

Solutions

A solution is a homogenous mixture of two or more substances. In such a mixture, a **solute** is a substance dissolved in another substance, known as a **solvent**.

Solute + Solvent → Solution

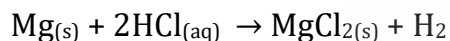
The most common solvent in nature is water, it is referred to as universal solvent because it can dissolve more substances than any other liquid.

Types of solution:

There are two types of solution: Aqueous solution and Chemical solution.

Aqueous Solution is a solution with water as solvent.

Chemical Solution is a solution of a solute in a solvent accompanied by a chemical reaction. e.g dissolution of magnesium in dilute hydrochloric acid.



Neither the magnesium nor the hydrochloric acid can be recovered by evaporation or distillation. In the chemical change, new molecules of MgCl_2 and H_2 are formed.

Suspensions:

Suspensions are heterogeneous mixtures of undissolved particles in a given medium. The particles in a suspension are usually large enough to be seen without the aid of an instrument and they settle at the bottom of the containing vessel. Example: muddy water, chalk, and water mixture of dust particles, air, fog, and milk of magnesia.

Colloidal Solution

What is a Colloidal Solution?

A colloidal solution or false solution is a mixture in which the substances are regularly suspended in a fluid. A colloid is a very tiny and small material that is spread out uniformly all through another substance.

In colloidal solutions, the individual solute particles are larger than the particles of the true solution but not large enough to be seen by the naked eye. Some examples of colloids are starch and albumen.

In colloidal or false solution, the liquid solvent is known as dispersion medium while the solid solute particle is known as dispersed substance. The dispersion and dispersed substance may be solid, liquid or gas.

Examples of Colloids:

1. Sols and Gels:

Sol is the dispersion of solid particles in a liquid medium, e.g. starch solution consists of a starch powder dispersed in water. Most sols can solidify under certain conditions to form gels e.g natural honey. Other examples of sols are glue, gelatin and clay.

2. Emulsion:

This is the dispersion of a liquid in another liquid. e.g milk, hair cream, cod liver oil. Paints are liquid solutions dispersed in water or alcohol. The process of mixing liquids to form an emulsion is called emulsification.

3. Aerosol:

This is the dispersion of a liquid or solid in a gas

1. Smoke and harmattan dust are examples of colloidal states of solid (state) in gas.
2. Fog, insecticide, and perfumes are examples of colloidal states of liquid in gas.

Difference between True & False solution

True solution:

A true solution is a homogenous mixture of two or more substances in which the substances are dissolved (solute) in solvent. The solute particles which are simple molecules or ions are too small to be seen by the naked eye. They are also called crystalloid solutions.

Example: aqueous solutions of sodium chloride.

Difference between True and False solution:

S/N	True Solution	False Solution
1	The solutes can pass through a filter paper	The solutes cannot pass through a filter paper
2	The solution can be dialyzed i.e the solute can diffuse through a semi-permeable membrane	The solution cannot be dialyzed
3	The solution does not scatter light rays i.e solution does not undergo the Tyndall effect.	The solution can scatter light rays i.e the solution exhibits the Tyndall effect

Solubility

The solubility of a solute in a solvent at a particular temperature is the maximum amount of the solute in moles or grams that will saturate 1dm³ of the solvent at that temperature.

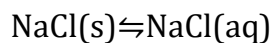
Although some substances are soluble in water, some are more soluble than others. Solubility is a means of comparing the extent to which different solutes can dissolve in a particular solvent at a given temperature.

Saturated and Unsaturated Solution:

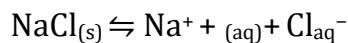
Table salt (NaCl) readily dissolves in water. For example, if you have a beaker of water and you add salt and stir until it dissolves. You keep adding salt till you get to a point that no more salt will dissolve, irrespective of how vigorously you stir it.

It is known that the action of water results in the individual ions breaking apart from the salt crystals and entering the solution, where they remain hydrated by water molecules. What also happens is that some of the dissolved ions collide back again with the crystal and remain there. **Recrystallization** is the process of dissolved solute returning to the solid-state.

At some point, the rate at which the solid salt is dissolving becomes equal to the rate at which the dissolved solute is recrystallizing. This point is known as the solution equilibrium, where the total amount of dissolved salt remains unchanged. Solution equilibrium can be represented by two equations.



While this shows the change of state back and forth between solid and aqueous solutions, the preferred equation also shows the dissociation that occurs as ionic solid dissolves.



