the stoichiometric equation under consideration.

10. Explain the concept of entropy and enthalpy departures. (Apr/May 2011)

The departure functions are defined as the difference between the thermodynamic property at the specified temperature and pressure and the property that the substance would have exhibited at the same temperature and pressure (ideal gas condition).

Properties in the ideal state represented with the superscript *id*, the residual enthalpy ( $H^R$ ) and residual entropy ( $S^R$ ) are defined as

$$H^R = H - H^{id}$$

$$S^R = S - S^{id}$$

$H^R$  and  $S^R$  are known as **enthalpy departure** and **entropy departure**. These represent hypothetical property changes because a gas cannot be both real and ideal at a given P and T.

11. What is standard Gibbs free energy change of a chemical reaction and how is it related to the equilibrium constant? (Apr/May 2011)(Nov/Dec 2010,2008) (May/June 2009)

The standard free energy change depends on the temperature, the specification of standard state for each component and the number of moles involved in the stoichiometric equation under consideration. It is independent of pressure at equilibrium. Temperature in the standard state is the same as that in the equilibrium state.

$$\sum_i \nu_i \mu_i^0 = -RT \ln \frac{a^l a^m}{a_A^a a_B^b}$$

The left hand side gives the standard free energy change  $\Delta G^0$ , accompanying the reaction when each of the reactants and the products is in its standard state.

$$\Delta G^0 = -RT \ln K$$

12. Define van't Hoff equation. (Apr/May 2011) (May/June 2007)

$$\frac{d \ln K}{dT} = \frac{\Delta H^0}{RT^2}$$

This equation is known as van't Hoff equation, predicts the effect of temperature on the equilibrium constant and hence on the equilibrium yield.

$\Delta H^0$  - Standard heat of reaction. If  $\Delta H^0$  is negative, i.e. if the reaction is exothermic, the equilibrium constant decrease as the reaction temperature increases. If  $\Delta H^0$  is positive, i.e. if the reaction is an endothermic reaction, the equilibrium constant will increase with increase in temperature.

13. State the effect of temperature of Equilibrium constant. (Apr/May 2010)

An increase in temperature will shift the equilibrium state in the direction of absorption of heat. That is, the equilibrium will shift in the endothermic direction if the temperature is raised, for then, energy is absorbed as heat.

Similarly, equilibrium can be expected to shift in the exothermic direction if the temperature is lowered, for then the reduction in temperature is opposed. Thus, an endothermic reaction is favored by an increase in temperature and an exothermic reaction is favoured by a decrease in temperature.

The effect of temperature on equilibrium constant is quantitatively expressed by van't Hoff equation.

14. How does the standard heat of reaction related to standard Gibbs-energy change of reaction? (Apr/May 2010)

The standard free energy of the reaction and standard heat of reaction are related to the free energy and enthalpy of individual species respectively as given below.

$$\Delta G^0 = \sum_i \nu_i G_i^0, \quad \Delta H^0 = \sum_i \nu_i H_i^0$$

The relationship between standard heat of reaction and standard Gibbs-energy change of reaction is given by

$$\left( \frac{d \Delta G^0}{RT} \right) = \frac{\Delta H^0}{RT^2}$$

$$\left( \frac{dT}{T} \right) = \frac{RT^2}{T^2}$$

15. List down the causes of entropy change in chemical systems. (Apr/May 2010)

In an irreversible process, a decrease in entropy may occur either in the system or in the surroundings. These statements require only that the sum of the entropy changes of the system and the surroundings together be positive in an irreversible process like the isothermal expansion of a gas. If the same expansion were carried out reversibly, the increase in the entropy of the gas will be compensated by a decrease in the entropy of the surroundings that results because of the withdrawal of heat. If this heat exchange also were accomplished reversibly, the net change in entropy would be zero.

16. What do you understand by the number of independent reactions in a chemically reacting system? (Apr/May 2010)

The number of independent reactions that must be considered as the least number that includes every reactant and product present to an appreciable extent in all phases of the equilibrium system, and accounts for the formation of each product from the original reactants.

17. How does the dilution of a reaction mixture with an inert gas effect the degree of conversion in a gas phase reaction? (May/June 2009)

Diluting the reaction mixture with an inert material will increase total number of moles in the reaction mixture (N). This will result in an increased conversion, if  $v$  is positive. That is, if the reaction proceeds with an increase in the number of moles, presence of inerts in the system will increase the equilibrium yield.

18. What do you understand by the term “available energy”? (Nov/Dec 2009)

Available energy is the greatest amount of mechanical work that can be obtained from a system or body, with a given quantity of substance, in a given initial state, without increasing its total volume or allowing heat to pass to or from external bodies, except such as at the close of the processes are left in their initial condition. In this definition, the initial state of the body is supposed to be such that the body can be made to pass from it to states of dissipated energy by reversible processes.

19. Is the Gibbs free energy change of a chemical reaction related to the work done by the system? Give an example. (Apr/May 2008)

Yes. The value of  $\Delta G$  in any process is quite definite, no matter under what conditions the process is carried out, but only the temperature and pressure are constant the free energy change would represent the maximum net work available from the given change in state.

(eg) The maximum electrical work that could be done by the system undergoing a given change in state is less than the maximum work,  $-\Delta A$ , by the expansion work and is measured by the decrease in the Gibbs free energy,  $-\Delta G$ .

20. How the number of independent reactions in a chemically reacting system is determined?
- For each chemical compound present in the system, an equation for its formation reaction from its elements is written. ( $F = C - \pi - r + 2$ )
  - The elements that are not present in the system are eliminated by properly combining the equations written in step (i).  
The number of equations,  $r$  that results from the above procedure is equal to the number of independent chemical reactions occurring.
21. What do you understand by the principle of increase in entropy? (Apr/May 2008)  
The principle of increase in entropy with reference to an isolated system means that the only processes that can occur in an isolated system are those that have an increase in entropy associated with them. The universe is a perfect example of an isolated system and all naturally occurring processes in the universe are accompanied by an increase in entropy and are irreversible. Hence we can say that the entropy of the universe goes on increasing.
22. Give an explanation of the effect of the pressure on a first order reaction. (May/June 2006)  
Increasing the pressure on a reaction involving reacting gases increases the rate of reaction. Changing the pressure on a reaction which involves only solids or liquids has no effect on the rate.
23. Give an explanation of the effect of the temperature on a first order reaction. (May/June 2006)  
The fraction of molecules whose kinetic energy exceeds the activation energy increases quite rapidly as the temperature is raised. This is the reason, all chemical reaction proceed more rapidly at higher temperature.
24. What reaction conditions affect the equilibrium conversion in chemical reactions?  
Temperature, pressure, excess amount of reactants, initial amount of products and inert substances.
25. What is the significance of free energy calculations in the thermodynamic analysis of chemical reactions?  
To find the equilibrium compositions, from free energy calculations, we can find the feasibility of a reaction.
- $\Delta G^0 < 0$ , the reaction is promising.
  - $0 < \Delta G^0 < 40,000$  kJ/kmol, the reaction may or may not be possible and needs further study.
  - $\Delta G^0 > 40,000$  kJ/kmol, the reaction is very unfavorable.
- These guides may be useful as an approximate criterion for ascertaining the feasibility of chemical reactions.
26. What is quasistatic process? (May/June 2006)  
Consider the special case of an interaction of the system A with its surroundings which is carried out so slowly that A remains arbitrarily close to equilibrium at all times. Such a process is said to be quasistatic for the system.
- $dQ = dE + dW$   
 $dQ$ - infinitesimal heat  
 $dE$ - infinitesimal work  
 $dW$  – environment

27. How you evaluate the entropy changes accompanying chemical reactions?

The entropy changes accompanying chemical reactions are evaluated through the use of absolute entropies of the various components taking part in the reaction. Let  $S_P$  denote the sum of the entropies of the reactants and  $S_R$  denotes that of the products. Then the entropy change accompanying the reaction by

$$\Delta S = S_P - S_R$$

28. What are Giauque functions?

Data for calculation of standard free energy of reactions are sometimes tabulated as Giauque functions. These are Gibbs free energy functions that vary very slowly with temperature. Two such functions are in general use – the first is referred to 0 K and the second referred to 298 K. These are written as

$$\phi_0 = \frac{G^0 - H^0}{T}, \quad \phi_{298} = \frac{G^0 - H^0_{298}}{T}$$

29. What will happen if the system is not in chemical equilibrium?  
 If the system is not in chemical equilibrium, the reaction occurring must be irreversible and the total Gibbs free energy must decrease at constant temperature and pressure.
30. Define heterogeneous reaction equilibria.  
 In the study of heterogeneous reaction equilibria, we are concerned with a gas phase that is in equilibrium with a liquid or a solid phase. When the heterogeneous system is in equilibrium we would have to consider the equilibrium with respect to chemical reactions in the gas phase as well as the phase equilibria between the components in the gas phase and the liquid or the solid phase as the case may be.
31. What is the effect of presence of inert materials?  
 Diluting the reaction mixture with an inert material will increase the total number of moles in the reaction mixture. This will result in an increased conversion if  $v$  is positive. That is, if the reaction proceeds with an increase in the number of moles, presence of inerts in the system will increase the equilibrium yield. The presence of inerts will decrease conversion if the reaction is accompanied by a decrease in the number of moles, and the inerts present in the system will have no influence on the degree of completion if  $v$  is zero, if there is no change in the number of moles during a reaction.
32. What is effect of presence of excess of reactants?  
 When the reactants are not present in stoichiometric proportions, increasing the number of moles of the excess reactant will result in increase in the number of moles of the products and improved conversion of the limiting reactant at equilibrium.
33. What is the effect of addition of inert gas at constant volume?  
 When an inert gas is added to the system in equilibrium at constant volume, the total pressure will increase. But the concentrations of the products and reactants (i.e. ratio of their moles to the volume of the container) will not change.
34. What is the effect of addition of inert gas at constant pressure?  
 When an inert gas is added to the system in equilibrium at constant pressure, then the total volume will increase. Hence, the number of moles per unit volume of various reactants and products will decrease. Hence, the equilibrium will shift towards the direction in which there is increase in number of moles of gases.

35. What is the effect of presence of products?

If the initial reaction mixture contained any of the products of the reaction, then the number of moles of that product formed by the reaction so as to establish equilibrium will decrease. Therefore, the addition of the products to the original reactant stream decreases the equilibrium conversion.

#### PART B

1. Methanol is produced by the following reaction:  $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightarrow \text{CH}_3\text{OH(g)}$ . The standard heat of formation of  $\text{CO(g)}$  and  $\text{CH}_3\text{OH(g)}$  at 298 K are -110,500 J/mol and -200,700 J/mol respectively. The standard free energies of formation are -137,200 J/mol and -162,000 J/mol respectively. Calculate the standard free energy change and determine whether the reaction is feasible at 298K. Determine the equilibrium constant at 400 K assuming that the heat of reaction is constant. (May/June 2015, 2012,13) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.442)
2. Derive the effect of pressure and temperature on the equilibrium constants. (May/June 2012,13) (Nov/Dec 2008) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.419-421)
3. (i) Derive the equilibrium criteria for homogeneous chemical reactions. (8) (Nov 2009,10) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.402-404)  
(ii) Explain the factors affecting equilibrium conversion (8) (Nov 2009,10) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.422-423)
4. Prove that  $K_a = K_f = K_p$  with example. (Nov/Dec 2013) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.404-407)
5. A gaseous mixture containing 30%  $\text{CO}$ , 50%  $\text{H}_2$  and the rest inert gas is sent to a reaction chamber for methanol synthesis. The following reaction occurs at 635 K and 310 bar.  
$$\text{CO (g)} + 2\text{H}_2\text{ (g)} \rightarrow \text{CH}_3\text{OH (g)}$$
Assuming that the gas mixture behaves as an ideal solution, calculate the percent conversion of  $\text{CO}$  given that  $K_f = 5 \times 10^{-5}$  and  $K_\phi = 0.35$ . (May/June 2009) (Apr/May 2008) (Narayanan K.V“*A Text Book of Chemical Engineering Thermodynamics*” Page No.444)
6. The standard heat of formation and standard free energy of formation of  $\text{NH}_3$  at 328 K are -46,100 J/mol & 13,650 J/mol respectively. Calculate the equilibrium constant for the reaction.

$N_2(g) + 3H_2(g) \rightarrow 2NH_3$  at 500 K assuming that the standard heat of reaction is constant in (g)

the temperature range of 328 K to 500 K. (Apr/May 2017)

(Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.417)

**PART – C**

1. Explain how the equilibrium constants expressed for gas and liquid phase reactions. (Apr/May2017) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.404-407)
2. The gases from the pyrites burner of a contact sulphuric acid plant have the following composition:  $SO_2 = 7.8\%$ ,  $O_2 = 10.8\%$  and  $N_2 = 81.4\%$ . This is then passed into a converter where the  $SO_2$  is converted to  $SO_3$ . The temperature and pressure in the converter are 775 K and 1 bar. The equilibrium constant for the reaction  $SO_2 + 1/2 O_2 \rightarrow SO_3$  may be taken as

- $K_e = 85$ . Calculate the composition of gases leaving the converter. (May/June 2016) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.445)
3. What is the influence of temperature on equilibrium constant and derive Van't Hoff's equation. (Nov/Dec 2013) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.409-413)
  4. (i) Describe the effect of reaction conditions on chemical equilibrium conversion. (Apr/May 2014) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.422-423)  
(ii) Derive the equation relating equilibrium constant and standard free energy change. (Apr/May 2014, 2010) (Narayanan K.V "A Text Book of Chemical Engineering Thermodynamics" Page No.413-415)

**UNIT V -THERMODYNAMIC DESCRIPTION OF MICROBIAL GROWTH AND  
PRODUCT FORMATION**

**PART A**

1. Mention the expression for Gibbs energy for thermodynamics of maintenance. (Apr/May 2017)  
The expression for Gibbs energy for thermodynamics of maintenance is given by

$$\mu = \left[ \frac{(-q_s^{\max})C_s - (-m_s)}{K_s + C_s} \right] Y_{SX}^{\max}$$

- $C_s = 0$ ,  $\mu = m_s Y_{SX}^{\max} = -k_d$
- $C_s \gg K_s$ ,  $\mu = [-q_s^{\max} - (-m_s)] Y_{SX}^{\max} = \mu^{\max}$
- $\mu = 0$ ,  $(-q_s) = (-m_s)$ , which occurs at  $C_s = C_s^{\min}$ .

2. Define specific growth rate. (Apr/May 2017)

It is defined as the rate of increase of biomass of a cell population per unit of biomass concentration. It can be calculated in batch cultures, since during a defined period of time, the rate of increase in biomass per unit of biomass concentration is constant and measurable.

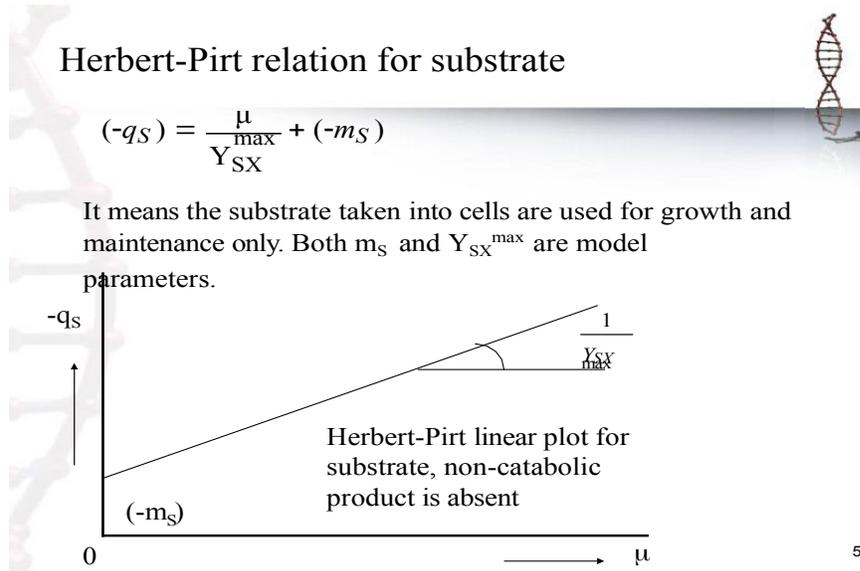
3. What do you understand by Basal Metabolic rate? (May/June 2016)

Basal metabolic rate is the rate at which food is converted into heat transfer and work done while the body is at complete rest. The body adjusts its basal metabolic rate to compensate (partially) for over-eating or under-eating. The body will decrease the metabolic rate rather than eliminate its own fat to replace lost food intake.

4. Brief on Herbert-Pirt equation. (May/June 2016)

$$(-q_s) = \frac{\mu}{Y_{SX}^{\max}} + (-m_s)$$

It means the substrates taken into cells are used for growth and maintenance only. Both  $m_s$  and  $Y_{SX}^{\max}$  are model parameters.



Combination of the  $q_s$  equation with Herbert-Pirt relation

$$\mu = \left[ \frac{(-q_s^{\max})C_s - (-m_s)}{K_s + C_s} \right] Y_{SX}^{\max}$$

- $C_S = 0$ ,  $\mu = m_S Y_{SX}^{\max} = -k_d$
- $C_S \gg K_S$ ,  $\mu = [-q_S^{\max} - (m_S)] Y_{SX}^{\max} = \mu^{\max}$
- $\mu = 0$ ,  $(-q_S) = (-m_S)$ , which occurs at  $C_S = C_S^{\min}$ .

The specific growth rate equation based on single substrate is then:

$$\mu = \mu_{\max} \frac{C_s - C_s^{\min}}{K_s + C_s}$$

5. Name the important parameters which describe growth of organism.  
Growth of organisms is usually described by four parameters which belong to the hyperbolic substrate uptake relation ( $\mu_{\max}$ ,  $k_s$ ) and the Herbert-Pirt relation ( $Y_{\max_{SX}}$ ,  $m_s$ ). The values of these four parameters are essential to design processes in which growing organisms are used.

6. Define heterotrophic growth.

The biomass composition formula  $C_1H_{1.8}O_{0.5}N_{0.2}$  shows that synthesis of biomass requires a carbon source and an N-Source. In addition there is a need for an electron donor (D). When growth uses an organic compound as substrate, then the substrate is both carbon and electron donor. This is called heterotrophic growth.

7. Define autotrophic growth.

When growth uses  $CO_2$  as C-Source, then there is a need for a separate electron donor to reduce  $CO_2$  to biomass. This is called autotrophic growth.

8. Define operational yield.

The operational yield  $Y_{DX}$  (Cmol X/mol electron donor) is defined as the ratio of  $\mu$  and  $(-q_D)$ :

$$Y_{DX} = \frac{\mu}{-q_D} = \frac{\mu}{\mu + (-m_{D/DX} \mu)} = \frac{Y_{\max_{DX}}}{1 + m_{D/DX} Y_{\max_{DX}}}$$

9. Write the significance of operational biomass yield.

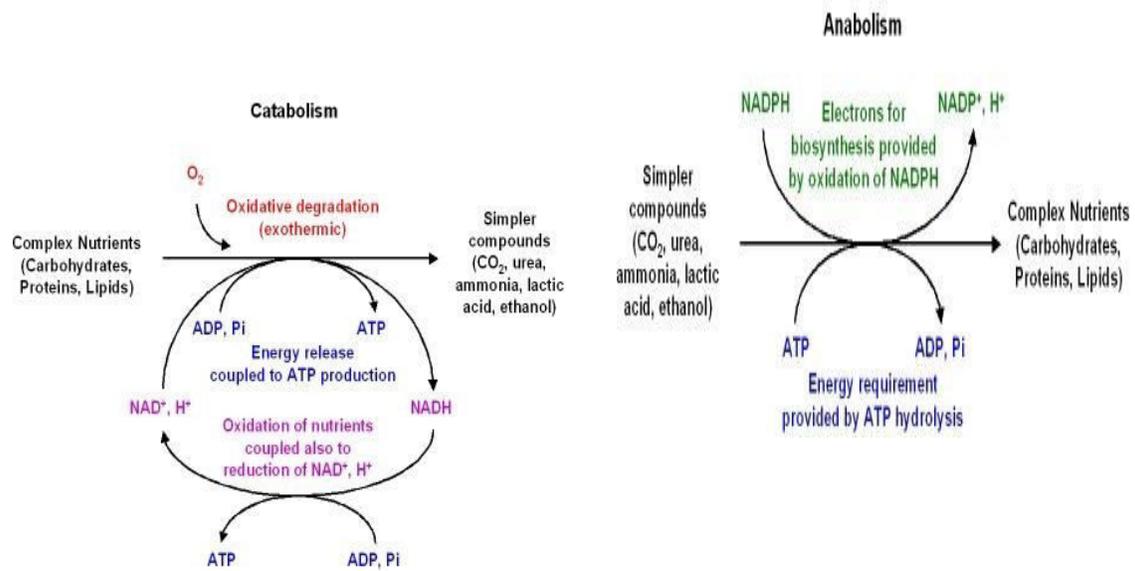
The operational biomass yield  $Y_{DX}$  is a hyperbolic function in  $\mu$ .  
At high  $\mu$ : ( $\mu \gg (-m_{D/DX} Y_{\max_{DX}})$ ) the operational biomass yield approaches asymptotically the maximum yield.

At low  $\mu$ : ( $\mu \ll (-m_{D/DX} Y_{\max_{DX}})$ ) the operational biomass yield  $Y_{DX}$  drops to zero.

$$Y_{DX} = \frac{\mu}{-q_D} = \frac{\mu}{\mu + (-m_{D/DX} \mu)} = \frac{Y_{\max_{DX}}}{1 + m_{D/DX} Y_{\max_{DX}}}$$

10. Define Gibbs energy based coupling of catabolism to anabolism.

In catabolism, an electron acceptor performs a redox reaction with an electron donor leading to the production of energy. This energy is coupled to anabolism to derive the anabolic reaction.



11. How Gibbs energy of a catabolic reaction is obtained?

The Gibbs energy of a catabolic reaction is obtained by first calculating the correct stoichiometry of the complete catabolic reaction for the consumption of 1 mol electron donor,

after which are calculates  $-\Delta G_R^{01} = \Delta G_{cat}^{01}$  (which is the produced catabolic energy under biochemical standard conditions).

12. Define biochemical standard conditions.

Biochemical standard conditions, indicated with superscript 01, (ie) 298 K, 1 bar, 1 mol/l, and pH 7 ( $H^+$  concentration of  $10^{-7}$  mol/l).

13. Write the equation for Heterotrophic growth.

a electron donor / C –source + b N- source + cH<sup>+</sup> + dH<sub>2</sub>O + e CO<sub>2</sub> + 1 C<sub>1</sub>H<sub>1.8</sub> O<sub>0.5</sub> N<sub>0.2</sub> = 0

14. Write the equation for Autotrophic growth.

f CO<sub>2</sub> + a electron donor / C –source + b N- source + cH<sup>+</sup> + dH<sub>2</sub>O + e Oxidized electron donor + 1 C<sub>1</sub>H<sub>1.8</sub> O<sub>0.5</sub> N<sub>0.2</sub> = 0.

15. Define degree of reduction.

Degree of reduction ( $\delta_i$ ) is a stoichiometric quantity which can be calculated for each chemical compound for which the elemental composition is known.  $\delta_i$  reflects the amount of electrons available in a compound.

16. How degree of reduction is calculated?

Degree of reduction  $\delta_i$  is calculated by writing the redox half reaction in which compound i is converted in a set of reference compounds which are CO<sub>2</sub>, H<sub>2</sub>O, H<sup>+</sup>, Fe<sup>3+</sup>, N<sub>2</sub> and electrons. The amount of produced electrons equals  $\delta_i$ . Using this redox half reaction approach we can calculate the degree of reduction of elements and of electric charge.

17. How the complete stoichiometry of the anabolic reaction is obtained?

The complete stoichiometry of the anabolic reaction can be obtained from the elemental and charge balances and that it can be calculated from the balance of degree of reduction that the amount of electron donor needed in the anabolic reaction equals  $(\delta_X / \delta_D)$  mol electron donor / C mol X.

18. Write down the equations used to calculate the Gibbs energy of formation under nonstandard condition?

The effect of nonstandard concentration at 25°C on Gibbs energy of formation (KJ/mol) of a compound I follow from:

$$\text{Dissolved compound: } \Delta G_{f_i} = \Delta G_{f_i}^0 + RT \ln(C_i/1)$$

$$\text{Gaseous compound : } \Delta G_{f_i} = \Delta G_{f_i}^0 + RT \ln(P_i/1)$$

$$\text{Proton : } \Delta G_{f_i} = -39.87 + RT \ln(H^+/10^{-7})$$

$\Delta G_{f_i}$  is the Gibbs energy of formation.

$C_i/1$  is the dissolved concentration of compound i ( $C_i$ , mol/l) divided by the standard con. (1 mol/l)

$P_i/1$  is the partial pressure of compound I ( $P_i$  atm), divided by the standard pressure (1 atm).

For  $H^+$  the biochemical standard is at  $H^+ = 10^{-7}$  M

19. How the effect of temperature on the Gibbs energy of formation is obtained?

The effect of temperature (at standard concentration, pressure) on the Gibbs energy of formation is obtained from the Van't Hoff relation

$$\Delta G_{f_i}^0(T) = \Delta H_{f_i}^0 - T\Delta S_{f_i}^0$$

!

The value of the enthalpy of formation  $\Delta H_0$  is obtained from the standard thermodynamic tables.

20. Define ETC.

ETC – Electron Transport Chain. The ETC consists of electron processing proteins embedded in membranes. Because cells are limited in the amount of membrane area and the amount of ETC protein which can be placed in membranes is also physically (space) limited it is to be expected that there is a limit in the electron transport rate per C mol X.

21. Define pmf.

Proton motive force (pmf). The pmf equals about 15 KJ of Gibbs energy for 1 mol H<sup>+</sup>, and therefore one might expect that a catabolic reaction needs to generate at least 15 KJ of Gibbs energy in order to create pmf.

22. Define yield factor.

Yield factor is used to quantify the nutrient requirements and production characteristics of an organism.

23. Define Theoretical yield.

Theoretical yield is defined as the ratio of total mass or moles of product formed to mass or moles of reactant used to form that particular product.

24. Define apparent yield.

Apparent yield is defined as the ratio of mass or moles of product present to total mass or moles of reactant consumed.

25. Define observed yield.

Observed yield is particularly important for cell metabolism because there are always many reactions occurring at the same time. The observed biomass yield based on total substrate consumption is:

$$Y'_{XS} = \frac{-\Delta X}{\Delta S_T}$$

26. Define RQ.

RQ –Respiratory Quotient.

$$RQ = e / a$$

RQ is defined as the moles of CO<sub>2</sub> produced per mole of oxygen consumed. RQ values provide an indication of metabolic state and can be used in process control.

27. Define overall and instantaneous yields.

$\Delta F$  and  $\Delta G$  can be calculated as the difference between initial and final values, this gives an overall yield. If  $r_F$  and  $r_G$  are volumetric rates of production and consumption of F and G. instantaneous yield may be calculated as follows:

$$Y_{FG} = \lim_{\Delta G \rightarrow 0} \frac{-\Delta F}{\Delta G} = \frac{-dF}{dG} = \frac{-dF/dt}{dG/dt} = \frac{r_F}{r_G}$$

28. Define  $Y_{\text{kcal}}$ .

$Y_{\text{kcal}}$  is defined as the ratio of mass or moles of biomass formed per kilocalorie of heat evolved during fermentation.

29. Define yield.

Yield is defined as the ratio of amount of product formed or accumulated per amount of reactant provided or consumed.

30. Define yield coefficient.

Yield coefficients can be written

as,

$$Y_{FG} = \frac{-\Delta F}{\Delta G}$$

$Y_{FG}$  – yield factor. F and G are substances involved in metabolism

$\Delta F$  – mass or moles of F produced

$\Delta G$  – mass or moles of G consumed.

-ve sign is required because  $\Delta G$  for a consumed substance is negative in value, yield is calculated as a positive quantity.

31. Define Catabolism.

Catabolism is the pathway that breaks down molecules into smaller units and produces energy.

32. Define Anabolism

Anabolism is the building up of molecules from smaller units. Anabolism uses up the energy produced by the catabolic break down of your food to create molecules more useful to your

body.

33. Give some examples of anabolic products.

- (i) Amino acid
- (ii) Nucleotide
- (iii) Protein

(iv) Antibiotic

(v) lipid

34. Define doubling time.

Doubling time ( $t_d$ ) is the time required for the concentration of biomass of a population of suspension cells to double. One of the greatest contrasts between the growths of cultured plant cells refers to their respective growth rates. The doubling time ( $t_d$ ) can be calculated according to the following equation

$$t_d = \frac{\ln 2}{\mu}$$

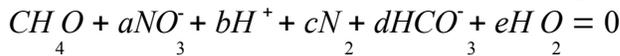
35. Critical dilution rate

The maximal value for  $D (= \mu)$  attainable in the chemostat, is achieved when the maximal  $C_S$  is achieved. At critical dilution rate,  $C_S \rightarrow C_{S,in}$ .

$$D_{crit} = \mu^{max} \frac{C_{S,in} - C_{S,min}}{K_S + C_{S,in}} \approx \mu^{max}$$

**PART B**

1. Derive Herbert –Pirt Relation for electron donor consumption and explain the terms. (Apr/May 2017) (or) How to calculate the heat in operational stoichiometry using the Herbert –Pirt Relation for Electron Donor. (Christiana D. Smolke, Page no. 11.4 – 11.17)
2. Explain the thermodynamic relation to calculate the biomass yield on electron donor. (Apr/May 2017) (or) Discuss about the thermodynamics of microbial growth stoichiometry. (May/Jun 2016) (Christiana D. Smolke, Page no. 11.2-11.3)
3. Explain about the formation thermodynamics. (May/Jun 2016) (Explain thermodynamics and stoichiometry of Product Formation. (Christiana D. Smolke, Page no. 11.17-11.19)
4. Giving example find the stoichiometric coefficient for calculation of the anabolic reaction for autotrophic growth. (Christiana D. Smolke, Page no. 11.3-11.4)
5. Giving example find the stoichiometric coefficient for calculation of the anabolic reaction for heterotrophic growth. (Christiana D. Smolke, Page no. 11.3)
6. Calculate the stoichiometric coefficient and Gibbs free energy for catabolic reactions.



Data:

Composition	$\Delta G_f^0$ (KJ/mol)
$H_2O$	-237.18
$HCO_3^-$	-586.85
$CO_2$	-394.359
$H^+$	-39.87
$CH_4O$	-175.39
$N_2$	0
$NO_3^-$	-111.34

(Christiana D. Smolke, Page no. 11.7-11.9)

### **PART C**

1. Explain in detail about calculation of the electron donor needed for anabolism using the balance of degree of reduction. (Christiana D. Smolke, Page no. 11.4-11.5)
2. Write short notes on the elemental balance used in stoichiometric calculations. (Apr/May 2015)(Class notes)
3. Write in detail about the correlations to find the amount of Gibbs energy generated in the anabolic reaction for the synthesis of 1 Cmol of synthesis.  
(Christiana D. Smolke, Page no. 11.10-11.12)



12. (a) Derive an expression for fugacity and fugacity coefficient of pure species.

Or

- (b) Briefly derive the Gibbs Duhem equation.
13. (a) At 750mm Hg pressure, the A-B azeotrope boils at 65°C and contains 25 mole % of A. The vapour pressure of A and B are 1000 mm and 300 mm of Hg respectively at 65°C. Calculate the composition of vapour at this temperature in equilibrium with liquid analyzing 10 mole % of A. What is the total pressure at this condition?

Or

- (b) Construct a P-X-Y diagram for the cyclohexane (i) benzene (ii) system at 313.15K, the vapor pressures are  $P_1^s = 24.62$  kpa and  $P_2^s = 24.41$  kpa. The liquid phase activity coefficients are given by  $\ln \gamma_1 = 0.458x_2^2$  and  $\ln \gamma_2 = 0.458x_1^2$ .
14. (a) The standard heat of formation and std free energy of formation of  $\text{NH}_3$  at 328K are  $-46,100$  J/mol and  $13,650$  J/mol respectively. Calculate the equilibrium constant for the reaction.  $\text{N}_2(\text{g}) + 3\text{H}_2 \rightarrow 2\text{NH}_3$  at 500K assuming that the standard heat of reaction is constant in the temperature range of 328 K to 500 K.

Or

- (b) Explain how the equilibrium constants expressed for gas and liquid phase reactions.
15. (a) Derive Herbert —Pirt relation for electron donar consumption and explain the terms.

Or

- (b) Explain the thermodynamic relation to calculate the biomass yield on electro donar.

PART C — (1 × 15 = 15 marks)

16. (a) A solution consists of 40% methanol (species 1) and 60% water (species 2). Assume that methanol is completely miscible in water and that the solution behaves according to Raoult's Law. The saturation pressure correlations for the pure components are  $\ln P_1^s = 20.61 - 4719.2/T$ .  
 $\ln P_2^s = 20.60 - 5205.2/T$
- (i) If the temperature is maintained at 20°C, at what pressure will a vapour bubble begin to form?

- (ii) At this pressure and at 20°C, determine the ratio of moles of vapour in the vapour-liquid mixture and the vapour phase composition?
- (iii) At 20°C, what is pressure at which virtually the entire liquid has vapourized? Determine the liquid composition and the quality at this pressure?

Or

- (b) Describe the relationship for Solid- Liquid and Solid —Vapour phase transition.
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Reg. No.

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**Question Paper Code : 57123**

**B.E. /B. Tech. DEGREE EXAMINATION, MAY/JUNE 2016**

**Fourth Semester**

**Biotechnology**

**BT 6402 – APPLIED THERMODYNAMICS FOR BIOTECHNOLOGISTS**

**(Regulation 2013)**

**Time : Three Hours**

**Maximum : 100 Marks**

**Any missing data can be suitably assumed.**

**Use of all thermodynamic and refrigeration tables and charts are allowed.**

**Answer ALL questions.**

**PART – A (10 × 2 = 20 Marks)**

1. Discuss on volume expansivity.
2. Define the principle of corresponding states.
3. Differentiate between Clayperon and Clausius - Clayperon equations.
4. State the fugacity criterion for phase equilibrium.
5. Differentiate bubble point & dew point temperature.
6. What is an azotrope ? Under what conditions do azeotropes generally form ?
7. Define partial molar property.
8. Define equilibrium constant  $K_e$  of a chemical reaction. How is it related to  $K_f$  and  $K_p$  ?
9. What do you understand by Basal Metabolic Rate ?
10. Brief on Herbert-Pirt equation.

