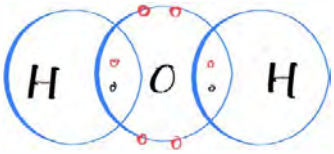
Water

Formula : H_2O

Chemical name : Dihydrogen oxide

Molecular mass : $(1 \times 2) + (1 \times 16) = 18u$

Electron Dot structure :



Introduction :

More than 70% of Earth's area is occupied with water. However, hardly 2.5% of this water makes up the world's supply of fresh water, including the frozen water in polar ice caps and glaciers.

Water exists in three states :
(i) Solid (ice)
(ii) Liquid (water)
(iii) Gas (water vapour)

Water has the ability to dissolve a wide range of substances because it has a high dielectric constant.

Physical Properties of water :

1. Nature : Clear, transparent liquid, odourless tasteless.

2. Boiling Point : 100°C under normal pressure

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- Boiling point is proportional to Atmospheric pressure
- Boiling point is proportional to impurities added.

3. Freezing and Melting point : 0°C (at 1 atm)

- Freezing point is inversely proportional to dissolved impurities.

4. Density : At 4°C, water has its maximum density and minimum volume.

5. Anomalous expansion of water:
When water is cooled, it first contracts in volume but below 4°C, it starts expanding and continues to do so till the temperature reaches 0°C, the point at which it freezes into ice.

6. Latent heat of fusion of ice:
The amount of heat energy required by ice to change into water is called latent heat of fusion of ice.
Its specific value is 336 J/g or 80 cal/g.

7. Latent heat of vapourization of water:
The amount of heat energy required by water to change into vapours at its boiling point without change in temperature.
Its specifix value is 2268 J/g or 540 cal/g.

8. Specific Heat Capacity:
The fixed amount of heat energy absorbed by 1g of water, when heated through 1°C.

Air dissolved in water

The composition of air dissolved in water is 33% oxygen, 66% nitrogen and 1% carbon dioxide.

Importance of dissolved air

1. Marine life use the dissolved oxygen for respiration.
2. Aquatic plants use the dissolved carbon dioxide for photosynthesis to prepare their food.

Solutions

A solution is a homogeneous mixture of two or more components whose composition may be gradually changed by changing the relative amounts of the components.

Components of solution

1. **Solute :** The substance that dissolves in the solvent to form a solution is known as solute.
2. **Solvent :** The medium of dissolution that allows one or more components to dissolve in it to form a solution.

A solution which is made up of two components is called Binary solution. Solutions which are made up three or four components are called ternary and quaternary solutions respectively.

In a salt solution, salt is solute and water is solvent.

True Solution

A solution in which the size of the solute particles is about 10^{-10} m.

Characteristics

1. It is a homogeneous mixture, clear, transparent.
2. It does not scatter light.
3. Its components cannot be separated by filteration.
4. The solute particles in a solution do not settle down.

Aqueous solution	Non-Aqueous Solution
Water is solvent	Other than water is solvent

Dilute Solution

A solution in which the amount of solute is less compared to amount of solvent.

Concentrated Solution

A solution in which the amount of solute is more compared to amount of solvent.

Saturated Solution

A solution that cannot dissolve any more of the solute at a given temperature.

Effect of cooling

The solubility of a solid usually decreases with fall in temperature.

Effect of heating

If a saturated solution is heated to a higher temperature, then it becomes unsaturated.

Supersaturated Solution

A supersaturated solution at a particular temperature is one that is more concentrated than its saturated solution at that temperature.

Concentration of a Solution

(1) Mass Percent

It is defined as the mass of solid solute in grams present in 100 grams of solution.

$$\text{Mass \%} = \frac{\text{Mass of Solute}}{\text{Mass of Solution}} \times 100$$

(2) Volume Percent

It is defined as the volume of solute in millilitres present in 100 mL of a solution.

$$\text{Volume \%} = \frac{\text{Volume of Solute}}{\text{Volume of Solution}} \times 100$$

Solubility

The amount of solute that dissolves in 100g

(3) By the addition of washing soda

$Ca(HCO_3)_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaHCO_3$

$Mg(HCO_3)_2 + Na_2CO_3 \longrightarrow MgCO_3\downarrow + 2NaHCO_3$

Removal of Permanent hardness :

Hard water is treated with a calculated quantity of soda ash.