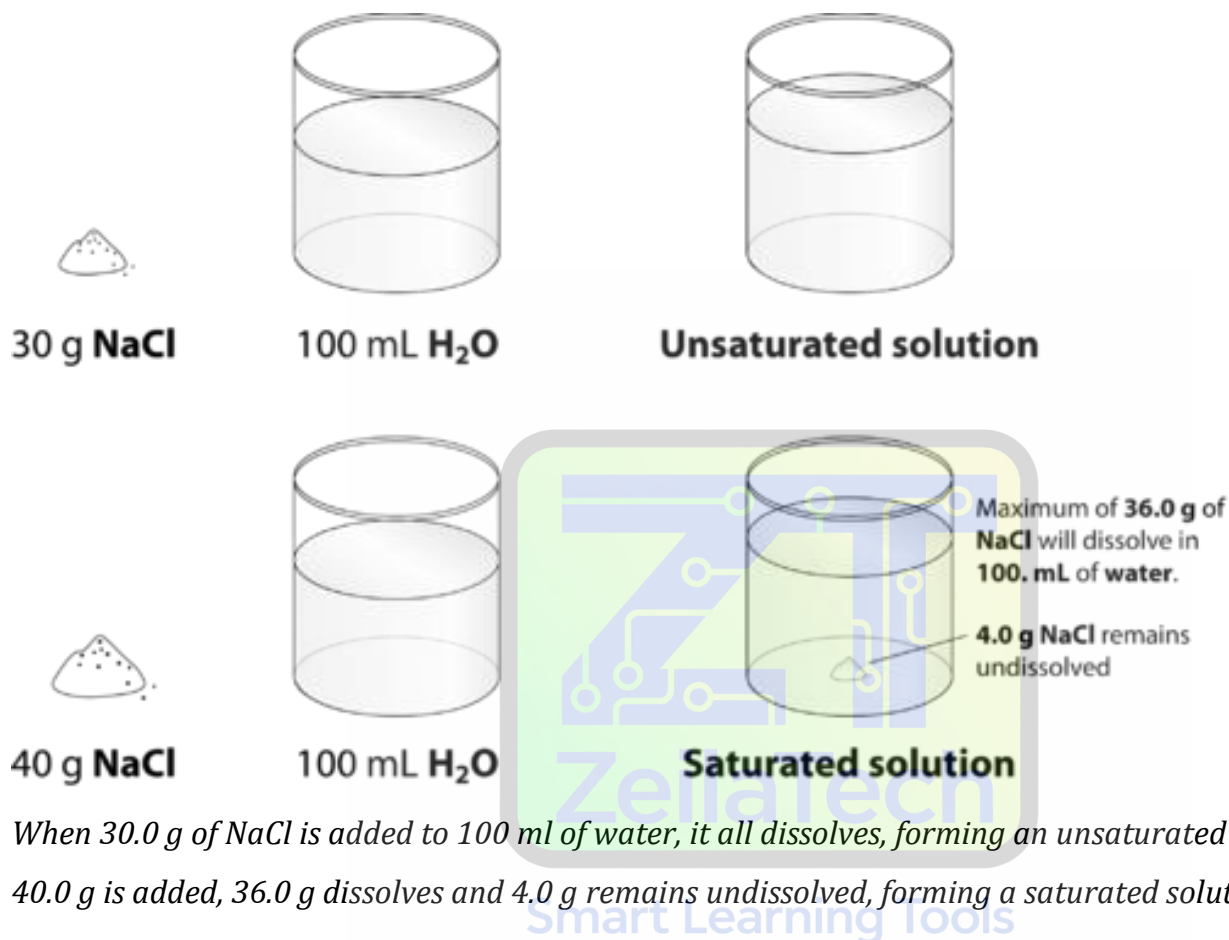
When no more solute will dissolve and the solution equilibrium point is reached, the solution is said to be saturated.

Saturated solution of a solute at a particular temperature is one which contains as much solute as it can dissolve at that temperature in the presence of undissolved solute particles.

In a saturated solution, the dissolved solutes and the undissolved solutes are in equilibrium at a particular temperature. Any change in temperature will disturb the equilibrium and the system must alter to counter the change.

The maximum amount of NaCl that will dissolve in 100g of water, at 20°C is 36.0g. Past this point, if any more NaCl is added, it will not dissolve because the solution is saturated.

What if more water is added to the solution instead? Now more NaCl would be capable of dissolving in the additional solvent. An unsaturated solution of a solute at a particular temperature is one that will dissolve more solute at that temperature if added until the solution becomes saturated.



When 30.0 g of NaCl is added to 100 ml of water, it all dissolves, forming an unsaturated solution. When 40.0 g is added, 36.0 g dissolves and 4.0 g remains undissolved, forming a saturated solution.

The figure above illustrates the above process and shows the distinction between unsaturated and saturated.

How can you tell if a solution is saturated or unsaturated? If more solute is added and it does not dissolve, then the original solution was saturated. If the added solute dissolves, then the original solution was unsaturated. A solution that has been allowed to reach equilibrium but which has extra undissolved solute at the bottom of the container must be saturated.

Supersaturated Solution:

This is a solution which contains more solute than it can normally dissolve at a given temperature. A supersaturated solution is very unstable and is capable of releasing excess solute if disturbed.

Determination of Solubility:

A saturated solution is prepared at a specified temperature. The mass or volume of the saturated solution is taken in a weighed container. The weight of the solution is noted before the solution is heated to dryness. From the calculation, the mass of solvent and solute in the sample can be determined.

