Class - IX

Colligative Properties

Raoult's Law - Relative Lowering Of Vapour Pressure

Teaching Task

Q1) Ans :- D.

Solution :- Lesser is the concentration of solution greater is the vapour pressure.

$$\underset{(0.25M)}{P_2} < \underset{(0.1M)}{P_1} < \underset{(0.01M)}{P_3}$$

Q2) Ans :- D.

Solution :- $K.E = \frac{3}{2} K_B T.$

$K.E \propto T.$

When the liquid is in equilibrium with its vapour pressure at its boiling point, the molecules in two phases have same kinetic energy as they are at same temperature.

Q3) Ans :- C.

Solution :- 1 mole each of solute is taken in 5 mole water. So mole fraction of each solute same.

→ Relative decrease in vapour pressure will depend on no. of ions.

			No. of ions
A)	$NaCl \rightarrow$	$Na^+ + Cl^-$	2
B)	$K_2SO_4 \rightarrow$	$2K^+ + SO_4^{2-}$	3.
C)	$Na_3PO_4 \rightarrow$	$3Na^+ + PO_4^{3-}$	4.
D)	Glucose →	No ionisation	1

∴ D < A < B < C.

Q4) Ans:- C.

Solution:- 10% solution → 10g of glucose, 90gm of water in 100gm of solution

No. of moles of water = $\frac{90}{18}$ = 5 moles.

No. of moles of glucose = $\frac{10}{180}$ = 0.056 moles.

Total moles = 5+0.056 = 5.056 moles.

Mole fraction of water = $\frac{5}{5.056}$ = 0.988.

∴ Final vapour pressure = $P \times X_{water}$.

= 30 × 0.988 = 29.6 mm.

Q5) Ans:- C.

Solution:- Mole fraction of solute,

$$X_2 = \frac{-\Delta P}{P_1^*} = \frac{3000-2985}{3000} = 0.005.$$

$$X_2 = \frac{m_2/M_2}{\frac{m_1}{M_1}+\frac{m_2}{M_2}} \simeq \frac{\frac{m_2}{M_2}}{\frac{m_1}{M_1}}$$

$$0.005 = \frac{5/M_2}{100/18}.$$

$$0.005 = \frac{5}{M_2} \times \frac{18}{100}$$

$$M_2 = \frac{5}{0.005} \times \frac{18}{100} = \frac{\overset{10}{\cancel{5}} \times 18}{\cancel{0.5}} = 180\ g\,mol^{-1}$$

Q6) Ans:- B

Solution:- Here at, Constant temperature for the system.

V changes to $\frac{V}{2}$, P changes to 2P.

But vapour pressure only depends on solvent and temperature.

So $V.P_{initial} = VP_{final}$

$= 17.54$ mm Hg

Q7) Ans:- B

Solution:- As both solution are at equilibrium, mole fractions of solutions will be same.

Solution 1:- 2% of X.

$$\text{Mole fraction} = \frac{\frac{98}{18}}{\frac{2}{M} + \frac{98}{18}} = \frac{\frac{98}{18}}{\frac{36+98M}{18M}} = \frac{98M}{36+98M} \quad \text{—(1)}$$

Solution 2:- 5% by weight

$$\text{Mole fraction} = \frac{95/18}{\frac{5}{60} + \frac{95}{18}} = \frac{\frac{95}{18}}{\frac{90+5700}{60\times18}} = \frac{95\times60}{5790} \quad \text{—(2)}$$

Equate 1 & 2.

$$\frac{98M}{36+98M} = \frac{5700}{5790}$$

$$98M = \frac{5700}{5790} \times (36+98M) \Rightarrow M = 23.15$$

Q8) Ans:- C.

Solution:- $P_{total} = P_A^o X_A + P_B^o X_B$

$= P_A^o X_A + P_B^o (1 - X_A)$

$= P_A^o X_A + P_B^o - P_B^o X_A$

$= P_B^o + X_A (P_A^o - P_B^o)$.

Given $P_{total} = 254 - 119 X_A$.

$P_B^o = 254$ $\quad P_A^o - P_B^o = -119$.

