

# NCERT Solutions for Class 12 Chemistry

## Chapter 1 The Solid State

### NCERT IN-TEXT QUESTIONS

Question 1.

Why are solids rigid?

Answer:

Solids are rigid because the constituent particles are very closely packed. They don't have any translatory movement and can only oscillate about their mean positions.

Question 2.

Why do solids have a definite volume?

Answer:

The constituent particles of a solid have fixed positions and are not free to move about, i.e., they possess rigidity. That is why they have definite volume.

Question 3.

Classify the following as amorphous and crystalline solids; polyurethane, naphthalene, benzoic acid, Teflon, potassium nitrate, cellophane, polyvinyl chloride, fibre glass, copper.

Answer:

Amorphous solids: Polyurethane, naphthalene, Teflon, cellophane, polyvinyl chloride, fiberglass. Crystalline solids: Benzoic acid, potassium nitrate, copper.

Question 4.

Why is glass considered a supercooled liquid?

Answer:

Glass is an amorphous solid. Like liquids, it has a tendency to flow, though very slowly. This can be seen from the glass panes of windows or doors of very old buildings which are thicker at the bottom than at the top. Therefore, glass is considered as a supercooled liquid.

Question 5.

The Refractive index of a solid is observed to have the same value along with all the directions. Comment on the nature of the solid. Would it show cleavage property?

Answer:

As the solid has the same refractive index along with all the directions, it is isotropic in nature and is, therefore, an amorphous solid. It is not expected to show a clean cleavage when cut with a special type of knife. It will break into pieces with irregular surfaces.

Question 6.

Classify the following solids in different categories based on the nature of intermolecular forces operating in them: Potassium sulphate, tin, benzene, urea, ammonia, water, zinc sulphide, graphite, rubidium, argon, silicon carbide

Answer:

Potassium sulphate = Ionic Tin=Metallic.

Benzene = Molecular (non-polar)

Urea=Molecular (polar).

Ammonia=Molecular (H-bonded)

Water = Molecular (H-bonded)

Zinc sulphide = Ionic Graphite=Covalent Rubidium Metallic Argon = Molecular (non-polar)

Silicon Carbide=Covalent

Question 7.

A solid substance 'A' is a very hard and electrical insulator both in the solid-state as well as in the molten state. It has also the very high melting point. Is the solid metal like silver or network solid like silicon carbide (SiC)?

Answer:

Since the solid behaves as an insulator even in the molten state, it cannot be metal like silver. Therefore, it is a covalent or network solid like SiC.

Question 8.

Ionic solids conduct electricity in molten state but not in solid state. Explain

Answer:

In a solid-state, the ions cannot move, they are held by strong electrostatic forces of attraction. So, ionic solids do not conduct electricity in the solid state. However, in the molten state, they dissociate to give free ions and hence conduct electricity.

Question 9.

What types of solids are electrical conductors, malleable and ductile? (C.B.S.E. Outside Delhi 2013)

Answer:

Metallic solids exhibit these characteristics. Their atoms are linked to one another by metallic bonds.

Question 10.

Give the significance of a 'lattice point'.

Answer:

Each lattice point represents one constituent particle of the solid. This constituent particle may be an atom, a molecule or an ion.

Question 11.

Name the parameters which characterize a unit cell.

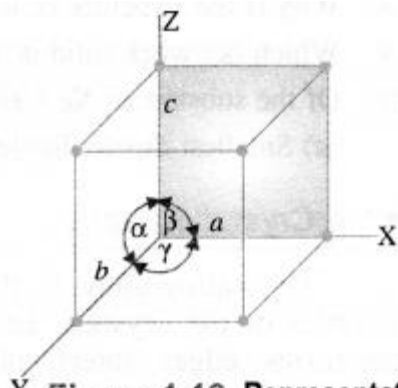
Answer:

A unit cell is characterized by two types of parameters. These are edges (a, b, c)

which may or may not be mutually perpendicular, and angles between the edges ( $\alpha$ ,  $\beta$ , and  $\gamma$ ).

**(i) Edges or edge lengths.** The edges  $a$ ,  $b$  and  $c$  represent the dimensions of the unit cell in space along the three axes. The edges may or may not be mutually perpendicular.

**(ii) Angles between the edges.** There are three angles between the edges. These are denoted as  $\alpha$  (between  $b$  and  $c$ ),  $\beta$  (between  $a$  and  $c$ ), and  $\gamma$  (between  $a$  and  $b$ ). Thus, a unit cell may be characterized by six parameters as shown in Fig. 1.12. The various types of crystal systems differ with respect to edge lengths as well as angles between the edges.



**Figure 1.12. Representation of dimensions of a unit cell.**

Question 12.

Distinguish between

- (i) Hexagonal and monoclinic unit cells
- (ii) Face-centred and end-centered unit cells.

Answer:

(i)

Hexagonal unit cell	Monoclinic unit cell
$a=b \neq c$	$a \neq b \neq c$
$\alpha = \beta = 90^\circ$	$\alpha = \gamma = 90^\circ$
$\gamma = 120^\circ$	$\beta \neq 90^\circ$

(ii)

Face-centred unit cell	End-centred unit cell
A Face-centred unit cell the constituent particles are present at the corners and one at the centre of each face.	An End-centred unit cell contains particles at the corners and one at the centre of any two opposite faces.
Total no of particles in a face centered unit cell= 4	Total no. of particles in an end centered unit cell = 2

Question 13.

Explain how many portions of an atom located at the

- (i) corner and
- (ii) body centre of a cubic unit cell is a part of the neighbouring unit cell.

Answer:

- (i) An atom located at the corner is shared by eight unit cells. Therefore, its contribution to a particular unit cell is  $1/8$ .
- (ii) An atom located at the body of the unit cell is not shared by any unit cell. It belongs to one particular unit cell only.

Question 14.

What is the two-dimensional coordination number of a molecule in a square close-packed layer?

Answer:

In 2D, square close-packed layer, an atom touches 4 nearest neighbouring atoms. Hence, its CN=4

Question 15.

A compound forms a hexagonal close-packed structure. What is the total number of voids in 0.5 mol of it? How many of these are tetrahedral voids?

Answer:

No. of atoms in 0.5 mole of the compound =  $0.5 \times N_0 = 0.5 \times 6.022 \times 10^{23} = 3.011 \times 10^{23}$

No. of octahedral voids = No. of atoms =  $3.011 \times 10^{23}$

No. of tetrahedral voids =  $2 \times 3.011 \times 10^{23} = 6.022 \times 10^{23}$

Total no. of voids =  $(3.011 + 6.022) \times 10^{23} = 9.033 \times 10^{23}$

Question 16.

A compound is formed by two elements M and N. The element N forms ccp and atoms of M occupy  $1/3$ rd of tetrahedral voids. What is the formula of the compound?

Answer:

Atoms of N from ccp, therefore, if the lattice points are n, then

No. of atoms of N = n

No. of oct voids = n

No. of td voids =  $2n = 2 \times 1n/3 = 2n/3$

$\therefore$  Formula of the compound is: M : N

$2/3 n : n$

2n : 3n

2 : 3

i.e.,  $M_2N_3$

Question 17.

Which of the following lattices has the highest packing efficiency :

- (i) simple cubic
- (ii) body-centered cubic and
- (iii) hexagonal close-packed lattice?

Answer:

The packing efficiency of the different types of arrangement is :

- (i) Simple cubic = 52.4%
- (ii) Body-centred cubic = 68%
- (iii) Hexagonal close-packed = 74%

this means that hexagonal close-packed arrangement has the maximum packing efficiency (74%).

Question 18.

An element with a molar mass  $2.7 \times 10^{-2} \text{ kg mol}^{-1}$  forms a cubic unit cell with an edge length of 405 pm. If its density is  $2.7 \times 10^3 \text{ kg m}^{-3}$ , what is the nature of the cubic unit cell?

Answer:

$$d = \frac{Z \times M}{a^3 N_A}$$

Given: Density,  $d = 2.7 \times 10^3 \text{ kg m}^{-3}$

$$a = 405 \text{ pm}$$

$$= 405 \times 10^{-12} \text{ m}$$

$$M = 2.7 \times 10^{-2} \text{ kg mol}^{-1}$$

$$\Rightarrow Z = \frac{d a^3 N_A}{M}$$

$$= \frac{(2.7 \times 10^3)(405 \times 10^{-12})^3 (6.022 \times 10^{23})}{2.7 \times 10^{-2}}$$

$$= 3.99 \approx 4$$

Therefore, it is a *fcc* unit cell.

Question 19.

What type of defect can arise when a solid is heated? Which physical property is affected by it and in what way?

Answer:

When a solid is heated, some atoms or ions may leave the crystal lattice. As a result, vacancies are created and this leads to vacancy defects in the crystalline solid. Since the number of atoms/ions per unit volume decreases, the vacancy defects lead to a decrease in the density.

Question 20.

What type of stoichiometric defect is shown by:

- (i) ZnS
- (ii) AgBr

Answer:

- (i) ZnS shows Frenkel defect
- (ii) AgBr shows Frenkel as well as Schottky defect.

Question 21.

Explain how vacancies are introduced in the ionic solid when a cation of higher valence is added as an impurity to it.

Answer:

Let us consider an ionic solid sodium chloride ( $\text{Na}^+\text{Cl}^-$ ) to which a small amount of strontium chloride ( $\text{SrCl}_2$ ) has been added to act as an impurity. Since the crystal as a whole is to remain electrically neutral, two  $\text{Na}^+$  ions have to leave their sites to create two vacancies. Out of these, one will be occupied by  $\text{Sr}^{2+}$  ion while the other will be vacant. Thus, vacancies will be created in the ionic solid. When a cation of higher valency is added as an impurity in the ionic solid, some of the sites of the original cations are occupied by the cations of higher valency. Each cation of higher valency replaces two or more original cations and occupies the site of one original cation and the other site(s) remains vacant.

Question 22.

Ionic solids which have anionic vacancies due to metal excess defect, develop colour. Explain with the help of a suitable example.

Answer:

Let us illustrate by sodium chloride ( $\text{Na}^+\text{Cl}^-$ ) crystals. Upon heating in the atmosphere of sodium ( $\text{Na}$ ) vapours, sodium atoms get deposited on the surface of the crystals. The  $\text{Cl}^-$  ions from the crystal lattice leave their sites and diffuse into the surface. They tend to combine with sodium atoms present in the vapours which in turn get ionised to form  $\text{Na}^+$  ions by releasing electrons. The latter is trapped by the anionic vacancies created by  $\text{Cl}^-$  ions in order to maintain the crystals electrically neutral. Now, the electrons absorb radiations corresponding to a certain colour from white light and start vibrating. They emit radiations corresponding to yellow colour. That is how the crystals of sodium chloride develop yellow colour. These electrons are called F-centres because these are responsible for colours (In German, F = Farbe meaning colour).

Question 23.

A group 14 element is to be converted into an n-type semiconductor by doping it with a suitable impurity. To which group should the impurity element belong?

Answer:

n-type semiconductors are conducting due to the presence of excess negatively charged electrons. In order to convert group 14 elements (e.g. Si, Ge) into n-type semi-conductors, doping is done with some elements of group 15 (e.g. P, As)

Question 24.

What type of substances would make better permanent magnets; ferromagnetic or ferrimagnetic? Justify your answer. (C.B.S.E. Outside Delhi 2013)

Answer:

Ferromagnetic substances make better permanent magnets than ferrimagnetic substances. The metal ions of a ferromagnetic substance are grouped into small regions known as domains and these are randomly oriented. Under the influence of the applied magnetic field, all domains are oriented in the direction of the magnetic field and as a result, a strong magnetic field is produced. The ferromagnetic substance behaves as a magnet. This characteristic of the domains persists even when the external magnetic field is removed. This imparts permanent magnetic character to these substances. However, this property is lacking in ferrimagnetic substances. Therefore ferromagnetic substances are better magnets.

## NCERT EXERCISE

Question 1.

Define the term 'amorphous'. Give a few examples of amorphous solids.

Answer:

Amorphous solids are those solids in which the constituent particles may have short-range order but do not have a long-range order. They have irregular shapes and are isotropic in nature. They do not undergo a clean cleavage. They do not have sharp melting points or definite heat of fusion. E.g.: Glass, rubber, and plastics.

Question 2.

What makes a glass different from a solid such as quartz? Under what conditions could quartz be converted into glass?

Answer:

Glass is made up of  $\text{SiO}_4$  tetrahedral units. These constituent particles have short-range order only. Quartz is also made up of  $\text{SiO}_4$  tetrahedral units. On heating it softens and melts over a wide range of temperature. It is a crystalline solid having long-range ordered structure. It has a sharp melting point. Quartz can be converted into glass by first melting and then rapidly cooling it.

Question 3.

Classify each of the following solids as ionic, metallic, molecular, network (covalent), or amorphous:

- (a) Tetra phosphorus decoxide ( $\text{P}_4\text{O}_{10}$ )
- (b) Graphite
- (c) Brass
- (d) Ammonium phosphate ( $(\text{NH}_4)_3\text{PO}_4$ )
- (e) SiC
- (f) Rb
- (g)  $\text{I}_2$
- (h) LiBr
- (i)  $\text{P}_4$
- (j) Si
- (k) Plastic.

Answer:

- (a) Molecular solid



- (b) Covalent (Net-work) solid
- (c) Metallic solid
- (d) Ionic solid
- (e) Covalent solid (Network)
- (f) Metallic solid
- (g) Molecular solid
- (h) Ionic solid
- (i) Molecular solid
- (j) Covalent solid
- (k) Amorphous solid.

Question 4.

- (a) What is meant by the term coordination number?
- (b) What is the coordination number of atoms
  - (i) in a cubic close-packed structure
  - (ii) in a body-centered cubic structure?

Answer:

- (i) The number of nearest neighbours of a particle in its close packing is called its coordination number.
- (ii) (a) 12, (b) 8.

Question 5.

How can you determine the atomic mass of an unknown metal if you know its density and the dimensions of its unit cell? Explain.

Answer:

Let the edge length of a unit cell = a

Density = d

Molar mass = M

The volume of the unit cell = a<sup>3</sup>

Mass of the unit cell = No. of atoms in unit cell x Mass of each atom = Z × m

**Mass of an atom present in the unit cell**

$$= m = \frac{M}{N_a}$$

$$\therefore d = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}} = \frac{Z \cdot m}{a^3} = \frac{Z \cdot M}{a^3 N_a}$$

$$\therefore \text{Atomic mass, } M = \frac{d \cdot a^3 \cdot N_a}{Z}$$

Question 6.

- (a) Stability of a crystal is reflected in the magnitude of the melting point. Comment.
- (b) Collect the melting point of

- Ice

- ethyl alcohol
- diethyl ether
- methane from a data book. What can you say about intermolecular forces between the molecules?

Answer:

(a) Higher the melting point, greater are the forces holding the constituent particles together and hence greater is the stability.

(b) The intermolecular forces in water and ethyl alcohol are mainly hydrogen bonding. The higher melting point of water than alcohol shows that hydrogen bonding in ethyl alcohol molecules is not as strong as in water molecules. Diethyl ether is a polar molecule. The intermolecular forces present in them are the dipole-dipole attraction. Methane is a non-polar molecule. The only forces present in them are the weak Vander Waal's forces (London / dispersion forces).

Question 7.

