MADE EASY

GATE 2023

CHEMICAL ENGINEERING

Memory based Questions & Solutions

Exam held on 11th Feb, 2023 Afternoon Session

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SECTION - A GENERAL APTITUDE

Q.1 Reference : ? : : guidelines : Implement

(a) Site (b) Sight
(c) Plagiarism (d) Cite

Ans. (d)

End of Solution

Q.2 The village was nestled in green spots _______ the ocean and the hills

(a) Through (b) At
(c) Between (d) On

Ans. (c)

End of Solution

Q.3 Sand and cement are mixed in ratio of 3 : 1. Cost of sand and cement are in 1 : 2. If the total cost of sand and cement is Rs. 1000, then cost of cement is

(a) 200 (b) 600
(c) 800 (d) 400

Ans. (d)

	Sand		Cement
Quantity	$3x$	:	$1x$
Cost	$1y$	:	$2y$
Total cost	$3xy$	:	$2xy$

$$\text{Total cost} = 3 : 2$$

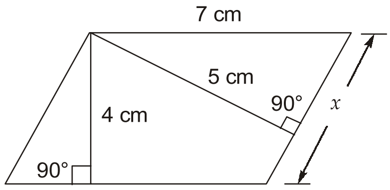
$$\text{Cost of cement} = \frac{2}{5} \times \text{Total cost}$$

$$\text{Total cost} = 1000 \text{ Rs.}$$

$$\text{Cost of cement} = \frac{2}{5} \times 1000 = 400 \text{ Rs.}$$

End of Solution

Q.4 The value of X = ?



given parallelogram

(a) $\frac{21}{8}$ cm (b) $\frac{35}{4}$ cm

(c) $\frac{16}{3}$ cm (d) $\frac{28}{5}$ cm

Ans. **(d)**

Area of parallelogram = Base × Height

So, $4 \times 7 = 5 \times x$

$$x = \frac{28}{5} \text{ cm}$$

End of Solution

■■■■

SECTION - B TECHNICAL

Q.5 Which of the following options represent the major constituent of oleum?

(a) H_2SO_4 and HCl
(b) H_2SO_4 and HNO_3
(c) Conc. H_2SO_4 and petroleum jelly
(d) H_2SO_4 and SO_3

Ans. (d)

Oleum is a term referring to solutions of various compositions of SO_3 in H_2SO_4 having chemical formula of $H_2S_2O_7$.

End of Solution

Q.6 Match the following:

	List-I		List-II
P.	Acetaldehyde	1.	Sulphate
Q.	H_2SO_4	2.	Electric furnace
R.	Pulp	3.	Wacker
S.	Phosphorous	4.	Contact

Codes:

(a) P - 4, Q - 3, R - 1, S - 2
(b) P - 3, Q - 4, R - 1, S - 2
(c) P - 1, Q - 2, R - 4, S - 3
(d) P - 2, Q - 1, R - 3, S - 4

Ans. (b)

End of Solution

Q.7 Match the following:

	List-I		List-II
P.	$C_2H_6 + Cl_2 \rightarrow \text{Chlorobenzene} + HCl$	1.	Oxide of metal
Q.	$C_2H_4 + \frac{1}{2}O_2 \rightarrow \text{Ethylene oxide}$	2.	V_2O_5
R.	$CH_3OH + \frac{1}{2}O_2 \rightarrow HCHO + H_2O$	3.	$FeCl_3$
S.	$\text{Naphthalene} + O_2 \rightarrow \text{Phthalic anhydride}$	4.	Ag_2O

Codes:

(a) P - 4, Q - 3, R - 1, S - 2
(b) P - 2, Q - 4, R - 1, S - 3
(c) P - 3, Q - 4, R - 1, S - 2
(d) P - 3, Q - 2, R - 4, S - 1

Ans. (c)

End of Solution

Q.8 Nitrile rubber is manufactured via polymerization of _______ choose the correct monomer.

(a) Butadiene and styrene
(b) Acrylonitrile and styrene
(c) Acrylonitrile and butadiene
(d) Butadiene and isophere

Ans. (c)

Nitrile rubber is manufactured via polymerization, the correct monomers are acrylonitrile and butadiene.