**PART – B (5 × 16 = 80 Marks)**

11. (a) Air initially at 390 K and 8 bar is expanded reversibly and isothermally to such a pressure that when it is cooled to 340 K at constant volume its pressure is 2 bar. Calculate the work, heat transferred, change in internal energy and change in enthalpies. Assume air to be ideal gas. (16)

**OR**

- (b) A 0.017 m<sup>3</sup> tank contains 1 kg of refrigerant-134a at 110 °C. Determine the pressure of the refrigerant, using (1) the ideal-gas equation, (2) the generalized compressibility chart, and (3) the refrigerant tables. (16)

12. (a) Find the van Laar constants for the binary system benzene (1)-ethanol (2) using the following data : (16)

$x_1$	0.1	0.3	0.45	0.7	0.9
$p_1^s$ kPa	73.31	68.64	63.98	67.98	81.31
$p_2^s$ kPa	75.98	69.64	67.98	69.31	79.98

**OR**

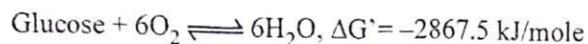
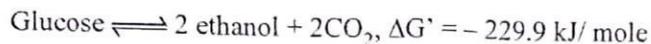
- (b) Two substances A and B are known to form ideal liquid solutions. A vapour mixture containing 50% (mol) A and 50% B is at 311 K and 101.3 kPa. This mixture is compressed isothermally until condensation occurs. At what pressure, does condensation occur and what is the composition of the liquid that forms ? The vapour pressures of A and B are 142 kPa and 122 kPa respectively. (16)

13. (a) A vapour mixture containing 18% ethane, 17% propane, 62% isobutene and the rest n-butane is subjected to partial condensation so that 75% of the vapour is condensed. If the condenser temperature is 300 K, determine the pressure. (16)

**OR**

- (b) At 300 K, the vapour pressure of benzene (A) and toluene (B) are 16 kPa and 5 kPa respectively. Determine the partial pressures and weight composition of the vapour in equilibrium with a liquid mixture consisting of equal weights of the two components. (16)

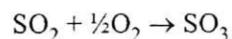
14. (a) Given the following information:



Calculate the number of moles of  $\Delta\text{TP}$  that could be synthesized from  $\text{ADP} + \text{Pi}$  upon complete oxidation of one mole of ethanol to  $2\text{CO}_2 + 3\text{H}_2\text{O}$ . Assume an efficiency of energy conservation of 44% under standard conditions. The synthesis of ATP requires 32340 Joules/mole. (16)

**OR**

- (b) The gases from the pyrites burner of a contact sulphuric acid plant have the following composition:  $\text{SO}_2 = 7.8\%$ ,  $\text{O}_2 = 10.8\%$  and  $\text{N}_2 = 81.4\%$ . This is then passed into a converter where the  $\text{SO}_2$  is converted to  $\text{SO}_3$ . The temperature and pressure in the converter are 775 K and 1 bar. The equilibrium constant for the reaction



may be taken as  $K_e = 85$ . Calculate the composition of gases leaving the converter. (16)

15. (a) Discuss about the thermodynamics of microbial growth stoichiometry. (16)

**OR**

- (b) Explain about the formation thermodynamics. (16)



- (b) (i) Express the volume expansivity and the isothermal compressibility as functions of density  $\rho$  and its partial derivatives. For water at  $50^\circ\text{C}$  and 1 bar,  $K_T = 44.18 \times 10^{-6} \text{ bar}^{-1}$ . To what pressure must water be compressed at  $50^\circ\text{C}$  to change its density by 1%. Assume  $K_T$  to be independent of pressure. (8)
- (ii) With the help of Maxwell equations prove that the specific heats of ideal gases are functions of temperature only. (8)
12. (a) (i) Describe schematically an experimental technique for the determination of volume change and enthalpy change on mixing. (8)
- (ii) A vessel is divided into two parts. One part contains 2 mol nitrogen gas at 353 K and 40 bar and other contains 3 mol argon gas at 423 K and 15 bar. If the gases are allowed to mix adiabatically by removing the partition determine the change in entropy. Assume that the gases are ideal and  $C_v$  is equal to  $5/2 R$  for nitrogen and  $3/2 R$  for argon. (8)

Or

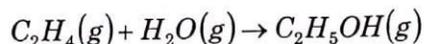
- (b) (i) Discuss the variable pressure and variable temperature modifications of Gibbs- Duhem equations. (8)
- (ii) The enthalpy of a binary liquid mixture containing components 1 and 2 at 298 K and 1.0 bar is given by
- $$H = 400x_1 + 600x_2 + x_2 + x_1x_2(40x_1 + 4x_2)$$
- where  $H$  is in J/mol, Determine
- (1) Pure component enthalpies and
- (2) Partial molar enthalpies. (8)
13. (a) (i) Water (1) - hydrazine (2) system forms an azeotrope containing 58.5 % (mol) hydrazine at 393 K and 101.3 kPa. Calculate the equilibrium vapour composition for a solution containing 20 % (mol) hydrazine. The relative volatility of water with reference to hydrazine is 1.6 and may be assumed to remain constant in the temperature range involved. The vapour pressure of hydrazine at 393 K is 124.76 kPa. (8)
- (ii) Construct the P-x-y diagram for the cyclohexane (1) - benzene (2) system at 313 K the vapour pressures are  $P_1^s = 24.62 \text{ kPa}$  and  $P_2^s = 24.41 \text{ kPa}$ . The liquid-phase activity coefficients are given by
- $$\ln \gamma_1 = 0.458x_2^2, \ln \gamma_2 = 0.458x_1^2. \quad (8)$$

Or

- (b) (i) Liquids A and B form an azeotrope containing 46.1 mole per cent A at 101.3 kPa and 345 K. At 345 K, the vapour pressure of A is 84.8 kPa and that of B is 78.2 kPa, Calculate the Van Laar constants. (8)

- (ii) A vapor mixture of 20 mole percent methane, 30 mole percent ethane and 50 mole percent propane is available at 30°C. Making use of the K factors determine the pressure at which condensation begins if the mixture is isothermally compressed. Also estimate the composition of the first drop of liquid that forms. (8)

14. (a) (i) In a chemical laboratory, it is proposed to carry out the reaction



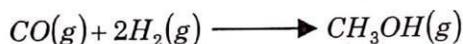
at 1 bar and 298 K. Calculate the standard Gibbs free energy change at 298 K and predict whether it is feasible to carry out the given reaction or not. Also calculate the equilibrium constant. (8)

- (ii) Describe the factors affecting equilibrium conversion. (8)

Or

- (b) (i) The equilibrium constant for the reaction  $A \rightarrow B$  is doubled when temperature is changed from 25°C to 35°C. Calculate the enthalpy of reaction. (8)

- (ii) Methanol is produced by the following reaction :



Standard heat of formation of CO (g) and CH<sub>3</sub>OH (g) at 298 K are -110,500 J/mol and 200,700 J/mol respectively. The standard free energies of formation are -137,200 J/mol and 162,000 J/mol respectively.

- (1) Calculate the free energy change and determine whether the reaction is feasible at 298 K.  
(2) Determine the equilibrium constant at 400 K assuming that the heat of reaction is constant.

15. (a) (i) Describe briefly about the functions of ATP and NADH in the metabolic pathway. (8)  
(ii) Write short notes on the elemental balance used in Stoichiometric calculations. (8)

Or

- (b) (i) Discuss about the oxygen consumption and heat evolution in aerobic cultures. (8)  
(ii) Estimate the theoretical growth and product yield coefficients for ethanol fermentation by *S.cerevisiae* as described by the following overall reaction.



## BT8303 BASIC INDUSTRIAL BIOTECHNOLOGY

	TITLE	REFERENCE BOOK	PAGE NO.
<b>UNIT I - INTRODUCTION TO INDUSTRIAL BIOPROCESS</b>			<b>9</b>
1.	Fermentation - Bacterial, Fungal and Yeast, Biochemistry of fermentation.	Prescott, S.C. and Cecil G. Dunn, "Industrial Microbiology", Agrobios (India), 2005.	Chapter 1
2.	Traditional and Modern Biotechnology	Prescott, S.C. and Cecil G. Dunn, "Industrial Microbiology", Agrobios (India), 2005.	Chapter 12
3.	A brief survey of organisms, processes, products.	Cruger, Wulf and Anneliese Crueger, "Biotechnology: A Textbook of Industrial Microbiology",	Pg.No 9-50, 64-107, 111-121.
4.	Upstream and Downstream processing in Bioprocess.	Satyanarayana, U. "Biotechnology" Books & Allied (P) Ltd., 2005	Pg.No 239-267, 270-280
5.	Basic concepts of Process flow Sheet - block diagrams, pictorial representation.	Research Internet Papers	10 pages
<b>UNIT II PRODUCTION OF PRIMARY METABOLITES</b>			<b>9</b>
1.	Primary Metabolites -	Satyanarayana, U. "Biotechnology" Books & Allied (P) Ltd., 2005	Pg.No 254
2.	Production of commercially important primary metabolites like Organic acids, and Amino acids.	Satyanarayana, U. "Biotechnology" Books & Allied (P) Ltd., 2005	Pg.No 318-322
3.	Production of commercially important primary metabolites like Alcohols	Satyanarayana, U. "Biotechnology" Books & Allied (P) Ltd., 2005	Pg.No 344-354

<b>UNIT III PRODUCTION OF SECONDARY METABOLITES</b>			<b>9</b>
1.	Secondary Metabolites -	Satyanarayana, U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No 255
2.	Production processes for various classes of secondary metabolites: Antibiotics and Vitamins	Satyanarayana, U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No 329-343
3.	Production processes for various classes of secondary metabolites: Steroids.	Cruger, Wulf and anneliese Crueger, “Biotechnology: A Textbook of Industrial Microbiology”,	Pg.No 286-301
<b>UNIT IV PRODUCTION OF ENZYMES AND OTHER BIOPRODUCTS 9</b>			
1.	Production of Industrial Enzymes, Biopesticides and Biofertilizers.	A.H. Patel “ Industrial Microbiology” Macmillan and Satyanarayana,U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No137, Pg.No 188. And Pg.No 645-657, 598
2.	Production of Biopreservatives, Biopolymers, Biodiesel.	Satyanarayana,U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg. No 395-398,382-392, Internet Notes
3.	Production of Cheese, Beer, and SCP	Satyanarayana,U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No373-380, 362-370
4.	Production of Mushroom culture & Bioremediation.	Satyanarayana,U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No 380-381, 718, Pg No727

**UNIT V PRODUCTION OF MODERN BIOTECHNOLOGY PRODUCTS 9**

1.	Production of recombinant proteins having therapeutic and diagnostic applications: Vaccines.	Satyanarayana,U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No 199-212
2.	Bioprocess strategies in Plant Cell Culture	Satyanarayana,U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No 497-522
3.	Bioprocess strategies in Animal Cell culture.	Satyanarayana,U. “Biotechnology” Books & Allied (P) Ltd., 2005	Pg.No 407-414

## **PART A**

### **UNIT I INTRODUCTION TO INDUSTRIAL BIOPROCESS 9**

**Fermentation - Bacterial, Fungal and Yeast, Biochemistry of fermentation. Traditional and Modern Biotechnology - A brief survey of organisms, processes, products. Basic concepts of Upstream and Downstream processing in Bioprocess, Process flow sheeting - block diagrams, pictorial representation.**

## **PART-A**

### **1. Define Fermentation with example Nov/Dec 2016, 2017**

It is a metabolic process that converts sugar to acids, gases, or alcohol. It occurs in yeast and bacteria, and also in oxygen-starved muscle cells, as in the case of lactic acid fermentation. Fermentation is also used more broadly to refer to the bulk growth of microorganisms on a growth medium, often with the goal of producing a specific chemical product. French microbiologist Louis Pasteur is often remembered for his insights into fermentation and its microbial causes. The science of fermentation is known as zymology.

### **2. What is Modern Biotechnology?**

Modern biotechnology refers to a number of techniques that involve the intentional manipulation of genes, cells and living tissue in a predictable

and controlled manner to generate changes in the genetic make-up of an organism or produce new tissue. Examples of these techniques include: recombinant DNA techniques (r DNA or genetic engineering), tissue culture and mutagenesis

### **3. What is Traditional Biotechnology?**

Traditional biotechnology refers to a number of ancient ways of using living organisms to make new products or modify existing ones. In its broadest definition, traditional biotechnology can be traced back to human's transition from hunter-gatherer to farmer. As farmers, humans collected wild plants and cultivated them and the best yielding strains were selected for growing the following seasons.

### **4. Comment on GRAS and GILSP**

Some organism are termed GRAS ie. Generally Recognized As Safe. or Assessment of hazardous organism are known pathogenicity of organism, virulence level, number of organisms required to initiate infection, routes of infection, known incidence of infection, local existence of vectors and reserves of micro organisms, volume of organisms used in process, techniques used for cultivation and harvesting and prophylaxis and treatment facility. Good industrial large scale practice (GILSP) involves safe and highly productive organism for the process.

### **5. What are the general requirements of a bioreactor?**

The design and construction of biochemical reactors must preclude foreign contamination (sterility). Furthermore, non-septic conditions should

be maintained during the fermentation and ensure containment.

(2) Optimal mixing with low, uniform shear achieved by proper design of agitator and aerator

(3) Adequate mass transfer (oxygen) achieved by monitoring the speed of agitator and aerator

(4) Clearly defined flow conditions that can be maintained by proper opening valves and monitoring devices

(5) Feeding of substrate with prevention of under or overdosing by proper feed ports and monitoring

(6) Suspension of solids

(7) Gentle heat transfer

(8) Compliance with design requirements such as: ability to be sterilized; simple construction; simple measuring, control, regulating techniques; scaleup; flexibility; long term stability; compatibility with up- downstream processes; antifoaming measures.

## 6. What is a Process Flow Diagram?

A **process flow diagram** (PFD) is a **diagram** commonly used in chemical and **process** engineering to indicate the general **flow** of plant **processes** and equipment. The PFD displays the relationship between major equipment of a plant facility and does not show minor details such as piping details and designations.

## **7. What is a process flow chart?**

A flowchart is a picture of the separate steps of a process in sequential Order. Elements that may be included are: sequence of actions, materials or service entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements.

## **8 . When to Use a Flowchart?**

The process described can be anything: a manufacturing process, an administrative or service process, a project plan. This is a generic tool that can be adapted for a wide variety of purposes

## **9. Comment on Batch Fermentations**

A tank of fermenter is filled with the prepared mash of raw materials to be fermented. The temperature and pH for microbial fermentation is properly adjusted, and occasionally nutritive supplements are added to the prepared mash. The mash is steam-sterilized in a pure culture process. The inoculum of a pure culture is added to the fermenter, from a separate pure culture vessel. Fermentation proceeds, and after the proper time the contents of the fermenter, are taken out for further processing. The fermenter is cleaned and the process is repeated. Thus each fermentation is a discontinuous process divided into batches.

## **10 Comment on Continuous Fermentation**

Growth of microorganisms during batch fermentation confirms to the characteristic growth curve, with a lag phase followed by a logarithmic phase. This, in turn, is terminated by progressive decrements in the rate of growth until the stationary phase is reached. This is because of limitation of one or

more of the essential nutrients. In continuous fermentation, the substrate is added to the fermenter continuously at a fixed rate. This maintains the organisms in the logarithmic growth phase. The fermentation products are taken out continuously. The design and arrangements for continuous fermentation are somewhat complex.

## **11. Write notes on Yeast Fermentation**

Fermentation does not necessarily have to be carried out in an anaerobic environment. For example, even in the presence of abundant oxygen, yeast cells greatly prefer fermentation to aerobic respiration, as long as sugars are readily available for consumption (a phenomenon known as the Crabtree effect). Fermentation reacts NADH with an endogenous, organic electron acceptor. Usually this is pyruvate formed from the sugar during the glycolysis step.

During fermentation, pyruvate is metabolized to various compounds through several processes:

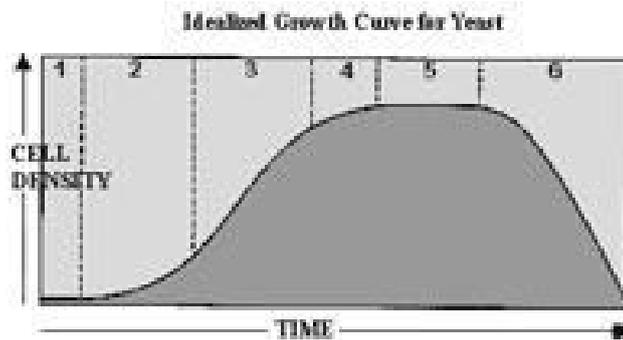
Ethanol fermentation, alcoholic fermentation, is the production of ethanol and carbon dioxide

Lactic acid fermentation refers to two means of producing lactic acid:

1. **Homolactic fermentation** is the production of lactic acid exclusively
2. **Heterolactic fermentation** is the production of lactic acid as well as other acids and alcohols.

Sugars are the most common substrate of fermentation, and typical examples of fermentation products are ethanol, lactic acid, carbon dioxide, and hydrogen gas (H<sub>2</sub>). However, more exotic compounds can be produced by

fermentation, such as butyric acid and acetone. Yeast carries out fermentation in the production of ethanol in beers, wines, and other alcoholic drinks, along with the production of large quantities of carbon dioxide. Fermentation occurs in mammalian muscle during periods of intense exercise where oxygen supply becomes limited, resulting in the creation of lactic acid.



## 12. Comment on Fungal fermentation

Industrial fermentation with fungi is used to produce a number of commercial products. Fungal metabolism is exploited to manufacture ethanol, citric acid, steroids, antibiotics and other substances with applications in the food, fuel, chemical and pharmaceutical industries.

Fungi have been used for thousands of years to modify foods and beverages. Bread made without yeast fungi is flat. The addition of yeast to flat bread dough causes the dough to rise during baking. The result is the soft texture we associate with bread. Yeasts are used in different cultures to make other modified foods. Yogurt, beer, and wine were invented in Europe and the Middle East. Saki, soy sauce, miso, tempeh, ont-jom and similar products were invented in the Far East.

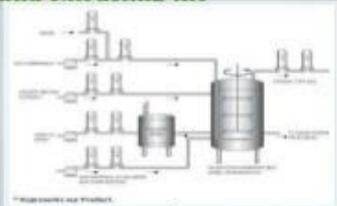
## 13. Features of Upstream Process: (NOV/DEC)-2014, 2017

What do you mean by upstream & downstream process?

❖ **The upstream processing in biotechnology involves identifying and extracting the raw materials. This forms the initial process of fermentation.**

➤ **Upstream process**-it deals with the:

- Inoculum preparation which includes screening or microorganisms and selection of suitable strain and genetic modification of the organism if needed.
- Preparation of culture media having suitable growth parameters at laboratory scale
- Scale up of the entire process.
- Inoculation.



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#### 14. Features of Downstream Process:

**Downstream process-**

- ❖ When the products are subjected to a series of processes including separation and purification which are collectively known as **Downstream processing**.
- ❖ It is also known as **product recovery**.
- ❖ Materials –upstream-finished products

**The downstream processing deals with:**

- Solid-liquid separation
- Release of intracellular products
- Concentration
- Purification
- Formulation

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#### 15. What are the stages in down stream processing? (NOV/DEC)-2015

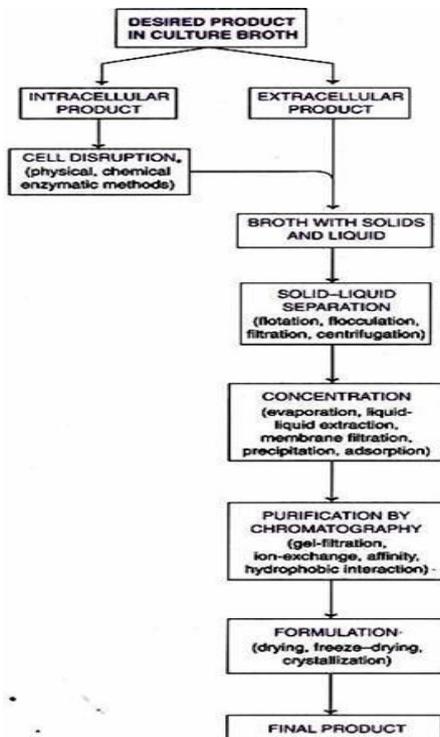


Fig. 20.1 : A summary of the major steps in downstream processing.

**16. Write the advantages in using bacteria and fungi in the fermentation process? (NOV/DEC)-2015**

Mixed-culture fermentations offer a number of **advantages** over conventional single-culture fermentations:

- ⊖ Product yield may be higher. Yogurt is made by the fermentation of milk with *Streptococcus thermophilus* and *Lactobacillus bulgaricus*.
- ⊖ The growth rate may be higher. In a mixed culture one microorganism may produce needed growth factors or essential growth compounds such as carbon or nitrogen sources beneficial to a second microorganism. It may alter the pH of the medium, thereby improving the activity of one or more enzymes. Even the temperature may be elevated and promote growth of a second microbe.
- ⊖ Mixed cultures are able to bring about multistep transformations that would be impossible for a single microorganism. Examples are the *miso* and *shoyu* fermentations in which *Aspergillus oryzae* strains are used to make *koji*. *Koji* produces amylases and proteases, which break down the starch in rice and proteins in soybeans. In the *miso* and *shoyu* fermentations, these compounds are then acted on by lactic acid bacteria and yeast to produce flavor compounds and alcohol.

**17. Write the disadvantages in using bacteria and fungi in the fermentation process? (NOV/DEC)-2015**

Mixed-culture fermentations also have some disadvantages.

- ⊖ Scientific study of mixed cultures is difficult. Obviously, it is more difficult

to study the fermentation if more than one microorganism is involved. That is why most biochemical studies are conducted as single-culture fermentations because one variable is eliminated.

- ⊖ Defining the product and the microorganisms employed becomes more involved in patent and regulatory procedures.
- ⊖ Contamination of the fermentation is more difficult to detect and control.
- ⊖ When two or three pure cultures are mixed together, it requires more time and space to produce several sets of inocula rather than just one.
- ⊖ One of the worst problems in mixed-culture fermentation is the control of the optimum balance among the microorganisms involved. This can, however, be overcome if the behavior of the microorganisms is understood and this information is applied to their control.

#### 18. what is Flocculation?

In flocculation, the cells (or cell debris) form large aggregates to settle down for easy removal. The process of flocculation depends on the nature of cells and the ionic constituents of the medium. Addition of flocculating agents (inorganic salt, organic polyelectrolyte, mineral hydrocolloid) is often necessary to achieve appropriate flocculation.

#### 19. Comment on Microbial Fermentation(NOV/DEC)-2014

**Industrial fermentation** is the intentional use of **fermentation** by **microorganisms** such as **bacteria** and **fungi** to make products useful to humans. The rate of fermentation depends on the concentration of microorganisms, cells, cellular components, and enzymes as well as temperature, pH and for **aerobic fermentation** oxygen. Product recovery frequently involves the concentration of

the dilute solution. Nearly all commercially produced enzymes, such as lipase, invertase and rennet, are made by fermentation with genetically modified microbes.

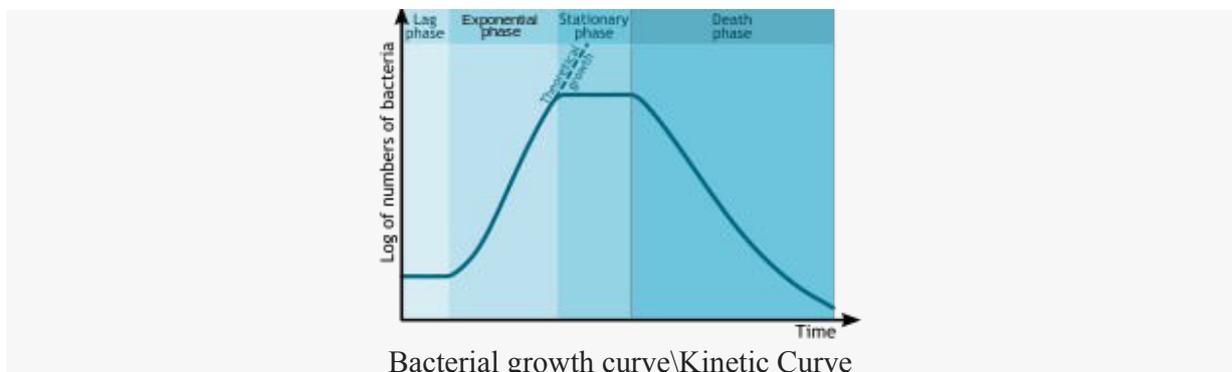
## 20. Comment on the four different types of fermentation

In general, fermentations can be divided into four types:

- ⊘ Production of biomass (viable cellular material)
- ⊘ Production of extracellular metabolites (chemical compounds)
- ⊘ Production of intracellular components (enzymes and other proteins)
- ⊘ Transformation of substrate (in which the transformed substrate is itself the product)

These types are not necessarily disjoint from each other, but provide a framework for understanding the differences in approach. The organisms used may be bacteria, yeasts, molds, algae, animal cells, or plant cells. Special considerations are required for the specific organisms used in the fermentation, such as the dissolved oxygen level, nutrient levels, and temperature.

## 21. Plot the different Phases of microbial growth and comment.



When a particular organism is introduced into a selected growth medium, the medium is inoculated with the particular organism. Growth of the inoculum does not occur immediately, but takes a little while. This is the period of adaptation, called the lag phase.

Following the lag phase, the rate of growth of the organism steadily increases, for a certain period—this period is the log or exponential phase.

After a certain time of exponential phase, the rate of growth slows down, due to the continuously falling concentrations of nutrients and/or a continuously increasing (accumulating) concentration of toxic substances.

This phase, where the increase of the rate of growth is checked, is the deceleration phase. After the deceleration phase, growth ceases and the culture enters a stationary phase or a steady state.

The biomass remains constant, except when certain accumulated chemicals in the culture lyse the cells (chemolysis). Unless other micro-organisms contaminate the culture, the chemical constitution remains unchanged.

If all of the nutrients in the medium are consumed, or if the concentration of toxins is too great, the cells may become **senescent** and begin to die off. The total amount of biomass may not decrease, but the number of viable organisms will decrease.

### **18. What is submerged fermentation and give example? (NOV/DEC)-2014**

Submerged fermentation (SmF) utilizes free flowing liquid substrates, such as corn steep liquor, molasses and nutrient broths. The enzymes and bioactive compounds are secreted into the fermentation broth. The substrates are utilized quite rapidly and hence need to be constantly supplemented with nutrients. This fermentation technique is best suited for microorganisms such as bacteria that require high moisture.

At **Karyotica** we have developed cutting edge SmF platform for production

various enzymes including protease, Asperginase and many other biocatalysts. All our recombinant range of enzymes are mainly produced through SmF process.

### **19. What is Bioprocess Engineering?**

Bioprocess – A series of physiological reactions or operations carried out for the production of specific substances. Eg. fermentation. Bioprocess Engineering – the modification and regulation of bioprocess in order to produce a large amount of the desired product

### **20. What are the Main components of a fermentor?**

Base components like the drive motor, heaters, pumps, gas control. ≡ Vessels & accessories. Peripheral equipments such as reagent bottles. ≡ Instrumentation & sensors.

### **21. Explain each Component of a fermentor & its Uses**

The components of the fermentor combine to perform the following operations: Provide operation free from contamination. Maintain specific temperature. Provide adequate mixing & aeration. Control the ph of the culture. Allow monitoring & or the control of dissolved oxygen. Facilitates the growth of wide range of organisms ≡

### **22. Give the major types of bioreactor Nov/Dec 2016**

Based on the designs of the bioreactors, they can be grouped into the following types.

- a) Continuous stirred tank bioreactors
- b) Bubble Column Bioreactors
- c) Airlift Bioreactors
- d) Fluidized Bioreactors

- e) Packed Bioreactors
- f) Photobioreactors

### **23. What are Molasses?**

It is a byproduct of sugar industry and is one of the cheapest source of carbohydrates. Sugarcane molasses (sucrose around 48%) and sugar beet molasses (sucrose around 33%) are commonly used. Molasses also contains nitrogenous substances, vitamins and trace elements. Variation in the composition of the molasses also occurs which is mostly dependent on the climatic conditions and production process.

### **24. What is Whey?**

It is a byproduct of dairy industry and is produced worldwide. Most of it is consumed by humans and animals. Whey is a reasonably good source of carbon for the production of alcohol, SCP, Vitamin B12, Lactic acid and gibberelic acid. Storage of Whey is a limiting factor for its widespread use in fermentation industry.

### **25. What is Batch Sterilization?**

The culture media are subjected to sterilization at 121C in batch volumes, in the bioreactor. Batch Sterilization can be done by injecting the steam into the medium (direct method) or injecting the steam into the interior coils (indirect method). For the direct batch sterilization, the steam should be pure and free from all chemical additives.

### **26. What is Continuous Sterilization?**

This is carried out at 140C for a very short period of time ranging from 30-120 secs. (This in contrast to the batch fermentation done at 121C for 20-60mins). This is based on the principle that the time required for killing microorganisms is

much shorter and at higher temperature. Continuous Sterilization is carried out by directly injecting the steam or by means of heat exchangers. The main advantage with Continuous Sterilization is that about 80-90% of the energy is conserved.

### **27. What is fermentation?**

Fermentation is a metabolic process that produces chemical changes in organic substrates through the action of enzymes.

Chemical breakdown of a substance by bacteria, yeast or other microorganisms.

### **28. Comment on continuous culture:**

The continuous culture of micro-organisms is a technique of increasing importance in microbiology. The essential feature of this technique is that microbial growth in a continuous culture takes place under steady-state conditions; that is, growth occurs at a constant rate and in a constant environment. Comment on Batch Culture. Batch Culture Fermentation is carried out in a closed fermenter, with nothing added or removed during the process (except venting of gas). Microorganisms and nutrients are left for a set period of time, during which the nutrient stock is depleted.

### **29. Define batch fermentation process**

Batch fermentation is a closed culture system, because initial and limited amount of sterilized nutrient medium is introduced into the fermenter.

### **30. Define submerged culture process**

Submerged culture is a method for growing pure cultures of aerobic bacteria in which microorganisms are incubated in a liquid medium subjected to continuous, vigorous agitation.

### **31. Define surface culture method**

In this method the organism is allowed to grow on the surface of liquid medium

Without agitation. After an appropriate incubation period the culture filtrate is separated from the cell mass and is processed to recover the desirable product.

### **32. Comment on anaerobic fermentation.**

Anaerobic fermentation occurs in the fermentation vessel once the oxygen is discharged and replaced with N<sub>2</sub>, CO<sub>2</sub> or another by product of the fermentation process.

### **33. Comment on aerobic fermentation**

Aerobic fermentation is metabolic process by which cells metabolize sugars via fermentation in the presence of oxygen and occurs through the repression of normal respiratory metabolism.

### **34. Short notes on different type of sterilization method.**

1. Wet heat (Autoclaving)
2. Dry heat (flaming, baking)
3. Filtration
4. Solvents
5. Radiation

1. Wet heat: Using pressurised steam to heat the material to be sterilised.

Autoclaving kills microbes by hydrolysis and coagulation of cellular proteins.

2. Dry heat: Dry heating has one crucial difference from autoclaving
3. Filtration: Filtration is a great way of quickly sterilizing solutions without heating. By passing the solution through a filter with a pore diameter that is too small for microbes to pass through.
4. Solvents: Ethanol is commonly used as a disinfectant.
5. Radiation: UV, X-ray and gamma rays are all types of electromagnetic radiation that have profoundly damaging effects on DNA. So make excellent tools for sterilization.

**35. Comment on pH and biomass reduction in fermentation technology**

pH control is achieved by acid or alkali addition, which is controlled by an auto titration. Autotitration in turn is connected to the pH probe. Let us consider yeast like a biomass inactive dried primary food yeast in powdered form is used directly as a dietary supplements.

**36.Name any two significant milestones in the history of biotechnology?**

Alexander Fleming (1881-1955) British bacteriologist observed that on a plate culture of bacteria which had become contaminated by a mould bacterial growth in the vicinity of the mould colony was inhibited.

Louis Pasteur investigated (1861) Butyric acid fermentation.

**37.What are the factors influencing success of fermentation?**

The yield per unit biomass is influenced by several factor which include the producing strain, medium composition (carbohydrate and nitrogen sources, cations, and etc.), fermentation conditions (pH, temperature, agitation and aeration) as well and mode of fermentation (batch, fed-batch and continuous fermentations).

**38. Write a list of products relating to Modern biotechnology?**

Some of the biotech- based health products include the biological drugs such as vaccines, antibodies, antibiotics, recombinant proteins (e.g. hormones, enzymes, growth factors, blood products, etc), diagnostic tests and kits, cell therapy products and gene therapy

**39. What you understand by downstream processing?**

Downstream processing refers to the recovery and purification of biosynthetic products, particularly pharmaceuticals, from natural sources such as animal or plant

tissue or fermentation broth, including the recycling of salvageable components and the proper treatment and disposal of waste.

**40. What is the use of cell disruption during downstream processing?**

Cell disruption is an essential part of biotechnology and the downstream processes related to the manufacturing of biological products. The disruption of cells is necessary for the extraction and retrieval of the desired products, as cell disruption significantly enhances the recovery of biological products.

**41. Write the name of following pictorial.**

**42. What are the advantages of STRs?**

Efficient gas transfer to growing cells  
Good mixing of the contents and flexible operating conditions.

**43. What is photobioreactor?**

The bioreactors specialised for fermentation that can be carried out either by exposing to sunlight or artificial illumination.

e.g: beta –carotene, astaxanthin.

**44. What are the modes of operation of conventional bioreactor?**

1. Sterilization
2. Inoculation and sampling
3. Aeration
4. Control systems
5. Cleaning

**45. Limitation of solid substrate (solid state) fermentation**

- The microorganisms that tolerate only low moisture content can be used.

- Precise monitoring of SSF (e.g O<sub>2</sub> and CO<sub>2</sub> level, moisture content) is not possible.
- The organisms grow slowly and consequently there is a limitation in product formation.
- Ethanol production creates problems, and it is very difficult to regulate the growth environment.

## PART –B

1. Explain in detail the traditional and modern biotechnology outlook with suitable examples. (Nov.Dec 2015, **Nov/Dec 2016**).

Ans: Text Book U.Satyanarayana , Pg No- 3-5and Research Article from Internet source.

2. Comment on Historical overview of Industrial Fermentation Process some few methods and their respective advantages and disadvantages. (May/Jun 2013, May/Jun 2011, April/May 2015).

Ans: Text Book U.Satyanarayana , Pg No- 4-5 and Research Article from internet source.

3. Write in detail about upstream and downstream processing for obtaining product of your interest through modern biotechnology. Present the above process in the form of flow chart/block diagram or pictorial representation. (May/Jun 2013, May/Jun 2011, April/May 2015, **Nov/Dec 2016, Nov/Dec 2017**).

Ans: Biotechnology by U.Satyanarayana Pg.No: UPS – 252-254 and DSP 270-271

4. Write in detail about downstream processing for obtaining product of your interest through modern biotechnology. Present the above process in the form of process flow chart/block diagram or pictorial representation. (May/Jun 2013, May/Jun 2012, April/May 2015, Nov/Dec2015, **Nov/Dec 2017**).

Ans: Biotechnology by U.Satyanarayana Pg.No: 270-280

5. What are the main utilities of Fermentor? Describe functions of main components of the fermentor.(May/Jun 2013, May/Jun 2011,

April/May2015).

Ans: Biotechnology by U.Satyanarayana Pg.No: 239-254: Text Book of Industrial Fermentation by Wulf crueger: Pg No: 64-107

6. What is the main role of microorganism in fermentation? Explain in detail the design and selection of a strain for the fermentation process. (May/Jun 2013, May/Jun 2011, April/May 2015).

Ans: Biotechnology by U.Satyanarayana Pg.No: 254-269: Text Book of Industrial Fermentation by Wulf crueger: Pg No:4-7, 9-20, 111

7. Comment on Process flow sheeting –Elaborate the block diagrams, draw a pictorial representation for any one product of your interest. (Nov.Dec 2015, **Nov/Dec 2016**)

Answer: Pg No: 67-72, K.G Ramawat & Shailey Goyal, Comprehensive Biotechnology

8. Write a detailed note on the Biochemistry of Fermentation by the microbes. . (Nov.Dec 2015) Answer: Pg No: 123-128, Dubey,R.C. Text Book of Biotechnology

9. Write short note on the different types of Batch fermentation & Fed Batch Fermentation Nov.Dec 2015

Answer: Pg No:675-679, Prescott & Dunn, Industrial Biotechnology

**Primary Metabolites- Production of commercially important primary metabolites like organic acids, amino acids, alcohols and vitamins.**

### **PART - A**

#### **1. What are metabolites?**

Metabolites – The cells have the ability to produce certain metabolic products when they are cultured in a specific nutrient medium. The metabolites are grouped into 2 categories: secondary & primary metabolites. The classification of which is mainly based upon the utility of the metabolites for the growth of the organism.

