Lecture-8

Solutions, Solubility & Gas Laws

Text

"Chemistry Fundamentals"

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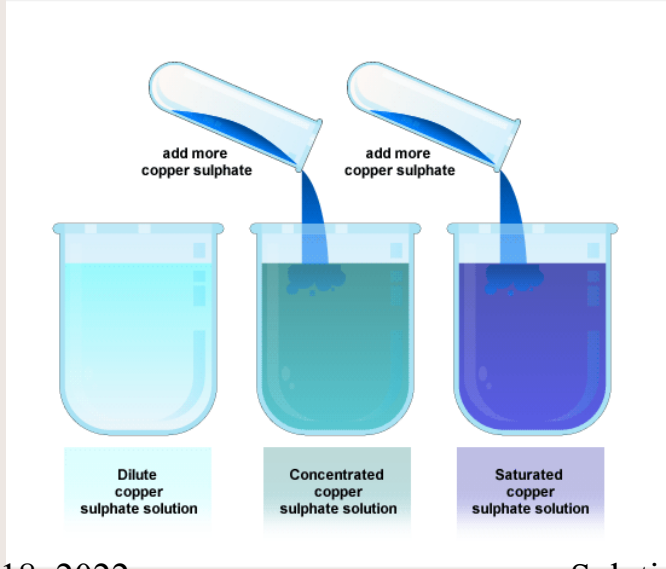
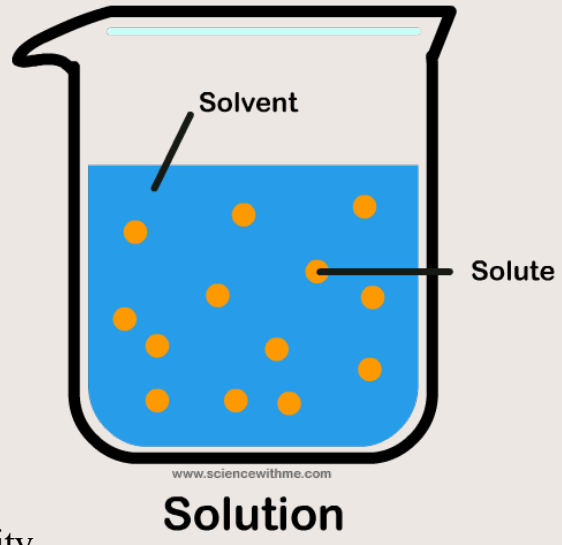
What is a solution?

- A solution is a homogeneous mixture of two or more pure substances, which may be solids, liquids, gases or a combination of these and composed of only one phase.
- A homogeneous mixture is a physical combination in which particles of one or more substances (solute) are distributed uniformly throughout another substance (solvent) at the molecular or ionic level.
- Generally, in a solution the percentage of solvent is more than 50 percent.

Types of solution

1. Depending on the three physical states- (9 types)
2. Depending on the temperature- (2 types)
3. Depending on the equilibrium-(3 types)





(i) Depending on the three physical states- gas, liquid and solid (9 types):

Solution	Example
1. Gas in gas	• Air. (78% N_2 21%. O_2, 0.93% Ar, other gases)
2. Gas in liquid	• Soda water (CO_2 in liquid)
3. Gas in solid	• H_2 absorbed by heated palladium
4. Liquid in gas	• water vapor in air
5. Liquid in liquid	• alcohol ~~in water~~
6. Liquid in solid	
7. Solid in gas	• mercury in gold
8. Solid in liquid	• camphor in air
9. Solid in solid	• sugar solution • Ni-Cu alloy

(ii) Depending on the temperature-(2 types)

1. *Exothermic solution*: The process of dissolution of a solute in solvent involving evolution of heat energy due to breaking and formation of bonds. Examples: CaO or NaOH or strong acids in H_2O etc.
2. *Endothermic solution*: The process of dissolution of a solute in solvent involving absorption of heat energy due to breaking and formation of bonds. Examples: NH_4NO_3 or glucose in H_2O, evaporation of H_2O etc.

