#457420

Topic: Solutions

Define the term solution. How many types of solutions are formed? Write briefly about each type with an example

Solution

Solutions are homogeneous mixtures of two or more than two components.

There are three types of solutions.

(i) Gaseous solution:

The solvent is a gas and solute may be liquid, solid or gas.

Example includes a mixture of oxygen and nitrogen gases.

(ii) Liquid solution:

The solvent is a liquid and the solute may be gas, liquid or solid.

Example includes a solution of ethanol in water.

(iii) Solid solution:

The solvent is a solid. The solute may be gas, liquid or solid.

Example includes a solution of copper in gold.

#457421

Topic: Solutions

Give an example of a solid solution in which the solute is a gas.

Solution

An example of a solid solution in which the solute is a gas is a solution of hydrogen gas in palladium. It is an interstitial solid solution.

The solvent is a solid.

#457422

Topic: Expressing concentration of solutions

Define the following terms:

(i) Mole fraction (ii) Molality (iii) Molarity (iv) Mass percentage.

Solution

(i) Mole fraction

It is the ratio of the number of moles of a particular component to the total number of moles of all the components in the mixture. It is denoted by symbol χ.

(ii) Molality

It is the number of moles of the solute per kilogram of the solvent. It is the ratio of the number of moles of solute to mass of solvent in kg.

(iii) Molarity

It is the number of moles of solute per litre of the solution. It is the ratio of the number of moles of solute to volume of solution in litre.

(iv) Mass percentage

It is the mass of the solute (in grams) present in 100 g of the solution.

#457423

Topic: Expressing concentration of solutions

Concentrated nitric acid used in laboratory work is 68% nitric acid by mass in aqueous solution. What should be the molarity of such a sample of the acid if the density of the solution is $1.504\ g\ m_L{}^{-1}$?

Solution

The molar mass of nitric acid is 63 g/mol.

It is given that the nitric acid used in laboratory is 68% by mass in aqueous solution.

100 g of solution contains 68 g of nitric acid or $\frac{68}{63} = 1.079$ moles of nitric acid.

Density of solution is 1.504 g/mL.

100 g of solution corresponds to $\frac{100}{1.504} = 66.5$ mL or 0.0665 L

Molarity of the solution is the number of moles of nitric acid present in 1 L of solution.

It is $\frac{1.079}{0.0665} = 16.22$ M

Hence, the molarity should be 16.22 g/mL.

#457425

Topic: Expressing concentration of solutions

A solution of glucose in water is labelled as 10% w/w, what would be the molality and mole fraction of each component in the solution? If the density of solution is $1.2\ g\ mL^{-1}$, then what shall be the molarity of the solution?

Solution

10% w/w glucose solution corresponds to 10 g glucose present in 100 g of solution which contains 90 g of water.

(i) Molality is the number of moles of glucose present in 1 kg of water. Number of moles of glucose is the ratio of mass (10 g) of glucose to its molar mass (180 g/mol).

Molality $= \frac{10}{180 \times 0.090} = 0.618$ m

Note: 90 g corresponds to 0.090 lg.

(ii) Molarity is the ratio of number of moles of glucose to volume of solution (in L).

Since, denstiy of solution is 1.20 g/mL, the volume of solution is $\frac{100}{1.20}$ mL or $\frac{100}{1.20 \times 1000}$ L.

Molarity $= \frac{10}{180 \times \frac{100}{1.20 \times 1000}} = 0.667$ M

(iii) Number of moles of glucose $= \frac{10}{180} = 0.0556$

Number of moles of water $= \frac{90}{18} = 5.0$

Mole fraction of glucose $= \frac{0.0556}{0.0556 + 5.0} = 0.011$

Mole fraction of water $= 1 - 0.011 = 0.989$

#457427

Topic: Expressing concentration of solutions

How many mL of $0.1\ M\ HCl$ are required to react completely with $1\ g$ mixture of Na_2CO_3 and $NaHCO_3$ containing equimolar amounts of both?

Solution

Let the mixture contains x g of sodium carbonate and $1 - x$ g of sodium bicarbonate.

The molar masses of sodium carbonate and sodium bicarbonate are 106 g/mol and 84 g/mol respectively

The number of moles of sodium carbonate and sodium bicarbonates are $\frac{x}{106}$ and $\frac{1-x}{84}$ respectively.

Since, it is an equilmolar mixture,

$\frac{x}{106} = \frac{1-x}{84} 84x = 106 - 106x 190x = 106 x = 0.5579$

Number of moles of sodium carbonate $= \frac{0.5579}{106} = 0.005263$

Number of moles of sodium hydrogen carbonate $= \frac{1 - 0.5579}{84} = 0.005263$

One mole of sodium carbonate will react with 2 moles of HCl and 1 mole of sodium bicarbonate will react with 1 mole of HCl.

Total number of moles of HCl that will completely neutralize the mixture $= 2 \times 0.005263 + 0.005263 = 0.01578$ moles

Volume of $0.1\ M\ HCl$ required $= \frac{0.01578}{0.1} = 0.158\ L = 158$ mL.