#### **2. What are Primary essential metabolites? Nov/Dec 2014, 2015,2016**

Primary metabolites are involved in growth, development, and reproduction of the organism. The primary metabolite is typically a key component in maintaining normal physiological processes; thus, it is often referred to as a central metabolite. Primary metabolites are typically formed during the growth phase as a result of energy metabolism, and are deemed essential for proper growth.

#### **3. Comment on the examples of Primary metabolites Nov/Dec 2014, Nov/Dec 2017**

It includes alcohols such as ethanol, lactic acid, and certain amino acids. Within the field of industrial microbiology, alcohol is one of the most common primary metabolites used for large- scale production. Specifically, alcohol is used for processes involving fermentation which produce products like beer and wine. Additionally, primary metabolites such as amino acids-- including L-glutamate and Llysine, which are commonly used as supplements-- are isolated via the mass

production of a specific bacterial species, *Corynebacteria glutamicum*. Another example of a primary metabolite commonly used in industrial microbiology includes citric acid. Citric acid, produced by *Aspergillus niger*, is one of the most widely used ingredients in food production.

#### **4. What is growth curve?**

Growth curve – a graphic representation of the growth of the bacteria (or population changes) in a culture medium. Exponential phase – period of culture growth when cells divide steadily at a constant rate. Also called as log phase / logarithmic phase. Stationary phase – the interval directly following a growth phase when the number of viable bacteria remains constant.

#### **5. Comment on the production of lactic acid.**

Lactic acid and its production by lactic acid bacteria have a long history in the food industry and microbial processes for lactic acid production were established early in the past century. However, the large-scale commercial production of the purified acid by microorganism relatively new. The production of the biodegradable plastic polylactide (used, for instance, in food containers) led to increased interest in optically pure lactic acid. This accounts for the recent shift from chemical to microbial production processes. The filamentous fungus *Rhizopus oryzae* is another natural producer that has the advantage of growing on mineral medium and carbon sources such as starch or xylose.

#### **6. How is ethanol produced commercially?**

Ethanol fermentation, also referred to as alcoholic fermentation, is a biological process in which sugars such as glucose, fructose, and sucrose are converted into cellular energy and thereby produce ethanol and carbon dioxide as metabolic waste products. Because yeasts perform this process in the absence of oxygen, ethanol

fermentation is classified as anaerobic. Ethanol fermentation occurs in the production of alcoholic beverages and ethanol fuel, and in the rising of bread dough.

**7. Write any two importance of production medium in antibiotic production by microorganisms. Nov/Dec 2014**

Antibiotic production employs a variety of media, a different one for each stage of operation. A typical medium has about 10% (w/v) solids. Generally, yields are much higher on complex media. In some cases, a suitable precursor for the antibiotic is also provided as in the case of penicillin G production, where phenylacetic acid or phenoxyacetic acid is used as precursor. As antibiotics are secondary metabolites, the production medium is so designed that a key nutrient becomes limiting at a critical stage to initiate the secondary metabolism in the organism (e.g., glucose for penicillin production and phosphate for several antibiotics produced by *Streptomyces*).

**8. Comment on Vitamin B12**

Vitamin B12 (cyanocobalamin) is a water soluble vitamin with complex structure. The empirical formula of cyanocobalamin is  $C_{63}H_{90}N_{14}O_{14}PCO$ . The structure of vitamin B12 consists of a corrin ring with a central cobalt atom. The corrin ring is almost similar to the tetrapyrrole ring structure found in other porphyrin compounds e.g. heme (with Fe) and chlorophyll (with Mg).

The corrin ring has four pyrrole units. Cobalt present at the centre of the corrin ring is bonded to the four pyrrole nitrogen's. Cobalt also binds to dimethylbenzimidazole and amino isopropanol. Thus, cobalt atom present in vitamin B12 is in a coordination state of six.

## **9. Write notes on genetically engineered strains for vitamin B12 production:**

By employing modern techniques of genetic engineering, vitamin B12 production can be enhanced. A protoplast fusion technique between *Protaminobacter ruber* and *Rhodospseudomonas spheroides* resulted in a hybrid strain called *Rhodospseudomonas protamicus*. This new strain can produce as high as 135 mg/l of vitamin B12 utilizing carbon source.

## **9. What are the factors affecting Beta carotene Production?**

Trisporic acid which can act as a microbial sexual hormone improves production yield of  $\beta$ - carotene.  $\beta$ -ionones enhance p-carotene synthesis by increasing the activity of enzymes, and not by their direct incorporation into  $\beta$ -carotene. When the fermentation medium is supplemented with purified kerosene,  $\beta$ -carotene production is almost doubled. Kerosene increases the solubility of hydrophobic substrates.

## **10. Comment on the Microbial Production of Gibberellins**

So far only one microorganism, the fungus namely *Gibberella fujikuroi* has been found to produce gibberellins. This is actually a pathogenic fungus of rice seedlings. Gibberellin production can be carried out by using a glucose-salt medium at pH 7.5 and temperature 25°C for 2-3 days. The fermentation process is conducted in aerated submerged process. After the growth of the fungus is maximum, the production of gibberellins commences.

## **11. Comment on the applications of Citric Acid**

1. Citric acid, due to its pleasant taste and palatability, is used as a flavoring agent

in foods and beverages e.g., jams, jellies, candies, desserts, frozen fruits, soft drinks, wine. Besides brightening the colour, citric acid acts as an antioxidant and preserves the flavors of foods.

2. It is used in the chemical industry as an antifoam agent, and for the treatment of textiles. In metal industry, pure metals are complexed with citrate and produced as metal citrates.

3. In pharmaceutical industry, as trisodium citrate, it is used as a blood preservative. Citric acid is also used for preservation of ointments and cosmetic preparations. As iron citrate, it serve as a good source of iron.

4. Citric acid can be utilized as an agent for stabilization of fats, oils or ascorbic acid. It forms a complex with metal ions (iron, copper) and prevents metal catalysed reactions. Citric acid is also used as a stabilizer of emulsions in the preparation of cheese.

5. In detergent/cleaning industry, citric acid has slowly replaced polyphosphates.

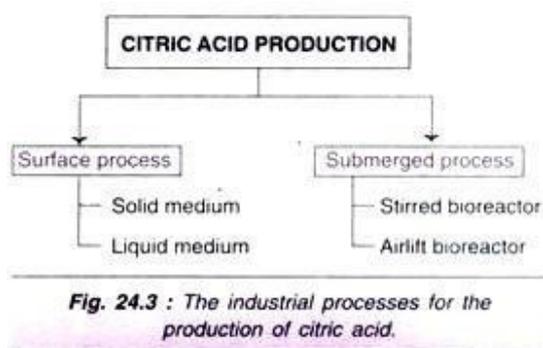
### **13. Write note on Microbial Strains for Citric Acid Production**

Many microorganisms can produce citric acid. The fungus *Aspergillus Niger* is most commonly used for industrial production of citric acid. The other organisms (although less important) include *A. clavatus*, *A. wentii*, *Penicillium luteum*, *Candida catenula*, *C. guilliermondii* and *Corynebacterium sp.* For improved industrial production of citric acid, mutant strains of *A. Niger* have been developed. The strains that can tolerate high sugar concentration and low pH with reduced synthesis of undesirable byproducts (oxalic acid, isocitric acid and

gluconic acid) are industrially important.

### Comment on the Production Processes for Citric Acid:

There are two processes by which citric acid can be industrially produced — the surface process and submerged process (Fig. 24.3).



### 14. Write a note on the Production of Citric Acid from Alkanes:

Both yeasts and bacteria can be used for citric acid production from n-alkanes (C<sub>9</sub>- C<sub>23</sub> hydrocarbons). The citric acid yield is better from hydrocarbons compared to sugars

i.e. 145% of citric acid from paraffin. The most commonly used organism is *Candida lipolytica*. The fermentation can be carried out in batch, semi-continuous or continuous modes. The pH should be kept above 5. The major limitations of citric acid production from alkanes are—very low solubility of alkanes and increased production of unwanted isocitric acid.

### **15. Write note on applications of Gluconic acids**

1. Gluconic acid is used in the manufacture of metals, stainless steel and leather, as it can remove the calcareous and rust deposits.
2. It is used as an additive to foods and beverages.
3. Gluconic acid has pharmaceutical applications — calcium and iron therapy.
4. Sodium gluconate is used as a sequestering agent in many detergents.
5. Gluconate is used for desizing polyester or polyamide fabrics.
6. It is utilized in the manufacture of highly resistant (to frost and cracking) concrete.

### **17. Comment on Microorganisms used for producing Acetic acid**

The commercial production of acetic acid is carried out by a special group of acetic acid bacteria, which are divided into two genera. *Gluconobacter* that oxidizes ethanol exclusively to acetic acid. *Acetobacter* that oxidizes ethanol first to acetic acid, and then to CO<sub>2</sub> and H<sub>2</sub>O. These over-oxidizers are Gram-negative and acid tolerant e.g. *A. aceti*, *A. peroxidans*, *A. pasteurianus*.

### **18. Comment on L-Ascorbic Acid and its applications (NOV/DEC)-2015**

L-Ascorbic acid is the commonly used chemical name for the water soluble vitamin C. This vitamin forms a redox system and participates in several biological processes. It is intimately involved in the biosynthesis of collagen, the most abundant protein in the human body. Vitamin C also protects the body against

carcinogenic nitrosamines and free radicals. The deficiency of ascorbic acid causes scurvy.

### ***Applications of Ascorbic Acid:***

Because of the wide range of physiological and beneficial functions of ascorbic acid, its commercial production assumes significance. Vitamin C is mainly used in food and pharmaceutical industries.

### **19. Write note on two-step fermentation process of L-Ascorbic acid (NOV/DEC)-2015**

In this, D-glucose is converted to 2, 5-diketogluconic acid by *Erwinia*, *Acetobacter* or *Gluconobacter* sp. In the second step, *Corynebacterium* sp converts 2, 5-diketogluconic acid to 2- keto-L-gluconic acid, (Fig. 24.10A). It is also possible to involve *Bacillus megaterium* for converting L-sorbose to 2-keto-L-gluconic acids. The latter, by chemical reactions, can be converted to ascorbic acid.

### **20. Write note on production process of Acetic acid**

For every molecule of ethanol oxidised, one molecule of acetic acid is produced. Thus, high- yielding strains can produce 11-12% acetic acid from 12% alcohol. For optimal production, adequate supply of oxygen is very essential. Insufficient O<sub>2</sub>, coupled with high concentration of alcohol and acetic acid result in the death of microorganisms. Surface fermentation or submerged fermentation processes can be carried out to produce acetic acid. Trickling generation process, a type of surface fermentation, is very commonly used.

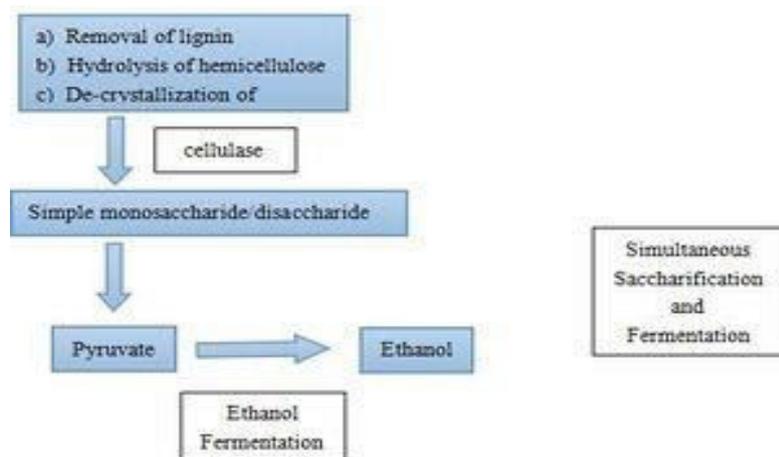
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### **21. Comment on *Saccharomyces cerevisiae* and ethanol production**

S *accharomyces cerevisiae* is an unicellular yeast, capable of utilizing

glucose but not xylose as energy source because it lacks xylose reductase(XR) and xylitol dehydrogenase(XDH). Since xylose is derived from lignocellulose, not being able to ferment xylose is energetically and economically inefficient.

## 21. Comment on microbial biofuel production via ethanol fermentation



## 22. Comment on Beer production

Beer is the most consumed alcoholic beverage in the world. It is made most often of malted barley and malted wheat. Sometimes a mixture of starch sources can be used, such as rice. Unmalted maize can be added to the barley or wheat to lower cost. Potatoes, millet and other foods high in starch are used in different places in the world. Amino acids can be produced by microorganisms by utilizing several carbon sources e.g. **glucose**, **fructose**, alkanes, **ethanol**, glycerol, propionate. Certain industrial byproducts like molasses and starch hydrolysate can also be used.

## 25. Write notes on Wine production

Wine is made from grapes or other fruit. The grapes are first cleaned of leaves and stems and the fruit is crushed into must that is ready for fermentation. The yeasts used for the fermentation grow a film on the fruit or in the environment. These wild

strains play an important role in the final properties of the drink. However, cultivated strains of *Saccharomyces cerevisiae* are often added to improve the consistency of the final product. There are hundreds of commercially available yeast strains for wine fermentation.

**26. What are some of the uses of Ethanol? Nov/**

**Dec 2016 Drinks:** The "alcohol" in alcoholic drinks is simply ethanol.

**Industrial methylated spirits (meths):** Ethanol is usually sold as industrial methylated spirits which is ethanol with a small quantity of methanol added and possibly some colour.

**As a fuel:** Ethanol burns to give carbon dioxide and water and can be used as a fuel in its own right, or in mixtures with petrol (gasoline). "Gasohol" is a petrol / ethanol mixture containing about 10 - 20% ethanol.

**As a solvent:** Ethanol is widely used as a solvent. It is relatively safe, and can be used to dissolve many organic compounds which are insoluble in water. It is used, for example, in many perfumes and cosmetics.

**27. Write the three approaches of AA large scale production**

For the large- scale production of amino acids, microbiological methods are employed. There are three different approaches.

1. Direct fermentation methods:
2. Conversion of metabolic intermediates into amino acids:
3. Direct use of microbial enzymes or immobilized cells:

## **28. What is meant by Auxotrophic Mutation?**

These mutants are characterized by a lack of the formation of regulatory end product (i.e. repressor or regulatory effector). The intermediates of the metabolic pathways accumulate and get excreted.

## **29. Write the major molecular ways of strain development for AA**

The following are the major ways of strain development. In fact, several methods are combined to successfully develop a new strain for producing amino acids.

**Auxotrophic mutation**

**Genetic recombination**

**Recombinant DNA technology**

## **30. Write note on genetically engineered strains for vitamin B12 production**

By employing modern techniques of genetic engineering, vitamin B12 production can be enhanced. A protoplast fusion technique between *Protaminobacter ruber* and *Rhodospseudomonas spheroides* resulted in a hybrid strain called *Rhodospseudomonas protamicus*. This new strain can produce as high as 135 mg/l of vitamin B12 utilizing carbon source.

## PART B

1. Comment on the commercial importance or uses of amino acids (Nov/Dec 2016).
2. Explain primary metabolite production and the steps involved in the production process of any one or two amino acids. Comment on the commercial uses of amino acids (May/Jun 2013, May/Jun 2011, April/May 2015,).

Ans: Biotechnology by U.Satyanarayana Pg.No:344-361: Text Book of Industrial Fermentation by Wulf crueger Pg.No: 150-169

3. Elaborate the steps involved in the production process of any one commercially important alcohol and any one vitamin.(May/Jun 2013, May/Jun 2011, April/May 2015).

Ans: Biotechnology by U.Satyanarayana Pg.No:311-316, 355-361: Text Book of Industrial Fermentation by Wulf crueger Pg.No:124-131, 219-226.

4. How will you increase the production of riboflavin? Explain with neat process Flow sheet. (May/Jun 2013, May/Jun 2011, April/May 2015).

Ans: Biotechnology by U.Satyanarayana Pg.No:357-358.

5. Elaborate the steps involved in the production process of any one commercially important alcohol. Ans: Biotechnology by U.Satyanarayana Pg.No:357-358311-312.

6. Elaborate the steps involved in the production process of any one

commercially important Acetic Acid (**Nov/Dec 2016**)

Ans: Biotechnology by U.Satyanarayana Pg.No:344-354: Text Book of Industrial Fermentation by Wulf crueger Pg.No:15-169

7. Explain the commercial importance and production process of any one organic acid (citric acid by submerged fermentation). (May/Jun 2013, May/Jun 2011, April/May 2015, **Nov/Dec 2016, Nov/Dec 2017**).

Ans: Biotechnology by U.Satyanarayana Pg.No: 318-324: Text Book of Industrial Fermentation by Wulf crueger Pg.No: 134-148

8. Write a brief account on the Primary Metabolites and Primary Essential Metabolites and draw a graph explaining the different phases of growth

Ans: Biotechnology by U.Satyanarayana

9. Write a detailed overview of Microbial Overproduction of Vitamins and the strain improvement process **Nov/Dec 2017**

Ans: Biotechnology by U.Satyanarayana

**Secondary Metabolites- Production processes for various classes of secondary metabolites: Antibiotics and Steroids.****PART A****1. Write notes on Antibiotics and the screening Process**

Useful antibiotics are often discovered using a screening process. To conduct such a screen, isolates of many different microorganisms are cultured and then tested for production of diffusible products that inhibit the growth of test organisms. Most antibiotics identified in such a screen are already known and must therefore be disregarded. The remainder must be tested for their selective toxicities and therapeutic activities, and the best candidates can be examined and possibly modified.

A more modern version of this approach is a rational design program. This involves screening directed towards finding new natural products that inhibit a specific target, such as an enzyme only found in the target pathogen, rather than tests to show general inhibition of a culture.

**2. Define Secondary Metabolites & its Characteristics Nov/Dec 2014, 15,16**

Secondary metabolites are typically organic compounds produced through the modification of primary metabolite synthases. Secondary metabolites do not play a role in growth, development, and reproduction like primary metabolites do, and are typically formed during the end or near the stationary phase of growth. Examples of secondary metabolites with importance in industrial microbiology include atropine and antibiotics such as erythromycin and bacitracin.

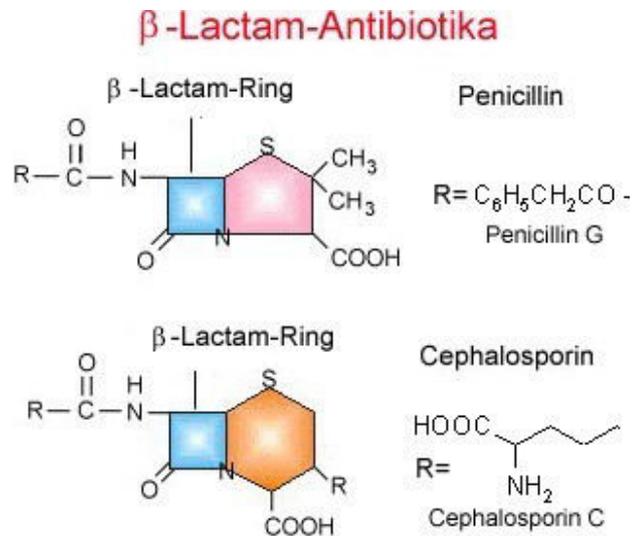
**3. Write any two importance of production medium in antibiotic production by microorganisms. Nov/Dec 2014,15**

Antibiotic production employs a variety of media, a different one for each stage of operation. A typical medium has about 10% (w/v) solids. Generally, yields are much higher on complex media. In some cases, a suitable precursor for the antibiotic is also provided as in the case of penicillin G production, where phenylacetic acid or phenoxyacetic acid is used as precursor. As antibiotics are secondary metabolites, the production medium is so designed that a key nutrient becomes limiting at a critical stage to initiate the secondary metabolism in the organism (e.g., glucose for penicillin production and phosphate for several antibiotics produced by *Streptomyces*).

**4. Write the importance of precursors in secondary metabolite production.**

Inducer induces the production of a secondary metabolite, for eg., the presence of starch induce the production of Amylase enzyme, because during lag phase the limiting reactant like glucose level will be low, it is necessary for bacteria to survive so it will release amylase enzyme to break starch and yield glucose from that, thus the presence of Starch only induce the amylase enzyme which is the secondary metabolite.. Similarly precursors are used for the production of a particular metabolite, eg., for Penicillin G production phenylethylamine is needed , which only incorporated into the penicillin to yield Penicillin G, corn steep liquor contains phenylethylamine which is acting as a precursor for Penicillin G production.

**5. Draw the structures of  $\beta$ -lactam ring. Nov/Dec 2014,15**



**6. Are enzymes secondary metabolites? Give two examples of polysaccharide degrading enzymes.**

Enzymes belong to primary metabolite because they are directly involved in normal growth, development and reproduction. In other words, an organism would die without enzymes.

Two polysaccharide degrading enzymes include alginate lyase and cellulase.

**7. Differentiate between sterols and steroids. Nov/dec 2014,15**

Sterols are an important class of organic molecules. They occur naturally in plants, animals and fungi, with the most familiar type of animal sterol being cholesterol. Cholesterol is vital to cellular function, and a precursor to fat-soluble vitamins and steroid hormones.

A steroid is a terpenoid lipid characterized by its sterane core and additional functional groups. The core is a carbon structure of four fused rings: three cyclohexane rings and one cyclopentane ring. The steroids vary by the functional groups attached to these rings and the oxidation state of the rings.

## **8. What are aminoglycoside antibiotics? Nov/Dec 2014, 2015**

Aminoglycoside antibiotics – a class of antibiotics, which disrupt the normal synthetic sequence of protein synthesis. Aminoglycosides have several potential antibiotic mechanisms, some as protein synthesis inhibitors, although their exact mechanism of action is not fully known:

They interfere with the proofreading process, causing increased rate of error in synthesis with premature termination. Also, there is evidence of inhibition of ribosomal translocation where the peptidyltRNA moves from the A-site to the P-site. They can also disrupt the integrity of bacterial cell membrane.

## **9. What are the different types of penicillin?**

There are 4 classes of penicillins, based upon their ability to kill various types of bacteria. From narrow to broad range of effectiveness they include:

**Natural Penicillins** (Penicillin G, Procaine, Penicillin G, Penicillin V, ≡ Benzathine).

**Penicillinase-Resistant Penicillins** (Cloxacillin, Dicloxacillin, Methicillin, ≡ Nafcillin, Oxacillin).

**Aminopenicillins (Ampicillin, Amoxicillin, Bacampicillin).**

The aminopenicillins were the first penicillins discovered to be active against gram-negative bacteria (such as *E. coli* and *H. influenzae*).

**Extended Spectrum Penicillins** (sometimes called anti-pseudomonal ≡ penicillins).

## **10. Give the uses of Antibiotics. Nov/Dec 2014, 2015**

**Cell wall synthesis inhibitors** usually stop bacteria from forming their cell walls. They kill bacteria and not human cells because human cells do not form cell walls. Examples of cell wall synthesis inhibitors are beta lactams, semisynthetic penicillins, and bacitracin.

**Cell membrane inhibitors** kill bacterial cells by disorganizing the outer membranes of bacteria. An example of a cell membrane inhibitor is polymyxin.

**Protein synthesis inhibitors** interfere with the process of translation in protein synthesis. Their action is usually on the ribosomes. Examples of protein synthesis inhibitors are tetracyclines, chloramphenicol, macrolides, and aminoglycosides.

**Chemotherapeutic agents** affecting the synthesis of nucleic acids block the division and growth of cells by inhibiting synthesis of DNA and RNA. Most of these agents affect both animal and bacteria cells, so they cannot be used as an antibiotic. However, nalidixic acid and rifamycins are selectively active towards bacteria. **Competitive inhibitors** are mostly synthetic. These drugs work by disrupting the metabolic rate of bacteria. Some examples include sulfonamides, isoniazid, para aminosalicylic acid, and ethambutol

#### **11. Comment on Biotransformation in steroids Nov/Dec 2014, 2015, Nov/Dec 2017**

Biotransformation (regiospecific and stereospecific bioconversion) is a biological process whereby an organic compound is modified into reversible product. It involves simple, chemically defined reactions catalyzed by enzymes present in the cell.

#### **Microbial transformation**

- When the transformation of the organic compounds is carried out by microorganism then the process is called as microbial transformation.

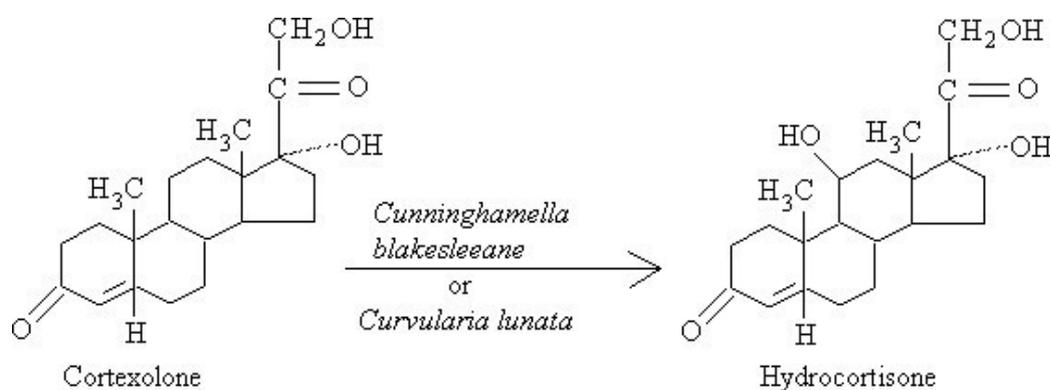
#### **12. Write note on Hydroxylation Nov/Dec 2014, 2015**

- Hydroxylation involves the substitution of hydroxyl group directly for the

hydrogen at the position, in the steroid with a retention of configuration.

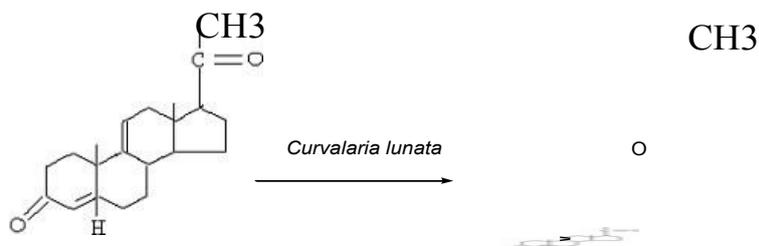
The oxygen atom in the hydroxyl group is derived from molecular oxygen (gaseous), not from water, and the hydroxyl group thus formed always retains the stereochemical configuration of the hydrogen atom that has been replaced.

Example: Certain microorganisms can introduce hydroxyl groups at any of several of the carbon atoms of the steroid molecule.



### 13. Write note on Epoxydation

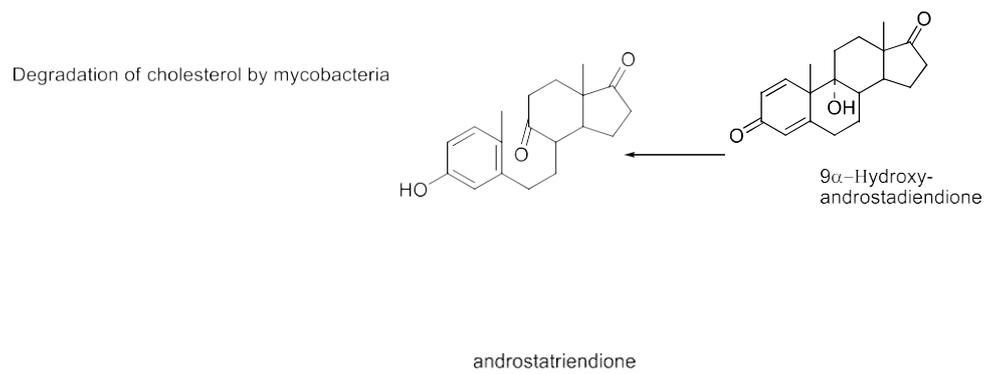
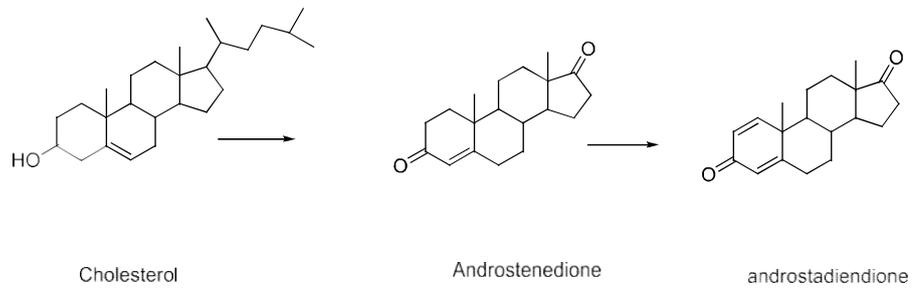
The epoxidation of steroidal double bonds is a rare example of biological epoxidation. The 9,11-epoxidation of 9(11)-dehydro-compounds, and the 14, 15-epoxidation of 14(15)- dehydrocompounds, using *Curvularia lunata*.



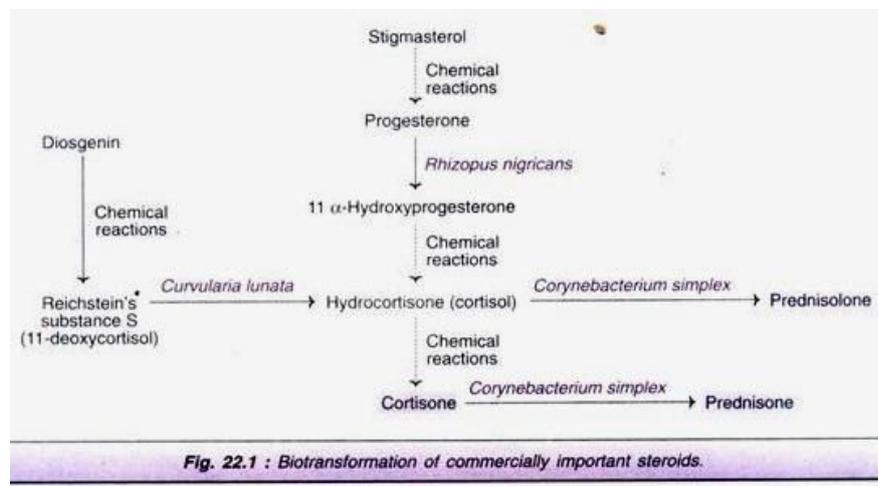
#### 14. Comment on Fermentation condition of steroids

<b>M/O</b>	<b>Steroid substrate</b>	<b>Steroid product</b>	<b>Length of incubation , tempera aeration</b>
<i>Alcaligenes faecalis</i>	<b>Cholic acid</b>	<b>Ketocholic acids (90-100%)</b>	<b>2 days (monoketo acid) 4 days (diketo acid) 6 days (triketo acid) 37-39 ,surface culture</b>
<i>Fusarium solani</i>	<b>Progesterone</b>	<b>1,4-androstadiene-3, 17-dione(85%)</b>	<b>4 days , 25 C , rotary shaker (1</b>
<i>Corynebacterium mediolanum</i>	<b>21-acetoxy - 3 β-hydroxy - 5-pregnen-20-one</b>	<b>21-hydroxy-4-pregnene-3, 20-dione (30%)</b>	<b>6 days , 36-37 C , pure oxygen agitation</b>  ↓

## 15. Comment on steroid degradation



## 16. Write the flow sheet for Biotransformation of Steroids



## 17. Comment on the Industrial production of Antibiotics

Antibiotics are produced industrially by a process of fermentation, where the source microorganism is grown in large containers (100,000–150,000 liters or more) containing a liquid growth medium. Oxygen concentration, temperature, pH and nutrient levels must be optimal, and are closely monitored and adjusted if necessary. As antibiotics are secondary metabolites, the population size must be controlled very carefully to ensure that maximum yield is obtained before the cells die. Once the process is complete, the antibiotic must be extracted and purified to a crystalline product. This is easier to achieve if the antibiotic is soluble in organic solvent. Otherwise it must first be removed by ion exchange, adsorption or chemical precipitation.

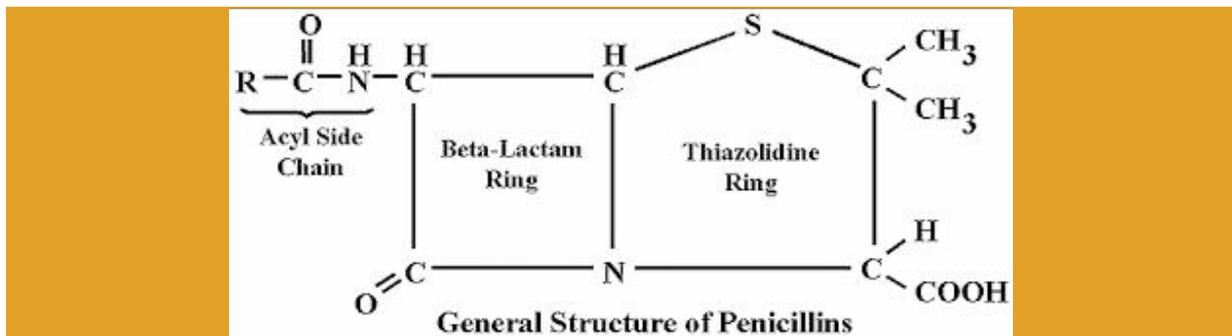
## 18. Write note on strains used for microbial production

Microorganisms used in fermentation are rarely identical to the wild type. This is because species are often genetically modified to yield the maximum amounts of antibiotics. Mutation is often used, and is encouraged by introducing mutagens such as ultraviolet radiation, x-rays or certain chemicals. Selection and

further reproduction of the higher yielding strains over many generations can raise yields by 20-fold or more. Another technique used to increase yields is gene amplification, where copies of genes coding for enzymes involved in the antibiotic production can be inserted back into a cell, via vectors such as plasmids. This process must be closely linked with retesting of antibiotic production.

### 19. Note on the structure of Penicillin

Penicillin was the first naturally occurring antibiotic discovered. It is obtained in a number of forms from *Penicillium* moulds. Penicillin is not a single compound but a group of closely related compounds, all with the same basic ring-like structure (a  $\beta$ -lactam) derived from two amino acids (valine and cysteine) via a tripeptide intermediate. The third amino acid of this tripeptide is replaced by an acyl group (R) and the nature of this acyl group produces specific properties on different types of penicillin.



## 20. What are the types of Penicillin?

**There are two different type of penicillin**

**Biosynthetic penicillin is natural penicillin that is harvested from the mould itself**

**Through fermetation**

There are two different types of penicillin.

**B** *biosynthetic penicillin* is natural penicillin that is harvested from the mould itself through

fermentation.

**S** *semi-synthetic penicillin* includes semi synthetic derivatives of penicillin - like

**A** mpicillin,

Penicillin V, Carbenicillin, Oxacillin, Methicillin, etc.

**T** hese compounds consist of the basic Penicillin structure, but have been purposefully modified

**c** hemically by removing the acyl group to leave 6-aminopenicillanic acid and then adding a acyl

groups that produce new properties.