Nitrile rubber also known as nitrile butadiene rubber i.e. (BUNA-N) which is composed of acrylonitrile and butadiene.

End of Solution

Q.9 $\lim_{x \to 0} \frac{2x}{e^x - 1}$

(a) 1
(b) 2
(c) 0
(d) ∞

Ans. (b)

From, L-Hospital rule, we get

$$\lim_{x \to 0} \frac{f'(x)}{g'(x)} = \frac{2}{e^x} = \frac{2}{e^0} - 2$$

End of Solution

Q.10 Given $\vec{v} = zx\hat{i} + 2xy\hat{j} + 3yz\hat{k}$, then divergence of $\vec{v}$ at (3, 2, 1) is?

(a) 13
(b) 0
(c) 3
(d) 4

Ans. (a)

Given: $\vec{v} = zx\hat{i} + 2xy\hat{j} + 3yz\hat{k}$

For divergence, we know

$$\nabla \cdot \vec{v} = \frac{\partial}{\partial x}(zx) + \frac{\partial}{\partial y}(zxy) + \frac{\partial}{\partial z}(zyx)$$

$$\nabla \cdot \vec{v} = z + 2x + 3y \text{ at } [3, 2, 1]$$

$$\nabla \cdot \vec{v} = 1 + 2 \times 3 + 3 \times 2 = 13$$

End of Solution

Q.11 If $A = \begin{bmatrix} 10 & 6 \\ 6 & 10 \end{bmatrix}$ then the sum of eigen values of A^3 is ________.

Ans. (4160)

$$A = \begin{bmatrix} 10 & 6 \\ 6 & 10 \end{bmatrix}$$

For eigen values, we have

$$|A - \lambda I| = 0$$

$$\begin{vmatrix} 10-\lambda & 6 \\ 6 & 10-\lambda \end{vmatrix} = 0$$

$$(10 - \lambda)^2 - 36 = 0$$

$$100 + \lambda^2 - 20\lambda - 36 = 0$$

$$\lambda^2 - 20\lambda + 64 = 0$$

$$\lambda = \frac{20 \pm \sqrt{400 - 4 \times 64}}{2}$$

$$\lambda = 16, 4$$

$$\lambda^3 = (16)^3 \text{ and } (4)^3$$

$$\text{Sum of eigen values} = (16)^3 + (4)^3 = 4160$$

End of Solution

Q.12 If Z_1 and Z_2 are complex number then $\frac{|Z_1 + Z_2|}{|Z_1| + |Z_2|}$ is

(a) > 1
(b) < 1
(c) < 0
(d) = 1

Ans. (b)

Given: $f(Z) = \frac{|Z_1 + Z_2|}{|Z_1| + |Z_2|}$

From the property of triangle inequality, we have

$$|Z_1 + Z_2| = |Z_1| + |Z_2|$$

$$\frac{|Z_1 + Z_2|}{|Z_1| + |Z_2|} \leq 1$$

End of Solution

Q.13 Consider $\frac{d^2x}{dt^2} = -w^2x$ with $x(0) = 1$ and $\left(\frac{dx}{dt}\right)_{t=0} = 0$ then position of particle at $x\left(\frac{3\pi}{w}\right)$ will be?

Ans. (–1)

$$\frac{d^2x}{dt^2} + -w^2x = 0$$

$$(D^2 + w^2) = 0$$

$$D = \pm wi$$

$$i = C_1 \cos wt + C_2 \cos wt$$

$$\frac{dx}{dt} = -C_1 w \cos wt + C_2 w \cos wt$$

Using Boundary conditions, we get

$$x = 1 \text{ at } t = 0$$

$$[1 = C_1]$$

and $$\frac{dx}{dt} = 0 \text{ at } t = 0$$

$$[0 = C_2]$$

Therefore, $$x = \cos wt$$

Now, at $$t = \left(\frac{3\pi}{w}\right)$$

$$x = \cos w \cdot \frac{3\pi}{w} = -1$$

End of Solution

Q.14 If $u(r) = 4\left[\left(\frac{1}{r}\right)^{12} - \left(\frac{1}{r}\right)^{6}\right]$ then $\left(\frac{du}{dr}\right)_{r=1} = ?$