#457430

Topic: Expressing concentration of solutions

A solution is obtained by mixing $300\ g$ of 25% solution and $400\ g$ of 40% solution by mass. Calculate the mass percentage of the resulting solution

Solution

Given that a solution is obtained by mixing 300 g of 25% solution and 400 g of 40% solution by mass.

Total mass of solution $= 300 + 400 = 700$ g

Mass of solute $= 0.25 \times 300 + 0.40 \times 400 = 75 + 160 = 235$ g

Mass percentage of solution $= \dfrac{235}{700} \times 100 = 33.6\%$

#457431

Topic: Expressing concentration of solutions

An antifreeze solution is prepared from $222.6\ g$ of ethylene glycol ($C_2H_6O_2$) and $200\ g$ of water. Calculate the molality of the solution. If the density of the solution is $1.072\ g\ mL^{-1}$, then what shall be the molarity of the solution?

Solution

Since, ethylene glycol is in excess, it is a solvent and water is a solute.

Molar mass of water is 18 g/mol.

Number of moles of solute $= \dfrac{200}{18} = 11.11$ moles

Molality is the number of moles of solute in 1 kg of solvent.

222.6 g of ethylene glycol corresponds to 0.2226 kg.

Molality $= \dfrac{11.11}{0.2226} = 49.9$ m

Total mass of solution $= 222.6 + 200 = 422.6$ g

Density of solution $= 1.072$ g/mL

Volume of solution $= \dfrac{\text{Mass}}{\text{Density}} = \dfrac{422.6}{1.072} = 394$ ml or 0.394 L

Molarity is the number of moles of solute in 1 L of solution.

Molarity $= \dfrac{11.11}{0.394} = 28.2$ M

#457432

Topic: Expressing concentration of solutions

A sample of drinking water was found to be severely contaminated with chloroform ($CHCl_3$) supposed to be a carcinogen. The level of contamination was $15\ ppm$ (by mass):

(i) express this in percent by mass

(ii) determine the molality of chloroform in the water sample.

Solution

15 ppm corresponds to 15 g chloroform in $1000,000$ g of solution.

(i) Percent by mass $= \dfrac{\text{Mass of chloroform}}{\text{Mass of solution}} \times 100$

Percent by mass $= \dfrac{15}{1000,000} \times 100 = 1.5 \times 10^{-3}\%$

(ii) Molality $= \dfrac{\text{Mass of chloroform}}{\text{Molar mass of chloroform} \times (\text{Mass of solution} - \text{mass of chloroform})} \times 1000$ (all masses in g)

Molality $= \dfrac{15}{119.5 \times (1000,000 - 15)} \times 1000 = 1.255 \times 10^{-4}$ m.

#457433

Topic: Ideal and non-ideal solutions

What role does the molecular interaction play in a solution of alcohol and water?

Solution

The presence of molecular interactions (inter-molecular hydrogen bonds) in a solution of alcohol and water lead to positive deviation from Raoult's law. The solution does not follow ideal behavior. In other words, solution becomes non ideal. The vapour pressure increases and the boiling point decreases.

#457434

Topic: Solutions of solids or gases in liquids

Why do gases always tend to be less soluble in liquids as the temperature is raised?

Solution

Dissolution of gas in liquid is an exothermic process and heat is evolved during dissolution.

Gas + Liquid $\rightleftharpoons$ Solution + Heat

With increase in temperature, heat is supplied which shifts the equilibrium in the backward direction.

Hence, gases always tend to be less soluble in liquids as the temperature is raised.

#457435

Topic: Solutions of solids or gases in liquids

State Henrys law and mention some important applications?

Solution

According to Henry's law, the solubility of gas in a liquid is directly proportional to the pressure of the gas.

$X = K_h \times P$

X is the mole fraction of gas, K_h is the Henry's law constant and P is the partial pressure of the gas.

Important applications:

1) In packing of soda cans: Soda water bottles are always packed under higher pressure to increase the solubility of CO_2 gas.

2) In deep see diving: Nitrogen is more soluble than Helium in our blood. In the deep see, the pressure is higher than at the surface of water. When diver tries to come rapidly towards the surface of water, pressure decreases and dissolved nitrogen comes back from blood and makes bubbles in veins. Hence, divers use oxygen diluted with helium.

#457437

Topic: Solutions of solids or gases in liquids

The partial pressure of ethane over a solution containing $6.56 \times 10^{-3} g$ of ethane is 1 bar. If the solution contains $5.00 \times 10^{-2} g$ of ethane, then what shall be the partial pressure of the gas?

Solution

According to Henry's law, the solubility of gas in a liquid is directly proportional to the pressure of the gas.

$X = K_h \times P$

X is the mole fraction of gas, K_h is the Henry's law constant and P is the partial pressure of the gas.

Also mole fraction of ethane will be directly proportional to its mass.