The solubility in moles per dm^3 can be found by using this formula

$$\text{No. of Moles} = \frac{\text{mass of substance}}{\text{molar mass}}$$

Calculations on Solubility

Example 1

30cm^3 of a saturated solution of a salt NaX was dissolved in water at 25°C , was evaporated to dryness and only 2.5g of solid was left. Calculate the solubility of the salt in water at 25°C in moles/ dm^3 (Na = 23, X = 19)

Solution

30cm^3 of saturated solution contains 2.5g

1000cm^3 of the solution will contain

$$\frac{1000\text{cm}^3}{30\text{cm}^3} \times \frac{2.5\text{g}}{1} \\ = 83.3\text{g}/\text{dm}^3$$

$$\text{Solubility in mols}/\text{dm}^3 = \frac{\text{Solubility in g}/\text{dm}^3}{\text{Molar Mass}}$$

$$\text{Molar mass of NaX} = 23 + 19 = 42$$

$$= \frac{83.3}{42} = 1.98\text{mol}/\text{dm}^3$$

Or

$$\text{Solubility} = \frac{\text{Mass of solute}}{\text{Volume of solvent}} \times \frac{1000}{\text{Molar Mass}}$$

$$= \frac{2.5}{30} \times \frac{1000}{42}$$

$$= 1.98\text{mol}/\text{dm}^3$$

Example 2

At 25°C 23g of KCl dissolved in 100cm³ of water to give a saturated solution. What is the solubility of the salt in

1. Grammes per dm³ of the solvent at this temperature
2. Moles per dm³ [K=39, Cl=35.5]

Solution

$$\begin{aligned} \text{(1) Solubility in g/dm}^3 &= \frac{\text{Mass of solute}}{\text{Volume of solvent}} \times \frac{1000}{1} \\ &= \frac{23\text{g}}{100\text{cm}^3} \times \frac{1000\text{cm}^3}{1} \\ &= 230\text{g/dm}^3 \end{aligned}$$

$$\text{(2) RMM of KCl} = 39 + 35.5 = 74.5$$

$$\begin{aligned} \text{Solubility in mol/dm}^3 &= \frac{\text{Solubility in gdm}^{-3}}{\text{Molar mass}} \\ &= \frac{230}{74.5} \\ &= 3.09\text{mol/dm}^3 \end{aligned}$$

Example 3

An evaporating dish weighed 31.18g, when filled with saturated solution of copper tetraoxosulphate(vi) solution at 32°C it weighed 48.39g, after evaporation to dryness the evaporating dish and residue weighed 33.98g.

Calculate the solubility of copper (II) tetraoxosulphate (IV) crystal at 32°C in grammes per 100g of solvent.

Solution

At 32°C

Mass of evaporating dish + CuSO ₄ solid		33.98g
Mass of evaporating dish	-	31.18g
Mass of CuSO _{4(s)} solid	=	<u>2.80g</u>
Mass of evaporating dish + CuSO _{4(aq)} solution		48.39g
Mass of evaporating dish + CuSO _{4(s)} solid	-	33.98g
Mass of solvent	=	<u>14.41g</u>

14.41g of solvent was saturated by 2.80g of $\text{CuSO}_{4(s)}$ solid

1g of solvent was saturated by $\frac{2.80}{14.41}$ of $\text{CuSO}_{4(s)}$ solid

100g of solvent was saturated by

$$\frac{2.80}{14.41} \times \frac{100}{1} \text{ of } \text{CuSO}_{4(s)}$$

$$= 19.43\text{g}/100\text{g of solvent}$$

Example 4

250cm³ of saturated solution of Sodium Chloride contains 5.85g of the salt dissolved in it at room temperature. What is the solubility of the salt in (i) g/dm³ (ii) mole/dm³ [Na =23, Cl =35.5]

Solubility in g/dm³ =

$$\frac{\text{Mass of solute}}{\text{vol/mass of solvent}} \times \frac{1000}{1}$$

$$= \frac{5.85\text{g}}{250\text{cm}^3} \times \frac{1000}{1}$$

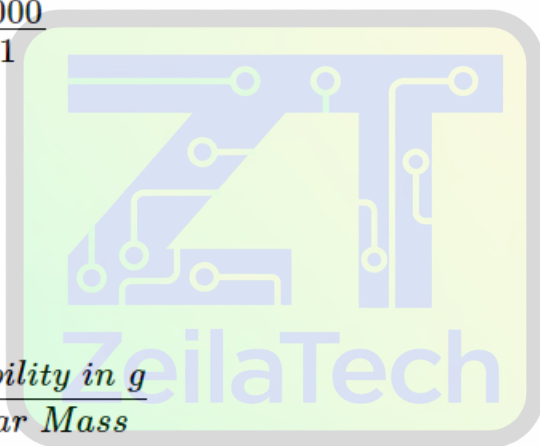
$$= 23.4\text{g}/\text{dm}^3$$

$$\text{Solubility in mol}/\text{dm}^3 = \frac{\text{Solubility in g}}{\text{Molar Mass}}$$

$$\text{Molar mass of NaCl} = 23 + 35.5 = 58.5$$

$$= \frac{23.4}{58.5}$$

$$= 0.4\text{mol}/\text{dm}^3$$



Smart Learning Tools

Solubility Curves or Graph

Solubility curves are the graphical representations of the solubility of different solutes in a particular solvent at different temperatures.

