9. Which one of the following electrolytes has the same value of van't Hoff factor (i) as that of $Al_2(SO_4)_3$ (if all are 100% ionised)?

(a) $Al(NO_3)_3$ 4
(b) $K_4[Fe(CN)_6]$ 5 ✓
(c) K_2SO_4 3
(d) $K_3[Fe(CN)_6]$ 4

$\alpha = \frac{i-1}{K-1}$, $\alpha = 1$, $i = K$

Q) $K_4[Fe(CN)_6]$ $\alpha = 50\%$, $i = ?$

$\frac{50}{100} = \frac{i-1}{5-1}$

10. Of the following 0.10 m aqueous solutions, which one will exhibit the largest freezing point depression?

(a) KCl (b) $C_6H_{12}O_6$

(c) $Al_2(SO_4)_3$ (d) K_2SO_4 (2014)

LOVP↑ ElBP↑
DiFP↑ OP↑

1
a) 0.1M NaCl
b) 0.1M $MgCl_2$
c) 0.1M $AlCl_3$
d) 0.1M $Al_2(SO_4)_3$

2
a) 0.1M NaCl
b) 0.2M $MgCl_2$
c) 0.3M $AlCl_3$
d) 0.4M $Al_2(SO_4)_3$
C×i

3
1% NaCl — 1 — $\frac{1}{58.5} \times 2$
1% $MgCl_2$ — 2 — $\frac{1}{95} \times 3$
1% $AlCl_3$ — 3 — $\frac{1}{133.5} \times 4$

4)
1% Urea — $\frac{1}{60} \times 1$
1% glucose — $\frac{1}{180} \times 1$
1% NaCl — $\frac{1}{58.5} \times 2$

5)
0.1N NaCl — $\frac{0.1}{1} \times 2$
0.1N $MgCl_2$ — $\frac{0.1}{2} \times 3$
0.1N $Al_2(SO_4)_3$ — $\frac{0.1}{6} \times 5$

$N = M \times nf$

11. How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2.0 M HNO_3? The concentrated acid is 70% HNO_3.

(a) 70.0 g conc. HNO_3
(b) 54.0 g conc. HNO_3
(c) 45.0 g conc. HNO_3 ✓
(d) 90.0 g conc. HNO_3

$$M = \frac{w}{M'} \times \frac{10^3}{V(mL)}$$

$$2 = \frac{w}{63} \times \frac{1000}{250}$$

13. Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 25°C are 200 mm Hg and 41.5 mm Hg respectively. Vapour pressure of the solution obtained by mixing 25.5 g of $CHCl_3$ and 40 g of CH_2Cl_2 at the same temperature will be (Molecular mass of $CHCl_3$ = 119.5 u and molecular mass of CH_2Cl_2 = 85 u)

(a) 173.9 mm Hg (b) 615.0 mm Hg

(c) 347.9 mm Hg (d) 285.5 mm Hg *(2012)*

$P^0_{CHCl_3} = 200$, $P^0_{CH_2Cl_2} = 41.5$

$n_{CHCl_3} = \frac{25.5}{119.5} = 0.213$

$n_{CH_2Cl_2} = \frac{40}{85} = 0.470$

$x_{CHCl_3} = 0.31$

$x_{CH_2Cl_2} = 0.69$

$P_T = P^0_A x_A + P^0_B x_B$

$= 90.63$

16. A 0.1 molal aqueous solution of a weak acid is 30% ionized. If K_f for water is 1.86°C/m, the freezing point of the solution will be

(a) – 0.18°C (b) – 0.54°C

(c) – 0.36°C (d) – 0.24°C *(2011)*

$\Delta T_f = i K_f m$

$\alpha = \frac{i-1}{K-1}$, $i = 1+\alpha$

$i = 1.3$

$1.3 \times 1.86 \times 0.1 = 0.24$

$\Delta T_f = T_f^0 - T_f$

$0 - 0.24 = -0.24°C$

19. A solution of sucrose (molar mass = 342 g mol^{-1}) has been prepared by dissolving 68.5 g of sucrose in 1000 g of water. The freezing point of the solution obtained will be (K_f for water = 1.86 K kg mol^{-1})

(a) – 0.372°C (b) – 0.520°C

(c) + 0.372°C (d) – 0.570°C **(2010)**

$\Delta T_f = K_f m \longrightarrow \frac{w}{M'} \frac{\times 10^3}{W}$

$\hookrightarrow 0.372$

$T_f = -0.372$

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20. 0.5 molal aqueous solution of a weak acid (HX) is 20% ionised. If K_f for water is 1.86 K kg mol^{-1}, the lowering in freezing point of the solution is