$WP' = W'P$

W is the mass of ethane in first solution and P is the partial pressure of ethane in first solution.

W' is the mass of ethane in second solution and P' is the partial pressure of ethane in second solution.

$6.56 \times 10^{-3} \times P' = 5.00 \times 10^{-2} \times 1 P' = 7.6$

Hence, the partial pressure of gas will be 7.6 bar.

#457439

Topic: Ideal and non-ideal solutions

What is meant by positive and negative deviations from Raoult's law and how is the sign of $\Delta_{mix}H$ related to positive and negative deviations from Raoult's law?

Solution

Positive deviation from Raoult's law occurs when the total vapour pressure of the solution is more than corresponding vapour pressure in case of ideal solution.

$P = P_A + P_B > P_A^o X_A + P_B^o X_B$

Negative deviation from Raoult's law occurs when the total vapour pressure of the solution is less than corresponding vapour pressure in case of ideal solution.

$P = P_A + P_B < P_A^o X_A + P_B^o X_B$

For positive deviation from Raoult's law, $\Delta_{mix}H$ has positive sign .

For negative deviation from Raoult's law, $\Delta_{mix}H$ has negative sign.

#457440

Topic: Vapour Pressure of Liquid Solutions and Raoult's Law

An aqueous solution of 2% non-volatile solute exerts a pressure of 1.004 bar at the normal boiling point of the solvent. What is the molar mass of the solute?

Solution

At boiling point, the vapour pressure of pure water is 1 atm or 1.004 bar.

Vapour pressure of solution is 1.004 bar.

Mass of solute is 2 g.

Mass of solution is 100 g.

Mass of solvent is $100 - 2 = 98$ g

Applying Raoult's law, we get

$$\frac{P^o - P}{P} = x_2 = \frac{W_2 M_1}{M_2 W_1}$$

$$\frac{1.013 - 1.004}{1.013} = \frac{2 \times 18}{M_2 \times 98} \implies M_2 = 41.35 \text{ g/mol}$$

#457442

Topic: Vapour Pressure of Liquid Solutions and Raoult's Law

Heptane and octane form an ideal solution. At $373\ K$, the vapour pressures of the two liquid components are $105.2\ kPa$ and $46.8\ kPa$ respectively. What will be the vapour pressure of a mixture of $26.0\ g$ of heptane and $35\ g$ of octane?

Solution

The molar masses of heptane and octane are 100 g/mol and 114 g/mol respectively.

26 g of heptane corresponds to $\frac{26}{100} = 0.26$ moles

35 g of octane corresponds to $\frac{35}{114} = 0.31$ moles

Mole fraction of heptane $X = \frac{0.26}{0.26 + 0.31} = 0.456$

Mole fraction of octane $X' = 1 - 0.456 = 0.544$

Partial pressure of heptane $p = 0.456 \times 105.2 = 47.97$ kPa

Partial pressure of octane $p' = 0.544 \times 46.8 = 25.46$ kPa

Vapour pressure of solution $P = p + p' = 47.97 + 25.46 = 73.43$ kPa

#457443

Topic: Ideal and non-ideal solutions

The vapour pressure of water is $12.3\ kPa$ at $300\ K$. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it.

Solution

The vapour pressure of water is 12.3 kPa at 300 K. We need to calculate the vapour pressure of 1 molal solution of a non-volatile solute in it.

1000 g of water contains 1 mole of solute.

Molar mass of water is 18 g/mol.

Number of moles of water $= \frac{1000}{18} = 55.56$ mol

Mole fraction of the solute in the solution is $x = \frac{1}{1 + 55.56} = 0.0177$.

The relative lowering in the vapour pressure is equal to the mole fraction of solute.

$\frac{p^0 - p}{p^0} = x \frac{12.3 - p}{12.3} = 0.0177 \implies p = 12.08$

Hence, the vapour pressure of the solution is 12.08 kPa.

#457445

Topic: Ideal and non-ideal solutions

Calculate the mass of a non-volatile solute (molar mass $40\ g\ mol^{-1}$) which should be dissolved in $114\ g$ octane to reduce its vapour pressure to 80%.

Solution

Let p be the vapour pressure of pure octane. The vapour pressure of solution will be $\frac{80}{100}p = 0.8\ p$.

Molar mass of solute (M) and octane (m) are 40 g/mol and 114 g/mol respectively. Mass of octane, w is 114 g.

$\frac{p - p^{'}}{p} = \frac{Wm}{Mw} \frac{p - 0.8p}{p} = \frac{W \times 114}{40 \times 114} W = 8\ g$

Hence, 8 g of solute are required.

#457447

Topic: Ideal and non-ideal solutions

A solution containing $30\ g$ of non-volatile solute exactly in $90\ g$ of water has a vapour pressure of $2.8\ kPa$ at $298\ K$. Further, $18\ g$ of water is then added to the solution and the new vapour pressure becomes $2.9\ kPa$ at $298\ K$. Calculate:

(i) molar mass of the solute (ii) vapour pressure of water at $298\ K$.