$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$
(Soda ash)

$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$

If some magnesium sulphate is also present in water, lime is also used along with soda-ash.

$MgSO_4 + Na_2CO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow +$
$CaCO_3\downarrow + Na_2SO_4$

If hardness is both temporary and permanent:

Permutit Process : Permutit is an artificial zeolite. Chemically, it is hydrated sodium aluminate or thosilicate, having the formula $Na_2Al_2Si_2O_8 \cdot xH_2O$. (or NaP)

A tall cylinder is loosely filled with lumps of permutit. When hard water containing calcium and magnesium ions percolates through these lumps, exchange of ions takes place.

The sodium permutit is slowly changed into calcium and magnesium permutit, and with the removal of calcium and magnesium ions, the water becomes soft.

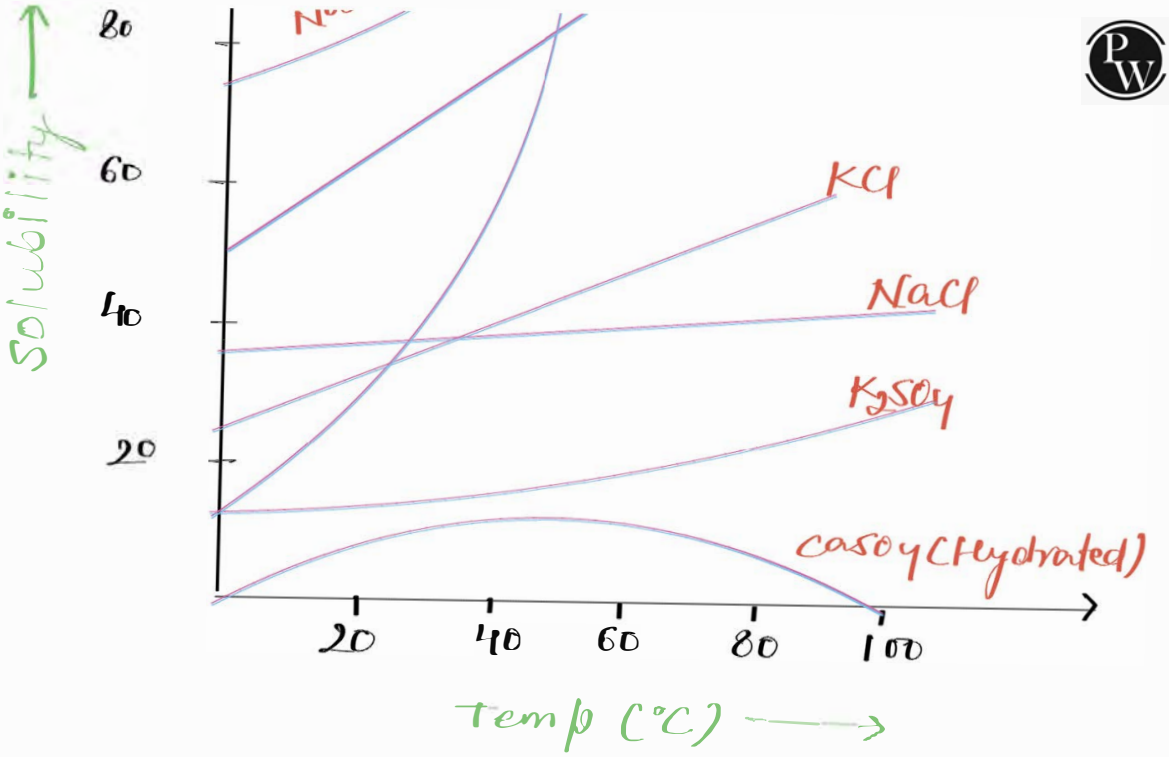
When no longer active, the permutit is regenerated by running a concentrated solution of brine over it and removing the calcium chloride formed by repeated washing.