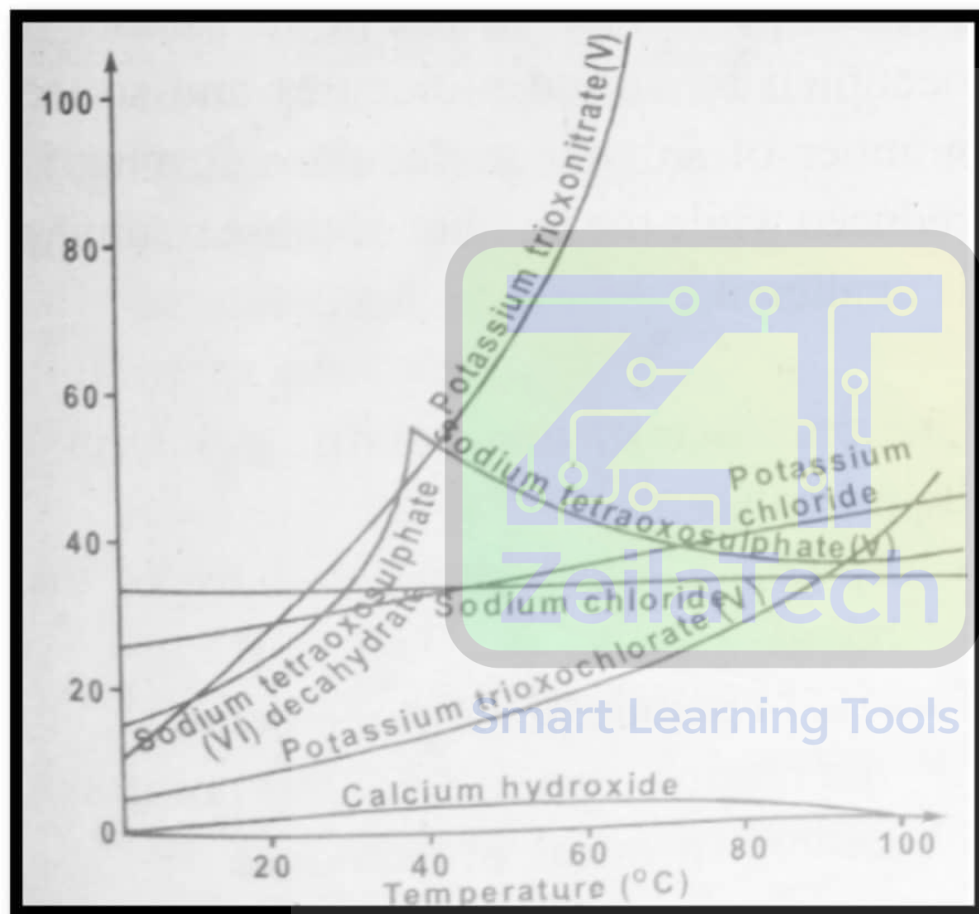
The curves are obtained by plotting the solubility of solutes against the temperature.

In ionic solids e.g KClO_3 and KNO_3 ; the solubility increases with an increase in temperature.

Gases e.g CO_2 , CH_4 the solubility decreases with an increase in temperature.

In salts like NaCl , solubility does not change with temperature.

For hydrated salts, the solubility increases to a point known as transition point and drops when it loses its water of crystallization e.g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$



Solubility Curve

Deduction from the Solubility Curve:

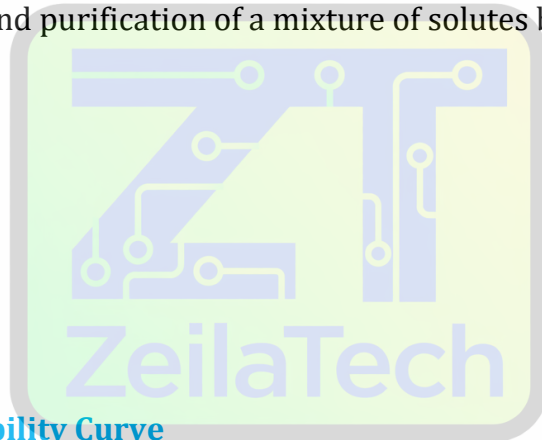
1. $\text{Ca}(\text{OH})_2$ has the lowest solubility of the six compounds.
2. The solubility of $\text{Ca}(\text{OH})_2$ and NaCl are independent of temperature .
3. The solubility of KClO_3 and KNO_3 increases with an increase in temperature.
4. The solubility of potassium chloride increases at a constant rate with rising in temperature
5. Na_2SO_4 shows a solubility curve with a sharp break at 36°C . This is because the salt exists in solution as $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ at a temperature below 36°C but gives up water of crystallization to become Na_2SO_4 at a temperature above 36°C

Significance of Solubility Curve:

1. It enables us to read off solubilities at any required temperature covered by the graph
2. It enables us to determine the mass of solute that will crystallize or precipitate out when a saturated solution is cooled.
3. It enables us to know the order in which solutes will separate during fractional crystallization.
4. It enables us to predict the temperature at which a hot solution of known concentration will begin to crystallize.