How will you distinguish between the following pairs of terms:

- (i) Cubic close packing and hexagonal close packing?
- (ii) Crystal lattice and unit cell?
- (iii) Tetrahedral void and octahedral void?

Answer:

**(i) Cubic close packing:** When the third layer is placed over the second layer in such a way that the spheres cover the octahedral voids, a layer different from first (A) and second (B) is produced. If we continue packing in this manner, then packing is obtained where the spheres in every fourth layer will vertically aligned. This pattern of packing spheres is called the ABCABC pattern or cubic close packing.

**Hexagonal close-packing:** When a third layer is placed over the second layer in such a manner that the spheres cover the tetrahedral void, a three-dimensional close packing is obtained where the spheres in every third or alternate layer are vertically aligned. If we continue packing in this manner, then the packing obtained would be called ABAB pattern or hexagonal close packing.

**(ii) Crystal lattice:** It is a regular arrangement of the constituent particles (i.e., ions, atoms or molecules) of a crystal in three-dimensional space.

**Unit cell:** The smallest three-dimensional portion of a complete space lattice which when repeated over and over again in different directions produces the complete crystal lattice is called the unit cell.

**(iii) Tetrahedral void:** A simple) the triangular void in a crystal is surrounded by four spheres and is called a tetrahedral void.

**Octahedral void:** A double triangular void is surrounded by six spheres and is called an octahedral void.

Question 8.

How many lattice points are there in one unit cell of each of the following lattices

- (a) face-centered-cubic
- (b) face centred tetragonal
- (c) body-centered cubic?

Answer:

(i) In the face-centered cubic arrangement, a number of lattice points are = 8 (at comers) + 6 (at face centres)

Lattice points per unit cell =  $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$ .

(ii) In face centred tetragonal, number of lattice points are = 8 (at comers) + 6 (at face centres)

Lattice points per unit cell =  $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

(iii) In body centred cubic arrangement, number of lattice points are = 8 (at comers) + 1 (at body centres)

Lattice points per unit cell =  $8 \times \frac{1}{8} + 1 = 2$

Question 9.

Explain:

- (i) The basis of similarities and differences between metallic and ionic crystals.
- (ii) Ionic solids are hard and brittle.

Answer:

**(i) Basis of similarities.** The basis of similarities between the metallic and ionic crystals are the presence of strong electrostatic forces of attraction. These are present among the ions in the ionic crystals and among the kernels and valence electrons in the metallic crystals. That is why both metals and ionic compounds are good conductors of electricity and have high melting points.

**Basis of differences.** The basis of differences in the absence of mobility of ions in the ionic crystals while the same is present in the valence electrons and kernels in the case of metallic crystals. As a consequence, the ionic compounds conduct electricity only in the molten state while the metals can do so even in the solid-state.

**(ii) The ionic solids** are hard and brittle because of strong electrostatic forces of attraction which are present in the oppositely charged ions.

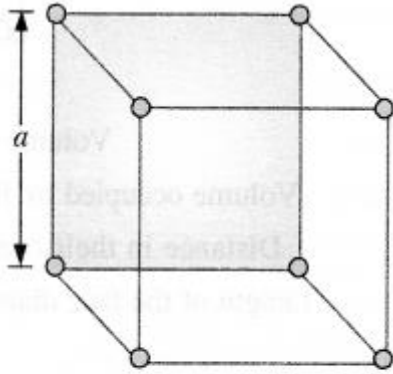
The ionic solids are hard because of the presence of strong inter-ionic forces of attraction in the oppositely charged ions. These ions are arranged in three-dimensional space. The ionic solids are brittle because the ionic bond is non-directional.

Question 10.

Calculate the efficiency of packing in the case of metal crystal for:

- (i) Simple cubic
- (ii) Body centered cubic
- (iii) Face centered cubic (with the assumption that the atoms are touching each other). (C.B.S.E. Outside Delhi 2011) Answer:

**(i) Simple cubic:** We know that in a simple cubic unit cell, there is one atom (or one sphere) per unit cell. If  $r$  is the radius of the sphere, the volume occupied by one sphere present in the unit cell =  $\frac{4}{3}\pi r^3$ .



**Figure 1.35. Simple cubic unit cell**

Edge Length of unit cell ( $a$ ) =  $2r$

Volume of cube ( $a^3$ ) =  $(2r)^3 = 8r^3$

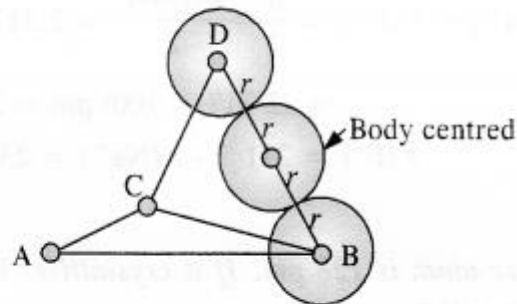
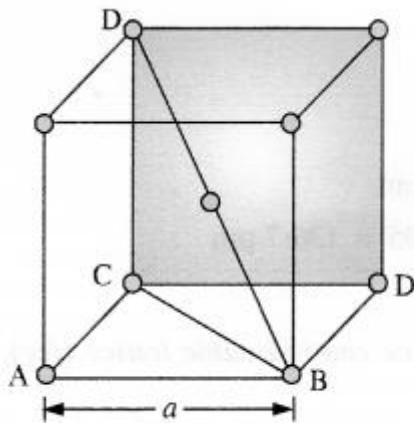
Volume occupied by sphere =  $\frac{4}{3} \pi r^3$

$$\text{Percentage of the occupied volume} = \frac{\text{Volume of sphere}}{\text{Volume of cube}} \times 100 = \frac{\frac{4}{3} \pi r^3}{8r^3} \times 100$$

$$\text{Packing efficiency} = \frac{1}{6} \times 3.143 \times 100 = \mathbf{52.4\%}$$

$$\text{Packing fraction} = 0.524$$

**(ii) Body-centred cubic:** We know that a body-centred cubic unit cell has 2 spheres (atoms) per unit cell. If  $r$  is the radius of the sphere Volume of one sphere =  $\frac{4}{3}\pi r^3$



**Figure 1.37. Body centred cubic unit cell.**

$$\text{Edge length of unit cell } (a) = \frac{4}{\sqrt{3}} r.$$

$$\text{Volume of cube } (a)^3 = \left(\frac{4}{\sqrt{3}} r\right)^3 = \frac{64}{3\sqrt{3}} r^3.$$

$$\text{Volume occupied by two spheres per unit cell} = 2 \times \frac{4}{3} \pi r^3 = \frac{8}{3} \pi r^3$$

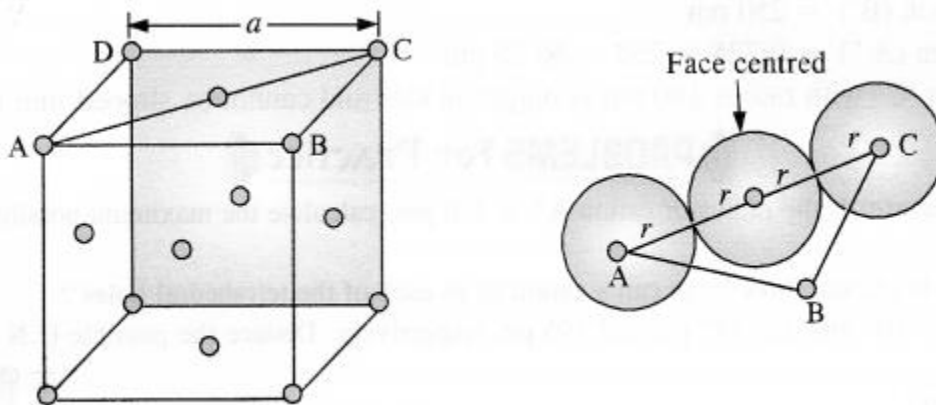
$$\therefore \text{Percentage volume occupied} = \frac{\text{Volume of spheres}}{\text{Volume of cube}} \times 100 = \frac{\frac{8}{3} \pi r^3}{\left(\frac{64}{3\sqrt{3}}\right) r^3} \times 100$$

$$\text{Packing efficiency} = \frac{\frac{8}{3} \times 3.143 \times 100}{\frac{64}{3} \times \frac{1}{\sqrt{3}}} = \frac{1}{8} \times 3.143 \times \sqrt{3} \times 100$$

$$= 0.125 \times 3.143 \times 1.732 \times 100 = \mathbf{68\%}$$

$$\text{Packing fraction} = \mathbf{0.68}$$

(iii) **Face centred cubic:** We know that a face centred cubic unit cell (fcc) contains four spheres (or atoms) per unit cell.



**Figure 1.36. Faced centred cubic unit cell.**

$$\text{Edge length of unit cell } (a) = \sqrt{8} r$$

$$\text{Volume of the cube } (a^3) = (\sqrt{8} r)^3 = 8 \sqrt{8} r^3$$

$$\text{Volume occupied by four spheres} = \frac{16}{3} \pi r^3$$

$$\text{Percentage of the occupied volume} = \frac{\text{Volume of spheres}}{\text{Volume of cube}} \times 100$$

$$\text{Packing efficiency} = \frac{\frac{16}{3} \pi r^3}{8 \sqrt{8} r^3} \times 100 = \frac{2\pi}{3\sqrt{8}} \times 100 = \frac{2 \times 3.143}{3 \times 2.8284} \times 100 = \mathbf{74\%}$$

$$\text{Packing fraction} = 0.74$$

Question 11.

Silver crystallizes in a face centered cubic lattice with all the atoms at the lattice points. The length of the edge of the unit cell as determined by X-ray diffraction studies is found to be  $4.077 \times 10^{-8}$  cm.

The density of silver is  $10.5 \text{ g cm}^{-3}$ . Calculate the atomic mass of silver. (C.B.S.E. Sample Paper 2012)(Uttarakhand Board 2015)

Answer:

$$\text{We know that } \rho = \frac{Z \times M}{a^3 \times N_0 \times 10^{-30}} \text{ or } M = \frac{\rho \times a^3 \times N_0 \times 10^{-30}}{Z}$$

According to available data :

$$\text{Edge length (a)} = 4.077 \times 10^{-8} \text{ cm} = 4.077 \times 10^{-8} \times 10^{10} = 407.7 \text{ pm}$$

$$\text{No. of atoms per unit cell (Z)} = 4 ; \text{ Density of silver} = 10.50 \text{ g cm}^{-3} \quad (\because \text{fcc structure})$$

$$\text{Avogadro's Number (No.)} = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$\therefore$  Atomic mass of the element (M)

$$= \frac{(10.50 \text{ g cm}^{-3}) \times (407.7)^3 \times (6.022 \times 10^{23} \text{ mol}^{-1}) \times (10^{-30} \text{ cm}^3)}{4} = 107.09 \text{ g mol}^{-1}$$

Question 12.

A cubic solid is made up of two elements P and Q. Atoms of Q are at the corners of the cube and P at the body centre. What is the formula of the compound? What are the coordination numbers of P and Q?

Answer:

As atom Q are present at the 8 comers of the cube, therefore, number of atoms of Q in the unit cell =  $8 \times \frac{1}{8} = 1$ .

As atoms P are present at the body centre, therefore a number of atoms P in the unit cell = 1.

$\therefore$  The formula of the compound = PQ

Co-ordination number of each P and Q = 8.

Question 13.

Niobium crystallizes in a body-centered cubic structure. If the density is  $8.55 \text{ g cm}^{-3}$ , calculate the atomic radius of niobium given that the atomic mass of niobium is  $93 \text{ g mol}^{-1}$ . (C.B.S.E. Delhi 2008)

Answer:

**Step I.** Calculation of edge length of unit cell.

No. of particles in b.c.c. type unit cell (Z) = 2

Atomic mass of the element (M) =  $93 \text{ g mol}^{-1}$

No. of particles in b.c.c. type unit cell (Z) = 2

Atomic mass of the element (M) =  $93 \text{ g mol}^{-1}$

$$\text{Mass of the unit cell} = \frac{Z \times M}{N_0} = \frac{2 \times (93 \text{ g mol}^{-1})}{(6.022 \times 10^{23} \text{ mol}^{-1})} = 30.89 \times 10^{-23} \text{ g}$$

$$\text{Density of unit cell } (\rho) = 8.55 \text{ g cm}^{-3}$$

$$\text{Volume of unit cell } (a^3) = \frac{\text{Mass of unit cell}}{\text{Density of unit cell}} = \frac{(30.89 \times 10^{-23} \text{ g})}{(8.55 \text{ g cm}^{-3})}$$

$$= 3.613 \times 10^{-23} \text{ cm}^3 = 36.13 \times 10^{-24} \text{ cm}^3$$

$$\text{Edge length of unit cell } (a) = (36.13 \times 10^{-24} \text{ cm}^3)^{1/3} = 3.31 \times 10^{-8} \text{ cm} = 331 \text{ pm}$$

**Step II.** Calculation of radius of unit cell

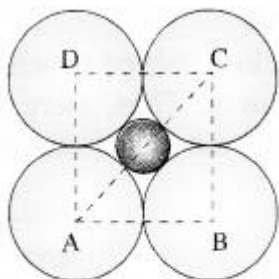
$$\text{For b.c.c. structure, } r = \frac{\sqrt{3}a}{4} = \frac{\sqrt{3} \times (3.31 \times 10^{-8} \text{ cm})}{4} = 1.43 \times 10^{-8} \text{ cm} = 143 \text{ pm.}$$

Question 14.

If the radius of octahedral void is  $r$  and the radius of the atom in close packing is  $R$ , derive the relation between  $r$  and  $R$ . (C.B.S.E. Sample Paper 2017)

Answer:

Let length of each side of the square is  $a$  and the radii of the void and the sphere are  $r$  and  $R$  respectively. Consider the right angled triangle  $ABC$ .



**Figure 1.31. Cross-section of an octahedron showing an octahedral void.**

$$AC = \sqrt{AB^2 + BC^2} = \sqrt{a^2 + a^2} = \sqrt{2a}$$

As  $AC = 2r + 2R$  ...(i)

$$\sqrt{2a} = 2r + 2R$$

Now  $AB = 2R$  or  $a = 2R$  ...(ii)

Dividing Eqn. (i) by Eqn. (ii), we get

$$\frac{\sqrt{2a}}{a} = \frac{2r + 2R}{2R}$$

$$\sqrt{2} = \frac{r}{R} + 1$$

$$\frac{r}{R} = \sqrt{2} - 1 = 1.414 - 1 = 0.414$$

Thus for an octahedral void ;  $\frac{r_{\text{void}}}{r_{\text{sphere}}} = 0.414$

∴ Radius of octahedral void is  $0.414R$  (or 41.4% as compared to that of the sphere).

Question 15.

Copper crystallises into a fcc lattice with edge length  $3.61 \times 10^{-8}$  cm. Show that the calculated density is in agreement with its measured value of 8.92 g cm. (C.B.S.E. Delhi 2009 Comptt.)