Solution

Weight of solute, $W_B = 30$ g

Weight of water, $W_A = 90$ g

Vapour pressure of solution $P_A = 2.8$ kPa

According to Raoult's law, $\dfrac{P_A^o - P_A}{P_A^o} = X_B \simeq \dfrac{W_B M_A}{M_B W_A}$

$$\frac{P_A^o - 2.8}{P_A^o} = \frac{30 \times 18}{M_B \times 90}$$

$$\frac{2.8}{P_A^o} = \frac{M_B - 6}{M_B} \;......(1)$$

Weight of solute $W_B = 30$ g

Weight of water $W_A = 90 + 18 = 108$ g

Vapour pressure of solution $P_A = 2.9$ kPa

According to Raoult's law, $\dfrac{P_A^o - P_A}{P_A^o} = X_B \simeq \dfrac{W_B M_A}{M_B W_A}$

$$\frac{P_A^o - 2.9}{P_A^o} = \frac{30 \times 18}{M_B \times 108}$$

$$\frac{2.9}{P_A^o} = \frac{M_B - 5}{M_B} \;......(2)$$

Divide equation (1) by equation (2), we get

$$\frac{2.8}{2.9} = \frac{M_B - 6}{M_B - 5}$$

$M_B = 34$ g/mol

Substituting the values of M_B in equation (1), we get

$$\frac{2.8}{P_A^o} = \frac{34 - 6}{34}$$

$P_A^0 = 3.4$ kPa

#457449

Topic: Depression in freezing point

A 5% solution (by mass) of cane sugar in water has freezing point of $271K$. Calculate the freezing point of 5% glucose in water if freezing point of pure water is 273.15 K.

Solution

The depression in the freezing point of the solution is given by

$\Delta T_f =$ freezing point of water $-$ freezing point of solution

$\Delta T_f = 273.15 - 271 = 2.15$ K

Molar masses of glucose and sucrose are 180 g/mol and 342 g/mol respectively.

100 g of solution will contain 5 g of glucose or 5 g of sucrose.

Number of moles of glucose $= \dfrac{5}{180} = 0.028$ moles

Number of moles of sucrose $= \dfrac{5}{342} = 0.0146$ moles

Mass of solvent = total mass of solution - mass of solute $= 100 - 5 = 95$ g or 0.095 kg

Molality of sucrose solution $= \dfrac{0.0146}{0.095} = 0.154$ m

$$K_f = \frac{\Delta T_f}{\text{molality}} = \frac{2.15}{0.154} = 13.97$$

For glucose solution, $\Delta T_f = K_f \times m = 13.97 \times 0.29 = 4.08$

Freezing point of 5% glucose solution in water = freezing point of water - $\Delta T_f = 273.15 - 4.08 = 269.07$ K

#457450

Topic: Depression in freezing point

Two elements A and B form compounds having formula AB_2 and AB_4. When dissolved in 20 g of benzene (C_6H_6), 1 g of AB_2 lowers the freezing point by 2.3 K whereas 1.0 g of AB_4 lowers it by 1.3 K. The molar depression constant for benzene is 5.1 $K\ kg\ mol^{-1}$. Calculate atomic masses of A and B.

Solution

In case of compound AB_2:

$$M_B = \frac{K_f W_B \times 1000}{W_A \Delta T_f}$$

$\Delta T_f = 2.3K$, $W_B = 1.0g$, $W_A = 20.0g$, $K_f = 5.1 KKg/mol$

$$M_B = \frac{5.1 \times 1.0 \times 1000}{20.0 \times 2.3} = 110.87 \text{ g/mol}$$

In case of compound AB_4:

$\Delta T_f = 1.3K$, $W_B = 1.0g$, $W_A = 20.0g$

$$M_B = \frac{5.1 \times 1.0 \times 1000}{20.0 \times 1.3} = 196.15 \text{ g/mol}$$

Let a g/mol and b g/mol be the atomic masses of A and B respectively.

$M_{AB_2} = a + 2b = 110.87 \ldots\ldots (i)$

$M_{AB_4} = a + 4b = 196.15 \ldots\ldots\ldots (ii)$

Substracting equation (ii) from equation (i), we have

$-2b = -85.28$

Atomic mass of B is $b = 42.64$.

Substituting the values of b in equation (i), we get

$a + 2 \times 42.64 = 110.87$

Atomic mass of A is $a = 25.59$ g/mol.

#457452

Topic: Osmotic pressure

At $300\ K$, $36\ g$ of glucose present in a litre of its solution has an osmotic pressure of $4.98\ bar$. If the osmotic pressure of the solution is 1.52 bars at the same temperature, what would be its concentration?

Solution

As per van't Hoff equation, the relationship between the osmotic pressure and the molar concentration is $\Pi = CRT$. Here, R is the ideal gas constant and T is absolute temperature.

