sns academy

an International CBSE Finger Print School

Coimbatore

SUBJECT – CHEMISTRY

GRADE-XII

SOLUTIONS

TOPIC – SOLUBILITY & HENRY'S LAW

SOLUTIONS

SOLUBILITY

SOLUBILITY

- **Solubility of a substance is its required amount of solute that can be dissolved in a specified amount of solvent to make a saturated solution at a specified temperature and pressure.**

SOLUBILITY

Factors influencing Solubility:

- Nature of solute
- Nature of solvent
- Temperature
- Pressure

Let us discuss the effect of these factors on solutions of a solid in a liquid.

SOLUBILITY

A) Solubility of solid in a liquid:-

Nature of solute and solvent

- Polar solute dissolves in polar solvent
- Non - polar solute dissolves in non-polar solvent

SOLUBILITY

A) Solubility of solid in a liquid:-

Effect of temperature:

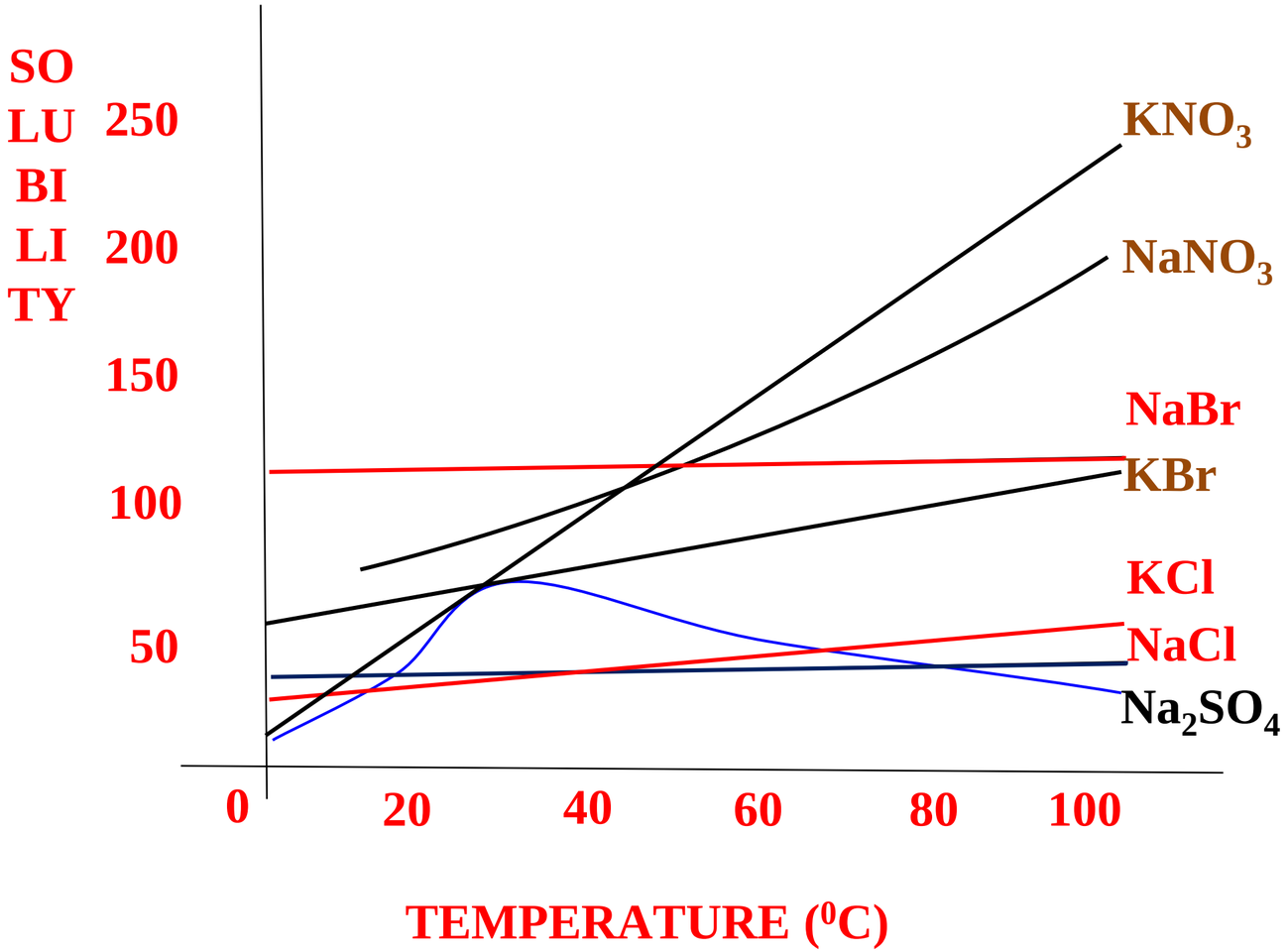
- The solubility of a solid in a liquid affected by temperature.
- Enthalpy change in solution is denoted as ΔH_{sol}
- If the dissolution process is endothermic ($\Delta H_{sol} > 0$), the solubility should increase with rise in temperature.

