A First Year blog on Types of Reactions (for the week commencing the 13th of October 2019)

- There are many different types of reactions in Chemistry. Here are just some of them (alphabetically).

Acid-Base Reactions

- This is quite possibly the most discussed reaction (certainly at GCSE Level) in Chemistry. In this reaction, an Acid and a Base (*an "Alkali" is a soluble Base*) react together and neutralise each other.

- At GCSE Level, the reaction that is examined tends to be that of a Strong Acid and a Strong Base[1] e.g.

Hydrochloric Acid		Sodium Hydroxide		Water		Sodium Chloride
HCl (aq)	**+**	**NaOH (aq)**	**—>**	**H_2O (l)**	**+**	**NaCl (aq)**

- At GCSE Level you learnt this reaction as "Acid plus Base gives Salt plus Water" but now you must forget that little ditty because the "Salt" in an Acid-Base Neutralisation reaction is an irrelevance. "Salts" in Acid-Base reactions are just "*spectator ions*" and do nothing other than bring their companions to the reaction. It is the Water that is the important product in an Acid-Base reaction, and this is exemplified by the generic equation of the reversible reaction

A Proton		An Hydroxide ion		Water
H^+(aq)	**+**	**OH^-(aq)**	**⇌**	**H_2O (l)**

- Please note the State Symbols that are used [(s) for solid, (l) for liquid, (g) for gaseous, and (aq) for aqueous], and also the change in the production symbol. For a Strong Acid-Strong Base reaction the symbol that is used is "—>" to symbolise the reaction going to completion; but, for a Weak Acid-Weak Base reaction, then the symbol that is used is "⇌" because, by definition, Weak Acids and Weak Bases engage in **reversible reactions** that do **not** go to completion, and instead reach a position of **dynamic equilibrium** long before completion.

- If
  SA = **Strong Acid** and **WA** = **Weak Acid** , and
  SB = **Strong Base** and **WB** = **Weak Base** , then
  in Acid-Base reactions, there are therefore four possible combinations viz[2].

		Sulphuric Acid		Potassium Hydroxide		Water		Potassium sulphate
SA/SB	e.g.	H_2SO_4 (aq)	+	2KOH (aq)	—>	$2H_2O$ (l)	+	K_2SO_4 (aq)
		Nitric Acid		Ammonium		Water		Ammonium Nitrate
SA/WB	e.g.	HNO_3(aq)	+	NH_4OH (aq)	—>	H_2O (l)	+	NH_4NO_3 (aq)
		Sodium Hydroxide		Ethanoic Acid		Water		Sodium Acetate
SB/WA	e.g.	NaOH (aq)	+	CH_3COOH (aq)	—>	H_2O (l)	+	$NaCH_3COO$ (aq)
		Ammonium		Propanoic Acid		Water		Ammonium Proprionate/ Ammonium Propanoate
WB/WA	e.g.	NH_4OH (aq)	+	C_2H_5COOH (aq)	⇌	H_2O (l)	+	$NH_4C_2H_5COO$ (aq)

[1] "Strong" Acids or Bases are those that react "completely" once the reaction has started. The reaction is said to "**go to completion**". In contrast, when only a very small proportion of "Weak" Acids/Bases have reacted, then the reaction reaches a position of "**dynamic equilibrium**".

[2] "viz." is an abbreviation that stands for "videre licet" in Latin. The English translation of which is "namely".

<u>Combination Reactions (please see under Synthesis Reactions)</u>

<u>Combustion Reactions (please see under Oxidisation Reactions)</u>

<u>Decomposition Reactions (AB —> A + B)</u>

- A "Decomposition" Reaction is one where a substance breaks down into its chemical constituents. For Example, Carbonic Acid is stable in its dry state, but in aqueous form it is unstable and breaks down into