(a) 0.56 K (b) 1.12 K

(c) –0.56 K (d) –1.12 K *(2007)*

$i = 1 + \alpha$, $\Delta T_f = i K_f m$

28. A solution of urea (mol. mass 56 g mol^{-1}) boils at 100.18°C at the atmospheric pressure. If K_f and K_b for water are 1.86 and 0.512 K kg mol^{-1} respectively, the above solution will freeze at

(a) 0.654°C (b) – 0.654°C
(c) 6.54°C (d) – 6.54°C *(2005)*

a) $\Delta T_f = i K_f m$ b) $\Delta T_b = i K_b m$

$\Delta T_b = T_b - T_b^0$

$100.18 - 100 = 0.18$

$$\frac{\Delta T_f}{\Delta T_b} = \frac{K_f}{K_b}$$

$$\frac{\Delta T_f}{0.18} = \frac{1.86}{0.518}$$

25. The mole fraction of the solute in one molal aqueous solution is

(a) 0.009 (b) 0.018
(c) 0.027 (d) 0.036 *(2005)*

molality : 1 mole → 1 kg H_2O

1 mole of solute → $\frac{1000}{18}$ moles

$$X_{solute} = \frac{1}{\frac{1000}{18}+1} = 0.018$$

35. The depression in freezing point of 0.1 M aqueous solutions of HCl, $CuSO_4$ and K_2SO_4 are in the ratio

(a) 1 : 1 : 1.5 (b) 1 : 2 : 3

(c) 1 : 1 : 1 (d) 2 : 4 : 3 *(2017)*

$\Delta T_f = i K_f m$, $\Delta T_f \propto i$

HCl = 2

$CuSO_4$ = 2

K_2SO_4 = 3

1 : 1 : 1.5

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50. The vapour pressure of pure benzene at a certain temperature is 0.850 bar. A non-volatile, non-electrolyte solid weighing 0.5 g is added to 39.0 g of benzene (molar mass 78 g/mol). The vapour pressure of the solution then is 0.845 bar. What is the molecular mass of the solid substance?

(a) 58 (b) 180

(c) 170 (d) 145 *(2007)*

$$\frac{p^o - p_s}{p^o} = X_{solute} = \frac{n_{solute}}{n_{solvent}}$$

37. The freezing point of a solution containing 0.2 g of acetic acid in 20.0 g benzene is lowered by 0.45°C. The degree of association of acetic acid in benzene is (Assume acetic acid dimerises in benzene and K_f for benzene = 5.12 K kg mol^{-1}, M_{observed} of acetic acid = 113.78)

(a) 94.5% ✓

(b) 54.9%

(c) 78.2%

(d) 100%

(2016)

$$i = \frac{\text{Normal } M'}{\text{Observed } M'} \qquad \frac{60}{113} = 1 - \alpha + \frac{\alpha}{2}$$

$$2CH_3COOH \rightleftharpoons (CH_3COOH)_2$$

$2CH_3COOH$	$(CH_3COOH)_2$
1	0
$1-\alpha$	$\alpha/2$

$$\alpha = \frac{i-1}{K-1}$$

57. For 1 molal aqueous solution of the following compounds, which one will show the highest freezing point?

(a) $[Co(H_2O)_6]Cl_3$ 4
(b) $[Co(H_2O)_5Cl]Cl_2.H_2O$ 3
(c) $[Co(H_2O)_4Cl_2]Cl.2H_2O$ 2
(d) $[Co(H_2O)_3Cl_3].3H_2O$ 1 ✓

(2018)

58. The mass of a non-volatile, non-electrolyte solute (molar mass = 50 g mol^{-1}) needed to be dissolved in 114 g octane to reduce its vapour pressure to 75%, is

(a) 50 g (b) 37.5 g

(c) 75 g (d) 150 g *(Online 2018)*

$\frac{p^0 - p_s}{p^0} = \frac{n}{N}$

$\frac{p^0 - p_s}{p_s} = \frac{n}{N}$ ✓

$M'_{solute} = 50$, $M'_{octane} = 114$

$\frac{p^0 - 0.75p^0}{0.75p^0} = \frac{\frac{w}{50}}{1}$

$w = 16.66g$

$n_{octane} = \frac{114}{114} = 1$

62. The solubility of N_2 in water at 300 K and 500 torr partial pressure is 0.01 g L^{-1}. The solubility (in gL^{-1}) at 750 torr partial pressure is

(a) 0.0075 (b) 0.005
(c) 0.02 (d) 0.015

P_p = mF × solubility

$$\frac{P_1}{P_2} = \frac{S_1}{S_2}, \quad \frac{500}{750} = \frac{0.01}{S_2}$$

S_2 = 0.015 g/L

60. 5 g of Na_2SO_4 was dissolved in x g of H_2O. The change in freezing point was found to be 3.82 °C. If Na_2SO_4 is 81.5% ionised, the value of x (K_f for water = 1.86 °C kg mol^{-1}) is approximately (molar mass of S = 32 g mol^{-1} and that of Na = 23 g mol^{-1})