NaCl

(iii) Depending on the equilibrium- (3 types)

1. A **saturated solution** is a solution containing the maximum concentration of a solute under certain temperature and pressure. Additional solute will not dissolve in a saturated solution and simply settle down as undissolved solids.

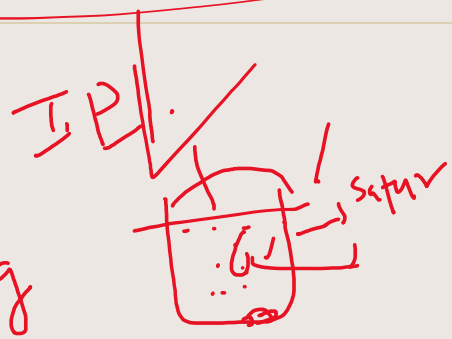
There exists a dynamic equilibrium between the undissolved solute molecules and the solute molecules in saturated solution.

Solute molecules (undissolved) $\rightleftharpoons$ Solute molecules (in solution)

NTP

STP → 0°C / 273K . 1atm / 1013.25 Pa

SATP — 25°C / 298



100g

NaCl — 5g → 100g

> 5g → ~~super~~ saturated

Unsaturated < 5g →

1g / 100g . 2g / 100g .

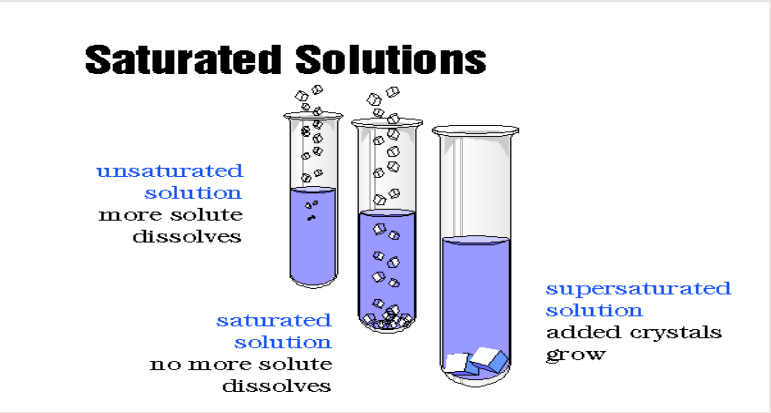
(iii) Depending on the equilibrium- (contd.)

2. *A **supersaturated solution*** is a solution containing more solute than a saturated solution. The solubility of a solution increases as the temperature or pressure is increased. This means that as the temperature rises, more solute can be dissolved. Increased pressure also increases maximum possible saturation and allows for a supersaturated solution.

(iii) Depending on the equilibrium- (contd.)

3. *An **unsaturated solution*** is a solution containing less solute than a saturated solution. An unsaturated solution has room for additional solute to be added and fully dissolved, without settling and sedimentation occurring.

Saturated 5g
Super satu → >5 g
Unsaturated <5 g
maximum 5g NaCl ↓ 100 g H_2O



Properties of Solvent

- **What is Solvents?**
- The vast majority of chemical reactions are performed in solution. The solvent fulfills several functions during a chemical reaction. It solvates the reactants and reagents so that they dissolve.

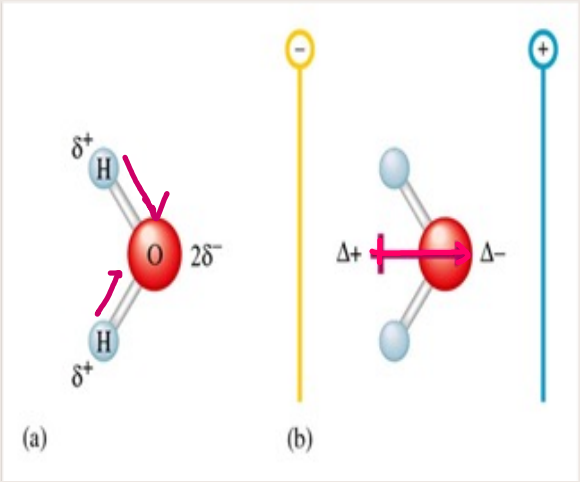
- **A good solvent should meet the following criteria:**
- It should be inert to the reaction conditions.
- It should dissolve the reactants and reagents.
- It should have an appropriate boiling point.
- It should be easily removed at the end of the reaction.