Answer:

$$\text{Density of unit cell } (\rho) = \frac{Z \times M}{a^3 \times N_0 \times 10^{-30}}$$

According to available data,

Edge length ( $a$ ) =  $3.61 \times 10^{-8} \text{ cm} = 361 \text{ pm}$  ; Atomic mass of Cu( $M$ ) =  $63.5 \text{ g mol}^{-1}$

No. of atoms per unit cell ( $Z$ ) = 4 ; Avogadro's Number ( $N_0$ ) =  $6.022 \times 10^{23} \text{ mol}^{-1}$

$$\text{Density of unit cell} = \frac{4 \times (63.5 \text{ g mol}^{-1})}{(361)^3 \times (6.022 \times 10^{23} \text{ mol}^{-1}) \times (10^{-30} \text{ cm}^3)} = 8.97 \text{ g cm}^{-3}$$

The calculated value of the density is nearly the same as the measured value.

Question 16.

Analysis shows that nickel oxide has formula  $\text{Ni}_{0.98}\text{O}$ . What fraction of nickel exists as  $\text{Ni}^{2+}$  and as  $\text{Ni}^{3+}$  ions ?

Answer:

The ratio of Ni and O atoms in pure nickel oxide ( $\text{NiO}$ ) = 1:1

Let  $x$  be the no. of Ni (II) atoms replaced by Ni (III) atoms in the oxide.

$\therefore$  No. of Ni (II) atoms present =  $(0.98 - x)$

Since the oxide is neutral in nature,

Charge on Ni atoms = Charge on oxygen atoms

$$2(0.98 - x) + 3x = 2$$

$$1.96 - 2x + 3x = 2$$

$$x = 2 - 1.96 = 0.04$$

$$\% \text{ of Ni (III) atoms in nickel oxide} = \frac{\text{No. of Ni (III) atoms}}{\text{Total no. of Ni atoms}} \times 100 = \frac{0.04}{0.98} \times 100 = 4.01\%$$

$$\% \text{ of Ni (II) atoms in nickel oxide} = 100 - 4.01 = 95.99\%$$

Question 17.

What is a semiconductor? Describe the two main types of semiconductors and contrast their conduction mechanism.

Answer:

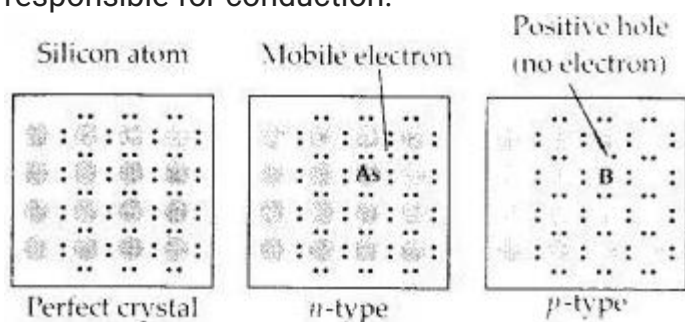
Those solids which have intermediate conductivities ranging from  $10^{-6}$  to  $10^4 \text{ ohm}^{-1} \text{ m}^{-1}$  are classified as semiconductors. As the temperature rises, there is a rise in conductivity value because electrons from the valence band jump to the conduction band.

**(i) n-type semiconductor:** When a silicon or germanium crystal is doped with group 15 elements like P or As, the dopant atom forms four covalent bonds like Si or Ge atom but the fifth electron, not used in bonding, becomes delocalized and continues its share towards electrical conduction. Thus silicon or germanium doped with P or As is called an n-type semiconductor, a indicative of negative since it is the electron that conducts electricity.

**(ii) p-type semiconductor:** When silicon or germanium is doped with group 13 elements like B or Al, the dopant is present only with three valence electrons. An electron vacancy or a hole is created at the place of the missing fourth electron. Here, this hole moves throughout the crystal-like a positive charge giving rise to



electrical conductivity. Thus Si or Ge doped with B or Al is called p-type semiconductor, p stands for the positive hole since it is the positive hole that is responsible for conduction.



Question 18.

Non-stoichiometric cuprous oxide ( $\text{Cu}_2\text{O}$ ) can be prepared in the laboratory. In this oxide, the copper to oxygen ratio is slightly less than 2:1. Can you account for the fact that this substance is a p-type semiconductor?

Answer:

The ratio less than 2: 1 in  $\text{Cu}_2\text{O}$  shows that some cuprous ( $\text{Cu}^+$ ) ions have been replaced by cupric ( $\text{Cu}^{2+}$ ) ions. To maintain electrical neutrality, every two  $\text{Cu}^+$  ions will be replaced by one  $\text{Cu}^{2+}$  ion thereby creating a hole. As conduction will be due to the presence of this positive hole, hence it is a p-type semiconductor.

Question 19.

Ferric oxide crystallizes in a hexagonal close-packed array of oxide ions with two out of every three octahedral holes occupied by ferric ions. Derive the formula of ferric oxide.

Answer:

There is one octahedral hole for each atom in the hexagonal close-packed arrangement.

If the number of oxide ions ( $\text{O}^{2-}$ ) per unit cell is 1, then the number of  $\text{Fe}^{3+}$  ions =  $\frac{2}{3} \times$  octahedral holes =  $\frac{2}{3} \times 1 = \frac{2}{3}$ .

Thus, the formula of the compound =  $\text{Fe}^{2/3}\text{O}^1$ , or  $\text{Fe}_2\text{O}_3$ .

Question 20.

Classify each of the following as being either a p-type or an n-type semiconductor.

(i) Ge doped with In

(ii) B doped with Si.

Answer:

(i) Ge belongs to group 14 and In belongs to group 13, therefore an electron-deficient hole is created and hence it is an n-type semiconductor.

(ii) B belongs to group 13 and Si belongs to group 14, therefore there will be a free electron and hence it is an n-type semiconductor.

Question 21.

Gold (atomic radius = 0.144 nm) crystallizes in a face-centered unit cell. What is the length of a side of the cell?

Answer:

For fcc lattice, edge length,  
 $a = 2\sqrt{2} \times 0.144 \text{ nm} = 0.407 \text{ nm}$

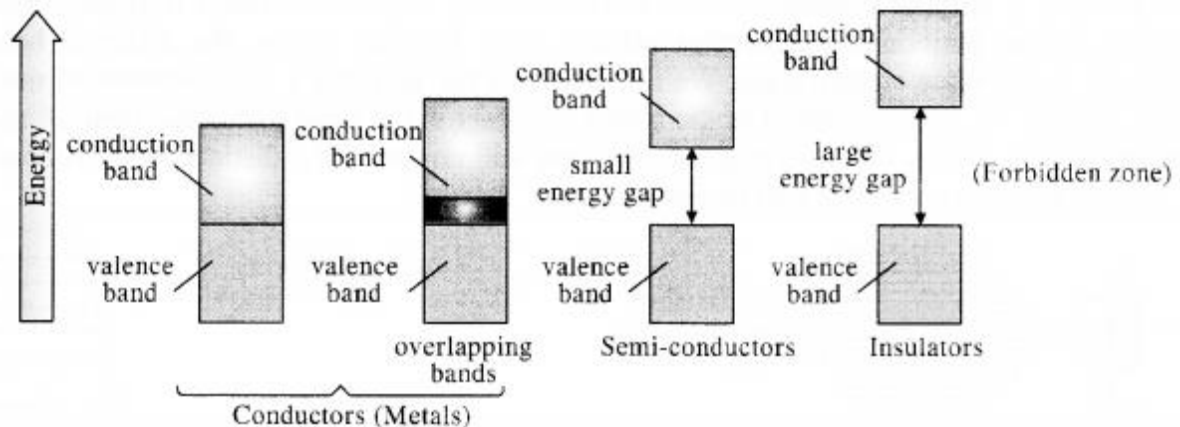
Question 22.

In terms of Band Theory, what is the difference

- (i) between a conductor and an insulator
- (ii) between a conductor and semi-conductor?

Answer:

The variation in the electrical conductivity of the solids can be explained with the help of the band theory.



**Figure 1.56.** Explanation for the electrical conductivity in conductors, semi-conductors and insulators with the help of band theory.

- (i) In insulators, the energy gaps are very large and the no electron jump is feasible from the valence band to the conduction band. The energy gaps also called forbidden zones. The insulators, therefore, do not conduct electricity.
- (ii) In semi-conductors, there is a small energy gap between the valence band and conduction band. However, some electrons may jump to the conduction band and these semiconductors can exhibit a little electrical conductivity.

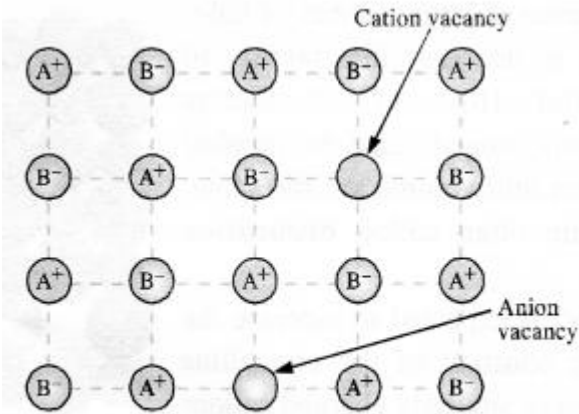
Question 23.

Explain the following terms with suitable examples.

- (i) Schottky defect,
- (ii) Frenkel defect,
- (iii) Interstitials,
- (iv) F-centres.

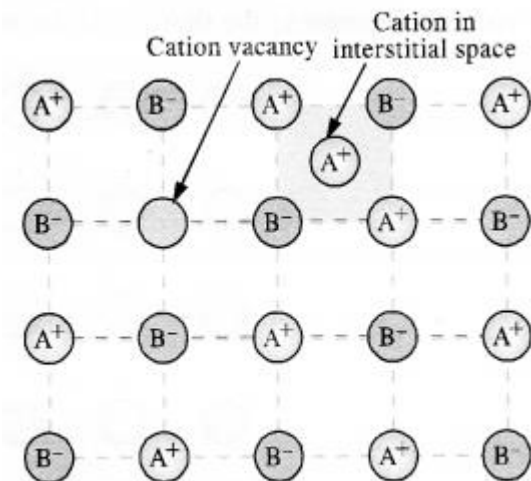
Answer:

**(i) Schottky defect:** This arises because certain ions are missing from the crystal lattice and vacancies or holes are created at their respective positions. Since a crystal is electrically neutral, the number of such missing cations ( $A^+$ ) and anions ( $B^-$ ) must be the same. e.g., KCl, NaCl, KBr, etc.



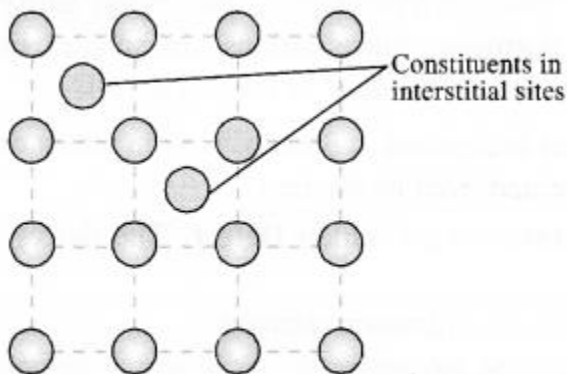
**Figure 1.46. Schottky defect in crystal**

(ii) **Frenkel defect:** It results when certain ions leave their normal sites and occupy positions elsewhere in the crystal lattice. Holes are created at their respective positions. Since cations are smaller in size as compared to anions normally these are involved in Frenkel defect. e.g., AgBr, ZnS, etc.



**Figure 1.47. Frenkel defect in Crystal.**

(iii) **Interstitials:** This defect is noticed when constituent particles (atoms or molecules) occupy the interstitial sites in the crystal lattice. As a result, the number of particles per unit volume increases and so the density of the solid.



**Figure 1.44. Interstitial defect**

**(iv) F-centres:** These are the anionic sites occupied by unpaired electrons. F-centres impart colour to crystals. The colour results by the excitation of electrons when they absorb energy from the visible light falling on the crystal.

Question 24.

Aluminium crystallises in a cubic close-packed structure. Its metallic radius is 125 pm.

(a) What is the length of the side of the unit cell?

(b) How many unit cells are there in 1.00 cm<sup>3</sup> of aluminum? (C.B.S.E. Outside Delhi 2013)

Answer:

**Step I.** Calculation of length of side of the unit cell

For f.c.c. unit cell,  $a = 2\sqrt{2}r = 2\sqrt{2} \times (125\text{pm}) = 2 \times 1.4142 \times (125\text{ pm}) = 354\text{ pm}$ .

**Step II.** Calculation of no. of unit cells in 1.00 cm<sup>3</sup> of aluminium.

Volume of one unit cell =  $(354\text{ pm})^3 = (354 \times 10^{-10}\text{ cm})^3 = 44174155 \times 10^{-30}\text{ cc}$ .

$$\text{No. of unit cells in 1.00 cc of Al metal} = \frac{1(\text{cc})}{44174155 \times 10^{-30}(\text{cc})} = 2.26 \times 10^{22}$$

Question 25.

If NaCl is doped with 10<sup>-3</sup> mol % of SrCl<sub>2</sub>, what is the concentration of cation vacancies?

Answer:

$$\text{Density } (\rho) = \frac{z \times M}{a^3 \times N_0 \times 10^{-30}} \text{ or } z = \frac{\rho \times a^3 \times N_0 \times 10^{-30}}{M}$$

Edge length ( $a$ ) = 430 pm = 430 ; Atomic mass of Na ( $M$ ) = 23 amu = 23 g mol<sup>-1</sup>

Avogadro's No. ( $N_0$ ) = 6.022 × 10<sup>23</sup> mol<sup>-1</sup> ; Density of Na ( $\rho$ ) = 0.9623 g cm<sup>-3</sup>

$$z = \frac{(0.9623\text{g cm}^{-3}) \times (430)^3 \times (6.022 \times 10^{23}\text{mol}^{-1}) \times (10^{-30}\text{ cm}^3)}{(23\text{ g mol}^{-1})} = 2 \text{ (bcc structure)}$$

Question 26.

Explain the following with suitable examples.

- (a) Ferromagnetism
- (b) Piezoelectric effect
- (c) Paramagnetism
- (d) Ferrimagnetism
- (e) Antifluoride structure
- (f) 12 – 16 and 13 – 15 compounds.

Answer:

**(a) Ferromagnetism:** A few solids like iron, cobalt, nickel, gadolinium and CeO<sub>2</sub> are attracted very strongly by magnetic fields. These are known as ferromagnetic solids. Apart from that, they can be even permanently magnetised or become permanent magnet. e.g., Fe, Ni, Co and CrO<sub>2</sub>

**(b) Piezoelectric effect:** A dielectric crystal which has a resultant dipole moment can produce electricity or show the electrical property when external pressure is applied. Such a crystal is known as piezoelectric crystal and this property is called piezoelectricity or pressure electricity. e.g.,  $\text{PbZrO}_2$ ,  $\text{NH}_4\text{H}_2\text{PO}_4$  etc.

**(c) Paramagnetism:** These are the solids attracted by a magnet. Actually, the atoms of the elements present have certain unpaired electrons. Their spins or magnetic moments may lead to magnetic characters. Many transition metals such as Co, Ni, Fe, Cu, etc. and their ions are paramagnetic. e.g.,  $\text{O}_2$ ,  $\text{Cu}^{2+}$ ,  $\text{Fe}^{3+}$ , etc

**(d) Ferrimagnetism:** They have certain resultant magnetic moment or magnetic character which is of permanent nature. However, ferrimagnetic solids are less magnetic than ferromagnetic solids. For example, magnetic oxide of iron ( $\text{Fe}_3\text{O}_4$ ) and ferrites with general formula  $\text{MFe}_2\text{O}_4$ . e.g.,  $\text{Fe}_3\text{O}_4$

**(e) Antifluorite structure:** In this structure, the positions of the cations and anions as compared to fluorite structure get reversed i.e. the smaller cations occupy the position of fluoride ions while the anions with bigger size occupy the positions of calcium ions. e.g.,  $\text{Li}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{Rb}_2\text{O}$  and  $\text{Rb}_2\text{S}$ .