SOLUBILITY

A) Solubility of solid in a liquid:-

Effect of temperature:

- If the dissolution process is exothermic ($\Delta H_{sol} < 0$), the solubility should decrease with rise in temperature.
- Generally, the solubility of solid solutes in liquid solvents increases with increasing temperature
- NaCl solubility is not much affected by increase of temperature


SO
LU
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20
40
60
80
100
KNO3
NaNO3
NaBr
KBr
KCl
NaCl
Na2SO4
TEMPERATURE (0C)

SOLUBILITY

A) Solubility of solid in a liquid:-

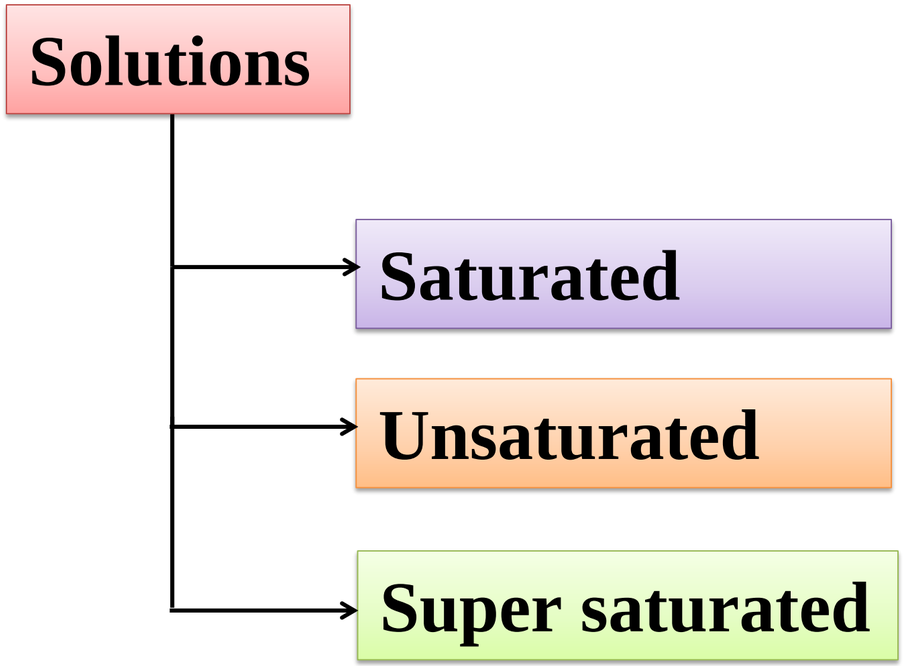
Effect of pressure:

- **Pressure does not have any significant effect on solubility of solids in liquids.**
- **This is because solid and liquid are less compressible compared to gases.**

TYPES OF SOLUTIONS BASED ON SOLUBILITY

SOLUBILITY

Types of solutions based on solubility



Saturated solution:

- A solution in which no more amount of solute can be dissolved at the same temperature and pressure

- There exists an equilibrium between dissolved solute molecules and undissolved solute molecules in the solution is called a ***saturated solution***.