$C_1 = \frac{36}{180}$ M

(Note: Molar mass of glucose is 180 g/mol and molar concentration is the ratio of number of moles of glucose to volume of solution in L. Number of moles is the ratio of mass to molar mass).

$\Pi_1 = 4.98$ bar

$C_2 = ?$

$\Pi_2 = 1.52$ bar

$4.98 = \frac{36}{180}$ RT ......(i)

$1.52 = C_2$ RT ......(ii)

Divide equation (ii) with equation (i),

$$\frac{C_2}{36} \times 180 = \frac{1.52}{4.98}$$

$C_2 = 0.061\ M$

Hence, second solution has concentration of $0.061\ M$.

#457459

Topic: Solutions of solids or gases in liquids

Based on solute-solvent interactions, arrange the following in order of increasing solubility in n-octane and explain.

Cyclohexane, KCl, CH_3OH, CH_3CN

Solution

n-Octane is non polar and can dissolve non-polar solutes. It cannot dissolve polar (and ionic) solutes.

Cyclohexane is non polar. Hence, easily soluble in n-octane.

Methanol and acetonitrile are polar and have very low solubility in n-octane.

KCl is ionic compound and hence, insoluble in n-octane.

The increasing order for solubility in n-octane is as follows:

$KCl < CH_3OH < CH_3CN <$ Cyclohexane

#457460
Topic: Solutions of solids or gases in liquids

Amongst the following compounds, identify which are insoluble, partially soluble and highly soluble in water?

(i) phenol (ii) toluene (iii) formic acid (iv) ethylene glycol (v) chloroform (vi) pentanol

Solution

(i) Phenol is partially soluble in water.

(ii) Toluene is water insoluble.

(iii) Formic acid is water soluble.

(iv) Ethylene glycol is water soluble.

(v) Chloroform is water insoluble.

(vi) Pentanol is partially soluble in water.

#457461
Topic: Expressing concentration of solutions

If the density of some lake water is $1.25g\ mL^{-1}$ and contains $92\ g$ of Na^+ ions per kg of water, calculate the molality of Na^+ ions in the lake.

Solution

Mass of sodium ions $= 92$ g

Molar mass of sodium ions $= 23$ g/mol

Number of moles of sodium ions $= \dfrac{92g}{23g/mol} = 4$

Mass of water $= 1$ kg

Molality $= \dfrac{\text{number of moles of sodium ions}}{\text{Mass of water (in kg)}} = \dfrac{4}{1} = 4$ m

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#457463
Topic: Expressing concentration of solutions

If the solubility product of CuS is 6×10^{16}, calculate the maximum molarity of CuS in aqueous solution.

Solution

Let S M be the maximum possible molarity of CdS in aqueous solution.

$[Cd^{2+}] = [S^{2-}] = S$ M

Solubility product $K_{sp} = [Cd^{2+}][S^{2-}]6 \times 10^{-16} = S \times SS = 2.45 \times 10^{-8}$ M

Hence, the maximum molarity of CuS in aqueous solution is 2.45×10^{-8} M.

#457466
Topic: Expressing concentration of solutions

Calculate the mass percentage of aspirin ($C_9H_8O_4$) in acetonitrile (CH_3CN) when $6.5\ g$ of $C_9H_8O_4$ is dissolved in $450\ g$ of CH_3CN.

Solution

Mass percentage of aspirin in acetonitrile

$= \dfrac{\text{Mass of aspirin}}{\text{Mass of acetonitrile}} \times 100 = \dfrac{6.5}{450} \times 100 = 1.44\%$

#457467

Topic: Expressing concentration of solutions

Nalorphene ($C_{19}H_{21}NO_3$), similar to morphine, is used to combat withdrawal symptoms in narcotic users. Dose of nalorphene generally given is $1.5\ mg$. Calculate the mass of $1.510^{-3} m$ aqueous solution required for the above dose.

Solution

$$\text{Molality} = \frac{\text{Moles of solute}}{\text{Mass of solvent (in kg)}}$$

$$0.15 = \frac{\text{Moles of benzoic acid}}{\frac{250}{1000}}$$

$$\text{Moles of benzoic} = \frac{0.15 \times 250}{1000} = 0.0375$$

Molar mass of benzoic acid is 122 g/mol respectively.

Amount of benzoic acid $= 0.0375 \times 122 = 4.575$ g

#457469

Topic: Expressing concentration of solutions

Calculate the amount of benzoic acid (C_6H_5COOH) required for preparing $250\ mL$ of $0.15\ M$ solution in methanol.

Solution

Number of moles of benzoic acid required $= 0.15 \times \frac{250}{1000} = 0.0375$ moles

Molar mass of benzoic acid $= 7(12) + 6(1) + 2(16) = 84 + 6 + 32 = 122$ g/mol

Mass of benzoic acid required $= 122 \times 0.0375 = 4.575$ g

#457470

Topic: Abnormal molecular mass

The depression in freezing point of water observed for the same amount of acetic acid, trichloroacetic acid and trifluoroacetic acid increases in the order given above. Explain briefly.