**(f) 12 – 16 and 13 – 15 compounds:** A large variety of solid-state materials have been prepared by the combination of elements belonging to groups 13 and 15 or group 12 and 16. A few examples of compounds 13-15 combinations are InSb, AlP and GaAs. Similarly, compounds resulting from 12 – 16 combinations are AdS, CdSe, HgTe.

We hope the NCERT Solutions for Class 12 Chemistry Chapter 1 The Solid State help you. If you have any query regarding NCERT Solutions for Class 12 Chemistry Chapter 1 The Solid State, drop a comment below and we will get back to you at the earliest.

## NCERT Solutions for Class 12 Chemistry

### Chapter 2: Solutions

#### NCERT IN-TEXT QUESTIONS

Question 1.

Calculate the mass percent of benzene (C<sub>6</sub>H<sub>6</sub>) and carbon tetrachloride (CCl<sub>4</sub>) if 22 g of benzene is dissolved in 122 g of carbon tetrachloride.

Answer:

$$\begin{aligned} \text{Mass percent (Mass \%)} &= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100 \\ \text{Mass of benzene} &= 22 \text{ g ; Mass of carbon tetrachloride} = 122 \text{ g.} \\ \text{Mass percent of benzene} &= \frac{(22 \text{ g})}{(22 \text{ g} + 122 \text{ g})} \times 100 = \mathbf{15.28 \%} \\ \text{Mass percent of carbon tetrachloride} &= 100 - 15.28 = \mathbf{84.72 \%} \end{aligned}$$

Question 2.

Calculate the mole fraction of benzene in a solution containing 30% by mass of it in carbon tetrachloride.

Answer:

Let us start with 100 g of the solution in which

Mass of benzene = 30 g

Mass of carbon tetrachloride = 70 g

Molar mass of benzene (C<sub>6</sub>H<sub>6</sub>) = 6 × 12 + 6 × 1 = 78 g mol<sup>-1</sup>.

$$n_{\text{C}_6\text{H}_6} = \frac{(30 \text{ g})}{(78 \text{ g mol}^{-1})} = 0.385 \text{ mol}$$

Molar mass of carbon tetrachloride (CCl<sub>4</sub>) = 12 + 4 × 35.5 = 154 g mol<sup>-1</sup>

$$n_{\text{CCl}_4} = \frac{(70 \text{ g})}{(154 \text{ g mol}^{-1})} = 0.454 \text{ mol}$$

$$x_{\text{C}_6\text{H}_6} = \frac{n_{\text{C}_6\text{H}_6}}{n_{\text{C}_6\text{H}_6} + n_{\text{CCl}_4}} = \frac{(0.385 \text{ mol})}{(0.385 \text{ mol}) + (0.454 \text{ mol})} = \mathbf{0.459}$$

Question 3.

Calculate the molarity of each of the following solutions:

(a) 30 g of CO(NO<sub>3</sub>)<sub>2</sub>·6H<sub>2</sub>O in 4.3 L of solution

(b) 30 mL of 0.5 M H<sub>2</sub>SO<sub>4</sub> diluted to 500 mL.

Answer:

(a) Molar mass of CO(NO<sub>3</sub>)<sub>2</sub>·6H<sub>2</sub>O = 310.7 g mol<sup>-1</sup>

no. of moles = 30/310.7 = 0.0966

Vol. of solution = 4.3 L

Molarity = 0.0966/4.3 = 0.022M

(b) 1000 mL of 0.5M  $\text{H}_2\text{SO}_4$  contain  $\text{H}_2\text{SO}_4 = 0.5$  mole  
 30 mL of 0.5 M  $\text{H}_2\text{SO}_4$  contain  $\text{H}_2\text{SO}_4$   
 $= 0.5/1000 \times 30 = 0.015$  mole  
 Volume of solution = 500mL=0.5 L  
 Molarity =  $0.015/0.5 = 0.03\text{M}$

Question 4.

Calculate the mass of urea ( $\text{NH}_2\text{CONH}_2$ ) required to prepare 2.5 kg of 0.25 molal aqueous solution.

Answer:

$$\text{Molality of solution} = \frac{\text{Mass of urea} / \text{Molar mass of urea}}{\text{Mass of water in kg.}}$$

$$\text{Molality of solution} = 0.25 \text{ m} = (0.25 \text{ mol kg}^{-1})$$

$$\text{Molar mass of urea } (\text{NH}_2\text{CONH}_2) = 2 \times 14 + 1 \times 12 + 1 \times 16 + 4 \times 1 = 60 \text{ g mol}^{-1}.$$

$$\text{Mass of solvent (water)} = 2.5 \text{ kg}$$

$$(0.25 \text{ mol kg}^{-1}) = \frac{\text{Mass of urea}}{(60 \text{ g mol}^{-1}) \times (2.5 \text{ kg})}$$

$$\text{Mass of urea} = (0.25 \text{ mol kg}^{-1}) \times (60 \text{ g mol}^{-1}) \times (2.5 \text{ kg}) = \mathbf{37.5 \text{ g.}}$$

Question 5.

Calculate (a) molality (b) molarity and (c) mole fraction of KI if the density of 20% (mass/mass) aqueous KI is  $1.202 \text{ g mL}^{-1}$ .

Answer:

20% aq. KOH solution  $\Rightarrow$  20g of KI in 100g solution

$$\therefore \text{Mass of solvent} = 100 - 20 = 80 \text{ g}$$

$$\begin{aligned} \text{(i) Molality} &= \frac{\text{no. of moles of KI}}{\text{mass of solvent (kg)}} \\ &= \frac{0.120}{0.080} = 1.5 \text{ mol kg}^{-1} \end{aligned}$$

$$\begin{aligned} \text{(ii) Density of solution} &= 1.202 \text{ g mL}^{-1} \\ \text{Volume of solution} &= \frac{100}{1.202} = 83.2 \text{ mL} \\ &= 0.0832 \text{ L} \end{aligned}$$

$$\begin{aligned} \therefore \text{Molarity} &= \frac{0.120}{0.0832} = 1.44 \text{ M} \\ \text{(iii) No. of moles of KI} &= 0.120 \\ n_{\text{H}_2\text{O}} &= \frac{80}{18} = 4.44 \end{aligned}$$

$$\begin{aligned} x_{\text{KI}} &= \frac{0.120}{0.120 + 4.44} \\ &= \frac{0.120}{4.560} = 0.0263 \end{aligned}$$

Question 6.

H<sub>2</sub>S a toxic gas with rotten egg smell, is used for the qualitative analysis. If the solubility of H<sub>2</sub>S in water at S.T.P is 0.195 m ; calculate Henry's law constant.

Answer:

### Step I. Calculation of mole fraction of H<sub>2</sub>S

By definition, 0.195 m of the gas means that 0.195 mole of it is dissolved in 1000 g of water.

$$\text{No. of moles of water in 1000 g} = \frac{(1000 \text{ g})}{(18 \text{ g mol}^{-1})} = 55.55 \text{ mol}$$

$$\begin{aligned} \text{Mole fraction of H}_2\text{S} (x_{\text{H}_2\text{S}}) &= \frac{n_{\text{H}_2\text{S}}}{n_{\text{H}_2\text{S}} + n_{\text{H}_2\text{O}}} = \frac{(0.195 \text{ mol})}{(0.195 + 55.55) \text{ mol}} \\ &= \frac{(0.195 \text{ mol})}{(55.745 \text{ mol})} = 0.0035 \end{aligned}$$

### Step II. Calculation of Henry's Law constant

According to Henry's Law,

$$\begin{aligned} x_{\text{H}_2\text{S}} &= \frac{\text{Partial pressure of H}_2\text{S}}{K_{\text{H}} \text{ for H}_2\text{S}} \text{ at S.T.P.} \\ \therefore K_{\text{H}} \text{ for H}_2\text{S} &= \frac{(0.987 \text{ bar})}{(0.0035)} = 282 \text{ bar} \end{aligned}$$



Question 7.

Henry's Law constant for CO<sub>2</sub> in water is 1.67 × 10<sup>8</sup> Pa at 298 K. Calculate the quantity of CO<sub>2</sub> in 500 mL of soda water when packed under 2.5 atm pressure of CO<sub>2</sub> at 298 K. (D.S.B. 2008 Supp.)

Answer:

**Step I. Calculation of number of moles of CO<sub>2</sub>.**

According to Henry's Law,

$$\text{Mole fraction of CO}_2 (x_{\text{CO}_2}) = \frac{\text{Partial pressure of CO}_2}{K_H \text{ for CO}_2}$$

$$K_H = 1.67 \times 10^8 \text{ Pa} = \frac{(1 \text{ atm})}{(101325 \text{ Pa})} \times (1.67 \times 10^8 \text{ Pa}) = 1.648 \times 10^3 \text{ atm.}$$

$$x_{\text{CO}_2} = \frac{(2.5 \text{ atm})}{(1.648 \times 10^3 \text{ atm})} = 1.52 \times 10^{-3}; n_{\text{H}_2\text{O}} = \frac{(500 \text{ g})}{(18 \text{ g mol}^{-1})} = 27.78 \text{ mol}$$

$$x_{\text{CO}_2} = \frac{n_{\text{CO}_2}}{n_{\text{CO}_2} + n_{\text{H}_2\text{O}}} = \frac{n_{\text{CO}_2}}{n_{\text{H}_2\text{O}}} = \frac{n_{\text{CO}_2}}{(27.78 \text{ mol})}$$

(n<sub>CO<sub>2</sub></sub> has been neglected as the gas is very little soluble in water)

$$\therefore n_{\text{CO}_2} = x_{\text{CO}_2} \times (27.78 \text{ mol}) = (1.52 \times 10^{-3}) \times (27.78 \text{ mol}) = 0.0422 \text{ mol}$$

**Step II.** Mass of CO<sub>2</sub> dissolved in water = (0.0422 mol) × (44 g mol<sup>-1</sup>) = 1.857 g.

Question 8.

The vapour pressure of pure liquids A and B are 450 and 700 mm Hg respectively, at 350 K. Find out the composition of the liquid mixture if total vapour pressure is 600 mm Hg. Also find the composition of the vapour phase.

Answer:

$$P_A^{\circ} = 450 \text{ mm}, P_B^{\circ} = 700 \text{ mm}, P_{\text{total}} = 600 \text{ mm}$$

As  $P_{\text{total}} = P_A + P_B$

$$= x_A P_A^{\circ} + x_B P_B^{\circ}$$

(from Raoult's law)

$$= x_A P_A^{\circ} + (1 - x_A) P_B^{\circ}$$

$$= P_B^{\circ} + (P_A^{\circ} - P_B^{\circ}) x_A$$

$$\Rightarrow 600 = 700 + (450 - 700) x_A$$

or  $x_A = 0.40$

$$\therefore x_B = 1 - x_A = 1 - 0.40 = 0.60$$

$$\therefore P_A = x_A P_A^{\circ} = 0.40 \times 450 = 180 \text{ mm}$$

$$\therefore P_B = x_B P_B^{\circ} = 0.60 \times 700 = 420 \text{ mm}$$

$\therefore$  Mole fraction of A in vapour phase

$$= \frac{P_A}{P_A + P_B} = \frac{180}{180 + 420} = 0.30$$

and, Mole fraction of B in vapour phase

$$= 1 - 0.30 = 0.70$$

Question 9.

The vapour pressure of pure water at 298 K is 23.8 mm Hg. 50 g of Urea (NH<sub>2</sub>CONH<sub>2</sub>)

is added to 850 g of water. Calculate the vapour pressure of water for this solution and also its relative lowering in vapour pressure.

Answer:

**Step I.** Calculation of vapour pressure of water for the solution

According to Raoult's Law,

$$\frac{P_A^\circ - P_S}{P_S} = \frac{n_B}{n_A} = \frac{W_B}{M_B} \times \frac{M_A}{W_A}$$

$$P_A^\circ = 23.8 \text{ mm}; W_B = 50 \text{ g}; W_A = 850 \text{ g}; M_B = 60 \text{ g mol}^{-1}; M_A = 18 \text{ g mol}^{-1}$$

$$\frac{P_A^\circ - P_S}{P_S} = \frac{(50 \text{ g}) \times (18 \text{ g mol}^{-1})}{(60 \text{ g mol}^{-1}) \times (850 \text{ g})} = 0.0176$$

$$\frac{P_A^\circ}{P_S} - 1 = 0.0176 \text{ or } \frac{P_A^\circ}{P_S} = 1 + 0.0176 = 1.0176$$

Vapour pressure of water for the solution is the same as the vapour pressure of the solution ( $P_S$ ). It may be calculated as :

$$P_S = \frac{P_A^\circ}{1.0176} = \frac{(23.8 \text{ mm})}{(1.0176)} = 23.39 \text{ mm.}$$

**Step II.** Calculation of relative lowering in vapour pressure

$$\text{Relative lowering in V.P.} = \frac{P_A^\circ - P_S}{P_A^\circ} = \frac{(23.8 - 23.39) \text{ mm}}{(23.8 \text{ mm})} = 0.0172.$$

Question 10.

The boiling point of water at 750 mm Hg is  $99.63^\circ\text{C}$ . How much sucrose is to be added to 500 g of water so that it may boil at  $100^\circ\text{C}$ ? ( $K_b$  for water =  $0.52 \text{ K kg mol}^{-1}$ ).

Answer:

$$W_B = \frac{M_B \times \Delta T_b \times W_A}{K_b}$$

$$\text{Molar mass of sucrose (C}_{12}\text{H}_{22}\text{O}_{11}) (M_B) = 12 \times 12 + 22 \times 1 + 11 \times 16 = 342 \text{ g mol}^{-1}.$$

$$\text{Mass of water (W}_A) = 500 \text{ g} = 0.5 \text{ kg}$$

$$\text{Elevation in b.p. } (\Delta T_b) = 100^\circ\text{C} - 99.63^\circ\text{C} = 0.37^\circ\text{C} = 0.37 \text{ K}$$

$$\text{Molal elevation constant (K}_b) = 0.52 \text{ K kg mol}^{-1}.$$

$$W_B = \frac{(342 \text{ g mol}^{-1}) \times (0.37 \text{ K}) \times (0.5 \text{ kg})}{(0.52 \text{ K kg mol}^{-1})} = 121.7 \text{ g}$$

Question 11.

Calculate the mass of ascorbic acid (Vitamin C,  $\text{C}_6\text{H}_8\text{O}_6$ ) to be dissolved in 75 g of acetic acid to lower its melting point by  $1.5^\circ\text{C}$ .  $K_f = 3.9 \text{ K kg mol}^{-1}$ .