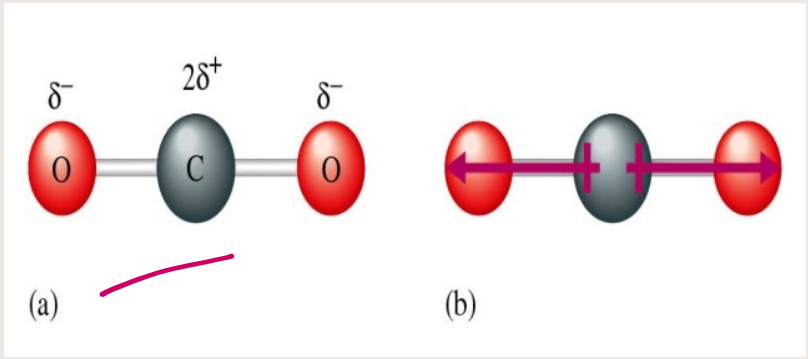
Properties of Solvent (contd.)

- Non-polar reactants will dissolve in non-polar solvents. Polar reactants will dissolve in polar solvents.
- For our purposes there are three measures of the polarity of a solvent:
- (a) **Dipole moment**,
- (b) **Dielectric constant**,
- (c) **Miscibility with water.**

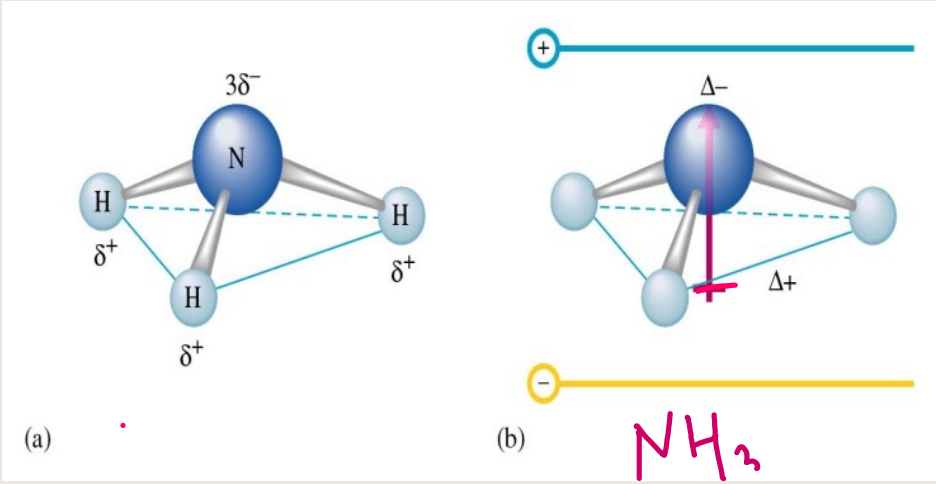
- ***Dipole moment***: It occurs due to equal amount of positive and negative charge separated by a distance within a molecule. Mathematically, $\mu = q \times r$; where μ = dipole moment, q = charge of atom in coulomb and r = distance between charges in Å. A knowledge of dipole moment is useful to know the extent of polar character and geometrical shape of a molecule.
- ***Dielectric constant***: The dielectric constant of a solvent may be defined as its capacity to weaken the force of attraction between the electrical charges in that solvent. It is a measure of the polarity of the solvent. Mathematically, F = e2/rD; where D = dielectric constant, e = charge, F = force of attraction and r = distance between charges.