These modern semi-synthetic penicillins have various specific properties such as resistance to stomach acids so that they can be taken orally, a degree of resistance to penicillinase (or  $\beta$ - lactamase) (a penicillin-destroying enzyme produced by some bacteria) and an extended range of activity against some Gram-negative bacteria. Penicillin G is the most widely used form and the

same one we get in a hypodermic

## 21. Penicillin Upstream process-Comment

**PENICILLIN:**

**1. Up stream process**

❖ Inoculum development: micro organism-*P.chrysogenum*

Strain development: *P.chrysogenum* NRRL 1951

planting & selection ↓

NRRL 1951 B.25

x-ray, uv, mutagen ↓

commercial strain



St Paul's college of pharmacy

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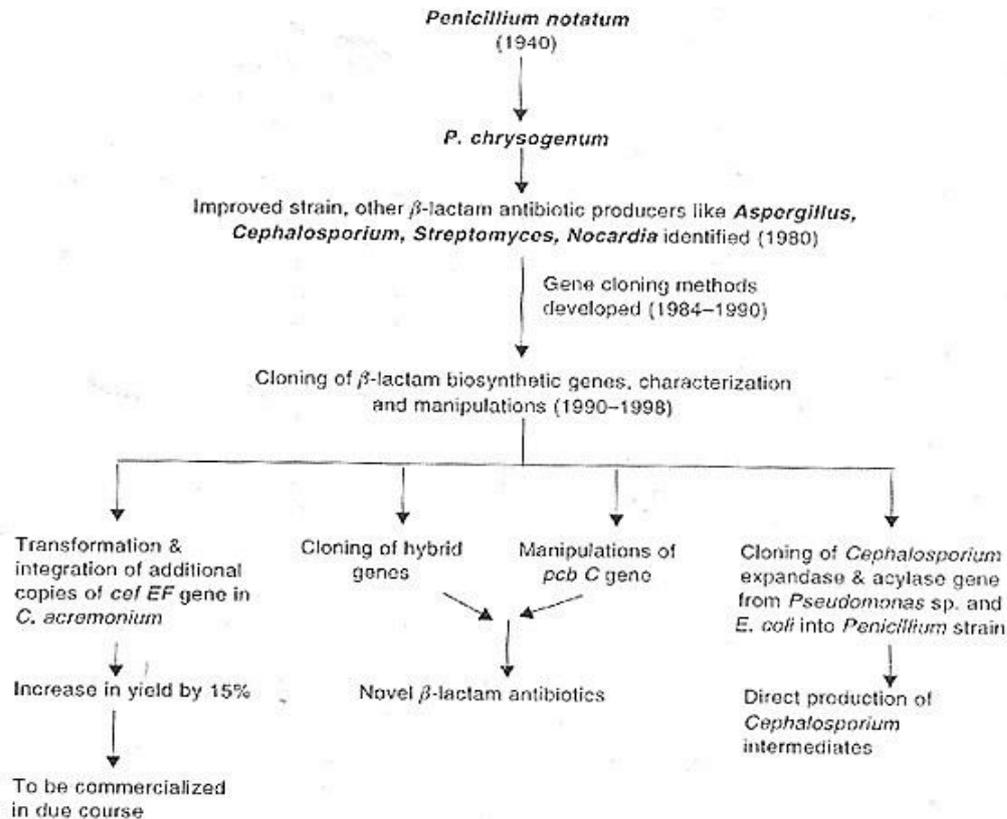
**22. List any four common antibiotics produced by industrial fermentation Nov/Dec 2017**

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<b>Cephalosporin</b>	<i>Cephalosporium acrimonium</i>
<b>Chloramphenicol</b>	<i>Streptomyces venezuelae</i>
<b>Erythromycin</b>	<i>Streptomyces erythreus</i>
<b>Griseofulvin</b>	<i>Penicillium griseofulvin</i>
<b>Penicillin</b>	<i>Penicillium chrysogenum</i>
<b>Streptomycin</b>	<i>Streptomyces griseus</i>
<b>Tetracycline</b>	<i>Streptomyces aureofaciens</i>
<b>Gentamicin</b>	<i>Micromonospora purpurea</i>

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**23. Manipulation of Genes for Penicillium Notatum Nov /Dec 2013**



## 24. Comment on SSf for Cephalosporin

Solid state fermentation systems were developed for the production of cephalosporins with *Streptomyces clavuligerus* and *Cephalosporium acremonium*.

*S. clavuligerus* NRRL 3585 was grown on moistened barley under optimum solid state fermentation conditions for 7 days; approximately 300 micrograms cephalosporins per g substrate were extracted from the kernels.

*C. acremonium* C-10 produced approximately 950 micrograms cephalosporin C per g substrate after 10 days of solid state fermentation.

## 25. Comment on production of Cephalosporin by *Acremonium* Nov /Dec 2013

Production of cephalosporin C employing *Acremoniumchrysogenum* ATCC 48272 under solid state fermentation was optimized. Different substrates like wheat bran, wheat rawa, bombay rawa, barley and rice bran were studied to optimize the best substrate. Wheat rawa showed the highest antibiotic yield. Physical and chemical parameters were optimized. The maximum productivity of cephalosporin C (22 281 µg/g) was achieved by employing wheat rawa and with optimized process parameters including 1% w/w soluble starch and 1% w/w yeast extract as additives, incubation period of 5 days, incubation temperature at 30 °C, 1.5:10 (v/w) ratio of salt solution to weight of wheat bran, inoculum level 10% v/w, moisture content of solid substrate 80% and pH 6.5.

## 26. Give the main classes of antibiotics? Nov /Dec 2016

The main classes of antibiotics are:

- (a) Beta-Lactams. Penicillins. Cephalosporins.
- (b) Macrolides.
- (c) Fluoroquinolones.
- (d) Tetracyclines.
- (e) Aminoglycosides.

## 27. Are beta lactams bacteriostatic or bactericidal?

Bactericidal antibiotics kill bacteria; bacteriostatic antibiotics slow their growth or reproduction. Antibiotics that inhibit **cell wall synthesis**: the Beta-lactam antibiotics (**penicillin derivatives (penams)**, **cephalosporins (cephems)**, **monobactams, & carbapenems**) and **vancomycin**.

### **28. Write note on new steroid production.**

New steroid fermentation processes that produce a variety of intermediates from sterols such as cholesterol and phytosterols have recently been developed. Especially, two fermentation processes for producing intermediates ADD and 4 AD, respectively, have been put into practice for the production of sex hormones and a diuretic drug, spironolactone.

### **29. Comment on Steroid Uses**

Steroids of plant origin can be transformed into steroids like those of animal origin. This transformation is done by using the fungus *Rhizopus stotonifer* through the process of hydroxylation and dehydrogenation. Such steroids can then be used for man and other animals

Such steroids are used

1. As anti-inflammatory drugs.
2. As anti-cancer drugs.
3. For developing immunity against asthma.
4. For organ transplantation.
5. For family planning.

### **30. Comment on the types of reaction in the Biotransformation of Steroids**

The microbial transformation of steroids broadly involves oxidation (introduction of hydroxyl groups, splitting of side chains, production of epoxides etc.) reduction (conversion of aldehydes or ketones to alcohols, hydration of double bonds), hydrolysis and ester formation.

## PART B

1. Explain the upstream and downstream processing of penicillin (Antibiotics) with the help of a flow sheet.(May/Jun 2013, May/Jun 2011, April/May 2015, **Nov/Dec 2016**).

Ans: Biotechnology by U.Satyanarayana Pg.No:332-334

2. Explain the upstream and downstream processing of streptomycin with the help of a flow sheet.

Ans: Biotechnology by U.Satyanarayana Pg.No:336-337

3. Write a detailed flow sheet with significance in the commercial production process of any one or two steroids from plant sources (**Nov/Dec 2016**).

Ans: Biotechnology by U.Satyanarayana Pg.No:306-310; Text Book of Industrial Fermentation by Wulf crueger Pg.No: 286-301

4. Write note on  $\beta$ -lactam antibiotics. Describe the fermentation of  $\beta$ -lactam antibiotics along with the bioparameters to be controlled.

Ans: Biotechnology by U.Satyanarayana Pg.No:329-335

5. Describe Secondary metabolites & its classes and compare the same with primary metabolites. **Nov/Dec 2017**

Ans: Biotechnology by U.Satyanarayana Pg.No:255-257;All classes of Sec.Metabolites mentioned above.

6. Describe genetic manipulationsof streptomycesalong with good antibiotic manufacturing practices?

Ans: Biotechnology by U.Satyanarayana Pg.No:34

## **PART C**

1. Discuss about the various secondary metabolites which are commercially produced for human use and also compare the primary and secondary metabolites. **Nov/Dec 2017** Ans: Biotechnology by U.Satyanarayana Pg.No:255-257;
2. Explain the Antibiotics production process with an example and discuss its advantages .  
**Nov/Dec 2017**  
Ans: Biotechnology by U.Satyanarayana Pg.No:336-337
3. Describe the importance of the production of biotransformed Steroid production.  
Ans: Biotechnology by U.Satyanarayana Pg.No:306-310; Text Book of Industrial Fermentation by Wulf crueger Pg.No: 286-301

## **UNIT IV PRODUCTION OF ENZYMES AND OTHER BIOPRODUCTS 9**

**Production of Industrial Enzymes, Biopesticides, Biofertilizers, Biopreservatives, Biopolymers, Biodiesel, Cheese, Beer, SCP & Mushroom culture. Bioremediation.**

### **PART A**

#### **1. Comment on the methods of Fermentation by Enzymes**

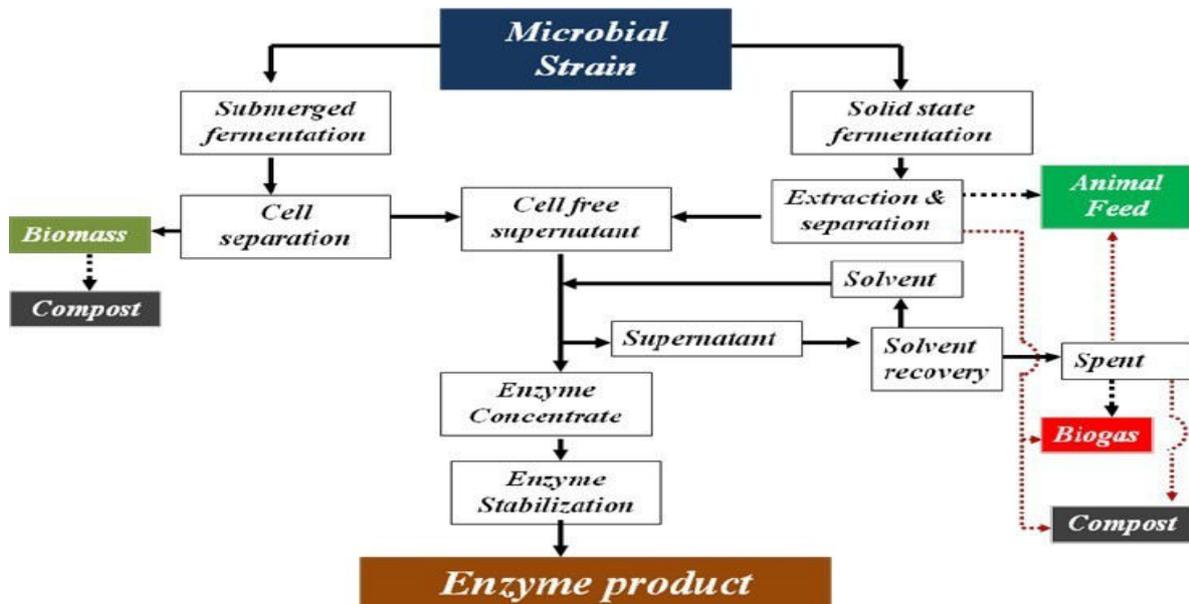
Mainly, there are two methods of fermentation which are used to produce enzymes. First is submerged fermentation and second is solid-state fermentation. In Submerged fermentation, the production of enzymes is done by microorganisms in a liquid nutrient media. Whereas in Solid- fermentation is carried out by cultivation of microorganisms and production of enzyme is done on a solid substrate. Compounds containing carbon in or on the substrate are busted down by the micro organisms thus producing the enzymes either extracellular or intracellular. The enzymes are isolated by various methods such as centrifugation, and for extracellular produced enzymes and lysing of cells for intracellular enzymes.

#### **2. What are the substrates used for enzyme production**

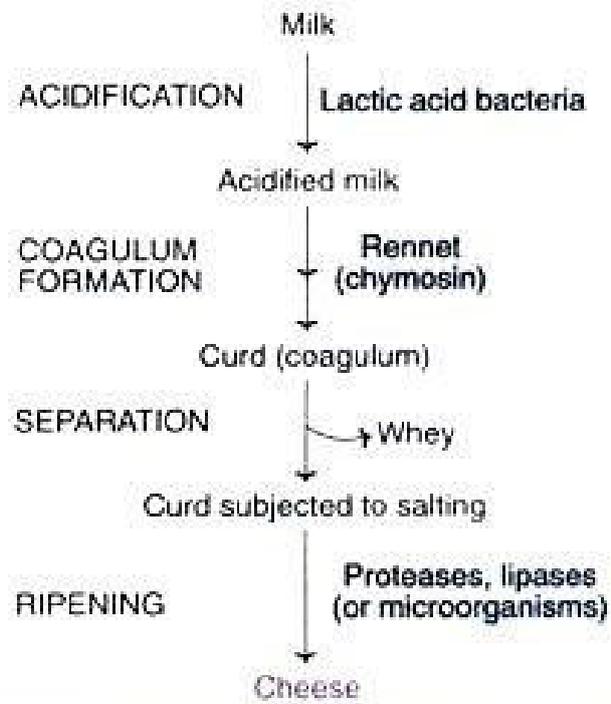
Agro-industrial residues are generally considered the best substrates for the SSF processes, and use of SSF for the production of enzymes is no exception to that. A number of such substrates have been employed for the cultivation of microorganisms to produce host of enzymes. Some of the substrates that have been used included sugar cane bagasse, wheat bran, rice bran, maize bran, gram bran,

wheat straw, rice straw, rice husk, soyhull, sago hampas, grapevine trimmings dust, saw dust, corncobs, coconut coir pith, banana waste, tea waste, cassava waste, palm oil mill waste, aspen pulp, sugar beet pulp, sweet sorghum pulp, apple pomace, peanut meal, rapeseed cake, coconut oil cake, mustard oil cake, cassava flour, wheat flour, corn flour, steamed rice, steam pre-treated willow, starch, etc. Wheat bran however holds the key, and has most commonly been used, in various processes.

### 3. Draw the process flow chart for enzyme production



4. Write the flow chart for Cheese production Nov /Dec 2014

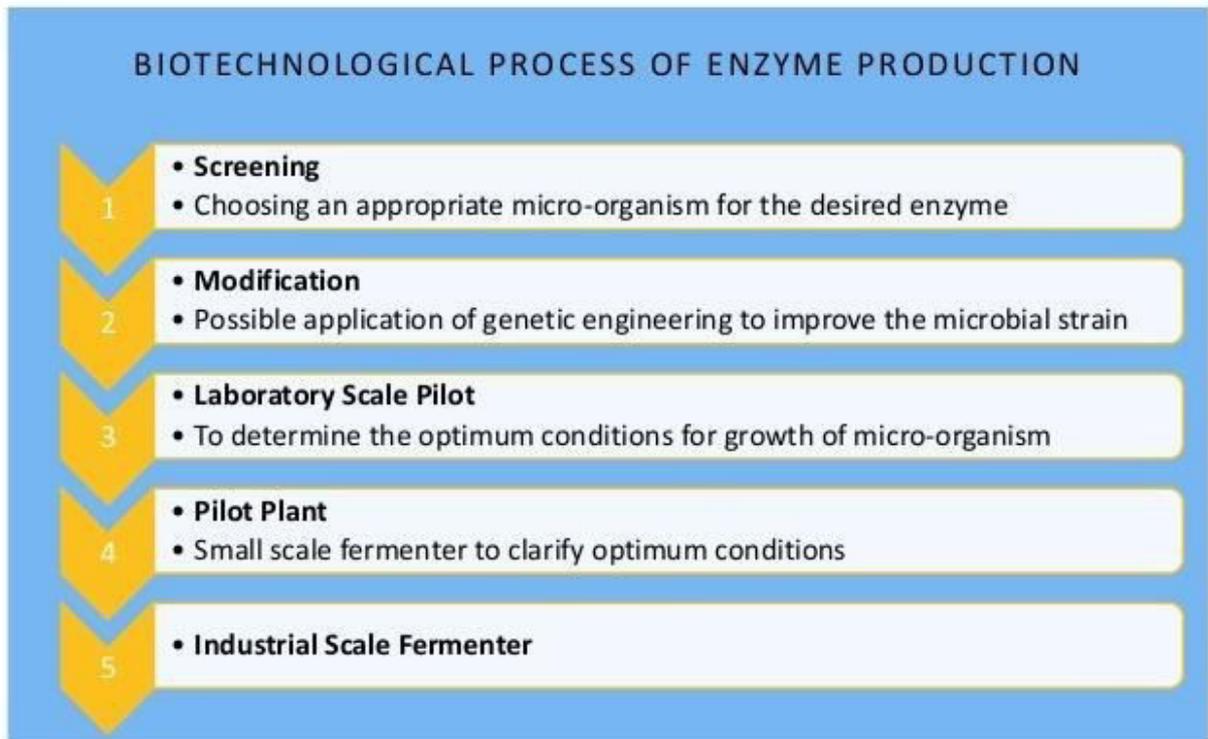


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**Fig. 28.2** : A diagrammatic representation of cheese production.

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## 5. Comment on process of Enzyme Production



## 6. Write note on Enzyme formulation?

## 7. Comment on Biopesticide categories

Biopesticides fall into three major classes: **Microbial** pesticides which consist of bacteria, **entomopathogenic fungi** or viruses (and sometimes includes the metabolites that bacteria or fungi produce). Entomopathogenic **nematodes** are also often classed as microbial pesticides, even though they are multi-cellular. Biochemical pesticides or herbal pesticides are naturally occurring substances that control (or monitor in the case of **pheromones**) pests and microbial diseases. Plant-incorporated protectants (PIPs) have genetic material from other species incorporated into their genetic material (*i.e.* **GM crops**). Their use is controversial, especially in many European countries. RNAi pesticides, some of which are topical and some of which are absorbed by the crop.

**Reason for Biopesticides:** Biopesticides have usually no known function in photosynthesis, growth or other basic aspects of plant physiology; however, their biological activity against insect pests, **nematodes**, fungi and other organisms is well documented. Every plant species has developed a built-in unique chemical complex structure that **protects it from pests.**

### **8. Write note on *Bacillus thuringiensis* Nov /Dec 2013**

*Bacillus thuringiensis*, a bacterial disease of Lepidoptera, Coleoptera and Diptera, is a well-known insecticide example. The toxin from *B. thuringiensis* (Bt toxin) has been incorporated directly into plants through the use of genetic engineering. The use of Bt Toxin is particularly controversial. Its manufacturers claim it has little effect on other organisms, and is more environmentally friendly than synthetic pesticides. However, at least one scientific study has suggested that it may lead to slight histopathological changes on the liver and kidneys of mammals with Bt toxin in their diet.

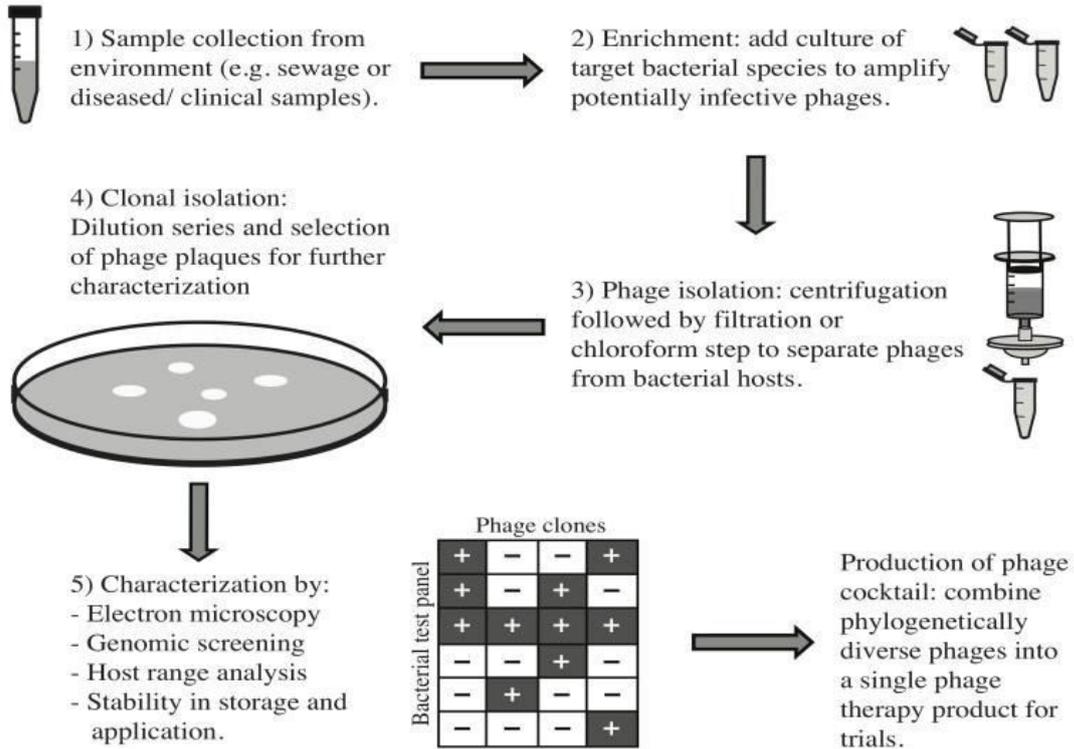
### **9. Write note on Microbial Insecticides**

Microbial insect control utilizes pathogenic microorganisms isolated from diseased insects during naturally occurring epidemics. Typically, such epidemics only occur when pest population densities are high and usually after appreciable damage have been done to crops. Over 400 species of fungi and more than 90 species of bacteria which infect insects have been described including *Bacillus thuringiensis*, varieties of which are manufactured and sold throughout the world primarily for the control of caterpillar pests and more recently mosquitoes and black flies.

Among fungal pesticides, five have been introduced since 1979, and three in 1981. Many countries with centrally planned economies have been using fungal pesticides successfully for many years. So far, more than 40,000 species of *Bacillus thuringiensis* have been isolated and identified as belonging to 39 serotypes. These organisms are active against either Lepidoptera, or Diptera or Coleoptera.

## 10. Comment on phage biopesticide production

### Typical production of phage biopesticide



## 11. What is Biopesticides?

### WHAT IS BIO-PESTICIDE?

- A compound that kills organisms by virtue of specific biological effects rather than as a broader chemical poison
- Differ from **biocontrol** agents in being passive agents, whereas biocontrol agents actively seek the pest
- The rationale behind replacing conventional **pesticides** with bio-pesticides is that the latter are more likely to be **selective** and **biodegradable** (FAO, 2005)



### WHY BIO-PESTICIDES?

- **Human and environmental safety**
- **Alternatives to conventional pesticides:**
  - 25 million cases of acute occupational pesticide poisoning in developing countries each year (WHO, 1990)
  - 14% of all known occupational injuries and 10% of all fatal injuries are caused by pesticides (ILO, 1996)
  - Obsolete pesticides stored in developing countries - 20,000 tonnes in Africa alone
- **Amenable to small-scale, local production in developing countries**
- **Address increased public awareness of environmental and food safety**
- **Fundamental component of Integrated Pest Management**
  - Natural enemies protected
  - Controls pests resistant to conventional pesticides
- **Products available in small, niche markets that are typically unaddressed by large agrochemical companies**

## 12. Comment on Biofertilizers

A bio-fertilizer provides the following benefits:

1. Since a bio-fertilizer is technically living, it can **symbiotically** associate with plant roots. Involved microorganisms could readily and safely convert complex organic material into simple compounds, so that they are easily taken up by the plants. Microorganism function is in long duration, causing improvement of the soil fertility. It maintains the natural habitat of the soil. It increases crop yield by 20-30%, replaces chemical **nitrogen** and **phosphorus** by 25%, and stimulates plant growth. It can also provide protection against drought and some soil-borne diseases.
2. Bio-fertilizers are cost-effective relative to chemical fertilizers. They have lower manufacturing costs, especially regarding nitrogen and phosphorus use.

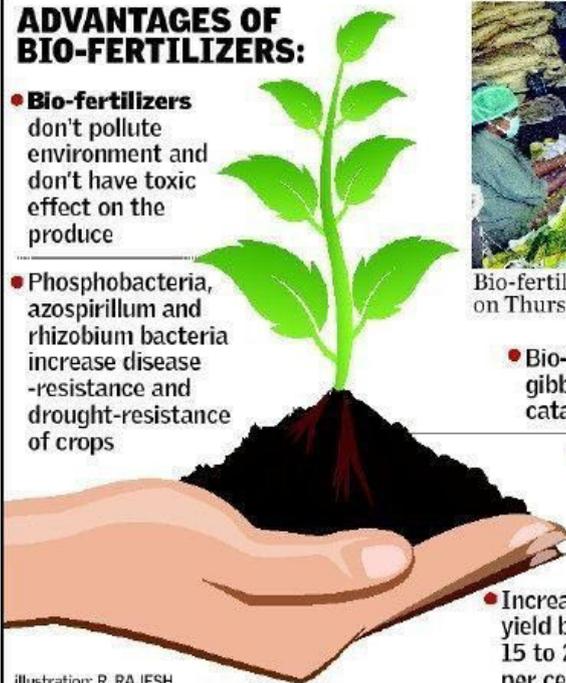
### 13. Comment on some of the important groups of Bio-fertilizers

1. **Azolla-Anabena symbiosis:** Azolla is a small, eukaryotic, aquatic fern having global distribution. Prokaryotic blue green algae Anabena azolla resides in its leaves as a symbiont. Azolla is an alternative nitrogen source. This association has gained wide interest because of its potential use as an alternative to chemical fertilizers.
2. **Rhizobium:** Symbiotic nitrogen fixation by Rhizobium with legumes contributes substantially to total nitrogen fixation. Rhizobium inoculation is a well-known agronomic practice to ensure adequate nitrogen.
- 3.

14.

**ADVANTAGES OF BIO-FERTILIZERS:**

- **Bio-fertilizers** don't pollute environment and don't have toxic effect on the produce
- Phosphobacteria, azospirillum and rhizobium bacteria increase disease -resistance and drought-resistance of crops

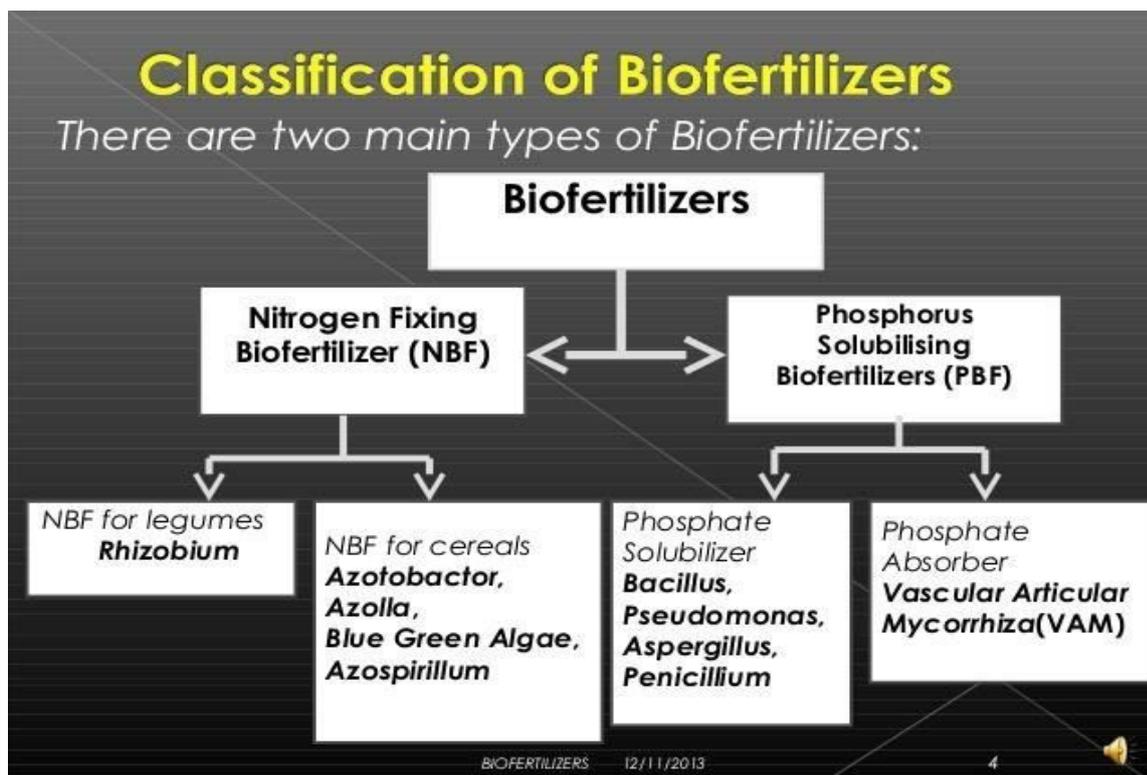


Bio-fertilizers being packed in Tuticorin on Thursday.-PHOTO: N. RAJESH

- Bio-fertilizers produce indole acetic acid, gibberellins, biotin and vitamin B that catalyse growth of crops and yield
- Cheaper than chemical fertilizers; 200 gram of solid bio-fertilizer is available for **Rs. 6** while a liquid bio-fertilizer costs **Rs. 280** per litre
- Can be used for paddy, pulses, small foodgrains, vegetables, coconut, sunflower, sesame, groundnut, cotton, banana and applied in orchards
- Increase yield by 15 to 20 per cent

illustration: R. RAJESH

15. Comment on the classification of Biofertilizers



## 16. What is Xanthan Gum?

# Xanthan Gum

**"Xanthan Gum is a microbial polysaccharide derived from the bacterium *Xanthomonas campestris*"**

Phew! Now that was one hard sentence. As listed earlier, Xanthan gum falls under two functions; as a Thickener, Stabilizer, texturizer and a Fat replacer.

It can be used with or as a substitute for Gelatine and Guar Gum. This ingredient is considered safe, and there doesn't seem to be any thing that suggests otherwise. Xanthan gum is great for people who are allergic to gluten. However there are some people who are allergic to Xanthan gum itself, and they may experience some mild symptoms upon digestion.



## **17. Comment on Biopreservatives Nov /Dec 2013**

A **preservative** is a substance or a chemical that is added to products such as food, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes. In general, preservation is implemented in two modes, chemical and physical. Chemical preservation entails adding chemical compounds to the product. Physical preservation entails processes such as refrigeration or drying. Preservative food additives reduce the risk of foodborne infections, decrease microbial spoilage, and preserve fresh attributes and nutritional quality. Some physical techniques for food preservation include dehydration, UV-C radiation, freeze-drying, and refrigeration. Chemical preservation and physical preservation techniques are sometimes combined.

## **18. Comment on the modes of action of preservatives**

Preservatives generally offer limited protection against viral contamination. Bactericides and fungicides may evince their effects on a variety of microbial cellular targets, for example; the cell wall, the cytoplasmic membrane or the cytoplasm. It is often difficult to assign a precise target for a specific class of preservative; the target can and does change with preservative concentration. As a consequence, preservatives can often interfere with several different microbial cellular mechanisms (Table 2). Such cytotoxicity may also affect mammalian cells. Hence inclusion levels should be minimal, consistent with adequate preservation. There is a regulatory expectation that the reason for preservative inclusion, proof of efficacy, safety information, control methods in finished product and details of labeling in the finished product should all be addressed by the applicant.

Table 2. Site of Preservative Activity in Microbial Cell		
Cell Wall	Cytoplasmic membrane	Cytoplasm
Phenols	2-Phenoxyethanol	2-Phenoxyethanol and other organic alcohols
Aryl and alkyl acids	Parabens	Aryl and alkyl acids
Organo mercurials	Organo mercurials	Halogenated preservatives
EDTA (edetic acid)	EDTA	
Chlorhexidine, cetrimide	Chlorhexidine, hexachlorophene	Chlorhexidine (high concentrations)
Glutaraldehyde	Formaldehyde donators e.g. bronopol, imidurea	Formaldehyde donators e.g. bronopol, imidurea
Anionic surfactants	Benzalkonium chloride (BKC)	

## 19. Comment on the reason for biopolymers

Synthetic polymers have become an essential part of our life due to their properties of durability, strength, lightness and cost. These very desirable properties have also made the plastics a source of environmental and waste management problem. Also these polymers are primarily derived from non renewable fossil (petrochemical) which are disappearing fast. Ideally the polymer should not only be biodegradable but also be produced from renewable resources. As a solution to this, biodegradable plastics (mainly polyhydroxyalkanoates (PHA)) have been developed through biotechnological routes. These are polyesters of various hydroxyalkanoates which are synthesized by numerous microorganisms as energy reserve materials when an essential nutrient such as nitrogen or phosphorus is limited in presence of excess carbon source. They are also completely degraded to water and carbon dioxide under aerobic conditions and to

methane under anaerobic conditions by microorganisms in soil, sea, lake water and sewage. But the main property which sets them apart from other polymers is their similar mechanical properties to the synthetically produced polymers like polypropylene. They can be used for the development of disposable items, packaging films, and also as biodegradable carriers.

## **20. What is PHB? Nov /Dec 2014**

Poly- $\beta$ -hydroxybutyrate (PHB), the most widespread and best characterized member of PHAs, is a homopolymer consisting of 3-hydroxybutyrate (HB). Organisms producing PHB include a wide variety of taxonomically different groups. Among all, *Wautersia eutropha* (formerly known as *Ralstonia eutropha* and *Alcaligenes eutrophus*) has been most extensively studied due to its ability to accumulate large amount of PHB from inexpensive sources. It features accumulation of biopolymer when there is a limitation of an essential nutrient such as nitrogen, phosphorous, magnesium or sulfur in the presence of excess carbon source. There is a need to understand the kinetics of growth and product formation by *Wautersia eutropha* under batch cultivation mode so that a mathematical description of the biological process can be established. This model will be highly instrumental in identification of right bioreactor configuration and appropriate cultivation strategy so that the biopolymer concentration and productivity by microbial cultivation can be enhanced.

## **21. Why do we need biofuels?**

Sustainable biofuels are essential to ensure a constant, secure supply of energy for individuals and industry. Advanced biofuels will reduce our dependency on fossil

fuels and limit our impact on the environment. It is also argued that investing in biofuel production may boost the economy of developing countries.

## **22. Comment on new approaches to biofuels**

‘Second-’ and ‘third-generation’ biofuels are generated from non-food crops. Microbes play a key role in the development of these biofuels. They are more sustainable than first-generation biofuels as they produce higher yields, reduce greenhouse gas production and do not compete with crops grown for food.

## **23. Comment on two major areas of biofuel research**

Two major areas of research are lignocellulosic biofuels and algae. Microbiologists are currently working in a number of areas to make biofuel production more efficient. These include: – Scaling-up the production of microbial cellulase that will break down celluloses into fermentable sugars. – Engineering yeast to tolerate higher concentrations of alcohol to increase bioethanol production. – Genetically modifying micro-organisms to ferment sugars more efficiently to increase bioethanol yields. – Optimizing microbial strains that will convert sugars into biobutanol as an alternative to bioethanol. – Finding algae that produce high yields of oils or are otherwise well-adapted for biodiesel production.