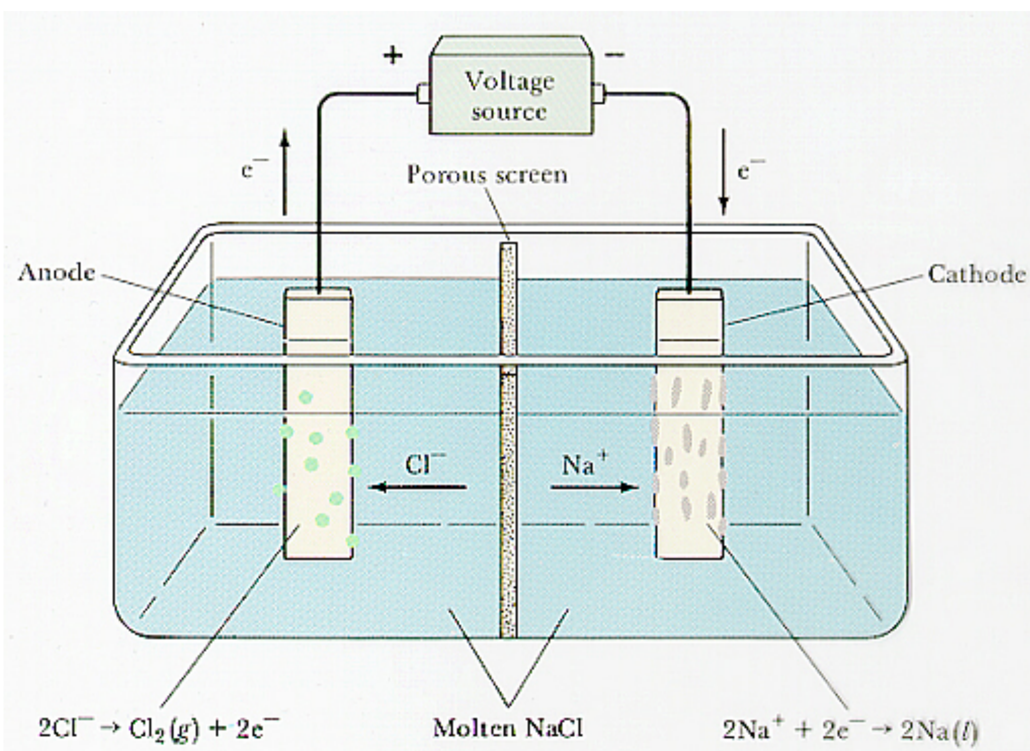
$$H_2CO_3\ (s)\ +\ nH_2O\ (l)\ \longrightarrow\ (n+1)H_2O\ (l)\ +\ CO_2\ (g)$$

Electrical Decomposition Reactions

- Where the composition is caused by an electrical current, then this is termed *Electrical Decomposition* e.g. Water is broken down into its constituent elements of Hydrogen and Oxygen when an electrical current is passed through the Water,

$$2H_2O(l)\ \xrightarrow{\text{Electric current}}\ 2H_2(g)\ +\ O_2(g$$

  and Aluminium is produced commercially by the electrical decomposition of its ore Bauxite, (roughly speaking, Al_2O_3), and Chlorine gas can be produced from Sodium Chloride (cf. below) – but the amount of electricity needed for such commercial operations is HUGE!



Oxidisation of Cl^- taking place at Anode
$Cl^-\ -\ e^-\ \longrightarrow\ Cl$
Cl^- losing electrons (OIL)

Reduction of Na^+ taking place at Cathode
$Na^+\ +\ e^-\ \longrightarrow\ Na$
Na^+ gaining electrons (RIG)

NB For an electrical current to pass through a medium, the electrical circuit must be "complete". There must therefore be **mobile charged** particles in the cell in order to carry the charge. Solid NaCl will **not** conduct electricity because although it has charged particles (viz. Na^+ and Cl^-) the particles are **not** mobile. However, both *aqueous* NaCl (aq), and *molten* NaCl NaCl (l) will conduct electricity – but the concentration of ions in the **aqueous** form is not large enough to make the operation profitable.

Thermal Decomposition Reactions

- Where the decomposition is caused by heat e.g.

Calcium Carbonate		Carbon Dioxide		Calcium Oxide (or Lime)
$CaCO_3$ (s)	—>	CO_2 (g)	+	CaO (s)

  then this is termed "Thermal Decomposition". When the Calcium Carbonate is heated in a closed system, the decomposition of Calcium Carbonate is a reversible reaction viz.

$$CaCO_3 (s) \rightleftharpoons CO_2 (g) + CaO (s)$$.

- The decomposition of Mercuric(II) Oxide, HgO, is another example of "Thermal Decomposition" but, because the reaction produces toxic fumes, it may not be performed for you in an English school lab. (However, the reaction can be seen on youtube.)

Displacement or Replacement Reactions

- **Double Displacement**
  (or Double Decomposition or Ion Exchange or Metathesis Reactions)

- A "Double Displacement" reaction (AB + CD —> AD + BC) is one where the ions exchange partners.

- If both sets of reactants and products are readily soluble in Water, then it is conceptually **not** possible to say that a reaction has occurred because every single ion will be isolated by and surrounded by molecules of Water, and thus there is no way of knowing who is "dancing" with whom (A with B, or A with D).

- However, if both sets of reactants are soluble in Water, but one of the products is either a solid or a gas, then it becomes possible to state that a reaction **has taken place** because your eyes tell you that something has happened. **Most inorganic nitrates are readily soluble in Water, and so also are most inorganic chlorides** (with the notable exceptions of Silver Chloride and Lead chloride). If therefore, aqueous solutions of Silver Nitrate and Sodium Chloride are mixed together, then a solid will be precipitated because Silver Chloride is insoluble in Water[3].