$P_B^o - P_A^o = +119$.

$254 - P_A^o = 119$.

$254 - 119 = P_A^o$

$P_A^o = 135$

Q9) Ans:- B

Solution:- p^o = Vapour pressure of pure solvent

p^s = V.P of solvent in solution.

X_2 = mole fraction of solute in solution.

$X_1 = 1 - X_2$ = molefraction of solvent in solution.

$$\frac{p^o - p^s}{p^o} = X_2$$

Decrease in V.P = 10mm of Hg.

$\frac{10}{p^o} = 0.2$

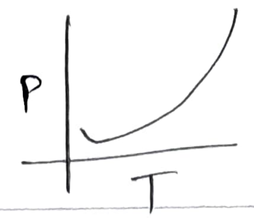
p^o = 50mm of Hg.

$\frac{20}{50} = X_2 \Rightarrow X_2 = 0.4$.

$X_1 = 1 - X_2 = 1 - 0.4 = 0.6$.

Q10) Ans:- C.

Solution:- Vapour pressure $\propto$ Temperature



Multiple correct Answer Type.

Q11) Ans:- A, B.

Solution:-

→ Boiling point of a solution is greater than pure solvent.

→ The temperature where the vapour pressure of liquid equals to atmospheric pressure is its boiling point.

Q12) Ans:- A, B, C, D.

Solution:- From the graph, we can observe that

$$P_A^\circ < P_B^\circ.$$

The vapour pressure at any x can be given as

$$P = (P_B^\circ - P_A^\circ) \times X_B + P_A^\circ.$$

$$X_A + X_B = 1$$

At $X_A = 1, X_B = 0 \rightarrow P = P_A^\circ < P_B^\circ$.

At $X_B = 1, X_A = 0 \rightarrow P = P_B^\circ > P_A^\circ$.

All the given statements are correct.

Q13) Ans:- D.

Solution:- Given 1 mole benzene, 1 mole toluene

V.P of $P^*_{benzene} = 100 mmHg$.

V.P of $P^*_{toluene} = 40 mm Hg$.

$X_{benzene} = \frac{1}{1+1} = 0.5$, $X_{toluene} = \frac{1}{1+1} = 0.5$

$P_{total} = X_{benzene} \times P^*_{benzene} + X_{toluene} \times P^*_{toluene}$

$= (0.5 \times 100) + (0.5 \times 40)$

$= 50 + 20 = 70 mm Hg$.

Q14) Ans:- A.

Solution:- $P_{toluene} = x_{toluene} \times P^*_{toluene} = 0.5 \times 40$

$= 20 mm Hg$

$P_{total} = 70 mm Hg$.

Mole fraction of toluene $X_{toluene} = \frac{20}{70}$

$= 0.2857$

$\cong 0.29$.

Q15) Ans:- C.

Solution:- The last trace of liquid will dissappear when the composition of the vapour.

$X_B = 0.5$ $X_T = 0.5$.

$\frac{1}{P} = \frac{X_T}{P_T^o} + \frac{X_B}{P_B^o} = \frac{0.5}{40} + \frac{0.5}{100}$

$\frac{1}{P} = \frac{50+20}{40 \times 100}$

$P = \frac{400}{7} = 57 mm Hg$.

Q16) Ans:- C

Solution:- According to Roult's law

$$P_A = P_A^{o} \times X_B$$

Partial pressure of solvent is equal to pure pressure of solvent multiplied by mole fraction of solvent

Integer Type.

Q17) Ans:- 6.

Solution:- Given

With Glucose

$w_2 = 100g$.

with urea.

$w_2 = 50g$, $w_1 = 1g$.

$$\Delta P = \frac{W_1 M_2}{W_2 M_1}.$$

ΔP is lowering of vapour pressure.

Vapour pressure of lowering is same for both the cases.

$$\frac{W_1 \times 18}{100 \times 180} = \frac{1 \times 18}{50 \times 60}.$$

$$W_1 = \frac{180}{30} = 6 = 6g.$$

Q18) Ans:- 4.