## **23. Expand and define SCP Nov /Dec 2014, Nov/Dec 2017**

**Single Cell Protein:** A variety of microorganisms and substrate are used to produce single cell proteins. Yeast is suitable for single cell protein production because of its superior **n nutritional quality**. The supplementation cereals with single cell proteins, especially yeast, make them as good as animal proteins. The

necessary factor considered for use of SCP is the demonstration of the absence of toxic and carcinogenic compounds originated from the substrates, biosynthesized by the microorganisms or formed during processing. High nucleic acid content and low cell wall digestibility are two of the most important factors limiting nutritional and toxicological value of yeast for animal or human consumption.

#### **24. What are the uses of biopolymers? Nov/Dec 2017**

**Sugar based polymers**, such as Polyactides, naturally degenerate in the human body without producing any harmful side effects. This is the reason why they are used for medical purposes. Polyactides are commonly used as surgical implants.

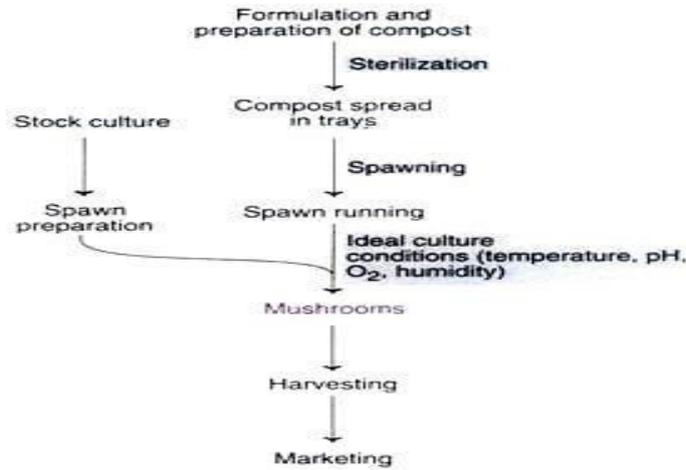
**Starch based biopolymers** can be used for creating conventional plastic by extruding and injection molding.

**Biopolymers based on synthetic** are used to manufacture substrate mats.

**Cellulose based Biopolymers**, such as cellophane, are used as a packaging material.

These chemical compounds can be used to make thin wrapping films, food trays and pellets for sending fragile goods by shipping.

#### **25. Draw a flow chart on Mushroom Cultivation**



**Fig. 29.5 : An overview of edible mushroom production.**

**26. What are the four main types of Biopolymers? (Nov/Dec 2016)**

There are four main types of biopolymer based respectively on:

1. Starch
2. Sugar
3. Cellulose
4. Synthetic materials

*Starch based polymers. Sugar based biopolymers. Sugar based biopolymers. Cellulose based biopolymers. Cellulose based biopolymers. Synthetic based biopolymers. Synthetic based biopolymers.*

**27. What are the advantages of using MO for SCP production? (Nov/Dec 2016)**

Large-scale production of microbial biomass has many advantages over the traditional methods for producing proteins for food or feed.

1. Microorganisms have a much higher growth rate (algae: 2–6 hours, yeast: 1–3 hours, bacteria: 0.5–2 hours). This also allows to select for strains with high yield and good nutritional composition quickly and easily compared to breeding.

2. Whereas large parts of the crop, such as stems, leaves and roots are not edible, single-cell microorganisms can be used entirely. Whereas parts of the edible fraction of crops contains is undigestible, many microorganisms are digestible at a much higher fraction.<sup>[4]</sup>
3. Microorganisms usually have a much higher protein content of 30–70% in the dry mass than vegetables or grains.<sup>[20]</sup> The amino acid profiles of many SCP microorganisms often have excellent nutritional quality, comparable to a hen's egg.

## 28. What are the different types of Bioremediation Process?

- **Microbial bioremediation** uses microorganisms to break down contaminants by using them as a food source.
- **Phytoremediation** uses plants to bind, extract, and clean up pollutants such as pesticides, petroleum hydrocarbons, metals, and chlorinated solvents.
- **Mycoremediation** uses fungi's digestive enzymes to break down contaminants such as pesticides, hydrocarbons, and heavy metals.

## 29. What is LAB?

Of special interest are lactic acid bacteria (LAB). Lactic acid bacteria have antagonistic properties which make them particularly useful as biopreservatives. When LABs compete for nutrients, their metabolites often include active antimicrobials such as lactic and acetic acid, hydrogen peroxide, and peptidebacteriocins. Some LABs produce the antimicrobial nisin which is a particularly effective preservative. These days LAB bacteriocins are used as an integral part of hurdle technology. Lactic acid bacteria and propionibacteria have been extensively studied for their efficacy against spoilage causing yeasts and molds in food spoilage.

### 30. What is the process of making cheese?

Starter cultures, or good bacteria, are added to start the cheese making **process**. They help determine the ultimate flavor and texture of the **cheese**. Next, a milk-clotting enzyme called rennet is added to coagulate the milk, forming a custard-like mass.

### PART B

1. Comment on the biosynthesis of biopesticides, biofertilizers (production formulation) and biodiesel with the help of a flow chart. Nov Dec 2013, 2014

Ans: Biotechnology by U.Satyanarayana Pg.No:644-645, 645-647,393,399:  
Industrial Biotechnology by A.H.Patel. Pg.No: 188-202

2. Give a detailed account on Biopreservatives, Biopolymers, and **Bioremediation** their characteristics, stages in their biosynthetic processes and their advantages and limitations. **Nov/Dec 2016**

Ans: Biotechnology by U.Satyanarayana Pg.No:382-392, 718-728

3. Describe in detail the large scale production of amylase. Ans: Biotechnology by U.Satyanarayana Pg.No:281-286.

4. Discuss in detail Bioremediation with examples. **Nov/Dec 2017**

Ans: Biotechnology by U.Satyanarayana Pg.No:727-728

5. Elaborate the important criteria for selection of microorganisms, basic production process of SCP in a detailed manner. **Nov/Dec 2016**

Ans: Text Book of Industrial Fermentation by Wulf crueger Pg.No: 306-315;  
Biotechnology by U.Satyanarayana Pg.No:373-380

### **PART C**

1. Elaborate the important criteria for selection of microorganisms, basic production process of Cheese & Beer, from any microorganism in a detailed manner. **Nov/Dec 2016.**

Ans: Biotechnology by U.Satyanarayana Pg.No:362-381, Text Book of Industrial Fermentation by Wulf crueger Pg.No: 306-315

2. Describe the biodiesel production by fermentation process in the industries (**Nov/Dec 2017**)

Ans: Text Book : U. Satyanarayana – Biotechnology Page No.(398 to 399)

3. Explain in detail the Industrial production of Enzymes and write in detail the commercial applications of the same

Ans: Text Book : U. Satyanarayana – Biotechnology Page No.(1398 to 1399)

4. Describe the production process of Mushroom culture. (**Nov/Dec 2017**)

## UNIT V PRODUCTION OF MODERN BIOTECHNOLOGY PRODUCTS (8)

**Production of recombinant proteins having therapeutic and diagnostic applications, Vaccines. Bioprocess strategies in Plant Cell and Animal Cell culture.**

### PART A

1. Write notes on production of recombinant DNA

#### **Protein Expression and Purification**



- Isolation of genes.
- Insertion of isolated gene to expression vector.
- Transfer of recombinant vector into host cell through Transformation.
- Identification and isolation of cells containing recombinant vector.
- Growth of cells through fermentation.
- Isolation and purification of protein.

## Production of Recombinant protein

- There are basically two methods for producing **recombinant proteins**.
- One is the molecular Cloning a laboratory method used to make **recombinant DNA**.
- The other method is the Polymerase chain reaction used to proceed the replication of any specific DNA sequence selected .
- The basic difference between the two methods is that molecular cloning incorporates the replication of the DNA within a living cell, whereas PCR replicates DNA in the test tube, without living cells.

7

### 2. Comment on the methods used to produce recombinant proteins

## 2. METHODS USED TO PRODUCE RECOMBINANT PROTEINS

### (i) Production of recombinant proteins in microbial bioreactors

#### Examples

- *E.coli* expression system
- *Saccharomyces cerevisiae*

### (ii) Mammalian cell derived bioreactors

- E.g. Chinese Hamster Ovary cell (CHO) bioreactors.

### ➤ (iii) Animal Bioreactors “Pharming”

Production of Recombinant Therapeutic Proteins in the Milk of Transgenic Animals Eg, Cows, sheep, pigs etc.

### 3. Comment on the applications of recombinantDNA

#### **APPLICATIONS**

- Several proteins are created from recombinant DNA (recombinant proteins) and are used in medical applications.
- Hematopoietic growth factor.
- Interferon's
- Hormones
- Recombinant protein vaccines
- Tissue/bone growth factors and clotting factors
- Biological response modifiers
- Monoclonal/Diagnostic/Therapeutic antibodies
- Recombinant proteins is extensively used in biotechnology, medicine and research.



15

#### 4. Comment on Recombinant Protein Production

##### Recombinant Protein Production

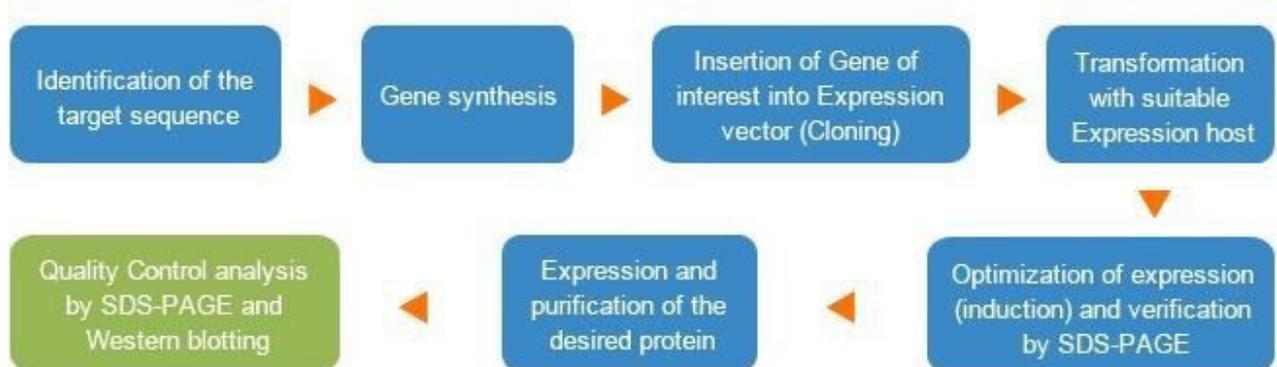
###### -Why?

- over-expression to get enough amount
- easy purification

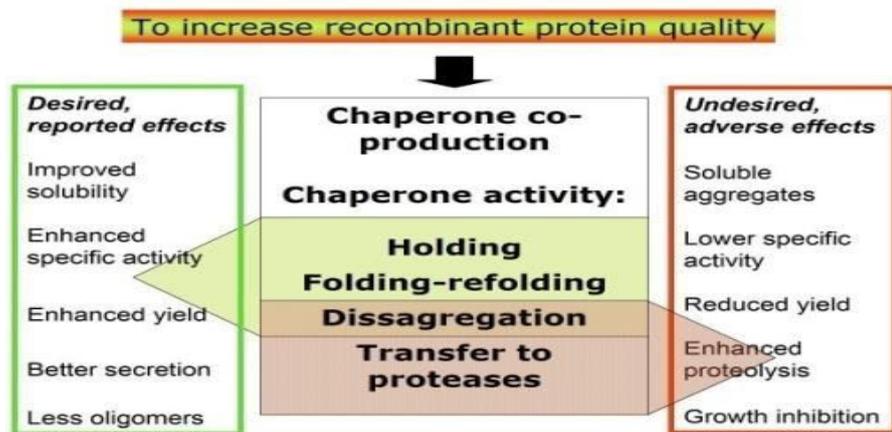
###### -Application

- functional studies
- structural studies
- vaccine/antigen/antibodies
- therapeutic drug
- industrial enzymes for reaction

#### 5. Steps of Recombinant protein production- Comment



## 6. Write notes to increase recombinant protein quality



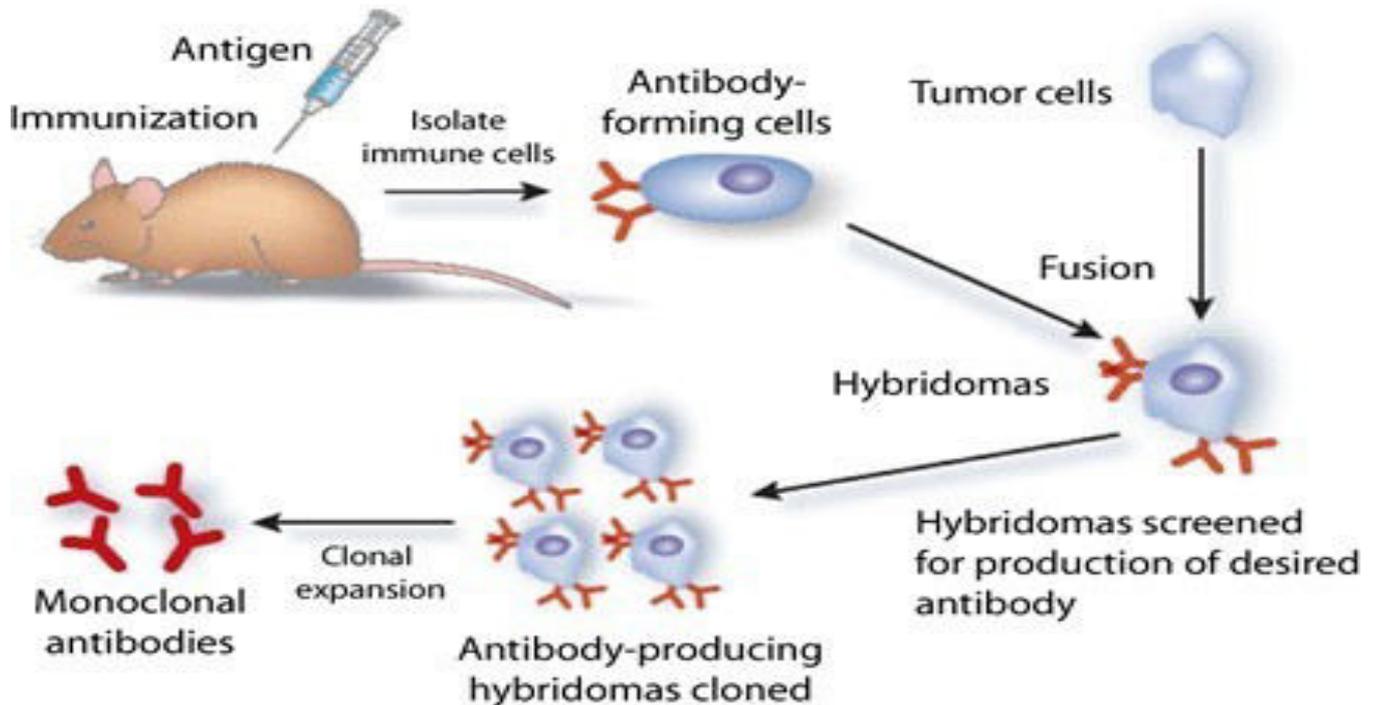
## 7. What are the potential problems in using microorganisms

There are some considerations and potential hazards when we consider the manipulation of the genetic material of microorganisms, for example:

- Risk of uncontrolled dispersal into the natural environment.
- Microorganisms are highly adaptable to different ecological niches and could disrupt those environments.
- Sideways transfer of genetic material to different species could occur.
- Unforeseen metabolic modifications could be hard to control.
- Creation of new pathogenic microorganisms is a possibility.

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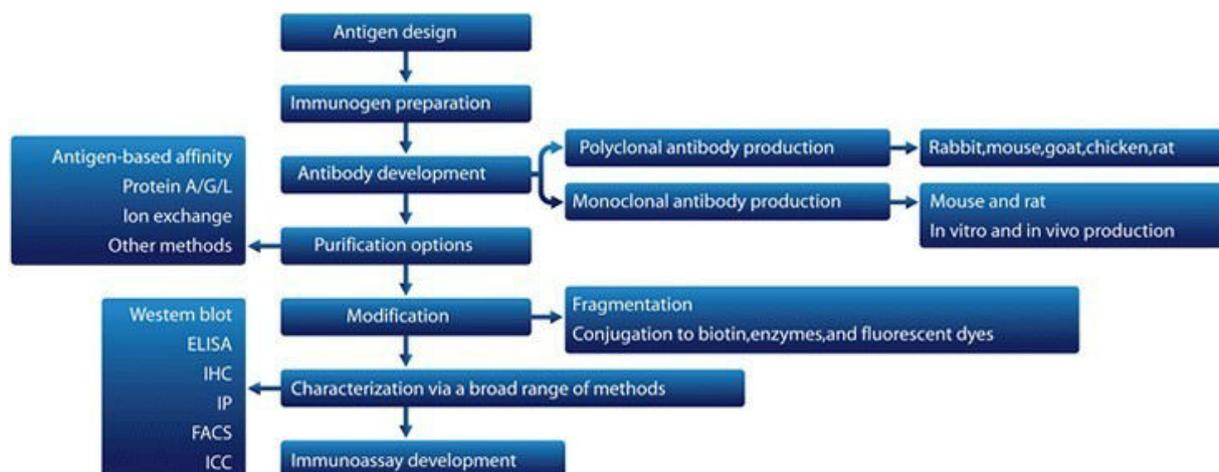
## 8. Production of Monoclonal Antibodies



## 9. What is the need for recombinant protein biopharmaceuticals?

Biopharmaceuticals currently represent the fastest-growing sector of the pharmaceutical industry, driven by a rapid expansion in the manufacture of recombinant protein-based drugs. Consequently, the efficient expression and production of these valuable biomolecules face challenges in improving their quantity and quality while minimizing time and cost. To meet these demands, an increasing variety of recombinant production platforms are being developed. Unfortunately, there is no “universal” production system which can guarantee high yields of recombinant protein, particularly as every biomolecule itself causes its own issues in terms of expression. To meet the demand, it is crucial to increase the throughput of expression, production and purification processes and systems.

## 10. Comment on various antibody design flow chart



## 11. Comment on the Production of recombinant protein therapeutics in cultivated mammalian cells.

Cultivated mammalian cells have become the dominant system for the production of recombinant proteins for clinical applications because of their capacity for proper protein folding, assembly and post-translational modification. Thus, the quality and efficacy of a protein can be superior when expressed in mammalian cells versus other hosts such as bacteria, plants and yeast. Recently, the productivity of mammalian cells cultivated in bioreactors has reached the gram per liter range in a number of cases, a more than 100-fold yield improvement over titers seen for similar processes in the mid-1980s. This increase in volumetric productivity has resulted mainly from improvements in media composition and process control. Opportunities still exist for improving mammalian cell systems through further advancements in production systems as well as through vector and host cell engineering.

## 12. Write notes on Protein Therapeutics and its advantages

In comparison to small-molecule drugs protein therapeutics have several very important advantages:

- specific directing and higher efficacy with low number of side effects,
- better PK and PD,
- the specific interactions with the molecular target cannot be imitated by any chemical compounds,
- they are well tolerated and, as they are naturally produced by body, it is less probable that they elicit immune response,
- the clinical development and approval time can be shorter than in case of small-molecule drugs,
- their unique structure and functions allow the comprehensive patent protection,
- the recombinant DNA technology allows to choose the expression system (e.g. bacteria, yeast, insect cells, mammalian cells) dictated by the costs or the need of modification within the structure.

### 13. clonal antibodies

Brand	Generic	Company	Therapeutic category	Indications
ReoPro	Abciximab	Eli Lilly	Blood modifier	Acute coronary syndrome
Rituxan	rituxumab	Genentech	Cancer	Non-Hodgkin's lymphoma
Herceptin	Trastuzumab	Genentech	Cancer	Breast cancer
Synagis	Palivizumab	MedImmune	Respiratory	Respiratory syncytial virus
Campath	Alemtuzumab	Schering AG	Cancer	Non-Hodgkin's lymphoma
Humira	Adalimumab	Abbott Labs	Anti-arthritis	Rheumatoid arthritis
Xolair Omalizumab	Omalizumab	Genentech	Respiratory diseases	Paediatric asthma, peanut allergies
Erbix	Cetuximab	Imclone Systems	Cancer	Colon cancer
Avastin	Bevacizumab	Genentech	Cancer	Colon cancer

### 14. Draw a flow chart for rec. therapeutic proteins

This flow chart below shows critical stages of an upstream production platform that relate to success of a therapeutic product.



### 15. Comment on the Expression of recombinant DNA

Following transplanted into the host organism, the foreign DNA contained within the recombinant DNA construct may or may not be expressed. That is, the DNA may simply be replicated without expression, or it may be transcribed and translated at a recombinant protein is produced.

Expression of a foreign gene requires restructuring the gene to include sequences that are required for producing an mRNA molecule that can be used by the host's translational apparatus (e.g. promoter, translational initiation signal, and transcriptional terminator). Specific changes to the host organism may be made to improve expression of the ectopic gene. In addition, changes may be needed to the coding sequences as well, to optimize translation, make the protein soluble, direct the recombinant protein to the proper cellular or extracellular location, and stabilize the protein from degradation.

#### **16. Justify the need for the industrial production of recombinant proteins Nov/Dec 2017**

The most notable applications of the recombinant technology having direct impact on humanity have been:

1. Large scale production of therapeutic protein such as insulin, hormones, vaccine and interleukins using recombinant microorganisms.
2. Production of humanized monoclonal antibodies for therapeutic application
3. Production of insect resistant cotton plant by incorporation of insecticidal toxin of *Bacillus thuringiensis* (Bt cotton plant).
4. Production of golden rice (rice having vitamin A) by incorporating three genes required for its synthesis in rice plant.
5. Bioremediation by the use of recombinant organisms &
6. Use of genetic engineering techniques in forensic medicine.

#### **18. Comment on the types of biomolecules produced through recombinant DNA technology Recombinant Hormones**

Insulin (and its analogs), growth hormone, follicle stimulating hormone, salmon calcitonin.

#### **Blood products**

Albumin, thrombolytics, fibrinolytics, and clotting factors ( Factor VII, Factor IX, tissue plasminogen activator, recombinant hirudin )

### **Cytokines and growth factors**

Interferons, interleukins and colony stimulating factors (Interferon,  $\alpha$ ,  $\beta$  and  $\gamma$ , erythropoietin, interleukin-2, GM-CSF, GCSF )

**Monoclonal antibodies and related products** Mouse, chimeric or humanized; whole molecule or fragment; single chain or bispecific; and conjugated (rituximab, trastuzumab, infliximab, bevacizumab)

**Recombinant Vaccines** Recombinant protein or peptides, DNA plasmid and anti-idiotypic (HBsAg vaccine, HPV vaccine).

**Recombinant Enzymes** Dornase- $\alpha$  (Pulmozyme), Acid glucosidase (Myozyme),  $\alpha$ -L- iduronidase (Aldurazyme) and Urate Oxidase.

**Miscellaneous products** Bone morphogenic protein, conjugate antibody, pegylated recombinant proteins, antagonist.

### **19. Comment on few value added transgenic crops**

Some of the value added transgenic crops include:

(a) Golden rice: containing beta carotene to overcome vitamin A deficiency in regions where rice is the staple food (b) Canola containing high levels of oleic acids and laurate (c) Barley containing feed enzymes (d) tomatoes which does not rot in room temperature (e) Other vegetables and fruits with delayed ripening as well as modified flavour characteristics.

Transgenic crops with improved nutrition quality have already been produced by introducing genes involved in the metabolism of vitamins, minerals and amino acids.

## **20) Write note on the application of Recombinant DNA in Environment**

A vast majority of applications of environmental biotechnology use naturally occurring microorganisms (bacteria, fungi, etc.) to identify and filter manufacturing waste before it is introduced into the environment.

For example when gene such as the mercury resistance gene (**mer**) or the toluene degradation (tol) gene is linked to genes that code for bioluminescence within living bacterial cells, the biosensor cells can signal extremely low levels of inorganic mercury or toluene that are present in contaminated waters and soils by emitting visible light, which can be measured with fiber- optic flurometers.

## **21. Comment on the bioreactor as a tool for large-scale culture of animal cells.**

Bioreactors play a key role in the field of biologics, where they are used for the production of recombinant therapeutic proteins by large-scale cultivation of animal cells. There are several types of bioreactors, including stirred-tank, airlift, hollow-fiber, and Rotary Cell Culture System (RCCS) designs. The stirred-tank bioreactor is one of the most commonly used types, and is used both for industrial applications and laboratory research. Important improvements have been made in the design of traditional bioreactors, and new types of bioreactor are also being developed such as Couette-Taylor bioreactor, multifunctional-membrane bioreactor, and shaking bioreactor.

Two main goals will be pursued: firstly, to increase output by high density

cultivation of animal cells to produce high value protein pharmaceuticals or viral vectors for clinical gene therapy; and secondly, to create a three-dimension space similar to that of an in vivo environment to regenerate tissue or organ and to reproduce valuable cells that are hard to culture in the traditional culture system.

## 21. What are anchorage dependent cells?

- **Anchorage Dependent cells**
  - **Require surface attachment to grow**
  - **They include mostly primary cells and cell lines such as :**
    - Chinese Hamster Ovary cells (CHO),**
    - Baby Hamster Kidney Cells (BHK) and**
    - Human Fibroblast cells (FS-4)**

## 22. What is meant by Passaging cells?

Passaging (also known as subculture or splitting cells) involves transferring a small number of cells into a new vessel. Cells can be cultured for a longer time if they are split regularly, as it avoids the senescence associated with prolonged high cell density. Suspension cultures are easily passaged with a small amount of culture containing a few cells diluted in a larger volume of fresh media. For adherent cultures, cells first need to be detached; this is commonly done with a mixture of trypsin-EDTA; however, other enzyme mixes are now available for this purpose. A small number of detached cells can then be used to seed a new culture. Some cell

cultures, such as RAW cells are mechanically scraped from the surface of their vessel with rubber scrapers.

#### **24. Comment on the applications of cell culture**

Biological products produced by recombinant DNA (rDNA) technology in animal cell cultures include enzymes, synthetic hormones, immunobiologicals (monoclonal antibodies, interleukins, lymphokines), and anticancer agents. Although many simpler proteins can be produced using rDNA in bacterial cultures, more complex proteins that are glycosylated (carbohydrate-modified) currently must be made in animal cells. An important example of such a complex protein is the hormone erythropoietin.

#### **25. Comment on Tissue Cultures**

**Tissue culture** is the general term for the removal of cells, tissues or organs from an animal or plant and their subsequent placement into an artificial medium environment for maintaining cell viability.

#### **26. Comment on Organ Culture**

The culture of whole organs or intact organ fragments with the intent to use cells as machinery to produce biological is called **Organ Culture**. When the cells are removed from the organ fragments prior to or during cultivation thus disrupting their normal relationships with neighboring cell, the technology is called **Cell Culture**.

#### **27. Comment on Primary Culture**

When cells are individually dissociated from an organism and placed into a suitable medium and support culture environment, they will attach, divide and grow. This cell culture is named **Primary Culture**. Cell culture may be initiated from normal, embryonic or malignant

**28. Define Totipotency Nov /Dec 2016**

**Totipotency** is the ability of a single cell to divide and produce all of the differentiated cells in an organism. Spores and zygotes are examples of **totipotent** cells. In the spectrum of cell potency, **totipotency** represents the cell with the greatest differentiation potential.

**29. What are 3 major applications of Genetic Engineering technology in antibiotic production?**

Directed mutation and selection, protoplast fusion, and both semirandom and specific recombinant DNA methods are examples of alternative procedures for manipulating the biosynthetic pathways of microorganisms for strain improvement and for new hybrid antibiotic synthesis.

**30. What is Pluripotency?**

**Pluripotent** cells can give rise to all of the cell types that make up the body; embryonic stem cells are considered **pluripotent**. Multipotent cells can develop into more than one cell type, but are more limited than **pluripotent** cells; adult stem cells and cord blood stem cells are considered multipotent.

**31. Name any two media used in plant and animal cell culture respectively**

**Nov/Dec 2017** Plant tissue culture media should generally contain some or all of

the following components: macronutrients, micronutrients, vitamins, amino acids or nitrogen supplements, source(s) of carbon, undefined organic supplements, growth regulators and solidifying agents.

Animal cell culture media attempts at serum-free **culture** by using serum substitutes (eg, several hormones and growth factors, transferrin, and selenite) grew in number and a variety of serum-free **media** was developed, with each **medium** tailored to researchers' **cell** type of interest.

## **PART B**

1. Describe in detail the therapeutic and diagnostic applications of recombinant proteins. Ans: Biotechnology by U.Satyanarayana Pg.No:213-226 **Nov /Dec 2017**
2. Write detailed notes on production and purification of insulin by r-DNA technology. **Nov/Dec 2016**  
Ans: Biotechnology by U.Satyanarayana Pg.No:189-192
3. Write the detailed steps and processes involved in the production of Vaccines **Nov/Dec 2017**  
Ans: Biotechnology by U.Satyanarayana Pg.No: 411-413
4. What are the strategies followed for bioprocessing of plant cell culture mass production? Nov /Dec 2014,15  
Ans: Biotechnology by U.Satyanarayana Pg.No:552-564
5. Discuss the Characterization of cultured cells & measurement of growth parameters of cultured cells. Nov /Dec 2014,15  
Ans: Biotechnology by U.Satyanarayana Pg.No:428-435
6. Explain in detail the various techniques in plant transformation. (**Nov/Dec 2016**)  
Ans: Biotechnology by U.Satyanarayana Pg.No:506-517.

## **PART C**

1. Discuss the application & production of secondary metabolites and application of plant tissue culture. Nov /Dec 2014  
  
Ans: Biotechnology by U.Satyanarayana Pg.No:806-817.
2. Comment on the contemporary challenges involved in the production of modern biotechnology products. Also provide the possible solutions to address them. **Nov /Dec 2017**  
  
Ans: Biotechnology by U.Satyanarayana Pg.No:325-328.
3. Describe the bioprocess strategies involved in Animal Cell Culture  
Nov /Dec 2014 Ans: Biotechnology by U.Satyanarayana Pg.No:113-18

# BT 8304 – BIOORGANIC CHEMISTRY

REGULATION 2017

## UNIT I BONDING AND STEREOCHEMISTRY PART-A

### 1. What is valence electrons of an atom.

These are the outermost electrons, the ones most likely to be involved in chemical bonding and reactions. For second-row elements these are the *2s* and *2p* electrons. Because four orbitals (*2s*, *2p<sub>x</sub>*, *2p<sub>y</sub>*, *2p<sub>z</sub>*) are involved, the maximum number of electrons in the valence shell of any second-row element is 8. Neon, with all its *2s* and *2p* orbitals doubly occupied, has eight valence electrons and completes the second row of the periodic table.

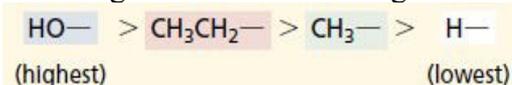
### 2. What is polar covalent bond?

Electrons in covalent bonds are not necessarily shared equally by the two atoms that they connect. If one atom has a greater tendency to attract electrons toward itself than the other, and the electron distribution is *polarized*, and the bond is referred to as a *polar covalent* bond.

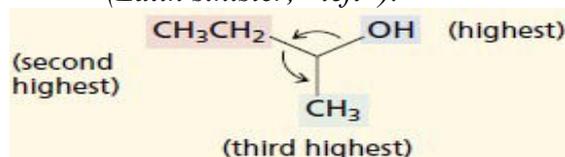
### 3. State Cahn–Ingold–Prelog R–S Notational System.

Cahn–Ingold–Prelog system otherwise called as the sequence rules.

⊘ Arrange the atoms according to their decreasing precedence

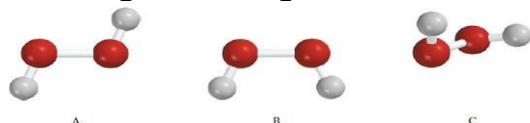


- Orient the molecule so that the lowest ranked substituent points away from you.
- If the order of decreasing precedence of the three highest ranked substituents appears in a clockwise sense, the absolute configuration is *R* (*Latin rectus*, “right,” “correct”). If the order of decreasing precedence is anticlockwise, the absolute configuration is *S* (*Latin sinister*, “left”).



### 4. What is conformation?

Conformations are different spatial arrangements of a molecule that are generated by rotation about single bonds. Eg. H<sub>2</sub>O<sub>2</sub>



### 5. Define Pauli exclusion principle

Two electrons may occupy the same orbital only when they have opposite, or “paired,” spins.

6. **Define Atomic number.**

The atomic number of a chemical element is the number of protons found in the nucleus of an atom of that element, and therefore identical to the charge number of the nucleus.

7. **Define Hund’s rule.**

Every orbital in a subshell is singly occupied with one electron before any one orbital is doubly occupied, and all electrons in singly occupied orbitals have the same spin.

8. **Define ionization energy**

The amount of energy that must be added to an atom to remove an electron is ionization energy. The ionization energy of sodium, for example, is 496 kJ/mol (119 kcal/mol).

9. **Define octet rule (2015)**

Atoms of low atomic number tend to combine in such a way that they each have eight electrons in their valence shells, giving them the same electronic configuration as a noble gas.

10. **Define electronegativity**

The tendency of an atom to draw the electrons in a covalent bond toward itself is referred to as its **electronegativity**. An electronegative element attracts electrons

11. **What do you mean by formal charges?**

A formal charge is the charge assigned to an atom in a molecule, assuming that electrons in a chemical bond are shared equally between atoms, regardless of relative electronegativity.

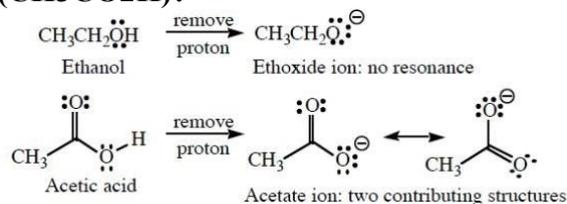
12. **What is resonance?**

Resonance structures are used when one Lewis structure for a single molecule cannot fully describe the bonding that takes place between neighboring atoms relative to the empirical data for the actual bond lengths between those atoms. The net sum of valid resonance structures is defined as a resonance hybrid, which represents the overall delocalization of electrons within the molecule.

13. **How does resonance influence the ability of a base to share electrons with a proton?**

A base that has resonance delocalization of the electron pair that is shared with the proton will be less basic than a base without resonance. Since a weaker base has a stronger conjugate acid, a compound whose conjugate base enjoys resonance stabilization will be more acidic.

14. **Which O-H proton is more acidic, ethanol (CH<sub>3</sub>CH<sub>2</sub>OH) or acetic acid (CH<sub>3</sub>CO<sub>2</sub>H)?**



Because acetate ion has resonance that delocalizes the electron pair to be shared with a proton and ethoxide ion does not, acetate ion is a weaker base than ethoxide ion.

15. **Define Arrhenius and Bronsted Lowry theories.**

**Arrhenius theory:** Acids are substances which produce hydrogen ions in solution.

Bases are substances which produce hydroxide ions in solution.

