**10.4 Water as a Solvent**

**Review**

* A solution is an evenly distributed mixture of atoms, molecules or ions. E.g. Atmosphere (Nitrogen Oxygen), salt water.
* When a solid, liquid or gas dissolves in water, an aqueous solution is formed.
* The dissolved solid, liquid or gas is called the solute.
* The water is called the solvent
* A heterogeneous mixture has visible distinguishable parts (sand and iron)
* A homogeneous mixture are not distinguishable (salt water)
* A great number of chemical process everyday involve substances dissolved in water
* Almost all biological process involve in an aqueous solution.
* When substances are dissolved in water the particles move freely and so interactions between reactants are very effective
* It is the polar nature of water molecules that enables water to dissolve a large number of substances
* Solutions have the following characteristics
  + They are homogeneous
  + The dissolved particles are too small to see
  + The proportion of dissolved solute varies from one solution to another.
* Water is not found pure in nature due to excellence as a solvent
* Estimated there are 10 billion tonnes of gold dissolved in the world’s oceans.
* Not all substances dissolve in water – oil (spills) Most gasses have low solubility

**Why do some substances dissolve?**

When on substance dissolves in another the following processes occur:

* The particles of the solute are separated from each other
* The particles of the solvent are separated from each other
* The solute and solvent particles attract each other.

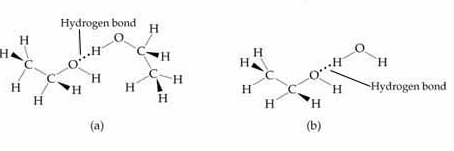
A solute will dissolve if the attraction between solute and solvent are stronger than the attraction between the solute-solute and solvent-solvent forces of attraction.

Substances that dissolve readily in water have ionic or polar covalent bonding and fall into one of three groups

* Polar covalent compounds that can form hydrogen bonds with water
* Polar covalent molecular compounds that ionise
* Ionic compounds

**Polar covalent compounds that can form hydrogen bonds with water**

* Some covalent molecular substances (sugar, ethanol) dissolve easily in water.
* These molecules are polar in in character, usually through one more –OH groups.
* Ethanol molecules contain a polar O-H bond, so there are hydrogen bonds between the ethanol molecules.

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* When ethanol dissolves in water:
  + Hydrogen bonds between water molecules are broken
  + Hydrogen bonds between ethanol molecules are broken
  + Hydrogen bonds between water molecules and ethanol molecules are formed
* As the ethanol molecules are now surrounded by the water molecules the solution forming process can be represented by:

C2H5OH(l) C2H5OH(aq)

* The more polar the molecules of a molecular compound the more likely it is to dissolve in water.
* Look at Vit A and Vit C on page 197
* In general, the larger the non-polar fraction of the molecule, the less soluble it is in water.
* Non-polar substances (oil) are insoluble in water because water molecules form hydrogen bonds with each other in preference to the weak attractions with non-polar molecules.
* Like dissolves like
  + Polar solutes will readily dissolve in polar solutes
  + Non-polar solutes readily dissolve in non-polar solutes
* Paint as example: oil and water based paints

**Polar Covalent Molecular compounds that ionise**

* Some compounds have one or more covalent bonds that are so highly polarised they break when placed in water.
* They break as a result of the electrostatic forces of attraction between the solute molecules and the water molecules. Hydrogen chloride is an example.
* This attraction results in the hydrogen-chloride bond breaking- taking both bonding electrons stay with the chlorine atom.
* Therefore an H+ forms a covalent bond with a water molecule.
* Two ions are then formed
  + The H3O+ ion and a Cl- ion
  + The H3O+ is known as a hydronium ion
* This hydrolysis process is called ionisation.
* The HCL molecules have ionised in water.
* The chlorine and hydronium ions will be surrounded by water molecules – they are hydrated ions.
* The ionisation process can be represented by the equation
  + HCl(g) + H2O(l) H3O+(aq) + Cl-(aq)
* In summary
  + Polar covalent bonds within molecules are broken, producing hydrogen ions and anions.
  + Covalent bonds forms between each H+ and an H2O molecule, giving H3O+ ions. Ion-dipole attractions between the newly formed ions and the polar water molecules are formed.
* Other polar covalent molecular compounds that ionise in water include the common acids, nitric acid (HNO3), sulphuric acid(H2SO4) and ethanoic acid (CH3COOH)