Uses or Application of Solubility Curve:

1. Pharmacists use it to determine the amount of solid drug that must be dissolved in a prescribed drug mixture.
2. Chemists and researchers use it to determine the most suitable solvent and various temperatures to be used for the extraction of chemicals from natural sources.
3. It helps in the separation and purification of a mixture of solutes by fractional crystallization.



Examples of Questions on Solubility Curve

Example 1

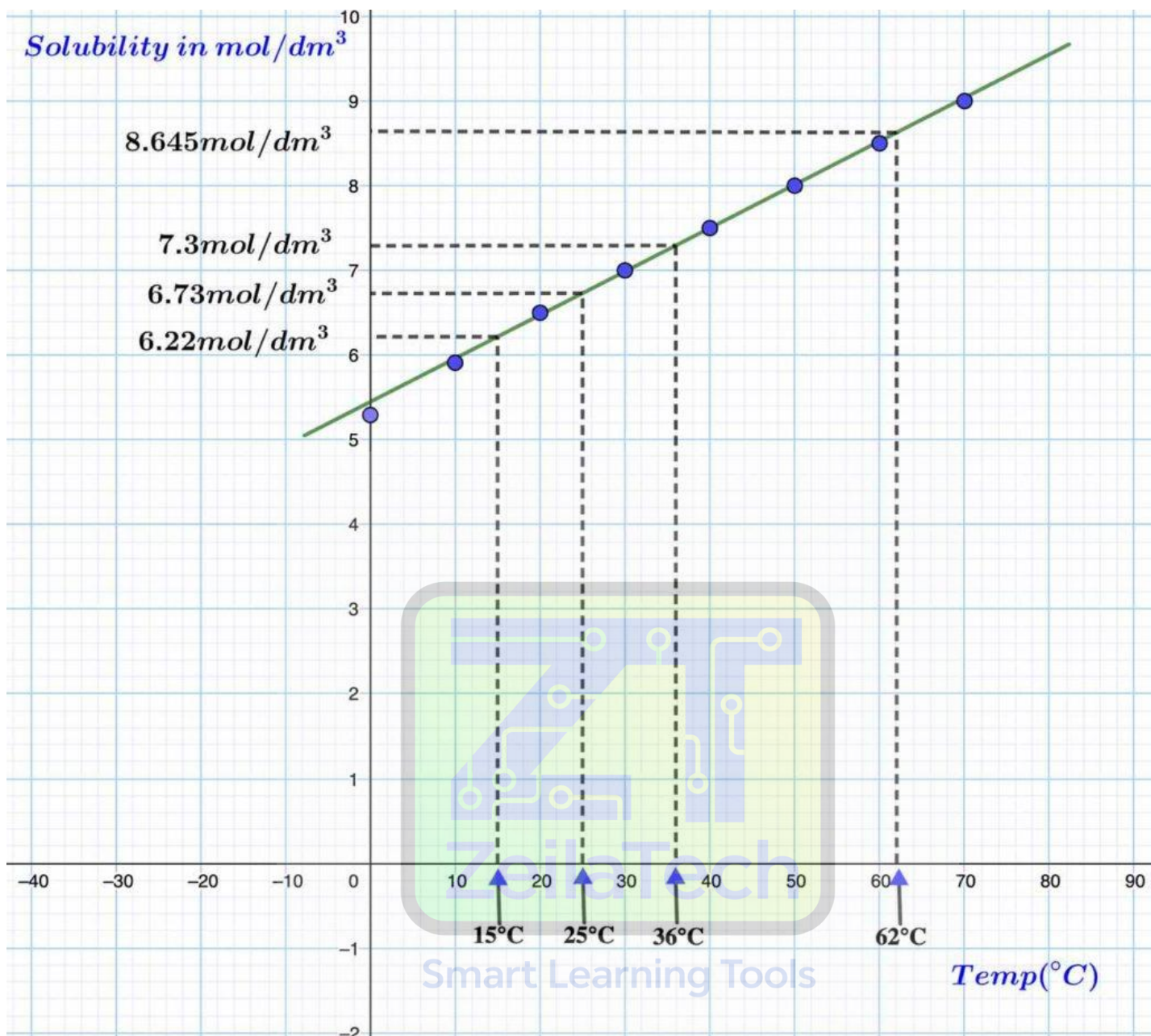
1. The solubility values of potassium trioxochlorate(V) at different temperatures are given thus

Temperature	0	10	20	30	40	50	60	70
Solubility (mol/dm ³)	5.3	5.90	6.5	7.00	7.5	8.00	8.5	9.00

Plot the solubility curve for KClO_3 from the result above. From your graph answer the question below

- (i) What is the solubility of KClO_3 at 25°C ?
- (ii) At what temperature will 1000cm^3 of water dissolve 7.3 moles of KClO_3 to form a saturated solution?
- (iii) What will be the mass of KClO_3 that crystallizes out of the solution when a saturated solution made in 1000g of water is cooled from 62°C to 15°C

Solution



(i) 6.75 mol/dm^3

(ii) 36°C

(iii) Trace the solubility of KClO_3 at both 62° and 15°C , then find the difference.