**Bronsted Lowry theories:** An acid is a proton (hydrogen ion) donor. A base is a proton (hydrogen ion) acceptor.

16. **Write about sp<sup>3</sup> hybridisation**

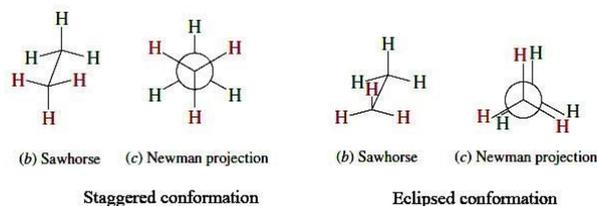
In, ethane, each methyl group consists of an sp<sup>3</sup>-hybridized carbon attached to three hydrogens by sp<sup>3</sup>-1s σ bonds. Overlap of the remaining half-filled orbital of one carbon

with that of the other generates a  $\sigma$  bond between them. In general, carbon will be  $sp^3$  hybridized when it is directly bonded to four atoms.

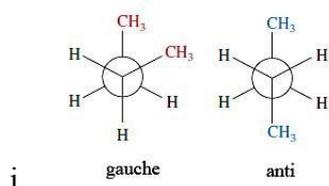
17. **What are stereoisomers?**

**Stereoisomers** are isomers that have their atoms bonded in the same order—that is, they have the same constitution, but they differ in the arrangement of atoms in space.

18. **Draw the Newman and sawhorse projections of ethane**



19. **Draw the Newman projection of butane**



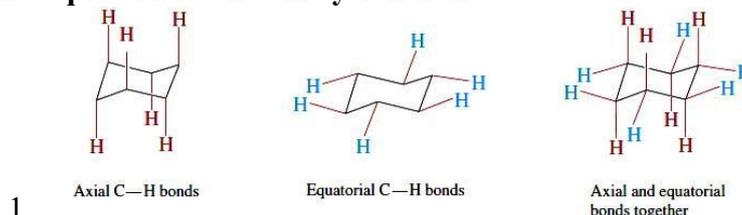
20. **What is meant by torsional strain ?**

The destabilization that comes from eclipsed bonds on adjacent atoms is called **torsional strain**



a. Torsion angle = 0°  
Eclipsed

21. **Draw the Axial and equatorial bonds in cyclohexane.**



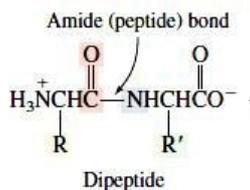
22. **Define D,L isomers?**

Rotation of the plane of polarized light in the clockwise sense is taken as positive (+), and rotation in the anticlockwise sense is taken as a negative (-) rotation. The classical terms for positive and negative rotations are dextrorotatory (D) and levorotatory (L)

23. **Write a note on optical activity**

Optical activity is the ability of a chiral substance to rotate the plane of **plane polarized light** and is measured using an instrument called a **polarimeter**. To be optically active, the sample must contain a chiral substance and one enantiomer must be present in excess of the other. A substance that does not rotate the plane of polarized light is said to be optically inactive. All achiral substances are optically inactive.

24. **Draw the conformation of peptide bond.**



i.

**25. Define configuration and specify the R and S isomers.(Nov 2011)**

The arrangement of atoms that characterizes a particular stereoisomer is called its configuration. The four groups attached to the asymmetric carbon atom are numbered 1,2,3,4 and ranked according to a set of sequence rules and if the view with respect to Fischer projection is clockwise it is specified as R isomer and in anti-clock wise it is S isomer.

**26. What is the Aufbau principle with example? (Dec 2016)**

The Aufbau Principle states that electrons enter the lowest energy orbitals first.

- a. The lower the principal quantum number (n) the lower the energy.
- b. Within an energy level, s orbitals are the lowest energy, followed by p, d and then f.
- c. F orbitals are the highest energy for that level.

**27. What do you mean by “electron configuration?”**

The electron configuration is the specific way in which the atomic orbitals are filled. The electron configuration reveals where all the electrons “live.”

**28. Define Valence electrons of an atom.**

These are the outermost electrons, the ones most likely to be involved in chemical bonding and reactions. For second-row elements these are the *2s and 2p electrons*. Because four orbitals (*2s, 2px, 2py, 2pz*) are involved, the maximum number of electrons in the **valence shell** of any second-row element is 8. Neon, with all its *2s and 2p orbitals doubly occupied*, has eight valence electrons and completes the second row of the periodic table.

**29. What is Chemical Bond and ionic bond?**

The attractive force between atoms in a compound is a chemical bond.

Ionic bond, is the force of attraction between oppositely charged species (ions).

Ions that are positively charged -cations;

Ions that are negatively charged are anions

**30. What is Hammond’s postulate? (Dec 2016)**

It states that that for any single reaction step, the geometry of the transition state for that step resembles the side to which it is closer in free energy.(It states that if there is an unstable intermediate on the reaction pathway, the transition state for the reaction will resemble the structure of this intermediate).

**PART – B**

**31. Explain about atom, electron, orbital, bonding, electronegativity and formal charge.**

**32. Discuss about acid-base equilibria and give Arrhenius and Bronsted Lowry theories.**

**33. Elaborate SP, SP2 and SP3 hybridization. (2015)**

**34. Explain in detail about the various conformational analysis of ethane, butane and cyclohexane.**

**35. Write an essay on “optical activity and chirality”.**

**36. Discuss about the conformation of the peptide bond and its stability. (2015)**

**PART – C**

- 37. Explain diagrammatically and energetically the conformers of ethane, and n-butane.**
- 38. Explain Stereochemical activity around tetrahedral carbon. (Dec 2016)**
- 39. Explain Conformation of the peptide bond. Why is trans confirmation stable? (Dec 2016)**

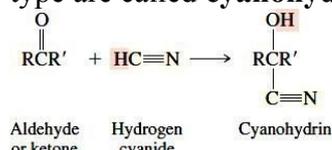
a.

## UNIT II MECHANISMS OF SUBSTITUTION AND ADDITION REACTIONS

### PART-A

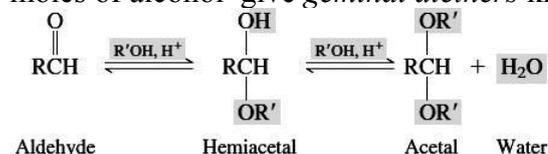
#### 40. What are cyanohydrins?

The product of addition of hydrogen cyanide to an aldehyde or a ketone contains both a hydroxyl group and a cyano group bonded to the same carbon. Compounds of this type are called **cyanohydrins**.



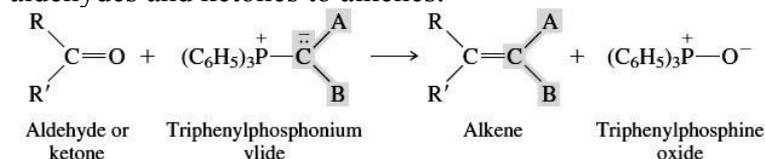
#### 41. What are hemiacetals and acetals? Describe its formation.

The product of nucleophilic addition of the alcohol to the carbonyl group of an aldehyde is called a **hemiacetal**. The reaction of one mole of the aldehyde with *two* moles of alcohol give *geminal diethers* known as **acetals**.



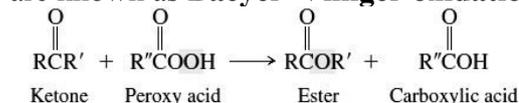
#### 42. What is Wittig reaction?

The **Wittig reaction** uses *phosphorus ylides* (called *Wittig reagents*) to convert aldehydes and ketones to alkenes.



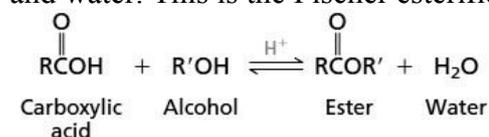
#### 43. Write the ester formation of ketone through Baeyer–Villiger oxidations

An oxygen from the peroxy acid is inserted between the carbonyl group of a ketone and one of the attached carbons of the ketone to give an *ester*. Reactions of this type are known as **Baeyer–Villiger oxidations**.



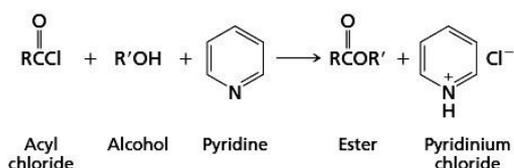
#### 44. What is Fischer esterification.

In the presence of an acid catalyst, alcohols and carboxylic acids react to form an ester and water. This is the Fischer esterification.



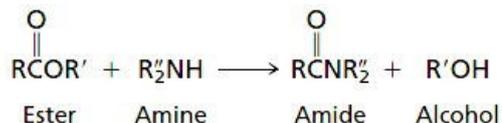
#### 45. How do you prepare an ester from acyl chloride?

Alcohols react with acyl chlorides by nucleophilic acyl substitution to yield esters. These reactions are typically performed in the presence of a weak base such as pyridine.



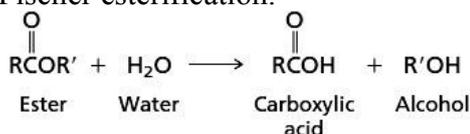
46. Write the reaction of ester with amines?

Esters react with ammonia and amines to form amides.

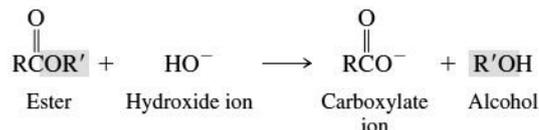


47. Write the reaction of acid catalysed ester hydrolysis.

Acid-catalyzed hydrolysis is an equilibrium-controlled process, the reverse of the Fischer esterification.

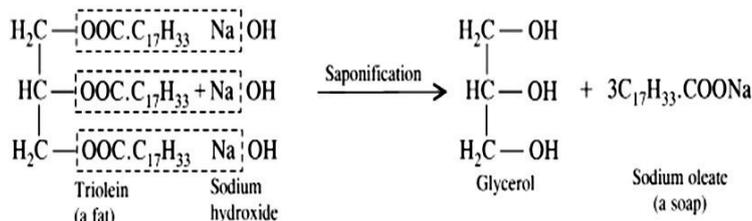


48. Write the reaction of ester hydrolysis in base. Ester hydrolysis in aqueous base is irreversible.



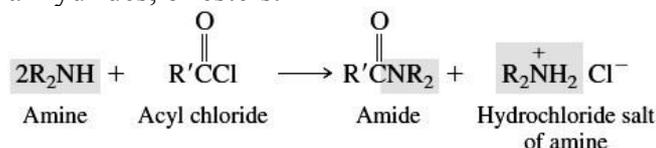
49. What is saponification?

Saponification is a process that produces soap, usually from fats and lye. In technical terms, saponification involves base (usually caustic soda NaOH) hydrolysis of triglycerides, which are esters of fatty acids, to form the sodium salt of a carboxylate.



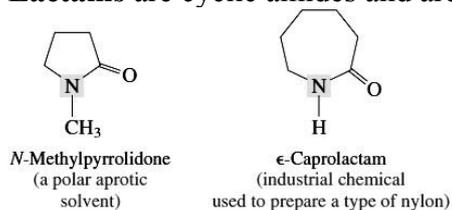
50. How amides can be prepared?

Amides are readily prepared by acylation of ammonia and amines with acyl chlorides, anhydrides, or esters.

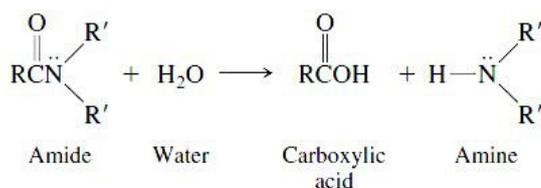


51. What are lactams?

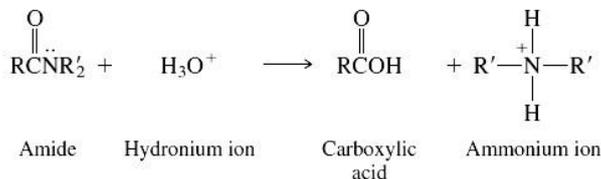
Lactams are cyclic amides and are analogous to lactones, which are cyclic esters.



52. Write the reaction of amide hydrolysis in water

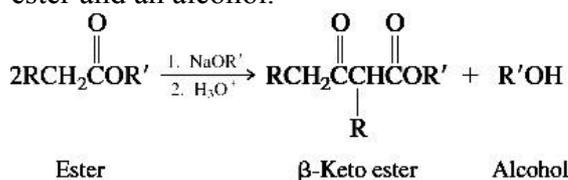


53. Write the reaction of amide hydrolysis in acid



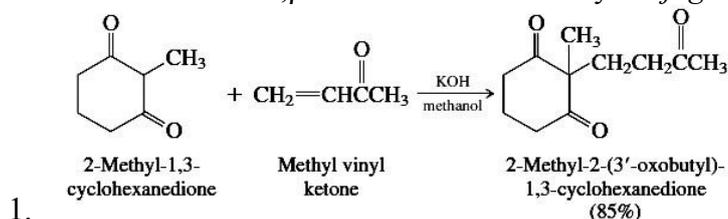
54. What is Claisen condensation?

On treatment with alkoxide bases, esters undergo self-condensation to give a  $\beta$ -keto ester and an alcohol.



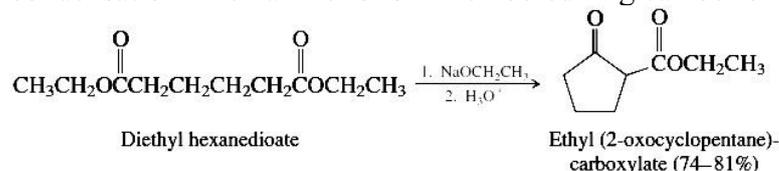
55. What is Michael reaction?

A synthetically useful reaction known as the **Michael reaction**, or **Michael addition**, involves nucleophilic addition of carbanions to  $\alpha,\beta$ -unsaturated ketones. The most common types of carbanions used are enolate ions derived from  $\beta$ -diketones. These enolates are weak bases and react with  $\alpha,\beta$ -unsaturated ketones by *conjugate addition*.



56. What is Dieckmann cyclization?

Esters of *dicarboxylic acids* undergo an intramolecular version of the Claisen condensation when a five- or six-membered ring can be formed.

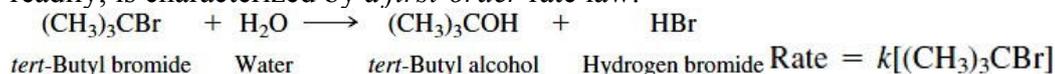


57. Name some nucleophile candidates for nucleophilic substitution reactions of alkyl halides

Alkoxide ion, Carboxylate ion, Hydrogen sulfide ion, Cyanide ion, Azide ion, Iodide ion.

58. What is SN1 reaction?

**Hughes and Ingold** observed that the hydrolysis of *tert*-butyl bromide, which occurs readily, is characterized by a *first-order* rate law:





64. **What is Barnase? (Dec 2016)**

**Barnase** (a portmanteau of "Bacterial" "RiboNucleASE") is a bacterial protein that consists of 110 amino acids and has ribonuclease activity. It is synthesized and secreted by the bacterium *Bacillus amyloliquefaciens*, but is lethal to the cell when expressed without its inhibitor barstar.

65. **What is solvolysis?**

- a. Solvolysis reactions are substitutions in which the nucleophile is the solvent in which the reaction is carried out. Solvolysis in *water converts an alkyl halide to an alcohol*.

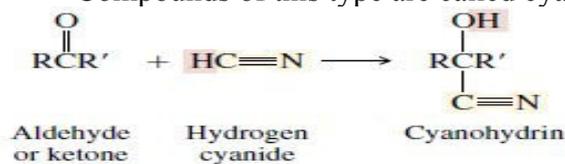
66. **Give the structure of the carbonyl group.** Hybridization of the carbonyl carbon is  $sp^2$ .

- a. Geometry of the carbonyl carbon is *trigonal planar*  
b. Attack by nucleophiles will occur with equal ease from either the top or the bottom of the carbonyl group.  
c. The carbonyl carbon is *prochiral*. That is, the carbonyl carbon is not the center of chirality, but it becomes chiral as the reaction proceeds.



67. **What is cyanohydrins?**

- a. The product of addition of hydrogen cyanide to an aldehyde or a ketone contains both a hydroxyl group and a cyano group bonded to the same carbon. Compounds of this type are called cyanohydrins.



**PART – B**

68. **Elaborate SN1 and SN2 reactions on tetrahedral carbon**

69. **Explain about nucleophilic addition reaction with Acetals and ketals.**

70. **Discuss Hydration mechanism of aldehydes and ketones in acidic and basic solution.**

71. **Describe acid and base catalyzed ester hydrolysis (2015)**

72. **Write in detail about reactions of carbonyl group with amines, ester hydrolysis in base (saponification), hydrolysis of amides. (2015)**

73. **Explain Ester enolates - Claisen condensation – Michael condensation. (2015)**

**PART – C**

74. **Explain the mechanism of an elimination reaction with an example. Explain the effect of steric hindrance on the rate of SN2 reactions**

75. **Explain reaction of carbonyl groups with amines, with an example. Explain the SN1 mechanism of nucleophilic substitution with hydrolysis of *tert*-butyl bromide along with energy diagram.**

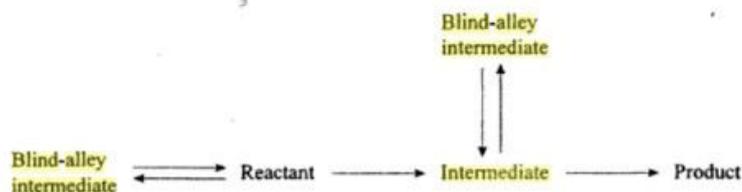
76. **Explain condensation reactions.**

## UNIT III KINETICS AND MECHANISM

### PART-A

#### 77. What is blind alley intermediate?

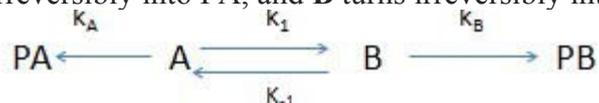
Blind alley intermediate which does not lead to product formation.



#### 78. Define Curtin-Hammetts principle.

The Curtin–Hammett principle applies to systems in which different products are formed from two substrates in equilibrium with one another. The rapidly interconverting reactants can be enantiomers, diastereomers, or constitutional isomers. Product formation must be irreversible, and the different products must be unable to interconvert.

For example, given species **A** and **B** that equilibrate rapidly while **A** turns irreversibly into **PA**, and **B** turns irreversibly into **PB**:

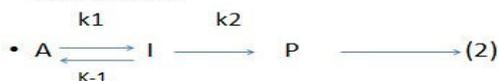


$K$  is the equilibrium constant between **A** and **B**, and  $k_1$  and  $k_2$  are the rate constants for the formation of **PA** and **PB**, respectively. When the rate of interconversion between **A** and **B** is much faster than either  $k_1$  or  $k_2$ , then the Curtin–Hammett principle tells us that the **PA**:**PB** product ratio is not equal to the **A**:**B** reactant ratio, but is instead determined by the relative energy of the transition states. If reactants **A** and **B** were at identical energies, the reaction would depend only on the energy of the transition states leading to each respective product. However, in a real-world scenario, the two reactants are likely at somewhat different energy levels, although the barrier to their interconversion must be low for the Curtin–Hammett scenario to apply. In this case, the product distribution depends both on the relative quantity of **A** and **B** and on the relative barriers to products **PA** and **PB**.

#### 79. Give rate law and its mechanism.

##### Rate law and Mechanism

- Need mechanistic hypothesis
- Steady state assumption
- Unimolecular decomposition of **A**/reaction of **A** with solvent



$$\text{Rate} = -d[\text{A}]/dt = d[\text{P}]/dt = [\text{A}] \cdot k_1 k_2 / (k_{-1} + k_2) = k'[\text{A}] \longrightarrow (3)$$

Rate laws are used in chemical engg. But knowledge is imp. To control the chemical flux in a process.

#### 80. Write Bodenstein attribute towards steady state and non-steady state. Steady state and non-steady state

- 'I' can be predicted from  $k_1$ ,  $k_{-1}$  and  $k_2$  and initial  $[\text{A}]$ .
- $k_{-1}$  or  $k_2 > k_1$ ;  $[\text{I}]$  is very small.
- Time dependency of **A** and **P** are first order.

Bodenstein attribute:

- d. When the concentration of the intermediate is very much smaller than that of reactants or products, the concentration of intermediates can be considered constant at a 'steady state' i.e
- e. Rate of formation = rate of break down.
- f. From equation 2 eqn 4a, 4b & 4c is obtained

$$d[I]/dt = [A] k_1 - [I](k_{-1} + k_2) = 0 \rightarrow (4a)$$

$$\text{Steady state condition: } k_1[A] = (k_{-1} + k_2)[I] \rightarrow (4b)$$

$$[I] = k_1 [A] / (k_{-1} + k_2) \rightarrow (4c)$$

**81. What is microscopic reversibility?**

In any equilibrium process, the sequence of intermediates and transition states encountered as reactants proceed to products in one direction must also be encountered, and in precisely the reverse order, in the opposite direction. This is called the **principle of microscopic reversibility**

**82. State Le Chatlier's principle.**

If a chemical system at equilibrium experiences a change in concentration, temperature, volume, or pressure, then the equilibrium shifts to counteract the imposed change and a new equilibrium is established.

**83. Define Hammond's postulate. (Nov 2011)**

It states that for any single reaction step, the geometry of the transition state for that step resembles the side to which it is closer in free energy. (It states that if there is an unstable intermediate on the reaction pathway, the transition state for the reaction will resemble the structure of this intermediate).

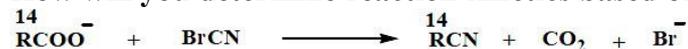
**84. What are the methods that are used to determine to Reaction Mechanism?**

- a. Kinetic Methods
- b. Non-Kinetic Methods

**85. What are the non kinetic methods of study of reaction mechanism?**

Identification of product  
Identification of intermediate  
Isotopic labeling  
Stereo chemical evidences

**86. How will you determine reaction kinetics based on isotopic labeling ?**



- i. Carbon has two isotopes.  $\text{C}^{14}$  is the radioactive. So we label the C in  $\text{RCOO}^-$  as  $\text{RC}^{14}\text{OO}$  but in the product  $\text{C}^{14}$  is present in acylcyanide.

**87. How will you determine acyloxygen in ester hydrolysis?**



$\text{O}^{18}$  in the products is found out by the help of mass spectrum i.e., the acid and the alcohol are analysed and the heavy isotope  $\text{O}^{18}$  is present in the acid i.e., confirms the acyloxygen cleavage present.

**88. Write the Arrhenius equation.**

$$i. k = A e^{-E_a/(RT)}$$

$k$  = Rate constant of a chemical reaction;  $A$  = Arrhenius constant;  $E_a$  = Activation energy;  $R$  = gas constant;  $T$  = Temperature

89. **Write the Eyring equation.**

$$i. \quad k = \frac{k_B T}{h} e^{-\frac{\Delta G^\ddagger}{RT}}$$

$k$  = reaction rate constant;  $T$  = absolute temperature;  $R$  = gas constant;  $k_B$  = Boltzmann constant;  $h$  = Planck's constant;  $\Delta G^\ddagger$  is the Gibbs energy of activation

90. **Write transition state theory.**

According to the theory, in between the state where molecules are reactants and the state where molecules are products, there is a state known as the transition state. During the transition state, the reactants are combined to form a species called the activated complex. The theory suggests that there are three major factors that determine whether a reaction will occur or not:

The concentration of the activated complex (the species of the transition state)

The rate at which the activated complex breaks apart

The way in which the activated complex breaks apart: whether it breaks apart to reform the reactants or whether it breaks apart to form a new complex, the products.

91. **What is a transition state?**

The transition state of a chemical reaction is a particular configuration along the reaction coordinate. It is defined as the state corresponding to the highest potential energy or free energy ( $\Delta G$ ) along this reaction coordinate.

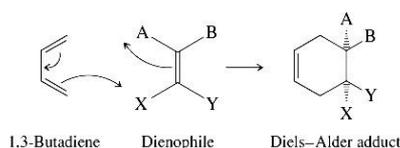
92. **Write the difference between kinetic product and thermodynamic product.**

Thermodynamic product- it is the most stable product. The thermodynamic product predominates when the reaction is reversible (thermodynamic control)

Kinetic product- It is the product that is formed most rapidly. The kinetic product predominates when the reaction is irreversible (kinetic control)

93. **Write the Diels- Alder reaction.**

The Diels–Alder reaction is the conjugate addition of an alkene to a diene. The alkene that adds to the diene is called the **dienophile**. Because the Diels–Alder reaction leads to the formation of a ring, it is termed a **cycloaddition** reaction. The product contains a cyclohexene ring as a structural unit.



94. **What is kinetic isotope effect?**

**Kinetic isotope effect (KIE)** refers to the change in the rate of a chemical reaction upon substitution of an atom in the reactants with one of its isotopes. Formally, it is defined as the ratio of rate constants for the reactions involving the light ( $k_L$ ) and the heavy ( $k_H$ ) isotopically substituted reactants

$$KIE = \frac{k_L}{k_H}$$

95. **What are primary and secondary isotope effects?**

**Primary isotope effect:** isotope effect attributed to a bond breaking event at  $X-H/X-D$  bond. **Secondary isotope effect:** isotope effect attributed to rehybridization or substitution remote from bonds undergoing reaction in the transition state.

96. **What are the types of secondary isotope effects?  $\alpha$  or  $\beta$  secondary isotope effects:**

based on whether the isotope is on a position  $\alpha$  or  $\beta$  to the bond that is changing.  $\alpha$  effect occurs when the atom undergoing reaction has the associated isotope.  $\beta$  effect

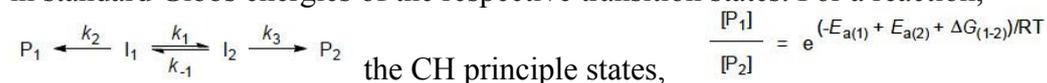
occurs when the associated isotope is on the atom neighboring that which is undergoing reaction.

97. **How is equilibrium constant and free energy related?**

$\Delta G^\circ = -RT \ln K_{eq}$ , where  $\Delta G^\circ$  = change in standard gibbs free energy; R= gas constant; T= temperature;  $K_{eq}$ = equilibrium constant

98. **What is Curtin-Hammett Principle?**

If the rates of reaction are much slower than the rate of interconversion, the Curtin-Hammett principle states that the product distribution is controlled by the difference in standard Gibbs energies of the respective transition states. For a reaction,



**PART-B**

99. **Elaborate Kinetic method – Rate law and mechanism .**

100. **Explain Transition states- Intermediates – Trapping of intermediates (2015)**

101. **Discuss about Microscopic reversibility – Kinetic and thermodynamic reversibility.**

102. **Discuss Primary and secondary isotopes effects.**

103. **Derive Arrhenius equation Eyring equation. (2015) Class notes**

104. **Discuss in detail about  $\Delta G$ ,  $\Delta S$ ,  $\Delta H$ , Thermodynamics of coupled reactions**

**PART-C**

105. **Write short notes on Rate law and mechanism. (Dec 2016)**

106. **Write short notes on Primary and secondary isotopes. (Dec 2016)**

107. **Write short notes on Microscopic reversibility and Eyring equation (Dec 2016)**

**UNIT IV CATALYSIS**

**PART-A**

108. **What are Cofactors, prosthetic groups and Coenzymes?**

Cofactors are non-proteinogenic compounds that are required for the catalytic activity of enzymes and which can bind to the enzyme either in a covalent or non-covalent bond. In the covalent bond, when the cofactor is permanently bound to the enzyme, the cofactor is called a prosthetic group. In case of a non-covalent binding of the cofactor to the enzyme it is called a coenzyme.

109. **What are NAD, NADP?**

NAD, NADP (Nicotinamide adenine dinucleotide, Nicotinamide adenine dinucleotide phosphate): Coenzymes functioning as carriers of hydrogen atoms and electrons in some oxidation – reduction reactions.

110. **Define protein.**

A biological macromolecule which composed of monomers of amino acid. All amino acids are linked by a peptide bond (CONH) to form a polypeptide. Proteins are employed as therapeutic agents, catalyst and materials.

111. **What is the mechanism of proton transfer?**

Proton transfer can catalyze reaction by stabilizing reactive intermediate either by neutralizing a strongly basic intermediate or by ionization of strongly acidic intermediate.

112. **What is biocatalysis? Give an example**

**Biocatalysis** is the use of natural catalysts, such as a catalytic protein which is most of the time referred to as an enzyme, to perform chemical transformations on organic compounds or biochemical reaction inside the living cells. Eg: **Urease** is an enzyme that catalyzes the conversion of urea to ammonia and carbon dioxide.

113. **What is covalent catalysis?**

In covalent catalysis, the enzyme contains a reactive group, usually a nucleophilic residue which reacts with the substrate through a nucleophilic attack.

114. **What is pKa ?**

An acid dissociation constant,  $K_a$ , is a quantitative measure of the strength of an acid in solution. It is the equilibrium constant for a chemical reaction known as dissociation in the context of acid-base reactions.  $pK_a = -\log_{10} K_a$

115. **Describe a proton transfer mechanism in enzyme catalysis?**

The initial step of the catalysis of serine protease involves the histidine of the active site accepting a proton from the serine residue. This prepares the serine as a nucleophile to attack the amide bond of the substrate. This mechanism includes donation of a proton from serine (a base, pKa14) to histidine (an acid, pKa6), made possible due to the local environment of the bases.

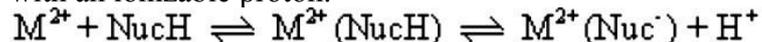
116. **Name some nucleophilic groups of enzymes.**

Carboxylates (Aspartate, glutamate), thiol (cystine), hydroxyl (Serine, tyrosine) **11. Describe the Schiff base formation in covalent catalysis of enzymes.**

117. Schiff bases appear to be an important intermediate in a number of enzymatic reactions involving interaction of an enzyme with an amino or a carbonyl group of the substrate. The condensation of a primary amine in an enzyme usually that of a lysine residue, with a carbonyl group of the substrate to form an imine, or Schiff base.

118. **How metal ion helps in enzyme catalysis?**

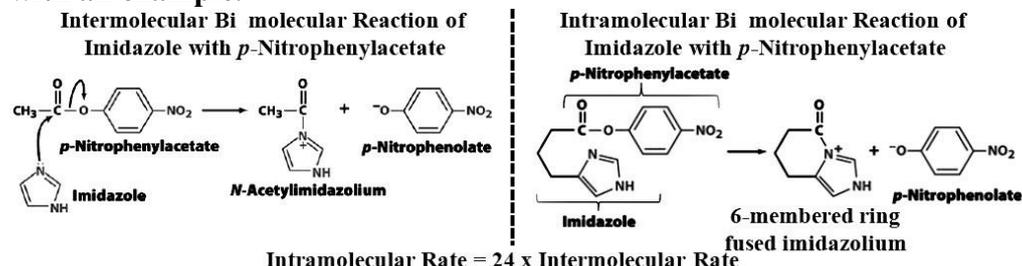
Metals ions act as electrophilic catalysts, stabilizing the increased electron density or negative charge that can develop during reactions Or provide a powerful nucleophile at neutral pH. Coordination to a metal ion can increase the acidity of a nucleophile with an ionizable proton.



119. **Give some examples for enzymes involved in metal ion catalysis.**

Carboxypeptidase A, Carbonic anhydrase, Enolase, Thermolysin

120. **Compare intermolecular reaction rate with intramolecular reaction rate with an example.**



121. **What is the significance of Km in Michaelis menten equation?**

- $K_m$  is a dissociation constant, so the smaller the  $K_m$  the stronger the interaction between E and S.
- If  $v_0$  is set equal to  $1/2 V_{max}$ , then the relation  $V_{max} / 2 = V_{max}[S] / K_m + [S]$  can be simplified to  $K_m + [S] = 2[S]$ , or  $K_m = [S]$ . This means that at one half

of the maximal velocity, the substrate concentration at this velocity will be equal to the  $K_m$ .

- c. Each enzyme has a characteristic  $K_m$  for a given substrate that show how tight the binding of the substrate is to the enzyme.

122. **What is turnover number?**

The constant,  $k_{cat}$  ( $\text{sec}^{-1}$ ), is called the **turnover number** because under saturating substrate conditions, it represents the number of substrate molecules converted to product in a given unit of time on a single enzyme molecule.

123. **What is an inclusion compound?**

An **inclusion compound (Clathrate)** is a complex in which one chemical compound (the "host") forms a cavity in which molecules of a second "guest" compound are located. Covalent or ionic bonds are not necessary for the inclusion complex.

124. **What is cyclodextrin? Mention its uses.**

Cyclodextrins are host molecules which form monomolecular inclusion compounds. Cyclodextrins are cyclic oligosaccharides which consist of 6( $\alpha$ - Cyclodextrins), 7 ( $\beta$  Cyclodextrins) or 8( $\gamma$  Cyclodextrins) glucopyranose units. Due to the hydrophilic outside the Cyclodextrin can be dissolved in water. The apolar cavity inside Cyclodextrin provides a hydrophobic matrix, that entrap variety of guest molecules, thereby forming inclusion complex.

125. **What is the principle of Phase transfer catalysis (PTC)?**

The principle of PTC is based on the ability of certain phase-transfer agents (the PT catalysts) to facilitate the transport of one reagent from one phase into another (immiscible) phase wherein the other reagent exists. Thus, reaction is made possible by bringing together the reagents which are originally in different phases.

126. **List out applications of Immobilized enzyme. (Nov/Dec 2011)**

Production of L amino acids from D,L-acyl amino acids using Aminoacylase.  
Production of high fructose corn syrup from starch using  $\alpha$  amylase, glucoamylase  
Production of aspartic acid from fumaric acid using Aspartase

127. **Define Damkohler Number. (Nov/Dec 2102)**

$$Da = \frac{\text{reaction rate}}{\text{convective mass transport rate}}$$

128. **Give an example of phase transfer catalysis. (Dec 2016)**

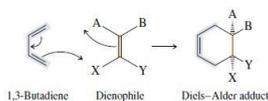
The principle of PTC is based on the ability of certain phase-transfer agents (the PT catalysts) to facilitate the transport of one reagent from one phase into another (immiscible) phase wherein the other reagent exists. Thus, reaction is made possible by bringing together the reagents which are originally in different phases.

- a. Eg. Extraction of penicillin with organic solvent

129. **What are coenzymes and give an example. (Dec 2016)**

NAD, NADP (Nicotinamide adenine dinucleotide, Nicotinamide adenine dinucleotide phosphate): Coenzymes functioning as carriers of hydrogen atoms and electrons in some oxidation – reduction reactions

130. **What is Diels-Alder adduct?**



The Diels–Alder reaction is the *conjugate addition of an alkene to a diene*. Using 1,3-butadiene as a typical diene, the Diels–Alder reaction may be represented by the general equation:

The alkene that adds to the diene is called the **dienophile**. Because the Diels–Alder reaction leads to the formation of a ring, it is termed a **cycloaddition** reaction.