Solution:- $P^*_{pentane} = 440\ mmHg$, $P^*_{Hexane} = 120\ mm\ Hg$

Mole fraction of pentane in the vapour phase

$$y_{pentane} = 0.478.$$

$$y_{hexane} = 1 - y_{pentane} = 1 - 0.478 = 0.522$$

$$y_{pentane} = \frac{x_{pentane} \times P^*_{pentane}}{P_{total}}.$$

$$y_{hexane} = \frac{x_{hexane} \times P^*_{hexane}}{P_{total}}.$$

$$\frac{y_{hexane}}{y_{pentane}} = \frac{x_{hexane} \times p^*_{hexane}}{x_{pentane} \times p^*_{pentane}}$$

$$\frac{0.522}{0.478} = \frac{120 \times (x_{hexane})}{440 \times (x_{pentane})}$$

$$\frac{x_{hexane}}{x_{pentane}} = \frac{0.522}{0.478} \times \frac{440}{120}.$$

$$\approx \frac{229.68}{57.36}$$

$$\approx 4.$$

Matrix Matching

Q19) **Ans:** A) 3 B) 1 C) 2 D) 5

Solution:

A) Lowering of vapour pressure → 3) $p^0 - p$

B) Relative lowering of vapour pressure → 1) $\frac{p^0 - p}{p^0}$

C) Roult's law → 2) $\frac{p^0 - p}{p^0} = \frac{w}{m} \times \frac{M}{W}$

D) Volatile liquids → 5) Low boiling point

Learner's Task

Q1) **Ans:** D

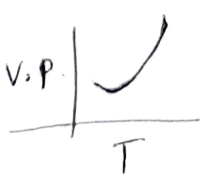
Solution: Rate of vapourisation depends on,

→ Nature of liquid
→ Temperature
→ Surface area of liquid
→ Flow of air over the surface.

Q2) **Ans:** C

Solution: As temperature increases, vapour pressure of a liquid increases exponentially

$V.P \propto T$



Q3) Ans:- D.

Solution:- The vapour pressure decreases as the no. of particles in the solution increases. Because it contains the most ions, it has the lowest vapour pressure

0.1M $Al_2(SO_4)_3$ has more ions. So it has lowest vapour pressure.

Q4) Ans:- D.

Solution:-

No. of Particles.

A) 0.1m Glucose → 1

B) 0.1m NaCl → $Na^+ + Cl^-$ → 2.

C) 0.1m $MgCl_2$ → $Mg^{+2} + 2Cl^-$ → 3.

D) 0.1m $Al_2(SO_4)_3$ → $2Al^{3+} + 3SO_4^{2-}$ → 5.

The relative lowering of vapour pressure is maximum for 0.1 m $Al_2(SO_4)_3$, as it produces the highest no. of ions in solution.

Q5) Ans:- A.

Solution:- Elevation of boiling point → $\Delta T_b \propto m$.

→ $\Delta T_b = K_b m$.

Elevation of the boiling point ∝ molality.

→ NaCl & $MgCl_2$ are ionic solid. So they have more boiling point.

→ 0.1m urea has the least B.P as it has least molal concentration.

Q6) Ans:- B

Solution:- For a dilute solution, Raoult's law states that the relative lowering of vapour pressure is equal to the mole fraction of solute.

Q7) Ans:- C

Solution:- Vapour pressure of the solution (P_s) is directly proportional to the mole fraction of solvent (X_B).

$$P_s \propto X_B$$

$$P_s = P_B^{\circ} X_B$$

Q8) Ans:- B

Solution:- Vapour pressure of mercury is very low because the forces of interaction b/w the individual metal atoms of mercury is quite a bit stronger than the cohesive molecular forces that holds together several molecules in case of alcohols, ethers & water.

Q9) Ans:- B

Solution:- Partial pressure of A = χ_A × pressure of A (pure)

$$= X P_A$$

Q10) Ans:- A

Solution:- Given 6g of urea, 90g of water.