Answer:

**Given:**  $\Delta T_f = 1.5^\circ$

Mass of  $\text{CH}_3\text{COOH}$ ,  $w_1 = 75\text{g}$

$M_1 = 60\text{ g mol}^{-1}$

$M_2 (\text{C}_6\text{H}_8\text{O}_6) = 176\text{ g mol}^{-1}$

$K_f = 3.9\text{ K kg mol}^{-1}$

**To find:**  $w_2 = ?$

**Solution:** Applying  $M_2 = \frac{1000K_f w_2}{w_1 \Delta T_f}$

or,  $w_2 = \frac{M_2 \times w_1 \times \Delta T_f}{1000 \times K_f}$

$$w_2 = \frac{176 \times 75 \times 1.5}{1000 \times 3.9} = 5.077\text{ g}$$

Question 12.

Calculate the osmotic pressure in pascals exerted by a solution prepared by dissolving 1.0 g of a polymer of molar mass 185,000 in 450 mL of solution at 37°C.

Answer:

$$\text{Osmotic pressure } (\pi) = CRT = \frac{W_B \times R \times T}{M_B \times V}$$

Mass of polymer ( $W_B$ ) = 1.0 g

Molar mass of polymer ( $M_B$ ) = 185,000 g mol<sup>-1</sup>

Volume of solution ( $V$ ) = 450 mL = 0.450 L

Temperature ( $T$ ) = 37 + 273 = 310 K

Solution constant ( $R$ ) =  $8.314 \times 10^3\text{ Pa L K}^{-1}\text{ mol}^{-1}$

$$\therefore \pi = \frac{(1.0\text{g}) \times (8.314 \times 10^3\text{ Pa L K}^{-1}\text{ mol}^{-1}) \times (310\text{K})}{(185,000\text{ g mol}^{-1}) \times (0.450\text{ L})} = 30.96\text{ Pa}$$

## NCERT EXERCISE

Question 1.

Define the term solution. What kinds of solutions are possible? Write briefly about each type of solution with an example.

Answer:

A true solution is a homogenous mixture of two or more substances. The constituent particle which is in larger amount is called a solvent and that in smaller quantity is called a solute.

## TYPES OF SOLUTION

Nature of solution	Solute	Solvent	Examples
<b>Solid solutions</b>	Gas	Solid	Gases adsorbed over metal surface (occlusion). Gases dissolved in minerals.
	Liquid	Solid	Mercury in an amalgam, Hydrated salts
	Solid	Solid	Alloys of metals <i>e.g.</i> Interstitial solid solutions.
<b>Liquid solutions</b>	Gas	Liquid	Aerated drinks
	Liquid	Liquid	Mixture of miscible liquids <i>e.g.</i> , alcohol in water, benzene in toluene.
	Solid	Liquid	Salts dissolved in water
<b>Gaseous solutions</b>	Gas	Gas	Air (Mixture of many gases)
	Liquid	Gas	Humidity in air
	Solid	Gas	Iodine vapours in air

Question 2.

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

Answer:

Solid in solid type. *E.g.*: Copper in gold. This type of solutions are called alloys.

Question 3.

Define the following terms :

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

Answer:

**(i) Mole fraction :**

The ratio of the number of moles of one component to the total number of moles of all the components present in the solution.

For a binary solution made up of components A and B,

$$\text{Mole fraction of A } (x_A) = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of B } (x_B) = \frac{n_B}{n_A + n_B}$$

$$\text{Sum of mole fractions } (x_A + x_B) = \frac{n_A}{n_A + n_B} + \frac{n_B}{n_A + n_B} = 1$$

**(ii) Molality:**

The number of gram moles of the solute dissolved in 1000 g (or kg) of the solvent.

$$\begin{aligned} \text{Mathematically, Molality } (m) &= \frac{\text{Gram moles of solute}}{\text{Mass of solvent in kg}} \\ &= \frac{\text{Mass of solute in grams} / \text{molar mass}}{\text{Mass of solvent in grams} / 1000} \end{aligned}$$

**(iii) Molarity:**

The number of gram formula mass of the solute dissolved per litre of the solution.

$$\begin{aligned} \text{Molarity (M)} &= \frac{\text{Gram moles of solute}}{\text{Volume of solution in litres}} \\ &= \frac{\text{Mass of solute in grams / molar mass}}{\text{Volume of solution in mL / 1000}} \end{aligned}$$

**(iv) Mass percentage:**

The number of parts by mass of one component (solute or solvent) per 100 parts by mass of the solution. If A and B are the two components of a binary solution,

$$\text{Mass percent of A} = \frac{W_A}{W_A + W_B} \times 100$$

$$\text{Mass percent of B} = \frac{W_B}{W_A + W_B} \times 100$$

**Question 4.**

Concentrated nitric acid used in laboratory work is 68% nitric acid by mass in an aqueous solution. What should be the molarity of such a sample of the acid if the density of the solution is 1.504 g mL<sup>-1</sup>?

Answer:

68% nitric acid by mass means that 68g mass of nitric acid is dissolved in 100g mass of solution. Molar mass of HNO<sub>3</sub> = 63g mol<sup>-1</sup>

$$\therefore 68\text{g of HNO}_3 = \frac{68}{63} = 1.079 \text{ mole.}$$

Density of solution = 1.504 g mL<sup>-1</sup> (given)

$\therefore$  Volume of solution

$$= \frac{\text{Mass}}{\text{Density}} = \frac{100}{1.504} = 66.5 \text{ mL}$$

$\therefore$  Molarity of solution

$$= \frac{\text{Moles of solute} \times 1000}{\text{Volume of solution in mL}}$$

$$= \frac{1.079 \times 1000}{66.5} = 16.23 \text{ M.}$$

**Question 5.**

A solution of glucose in water is labelled as 10 percent W/W. What would be the molality and mole fraction of each component in the solution? If the density of the solution is 1.2 g mL<sup>-1</sup>, then what should be the molarity of the solution? (C.B.S.E. 2013, Manipur Board 2015)

Answer:

**Step I. Calculation of molality of solution.**

$$\begin{aligned}
 \text{Mass of glucose in solution} &= 10 \text{ g} \\
 \text{Mass of solution} &= 100 \text{ g} \\
 \text{Mass of water in solution} &= (100 - 10) = 90 \text{ g} = 0.09 \text{ kg} \\
 \text{Molar mass of glucose (C}_6\text{H}_{12}\text{O}_6) &= 6 \times 12 + 12 \times 1 + 6 \times 16 = 180 \text{ g mol}^{-1} \\
 \text{Molality of solution (m)} &= \frac{\text{Mass of glucose} / \text{Molar mass of glucose}}{\text{Mass of solvent in kg}} \\
 &= \frac{10 \text{ g} / (180 \text{ g mol}^{-1})}{(0.09 \text{ kg})} = 0.617 \text{ mol/kg} = \mathbf{0.617 \text{ m}}.
 \end{aligned}$$

**Step II. Calculation of mole fraction of each component in solution.**

$$\begin{aligned}
 \text{No. of moles of glucose} &= \frac{\text{Mass of glucose}}{\text{Molar mass}} = \frac{(10 \text{ g})}{(180 \text{ g mol}^{-1})} = 0.055 \text{ mol} \\
 \text{No. of moles of water} &= \frac{\text{Mass of water}}{\text{Molar mass}} = \frac{(90 \text{ g})}{(18 \text{ g mol}^{-1})} = 5.0 \text{ mol} \\
 \text{Mole fraction of glucose} &= \frac{{}^n\text{C}_6\text{H}_{12}\text{O}_6}{{}^n\text{C}_6\text{H}_{12}\text{O}_6 + {}^n\text{H}_2\text{O}} = \frac{(0.055 \text{ mol})}{(0.055 \text{ mol}) + (5.0 \text{ mol})} = \mathbf{0.01} \\
 \text{Mole fraction of water} &= 1 - 0.01 = \mathbf{0.99}
 \end{aligned}$$

**Step III. Calculation of molarity of solution.**

$$\begin{aligned}
 \text{Mass of solution} &= 100 \text{ g} \\
 \text{Density of solution} &= 1.2 \text{ g mL}^{-1} \\
 \text{Volume of solution} &= \frac{\text{Mass of solution}}{\text{Density}} = \frac{(100 \text{ g})}{(1.2 \text{ g mL}^{-1})} = 83.33 \text{ mL} \\
 &= 0.08333 \text{ L} \\
 \text{Molarity of solution (M)} &= \frac{\text{Mass of glucose} / \text{Molar mass of glucose}}{\text{Volume of solution in litres}} \\
 &= \frac{(10 \text{ g}) / (180 \text{ g mol}^{-1})}{(0.08333 \text{ L})} = 0.67 \text{ mol L}^{-1} = \mathbf{0.67 \text{ M}}
 \end{aligned}$$

Question 6.

How many mL of a 0.1 M HCl are required to react completely with a 1 g mixture of  $\text{Na}_2\text{CO}_3$  and  $\text{NaHCO}_3$  containing equimolar amounts of two?

Answer:

**Step I. Calculation of mass of constituents in the mixture.**

Mass of the mixture = 1.0 g

Let the mass of  $\text{Na}_2\text{CO}_3$  =  $x$  g

$\therefore$  Mass of  $\text{NaHCO}_3$  =  $(1 - x)$ g

$$\text{Moles of } \text{Na}_2\text{CO}_3 = \frac{\text{Mass of } \text{Na}_2\text{CO}_3}{\text{Molar mass}} = \frac{(x \text{ g})}{(106 \text{ g mol}^{-1})} = \frac{x}{106} \text{ mol}$$

$$\text{Moles of } \text{NaHCO}_3 = \frac{\text{Mass of } \text{NaHCO}_3}{\text{Molar mass}} = \frac{(1 - x) \text{ g}}{(84 \text{ g mol}^{-1})} = \frac{1 - x}{84} \text{ mol}$$

According to available data :

Moles of  $\text{Na}_2\text{CO}_3$  = Moles of  $\text{NaHCO}_3$

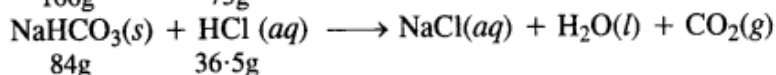
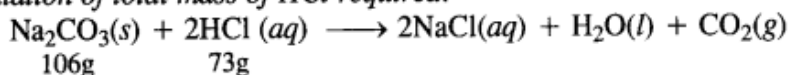
$$\therefore \left( \frac{x}{106} \text{ mol} \right) = \left( \frac{1 - x}{84} \text{ mol} \right)$$

or  $84x = 106 - 106x$  or  $x = \frac{106}{190} = 0.558 \text{ g}$

$\therefore$  Mass of  $\text{Na}_2\text{CO}_3$  in the mixture = 0.558 g

Mass of  $\text{NaHCO}_3$  in the mixture =  $(1 - 0.558) = 0.442 \text{ g}$

**Step II. Calculation of total mass of HCl required.**



Now, 106 g of  $\text{Na}_2\text{CO}_3$  require HCl = 73 g

$$0.558 \text{ g of } \text{Na}_2\text{CO}_3 \text{ require HCl} = \frac{(73\text{g}) \times (0.558\text{g})}{(106\text{g})} = 0.384 \text{ g}$$

Similarly, 84 g of  $\text{NaHCO}_3$  require HCl = 36.5 g

$$0.442 \text{ g of } \text{NaHCO}_3 \text{ require HCl} = \frac{(36.5\text{g}) \times (0.442\text{g})}{(84\text{g})} = 0.192 \text{ g}$$

$\therefore$  Total mass of HCl required =  $(0.384 + 0.192) = 0.576 \text{ g}$

**Step III. Calculation of volume of HCl required.**

Mass of HCl required = 0.576 g

Molarity of HCl solution = 0.1 M

$$\text{Molarity of solution (M)} = \frac{\text{Mass of HCl} / \text{Molar mass of HCl}}{\text{Volume of solution (V)}}$$

$$0.1 \text{ mol L}^{-1} = \frac{(0.576 \text{ g}) / (36.5 \text{ g / mol})}{V}$$

$$V = \frac{0.576 \times 1000}{36.5 \times 0.1} = 0.1578 \text{ L} = \mathbf{157.8 \text{ mL.}}$$

Question 7.

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.

Answer:

$$300\text{g of } 25\% \text{ solution will contain} = \frac{25 \times 300}{100}$$

$$= 75 \text{ g of solute.}$$

400g of 40% solution will contain

$$= \frac{40 \times 400}{100} = 160 \text{ g of solute.}$$

$$\therefore \text{ Total mass of solute} = 160 + 75 = 235\text{g}$$

$$\text{Total mass of solution} = 300 + 400 = 700\text{g}$$

Now, the percentage of solute in solution

$$= \frac{235}{700} \times 100 = 33.5\%$$

and, the percentage of water in solution

$$= 100 - 33.5\% = 66.5\%$$

Question 8.

An antifreeze solution is prepared from 222.6 g of ethylene glycol  $\text{C}_2\text{H}_4(\text{OH})_2$  and 200 g of water. Calculate the molality of the solution. If the density of the solution is  $1.072 \text{ g mL}^{-1}$ , then what shall be the molarity of the solution? (C.B.S.E. Delhi 2007)

Answer:

**Step I.** Calculation of molality of the solution.

$$\text{Mass of ethylene glycol} = 222.6 \text{ g}$$

$$\text{Molar mass of ethylene glycol} = 2 \times 12 + 6 \times 1 + 2 \times 16 = 62 \text{ g mol}^{-1}$$

$$\text{Mass of water} = 200 \text{ g} = 0.2 \text{ kg}$$

$$\text{Molality of solution (m)} = \frac{\text{Mass of ethylene glycol} / \text{Molar mass}}{\text{Mass of solvent in kg}}$$

$$= \frac{(222.6 \text{ g}) / (62 \text{ g mol}^{-1})}{0.2 \text{ kg}} = 17.95 \text{ mol kg}^{-1} = 17.95 \text{ m.}$$

**Step II.** Calculation of molarity of the solution.

$$\text{Total mass of solution} = \text{Mass of solute} + \text{Mass of solvent}$$

$$= 222.6 + 200 = 422.6 \text{ g}$$

$$\text{Density of solution} = 1.072 \text{ g mL}^{-1}$$

$$\text{Volume of solution} = \frac{\text{Mass of solution}}{\text{Density of solution}} = \frac{(422.6 \text{ g})}{(1.072 \text{ g mL}^{-1})} = 394.2 \text{ mL}$$

$$= 0.3942 \text{ L.}$$

$$\text{Molarity of solution (M)} = \frac{\text{Mass of ethylene glycol} / \text{Molar mass}}{\text{Volume of solution in litres}}$$

$$= \frac{(222.6 \text{ g}) / (62 \text{ g mol}^{-1})}{(0.3942 \text{ L})} = 9.10 \text{ mol L}^{-1} = 9.10 \text{ M.}$$

Question 9.

A sample of drinking water was found to be severely contaminated with chloroform ( $\text{CHCl}_3$ ) 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 a water sample.