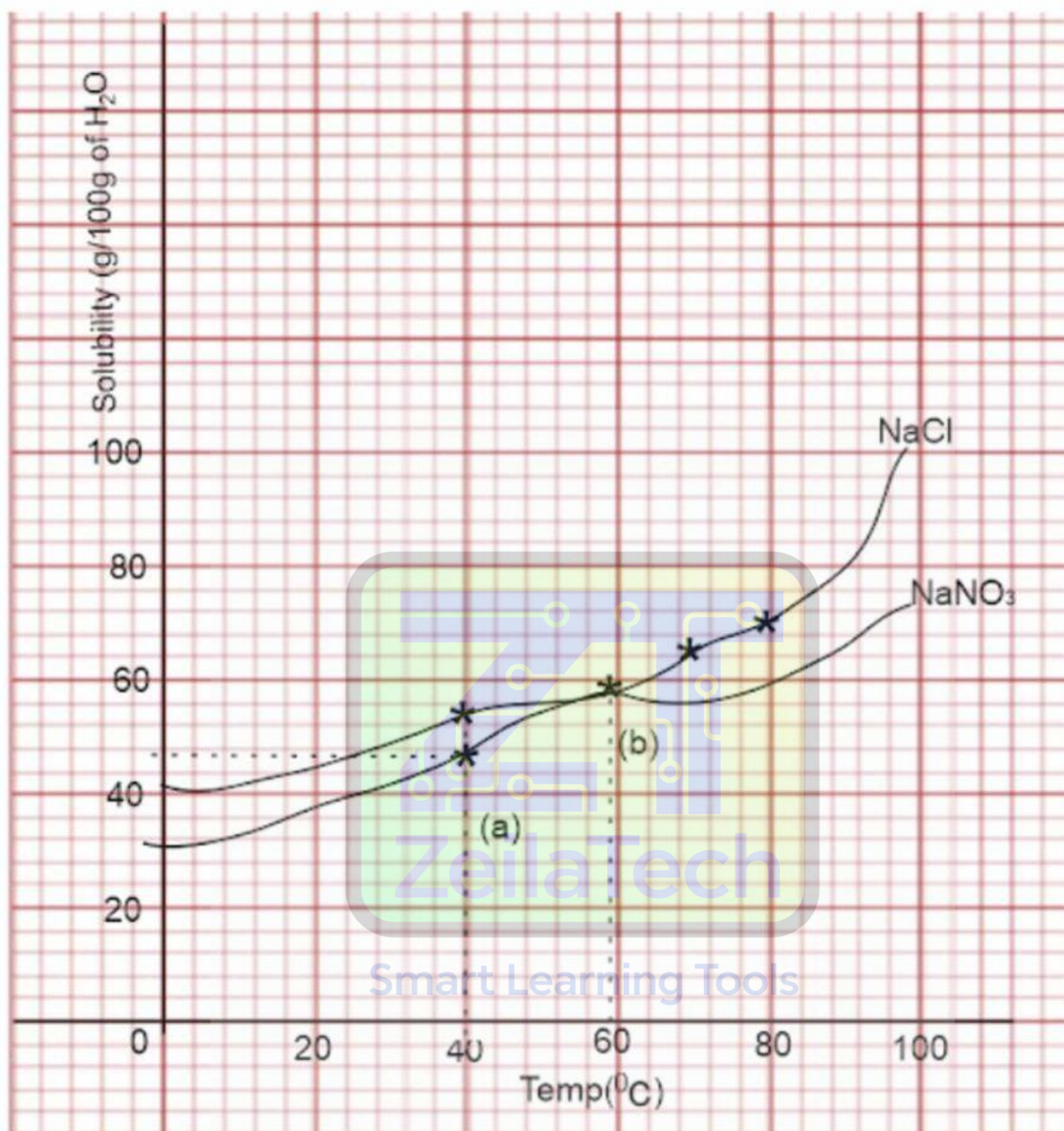
At 62°C (from the graph) = 8.645 mol/dm^3

At 15°C (from the graph) = 6.22 mol/dm^3

The mass that crystallizes out of the solution is $8.645 - 6.22 = 2.4 \text{ mol/dm}^3$

Example 2

The graph below, shows the Solubility curves of two salts, NaCl and NaNO₃



From figure———, answer the following questions:

1. What is the solubility of NaCl at 40°C?
2. At what temperature do the solubilities of NaCl and NaNO₃ equal?
3. 100g of water saturated with NaCl at 80°C is cooled to 65°C. What mass of NaCl will separate as crystals?
4. If 50g of water saturated with NaNO₃ at 40°C is heated to 70°C, how much more NaNO₃ will dissolve?
5. When 100g of water containing 88g of NaCl and 52g of NaNO₃ at 100°C is cooled to 55°C
 - (a) determine which of the two salts is saturated
 - (b) find the mass of the salt in (a) above that will precipitate(saturated).