$P = P^0 x$, P^0 = Boiling point of pure solvent

$$P = P^0 \frac{n_1}{n_1+n_2}$$

$$90g\ H_2O = \frac{90}{18} = 5\ \text{moles}.$$

$$6g,\ \text{of urea} = \frac{6}{60} = 0.1\ \text{moles}.$$

$$P = 760\left(\frac{0.1}{0.1+5}\right) = 760 \times 0.0196 = 14.89\ \text{Torr}.$$

Vapour pressure of solution $= 760 - 14.89$
$= 744.8$ mm of Hg.

JEE Main Level Questions

Q1) Ans:- A

Solution:- Vapour pressure of any substance increases non-linearly with temperature according to clausius - clapeyron relation.

The atmospheric pressure, boiling point of a liquid is the temperature at which which vapour pressure equals to ambient atmospheric pressure

Q2) Ans:- B.

Solution:- $Y_A = \frac{P_A^o X_A}{P_A^o X_A + P_B^o X_B}$

$$\frac{1}{Y_A} = \frac{P_A^o X_A + P_B^o X_B}{P_A^o X_A}$$

$$= \frac{P_A^o (1-X_B) + P_B^o X_B}{P_A^o X_A}$$

$$= \frac{P_A^o - P_A^o X_B + P_B^o X_B}{P_A^o X_A}$$

$$= \frac{P_A^o + X_B (P_B^o - P_A^o)}{P_A^o X_A} = \frac{\cancel{P_A^o}}{\cancel{P_A^o} X_A} + \frac{X_B (P_B^o - P_A^o)}{P_A^o X_A}$$

$$\frac{1}{Y_A} = \frac{1}{X_A} + C$$

Divide by P_B^o.

$y = mx + C \Rightarrow m = \frac{P_A^o}{P_B^o}$.

Q3) Ans:- B.

Solution:- $P = Ae^{-\Delta H/RT}$.

$$\log P = \log A - \frac{\Delta H}{RT}$$

$$= \left(-\frac{\Delta H}{R}\right)\frac{1}{T} + \log A.$$

↳ Negative slope.

$$\log P = \left(-\frac{\Delta H}{R}\right)\frac{1}{T} + \log A.$$

$\log P \to y$, $\left(-\frac{\Delta H}{R}\right) \to m$, $\frac{1}{T} \to x$, $\log A \to c$.

$x \to \frac{1}{T}$

$y \to \log P$.

Q4) Ans:- B.

Solution:- For urea $\Delta P_1 = X_{urea} P^o$.

$$X_{urea} = \frac{\frac{12}{60}}{\frac{12}{60} + \frac{68.4}{342}}$$

$$= \frac{0.2}{0.2+0.2} = \frac{0.2}{0.4} = 0.5.$$

$\Delta P_1 = 0.5 P^o$.

For sugar cane $\Delta P_2 = X_{sugarcane} P^o$.

$$X_{sugarcane} = \frac{\frac{68.4}{342}}{\frac{12}{60} + \frac{68.4}{342}} = \frac{0.2}{0.2+0.2}$$

$$= \frac{0.2}{0.4} = 0.5.$$

$\Delta P_2 = 0.5 P^o$.

Relative lowering pressure of both solutions are same.

Q5) Ans:- B.

Solution:- Given, $P_A^o = 100 mm Hg$, $P_B^o = 150 mm Hg$.

$n_A = 2$ moles, $n_B = 3$ moles

Vapour pressure $(P) = ?$

$$P = P_A^o x_A + P_B^o x_B.$$

$$= \overset{20}{\cancel{100}} \times \frac{2}{\cancel{5}} + \overset{30}{\cancel{150}} \times \frac{3}{\cancel{5}}$$

$$= 40 + 90$$

$$= 130 mm Hg$$

Q6) Ans:- C.

Solution:- Given $P_B^o - P_t = 0.225$ mm.

water, $P_B^o = 17.5$ mm

$$n_B = \frac{100}{18} = 5.55 \text{ moles.}$$

$$X_A = \frac{P_B^o - P_t}{P_B^o} = \frac{n_A}{n_A + n_B}$$

$$\frac{0.225}{17.5} = \frac{n_A}{n_A + 5.55}$$

$$0.225\, n_A + 1.248 = n_A(17.5)$$

$$1.248 = 17.5\, n_A - 0.225\, n_A$$

$$1.248 = 17.275\, n_A$$

$$n_A = \frac{1.248}{17.275} = 0.072 \text{ moles.}$$

$$\text{Molecular weight} = \frac{\text{Given weight}}{\text{no. of moles}}$$

$$= \frac{25}{0.072} \simeq 350$$

Q7) Ans:- C.