Answer:

(i) *Percentage (%) by mass of CHCl<sub>3</sub>*

$$= \frac{\text{Mass of CHCl}_3}{\text{Mass of solution}} \times 100 = \frac{(15 \cdot 0 \text{ g})}{(10^6 \text{ g})} \times 100 = 1 \cdot 5 \times 10^{-3}$$

(ii) *Molality of solution.*

Mass of solute = 15 g ; Mass of solution = 10<sup>6</sup> g

Mass of water = (10<sup>6</sup> - 15) ≈ 10<sup>6</sup>g.

$$\begin{aligned} \text{Molality of solution (m)} &= \frac{\frac{\text{Mass of CHCl}_3}{\text{Molar mass}}}{\text{Mass of water in kg}} = \frac{\frac{15 \text{ g}}{(119 \cdot 5 \text{ mol}^{-1})}}{(10^6 / 1000 \text{ kg})} \\ &= 1 \cdot 25 \times 10^{-4} \text{ mol kg}^{-1} = 1 \cdot 25 \times 10^{-4} \text{ m} \end{aligned}$$

Question 10.

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

Answer:

Alcohols dissolve in water due to the formation of intermolecular H-bonding with water.

Question 11.

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

Answer:

The dissolution of a gas in a liquid is exothermic in nature because the gas contracts in volume.

Gas + Liquid ⇌ Dissolved gas ; ΔH = - ve

An increase in temperature will favour the reverse process since it is of endothermic nature. Therefore, the solubility of the gas in the solution decreases with the rise in temperature.

Question 12.

State Henry's law and mention some important applications.

Answer:

Henry's law: According to this law, 'The mass of a gas dissolved per unit volume of a solvent at a constant temperature, is proportional to the pressure of the gas with which the solvent is in equilibrium'.

Let in unit volume of solvent, the mass of the gas dissolved is m and equilibrium pressure is P, then m ∝ P or m = KP, where K is a constant. We can understand

Henry's law by taking the example of soda water bottle. Soda water contains carbon dioxide dissolved in water under pressure.

Applications of Henry's law:

1. In the production of carbonated beverages: To increase the solubility of  $\text{CO}_2$  in soft drinks, soda water, beer etc. the bottles are sealed at high pressure.

2. In exchange of gases in the blood: The partial pressure of  $\text{O}_2$  is high in inhaled air, in lungs it combines with hemoglobin to form oxyhemoglobin. In tissues, the partial pressure of oxygen is comparatively low therefore oxyhemoglobin releases oxygen in order to carry out cellular activities.

3. In deep-sea diving: Deep-sea divers depend upon compressed air for breathing at high pressure underwater. The compressed air contains  $\text{N}_2$  in addition to  $\text{O}_2$ , which are not very soluble in blood at normal pressure. However, at great depths when the diver breathes in compressed air from the supply tank, more  $\text{N}_2$  dissolved in the blood and in other body fluids because the pressure at that depth is far greater than the surface atmospheric pressure. When the divers come towards the surface at atmospheric pressure, this dissolves nitrogen bubbles out of the blood. These bubbles restrict blood flow, affect the transmission of nerve impulses. This causes a disease called bends or decompression sickness. To avoid bends, as well as toxic effects of high concentration of nitrogen in the blood, the tanks used by scuba divers are filled with air diluted with helium (11.7% He, 56.2%  $\text{N}_2$ , and 32.1%  $\text{O}_2$ ).

4. At high altitudes: At high altitudes, the partial pressure of  $\text{O}_2$  is less than that at the ground level. This results in a low concentration of oxygen in the blood and tissues of the people living at high altitudes or climbers. The low blood oxygen causes climbers to become weak and unable to think clearly known as anoxia.

5. Aquatic life: The dissolution of oxygen (from air) in water helps in the existence of aquatic life in various water bodies like Lake, rivers, and sea.

Question 13.

The partial pressure over a saturated solution containing  $6.56 \times 10^{-2}$  g of ethane is 1 bar. If the solution contains  $5.0 \times 10^{-2}$  g of ethane, what shall be the partial pressure of the gas?

Answer:

According to Henry's law,

The mass of the gas (m) dissolved in solution  $\propto$  Partial pressure (p) (At constant

temperature)

$$\therefore \begin{aligned} (6.56 \times 10^{-2} \text{ g}) &\propto 1 \text{ bar} \\ (5.0 \times 10^{-2} \text{ g}) &\propto p \end{aligned}$$

$$\text{or } p = \frac{(5.0 \times 10^{-2} \text{ g})}{(6.56 \times 10^{-2} \text{ g})} \times (1 \text{ bar}) = \mathbf{0.762 \text{ bar.}}$$

Question 14.

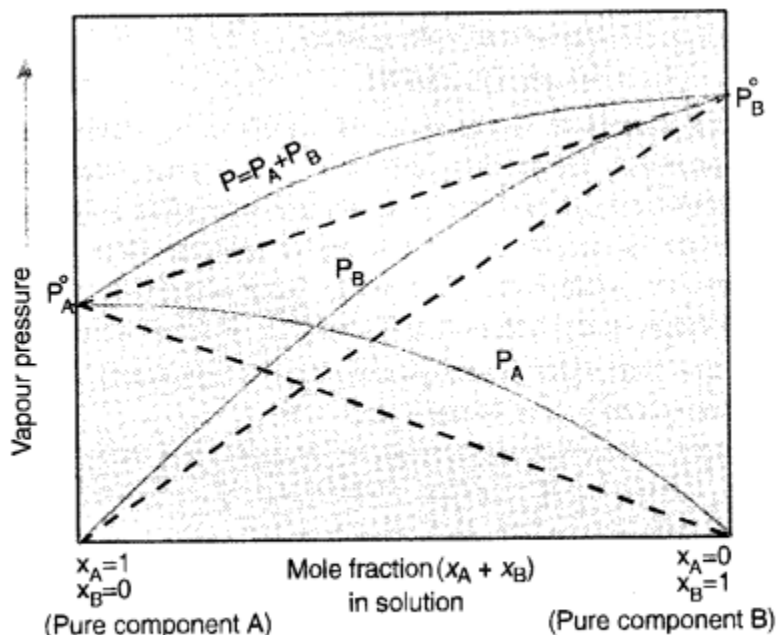
What is meant by positive and negative deviations from Raoult's law and how is the sign of  $\Delta H_{\text{sol}}$  related to positive and negative deviations from Raoult's law?

Answer:

**(a) Positive Deviation:**

**(i)  $\Delta V_{\text{mixing}}$  is positive:** This is quite likely also because in the presence of weak forces of interaction, interaction, the volume of the solution is bound to increase.

**(ii)  $\Delta H_{\text{mixing}}$  is positive:** Energy is needed to form the solution because the components of the solution have to be brought closer to form the solution. Thus, the process of mixing is of endothermic nature.



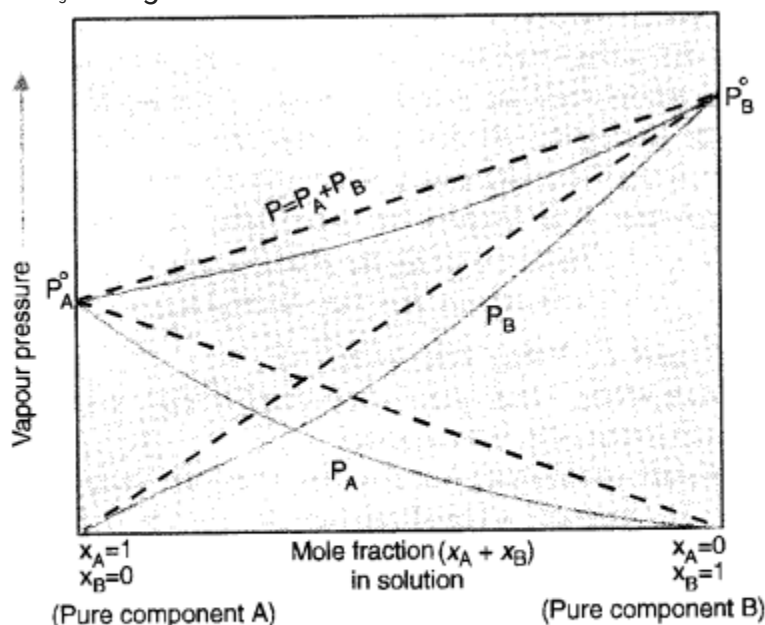
**Figure 2.12. Graphical representation of non-ideal solution having +ve deviation from Raoult's Law.**

**(b) Negative Deviation:**

**(i)  $\Delta V_{\text{mixing}}$  is negative:** Because of the increased forces of interaction, the molecules of the two components will come closer and as a result, there is a decrease in the volume of the solution.

**(ii)  $\Delta H_{\text{mixing}}$  is negative:** Energy is expected to be released because of the increase in the forces of interaction. Therefore, the process of mixing is exothermic in nature or

$\Delta H_{\text{mixing}}$  is negative.



**Figure 2.13. Graphical representation of non-ideal solution having -ve deviation from Raoult's Law.**

Question 15.

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?

Answer:

Vapour pressure of pure water at the boiling point

$$(P^\circ) = 1.013 \text{ bar}$$

Vapour pressure of solution ( $P_s$ ) = 1.004 bar

Mass of solute ( $w_2$ ) = 2g

Molar mass of solvent, water ( $M_1$ ) = 18g

Mass of solvent ( $w_1$ ) = 98g

Mass of solution = 100g

Applying Raoult's Law for dilute solutions,

$$\frac{P^\circ - P_s}{P^\circ} = \frac{n_2}{n_1 + n_2} \approx \frac{n_2}{n_1}$$

[Dilute solution being 2%]

$$\frac{P^\circ - P_s}{P^\circ} = \frac{n_2}{n_1} = \frac{W_2/M_2}{W_1/M_1}$$

$$\frac{(1.013 - 1.004)}{(1.013)} = \frac{2 \times 18}{M_2 \times 98}$$

$$\therefore M_2 = \frac{2 \times 18}{98 \times 0.009} \times 1.013 = 41.35 \text{ g mol}^{-1}$$

Question 16.

Heptane and octane form ideal solutions. At 373 K, the vapour pressure of the two liquid components is 105.2 k Pa and 46.8 k Pa respectively. If the solution contains 25 g of heptane and 35 g of octane, calculate:

- (i) Vapour pressure exerted by heptane
- (ii) Vapour pressure exerted by octane
- (iii) Vapour pressure exerted by the solution
- (iv) Mole fraction of octane in the vapour phase. (C.B.S.E. Sample Paper, 2010)

Answer:

$$\text{No. of moles of heptane } (n_B) = \frac{\text{Mass of heptane } (C_7H_{16})}{\text{Gram molar mass}} = \frac{(25 \text{ g})}{(100 \text{ g mol}^{-1})} = 0.25 \text{ mol}$$

$$\text{No. of moles of octane } (n_A) = \frac{\text{Mass of octane } (C_8H_{18})}{\text{Gram molar mass}} = \frac{(35 \text{ g})}{(114 \text{ g mol}^{-1})} = 0.307 \text{ mol}$$

$$\text{Mole fraction of heptane } (x_B) = \frac{n_B}{n_B + n_A} = \frac{(0.25 \text{ mol})}{(0.25 \text{ mol} + 0.307 \text{ mol})} = 0.449$$

$$\text{Mole fraction of octane } (x_A) = \frac{n_A}{n_B + n_A} = \frac{(0.307 \text{ mol})}{(0.25 \text{ mol} + 0.307 \text{ mol})} = 0.551$$

$$\text{Vapour pressure of pure heptane } (P_B^\circ) = 105.2 \text{ kPa}$$

$$\text{Vapour pressure of pure octane } (P_A^\circ) = 46.8 \text{ kPa}$$

$$(i) \quad \text{Vapour pressure of heptane } (P_B) = P_B^\circ x_B = (105.2 \text{ kPa} \times 0.449) = \mathbf{47.23 \text{ kPa}}$$

$$(ii) \quad \text{Vapour pressure of octane } (P_A) = P_A^\circ x_A = (46.8 \text{ kPa} \times 0.551) = \mathbf{25.79 \text{ kPa.}}$$

$$(iii) \quad \text{Total vapour pressure of solution } (P) = P_A + P_B = (47.23 + 25.79) = \mathbf{73.02 \text{ kPa.}}$$

$$(iv) \quad \text{Mole fraction of octane in the vapour phase} = \frac{P_A}{P_A + P_B} = \frac{(25.79 \text{ k Pa})}{(73.02 \text{ k Pa})} = \mathbf{0.353}$$

Question 17.

The vapour pressure of water is 12.3 kPa at 300 K. Calculate the vapour pressure of 1 molal solution in it.

Answer:

1 molal solution implies one mole of the solute dissolved in 1000 g (1 kg) of solvent i.e. water.

$$\therefore \quad \text{No. of moles of solute } (n_B) = 1 \text{ mol}$$

$$\text{No. of moles of water } (n_A) = \frac{\text{Mass of water}}{\text{Molar mass}} = \frac{(1000 \text{ g})}{(18 \text{ g mol}^{-1})} = 55.55 \text{ mol}$$

$$\begin{aligned} \text{Mole fraction of solute } (x_B) &= \frac{n_B}{n_B + n_A} = \frac{(1 \text{ mol})}{(1 \text{ mol} + 55.55 \text{ mol})} \\ &= \frac{1}{56.55} = 0.0177 \end{aligned}$$

$$\begin{aligned} \text{Vapour pressure of solution } (P_A) &= P_A^\circ x_A = P_A^\circ (1 - x_B) = 12.3 \text{ kPa} \times (1 - 0.0177) \\ &= 12.3 \text{ ka} \times 0.9823 = \mathbf{12.08 \text{ kPa.}} \end{aligned}$$

Question 18.

Calculate the mass of a non-volatile solute (molar mass 40 g mol<sup>-1</sup>) which should be

dissolved in 114 g octane to reduce its vapour pressure to 80%.

Answer:

$$P_s = 80\% \text{ of } P^\circ$$

$$= \frac{80}{100} P^\circ = 0.8 P^\circ$$

Let  $W$ g of solute is present in mixture.

$$\text{Moles of solute present} = \frac{W}{40} \text{ moles}$$

$$\begin{aligned} \text{Molar mass of octane, } C_8H_{18} \\ = 8 \times 12 + 18 = 114 \text{ g mol}^{-1} \end{aligned}$$

$$\therefore \text{Moles of octane} = \frac{114}{114} = 1 \text{ mol}$$

$$\text{Now, } \frac{P^\circ - P_s}{P^\circ} = x_2 = \frac{W/40}{\frac{W}{40} + 1}$$

$$\frac{P^\circ - 0.80 P^\circ}{P^\circ} = \frac{W/40}{W/40 + 1}$$

$$1 - 0.80 = \frac{W \times 40}{40(W + 40)} = \frac{W}{W + 40}$$

$$0.20 = \frac{W}{W + 40}$$

$$0.2 W + 8 = W$$

$$8 = W(1 - 0.2)$$

$$8 = 0.8 W$$

$$\therefore W = \frac{8}{0.8} = 10\text{g.}$$

Question 19.

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

(i) Molecular mass of the solute.