Saturated solution:

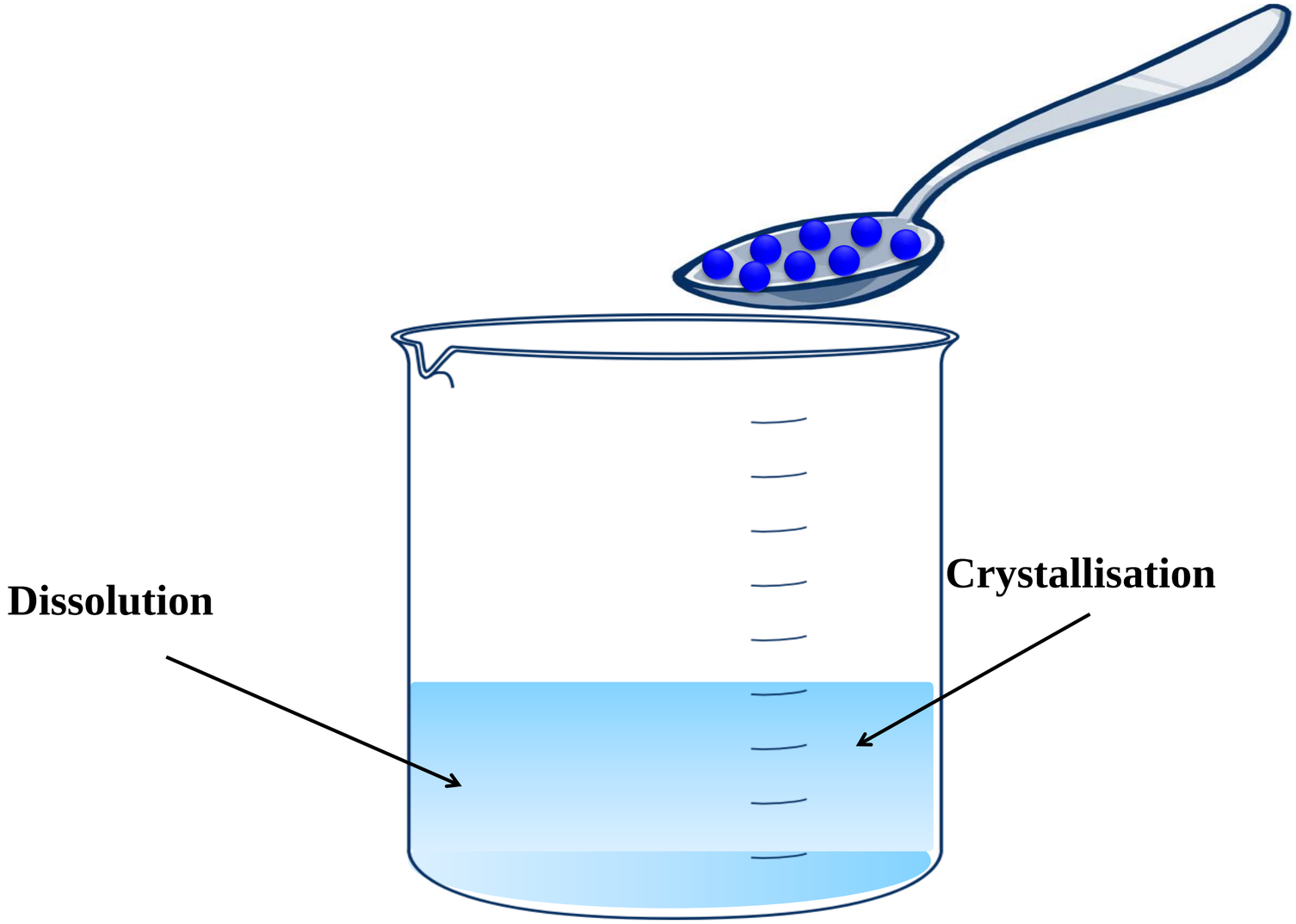
- Solvent holds as much solute as is possible at that temperature.
- Undissolved solid remains in flask.
- Dissolved solute is in dynamic equilibrium with solid solute particles.

What is dynamic equilibrium?

Dynamic equilibrium:

- When a solid solute is added to the solvent, some solute dissolves which is called ***dissolution***.

- Some solute particles colloid with other solute particles and get separated out of the solution which is called ***crystallisation***.