$CaP + 2NaCl \longrightarrow Na_2P + CaCl_2$

Softening hard water using ion exchange resins :

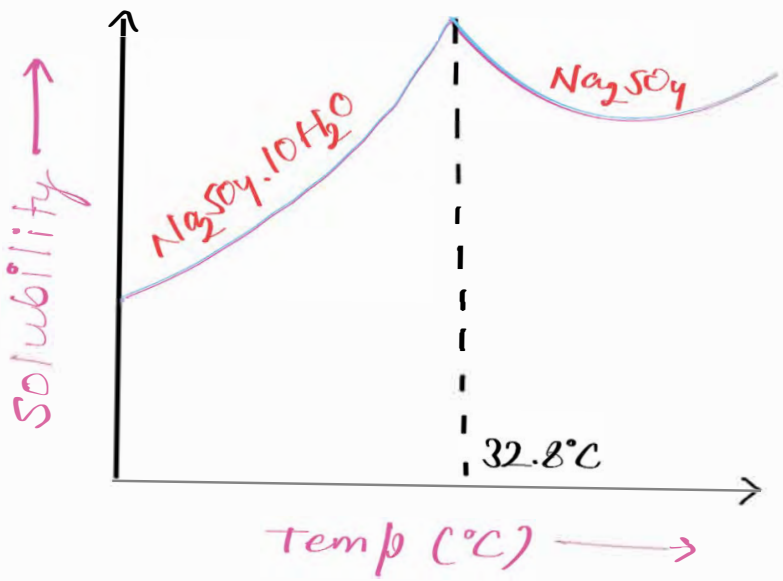
For scientific purposes even the presence of Na^+ ions and HCO_3^- ions and SO_4^{2-} ions is not desirable.

To remove these ions, water is passed through synthetically prepared cation and anion exchange resins one by one. The sodium ions are replaced by H^+ ions and HCO_3^- and SO_4^{2-} ions by OH^- ions and the water gets completely deionised.



Anomalous Solubility

$Na_2SO_4.10H_2O$ (Glauber's salt)



- In endothermic process, the solubility of solute increases with increase in temperature
- In exothermic process, the solubility of

solute decreases with increase in temperature.

Effect of Pressure on Solubility

Henry's Law: At any temperature, the mass of a gas dissolved by a fixed volume of a liquid is directly proportional to the pressure on the surface of the liquid.

Crystals and Crystallisation

Crystal: It is a homogeneous solid of definite geometrical shape.

Crystallisation: It is a process by which crystals of a substance are obtained by cooling a hot saturated solution.

Hydrated and Anhydrated substances

Hydrated substance: contains water of crystallisation. eg. $CuSO_4 \cdot 5H_2O$

Anhydrated substance: Donot contains water of crystallisation. eg. NaCl

Water of Crystallisation:

The fixed amount of water that is associated with some compounds which is an integrated part of their crystalline structure. eg. $CuSO_4 \cdot 5H_2O$ has 5 water of crystallisation.

Determination of water of crystallisation

Weight of crystals at R.T. = a g

Weight of residue after heating at 101 °C = b g

weight of water = (a − b) g

% of water of crystallisation = $\frac{(a-b)}{a} \times 100$

Deliquescence

Certain water soluble substances, when exposed to the atmosphere at ordinary temperatures, absorb moisture and ultimately dissolve in the absorbed water, forming a saturated solution. Such a substance is called a deliquescent substance and the phenomenon is called deliquescency.

Examples: NaOH, $CaCl_2$, KOH etc

Hygroscopy

Certain substances absorb moisture (water vapour) from the atmosphere when they are exposed to it but not enough to form solutions. Such substances are called hygroscopic substances. The phenomephon is known as Hygroscopy.

Examples: Conc. H_2SO_4, CaO etc

Drying or Desiccating agents

Drying agents are substances that can readily absorb moisture from other substances without chemically reacting with

them. for example : P_2O_5, CaO etc. These substances are also called desiccants or desiccating agents.

Dehydrating agents

Dehydrating agents are substances that can remove even the chemically combined water molecules from compounds.
For examples : Al_2O_3, conc. H_2SO_4 etc.

$$CuSO_4 \cdot 5H_2O \xrightarrow{\text{conc. } H_2SO_4} CuSO_4 + 5H_2O$$
(Blue) (white)

- Quicklime being basic in nature is suitable for drying NH_3, a basic gas.
- Liquids are dried by keeping them overnight over anhydrous Na_2SO_4 or $CaCl_2$ at room temperature.
- Solids are dried by spreading them on a watch glass or a dish and keeping it in a desiccator for some days.
- A desiccator is an air-tight glass vessel with a suitable drying agent placed at the bottom.

Soft and Hard water

- Water is said to be soft, if it readily forms lather with soap.
- Water is said to be hard, when it does not readily form lather with soap.
- Hardness in water is due to the presence of

bicarbonates, chlorides or sulphates of calcium or magnesium.