Solution

When strongly electron withdrawing groups are present on alpha C atom of acetic acid, the acid strength and the degree of dissociation increases. This increases the vant Hoff factor i and the depression in the freezing point. Trifluoroacetic is most acidic because fluorine is most electron withdrawing in nature. Hence, trifluoroacetic acid has maximum depression in the freezing point.

#457473

Topic: Abnormal molecular mass

Calculate the depression in the freezing point of water when $10\ g$ of $CH_3CH_2CHClCOOH$ is added to $250\ g$ of water. $Ka = 1.4 \times 10^{-3}$, $K_f = 1.86\ K\ kg\ mol^{-1}$

Solution

Molar mass of 2-chloro butanoic acid is 122.5 g/mol.

Number of moles $= \frac{10}{122.5} = 0.0816$ mol

Molality of solution $= \frac{0.0816 \times 1000}{250} = 0.3265$ m

Let α be the degree of dissociation and c be the initial concentration. The concentration after dissociation is as shown.

$CH_3CH_2CHClCOOHc(1-\alpha) \rightleftharpoons CH_3CH_2CHClCOO^- c\alpha + Hc\alpha^+$

The equilibrium constant expression is

$K = \frac{c\alpha \times c\alpha}{c(1-\alpha)} = c\alpha^2$

$\alpha = \sqrt{\frac{K}{c}} = \sqrt{\frac{1.4 \times 10^{-3}}{0.3265}} = 0.065$

Calculation of vant Hoff factor:

$CH_3CH_2CHClCOOH(1-\alpha) \rightleftharpoons CH_3CH_2CHClCOO^- \alpha + \alpha H^+$

$i = \frac{1-\alpha+\alpha+\alpha}{1} = 1+\alpha = 1 + 0.065 = 1.065$

The depression in the freezing point $\Delta T_f = iK_f m = 1.065 \times 1.86 \times 0.3265 = 0.647^o$

#457475

Topic: Abnormal molecular mass

19.5 g of CH_2FCOOH is dissolved in 500 g of water. The depression in the freezing point of water observed is 1.00^0C. Calculate the van't Hoff factor and dissociation constant of fluoroacetic acid.

Solution

Fluoroacetic acid has molecular mass of 78 g/mol.

Number of moles of fluoroacetic acid is $\frac{19.5}{78} = 0.25$.

Molality is the number of moles of solute in 1 kg of solvent.

Molality $= \frac{0.25}{\frac{500}{1000}} = 0.50$ m

Calculated depression in the freezing point.

$\Delta T_f = K_f \times m = 1.86 \times 0.50 = 0.93$ K

Van't Hoff factor is the ratio of observed freezing point depression to calculated freezing point depression.

$i = \frac{1.0}{0.93} = 1.0753$

Let c be the initial concentration of fluoro acetic acid and α be its degree of dissociation.

$CH_2FCOOHc(1-\alpha) \rightarrow CH_3FCOO^- c\alpha + H^+ c\alpha$

Total number of moles $= c(1-\alpha) + c\alpha + c\alpha = c(1+\alpha)$

$i = \frac{c(1+\alpha)}{c} = 1 + \alpha = 1.0753$

$\alpha = 0.0753$

$[CH_2FCOO^-] = [H^+] = c\alpha = 0.50 \times 0.0753 = 0.03765$

$[CH_2FCOOH] = c(1-\alpha) = 0.50(1-0.0753) = 0.462$

$K_a = \frac{[CH_2FCOO^-][H^+]}{[CH_2FCOOH]}$

$K_a = \frac{0.03765 \times 0.03765}{0.462}$

$K_a = 3.07 \times 10^{-3}$

#457476

Topic: Ideal and non-ideal solutions

Vapour pressure of water at $293\ K$ is $17.535\ mm\ Hg$. Calculate the vapour pressure of water at $293\ K$ when $25\ g$ of glucose is dissolved in $450\ g$ of water.

Solution

The molar masses of glucose and water are 180 g/mol and 18 g/mol respectively.

Number of moles of glucose $= \frac{25}{180} = 0.139$

Number of moles of water $= \frac{450}{18} = 25$

Mole fraction of glucose $= \frac{0.139}{0.139 + 25} = 0.0055$

Vapour pressure lowering is directly proportional to mole fraction

$\frac{P^0 - P}{P^0} = X \frac{17.535 - P}{17.535} = 0.0055 P = 17.438$

Hence, the vapour pressure of solution is 17.438 mm Hg.

#457477

Topic: Solutions of solids or gases in liquids

Henry's law constant for the molality of methane in benzene at $298\ K$ is $4.27 \times 105\ mm\ Hg$. Calculate the solubility of methane in benzene at $298\ K$ under $760\ mm\ Hg$.

Solution

It is given that the molality of methane in benzene at $298\ K$ is 4.27×10^5 mm of Hg.