Solution:- Given, $P_1^o - P_1 = 2\%$ $w_2 = 6g$, $w_1 = 90g$

$M_1 = 18g$.

Let Take, $P_1^o = 100$.

$$\frac{P_0^1 - P_1}{P_1^o} = \frac{w_2 \times M_1}{M_2 \times w_1}.$$

$$\frac{2}{100} = \frac{6 \times 18}{M_2 \times 90_5} \Rightarrow 2M_2 = \frac{600}{5}$$

$$M_2 = \frac{600}{10} \Rightarrow M_2 = 60$$

Q8) Ans:- C

Solution:- Given aq. solution contains 64% by weight of volatile liquid A.

$W_A = 64g$ $W_{H_2O} = 100 - 64 = 36g$.

$n_A = \frac{64}{128} = 0.5$, $n_{H_2O} = \frac{36}{18} = 2$

$X_A = \frac{0.5}{0.5+2} = \frac{0.5}{2.5} = \frac{1}{5}$

$X_{H_2O} = \frac{2}{0.5+2} = \frac{2}{2.5} = \frac{4}{5}$

$P^o_{H_2O} = 155mm$, $P_{total} = 145mm$.

$P_{total} = P_A^o X_A + P_B^o X_B$.

$= P_A^o X_A + P^o_{H_2O} X_{H_2O}$

$145 = P_A^o(\frac{1}{5}) + 155(\frac{4}{5})$.

$725 = P_A^o + 620$.

$P_A^o = 725 - 620 = 105mm$.

Q9) Ans:- C

Solution:- $P_t = P_A^o \chi_A + P_B^o \chi_B$.

Given, $P_t = 84mm$, $P_A^o = 70$, $\chi_A = 0.8$, $\chi_B = 1 - 0.8 = 0.2$

$84 = 70 \times (0.8) + P_B^o (0.2)$

$84 = 56 + P_B^o (0.2)$

$0.2 P_B^o = 84 - 56 = 28$.

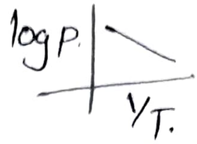
$P_B^o = \frac{28}{0.2} = 140$ mm of Hg.

Q10) Ans:- B.

Solution:- $P = Ae^{-\frac{\Delta H}{RT}}$

$$\log P = \log A - \frac{\Delta H}{RT}$$

Graph of $\log P$ vs $\frac{1}{T}$ would be obtained as a straight line with slope $-\frac{\Delta H}{R}$ and intercept A.



Advanced Level Questions

Q11) Ans:- A, B, C.

Solution:- Plot AD show show vapour pressure of B. Plot BC show vapour pressure of A. Plot CD show vapour pressure of liquid solution containing A & B.

Volatile components, $P = P_A + P_B$.

$EH = EF + EG$.

Q12) Ans:- A, B, D.

Solution:- Vapour pressure depends on the nature of solvent & temperature

→ Relative lowering of vapour pressure independent of temperature.

→ Lowering of vapour pressure increases with increase in concentration of the solution.

Q13) Ans:- D

Solution:- Lowering of vapour pressure not only depends on the molality but also depends on nature of solute & solvent.

Glucose dissolved in water, urea dissolved in benzene, two different solvents, lowering vapour pressure is not same

→ When a non-volatile solute added to a solvent, it causes the solvents vapor pressure to decrease because the solute particles occupy space at surface reducing the no. of solvent molecules that can escape into the vapour phase.

Q14) Ans:- C

Solution:- The water starts boiling a second time because when pressure cooker cools down pressure inside gets reduced. Reduced pressure brings down the boiling point of water.

→ Impurities increase the boiling point of water.