FIGURE





Dipole moment of (a) H_2O, (b) CO_2 and (c) NH_3

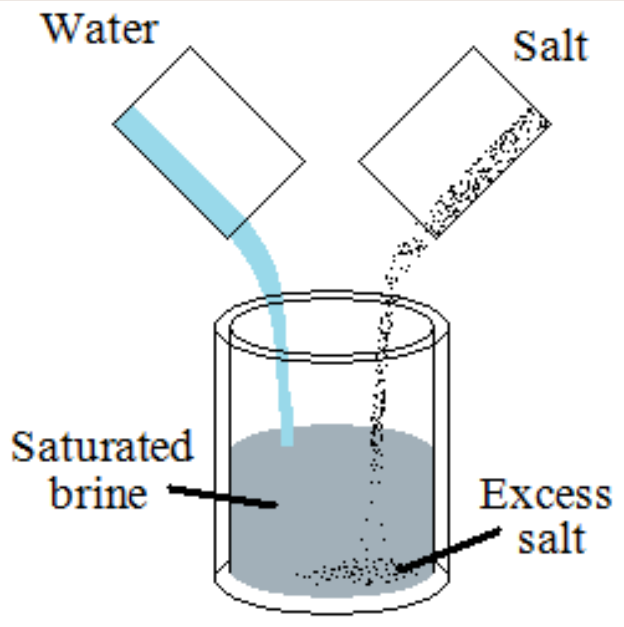


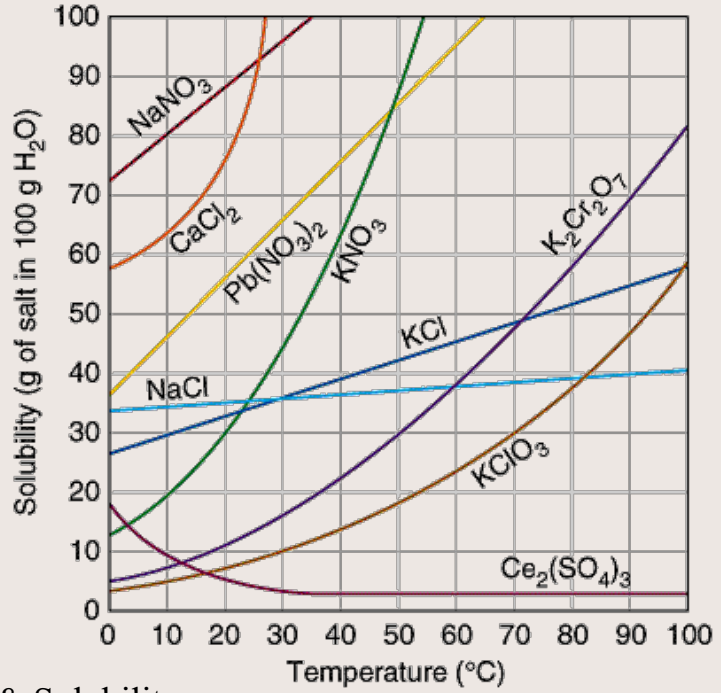
Properties of Solvent (contd.)

- Molecules with *large dipole moments* and *high dielectric constants* are considered **polar**.
- Those with *low dipole moments* and *small dielectric constants* are classified as **non-polar**.
- On an operational basis, solvents that are miscible with water are polar, while those that are not are non-polar.
- Chemists have classified solvents into three categories according to their polarity: (1) Polar protic - H_2O, NH_3, ethanol etc. (2) Dipolar aprotic –acetone (CH_3COCH_3), chloroform, Dichloromethane etc. and (3) Non-polar alkanes, tolune , carbon tetrachloride etc.

Solubility

The amount of a substance that dissolves in a given quantity of solvent at a given temperature to form a saturated solution is called its solubility.