Ans. (–24)

$$\frac{du}{dr} = 4[-12r^{-13} + 6r^{-7}]$$

At, $$r = 1$$

$$\frac{du}{dr} = 4[-12 + 6] = -24$$

End of Solution

Q.15 Using Simpson's $\frac{1}{3}^{rd}$ rule with step size 0.5 units evaluate $\int_{-1}^{1}\sqrt{1-x^2}\,dx$ ______. (Answer upto two decimal places)

Ans. **(1.5)**

$$f(x) = \int_{-1}^{1}\sqrt{1-x^2}\,dx, \quad h = 0.5$$

From Simpson's $\frac{1}{3}^{rd}$ rule, we have

$$\int f(x)dx = \frac{h}{3}[y_0 + y_n + 2[\text{even terms}] + 4\,(\text{odd terms})]$$

x	–1	–0.5	0	0.5	1
$f(x)$	0	0.87	1	0.87	0
	y_0	y_1	y_2	y_3	y_4

$$\int_{-1}^{1} f(x)dx = \frac{0.5}{3}[2x_1 + 4[0.87 + 0.87]]$$

$$= 1.49 \cong 1.5$$

End of Solution

Q.16 Water is flowing at a mass flow rate of 10 kg/s with density of 1000 kg/m^3. The inlet pressure of pump –20 kPa (guage) and exit pressure is 350 kPa (gauge). Elevation is same. Diameter of pipe at the inlet of pump is 70 mm and at exit 50 mm if efficiency of pump is 80%. Find the power required by pump (kW).

Ans. **(4.74)**

Given:

$$\dot{m} = 10 \text{ kg/s}, \quad \rho_w = 1000 \text{ kg/m}^3$$
$$P_S = -20 \text{ kPa (gauge)}, \quad P_D = 350 \text{ kPa (gauge)}$$
$$Z_1 = Z_2 \text{ (same)}, \quad g = 9.81 \text{ m/s}^2$$
$$d_S = 70 \text{ mm}, \quad d_D = 50 \text{ mm}, \quad \eta = 80\%$$

Now, from continuity, we have

$$\dot{m} = \rho AV, \quad A_1V_1 = A_2V_2$$

$$Q = \frac{10}{1000} = 0.01 \text{ m}^3/\text{s}$$

$$0.01 = \frac{\pi}{4}(0.07)^2 V_s \rightarrow V_s = 2.6 \text{ m/s}$$

$$0.01 = \frac{\pi}{4}(0.05)^2 \cdot V_D \rightarrow V_D = 5.1 \text{ m/s}$$

Now, applying Bernoulli's theorem between suction and discharge, we get

$$\frac{P_S}{\rho g} + \frac{V_S^2}{2g} + Z_1 + H_P = \frac{P_D}{\rho g} + \frac{V_D^2}{2g} + Z_2 + h_f$$

$$h_f \cong 0 \text{ (given)}$$
$$(Z_1 = Z_2)$$

Putting values, we get

$$\frac{-20\times10^3}{10^3\times g}+\frac{(2.6)^2}{2\times g}+H_P = \frac{35\times10^3}{10^3\times g}+\frac{(5.1)^2}{2\times g}$$

$$-20+\frac{(2.6)^2}{2}+gH_P = 350+\frac{(5.1)^2}{2}$$

$$gH_P = 383.005-\frac{(2.6)^2}{2}=379.625$$

$$\text{Power} = \frac{\rho g H_P\cdot Q}{\eta} = \frac{1000\times379.625\times0.01}{1000\times0.8}$$

$$P = 4.74 \text{ kW}$$

End of Solution

Q.17 The viscosity of an incompressible Newtonion fluid is measured using a capillary tube of diameter 0.5 mm and length 1.5 m. The fluid flow is laminar, steady and fully developed. For a flow rate of 1 cm^3/s the pressure drop across the length is 1 MPa. If viscosity is $k \times 10^{-3}$ Pa-s, the value of k is _____