(a) 15 g
(b) 45 g ✓
(c) 25 g
(d) 65 g

(Online 2017)

$Na_2SO_4 =$ $\alpha = \dfrac{i-1}{K-1}$ ($K \to 3$) $i = 1 + 2\alpha$

$= 1 + 2 \times 0.815 = 2.63$

$\Delta T_f =$

67. The degree of dissociation (a) of a weak electrolyte, $AxBy$ is related to van't Hoff factor (i) by the expression

(a) $\alpha = \dfrac{i-1}{(x+y-1)}$ (b) $\alpha = \dfrac{i-1}{(x+y+1)}$

(c) $\alpha = \dfrac{(x+y-1)}{i-1}$ (d) $\alpha = \dfrac{(x+y+1)}{i-1}$ **(2011)**

$A_xB_y = xA^{y+} + yB^{x-}$

$1-\alpha \quad x\alpha \quad y\alpha$

$i = 1-\alpha + x\alpha + y\alpha = 1 + \alpha(x+y-1)$

73. A 5.25% solution of a substance is isotonic with a 1.5% solution of urea (molar mass = 60 g mol^{-1}) in the same solvent. If the densities of both the solutions are assumed to be equal to 1.0 g cm^{-3}, molar mass of the substance will be

(a) 210.0 g mol^{-1}
(b) 90.0 g mol^{-1}
(c) 115.0 g mol^{-1}
(d) 105.0 g mol^{-1} *(2007)*

$\pi_1 = \pi_2$ $\qquad C_1 = C_2$

$C_1RT = C_2RT \qquad \frac{1.5/60}{V} = \frac{5.25/M}{V} \qquad M = 210$

70. On mixing, heptane and octane form an ideal solution. At 373 K, the vapour pressure of the two liquid components (heptane and octane) are 105 kPa and 45 kPa respectively. Vapour pressure of the solution obtained by mixing 25.0 g of heptane and 35 g of octane will be (molar mass of heptane = 100 g mol^{-1} and of octane = 114 g mol^{-1})

(a) 144.5 kPa (b) 72.0 kPa ✓

(c) 36.1 kPa (d) 96.2 kPa ***(2010)***

$$P_T = P_A^0 x_A + P_B^0 x_B$$

91. MX_2 dissociates into M^{2+} and X^- ions in an aqueous solution, with a degree of dissociation (α) of 0.5. The ratio of the observed depression of freezing point of the aqueous solution to the value of the depression of freezing point in the absence of ionic dissociation is ***(2014)***

$MX_2 \rightleftharpoons M^{2+} + 2X^-$

$1-\alpha \quad \alpha \quad 2\alpha$

$i = 1 + 2\alpha \quad \alpha = 0.5$

$i = 2$

79. Benzene and toluene form nearly ideal solutions. At 20°C, the vapour pressure of benzene is 75 torr and that of toluene is 22 torr. The partial vapour pressure of benzene at 20°C for a solution containing 78 g of benzene and 46 g of toluene in torr is

(a) 50 (b) 25
(c) 37.5 (d) 53.5 *(2005)*

$P_B = P_B^0 x_B$ → 75

$x_B =$

90. If the freezing point of a 0.01 molal aqueous solution of a cobalt(III) chloride-ammonia complex (which behaves as a strong electrolyte) is –0.0558°C, the number of chloride(s) in the coordination sphere of the complex is [K_f of water = 1.86 K kg mol^{-1}] ***(2015)***

$\Delta T_f = i K_f m \rightarrow 0.01$

$T_f = -0.0558$

$0.0558 \quad i = \frac{\Delta T_f}{K_f m} = 3$

$[Co(NH_3)_5Cl]Cl_2 \longrightarrow [Co(NH_3)_5Cl]^{+2} + 2Cl^-$

3

52. 1 g of monobasic acid, HA in 100 g of water lowers the freezing point by 0.168°. If 0.2 g of same acid requires 15.1 mL of N/10 alkali for complete neutralisation. The degree of dissociation of acid is [$K_f(H_2O) = 1.86\ K\ mol^{-1}\ kg$]

(a) 19.6%
(b) 27%
(c) 31%
(d) 34.3%

① meq of Base = meq of Acid

$\frac{15.1}{10} = \frac{0.2}{E} \times 10^3$

$E = M'$

② $m = \frac{w}{M'} \times \frac{10^3}{W}$

3) $\Delta T_F = i K_f m$

4) $\alpha = \frac{i-1}{K-1}$