Dissolution
Crystallisation

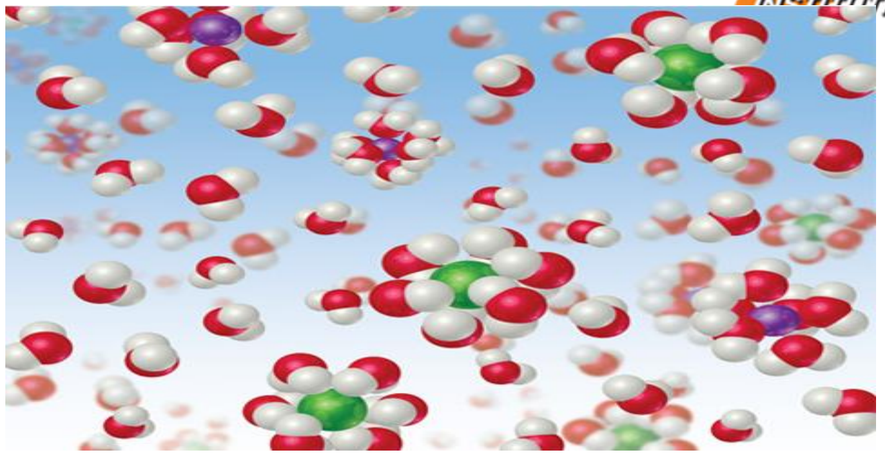
Dynamic equilibrium:

- **When the process of dissolution and crystallisation started to occur at the same rate under such conditions...**

The number of solute particles going into the solution	=	**The number of solute particles separating out of the solution**

This stage is known as Dynamic Equilibrium

Unsaturated solution:

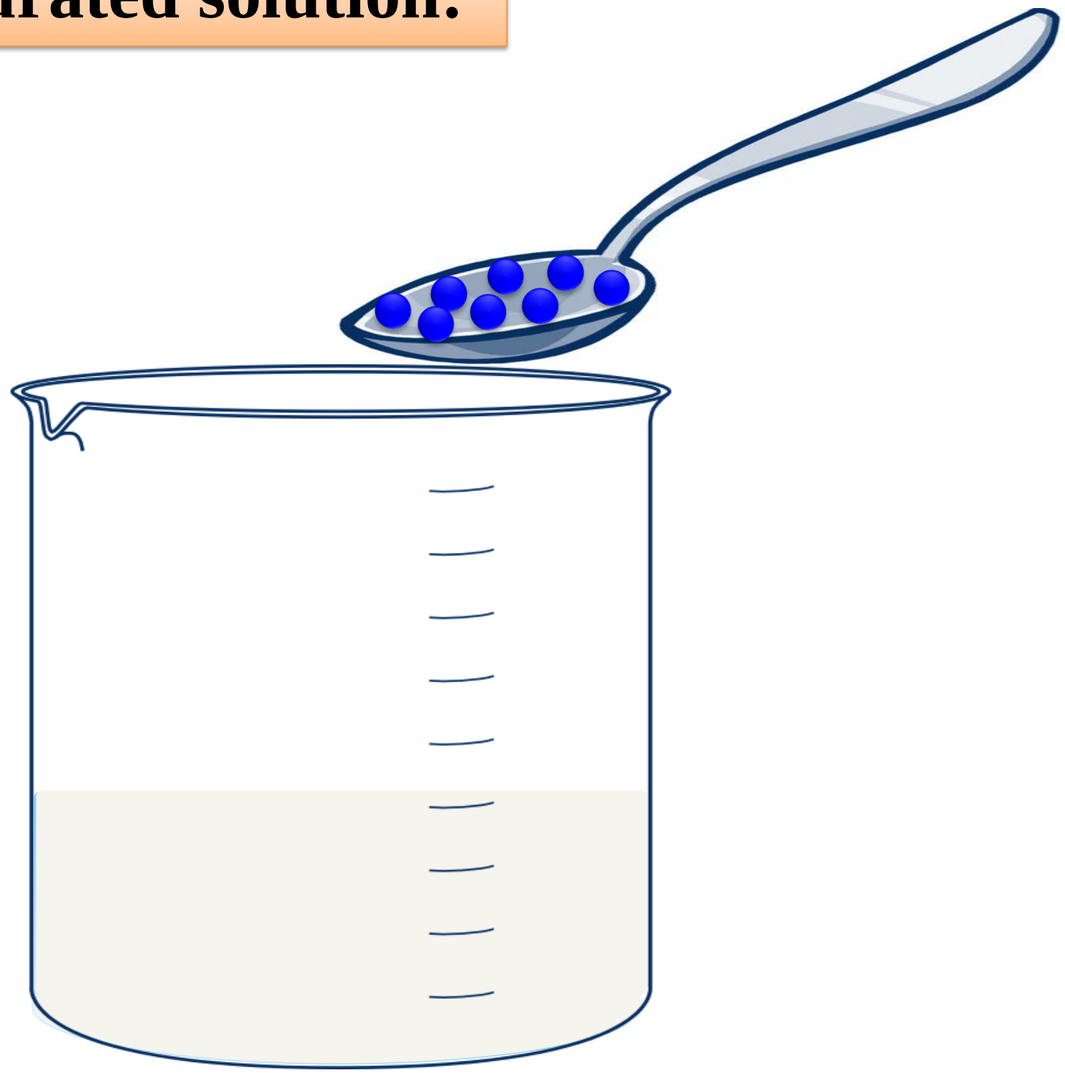


- A solution in which more amount of solute can be dissolved at the same temperature and pressure.
- The amount present is less than that in a saturated solution.

Super saturated solution:

- A solution in which there is more amount of solute than that is present in a saturated solution at the same temperature and pressure is called *super saturated solution*.
- Solvent holds more solute than is normally possible at that temperature.

Super saturated solution:



SOLUBILITY OF GAS IN A LIQUID

SOLUBILITY

B) Solubility of gas in a liquid:-

- **Do you know that gases also dissolve in water or other liquids like solid dissolves in water or liquids.**

- **Do you know that most important gas that dissolves to a small extent of 5-6 ppm in water and saves the whole flora and fauna under sea.**

[i.e aquatic life.(life forms in water)] **is oxygen.**

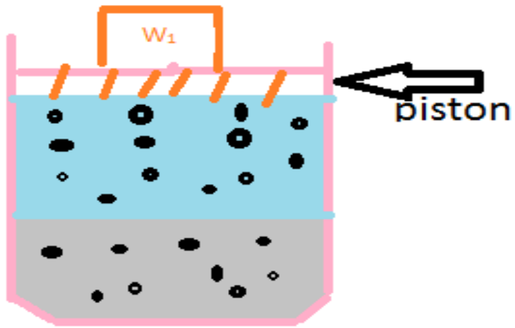
SOLUBILITY

B) Solubility of gas in a liquid:-

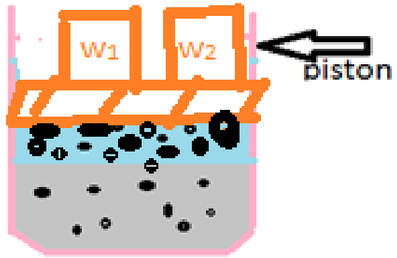
- **Hydrogen chloride gas, ammonia gas , sulphur dioxide gas etc. are highly soluble in water.**
- **Easily liquefiable gases are more soluble**
- **Solubility of gases is greatly affected by *pressure* and *temperature*.**

SOLUBILITY

Effect of pressure:



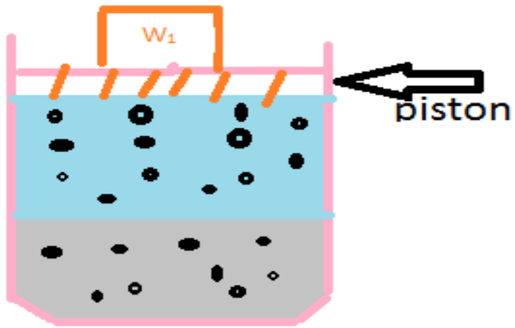
- Solubility of gases increases with increase of pressure.



- With the increase of weight on the piston solubility of gases increases.