$C = \frac{p}{k}$

$C = \frac{760\ mm\ Hg}{4.27 \times 10^5\ mm\ Hg/m}$

$C = 1.78 \times 10^{-3}$ m

Here, C is the molality of methane in benzene, p is the pressure of methane and k is the Henry's law constant.

#457478

Topic: Vapour Pressure of Liquid Solutions and Raoult's Law

$100\ g$ of liquid A (molar mass $140\ g\ mol^{-1}$) was dissolved in $1000\ g$ of liquid B (molar mass $180\ g\ mol^{-1}$). The vapour pressure of pure liquid B was found to be $500\ torr$. Calculate the vapour pressure of pure liquid A and its vapour pressure in the solution if the total vapour pressure of the solution is $475\ Torr$.

Solution

Number of moles is the ratio of mass to molar mass.

For liquid A, number of moles $= \dfrac{100}{140} = 0.714$

For liquid B, number of moles $= \dfrac{1000}{180} = 5.556$

Mole fraction of A $= \dfrac{0.714}{0.714 + 5.556} = 0.114$

Mole fraction of B $= 1 - 0.114 = 0.886$

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

$475 = P_A^o \times 0.114 + 500 \times 0.886$

$475 = 0.114 P_A^o + 443$

Vapour pressure of pure A, $P_A^o = 280.7$ torr

Vapour pressure of A in solution $= 280.7 \times 0.114 = 32$ torr

#457484

Topic: Ideal and non-ideal solutions

Vapour pressures of pure acetone and chloroform at $328\ K$ are $741.8\ mm\ Hg$ and $632.8\ mm\ Hg$ respectively. Assuming that they form ideal solution over the entire range of composition, plot p_{total}, $p_{chloroform}$, and $p_{acetone}$ as a function of $x_{acetone}$. The experimental data observed for different compositions of mixture is:

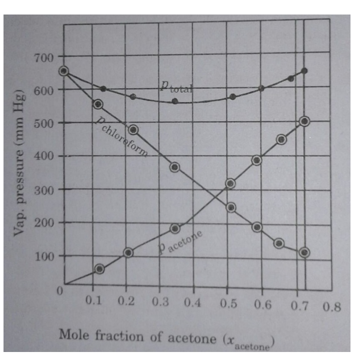
$100 x x_{acetone}$	0	11.8	23.4	36.0	50.8	58.2	64.5	72.1
$P_{acetone} / mm\ Hg$	0	54.9	110.1	202.4	322.7	405.9	454.1	521.1
$P_{chloroform} / mm\ Hg$	632.8	548.1	469.4	359.7	257.7	193.6	161.2	120.7

Plot this data also on the same graph paper. Indicate whether it has positive deviation or negative deviation from the ideal solution.

Solution

x (acetone)	0	0.118	0.234	0.360	0.508	0.508	0.582	1. 0.645 0.721
P (acetone, mm Hg)	0	54.9	110.1	202.4	202.4	322.7	405.9	454.1 521.1
P (chloroform, mm Hg)	632.8	548.1	469.4	359.7	359.7	257.7	193.6	151.2 120.7
P (total)	632.8	603.0	579.5	562.1	562.1	580.4	599.5	615.3 641.8

The plot of P (total) shows a dip downwards. This indicates negative deviation from ideal behaviour.



#457485

Topic: Vapour Pressure of Liquid Solutions and Raoult's Law

Benzene and toluene form ideal solution over the entire range of composition. The vapour pressure of pure benzene and toluene at 300 K are 50.71 $mm\ Hg$ and 32.06 $mm\ Hg$ respectively. Calculate the mole fraction of benzene in vapour phase if 80 g of benzene is mixed with 100 g of toluene.

Solution

Number of moles is the ratio of mass to molar mass.

The molar masses of benzene and toluene are 78 g/mol and 92 g/mol respectively.

Number of moles of benzene $= \frac{80}{78} = 1.026$

Number of moles of toluene $= \frac{100}{92} = 1.087$

Mole fraction of benzene, $X_B = \frac{1.026}{1.026 + 1.087} = 0.486$

Mole fraction of toluene, $X_T = 1 - 0.486 = 0.514$

$P_B = P_B^o \times X_B = 50.71 \times 0.486 = 24.65$ mm Hg

$P_T = P_T^o X_T = 32.06 \times 0.514 = 16.48$ mm of Hg

Total vapour pressure $= 24.65 + 16.48 = 41.13$ mm Hg

Mole fraction of benzene in vapour phase is as follows:

$Y_B = \frac{24.65}{41.13} = 0.60$

#457486

Topic: Solutions of solids or gases in liquids

The air is a mixture of a number of gases. The major components are oxygen and nitrogen with approximate proportion of 20% to 79% by volume at 298 K. The water is in equilibrium with air at a pressure of 10 atm. At 298 K, if the Henry's law constants for oxygen and nitrogen at 298 K are 3.30×107 mm and 6.51×107 mm respectively, calculate the composition of these gases in water.

Solution

The vapour pressure of air over water is 10 atm.