**Ionic Compounds**

* Ionic solids contain positive and negative ions held in a 3-dimensional lattice by strong electrostatic forces.
* When ionic substances such as NaCl are placed in water:
  + The positive ends of the water molecule are attracted to the negatively charged chloride ions.
  + The negative ends of the water molecules are attracted to the positively charged sodium ions.
  + Because water molecules are in a state of constant random motion, they pull the sodium and chloride ions on the outer layer of the lattice into the surrounding solution.



* When the sodium chloride has dissolved, the sodium and chlorine ions are surrounded by water molecules. The ions are said to be hydrated.
* The attraction between an ion and a polar molecule is described as an ion-dipole attraction.
* When an ionic compound is dissolved in water the positive and negative ions separate from one another. This process is called dissociation.
* The dissociation of sodium chloride can be represented by

H2O

* + NaCl(s) Na+(aq) + Cl-(aq)
* When writing equations for dissociation they rules for balancing still apply

H2O

K2CO3(s) 2K+(aq) + CO3-2(aq)

In summary, when an ionic compound dissovles in water

* Ionic bonds within the solid are broken
* Hydrogen bonds form between water molecules are broken
* Ion-dipole attraction between the ions and the polar water molecules are formed.
* Not all ionic compounds are soluble in water
* For insoluble ionic substances the energy required to separate from the lattice is much greater than the energy produced when the ions become hydrated.

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| A solubility guide for common ionic compounds |  | |
| Soluble Ionic Compounds | | |
| Most compounds of the following ions are soluble…. | | **Important exceptions** |
| Nitrate (NO3-) | | None |
| Ethanoate(acetate) (CH3COO-) | | None |
| Sodium, Potassium (Na+, K+) | | None |
| Ammonium (NH4+) | | None |
| Chloride (Cl-) | | AgCl, HgCl2, PbCl2 is slightly soluble |
| Bromide (Br-) | | AgBr, HgBr2, PbBr2 |
| Iodide (I-) | | AgI, HGI2, PBI2 |
| Sulfate (SO32-) | | BaSO4, PBSO4, CaSO4 is slightly soluble |
| Insoluble Ionic Compounds | | |
| Most compounds of the following ions are insoluble…. | | **Important exceptions** |
| Sulfide (S2-) | | Na2S, K2S, Li2S, (NH4)2S |
| Carbonate (CO32-) | | Na2CO3, K2CO3, Li2CO3 |
| Phosphate (PO43-) | | Na3PO4, K3PO4, Li3PO4 |
| Hydroxide (OH-) | | NaOH, KOH, BA(OH)2, CA(OH)2 is slightly soluble |

* The most commonly used solubility rules are that all nitrates, ammonium compounds and compounds of group1 metals are soluble.
* Although substances are usually described as soluble and insoluble this is a generalisation.
* Insoluble tend to dissolve sparingly and soluble dissolve to varying extents.
* Plus the solubility of substances varies with temperature.
  + Most solids become more soluble with temp rises while gases tend to become less soluble as the temp rises.

Worked Examples

Predict the following

1. Copper(II) nitrate (Cu(NO3)2)
2. Glycerol (CH2(OH)CH(OH)CH2(OH))
3. Octane (C8H18)
4. Nitric acid (HNO3)
5. Barium carbonate (BaCO3)

**Chapter Questions: 6 – 12**

**Chapter Review 13 -20, 25 – 28, 30-34**