SOLUBILITY

Effect of pressure:

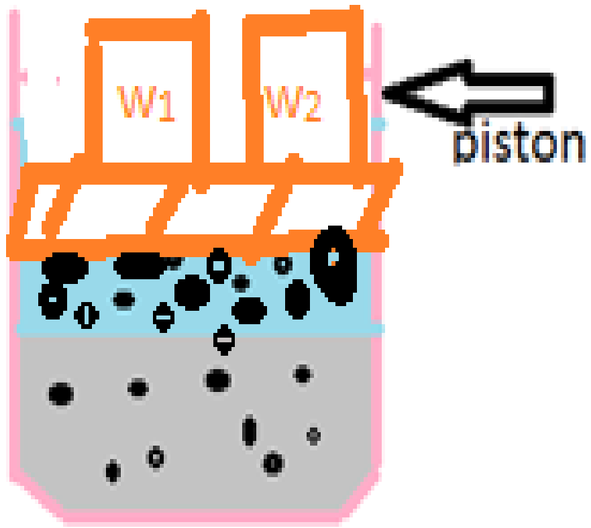


- **Assume this system to be in a state of Dynamic equilibrium.**

i.e. under the conditions such as P(pressure) and T(Temperature) rate of gaseous molecules entering and leaving the solution phase is the same.

SOLUBILITY

Effect of pressure:



W-indicates weight.
by increasing the weights
pressure on the gas molecules increases

Concentration of gas molecules per unit volume increases and interactions between solvent molecules and gas molecules increases resulting more solubility of the gas

SOLUBILITY

Effect of pressure:

Observations from the above figures:

Assume this system to be in a state of dissolution ⇆ crystallization equilibrium

Now, increase the pressure over the solution phase by compressing the gas to a smaller volume(shown in fig)

SOLUBILITY

Effect of pressure:

Observations from the above figures:

As a result increase the number of gaseous molecules per unit volume over the solution

This increase in the pressure of a gas above the solution increases the solubility of the gas until a new equilibrium is reached and thus it’s solubility increases.

SOLUBILITY

Effect of Temperature on the solubility of a gas

Q) Do you know what happens to gas, when it dissolves in water or any other solvent is heated ?

Answer

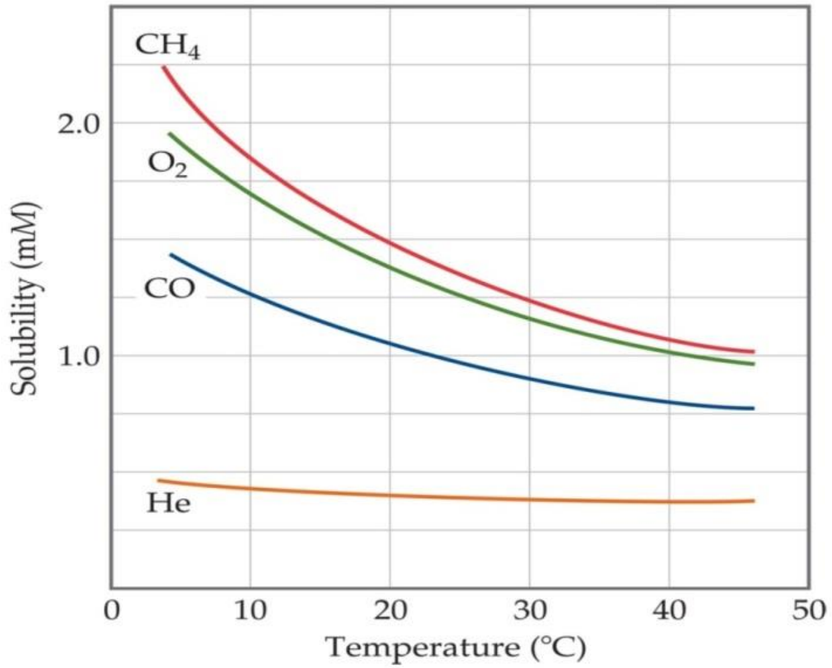
You observe that some bubbles emanate from water. It indicates gas is escaping in the form of bubbles from the solution.

Gas escaping from the liquid in which it is dissolved or from solution when heated indicates the solubility of the gas decreases with rise in temperature.

SOLUBILITY

Temperature and solubility of a gas

- Higher temperature drives gases out of solution.
- Carbonated soft drinks are more “bubbly” if stored in the refrigerator.
- Warm lakes have less O_2 dissolved in them than cool lakes.



- In the graph least soluble gas is He and most soluble gas is CH_4

SOLUBILITY

Important note

- When a gas is dissolved in liquid, heat is evolved during this process. Hence, it is an **exothermic** process
- Dissolution process follows Dynamic equilibrium, Lechatelier‘s principle. In Exothermic process the solubility should decrease with increase in temperature.