Solution

1. (Trace the graph from 40°C until you intercept NaCl). The solubility of NaCl at 40°C = 44g/100g of water
2. Locate the point of interception of the two graphs and trace towards the temperature (58°C)
3. Trace the graph of NaCl from 80°C

Trace the graph of NaCl from 68°C

The solubility of NaCl at 68°C = 68mol/dm³

On cooling from 80°C to 60°C = 76 – 68 = 8g/100g

4. At 40°C 100g of water will dissolve 52g of NaNO₃

At 70°C 100g of water will dissolve 62g of NaNO₃

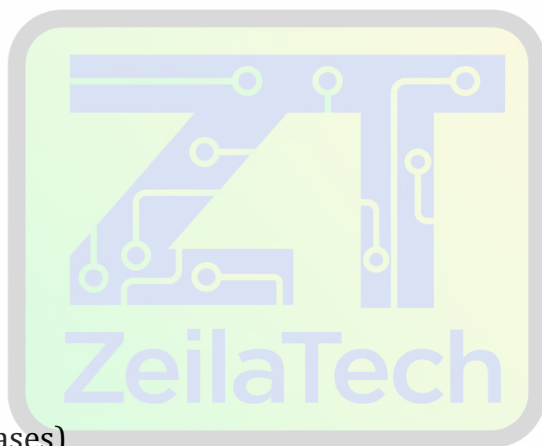
On heating from 40°C – 70°C = 62 – 52 = 10g

If 100g of water will dissolve 10g,

$$\frac{10 \times 50}{100} = 5g/100g \text{ of water}$$

Factors Affecting Solubility

1. Nature of the solute.
2. Nature of the solvent.
3. Temperature.
4. Pressure (applies only to gases)



Smart Learning Tools

Evaluation Questions

Question 1:

(a) Give two differences between true and false solution

(b) Write short notes on the following;

(i) sols

(ii) emulsion

(iii) aerosol

(iv) fog

Question 2:

(a) Define the following (i) saturated solution (ii) unsaturated solution (iii) supersaturated solution

(b) 13.5g of KNO_3 was completely dissolved in 50cm^3 of water. Calculate the solubility of KNO_3 in moles/ dm^3 [N = 14, O = 16, K = 39]

Question 3:

The table below was recorded by a group of students during an experimental investigation of solubility of KCl in water

Temp($^{\circ}\text{C}$)	0	10	20	30	40	50	60	70
Solubility (in mol/ dm^3)	3.9	4.4	5.0	5.5	6.2	6.7	7.4	8.0

(a) Plot the solubility curve for KCl from the result calculate

(b) The solubility of NaCl at 54°C

(c) The temperature at which 100cm^3 of water will dissolve 5.9 moles of KCl to form a saturated solution

(d) The least amount of water which will dissolve 0.5 mole of KCl at 46°C

(e) The mass of KCl precipitate when a saturated solution in 1000cm^3 of water is cooled from 66°C to 25°C

Question 4:

(a) What are solubility curves

(i) Give three uses of solubility curves

(b) 10.50g of potassium trioxonitrate (V) salt saturated 5g of solvent at 15°C calculate the solubility of potassium trioxonitrate(V) salt at that same temperature in

(i) grammes per dm^3

(ii) moles per dm^3

Question 5:

In an experiment to determine the solubility of a given salt Y, the following data were provided

Mass of dry empty dish = 7.16g

Mass of dish + saturated solution of salt Y = 17.85g

Mass of dish + salt Y = 9.30g

Temperature of solution = 20°C

Molar mass of salt Y = 100

Density of solution Y = 100gcm⁻³

Calculate the solubility of salt Y in

(i) g/dm³ of solution

(ii) Mol/dm³ of solution

SOLUTION**Question 1**

(a) Give two differences between true and false solution

Answer:

True Solution	False Solution
The solution can pass through a filter paper	The solution cannot pass through filter paper
The solution does not scatter light rays (doesn't undergo tyndall effect)	The solution can scatter light rays (undergoes tyndall effect)

(b) Write short notes on the following;

(i) Sols

Answer: This is the dispersion of solid particles in a liquid medium e.g. glue, gelatin and clay

(ii) Emulsion:

Answer: This is the dispersion of a liquid in another liquid e.g. Milk, hair cream, cod liver oil.

(iii) Aerosol

Answer: An aerosol is the dispersion of fine solid particles or liquid droplets in air or another gas.