(ii) Vapour pressure of water at 298 K. (C.B.S.E. Outside Delhi 2005)

Answer:

### Step I. Calculation of molecular mass of the solute.

In the first case :

$$\text{No. of moles of solute } (n_B) = \frac{\text{Mass of solute}}{\text{Molecular mass}} = \frac{(30 \text{ g})}{(M \text{ g mol}^{-1})} = \frac{30}{M} \text{ mol}$$

$$\text{No. of moles of water } (n_A) = \frac{\text{Mass of water}}{\text{Molecular mass}} = \frac{(90 \text{ g})}{(18 \text{ g mol}^{-1})} = 5 \text{ mol}$$

$$\text{Mole fraction of water } (x_A) = \frac{n_A}{n_A + n_B} = \frac{(5 \text{ mol})}{\left(5 \text{ mol} + \frac{30}{M} \text{ mol}\right)} = \frac{5}{\left(5 + \frac{30}{M}\right)} = \frac{M}{(6 + M)}$$

$$\text{Vapour pressure of solution } (P_A) = 2.8 \text{ kPa}$$

$$\text{According to Raoult's Law, } P_A = P_A^\circ x_A$$

$$(2.8 \text{ kPa}) = P_A^\circ \frac{M}{(6 + M)} \quad \dots(i)$$

In the second case :

$$\text{No. of moles of solute } (n_B) = \frac{30}{M} \text{ mol}$$

$$\text{No. of moles of water } (n_A) = \frac{\text{Mass of water}}{\text{Molecular mass}} = \frac{(108 \text{ g})}{(18 \text{ g mol}^{-1})} = 6 \text{ mol}$$

$$\text{Mole fraction of water } (x_A) = \frac{n_A}{n_A + n_B} = \frac{(6 \text{ mol})}{\left(6 \text{ mol} + \frac{30}{M} \text{ mol}\right)} = \frac{M}{(5 + M)}$$

$$\text{Vapour pressure of solution } (P_A) = 2.9 \text{ kPa}$$

$$\text{According to Raoult's Law, } P_A = P_A^\circ x_A$$

$$(2.9 \text{ kPa}) = P_A^\circ \frac{M}{(5 + M)} \quad \dots(ii)$$

Dividing eqn. (i) by eqn. (ii),

$$\frac{(2.8 \text{ kPa})}{(2.9 \text{ kPa})} = \frac{5 + M}{6 + M}$$

$$\text{or} \quad \frac{5 + M}{6 + M} = \frac{2.8}{2.9} \text{ or } 0.9655$$

$$\text{or} \quad 5 + M = 0.9655 \times 6 + 0.9655 M$$

$$\text{or} \quad 0.0345M = 0.793$$

$$\text{or} \quad M = \frac{0.793}{0.0345} = 23$$

### Step II. Calculation of vapour pressure of water

$$\text{According to Raoult's Law, } P_A = P_A^\circ x_A \text{ or } (2.8 \text{ kPa}) = P_A^\circ \frac{5}{\left(5 + \frac{30}{M}\right)}$$

$$\text{or} \quad (2.8 \text{ kPa}) = P_A^\circ \frac{5}{\left(5 + \frac{30}{23.0}\right)} = P_A^\circ \frac{5}{5 + 1.30} = P_A^\circ \frac{5}{6.30}$$

$$\text{or} \quad P_A^\circ = \frac{(2.8 \text{ kPa}) \times 6.30}{5} = 3.53 \text{ kPa.}$$

Question 20.

A 5% solution (by mass) of cane sugar in water has a freezing point of 271 K. Calculate the freezing point of a 5% glucose in water if the freezing point of pure water is 273.15 K. (C.B.S.E. Delhi 2008)

Answer:

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

**For cane sugar solution :**  
 $W_B = 5 \text{ g}; W_A = 100 - 5 = 95 \text{ g} = 0.095 \text{ kg};$   
 $M_B = 342 \text{ g mol}^{-1}$

$\therefore \Delta T_f = 273.15 - 271 = 2.15 \text{ K}$

$\therefore 2.15 \text{ K} = \frac{K_f \times (5 \text{ g})}{(342 \text{ g mol}^{-1}) \times (0.095 \text{ kg})} \quad \dots(i)$

**For glucose solution :**

$W_B = 5 \text{ g}; W = 100 - 5 = 95 \text{ g}; = 0.095 \text{ kg}$   
 $M_B = 180 \text{ g mol}^{-1}$

$\therefore \Delta T_f = \frac{K_f \times (5 \text{ g})}{(180 \text{ g mol}^{-1}) \times (0.095 \text{ kg})} \quad \dots(ii)$

Divide eqn. (ii) by eqn. (i),

$$\frac{\Delta T_f}{(2.15 \text{ K})} = \frac{(K_f) \times (5 \text{ g})}{(180 \text{ g mol}^{-1}) \times (0.095 \text{ kg})} \times \frac{(342 \text{ g mol}^{-1}) \times (0.095 \text{ kg})}{(K_f) \times (5 \text{ g})}$$

$$\Delta T_f = \frac{(342 \text{ g mol}^{-1})}{(180 \text{ g mol}^{-1})} \times 2.15 \text{ K} = 4.085 \text{ K}$$

Freezing point temperature of glucose solution =  $(273.15 - 4.085) \text{ K} = 269.07 \text{ K}$ .

Question 21.

Two elements A and B form compounds having molecular formulae  $AB_2$  and  $AB_4$ . When dissolved in 20 g of benzene, 1 g of  $AB_2$  lowers the freezing point by 2.3 K whereas 1 g of  $AB_4$  lowers it by 1.3 K. Molal depression constant for benzene is  $5.1 \text{ K kg mol}^{-1}$ . Calculate atomic masses of A and B. (C.B.S.E. Delhi 2004)

Answer:



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

**Step I. Calculation of the molecular masses of the two compounds.**

For the compound AB<sub>2</sub> :

$$W_B = 1 \text{ g} ; W_A = 20 \text{ g} = 0.02 \text{ kg} ; \Delta T_f = 2.3 \text{ K} ;$$

$$K_f = 5.1 \text{ K kg mol}^{-1}$$

$$\therefore M_B = \frac{(5.1 \text{ K kg mol}^{-1}) \times (1 \text{ g})}{(2.3 \text{ K}) \times (0.02 \text{ kg})} = 110.87 \text{ g mol}^{-1}$$

For the compound AB<sub>4</sub> ;

$$W_B = 1 \text{ g} ; W_A = 20 \text{ g} = 0.02 \text{ kg} ; \Delta T_f = 1.3 \text{ K} ;$$

$$K_f = 5.1 \text{ K kg mol}^{-1}.$$

$$\therefore M_B = \frac{(5.1 \text{ K kg mol}^{-1}) \times (1 \text{ g})}{(1.3 \text{ K}) \times (0.02 \text{ kg})} = 196.15 \text{ g mol}^{-1}.$$

**Step II. Calculation of the atomic masses of elements A and B.**

Let the atomic mass of element A = *a*

Let the atomic mass of element B = *b*

$$\therefore \text{Molecular mass of AB}_2 = a + 2b$$

$$\text{Molecular mass of AB}_4 = a + 4b$$

According to available information,

$$a + 2b = 110.87 \quad \dots(i)$$

$$a + 4b = 196.15 \quad \dots(ii)$$

Subtract eqn. (i) from (ii),

$$2b = (196.15 - 110.87) = 85.28 \text{ or } b = 85.28/2 = 42.64$$

Substituting the value of *b* in eqn. (i),

$$a + 2(42.64) = 110.87 \text{ or } a = 110.87 - 85.28 = 25.59$$

Thus, Atomic mass of element A = **25.59**

Atomic mass of element B = **42.64**

Question 22.

At 300 K, 36g of glucose present in a litre of its solution has an osmotic pressure of 4.08 bar. If the osmotic pressure of the solution is 1.52 bars at the same temperature, what would be its concentration?

Answer:

$$\pi = CRT$$

$$4.98 = \frac{W_1}{M_1} \times R \times 300$$

$$4.98 = \frac{36}{180} \times R \times 300$$

$$4.98 = 60 R \quad \dots(i)$$

In second case  $1.52 = C \times R \times 300 \dots(ii)$

Dividing equation (ii) by equation (i), we get

$$C = \frac{60 \times 1.52}{300 \times 4.98} = 0.06 \text{ M}$$

Question 23.

Suggest the most important type of intermolecular attractive interactions in the following pairs :

1. n-hexane and n-octane
2. I<sub>2</sub> and CCl<sub>4</sub>
3. NaClO<sub>4</sub> and water (H<sub>2</sub>O)
4. methanol and acetone
5. acetonitrile (CH<sub>3</sub>CN) and acetone (C<sub>3</sub>H<sub>6</sub>O).

Answer:

1. Both are non-polar. Hence, intermolecular interactions in them will be London/ dispersion forces (discussed in class XI)
2. Both are non-polar. Hence, intermolecular interactions in them will be London/ dispersion forces (discussed in class XI)
3. NaClO<sub>4</sub> gives Na<sup>+</sup> and ClO<sub>4</sub><sup>-</sup> ions in the solution while water is a polar molecule. Hence, intermolecular interactions in them will be ion-dipole interactions.
4. Both are polar molecules. Hence intermolecular interactions in them will be dipole-dipole interactions.
5. Both are polar molecules. Hence intermolecular interactions in them will be dipole-dipole interactions.

Question 24.

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

Cyclohexane, KCl, CH<sub>3</sub>OH, CH<sub>3</sub>CN.

Answer:

- (i) Cyclohexane and n-octane both are non-polar. Hence they mix completely in all proportions.
- (ii) KCl is an ionic compound while n-octane is nonpolar. Hence, KCl will not dissolve at all in n-octane.
- (iii) CH<sub>3</sub>OH and CH<sub>3</sub>CN both are polar but CH<sub>3</sub>CN is less polar than CH<sub>3</sub>OH. As the solvent is non-polar, CH<sub>3</sub>CN will dissolve more than CH<sub>3</sub>OH in n-octane.
- Thus the order of solubility will be KCl < CH<sub>3</sub>OH < CH<sub>3</sub>CN < Cyclohexane.

Question 25.

Among 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.

Answer:

(i) **phenol (C<sub>6</sub>H<sub>5</sub>OH)**: Is partially soluble in water due to weak dipole-dipole interactions in the molecules of phenol and water.

(ii) **toluene (C<sub>7</sub>H<sub>8</sub>)**: Is insoluble in water because it is an aromatic hydrocarbon (non-polar) while water is polar in nature.

(iii) **formic acid (HCOOH)**: Is highly soluble in water since it can form hydrogen bonding with water.

(iv) **ethylene glycol (HOCH<sub>2</sub>CH<sub>2</sub>OH)**: Is highly soluble in water since it can form hydrogen bonding with water.

(v) **chloroform (CHCl<sub>3</sub>)**: Is insoluble in water because it is an organic heavy liquid and forms a separate layer.

(vi) **pentanol (C<sub>5</sub>H<sub>11</sub>OH)**: Is partially soluble in water because the bulky C<sub>5</sub>H<sub>11</sub> group decreases its extent of hydrogen bonding with water.

Question 26.

If the density of some lake water is 1.25 g mL<sup>-1</sup> and contains 92g of Na<sup>+</sup> ions per kg of water, calculate the molality of Na<sup>+</sup> ions in the lake.

Answer:

**Molar mass of Na = 23 g mol<sup>-1</sup>**

**∴ No. of moles of Na<sup>+</sup> ions present**

$$= \frac{92}{23} = 4 \text{ moles}$$

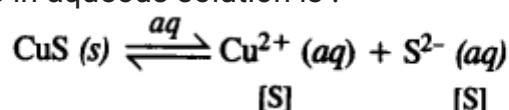
$$\therefore \text{Molality} = \frac{4 \times 1000}{1000} = 4 \text{ m.}$$

Question 27.

If the solubility product of CuS is 6 × 10<sup>-16</sup>, calculate the maximum molarity of CuS in aqueous solution.

Answer:

Dissociation of CuS in aqueous solution is :



$$\text{Solubility product (K}_{sp}\text{)} = [\text{Cu}^{2+} \text{ (aq)}] [\text{S}^{2-} \text{ (aq)}] = [\text{S}] \times [\text{S}]$$

$$[\text{S}] = (\text{K}_{sp})^{1/2} = (6 \times 10^{-16})^{1/2} = 2.45 \times 10^{-8} \text{ M}$$

By definition, K<sub>sp</sub> corresponds to the product of the ionic concentration of the salt in saturated solution and it represents the maximum molarity of the salt. Therefore, maximum molarity of the salt = 2.45 × 10<sup>-8</sup> M.

Question 28.

Calculate the mass percent of aspirin (C<sub>9</sub>H<sub>8</sub>O<sub>4</sub>) in acetonitrile (CH<sub>3</sub>CN) when 6.5 g of aspirin is dissolved in 450 g of CH<sub>3</sub>CN.

Answer:

$$\text{Mass percent (Mass \%)} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$\text{Mass of aspirin} = 6.5 \text{ g}; \text{ Mass of acetonitrile} = 450 \text{ g.}$$

$$\text{Mass percent of aspirin} = \frac{(6.5 \text{ g})}{(6.5 \text{ g} + 450 \text{ g})} \times 100 = 1.424\%$$

Question 29.

Nalorphene ( $\text{C}_{19}\text{H}_{21}\text{NO}_3$ ) similar to morphine is used to combat withdrawal symptoms in narcotic users. Dose of nalorphene generally given is  $1.5 \text{ mg}$ . Calculate the mass of  $1.5 \times 10^{-3} \text{ m}$  aqueous solution required for the above doze?

Answer:

$$\text{Molality (m)} = \frac{\text{Mass of solute/molar mass}}{\text{Mass of solvent in kg.}}$$

$$m = 1.5 \times 10^{-3} \text{ m} = 1.5 \times 10^{-3} \text{ mol kg}^{-1};$$

$$\text{Mass of solute} = 1.5 \text{ mg} = 1.5 \times 10^{-3} \text{ g};$$

$$\text{Molar mass of solute} = 19 \times 12 + 21 \times 1 + 14 + 3 \times 16 = 311 \text{ g mol}^{-1}.$$

$$(1.5 \times 10^{-3} \text{ mol kg}^{-1}) = \frac{(1.5 \times 10^{-3} \text{ g}) / (311 \text{ g mol}^{-1})}{\text{Mass of solvent}}$$

$$\text{Mass of solvent} = \frac{(1.5 \times 10^{-3} \text{ g})}{(311 \text{ g mol}^{-1}) \times (1.5 \times 10^{-3} \text{ mol kg}^{-1})} = 0.0032 \text{ kg} = 3.2 \text{ g.}$$

Question 30.

Calculate the amount of benzoic acid ( $\text{C}_6\text{H}_5\text{COOH}$ ) required for preparing 250 mL of 0.15 M solution in methanol. 0.15 M solution means that 0.15 mole of benzoic acid is dissolved in 1L of solution.

Answer:

**0.15 M solution means than 0.15 mole of benzoic acid is dissolved in 1L of solution.**

**Molar mass of  $\text{C}_6\text{H}_5\text{COOH}$**

$$= 12 \times 6 + 5 + 12 + 2 \times 16 + 1 = 122 \text{ g mol}^{-1}$$

$$\therefore 0.15 \text{ mol of } \text{C}_6\text{H}_5\text{COOH} = 0.15 \times 122 = 18.3 \text{ g}$$

**Thus, 1 L or 1000 mL of solution contain**

$$= 18.3 \text{ g of } \text{C}_6\text{H}_5\text{COOH}$$

**$\therefore$  250 mL of the solution will contain**

$$= \frac{18.3}{1000} \times 250 = 4.575 \text{ g of } \text{C}_6\text{H}_5\text{COOH.}$$

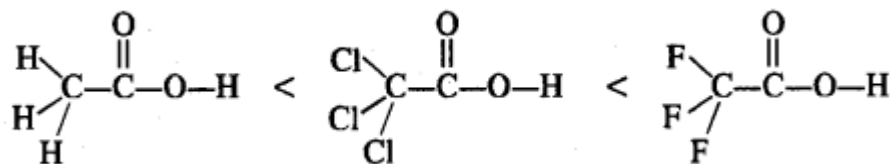
Question 31.