Ans. **(1)**

Given: $d = 0.5$ mm, $L = 1.5$ m
$\Delta P = 1$ MPa, $Q = 1$ cm^3/s
$\mu = k \times 10^{-3}$ Pa.s

Given the flow is laminar, steady and fully developed, thus we have

$$\frac{\Delta P}{L} = \frac{128\mu Q}{\pi d^4}$$

$$\mu = \frac{\Delta P \pi d^4}{128\times Q\times L}$$

Putting values, we get

$$\mu = \frac{10^6\times3.14\times(0.5\times10^{-3})^4}{128\times10^{-6}\times1.5} = 1.022 \times 10^{-3} \text{ Pa.s}$$

Thus, $k = 1.022 \cong 1$

End of Solution

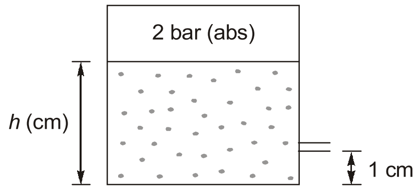
Q.18 Rotameter is used for

(a) Flow rate
(b) Pressure
(c) Temperature
(d) Dynamic pressure

Ans. **(a)**

End of Solution

Q.19



$D_T = 500$ mm, $D_N = 5$ mm
1 bar (atmospheric pressure)
g = 10 m/s^2

value of $\frac{dh}{dt}$ = ? at h = 51 cm

Ans. (1.45)

From mass balance, we get

$$\rho A_N V_N = \frac{dm}{dt} = \rho A_T \frac{dh}{dt}$$

$$\left(\frac{A_N}{A_T}\right) V_N = \frac{dh}{dt}$$

$$\frac{dh}{dt} = \left(\frac{d_N}{d_T}\right)^2 V_N \quad \text{...(i)}$$

where, d_N = Nozzle diameter, d_T = Tank diameter
V_N = Nozzle velocity

Applying Bernoulli's between tank water surface and nozzle exit, we get

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + \frac{h}{100} = \frac{P_2}{\rho g} + \frac{V_N^2}{2g} + \frac{1}{100}$$

$V_1 \cong 0$ (surface velocity)

$$\frac{2 \times 10^5}{10^3 \times 10} + \frac{h}{100} = \frac{10^5}{10^4} + \frac{(V_N)^2}{20} + \frac{1}{100}$$

$$20 + \frac{h}{100} - \frac{1}{100} = 10 + \frac{(V_N)^2}{20}$$

$$10 + \frac{h-1}{100} = \frac{V_N^2}{20}$$

$$V_N = \sqrt{20\left[10 + \frac{h-1}{100}\right]}$$

Putting V_N in equation (i), we get

$$\frac{dh}{dt} = \left(\frac{5}{500}\right)^2 \sqrt{20\left[10 + \frac{51-1}{100}\right]}$$

$$\frac{dh}{dt} = 1.45 \times 10^{-3} \text{ m/s} = 1.45 \text{ mm/sec}$$

End of Solution

Q.20 Consider pipe of constant diameter (D) through which the fully developed turbulent flow is occurring. Select the correct statements from the following.

(a) The value of Reynold's stress at the wall of the pipe is zero.

(b) The average Reynold stress over a sufficient long time is zero everywhere inside the pipe.

(c) The average value of $\left(\frac{\partial P}{\partial X}\right)$ pressure gradient in the flow direction is constant.

(d) The average velocity is half of the centre line velocity.