(iv) Fog

Answer: Colloidal state of liquid in gas

Question 2

(a) Define the following (i) saturated solution (ii) unsaturated solution (iii) supersaturated solution

Answer:

(i) Saturated solution of a solute at a particular temperature is one which contains as much as it can dissolve at that temperature in the presence of undissolved solute particles

(ii) Unsaturated solution of a solute at a particular temperature is one which will dissolve more solute at that temperature

(iii) Supersaturated solution is one that contains more solute than it can normally dissolve at a given temperature.

(b) 13.5g of KNO_3 was completely dissolved in 50cm^3 of water. Calculate the solubility of KNO_3 in moles/dm^3 [N = 14, O = 16, K = 39]

Solution

50cm^3 of water contains 13.5g

1000cm^3 of the solution will contain

$$\Rightarrow \frac{100\text{cm}^3}{50\text{cm}^3} \times \frac{13.5\text{g}}{1}$$

$$= 270\text{g/dm}^3$$

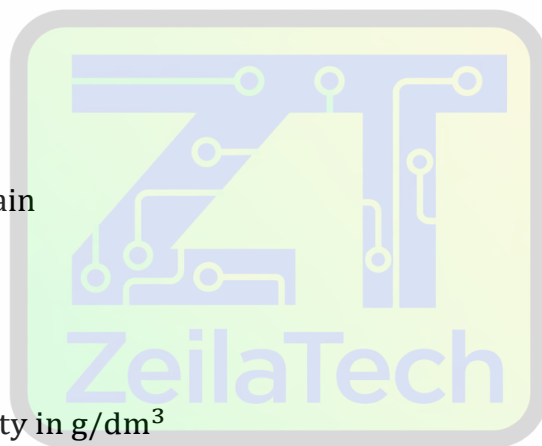
$$\text{Solubility in mols/dm}^3 = \frac{\text{Solubility in g/dm}^3}{\text{Molar Mass}}$$

$$\text{Molar mass of } \text{KNO}_3 = 39 + 14 + (16 \times 3)$$

$$\text{Molar mass of } \text{KNO}_3 = 101\text{g}$$

$$= 270 / 101$$

$$= 2.67 \text{ mol/dm}^3$$



Question 4

(a) What are solubility curves

Answer:

Solubility curves are graphical representations of the solubility of different solutes in a particular solvent at different temperatures.

(i) Give three uses of solubility curves

Uses of Solubility Curve

Answer:

- To determine the amount of solid drug that must be dissolved in a prescribed drug mixture.
- To determine the most suitable solvent and various temperatures to be used for the extraction of chemicals from natural sources
- In the separation and purification of a mixture of solute by fractional crystallization

(b) 10.50g of potassium trioxonitrate (V) salt saturated 5g of solvent at 15°C calculate the solubility of potassium trioxonitrate(V) salt at that same temperature in

(i) grammes per dm³

Solution:

5g of KNO₃ was saturated by 10.5g

1g of KNO₃ was saturated by $\frac{10.5}{5}$

$$1000 \text{ cm}^3 \text{ was saturated by } \frac{10.5}{5} \times \frac{1000}{1} \\ = 2100 \text{ gdm}^{-3}$$

or

$$\text{Solubility in g/dm}^3 = \frac{\text{mass of solute}}{\text{vol/mass of solvent}} \times \frac{1000}{1} \\ = \frac{10.5}{5} \times \frac{1000}{1} \\ = 2100 \text{ g/dm}^3$$

(ii) moles per dm³

Solution:

$$\text{Solubility in mol/dm}^3 = \frac{\text{Solubility in gdm}^{-3}}{\text{molar mass}}$$

$$\text{Molar mass} = \text{KNO}_3 = 39 + 14 + (16 \times 3) = 101$$

$$\text{Solubility in mol/dm}^3 = \frac{2100}{101} \\ = 20.79 \text{ mol/dm}^3$$

Question 5

In an experiment to determine the solubility of a given salt Y, the following data were provided

Mass of dry empty dish = 7.16g

Mass of dish + saturated solution of salt Y = 17.85g

Mass of dish + salt Y = 9.30g

Temperature of solution = 20°C

Molar mass of salt Y = 100

Density of solution Y = 1.00gcm⁻³

Calculate the solubility of salt Y in

(i) g/dm³ of the solution

Solution:

Mass of dish + saturated solution of salt Y		17.85g
Mass of empty dish	–	7.16g
Mass of saturated solution	=	10.69g
Mass of dish + salt Y		48.39g
Mass of empty dish	–	7.16g
Mass of solvent	=	2.14g

Volume of solution = 10.69cm³

Since volume of solution = mass / density

and density = 1.0g/dm³

10.69cm³ of solution Y contains 2.14g of salt Y

1cm³ of solution Y contains $\frac{2.14}{10.69}$

$$1000\text{cm}^3 = \frac{2.14 \times 1000}{10.69}$$

200.19g/dm³

(ii) Mol/dm³ of solution

Solution:

$$\text{Solubility in mol/dm}^3 = \frac{\text{solubility in g/dm}^3}{\text{Molar Mass Of Salt Y}}$$

$$= \frac{200.19}{100}$$

$$= 2.00\text{mol/dm}^3$$