#### **PART-B**

131. **Discuss in detail about Proton transfer.**
132. **Elaborate metal ions. (2015)**
133. **Describe Intra molecular reactions.**
134. **Explain about Covalent catalysis**
135. **Describe Catalysis by organized aggregates and phases Inclusion Complexation**

#### **PART-C**

136. **Explain in detail about proton transfer mechanism with the help of a co-enzyme catalyzed reaction. (Dec 2016)**
137. **Explain in detail the mechanism of covalent catalysis with an example that you have studied. (Dec 2016)**
138. **Describe Catalysis by organized aggregates and phases Inclusion Complexation**

### **UNIT V BIOORGANIC REACTIONS**

#### **PART A**

139. **What is protein sequencing?**  
Protein sequencing is a technique to determine the amino acid sequence of a protein, as well as which conformation the protein adopts and the extent to which it is complexed with any non-peptide molecules.
140. **What is N-terminal amino acid sequencing?**  
**N-terminal amino acid analysis:**  
Determining which amino acid forms the *N*-terminus of a peptide chain is useful for two reasons: to aid the ordering of individual peptide fragments' sequences into a whole chain, and because the first round of Edman degradation is often contaminated by impurities and therefore does not give an accurate determination of the *N*-terminal amino acid. A generalised method for *N*-terminal amino acid analysis follows:
  - a. React the peptide with a reagent that will selectively label the terminal amino acid.
  - b. Hydrolyse the protein.
  - c. Determine the amino acid by chromatography and comparison with standards.
141. **What is C-terminal amino acid sequencing?**  
**C-terminal amino acid analysis:**  
The number of methods available for C-terminal amino acid analysis is much smaller than the number of available methods of N-terminal analysis. The most common method is to add carboxypeptidases to a solution of the protein, take samples at regular intervals, and determine the terminal amino acid by analysing a plot of amino acid concentrations against time. This method will be very useful in the case of polypeptides and protein-blocked N termini. C-terminal sequencing would greatly help in verifying the primary structures of proteins predicted from DNA sequences and to detect any postranslational processing of gene products from known codon sequences.
142. **State Sanger's strategy for protein sequencing.** Sanger's strategy can be outlined as follows:

Determine what amino acids are present and their molar ratios.

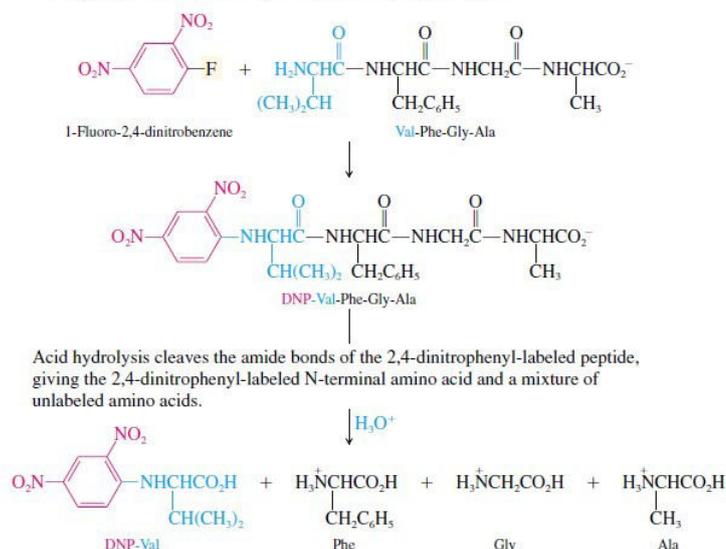
Cleave the peptide into smaller fragments, separate these fragments, and determine the amino acid composition of the fragments.

Identify the N-terminal and the C-terminal amino acid in the original peptide and in each fragment.

Organize the information so that the amino acid sequences of small fragments can be overlapped to reveal the full sequence.

143. **Give the Sanger's sequencing reaction.**

The reaction is carried out by mixing the peptide and 1-fluoro-2,4-dinitrobenzene in the presence of a weak base such as sodium carbonate. In the first step the base abstracts a proton from the terminal  $\text{H}_3\text{N}^+$  group to give a free amino function. The nucleophilic amino group attacks 1-fluoro-2,4-dinitrobenzene, displacing fluoride.



144. **What is bond fission?**

The breaking of the covalent bond of a molecule to form two or more fragment species is called bond fission.

145. **What are the types of bond fission?**

1) Homolytic fission 2) Heterolytic fission

146. **What is homolytic fission?**

In homolytic fission, one electron of the shared pair in the covalent bond goes with each of the bonded atoms forming free radicals. Organic reactions which proceed by homolytic fission are called free radical reactions/nonpolar reactions.

147. **What is heterolytic fission?**

In heterolytic fission, the bonding electron pair is shifted to the more electronegative atom. Heterolytic fission normally occurs in solution phase, in presence of polar solvents. The organic reactions which proceed by heterolytic fission are called ionic/polar reactions.

148. **What are oligomeric proteins? Give examples.**

Oligomeric proteins consist of two or more polypeptide chains, which are usually linked to each other by non-covalent interactions and never by peptide bonds. The molecular weight is usually in excess of 35,000. E.g.: lactate dehydrogenase, lactose synthase, pyruvate dehydrogenase and tryptophan synthase.

149. **Differentiate between peptide and amide bond.** N-substituted amide bond is peptide bond.

$\text{R-CO-NH}_2$  (amide bond)

$\text{R-CO-NH-R}$  (peptide bond)

150. **Mention the different kinds of non covalent bonding interaction that stabilizes the protein structure. (May 2011).**

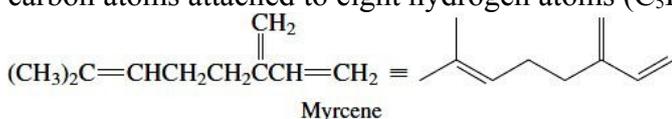
A number of non-covalent interactions such as hydrogen bonding, ionic interactions, Van Der Waals forces, and hydrophobic packing helps to stabilize the protein structure.

151. **What is solid state peptide synthesis (Dec '2012)**

SSPS allows the synthesis of natural peptides which are difficult to express in bacteria, the incorporation of unnatural amino acids, peptide/protein backbone modification, and the synthesis of D-proteins, which consist of D-amino acids.

152. **What are terpenes? Give an example.**

**Terpene**, any of a class of hydrocarbons occurring widely in plants and animals and empirically regarded as built up from isoprene, a hydrocarbon consisting of five carbon atoms attached to eight hydrogen atoms (C<sub>5</sub>H<sub>8</sub>).



153. **Write the classification of terpenes based on number of carbon atoms.**

Monoterpene(C-10), Sesquiterpene(C-15), Diterpene (C-20), Sesterpene(C-25), Triterpene(C-30) and Tetraterpene(C-40)

154. **Classify amino acids based on polarity. (May 2011).**

Based on polarity, amino acids are classified into four groups as follows,

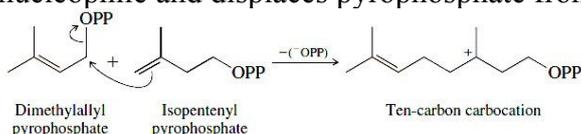
Non-polar amino acids- alanine, valine, leucine, isoleucine, phenyl alanine, glycine, tryptophan, methionine and proline.

Polar amino acids with no charge-serine, threonine, tyrosine, cysteine, glutamine and asparagine.

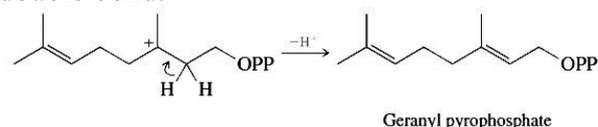
Polar amino acids with positive charge- lysine, arginine and histidine. Polar amino acids with negative charge- aspartic acid and glutamic acid

155. **Write about the C-C bond formation in synthesis of geranyl pyrophosphate**

Using the π-electrons of C-C double bond, isopentenyl pyrophosphate acts as a nucleophile and displaces pyrophosphate from dimethylallyl pyrophosphate.

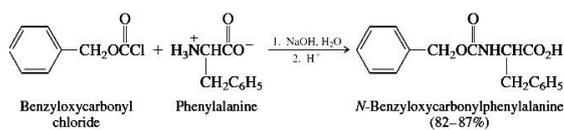


The tertiary carbocation formed in this step can react according to any of the various reaction pathways available to carbocations. One of these is loss of a proton to give a double bond.



156. **How amino groups are protected in SSPS?**

The reactivity of an amino group is suppressed by converting it to an amide, and amino groups are most often protected by acylation. The benzyloxycarbonyl group is one of the most often used amino-protecting groups. It is attached by acylation of an amino acid with benzyloxycarbonyl chloride.



157. **What is DNA sequencing?**

**DNA sequencing** is the process of determining the precise order of nucleotides within a **DNA** molecule. It includes any method or technology that is used to determine the order of the four bases—adenine, guanine, cytosine, and thymine—in a strand of **DNA**.

158. **Write the Sanger's strategy for amino acid sequencing.**

- a. Determine what amino acids are present and their molar ratios.
- b. Cleave the peptide into smaller fragments, separate these fragments, and determine the amino acid composition of the fragments.
- c. Identify the N-terminal and the C-terminal amino acid in the original peptide and in each fragment.
- d. Organize the information so that the amino acid sequences of small fragments can be overlapped to reveal the full sequence.

159. **What are restriction enzymes?**

An enzyme produced chiefly by certain bacteria, that has the property of cleaving DNA molecules at or near a specific sequence of bases.

160. **What are the steps involved in sanger di-deoxy method of sequencing.**

- a. Ability to synthesize faithfully a complementary copy of a single stranded DNA template using a synthetic 5'end labeled oligodeoxynucleotide as primer.
- b. Polymerization using low concentration of one the 4ddNTPs and in higher concentration of normal dNTPs, termination of growing point of the DNA chain using 2'3'-dideoxy nucleotide triphosphate as substrate,
- c. Separation of fragment using gel electrophoresis,
- d. Analyzing the separated fragments using autoradiography

161. **What is an isoelectric point (pI)?**

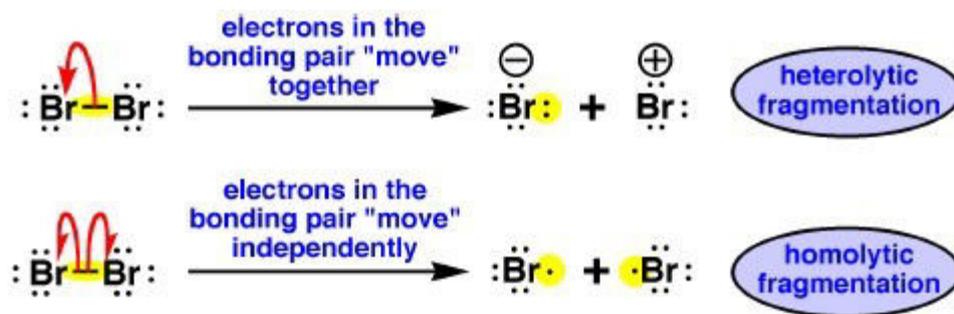
The pH of an aqueous solution at which the concentration of the zwitterions is a maximum is called the isoelectric point (pI).

162. **What is the effect of temperature on the stereochemistry of enzymatic reactions. (Dec 2016)**

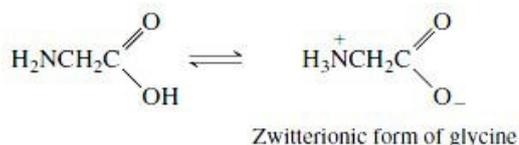
Stereoselectivity decreases at higher temperatures and in the presence of NADP analogues.

163. **Give examples of haemolytic and heterolytic reactions. (Dec 2016)**

Most organic transformations involve the movement of electron pairs (heterolytic reactions). There are a few important addition reactions, however, in which the electron reconfiguration involves the movement of single electrons. Whereas heterolytic bond cleavage leads to ion pairs, homolytic bond cleavage results in unpaired electrons – or free radicals. Some weak bonds have a tendency to fragment homolytically (e.g., peroxides, halogens). Chemists use a slight variation of curved arrow notation to show the movement of single electrons. For eg. heterolytic vs. homolytic fragmentation of Br<sub>2</sub>.



164. Give the structure of zwitter ion.



165. Define protein sequencing.

**Protein sequencing** is a technique to determine the amino acid sequence of a protein, as well as which conformation the protein adopts and the extent to which it is complexed with any nonpeptide molecules.

166. Give the type of amino acid sequencing.

N-terminal amino acid analysis

C-terminal amino acid analysis

#### PART-B

167. Elaborate Timing of Bond formation and fission with an example of C-C bond formation and fission

168. Explain about Acyl group transfer

169. Discuss Catalysis of proton transfer reactions

170. Describe Transfer of hydride ion

171. Write in detail about Alkyl group Transfer and Terpene biosynthesis (2015)

172. Explain Merrifield state peptide synthesis – Sanger method for peptide and DNA sequencing. (2015)

#### PART-C

173. Explain in detail about terpene biosynthesis. Explain solid phase peptide biosynthesis with a diagram.

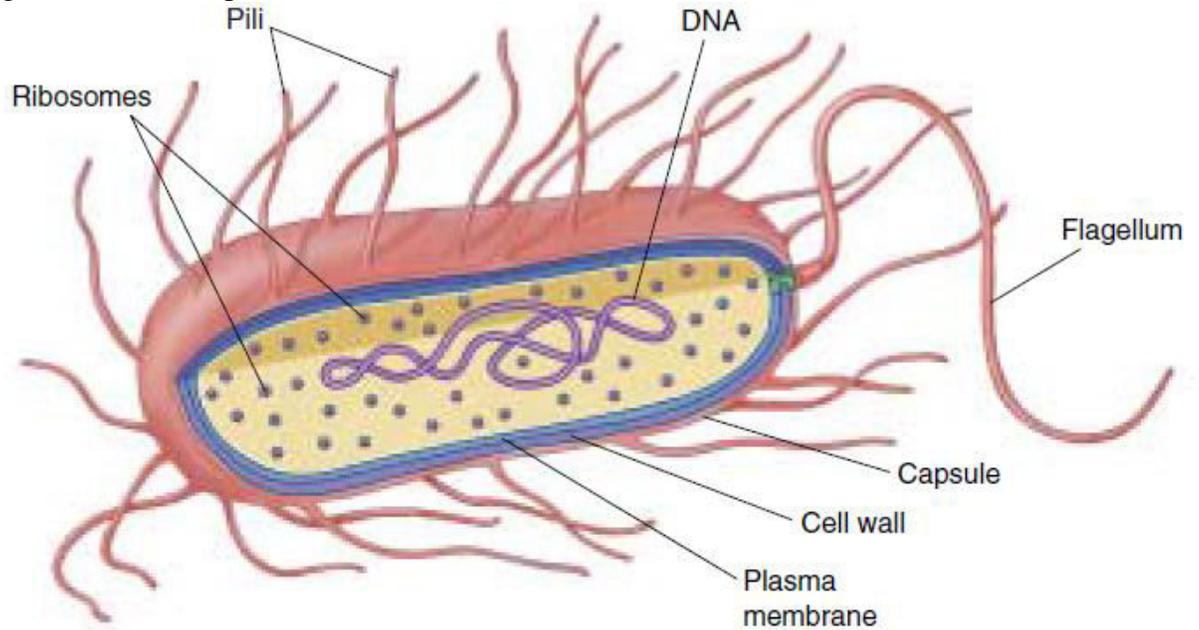
**UNIT I**  
**CELL STRUCTURE AND FUNCTION OF THE ORGANELLES**

**PART – A**

**TWO MARKS QUESTION AND ANSWERS**

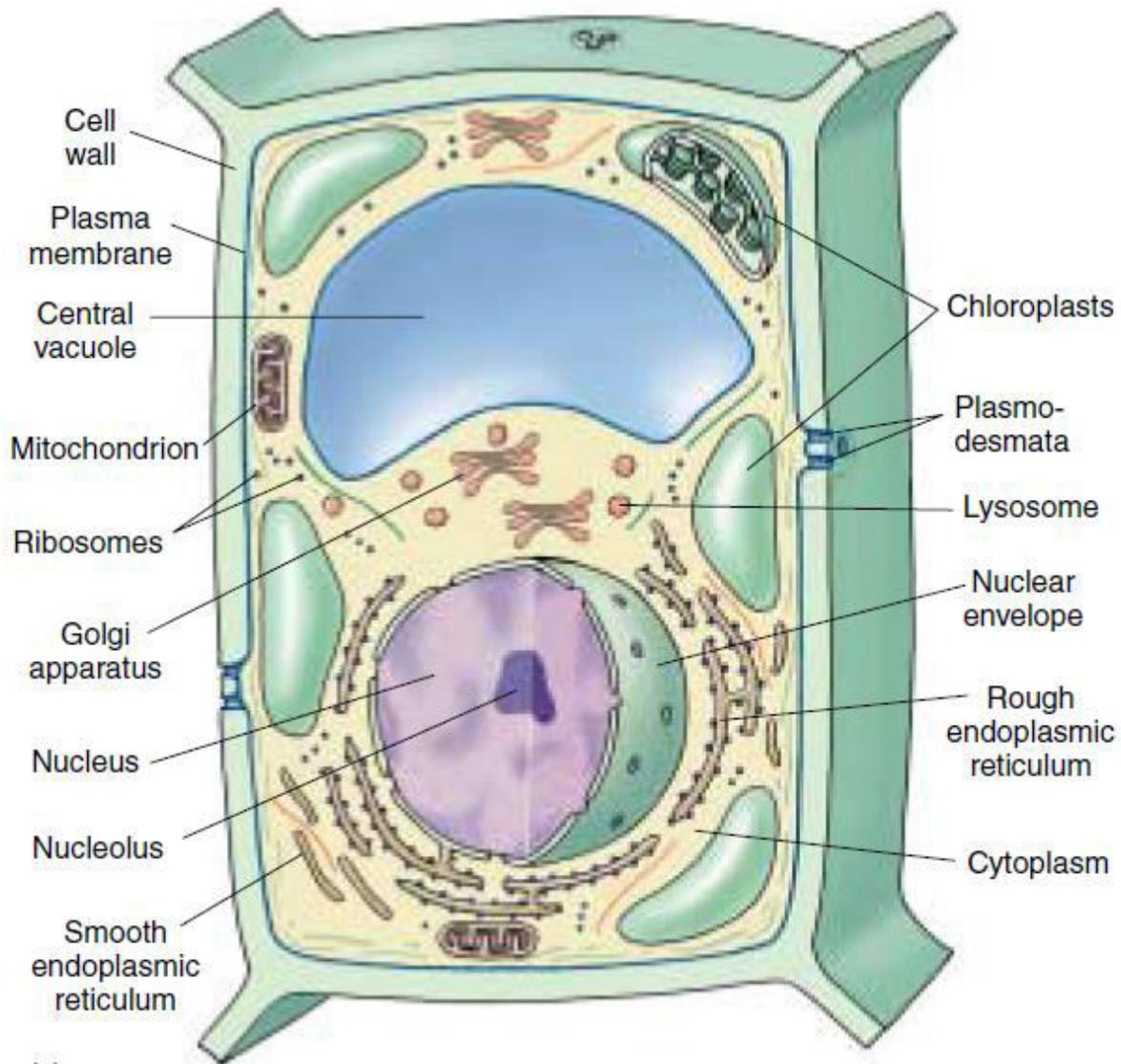
**1. Define prokaryotic cell and draw the structure of bacterial cell.**

Prokaryotic cell is the single closed compartment that is surrounded by plasma membrane. It lacks a defined nucleus and it lack histones. It has simple internal organization. Example: Bacteria.



**2. Define eukaryotic cell and draw the structure of plant cell.**

Single membrane (plasma membrane) surrounds the cell. But interior contains many membrane-limited compartments/organelles. It is the defining characteristics and segregation of cellular DNA within a defined nucleus which is bounded by double membrane. Example: fungi, yeast, plants and animals.



**3. What is the main role of lysosomes and peroxisomes?**

Lysosome is the acidic organelle and contains degradative enzymes. It is a single membrane vesicle containing hydrolytic enzyme which function for intracellular and extracellular digestion; digest materials taken in by endocytosis and pinocytosis.

Peroxisome is spherical form rich in oxidative enzyme and other such as catalase, peroxidase and D-amino acid oxidase common in plant cell carry our oxidative reactions. It degrades fatty acids and toxic components.

**4. Define cisternae. Write the types of endoplasmic reticulum.**

It is a network of closed, flattened membrane bound sac called cisternae. The types are smooth endoplasmic reticulum and rough endoplasmic reticulum. Smooth endoplasmic reticulum is smooth because of lack of ribosomes. The fatty acid and phospholipid synthesis takes place. The cytosolic face of rough endoplasmic reticulum has ribosomes. It synthesise certain membrane and organelle protein and virtually all protein to be secreted from cell.

**5. Define chloroplasts, thylakoid and grana.**

Chloroplast is spheroid/ovoid structures in plant cell and it contains complex system of thylakoid membrane in their interiors. These membranes contain pigments and enzymes that absorb light and produce ATP during photosynthesis.

Thylakoid is an extensive internal system of inter-connected membrane limited sac called thylakoid which are flattened to form disks. Thylakoid often form stack called grana and are embedded in matrix, the stroma.

6. **Write the properties of lipid bilayer.**

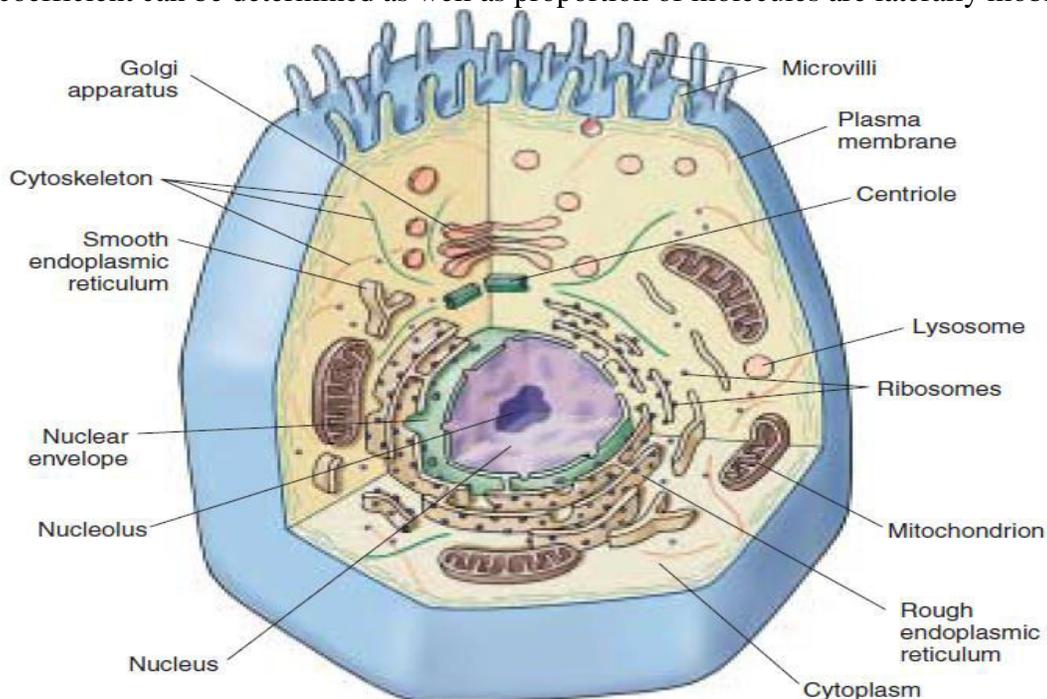
Hydrophobic core is an impermeable barrier that prevents the diffusion of water-soluble (hydrophilic) solutes across the membrane. The second property of bilayer is stability. It is maintained by hydrophobic and van der Waal interaction between lipid chains. Even though the exterior aqueous environment can vary ionic strength and pH, the bilayer has retained its strength and stability.

7. What are the classes of lipids and proteins found in biomembrane?

Phosphoglycerides, Spingholipids and steroids are the three classes of lipids found in biomembrane. All are amphipathic molecules having polar (hydrophilic head) and non-polar (hydrophobic tail). Integral protein, Lipid-anchored protein and Peripheral protein can be classified into three based on the nature of membrane-protein interaction.

8. What is FRAP? Draw the structure of animal cell.

The lateral movement of specific plasma membrane protein and lipid can be quantified by a technique called Fluorescence Recovery after Photo bleaching (FRAP). In this method, rate at which membrane lipid/protein molecules moved and their diffusion coefficient can be determined as well as proportion of molecules are laterally mobile.



9. Define lipid-anchored membrane protein.

Lipid-anchored membrane proteins are bound covalently to one/more lipid molecules. The hydrophobic carbon chain of attached lipid is embedded in one leaflet of membrane and anchors the protein to the membrane. The polypeptide chain itself does not enter the phospholipid bilayer.

10. What is osmosis?

Osmosis is defined as water move across such a semi-permeable membrane from a solution of low solute (high water) concentration to one of high solute (low water) concentration until total solute concentration and this water concentration on both sides are equal.

11. Define the term isotonic, hypertonic and hypotonic solution.

When most cells animal cells are placed in isotonic medium (one with total concentration of solute equal to that of cell interior) there is no net movement of water in/out of the cells.

a. In hypertonic solution (one with higher solute concentration than that of cell interior), water flows out of the cell and causing them to shrink.

b. In hypotonic solution (one with lower solute concentration than that cell interior), water flows into the cell and causing them to swell.

12. Define the term plasmodesmata and desmosome.

Adjacent plant cell are held together by a thin layer of cementing material called middle lamella. Such cells are further interconnected by fine channels passing through the cell wall and the middle lamella. These are called plasmodesmata.

Desmosome are composed of fine tonofilament that run across two parallel thickenings of cell in some regions, separated by intercellular spaces. It provide anchorage to the adjacent cells by strong point of attachments.

13. Define tight junction and explain the function of gap junction.

Tight junction is formed through fusion of plasma membrane of adjacent cells at the point of contact, without leaving an intercellular space. They may be belt-like/band-like in form, completely sealing off the area of contact.

The main role of gap junction/nexus is to form cellular adhesion and also to form intercellular communication by metabolic coupling and electrical coupling.

14. What is ECM? (Nov/Dec 2015) Explain the functions.(Nov/Dec 2014)

Cells frequently need to protect themselves from environment by developing extra cellular matrix (ECM) around a gap of cells. It is a complex structural entity that surrounds and supports cells. It often refers as connective tissue. The extracellular materials secreted from cell themselves perform a variety of functions:

They help in adhesion of cell layers.

They allow movement of cells to different locations.

They form sieve-like structures for flow of macromolecules.

They help in the formation of different layers of cells and

They provide extraneous structures.

15. What is CAM and SAM?

- a. Cell Adhesion Molecules (CAM) is family of proteins which have very high content of sialic acid responsible for cell aggregation. They may be seen from projecting from bilipid layer of plasma membrane.
- b. Substrate Adhesion Molecules (SAM) is a cell attaches to an artificial substrate, it starts secreting an extracellular material/microexudate. This microexudate/SAM contains fibronectin, heparin sulphate ,glycosaminoglycans and trace amounts of collagen.

16. What is collagen?

- a. Collagen is fibrous protein of high tensile strength. It is characteristic of connective tissue present in all animals abundant in skin, bone, tendons and cartilage. It is secreted in extracellular space from which it can be extracted. The collagen fibers are polymers composed of three polypeptide chains twisted around each other and bonded by hydrogen bonds and hence called trimers.

17. Define glysoaminoglycans.

Glycosaminoglycans are sugar polymers which are different from other glucose polymers (starch, glycogen etc.). These are amorphous in appearance, extremely viscous and occupy huge space. The carbohydrate chain of glycosaminoglycans exists as repeating disaccharide as wells in which one of the sugar is always an aminosugar, either N-acetylglucosamine or N-acetylgalactosamine.

18. What is cytoskeletal protein?

The interior of the cell matrix is well-organized and consists of reticulum of protein fibers responsible for its shape and organization. This has been named as cytoskeletal protein. It is composed of three well-defined fibrous components. They are Microfilament, Microtubule and Intermediate filament.

19. Explain the function of microfilament.

Muscle contraction, cell movement, nerve outgrowth, tubular gland formation, movement of intestinal microvilli, gastrulation and cytoplasmic streaming. In animal cells, cytokinesis and cell division are brought by microtubule of spindle.

20. Define tubulin and micelle.

Microtubule is a hollow cylindrical cell organelles of each microtubule made up of globular protein subunits called tubulin. The tubulin subunits are spirally arranged and it is formed in pair is called heterodimer.

21. Micelle is the amphipathic substances were found to emulsify mixtures of immiscible polar and non-polar liquids in the form of spherical droplets coated with monolayers; in

aqueous solution spherical micelles (i.e., bilayer envelopes) could be formed under certain conditions.

22. Write the importance of carbon and water to the cells. (Apr/May 2018)

Cells are composed of water, inorganic ions, and carbon-containing (organic) molecules. Water is the most abundant molecule in cells, accounting for 70% or more of total cell mass. The interactions of polar and nonpolar molecules with water and with each other play crucial roles in the formation of biological structures, such as cell membranes. Carbon is the basis of many of the complex organic compounds vital to life, such as the glucose ring (along with a single oxygen molecule), and the backbone of the polypeptide chains that form the different proteins in the bodies of living things.

23. Differentiate prokaryotic cell and eukaryotic cell with example. (Apr/May 2018)

Prokaryotic cell is the single closed compartment that is surrounded by plasma membrane. It lacks a defined nucleus and it lack histones. It has simple internal organization. Example: Bacteria.

Eukaryotic cell is the Single membrane (plasma membrane) surrounds the cell. But interior contains many membrane-limited compartments/organelles. It is the defining characteristics and segregation of cellular DNA within a defined nucleus which is bounded by double membrane. Example: fungi, yeast, plants and animals.

24. What are desmosomes? (Apr/May 2018) & (May/June 2016)

Desmosome are composed of fine tonofilament that run across two parallel thickenings of cell in some regions, separated by intercellular spaces. It provide anchorage to the adjacent cells by strong point of attachments.

25. What is the basic difference in the organization of DNA in prokaryotic and Eukaryotic cell? (May/June 2016)

Prokaryotic DNA:

Is found freely in the cytoplasm (within a region called the nucleoid)

Is naked (i.e. not bound with proteins and therefore doesn't form chromatin)

Genomes are compact (contain little repetitive DNA and no introns)

Eukaryotic DNA:

Is contained within a nucleus

Is bound to histone proteins

Genomes contain large amounts of non-coding and repetitive DNA (including introns)

26. What is the function of peroxisomes? (May/June 2016)

Peroxisome is spherical form rich in oxidative enzyme and other such as catalase, peroxidase and D-amino acid oxidase common in plant cell carry our oxidative reactions. It degrades fatty acids and toxic components.

27. Describe the function cell adhesion molecules. (May/June 2016)

The adhesion of cells to one another to provide organised tissue structure  
the transmission of extracellular cues and signals across the cell membrane  
the migration of cells through the regulation of CAM assisted adhesions

28. What are the functions of membrane bound proteins? (Nov/Dec 2014)

The functions of membrane bound proteins are Signal transduction, Cell-cell recognition, Intercellular joining, Enzymatic activity, Cell-cell recognition and Attachment to the cytoskeleton and extracellular matrix (ECM).

29. What is the significance of motor protein? (Nov/Dec 2014)

Motor proteins are enzymes that convert chemical energy into motion. Chemical energy is obtained from the hydrolysis of ATP and the motion is generated by the conformational changes depending on the bound nucleotide such as myosin, kinesin and dynein. Motor proteins play an important role in muscle contraction, cell migration, chromosome segregation, morphogenesis and beating of sperms and cilia.

30. What are the three types of endocytosis? (Nov/Dec 2014)

The three types are Phagocytosis, Pinocytosis and Receptor-Mediated Endocytosis.

31. What are functions of flagella and pili? (Nov/Dec 2015)

The function of flagella is to assist in locomotion, act as sensory organ and adhesion. The primary function of pili is to attach a bacterial cell to specific surfaces or to other cells. Pili can also aid in attachment between bacterial cells. Some bacteria are able to produce conjugation pili that allow for the transfer of DNA from one bacterial cell to another.

32. What is the importance of cytoskeleton protein? (Nov/Dec 2015)

The interior of the cell matrix is well-organized and consists of reticulum of protein fibers responsible for its shape and organization. This has been named as cytoskeletal protein. The cytoskeleton provides structure like our skeleton, but it also acts like a highway to transport materials around the cell, allows cells to move, and aids in cell division.

### **PART-B (16 MARKS QUESTIONS)**

33. Draw neatly the structure of prokaryotic and eukaryotic cell and differentiate between them.

34. Explain the location and functions of mitochondria, chloroplasts and nucleus.

35. Define clathrin. Elaborate the endoplasmic reticulum, golgi vesicles and endosome.

36. Describe in detail about the eukaryotic structure and its organelles.

37. Explain in detail about the lipid composition and structural organization of biomembrane.

38. Write elaborately about the bio membrane of protein.

39. Explain in detail about CAM and CJM.

40. Define ECM. Elaborate your answer.

41. Explain in detail about the cytoskeletal protein.
  42. Describe the process of peroxisome, lysosome, ribosome and vacuole.
  43. Explain about microtubule and microfilament.
  44. How the lipid composition influences the physical properties of membrane? Explain FRAP.
  45. Describe elaborately cell-cell junction.
  46. Define the term: Desmosome, gap junction, plasmodesmata and draw the structure of lipid bilayer.
  47. Describe in detail about intermediate filament, integral membrane protein and peripheral membrane protein.
- 
48. What are cytoskeletal proteins? Explain their types, structure and functions? (Apr/May 2018)
  49. Describe the structure and function of cell membrane and Give a detailed account on tight junctions. (Apr/May 2018)
  50. Draw a neat diagram explain the characteristic feature of eukaryotic cell and describe the function of their organelles. (May/June 2016)
  51. Explain the structure and function of microfilament, (May/June 2016)
  52. Explain about gap junctions and connexins. (May/June 2016)
  53. Describe the structure and functions of mitochondria and golgi apparatus. (Nov/Dec 2014)
  54. Elaborate the structural organization of cell membrane. (Nov/Dec 2014) & (Nov/Dec 2015)
  55. Describe the structure of prokaryotes. (Nov/Dec 2014) & (Nov/Dec 2015)
  56. Explain the structural organization of three types of cytoskeleton proteins. (Nov/Dec 2014)
  57. Describe cell-cell junction and cell-cell matrix junction. (Nov/Dec 2014)
  58. Describe the structure and functions of nucleus and mitochondria. (Nov/Dec 2015)
  59. Elaborate microtubule structure and function. (Nov/Dec 2015)
  60. Discuss about various types of cell junctions. (Nov/Dec 2015)

## UNIT II

### CELL DIVISION, CANCER, APOPTOSIS AND IMMORTALIZATION OF CELLS

#### PART – A

#### TWO MARKS QUESTION AND ANSWERS

1. What is cell cycle?

In eukaryotic cells, the cells are divided by a complex process of mitosis. Eukaryotic cell division takes place through a series of orderly events known as cell cycle.

2. What are the different phases of cell cycle?

The different phases of cell cycle are Gap1 (G1 phase), S phase, Gap 2 (G2 phase), Mitosis (M phase).

3. Define mitosis. (Apr/May 2018)

Mitosis is defined as the “division of a cell into two identical daughter cells each with a nucleus having the same amount of DNA, the same number of chromosome and the same amount of genes as the parent cell”.

4. What are types of mitosis occurs in organisms?

The types are intranuclear mitosis, extranuclear mitosis, anastral mitosis, astral mitosis, endomitosis, symmetrical mitosis and asymmetrical mitosis.

5. Define karyokinesis and cytokinesis.

The division of nuclei into two daughter nuclei is called karyokinesis. The division of cytoplasm into two daughter cells is called cytokinesis.

6. What are the phases of karyokinesis? Define cell plate.

It consists of four phases are prophase, metaphase, anaphase and telophase. The phragmoplasts are fuse together to form a flat disc like structure called cell plate.

7. Define phragmoplasts.

8. After the completion of karyokinesis in plant cell, a cell plate develops between the two daughter nuclei. Many small vesicles developed from golgi complex and endoplasmic reticulum get accumulated at the equatorial plane across the spindle fiber. These vesicles are called phragmoplasts.