Ans. (b, c)

End of Solution

Q.21 For a packed bed of uniform sized spherical particles of diameter D_p the pressure drop across the bed is given by Kozeny Carman where $Re_p < 1$. Under this condition minimum fluidization velocity is proportional to D_p^n, n is equal to

(a) 2
(b) –1
(c) 1
(d) –2

Ans. (a)

From Carman-Kozeny equation, we have

$$\frac{\Delta P}{L} = \frac{150\mu_f V_0 (1-\epsilon)^2}{(\phi_s d_p)^2 \epsilon^3} \quad \{\text{when } Re_p < 1\}$$

$$V_0 = \text{Fluidization velocity}$$

Under minimum fluidization condition, we have

$$g(\rho_p - \rho_f)(1-\epsilon) = \frac{150\mu_f V_0 (1-\epsilon)^2}{(\phi_s d_p)^2 \epsilon^3}$$

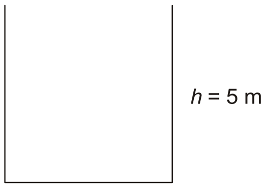
i.e.

$$V_0 \propto (D_p)^2$$

$$n = 2$$

End of Solution

Q.22



$\rho_f = 1 \text{ g/cm}^3$
$\rho_p = 0.8 \text{ g/cm}^3$
$R_{ep} < 1$ (Stokes regime)

$$V_t = \frac{g\,dp^2(\rho_p - \rho_f)}{18\mu}$$

$d_p = 100\ \mu\text{m}$
$\mu = 10^{-3}$ Pa-sec
$V_t = ?$

Ans. (1.1)

Given:
$\rho_f = 1 \text{ g/cm}^3$
$\rho_p = 0.8 \text{ g/cm}^3$
$R_{ep} < 1$ (Stokes regime)
$d_p = 100\ \mu\text{m}$
$\mu = 10^{-3}$ Pa.s
$V_t = ?$

From Stokes regime, we have

$$V_t = \frac{d_p^2(\rho_p - \rho_f)g}{18\mu_f}$$

$$V_t = \frac{(100 \times 10^{-6})^2(1000 - 800) \times 9.81}{18 \times 10^{-3}}$$

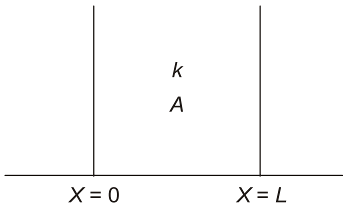
$$V_t = \frac{10^{-8} \times 200 \times 9.81}{18 \times 10^{-3}} = 1.09 \text{ mm/s} = 1.1 \text{ mm/s}$$

End of Solution

Q.23 Slab of thickness 'L' cross section 'A' and constant thermal conductivity 'k'. For steady state, one dimensional condition. The correct expression of resistance is

(a) $\frac{kA(T_1 - T_2)}{L}$
(b) $\frac{A}{Lk}$
(c) $\frac{L}{kA}$
(d) $\frac{k}{LA}$

Ans. (c)



From, conduction we have

$$\Sigma R = \frac{b}{kA}$$

$$R = \frac{L}{kA}, \text{ where } R = \text{Resistance}$$

k = Thermal conductivity
A = Cross-sectional area
L = Thickness of slab

End of Solution

Q.24 Match the following:

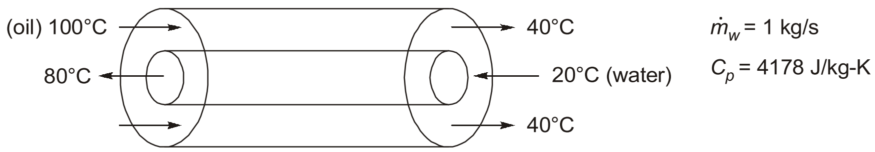
A. Thermal conduction	1. $Wm^{-2}\,K^{-1}$
B. Heat transfer coefficient	2. $Wm^{-1}\,K^{-1}$
C. Stefan-Boltzmann's constant	3. WK^{-1}
D. Heat capacity rate	4. $Wm^{-2}\,K^{-4}$

(a) A - 2, B - 1, C - 4, D - 3
(b) A - 1, B - 2, C - 3, D - 4
(c) A - 2, B - 4, C - 3, D - 4
(d) A - 3, B - 1, C - 4, D - 2

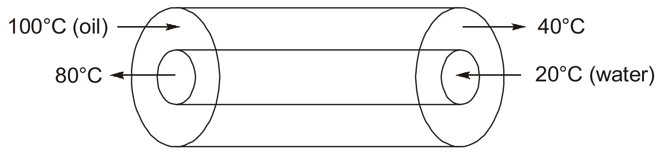
Ans. (a)

End of Solution

Q.25 Counter flow heat exchanger, find NTU?