The partial pressure of nitrogen $= P_{N_2} = \frac{79 \times 10}{100} = 7.9\ atm = 7.9 \times 760\ mm\ Hg = 6004$ mm Hg

The partial pressure of oxygen $P_{O_2} = \frac{20 \times 10}{100} = 2.0\ atm = 2.0 \times 760\ mm\ Hg = 1520$ mm Hg

According to Henry's law,

$P_{N_2} = K_H(N_2) \times X_{N_2}$

$X_{N_2} = \frac{P_{N_2}}{K_H(N_2)} = \frac{6004}{6.51 \times 10^7} = 9.22 \times 10^{-5}$

$X_{O_2} = \frac{P_{O_2}}{K_H O_2} = \frac{1520}{3.30 \times 10^7} = 4.6 \times 10^{-5}$

#457488

Topic: Abnormal molecular mass

Determine the amount of $CaCl_2 (i = 2.47)$ dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at $27^\circ C$.

Solution

According to Van't Hoff's equation, the osmotic pressure $\Pi = iCRT = \frac{in_BRT}{V}$.

Here, i is the Van't Hoff's factor, C is the molar concentration, R is the ideal gas constant, T is temperature, nB is the number of moles of calcium chloride and V is the volume of the solution.

$0.75 = \frac{2.47 \times n_B \times 0.082 \times 300}{2.5}$

$n_B = 0.0308$ mol

Molar mass of calcium chloride is 111 g/mol.

Amount of calcium chloride dissolved $= 0.0308 \times 111 = 3.42$ g.

#457489

Topic: Abnormal molecular mass

Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litre of water at $25^\circ C$, assuming that it is completely dissociated.

Solution

For complete dissociation of potassium sulphate, $K_2SO_4 \rightleftharpoons 2K^+ + SO_4^{2-}$, the Van't Hoff's factor (i) is 3. Molar mass of potassium sulphate is 174 g/mol.

According to Van't Hoff's equation,

$\Pi = iCRT$

$\Pi = \frac{W_BRT}{M_BV}$

$\Pi = \frac{3 \times 25 \times 10^{-3} \times 0.082 \times 298}{174 \times 2.0} = 5.27 \times 10^{-3}$ atm

Note: $\Pi =$ osmotic pressure

$C =$ molar concentration of potassium sulphate

$W_B =$ Mass of potassium sulphate

$M_B =$ Molar mass of potassium sulphate

#464353

Topic: Solutions

Write the steps you would use for making tea. Use the words solution, solvent, solute, dissolve, soluble, insoluble, filtrate and residue.

Solution

(i) Tea can be prepared by following steps:Take 100ml of water as solvent and boil it few minutes.

(ii) Now add one tea spoon sugar, one tea spoon tea leaves and 50ml of milk. Here sugar, tea leaves and milk are solute.

(iii) Now boil it again for few minutes so that sugar will dissolves in solution as sugar is soluble in water

(iv) Now filter the solution. Collect the filtrate in cup. The insoluble tea leaves will be left behind as residue.

#464371

Topic: Expressing concentration of solutions

Substance Dissolved	Temperature in K				
	283	293	313	333	353
	Solubility				
Potassium nitrate	21	32	62	106	167
Sodium chloride	36	36	36	37	37
Potassium chloride	35	35	40	46	54
Ammonium chloride	24	37	41	55	66

Pragya tested the solubility of three different substances at different temperatures and collected the data as given below(results are given in the following table, as grams of substance dissolved in 100grams of water to form a saturated solution).

(a) What mass of potassium nitrate would be needed to produce a saturated solution of potassium nitrate in 50grams of water at 313K?

(b) Pragya makes a saturated solution of potassium chloride in water at $353K$ and leaves the solution to cool at room temperature. What would she observe as the solution cools? Explain.

(c) Find the solubility of each salt at $293K$. Which salt has the highest solubility at this temperature?

(d) What is the effect of change of temperature on the solubility of a salt?

Solution

(a) At 313 K 62 g of potassium nitrate dissolved in 100 g of water. So to produce a saturated solution of potassium nitrate in 50 g of water we need $\frac{62}{100} \times 50 = 31\ g$ of potassium nitrate.

(b)Some soluble potassium chloride will separate out in the form of crystal at room temperature because the solubility of potassium chloride will decrease.

(c)

(i) Solubility of Potassium nitrate at 293 K is 32 g.

(ii) Solubility of sodium chloride at 293 K is 36 g.

(iii) Solubility of Potassium chloride at 293 K is 35 g.

(iv) Solubility of Ammonium chloride at 293 K is 37 g.

The solubility of Ammonium chloride is highest at this temperature.

(d)The solubility of salt increases with the increase in temperature.

#464377

Topic: Solutions

Identify the solutions among the following mixtures.

(a) Soil

(b) Sea water

(c) Air

(d) Coal

(e) Soda water.

Solution

Out of the above mixtures, sea water, air and soda water are solution. A solution is a homogeneous mixture of two or more substance.