Stalagmites and Stalactites

The conical pillar which grows downwards from the roof is called stalactite and the one which grows upward from the floor of the cave is called stalagmite. They meet after a time and form pillar like structures. In a year some grow less than even centimeter but some as tall as 100 cm.

Types of Hardness

Temporary hardness: Water that contain only hydrogen carbonates of calcium and magnesium is called temporary hard water.

It is called temporary because it can be removed by just boiling.

$$Ca(HCO_3)_2 \xrightarrow{Boil} CaCO_3\downarrow + H_2O + CO_2\uparrow$$

$$Mg(HCO_3)_2 \xrightarrow{Boil} MgCO_3\downarrow + H_2O + CO_2\uparrow$$

Permanent hardness: Water containing sulphates and chlorides of magnesium and calcium is called permanent hard water. This hardness cannot be removed by boiling.

Advantages of Hard water:

1. Hard water is used in the preparation of beverages and wines.

2. Calcium and magnesium salts present in hard water are essential for the growth of our bones and teeth.

Disadvantages of Hard water:

1. Hard water is not suitable for producing steam.

2. Hard water is also unfit for washing purposes.

Soaps and Detergents

- Soap is chemically a sodium salt of stearic acid ($C_{17}H_{35}COONa$, sodium stearate), can be represented as NaSt.

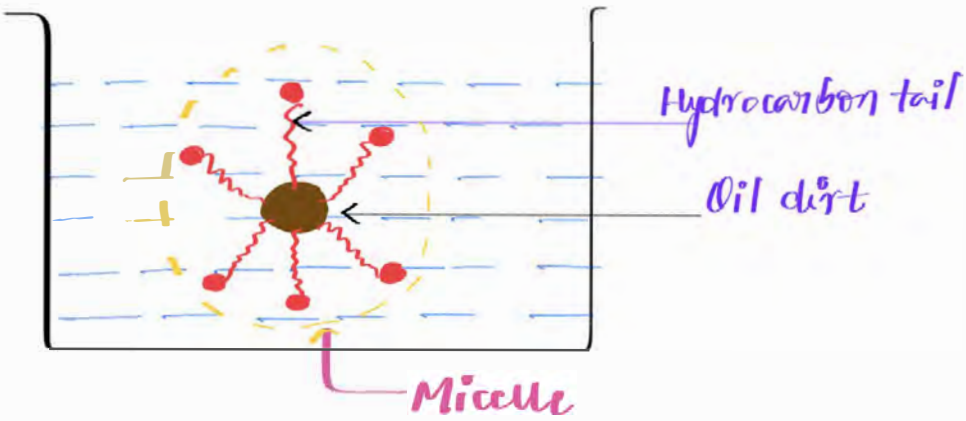
$$\underset{\text{(Soap)}}{2NaSt} + Ca(HCO_3)_2 \longrightarrow \underset{\text{(Scum)}}{CaSt_2\downarrow} + 2NaHCO_3$$

- Synthetic detergents are made up of sulphonating some higher alkenes with sulphuric acid and then converting them into their sodium salts by caustic soda.
Detergents are more soluble in water than soap and are unaffected by hardness of water.

Cleansing action of soaps and detergents

When a soap or detergent is dissolved in

water, the molecules gather as clusters called micelles. Their tails stick inwards and the head outwards. In cleansing, the hydrocarbon tail attaches itself to oil and dirt. When water is stirred, oil and dirt tend to lift off from the dirty surface and dissociate into fragments. The negatively charged heads present in water prevent the small globules from coming together and form aggregates. Thus, oil and dirt are removed from clothes when they are rinsed with water.



Removal of Hardness

Removal of temporary hardness :

(1) By Boiling, carbon dioxide is driven off and the soluble hydrogen carbonates are converted into insoluble carbonates and could be removed by filteration or decantation.

$$Ca(HCO_3)_2 \longrightarrow CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

(2) By Clark's process, lime is first thoroughly mixed with water in a tank and then fed into another tank containing hard water. Most of the calcium carbonate settles down.

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

(3) By the addition of washing soda

$$Ca(HCO_3)_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaHCO_3$$

$$Mg(HCO_3)_2 + Na_2CO_3 \longrightarrow MgCO_3\downarrow + 2NaHCO_3$$

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