Ans. (3)



Given:

$$\dot{m}_w = 1 \text{ kg/s}$$

$$C_{pw} = 4178 \text{ J/kg.K}$$

For NTU, we have,

$$\text{NTU} = \frac{U \cdot A}{(mC_p)_{\min}}$$

From energy balance,

$$(\dot{m}C_p)_{hot}[100-40] = (\dot{m}C_p)_{cold}[80-20]$$

$$(\dot{m}C_p)_{hot} = (\dot{m}C_p)_{cold}$$

Again, $1 \times 4178 \times (80-20) = U \cdot A \, \Delta T_{lmtd}$

$\because \quad \Delta T_{lmtd} = 20°C \quad \{\Delta T_1 = \Delta T_2 = 20°C\}$

$$UA = \frac{4178 \times 60}{20}$$

$$\therefore \quad (\text{NTU}) = \frac{UA}{(mC_p)_{\min}} = \frac{4178 \times 60}{20 \times 1 \times 4178} = 3$$

End of Solution

Q.26 For the total hemispherical emissive power from any surface, choose the correct ones from the following.

(a) Total emissive power is not a function of frequency.
(b) Total emissive power does not depend on the direction of emission.
(c) Total emissive power depends on the view factor of the surface.
(d) Total emissive power depends on the wavelength of the radiation.

Ans. (b, d)

End of Solution

Q.27 $\overline{M}_W = 45$ kg.kmol

$\rho = 2 \text{ kg/m}^3$

$U_{opt} = 0.6\ U_f$

$U_f = 0.15$ m/s

$\dot{m}_v = 0.1$ kmol/sec

Calculate the diameter of column

(a) $\frac{10}{\sqrt{\pi}}$ (b) $\frac{5}{\sqrt{\pi}}$

(c) $\frac{6}{\sqrt{\pi}}$ (d) $\frac{2}{\sqrt{\pi}}$

Ans. (a)

Given: $\dot{m}_v = 0.1$ kmol/s

$M = 45$ kg/kmol, $V_f = 0.15$ m/s

$\rho_v = 2 \text{ kg/m}^3$, $V_{\text{operating}} = 60\%$ of V_{flooding}

Diameter of column = ?

Now, $\dot{m}_v = \rho A V_{\text{operating}}$

$$A = \frac{\dot{m}_v}{\rho V_{\text{operating}}}$$

Since, $\dot{m}_v$ is in kmol/s, thus expression becomes

$$A = \frac{\dot{m}_v M}{\rho V_{\text{operating}}}$$

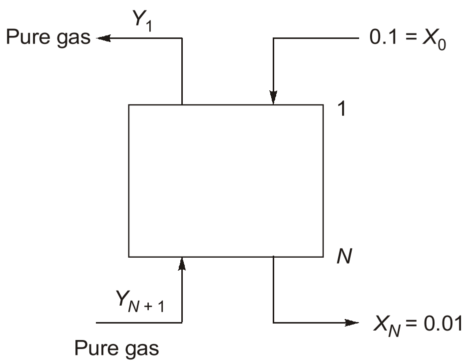
$$\frac{\pi}{4} d^2 = \frac{0.1 \times 45}{2 \times 0.60 \times 0.15}$$

$$d = \sqrt{\frac{100}{3.14}} = 5.64 \text{ m}$$

$$d = \frac{10}{\sqrt{\pi}}$$

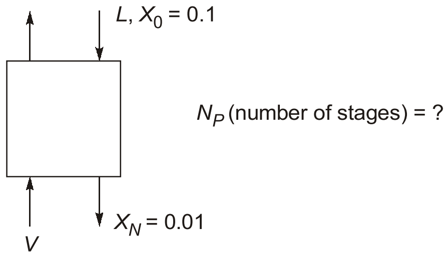
End of Solution

Q.28 Number of stages =



N_P = ?