Factors Affecting Solubility

(a) Nature of the solute and solvent

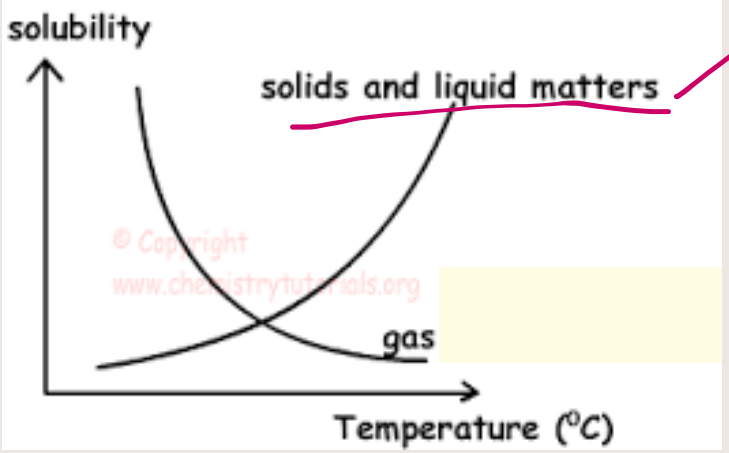
1. Ionic and polar substances dissolve in polar solvent, e.g. NaCl in H_2O.
2. Nonpolar substances are dissolved in nonpolar solvents, e.g. Napthalene, oil etc. in C_6H_6, CCl_4.

'Like dissolves like' - that means substances dissolve in chemically similar solvents.

Factors Affecting Solubility (contd.)

(b) Effect of temperature

A higher temperature increases both the rate of dissolution and also the solubility of the solute.



Except in case of gas

Factors Affecting Solubility (contd.)

(c) Rate of solution

1. At a low temperature the rate of solution is quite low. At higher temperature dissolution of more solute causes.
2. The rate of dissolution may be increased by shaking or stirring of the solvent-solute mixture.
3. **Particle size factor**: The process of solution being a surface phenomenon, the greater the surface of contact between the solvent and the solute, the higher will be rate of solution.

Mechanism of dissolution

How do the evolution and the absorption of heat arises?

To explain this, we have to analyze the process of dissolution of a solute in a solvent.

For example, the dissolution of common salt, NaCl in H_2O.

Mechanism of dissolution (contd.)

The process involves the following sequences:

a) H_2O molecules attack the Na^+ particles and detach these from crystal lattice against the attractive force of the adjoining particles i.e. the Cl^- ions.

b) The solvent particles may require to be pulled apart to make room for Na^+ particles.

c) The Na^+ particles are solvated (the interaction of ions of a solute with molecules of solvent) by the solvent molecules.

Mechanism of dissolution (contd.)

- Energy is required for operations (a) and (b) while as a result of operation (c) energy is liberated.
- When the energy requirement for the operations (a) and (b) is greater than that released from operation (c), the temperature of the system goes down i.e. **heat is absorbed** during the dissolution of NaCl molecule.

Mechanism of dissolution (contd.)

- The amount of heat absorbed is called **negative heat** of solution (**endothermic system**).
- When the energy requirement for the operations (a) and (b) is less than that released from operation (c), the temperature of the system goes up i.e. **heat is evolved** during the dissolution of NaCl molecule.
- The amount of heat evolved is called **positive heat** of solution (**exothermic system**).

Problem 1. Calculation of normality of strong acids, (a) 36% (w/w) HCl, specific gravity 1.18; (b) 96% (w/w) H_2SO_4, specific gravity 1.84.

Solution 1(a):

- Given, 36% (w/w) HCl, specific gravity 1.18
- Mol. Wt. of HCl = 36.5, gram-equiv-wt = 36.5
- ∴ 1 ml conc. HCl contains = 0.36 × 1.18 gm of HCl
- ∴ 1000 ml conc. HCl contains = 0.36 × 1.18 × 1000
- = 424.8 gm of HCl
- ∴ 36.5 gm of HCl in 1000ml solution = 1.0 N HCl
- ∴ 424.8 gm HCl in 1000ml = (1 x 424.8 gm) / 36.5 gm
- » = 11.64 N HCl Ans.

Next Class

Solubility-Product & pH