HENRY'S LAW

SOLUBILITY

Can you tell me who is the first person to give quantitative relationship between solubility of a gas in a solvent and pressure?

- **Mr. Henry**

SOLUBILITY

Henry's law

- The law states that at a constant temperature, the solubility of a gas in a liquid or solution is directly proportional to the partial pressure of the gas present above the surface of a liquid or solution
- Mole fraction of a gas in a solution is proportional to the partial pressure of the gas over the solution

SOLUBILITY

Henry's law

- **The partial pressure of the gas in vapour phase (p) is proportional to the mole fraction (X) of the gas in the solution.**

Henry's law is expressed as

$$P = K_H X$$

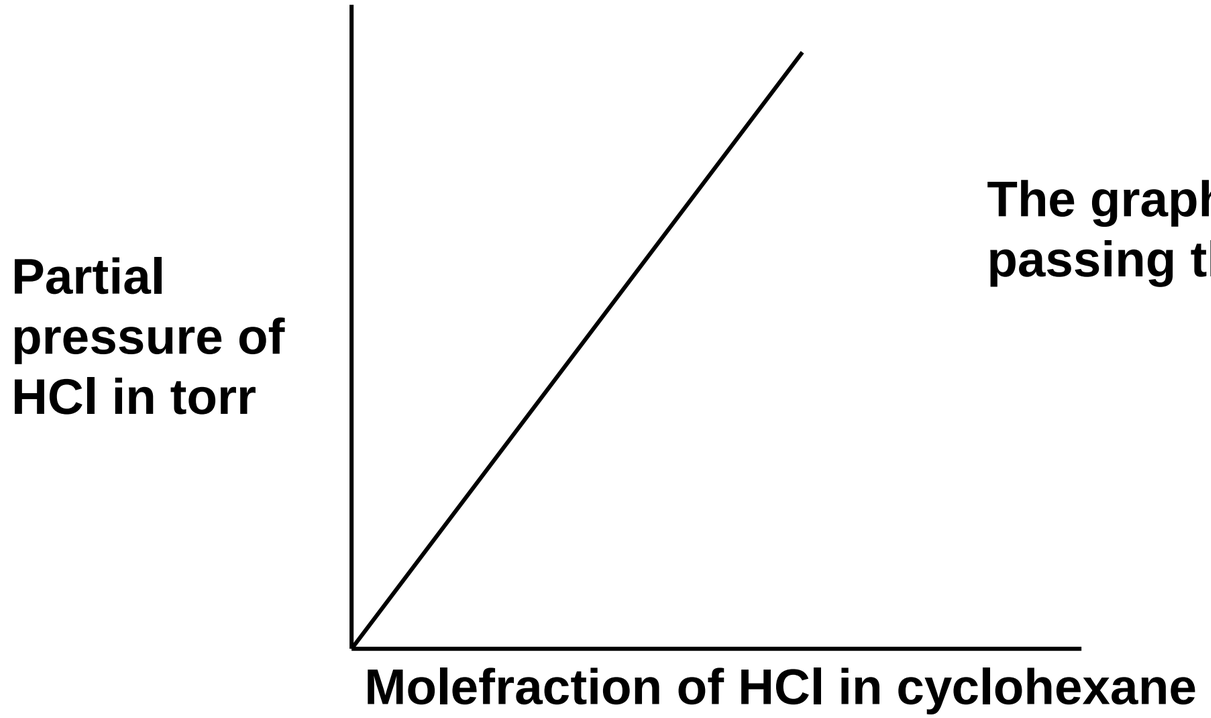
Here,

K_H **= Henry's law Constant**

Henry's law

Can you draw graph between partial pressure and mole fraction of gas in a solution from the above statement and predict the nature of the graph?

Yes Sir



The graph will be straight line passing through the origin

My Dear students can you guess the solubilities of the following gases in water? He,H_2,N_2, O_2,Ar,CO_2,Formaldehyde(HCHO),methane(CH_4), vinyl chloride (C_2H_3Cl) etc.