Ans. (3)



$y = 0$ (pure gas), $L = \frac{V}{2}$, $y = x$

Now, for stripping, we have

$$N_P = \frac{\ln\left[\left(\frac{X_0 - \frac{Y_{N+1}}{m}}{X_N - \frac{Y_{N+1}}{m}}\right)\left(1-\frac{1}{s}\right)+\frac{1}{s}\right]}{\ln s}$$

where, S = Stripping factor = 2

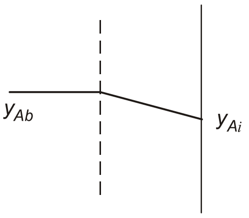
Putting values, we get

$$N_P = \frac{\ln\left[\left(\frac{0.1}{0.01}\right)(1-0.5)+0.5\right]}{\ln 2}$$

$$N_P = 2.46 \cong 3 \text{ stage}$$

End of Solution

Q.29



$y_{Ab} = 0.2$
$y_{Ai} = 0.1$

$$\frac{(N_A)_{ANB}}{(N_A)_{EMCD}} = ?$$

where, ANB = A non-diffusing B
EMCD = Equimolar counter diffusion

Ans. (1.176)

Now,

$$\frac{(N_A)_{ANB}}{(N_A)_{EMCD}} = \frac{D_{AB}P_T(y_{A_1} - y_{A_2})R_T\Delta z}{R_T\Delta z\, y_{Blm} \cdot D_{AB}P_T(y_{A_1} - y_{A_2})}$$

$$\frac{(N_A)_{ANB}}{(N_A)_{EMCD}} = \frac{1}{y_{Blm}} = \frac{1}{\dfrac{y_{B_1} - y_{B_2}}{\ln\left|\dfrac{y_{B_1}}{y_{B_2}}\right|}}$$

$$y_{B_1} = 1 - 0.2 = 0.8$$

$$y_{B_2} = 1 - 0.1 = 0.9$$

$$Y_{Blm} = \frac{0.8 - 0.9}{\ln\left|\dfrac{0.8}{0.9}\right|} = 0.85$$

$$\therefore \quad \frac{(N_A)_{ANB}}{(N_A)_{EMCD}} = \frac{1}{0.85} = 1.176$$

End of Solution

Q.30 Two equipment capitalized cost in serial

	A	B
Installed cost	16000 Rs.	32000 Rs.
Maintenance	2400 Rs.	1600 Rs.
Salvage value	1000 Rs.	?
Service life	1	2

Ans. (2180)

	A	B
Installed cost	16000 Rs.	32000 Rs.
Maintenance	2400 Rs.	1600 Rs.
Salvage value	1000 Rs.	?
Service life	1	2

Salvage of instrument (B) = ?

i = 10% per year

Now, given [both the instrument have equal capitalized cost], therefore

$$\left[V_0 + \frac{V_0 - V_s}{(1+i)^n - 1} + \frac{V_m}{i}\right]_A = \left[V_0 + \frac{V_0 - V_s}{(1+i)^n - 1} + \frac{V_m}{i}\right]_B$$

$$16000 + \frac{16000 - 1000}{(1.1)^1 - 1} + \frac{2400}{0.1} = 32000 + \frac{32000 - V_s}{(1.1)^2 - 1} + \frac{1600}{0.1}$$

$$142000 = \frac{32000 - V_s}{(1.1)^2 - 1}$$

$$V_s = 2180 \text{ Rs.}$$

End of Solution

Q.31 Burning of methane in a combustion process produces CO, CO_2 and water vapour, methane in feed is 100 mol/hr only 50% of methane reacts in the process. The theoretical oxygen required _______.