9. Define meiosis. (Apr/May 2018)

Meiosis is also called reduction division because the chromosome number is reduced to haploid from diploid. It takes place only in reproductive cells during the formation of gametes. The cells in which meiosis takes place are termed meiocyte. Meiosis produces four daughter cell from parent cell.

10. What is meant by heterotypic and homotypic division?

It is the first meiotic division during which the diploid cell is divided into two haploid cells. The daughter cell resulting from the divisions are different from the parent cell in chromosome number. Hence the first meiotic division is called heterotypic division.

It is the second meiotic division. During this division the two haploid cells are formed during the first meiotic division divide into four diploid cells. The daughter cells are similar to parent cells in the chromosome number. Hence this division is called homotypic division.

11. Define the term bivalent, diad, synapsis and bouquet stage.

Two homologous chromosomes approach each other and begin to pair. The pairing is called synapsis. Each pair consists of a maternal chromosome (the chromosome of the mother) and a paternal chromosome (the chromosome of the father). The pairs so termed are bivalents.

The pairing usually starts from ends, and proceed towards the centromere. This peculiar state of orientation, polarization and association is described as bouquet stage.

12. When separated in each chromosome the sister chromatids are connected by a centromere. This stage of the chromosome is called diad.

13. Define chiasmata.

The homologous chromosomes of each pair begin to separate because of the gradual disappearance of force of attraction between them. However, the two homologous chromosomes do not completely separate but remain attached together at one/more points as indicated by X arrangements known as chiasmata.

14. Define crossing over.

The two homologous chromosomes do not completely separate but remain attached together at one/more points as indicated by X arrangements known as chiasmata. The chromatids break at these points. The broken segments are interchanged. As a result a genetic recombination takes place. The interchange of chromatin material is described as crossing over.

15. Define tetrad.

Each individual chromosome of each bivalent begins to split longitudinally into two similar chromatids. As a result each bivalent now contains four chromatids. This is described as tetrad stage.

16. Write the significance of meiosis.

Gametes are produced by meiosis

If there is no meiosis, the chromosome number is doubled/quadrupled. This would result in formation of monstrosities (abnormal forms).

The constant number of chromosome in a given species is maintained by meiosis.

Owing to crossing over, the hereditary factors(gene) from male and female parents get mixed. This causes genetic variation among species variations are the raw materials for evolution.

17. What are the types of tumour?

There are two types of tumour. They are Benign and malignant tumour. Benign tumour are always localized and consists of well differentiated cell similar to tissue of origin. Such tumours never establish growth in other parts of the body. Malignant tumors are usually invasive type of tumour derived from single cell, thus monoclonal in character. Clusters/ group of malignant cells are detached from malignant neoplastic growth and get distributed to other location in the body through circulation where they establish secondary tumours. It can be called as metastasis.

18. Define the term carcinoma and sarcoma. Expand MAP and ERK.

Tumours originating from ectoderm/endoderm give rise to carcinoma. Tumours originating from mesoderm is called sarcoma. MAP- Mitogen-activated protein kinase and ERK-Extracellular signal regulated kinase.

19. Define ras.

20. Ras protein are prototype of large family of approximately 50 related proteins frequently called small GTP-binding protein because Ras and its relatives are about half the size of G-protein alpha subunit. While Ras protein regulate cell growth and differentiation. Activation of ERK is mediated by two upstream protein kinase which are coupled to growth factor receptor by a GTP-binding protein called Ras.

21. Differentiate apoptosis Vs necrosis.

Apoptosis ( Programmed Cell Death- PCD) is a well-defined process and regulated series of events and is an active process distinct from death in response to tissue damage; in which cells die in a process called necrosis. In apoptosis, content of the cell are not released in extracellular but in necrosis, contents are released leads to damage surrounding cells called inflammation.

22. Define stem cell.

Stem cells are undifferentiated biological cell give rise to renewing cell population of body through well directed pathway of differentiation. In mammals, stem cells are broadly divided as Embryonic stem cell (ESC) and Adult stem cell (ASC).

23. What are the sources of stem cell? Explain totipotent, pluripotent and multipotent stem cell.

Bone marrow, adipose tissue and Umbilical cord blood are the main sources of stem cell.

Totipotent stem cell also called omnipotent cell can differentiate into any type i.e., embryonic and extra-embryonic types to produce a complete viable organism. Pluripotent stem cell are descendants of totipotent cell and can differentiate into all kinds of cells in body since these cells are derived from any of three germ layers. Multipotent stem cell can differentiate into limited number of types which form closely related family of cells.

24. What is the feature of crossing over in meiosis? (Nov/Dec 2014)

Occurs at two levels, at gross chromosomal level (chromosomal recombination) and at DNA level (genetic recombination).

Occurs between non-sister chromatids of homologous chromosomes.

Exchange is normally reciprocal but sometimes unequal.

Frequency of crossing over is closely related to physical distance between genes located on chromosomes.

### **PART-B (16 MARKS QUESTIONS)**

25. What is cell cycle? Explain the phase of cell cycle with a neat diagram.
26. Describe in detail about mitosis and the significance of mitosis with a neat diagram.
27. Describe in detail about meiosis and the significance of meiosis with a neat diagram.
28. Explain the heterotypic division of meiosis with a neat diagram.
29. Explain in detail about the control of cell cycle with a neat diagrammatic representation.
30. How cell become cancerous? Explain the characteristics and types of cancer cells.
31. Describe in detail about the activation of Ras and Raf in oncogenesis.
32. Differentiate the morphological difference occur in apoptosis and necrosis with a neat diagram. How to activate caspase and its role?
33. Classify stem cell and explain it in detail. Write the applications of stem cell.
34. Explain in detail about cytokinesis in plant cell with a neat diagram and the significance of mitosis.
35. Describe in detail about the karyokinesis with a neat diagram and the significance of meiosis.
36. Classify the types of malignancies. What are the physiological properties of cancer cells?
37. How to activate and regulate Ras protein? Explain in detail.
38. Describe in detail about growth of cultured cells and maintenance of cell subpopulation.
39. Discuss the available cancer treatments and their side effects. Write the significance of
40. mitosis and meiosis.

#### **PART B**

41. Define cell cycle. Explain in detail of regulation of cell cycle. (Apr/May 2018),  
(Nov/Dec 2014) & (Nov/Dec 2015)
42. Explain the different phases of mitosis with a neat diagram. (Apr/May 2018) &  
(May/June 2016)
43. Explain the stages of meiosis. (Nov/Dec 2015)

**UNIT III**  
**TRANSPORT ACROSS CELL MEMBRANE**  
**PART – A**  
**TWO MARKS QUESTION AND ANSWERS**

1. What is passive transport?
2. In passive transport, the transported species always moves down its electrochemical gradient and is not accumulated above the equilibrium point.
3. Define active transport?
4. In active transport, the accumulation of solute above the equilibrium point. It is thermodynamically unfavorable (endergonic) and occurs only when coupled (directly/indirectly) to an exergonic process such as absorption of sunlight, an oxidation reaction, the breakdown of ATP/concomitant flow of some other chemical species down its electrochemical gradient.
5. What are the types of active transport?
6. The types are primary active transport and secondary active transport.

Primary active transport, solute accumulation is coupled directly to an exergonic chemical reaction such as conversion of ATP to ADP and inorganic phosphate.

Secondary active transport, occurs when endergonic transport of one solute is coupled to exergonic flow of different solute that was originally pumped by primary active transport.

7. Write a short note on permeases?  
All members of very large and diverse ABC superfamily of transport proteins contain two trans-membrane domain and two cytosolic ATP-binding domain. The plasma membrane of many bacteria contain numerous permeases belong to ABC superfamily. These proteins use the energy released by ATP hydrolysis to transport specific

amino acid, sugar, vitamins/even peptides into the cell. Example: Bacterial permeases, In *E. coli* histidine permeases.

8. Write a note on ion channels?

The plasma membrane contains channel proteins that allow the principal cellular ions ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Cl}^-$ ) to move through them at different rates down their concentration gradient. Ion concentration gradient generated by pumps and selective movement of ions through channels constitute the mechanism by which difference in voltage/electric potential is generated across plasma membrane.

9. Define ATP pumps and classify its classes.

ATP powered pump transport ions and small molecules against their concentration gradient. It is a transmembrane protein. It is located in cytosolic face of membrane (ATP) these proteins are called ATPases. Unless ions/other molecules are transported they cannot be hydrolysed (ATP) into ADP and  $\text{P}_i$ .

ATP Pumps are classified as P class, F class, V class and ABC superfamily. P, F and V transport ions only. ABC superfamily transport primarily small molecules.

10. Which drug is used to inhibit ATPase activity?

Drug Ouabain, which binds to specific region on exoplasmic surface of protein and specifically inhibits its ATPase activity, also prevent cells from maintaining their  $\text{Na}^+/\text{K}^+$  balance.

11. Define electrochemical gradient.

If a transported substance carries a net charge, its movement is influenced by both its concentration gradient and membrane potential, the electrical potential (voltage) across the membrane. The combination of these two forces called electrochemical gradient, determines energetically favorable direction of transport of charged molecule across the membrane.

12. Define facilitated diffusion.

Channel proteins transport water/specific types of ions and hydrophilic small molecules down their concentration gradient or electrical potential gradient. Such protein-assisted transport is referred as facilitated diffusion.

13. Differentiate between gated and non-gated channel.

Channel proteins form a hydrophilic passage way across the membrane through which multiple water molecules or ions move simultaneously at very rapid rate. Some ion channels are open much of time; these are referred as non-gated channel.

Most ion channels are open only in response to specific chemical/electric signal; these are referred as gated channel.

14. What are transporter and its types?

Transporters (also called carriers) move wide variety of ions and molecules across cell membranes. There are three types of transporters. They are Uniport, Symport and Antiport.

15. Define Uniport with an example.

16. Uniport transport a single type of molecule down its concentration gradient via facilitated diffusion. Example: Glucose and amino acid cross plasma membrane into most mammalian cells with the aid of uniporters.

17. Define cotransporter.

Antiport and symport couple the movement of one type of ion/molecule against its concentration gradient with the movement of one/more different ions down its concentration gradient. The proteins often called cotransporter refer ability to transport two different solute.

18. What is voltage – gated channel with an example?

Action potential is sudden membrane depolarization followed by rapid repolarization. An action potential resulting from sequential opening and closing of voltage gated Na<sup>+</sup> and K<sup>+</sup> channel in plasma membrane of neuron and muscle cells.

19. What is the ligand gated ion channel with an example?

The ligands for ion channels are synaptic neurotransmitters, the binding of which results in either opening/closing of channel. In either case, the ion gradient is altered, which changes the electrical potential across the membrane. Example: Acetylcholine.

20. Define agonist.

Drugs targeted to membrane receptors can have a variety of effects. They may elicit same biological effects as natural ligands. If so they are called agonists. Agonist which mimic the function of normal hormone by binding to its receptor and inducing normal response.

21. Define antagonist.

Antagonists inhibit the effect of natural ligand (hormone, neurotransmitter), agonist, partial agonist and even inverse agonist. Antagonist which bind to the receptor but induce no response.

22. Define partial agonist and inverse agonist.

Partial agonist, binds at same binding site and leads in absence of natural ligand to either a full/partial response. Inverse agonist, when applied to the receptor that has a basal or constitutive activity in absence of a bound ligand.

23. What are the types of antagonists?

The types of antagonists are competitive antagonists, non-competitive antagonists and irreversible antagonists.

24. Define allosteric antagonists.

Allosteric antagonists bind to an allosteric site on the receptor, inducing a conformational change in receptor so the ligand, agonist, partial agonist could not bind.

### **PART-B (16 MARKS QUESTIONS)**

25. Describe antagonist and its types with a neat picture.
26. Describe in detail about agonist with an example.
27. Describe ligand gated channel and explain with an example.
28. How the voltage gated ion channel works? Explain the operational mode of voltage gated ion Channel with a neat diagram.
29. Explain in detail about the depolarization, repolarization an resting state in voltage gate channel with an example.
30. Explain in detail about the different types of transporters with an example.
31. Describe the mechanism of action of Na<sup>+</sup>/K<sup>+</sup> ATPase.
32. Describe the mechanism of action of Ca<sup>2+</sup> ATPase.
33. Explain in detail about muscle Ca<sup>2+</sup> ATPase pump.
34. Define ATP pumps. Classify its types in detail with a neat diagram
35. Discuss the various ion channels and permeases.
36. Differentiate between passive and active transport with a neat diagram. Write a note on permeases.
37. Give a detail introduction about transporters and its types.
38. Explain about uniport and symport with a neat diagram.
39. Explain in detail about the ligand and voltage gated ion channel.

### **University Question Bank**

#### **PART A**

40. Give a brief note on Agonist. (Apr/May 2018)

Drugs targeted to membrane receptors can have a variety of effects. They may elicit same biological effects as natural ligands. If so they are called agonists. Agonist which mimic the function of normal hormone by binding to its receptor and inducing normal response.

41. What is the need for membrane transport? (Apr/May 2018)

Membrane transport is essential for cellular life. Transport may involve the incorporation of biological molecules and the discharge of waste products that are necessary for normal function. Membrane transport refers to the movement of particles (solute) across or through a membranous barrier. example, phospholipid bilayer. Membrane transport is dependent upon the permeability of the membrane, transmembrane solute concentration, and the size and charge of the solute.

42. What are the three types of endocytosis? (Nov/Dec 2014)

The three types of endocytosis are Phagocytosis, Pinocytosis and Receptor-mediated endocytosis.

43. What is lactose permease? (Nov/Dec 2014)

Lactose permease (LacY) is an integral protein that facilitate the passage of lactose. The active transport uses the energy of the electrochemical proton gradient, i.e. one  $H^+$  is transported in with each sugar (co-transport). The proteins play a critical role in transmembrane traffic. Malfunction of these transporters is associated with various pathophysiological conditions, such as diabetes and depression.

44. What are the roles of cyclin and cyclin dependent kinase? (Nov/Dec 2015)

Cyclin-dependent kinase, or CDK, is a type of enzymatic protein that resides in eukaryotic cells and plays a key role in cellular metabolism and renewal, a series of biological processes collectively referred to as the cell cycle. The mechanism of CDK activity is based on phosphorylation, or the process of contributing phosphate groups to substrate proteins. However, in order for a protein to be modified by phosphorylation, it must form a complex with another kind of protein known as cyclin. This is why this particular specialized protein is termed cyclin-dependent kinase.

45. Define facilitated diffusion. Give an example. (Nov/Dec 2015)

Facilitated diffusion is a form of facilitated transport involving the passive movement of molecules along their concentration gradient, guided by the presence of another molecule – usually an integral membrane protein forming a pore or channel. It does not directly involve ATP or GTP since the molecules are moving along their concentration gradient. Example: Glucose transporter, Ion channels.

46. Give the differences between symporter and antiporter with examples. (Nov/Dec 2015)

**Symport:** When the transported molecule and cotransported ion move in the same direction, the process is called symport. Example:  $Na^+$  linked symporter

**Antiport:** When the transported molecule and cotransported ion move in the opposite direction, the process is called antiport. Example: Glycerol-3-phosphate

47. What are the processes included in co-transport? (May/June 2016)

Cotransporters are proteins that transport two different solutes such as glucose and amino acids simultaneously across the cell membrane against a concentration gradient. It mediates coupled reactions in which an energetically unfavorable reaction (uphill movement of molecules) is coupled to an energetically favorable reaction. Cotransporters can be divided as Symport and Antiport.

48. What are the function of permeases? (May/June 2016)

Like the cell membrane, membranes of some organelles contain transport proteins, or permeases, that allow chemical communication between organelles. Permeases in the lysosomal membrane, for example, allow amino acids generated inside the lysosome to cross into the cytoplasm, where they can be used for the synthesis of new proteins. Communication between organelles is also achieved by the membrane budding processes of endocytosis and exocytosis, which are essentially the same as in the cell membrane.

### **PART B**

49. Explain in detail about K<sup>+</sup> pump and its transport mechanism with a neat sketch. (Apr/May 2018)
50. Explain in detail about calcium pump and its transport system. (Apr/May 2018)
51. Describe the various types of active transport and ion channels. (Nov/Dec 2014)
52. i) Discuss simple diffusion and facilitated diffusion. (Nov/Dec 2014)  
  
ii) Describe the types of agonist and antagonist with examples. (Nov/Dec 2014)
53. Describe various types of active transports with appropriate examples. (Nov/Dec 2015)
54. i) Explain agonist, antagonist and its types with examples. (Nov/Dec 2015)  
ii) Explain ion channels and its role in cells. (Nov/Dec 2015)
55. Explain the co-transport of Na<sup>+</sup> and K<sup>+</sup> by ATPase mechanism. (May/June 2016)
56. Describe co-transport and uniport systems. (May/June 2016)

## **UNIT IV**

### **SIGNAL TRANSDUCTION**

#### **PART – A**

#### **TWO MARKS QUESTION AND ANSWERS**

1. Define signal transduction.
2. The overall process of converting signals into cellular responses as well as individual steps in this process is termed as signal transduction.
3. What are the types of signaling?

Signaling by soluble extracellular molecules can be classified into three types. They are endocrine, paracrine and autocrine signaling based on the distance over which signal acts. Certain membrane-bound protein act as signals.

4. Define endocrine signaling.

The signaling molecules called hormones, act on target cells distant from their site of synthesis by cells of various endocrine organs. In animals, an endocrine hormone usually carried by blood/by other extracellular fluids from its site of release to its target.

5. Define paracrine signaling.

The signaling molecules released by a cell affect target cell only in close proximity. The conduction by a neurotransmitter of a signal from one nerve cell to another or from nerve cell to muscle cell occurs via paracrine signaling.

6. Define autocrine signaling.

Autocrine signaling, cell responds to substances that they themselves release. Some growth factors act and cultured cells often secrete growth factors that stimulate their own growth and proliferation.

7. How the external signals induce cellular responses?

Changes in activity/function of specific preexisting protein.

Changes in amounts of specific proteins produced by a cell, most commonly as the result of modification of transcription factor leading to activation/repression of gene transcription.

8. What are the classes of cell surface receptors?

G-protein coupled receptor, cytokine receptor, receptor tyrosine kinase, TGF- $\beta$  receptor, Hedgehog receptor, Wnt receptor and Notch receptor.

9. Write a short note on cytokine and Hedgehog receptor.

Cytokine receptor:

Associated with cytosolic JAK kinases

Activate cytosolic STAT transcription factor by phosphorylation.

Hedgehog receptor:

Hh ligand tethered to membrane of signaling cell by cholesterol anchor.

Control processing of transcription factor by Hh binding causes release from cytosolic complex.

10. Write the functions of cell surface receptors.

The largest family of cell surface receptor is G-protein coupled receptor, includes the receptor for many hormones, neurotransmitters, transmit signals to intracellular targets via intermediary action of G-proteins.

The receptor for most growth factor is protein tyrosine kinase.

The receptors for many cytokines act in association with non-receptor protein tyrosine kinases.

Other kinds of cell surface receptors include protein tyrosine phosphatase, protein-serine/threonine kinases and guanylylcyclase.

11. Write the function of G-protein coupled receptor.

It regulates the activity of a variety of intracellular targets in response to extracellular signals.

They regulate in channels.

They have distinct effect on nerve and skeletal muscle.

12. It has also effect on slowing heart muscle contraction.

13. What are the second messengers molecules?

The second messenger molecules are cyclic Adenosine Mono Phosphate, Phospholipids and Ca<sup>2+</sup>, Phosphotidyl inositol – 2-phosphate and cyclic Guanosine Mono Phosphate.

14. Write the functions of cAMP.

Most effects of cAMP are mediated by protein kinase A. cAMP can also directly regulate ion channels, independent of protein phosphorylation.

cAMP functions in this way as second messenger involved in sensing smells.

15. Define extracellular signaling.

Extracellular signaling molecules are synthesized and released by signaling cells and produce a specific response only in target cells that have receptor for signaling molecules.

16. How the signaling molecule induces cellular responses?

The signaling molecules act as ligand, which bind to structurally complementary site on extracellular/membrane-spanning domain of receptor. Binding of a ligand to its receptor causes a conformational change in cytosolic domain/domain of receptor that ultimately induces specific cellular responses.

17. What are G-protein coupled receptor and receptor tyrosine kinase?

G-protein coupled receptor:

Linked to a trimeric G protein that controls the activity of an effector protein (adenylyl cyclase)

Activate cytosolic/nuclear transcription factor via several pathways (protein kinase A)

Receptor tyrosine kinase:

Cytosolic domain with tyrosine kinase activity.

Activate cytosolic kinases (MAP Kinase) that translocate to nucleus and activate nuclear transcription factor by phosphorylation.

18. Write a note on Notch and Wnt receptor.

Notch receptor:

Ligand, delta is a transmembrane protein on signaling cell.

Cytosolic domain of notch released by proteolysis acts in association with nuclear transcription factor.

Wnt receptor:

Palmitoylated Wnt ligand binds seven transmembrane protein receptor complex.

Release on activated transcription factor from a multiprotein complex in the cytosol.

19. Write the mode of action of cytokine receptor.

Ligand induced receptor dimerization and cross phosphorylation of associated non-receptor protein tyrosine kinases. Then, the activated kinases then phosphorylate the receptor, providing phosphotyrosine, binding sites for the recruitment of downstream signaling molecules that contain SH2 domain.

20. Write the mode of action of Re-linked to enzymatic activities.

Protein tyrosine phosphatase remove phosphate group from phosphotyrosine residues these acting to counterbalance the effects of protein tyrosine kinases.

21. Write the example of autocrine and endocrine signaling.

The example of endocrine signaling - Steroid hormone and steroid receptor superfamily.

The example of autocrine signaling – lymphocytes & immune system.

22. Write the example of paracrine signaling. Expand GABA.

The example of paracrine signaling - nitric oxide, carbon monoxide and neurotransmitter. GABA-  $\gamma$ -amino butyric acid.

### **PART-B (16 MARKS QUESTIONS)**

23. Write a brief note on extracellular signaling.
24. Briefly describe the cell surface receptor and its functions with a neat diagram.
25. Explain in detail about the different classes of receptor with a neat diagram.
26. Describe endocrine signaling with a diagram.
27. Briefly describe paracrine signaling.
28. Explain about autocrine signaling with an example.
29. Explain in detail about cAMP pathway with a neat diagram.
30. Write a brief note on cGMP pathway.
31. Write a brief note on calmodulin and phorbol esters.
32. How phospholipase C activated by protein tyrosine kinase? Write a role of cGMP in photoreception.
33. Explain in detail about  $\text{PIP}_2$  – a second messenger.
34. Explain in detail about phospholipids and  $\text{Ca}^{2+}$  with a neat diagram
35. Describe in detail about second messenger with a neat diagram.
36. Write a short note on G-protein coupled receptor and Re-protein tyrosine kinase with a neat diagram
37. What are the steps involved in communication by extracellular signals? Write a brief note on direct cell-cell signaling.

### **University Question Bank**

#### **PART A**

38. Define autocrine signaling. (Apr/May 2018)

Autocrine signaling, cell responds to substances that they themselves release. Some growth factors act and cultured cells often secrete growth factors that stimulate their own growth and proliferation.

39. What is extracellular signaling? (Apr/May 2018)

Extracellular signaling molecules are synthesized and released by signaling cells and produce a specific response only in target cells that have receptor for signaling molecules.

40. Define hormone response element. ? (Nov/Dec 2014)

An HRE is a cis-regulatory DNA sequence for a hormone that acts by binding to a receptor that can act as a transcription factor, that is a binding site for the hormone-receptor complex.

42.

45. Give an example for a hormone which is soluble in Lipid and classified as Amine. (Nov/Dec 2014)

Estrogen and testosterone are lipid-soluble hormones and amino acid derived hormones are Epinephrine and Norepinephrine.

46. What is the role of hormone response elements? (Nov/Dec 2015)

An HRE is a cis-regulatory DNA sequence for a hormone that acts by binding to a receptor that can act as a transcription factor, that is a binding site for the hormone-receptor complex. Activated receptors bind to "hormone response elements", which are short specific sequences of DNA which are located in promoters of hormone-responsive genes.

For Example in the absence of hormone, some intracellular receptors do not bind their hormone response elements and silence transcription, but, when complexed to hormone, become activated and strongly stimulate transcription.

47. Write the biological significance of cGMP. (Nov/Dec 2015)

cGMP is an important molecule of the cell that takes part in various activities in cellular system. When guanylyl cyclase stimulation leads to elevated levels of cGMP, it then mediates biological responses, such as blood vessel dilation which increases blood flow.

48. The action of cGMP is regularly facilitated by stimulation of cGMP dependent protein kinases, although cGMP is a common regulator of ion channel conductance, glycogenolysis, cellular apoptosis and phosphodiesterases.

49. Give examples of secondary messengers. (May/June 2016)

The second messenger molecules are cyclic Adenosine Mono Phosphate, Phospholipids and Ca<sup>2+</sup>, Phosphatidylinositol – 2-phosphate and cyclic Guanosine Mono Phosphate.

50. What is meant by paracrine action? Give examples of paracrine factors. (May/June 2016)

The signaling molecules released by a cell affect target cells only in close proximity. The conduction by a neurotransmitter of a signal from one nerve cell to another or from nerve cell to muscle cell occurs via paracrine signaling.

The example of paracrine signaling - nitric oxide, carbon monoxide and neurotransmitter.

## **PART B**

51. Explain about endocrine signaling with two examples. (Apr/May 2018)

52. Write about secondary messengers in detail. (Apr/May 2018)

53. Explain with examples signal transduction by (Apr/May 2018)

- i) Cell Surface receptors
- ii) Cytosolic receptors.

54. Explain the general signal transduction through G protein-coupled

a. receptor with an example. (Nov/Dec 2014)

55. i) Elaborate signal transduction via insulin receptor and (Nov/Dec 2014)

a. ii) Explain second messengers. (Nov/Dec 2014)

56. Explain the signal transduction through G protein-coupled receptor by
  - a. epinephrine and its regulation (Nov/Dec 2015)
57. i) Describe the general signal transduction of steroid hormones. (May/June 2016)
58. (ii) Elaborate signal transduction via receptor tyrosine kinases. (May/June 2016)
59. Explain in detail how do cAMP act as secondary messenger Kinases. (May/June 2016)
60. Discuss in detail the G-Protein coupled receptor system. (May/June 2016)

**UNIT V**  
**TECHNIQUES USED TO STUDY CELLS**  
**PART – A**  
**TWO MARKS QUESTION AND ANSWERS**

1. Define immunofluorescence microscopy.

When a fluoro-chrome-antibody complex is added to a permeabilized cell or tissue section, the complex will bind to the corresponding antigen, which then light up when illuminated by the exciting wavelength, a technique called immunofluorescence microscopy.

2. Define flow cytometry.

A flow cytometry identifies different cells by measuring the light that they scatter and the fluorescence that they emit as they flow through a laser beam; thus it can sort out cells of particular type from a mixture. It separates different cell types. Some special cell types differ sufficiently in density that they can be separated on basis of this physical property.

3. Expand FACS.

FACS- Fluorescent Activated Cell Sorter, an instrument based on flow cytometry can select one cell from thousands of other cells.

4. Write the uses of flow cytometry.

Measurement of cell's DNA & RNA content and determination of its general shape and size.

FACS can make simultaneous measurements of size of cell and the amount of DNA.

5. Which technique is used to separate WBC and RBC?

Both WBC and RBC have very different densities because erythrocytes have no nucleus; thus these cells can be separated by equilibrium density centrifugation.

6. What is centrifugation?

The centrifugation is used to separate protein and nucleic acids. Separating and purifying the various organelles which differ in both size and density and thus undergo sedimentation at different rates.

7. Which technique is used to purify the impure organelle?

An impure organelle fraction obtained by differential centrifugation can be purified by equilibrium density-gradient centrifugation, which separate cellular components according to their density.

8. Define SEM.

Scanning Electron Microscope of metal coated unsectioned cells/tissues produces images that appear to be three-dimensional.

9. Define TEM.

In Transmission Electron Microscopy, the specimen is illuminated by a beam of electrons and electromagnetic lenses are used to focus the transmitted electrons to produce an image on the photographic film.

10. Define Electron Microscope.

In Electron Microscopy, live material cannot be observed and the light source is a beam of electrons that pass through a vacuum. The material has to be suitably prepared and inserted into the electron microscope after evacuating air with the help of vacuum pump.

11. Define fluorescence Microscope.

Fluorescence Microscope is like an ordinary compound microscope which is modified by incorporation of special filters that allow specific wavelength of light to pass through the specimen and cause fluorescence.

12. Which type of microscope is commonly used and what are the factors to determine the Quality?

The most common microscopic technique in use today is the bright-field microscopy which uses a compound microscope. Two factors determine the quality of a microscope: magnification and resolution.

13. Define Refractive index.

Refractive index is the ratio of phase velocity of light in a vacuum to that in a specified medium. An image is produced in which the degree of brightness or darkness of a portion of the specimen depends on the refractive index of that region.

14. Define cell fractionation.

Cell fractionation is a technique by which a cell is broken open by homogenization and separating cell organelles as well as macromolecules by centrifugation.

15. Define Magnifying Power.

The Magnifying power of a microscope is determined by multiplying the magnification of the objective and the magnification of the ocular lens.

16. Define Resolution.

Resolution is dependent on the wavelength of the beam used for illumination and the optical quality of the lens.

17. Write the formula of resolving power.

$$RP = \lambda / 2 \times NA$$

Where,

- i. RP is the resolution power
- ii.  $\lambda$  is the wavelength of the light used
- iii. NA is the numerical aperture of the objective of the microscope

18. What is direct immunostaining?

In direct immunostaining, an antibody that recognizes a antigen is coupled directly to an indicator (a fluorescent dye/an enzyme).

19. What is indirect immunostaining?

In Indirect immunostaining, is more sensitive method because a second antibody is coupled to the indicator. The second antibody recognizes a common epitope on the antigen-specific antibody. Multiple second antibodies can bind to first antibody, leading to an increased signal from the indicator compared to direct immunostaining.

20. What are the limitations of SEM?

The specimen cannot be observed in live condition

The thin specimen preparation is difficult.

Morphological alteration of cells occurs during thin specimen preparation.

Due to its high cost, it is not used in ordinary laboratories.

### **PART-B (16 MARKS QUESTIONS)**

21. Describe in detail about flow cytometry with a neat diagram.

22. Explain in detail about the working principle and limitations of SEM.

23. Explain in detail about the working principle of TEM with a neat diagram.

24. Describe about cell fractionation.

25. Define principle of SEM and draw a diagram. How the 3D models constructed from microscopy images of SEM?

26. Discuss the working principle of TEM. How metal shadowing is prepared?

27. Explain in detail about confocal microscopy.

28. Differentiate between the working principle of SEM and TEM.
29. Explain in detail about the immunostaining.
30. By which technique is used to locate protein in cells? Explain in detail.
31. What are the types of immunostaining? Write the limitations of conventional fluorescence microscope and uses of immunostaining.
32. By which technique is used to broken the cell and purify the contents? Explain in detail.
33. Draw a neat labeled diagram of flow cytometry. Expand FACS and its uses.
34. Which technique is used to separate mixed organelle? Describe the principle of bright-field light microscopy.
35. Explain in detail about Electron Microscopy with a neat diagram.

### **University Question Bank**

#### **PART A**

36. Write the principle of confocal microscopy? (Apr/May 2018)

The confocal microscope uses fluorescence optics. Instead of illuminating the whole sample at once, laser light is focused onto a defined spot at a specific depth within the sample. This leads to the emission of fluorescent light at exactly this point. A pinhole inside the optical pathway cuts off signals that are out of focus, thus allowing only the fluorescence signals from the illuminated spot to enter the light detector.

37. What do you mean by immunostaining? (Apr/May 2018)

The staining of a specific substance by using an antibody against it which is complexed with a staining medium (as horseradish peroxidase). The types are direct and indirect immunostaining.

38. What is the working principle of SEM? (Nov/Dec 2014)

In SEM, there are several electromagnetic lenses, including condenser lenses and one objective lens. Electromagnetic lenses are for electron probe formation. Two condenser lenses reduce the crossover diameter of the electron beam. The objective lens further reduces the cross-section of the electron beam and focuses the electron beam as probe on the specimen surface. Objective lens thus functions like a condenser.

Electron probe or beam is scanned across the specimen and the procedure is known as Raster scanning. Raster scanning causes the beam to sequentially cover a rectangular area on the specimen. The signal electrons emitted from the specimen are collected by the detector, amplified and used to reconstruct the image according to one-to-one correlation

between scanning points on the specimen and picture points on the screen of cathode ray tube (CRT). CRT converts the electronic signals to a visual display.

39. List out the techniques used to localize proteins in the cell. (Nov/Dec 2014)

Immunostaining, Confocal laser scanning Microscopy and Fluorescence Microscopy based techniques are used to localize protein in cells.

40. Write the principle of confocal microscopy. (Nov/Dec 2015)

The confocal microscope uses fluorescence optics. Instead of illuminating the whole sample at once, laser light is focused onto a defined spot at a specific depth within the sample. This leads to the emission of fluorescent light at exactly this point. A pinhole inside the optical pathway cuts off signals that are out of focus, thus allowing only the fluorescence signals from the illuminated spot to enter the light detector.

41. What are the general applications of microscopic techniques in cell biology? (Nov/Dec 2015)

Counting of cells using a hemocytometer utilizes light microscopy.

Microscopic analysis of blood samples is routinely used to determine the blood cell count, to detect the microbial infection, and to identify any changes in the cellular structures.

*Live cell imaging:* Inverted microscopes allow direct microscopy of the cultured cells.

*Cell biology:* Owing to its ability to operate on liquid samples, AFM has been used to study the real-time biological processes. Migrating epithelial cells, dynamics of membrane invaginations, conformational changes in membrane proteins, and assembly/disassembly of structural proteins have been studied in real time using Atomic Force Microscopy.

42. What are fixatives? (May/June 2016)

A chemical substance used to preserve or stabilize biological material prior to microscopy or other examination.

Fixative: A medium such as a solution or spray that preserves specimens of tissues or cells. Most biopsies and specimens removed at surgery are fixed in a solution such as formalin (dilute formaldehyde) before further processing takes place. Other common ingredients used in fixatives are alcohol, mercuric chloride, potassium dichromate and sodium sulfate.

43. What forms the basis of electron microscopy techniques? (May/June 2016)

In Electron Microscopy, live material cannot be observed and the light source is a beam of electrons that pass through a vacuum. The material has to be suitably prepared and inserted into the electron microscope after evacuating air with the help of vacuum pump. The types are TEM and SEM.

### **PART B**

44. Explain the principle, instrumentation and applications of flow cytometer. (Apr/May 2018)
45. Explain the protocol for the localization of cellular proteins. (Apr/May 2018)
46. Discuss cell fractionation method and cell sorting by flow cytometry. (Nov/Dec 2014)
47. i) Describe the studies on the cell using TEM and confocal microscopy. (Nov/Dec 2014)  
    (ii) Write a short note on immunostaining. (Nov/Dec 2014)
48. i) Discuss about cell sorting by flow cytometry  
    ii) Describe immunostaining with an example. (Nov/Dec 2015)
49. i) Describe the working principle and advantages of TEM and STEM in cell biology (Nov/Dec 2015)  
    ii) Discuss cell fractionation method and its applications (Nov/Dec 2015)
50. Explain in detail the principle, operation and application of SEM. (May/June 2016)
51. Explain in detail the principle, operation and application of Confocal  
    a. Microscopy. (May/June 2016)