No sir it is difficult

Do not you worry

Here is the answer for you

Gas	Temperature/K	K_H / kbar	Gas	Temperature/K	K_H / kbar
He	293	144.97	Ar	298	40.3
H_2	293	69.16	CO_2	298	1.87
N_2	293	76.48	HCHO	298	$1.83x10^{-5}$
N_2	303	88.84	CH_4	298	0.413
O_2	293	34.86	C_2H_3Cl	298	0.611
O_2	303	46.82			

1) In soft drinks and soda water, CO_2 is passed under high pressure and sealed why?

A. increases the solubility of CO_2, based on Henry's law

2) Scuba divers have high concentrations of dissolved atmospheric gases in blood why?

A. Scuba divers go deep into sea which results in high pressure under water, which causes more solubility of gases inhaled based on Henry's law.

3) When scuba diver comes to surface experiences a medical condition known as bends, which are painful and dangerous to life why?

A. When divers come to surface, pressure decreases, this releases the dissolved gases and leads to the formation of bubbles of nitrogen in the blood. This blocks capillaries and creates condition called bends.

4) What is the Scuba divers air tank composition ?

A. Air diluted with helium. He-11.7% + 56.2%N_2 + 32.1% oxygen

5) Why do people living at hill top or at higher altitudes experience a condition known as anoxia ?

A. At high altitudes the partial pressure oxygen is less than that on ground. This leads to low concentrations of oxygen in the blood and tissues of the people . This leads to weakness and inability to think properly for climbers

5) Between amonium chloride and sodium chloride which is more soluble with rise in temperature?

A. Ammonium chloride…as its enthalpy of dissolution is endothermic

MCQs

1.) Henry’s law applicable at constant

a) temperature

b) Pressure

c) volume

d) Temperature & pressure

Q) If N_2 gas is bubbled through water at 293K, how many millimoles of nitrogen gas would dissolve in 1.0 litre of water ? Assume that nitrogen exerts a partial pressure of 0.987bar. Given that Henry's law constant for nitrogen at 293K is 76.48kbar

Answer:

We know that solubility of a gas is related to mole fraction in aqueous solution

We know that one has to apply Henry's equation

$$P = K_H x$$

$P = 0.987$ bar, (From the data given)

$K_H = 76.48$k bar

$= 76,480$bar

Q) If N_2 gas is bubbled through water at 293K, how many millimoles of nitrogen gas would dissolve in 1.0 litre of water ? Assume that nitrogen exerts a partial pressure of 0.987bar. Given that Henry's law constant for nitrogen at 293K is 76.48kbar

Answer :

$$x = p/K_H$$

$$= 0.987/76480$$

$$= 1.29 \times 10^{-5} \qquad X = ?$$

$$X = n_1 / n_1 + n_2$$

$$\text{moles of water } n_2 = \text{w/m.w}$$

$$= 1000/18 = 55.55$$

(1.0 litre of water = 1000gm since density of water is 1gm/ml)

Q) If N_2 gas is bubbled through water at 293K, how many millimoles of nitrogen gas would dissolve in 1.0 litre of water ? Assume that nitrogen exerts a partial pressure of 0.987bar. Given that Henry's law constant for nitrogen at 293K is 76.48kbar

Answer :

since $n_1 << n_2$ $\therefore$ $x = n_1 / n_2$ $n_1 = x.n_2$

$= 1.29 \times 10^{-5} \times 55.55$

$= 7.16 \times 10^{-4}$ mol

1.0 mol = 1000 millimoles

$= 7.16 \times 10^{-4}$ mol ----?

$= 7.16 \times 10^{-4}$ mol x1000

= 0.716 millimole or mmol.

- **Solvent property is dielectric constant (breaking strength of solvent on interaction with solutes molecules)**

The energy terms :

1. Lattice energy

2. Hydration energy

1. Lattice energy :

The energy required when one mole of crystal is broken into its constituent ions or the energy released when one mole of a crystal is formed from its constituent ions or particles.

The dissolution process is *endothermic*

- **Solvent property is dielectric constant (breaking strength of solvent on interaction with solutes molecules)**

The energy terms :

1. Lattice energy

2. Hydration energy

2. Hydration energy

The amount of energy released when one mole of particles are surrounded by solvent molecules is called *hydration energy*.

The process is highly *exothermic*.

2. Hydration energy:

If lattice energy is *higher* than hydration energy, the solubility will be *less.*

If lattice energy is *lower* than hydration energy, the solubility will be *high.*


Thank you...