Ans. (200)

$CH_4 + 2CO_2 \rightarrow CO_2 + 2H_2O$

$CH_4 + \frac{3}{2}O_2 \rightarrow CO + 2H_2O$

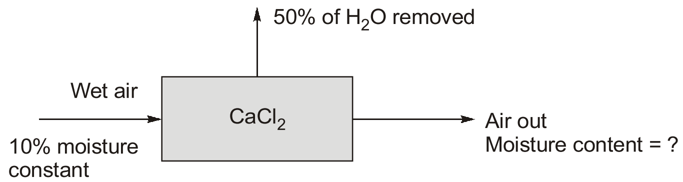
Given: CH_4 supply = 100 mol/hr

For theoretical oxygen requirement, complete combustion is only considered, i.e.

For 100 mole $CH_4 \rightarrow$ 200 mole O_2 is require.

End of Solution

Q.32



% mole fraction of H_2O at exit = ?

Ans. (5.3%)

Basis 100 mole of wet air

Thus, 10 mol = H_2O

90 mol = Dry air

After 50% H_2O removal, at exit we have

5 mol H_2O

90 mol dry air

$$X_{water} = \frac{5}{95} = 0.053 = 5.3\%$$

End of Solution

Q.33 John and Jane independently performed a thermodynamic experiment in which X and Y represent initial and final thermodynamic state of system. John performed under reversible condition for which change in entropy of system was ΔS_{rev}, Jane performed under irreversible condition for which change in entropy of system was $\Delta S_{irr.}$

(a) $\Delta S_{rev} = 2\Delta S_{irr}$
(b) $\Delta S_{rev} = \Delta S_{irr}$
(c) $\Delta S_{rev} < \Delta S_{irr}$
(d) $\Delta S_{rev} > \Delta S_{irr}$

Ans. (b)

Since entropy is a point function so that is why, it only depends on the initial and final state either performed by reversible path or irreversible path. Therefore the change in entropy in both the cases will be same.

End of Solution

Q.34 Which of the following is NOT correct for a Carnot engine?

(a) The engine is reversible.
(b) The engine efficiency is independent of source and sink temperature.
(c) This engine has the highest efficiency among all engines that operate between same source and sink.
(d) The total entropy of this system increases at the completion of each cycle of the engine.

Ans. (b)

End of Solution

Q.35 Given: $H = 40X_1 + 60X_2 + X_1X_2\,[4X_1 + 2X_2]$. The value of $\overline{H}_1^{\infty}$ is ________.

Ans. (42)

For $\overline{H}_1^{\infty}$, we have

$$\overline{H}_1 = H + X_2 \frac{dH}{dX_1}$$

$$H = 40X_1 + 60X_2 + X_1X_2\,[4X_1 + 2X_2]$$

$$H = -20X_1 + 60 + 2X_1 - 2X_1^3 \qquad \{\text{In terms of } X_1\}$$

Now,

$$\overline{H}_1 = 40X_1 + 60X_2 + X_1X_2\,[4X_1 + 2X_2] + X_2\frac{dH}{dX_1}$$

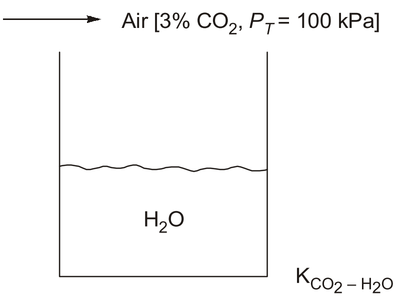
$$\frac{dH}{dX_1} = -20 + 2 - 6X_1^2 = -18 - 6X_1^2$$

$$\therefore \quad \overline{H}_1^{\infty} = 60 - 18 = 42 \qquad \{X_1 \to 0,\ X_2 \to 1\}$$

$$\overline{H}_1^{\infty} = 42$$

End of Solution

Q.36



$K_{CO_2-H_2O} = 12$ MPa

$X_{CO_2} = ?$ (in %)

Ans. (0.025)

From Henry law, we have

$$\overline{p}_i = X_iK_i = X_iH_i$$

$$y_iP_T = X_{CO_2} \cdot K_{CO_2}$$

$$0.03 \times 100 = X_{CO_2} \cdot 12000$$

$$X_{CO_2} = 2.5 \times 10^{-4} = 0.025\%$$

End of Solution

■■■■