Q15) Ans:- A

Solution:- $P = P^0 \times X_A \rightarrow 0.60 = 0.80 \times X_A \Rightarrow X_A = 0.75$

Mole fraction of B, $X_B = 1 - X_A$

$= 1 - 0.75 = 0.25$

Q16) Ans:- C

Solution:- Given, $X_B = 0.25$, $P_S = 0.8$.

$P_S - P_O = ?$

$$\frac{P_S - P_O}{P_S} = X_B.$$

$$\frac{P_S - P_O}{0.8} = 0.25$$

$$P_S - P_O = 0.25 \times 0.8 = \underline{0.2}$$

Integer Type

Q17) Ans:- 2.

Solution:- Given, $P_t = 84$ torr.

$X_A = 0.8$, $P_A^o = 70$ torr.

$X_B = 0.2$, $P_B = 7x \times 10^1$

$x = ?$

$$P_T = X_A P_A^o + X_B P_B^o$$

$$84 = 0.8 \times 70 + 0.2 P_B^o$$

$$P_B^o = 140 \text{ torr.}$$

$$= 14 \times 10^1$$

$$P_B^o = 7 \times 2 \times 10^1.$$

$$\underline{x = 2}$$

Q18) Ans:- 10

Solution:- Given $n_A = 1$ mole of A.

$n_B = 4$ moles of B.

$P_A^o = 400$ mm of Hg, $P_B^o = 600$ mm Hg.

$P_{solution} = X_A P_A^o + X_B P_B^o$.

$X_A = \frac{1}{5}$, $X_B = \frac{4}{5}$.

$P_{solution} = \frac{1}{5}(400) + \frac{4}{5}(600)$ [80, 120]

$= 80 + 480 = 560$.

After removing 1 mole of B,

$n_A = 1$, $n_B = 4 - 1 = 3$ moles of B.

$X_A' = \frac{1}{1+3} = \frac{1}{4} = 0.25$, $X_B' = \frac{3}{4} = 0.75$.

$P'_{solution} = X_A' P_A^o + X_B' P_B^o$.

$= 0.25(400) + (0.75) \times 600$.

$= 100 + 450 = 550$ mm Hg.

Decrease in vapour pressure $= P_{solution} - P'_{solution}$.

$= 560 - 550 = 10$ mm Hg.

Q19) Ans:- 2.

Solution:- Given $\frac{P_A^o}{P_B^o} = \frac{1}{2} \Rightarrow P_A^o = 1, P_B^o = 2$

$n_A = 1$, $n_B = 2$

$P_A = X_A P_A^o = \frac{1}{3} \times 1 = \frac{1}{3}$

$P_B = X_B P_B^o = \frac{2}{3} \times 2 = \frac{4}{3}$

$P_T = P_A + P_B = \frac{1}{3} + \frac{4}{3} = \frac{5}{3}$

$P_A = X_A \times P_T$

$\frac{1}{3} = X_A \times \frac{5}{3}$

$X_A = \frac{1}{5} = 0.2 = 2 \times 10^{-1}$

Matrix Matching

Q20) **Ans:-** A) R B) S C) Q D) P.

Solution:-

A) Molality → R) Independent of Temperature.

B) Relative lowering → S) Mole fraction of solute.

C) Roult's law. → Q) Dilute solutions vapour pressure.

D) $X_{solute} + X_{solvent}$ → P) Unity.

6. COLLIGATIVE PROPERTIES

Raoult's Law - Relative Lowering of Vapour Pressure

KEY

TEACHING TASK

1	2	3	4	5	6	7	8	9	10
D	D	C	C	C	B	B	C	B	C
11	12	13	14	15	16	17	18	19	
A,B	A,B,C,D	D	A	C	C	6	4	A-3,B-1,C-2,D-5	

LEARNERS TASK

CUQ'S

1	2	3	4	5	6	7	8	9	10
D	C	D	D	A	B	C	B	B	A

JEE MAIN LEVEL QUESTIONS

1	2	3	4	5	6	7	8	9	10
A	B	B	B	B	C	C	C	C	B

ADVANCED LEVEL QUESTIONS

11	12	13	14	15	16	17	18	19
A,B,C	A,B,D	D	C	A	C	2	10	2

20
A-R,B-S,C-Q,D-P