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. (C.B.S.E. 2008 Supp.)

Answer:

The depression in freezing point of a solute in water depends upon the number of particles or ions furnished by it in solution or upon its degree of dissociation ( $\alpha$ ). All the three organic acids ionise in aqueous solution. However, the relative order of acidic strengths is as given below.



This is linked with the electronegativity of the halogen atoms present. Fluorine (F) is more electronegative than (Cl). Under the circumstances, trifluoroacetic acid gives maximum ions in solution since it is the strongest acid. Consequently, the depression in freezing point ( $\Delta T_f$ ) is the maximum in this case and is the least for acetic acid which is the weakest acid.

Question 32.

Calculate the depression in the freezing point of water when 10 g of  $\text{CH}_3\text{CH}_2\text{CH}(\text{Cl})\text{COOH}$  is added to 250 g of water.  $K_a = 1.4 \times 10^{-3}$ ;  $K_f = 1.86 \text{ K kg mol}^{-1}$ . (C.B.S.E. 2008 Supp.)

Answer:

**Step I. Calculation of degree of dissociation of acid Mass of acid = 10 g**

$$\text{Mass of acid} = 10 \text{ g}$$

$$\text{Molar mass of acid} = 4 \times 12 + 35.5 + 2 \times 16 + 7 \times 1 = 122.5 \text{ g mol}^{-1}$$

$$\text{Molar concentration of acid} = \frac{(10 \text{ g}) / (122.5 \text{ g mol}^{-1})}{(0.25 \text{ L})} = 0.326 \text{ mol L}^{-1} = 0.326 \text{ M}$$

$$K_a = \frac{[\text{CH}_3\text{CH}_2\text{CH}(\text{Cl})\text{COO}^-(\text{aq})][\text{H}^+(\text{aq})]}{[\text{CH}_3\text{CH}_2\text{CH}(\text{Cl})\text{COOH}(\text{aq})]}$$

$$1.4 \times 10^{-3} = \frac{(0.326\alpha) \times (0.326\alpha)}{0.326(1-\alpha)} = (0.326\alpha^2).$$

$$\alpha^2 = \frac{1.4 \times 10^{-3}}{0.326} \text{ or } \alpha = \left( \frac{1.4 \times 10^{-3}}{0.326} \right)^{1/2}$$

$$= (42.9 \times 10^{-4})^{1/2} = 6.55 \times 10^{-2}.$$

**Step II. Calculation of Van't Hoff factor (i)**

Van't Hoff factor (i) and degree of dissociation ( $\alpha$ ) are related to each other as :

$$\alpha = \frac{i-1}{n-1} \text{ or } \alpha = \frac{i-1}{2-1} = i-1$$

$$i = \alpha + 1 = 0.0655 + 1 = 1.0655.$$

**Step III. Calculation of depression in freezing point ( $\Delta T_f$ )**

$$\Delta T_f = iK_f \times m = \frac{i \times K_f \times W_B}{M_B \times W_A}$$

$$= \frac{1.0655 \times (1.86 \text{ K kg mol}^{-1}) \times (10 \text{ g})}{(122.5 \text{ g mol}^{-1}) \times (0.25 \text{ kg})} = 0.65 \text{ K}$$

Question 33.

19.5 g of  $\text{CH}_3\text{FCOOH}$  is dissolved in 500 g of water. The depression in the freezing point of water observed is  $1.0^\circ\text{C}$ . Calculate Van't Hoff factor and dissociation constant of the acid:  $K_f = 1.86 \text{ K kg mol}^{-1}$ .

Answer:

**Step I. Calculation of Van't Hoff factor (i) for the acid**

$$\Delta T_f = iK_f m. \text{ or } i = \frac{\Delta T_f}{K_f m}$$

$$\Delta T_f = 1.0^\circ\text{C} = 1.0 \text{ K}; K_f = 1.86 \text{ K. kg mol}^{-1};$$

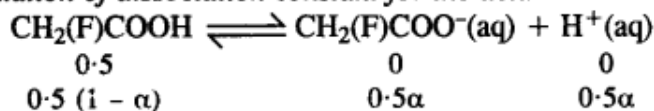
$$m = \frac{W_B}{M_B \times M_A} = \frac{(19.5\text{g})}{(78\text{g mol}^{-1}) \times (0.5\text{kg})} = 0.15 \text{ mol kg}^{-1}.$$

$$i = \frac{(1.0\text{K})}{(1.86\text{K kg mol}^{-1}) \times (0.5 \text{ mol kg}^{-1})} = 1.0753$$

**Step II. Calculation of degree of dissociation for acid**

$$\alpha = \frac{i - 1}{n - 1} = \frac{(1.0753 - 1)}{(2 - 1)} = 0.0753$$

**Step III. Calculation of dissociation constant for the acid**



$$\begin{aligned} K_a &= \frac{(0.5\alpha) \times (0.5\alpha)}{0.5(1 - \alpha)} = \frac{0.5 \times (0.0753)^2}{(1 - 0.0753)} \\ &= \frac{0.5 \times (0.0753)^2}{(0.9247)} = 3.07 \times 10^{-3}. \end{aligned}$$

Question 36.

100 g of liquid A (molar mass 140 g mol<sup>-1</sup>) was dissolved in 1000 g of liquid B (molar mass 180 g mol<sup>-1</sup>). The vapour pressure of pure liquid B was found to be 500 torrs. 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.

Answer:

**Step I. Calculation of vapour pressure of pure liquid A ( $P_A^\circ$ ).**

For an ideal solution :  $P = P_A^\circ x_A + P_B^\circ x_B$

$$\text{No. of moles of liquid A } (n_A) = \frac{W_A}{M_A} = \frac{(100\text{g})}{(140\text{g mol}^{-1})} = 0.7143 \text{ mol}$$

$$\text{No. of moles of liquid B } (n_B) = \frac{W_B}{M_B} = \frac{(1000\text{g})}{(180\text{g mol}^{-1})} = 5.5556 \text{ mol}$$

$$\begin{aligned} \text{Mole fraction of A } (x_A) &= \frac{n_A}{n_A + n_B} \\ &= \frac{(0.7143\text{mol})}{(0.7143\text{mol} + 5.5556\text{mol})} = \frac{0.7143\text{mol}}{6.2699} = 0.1139 \end{aligned}$$

$$\text{Mole fraction of B } (x_B) = 1 - 0.1139 = 0.8861$$

Vapour pressure of pure liquid B ( $P_B^\circ$ ) = 500 torr.

Total vapour pressure of solution (P) = 475 torr.

The value of  $P_A^\circ$  can be calculated as follows :

$$\begin{aligned} 475 \text{ torr} &= P_A^\circ \times 0.1139 + (500 \text{ torr}) \times (0.8861) \\ &= P_A^\circ \times 0.1139 + 443.05 \text{ torr} \\ P_A^\circ \times 0.1139 &= 475 \text{ torr} - 443.05 \text{ torr} = 31.95 \text{ torr} \\ P_A^\circ &= \frac{(31.95\text{torr})}{0.1139} = 280.5 \text{ torr} \end{aligned}$$

**Step II. Calculation of vapour pressure of A in the solution i.e.,  $P_A$**

$$\begin{aligned} \text{According to Raoult's law, } P_A &= P_A^\circ x_A \\ &= (280.5 \text{ torr}) \times 0.1139 = 32.0 \text{ torr} \end{aligned}$$

Question 37.

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

100 $x_{\text{acetone}}$	0	11.8	23.4	36.0	50.8	58.2	64.5	72.1
$p_{\text{acetone}}$ /mm Hg	0	54.9	110.1	202.4	322.7	405.9	454.1	521.1
$p_{\text{chloroform}}$ /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 the ideal solution.

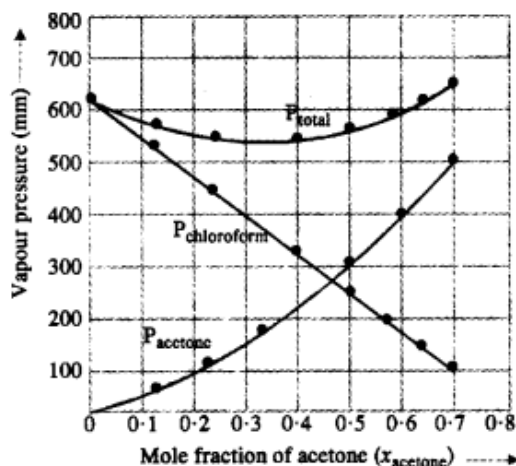
Answer:

From the available information:



$x_{\text{acetone}}$	:	0.1	0.118	0.234	0.360	0.508	0.582	0.645	0.721
$p_{\text{acetone}}/\text{mm Hg}$	:	0	54.9	110.1	202.4	322.7	405.9	454.1	521.1
$p_{\text{chloroform}}/\text{mm Hg}$	:	632.8	548.1	469.4	359.7	257.7	193.6	161.2	120.7
$p_{\text{total}} \text{ mm}$	:	632.8	603.0	579.5	562.1	580.4	599.5	615.3	641.8

The nature of the plots based upon the above data is as follows :



Since the plot or graph dips downwards, the solution shows a negative deviation from Raoult's Law.

Question 38.

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

Answer:

$$\text{Number of moles of benzene } (n_{\text{C}_6\text{H}_6}) = \frac{\text{Mass of benzene}}{\text{Molar mass}} = \frac{(80 \text{ g})}{(78 \text{ g mol}^{-1})} = 1.026 \text{ mol}$$

$$\text{Number of moles of naphthalene } (n_{\text{C}_{10}\text{H}_8}) = \frac{\text{Mass of naphthalene}}{\text{Molar mass}} = \frac{(100 \text{ g})}{(128 \text{ g mol}^{-1})} = 0.781 \text{ mol.}$$

$$\text{Mole fraction of benzene } (x_{\text{C}_6\text{H}_6}) = \frac{n_{\text{C}_6\text{H}_6}}{n_{\text{C}_6\text{H}_6} + n_{\text{C}_{10}\text{H}_8}} = \frac{1.026 \text{ mol}}{(1.026 \text{ mol} + 0.781 \text{ mol})} = 0.568$$

$$\text{Mole fraction of naphthalene } (x_{\text{C}_{10}\text{H}_8}) = 1 - 0.568 = 0.432$$

$$\begin{aligned} \text{Partial vapour pressure of benzene in solution } (p_{\text{C}_6\text{H}_6}) &= p_{\text{C}_6\text{H}_6}^{\circ} \times x_{\text{C}_6\text{H}_6} \\ &= (50.71 \text{ mm}) \times 0.568 = 28.80 \text{ mm.} \end{aligned}$$

$$\text{Partial vapour pressure of naphthalene in solution } (p_{\text{C}_{10}\text{H}_8}) = (32.06 \text{ mm} \times 0.432) = 13.85 \text{ mm.}$$

$$\text{Total vapour pressure of solution } (p) = (28.80 \text{ mm} + 13.85 \text{ mm}) = 42.65 \text{ mm}$$

$$\text{Mole fraction of benzene in vapour phase} = \frac{x_{\text{C}_6\text{H}_6} \times p_{\text{C}_6\text{H}_6}^{\circ}}{P_{\text{total}}} = \frac{0.568 \times (50.71 \text{ mm})}{(42.65 \text{ mm})} = 0.675$$

$$\begin{aligned} \text{Mole fraction of naphthalene in vapour phase} &= \frac{x_{\text{C}_{10}\text{H}_8} \times p_{\text{C}_{10}\text{H}_8}^{\circ}}{P_{\text{total}}} \\ &= \frac{0.432 \times (32.06 \text{ mm})}{(42.65 \text{ mm})} = 0.325 \end{aligned}$$

Question 39.

Air is a mixture of a number of gases. The major components are oxygen and nitrogen with the approximate proportion of 20% is to 79% by volume at 298 K. The water is in equilibrium with air at a pressure of 10 atm. At 298 K if Henry's law constants for oxygen and nitrogen at 298 K are  $3.30 \times 10^7$  mm and  $6.51 \times 10^7$  mm respectively, calculate the composition of these gases in water.

Answer:

**Step I. Calculation of partial pressure of oxygen and nitrogen.**

$$\text{Partial pressure of O}_2 (p_{\text{O}_2}) = (10\text{atm}) \times \frac{20}{100} = 2 \text{ atm}$$

$$\text{Partial pressure of N}_2 (p_{\text{N}_2}) = (10\text{atm}) \times \frac{79}{100} = 7.9 \text{ atm.}$$

**Step II. Composition of O<sub>2</sub> and N<sub>2</sub> dissolved in water**

The amount of gases dissolved in water is calculated in terms of their mole fractions.

$$x_{\text{O}_2} = \frac{p_{\text{O}_2}}{K_H} = \frac{(2 \times 760 \text{ mm})}{(3.30 \times 10^7 \text{ mm})} = 4.6 \times 10^{-5}$$

$$x_{\text{N}_2} = \frac{p_{\text{N}_2}}{K_H} = \frac{(7.9 \times 760 \text{ mm})}{(6.51 \times 10^7 \text{ mm})} = 9.22 \times 10^{-5}$$

Question 40.

Determine the amount of CaCl<sub>2</sub> ( $i = 2.47$ ) dissolved in 2.5 litre of water so that its osmotic pressure is 0.75 atm at 27°C.

Answer:

According to Van't Hoff equation :

$$\text{Osmotic pressure } (\pi) = i c R T = \frac{i n_B R T}{V}$$

$$i = 2.47 ; V = 2.5 \text{ L} ; R = 0.0821 \text{ L-atm K}^{-1} \text{ mol}^{-1}, T = 27 + 273 = 300 \text{ K}, \pi = 0.75 \text{ atm.}$$

$$n_B = \frac{\pi V}{i R T} = \frac{(0.75\text{atm}) \times (2.5\text{L})}{(2.47) \times (0.0821\text{L atm K}^{-1} \text{ mol}^{-1}) \times 300\text{K}} = 0.0308 \text{ mol}$$

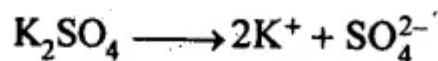
$$\begin{aligned} \text{Amount of CaCl}_2 \text{ dissolved} &= \text{No. of moles} \times \text{Gram molecular mass of CaCl}_2 \\ &= (0.0308 \text{ mol}) \times (111.0 \text{ g mol}^{-1}) = 3.42 \text{ g} \end{aligned}$$

Question 41.

Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K<sub>2</sub>SO<sub>4</sub> in 2 litre of water at 25°C, assuming that it is completely dissociated.

Answer:

Molar mass of  $K_2SO_4 = 174 \text{ g mol}^{-1}$



No. of ions produced = 3 i.e.,  $i = 3$

Using relation,  $\pi = iCRT$

$$= i \frac{n}{V} RT = i \times \frac{W}{M} \frac{RT}{V}$$

$$= \frac{3 \times 0.025 \times 0.0821 \times 298}{174 \times 2} = 5.27 \times 10^{-3} \text{ atm.}$$