Silver Nitrate		Sodium Chloride		Silver Chloride		Sodium Nitrate
$AgNO_3$ (aq)	+	NaCl (aq)	—>	AgCl (s)	+	$NaNO_3$ (aq)

[3] At GCSE Level, in order to distinguish one from the other, you learnt about the differential speed of the formation of AgCl/AgBr/AgI, and the difference in colour, and the differential solubility in (dilute or concentrated) Ammonia.

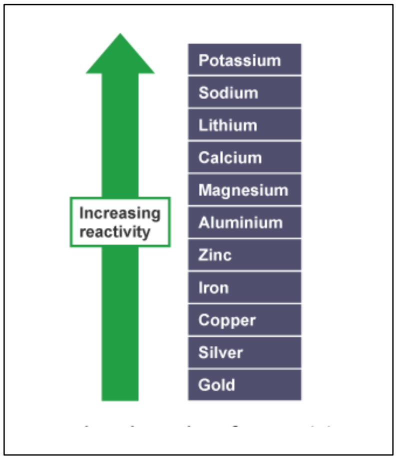
- Equally, it is possible to state that a reaction **<u>has</u> occurred** when two aqueous solutions generate a gas when mixed together (this is also called a Gas Evolution/Gas Generation reaction) e.g.

Sodium Carbonate   Hydrochloric Acid

Na_2CO_3 (aq) + 2HCl (aq) —> CO_2 (g) + H_2O (l) + 2NaCl (aq)

Single Displacement or Single Replacement Reactions (A + BC —> B + AC)

- It is common for this reaction to be used to demonstrate the Reactivity Series where one element (e.g. A above) will displace another element (e.g. B above) provided that A lies above B in the Reactivity Series e.g. BBC Bitesize gives the following table



The following reaction is often used in laboratory demonstrations of an Endothermic reaction

Zinc   Silver Nitrate   Zinc Nitrate   Silver

Zn (s) + 2$AgNO_3$ (aq) —> $Zn(NO_3)_2$ (aq) + 2Ag (s)

When the two Reactants are mixed together in a polystyrene cup, the temperature of the solution will RISE because heat is being sucked in from the outside air. The amount of heat involved can be calculated from the masses of the Products used, their specific Heat Capacities, and the subsequent rise in temperature. The formula that is used to calculate the change in Heat Energy is

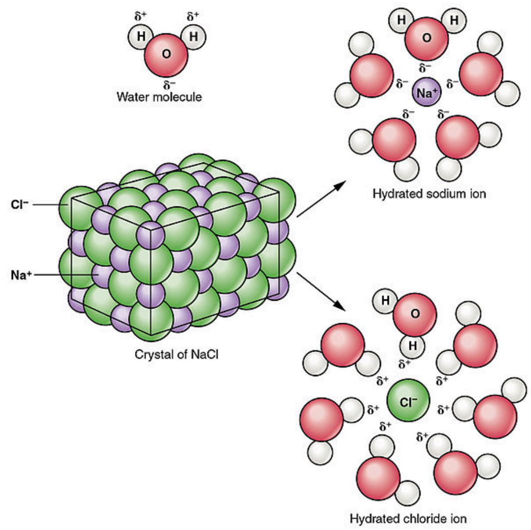
"$\Delta H = m . c . \Delta T$"

<u>Dissolution or Solvation Reactions</u>

- Chemistry LibreTexts says that "**Dissolution** means the process of dissolving or forming a **solution**. When dissolution happens, the **solute** separates into ions or molecules, and each ion or molecule is surrounded by molecules of **solvent**. The interactions between the solute particles and the solvent molecules is called **solvation**. A solvated ion or molecule is surrounded by solvent."

- When a solute such as Sodium Chloride dissolves in a solvent such as Water, then this is a Dissolution Reaction e.g.

NaCl (s) + H2O (l) —> NaCl (aq)



Source: Wikipedia

- If the solvent is not Water, then the reaction is called a Solvation Reaction.

Gas Generation Reactions

- When two Reactants generate a gas when mixed together, then this is called a Gas Evolution/Gas Generation reaction e.g.

  Sodium Carbonate + Hydrochloric Acid

  Na_2CO_3 (aq) + 2HCl (aq) —> CO_2 (g) + H_2O (l) + 2NaCl (aq)

- Most Acids will react with most metals to produce Hydrogen gas.

Neutralisation (see under Acid-Base Reaction)

Oxidisation reactions (OILRIG)

- When a substance loses electrons, then this is called an Oxidisation Reaction[4]. The GCSE mnemonic is

  O **O**xidisation
  I **I**nvolves
  L the **L**oss of Electrons.
  R **R**eduction
  I **I**nvolves
  G the **G**ain of Electrons.

[4] In Chemistry, this is often incorrectly written as an "Oxidation" reaction. In fact the verb is "to **Oxidise**".

- It is worth remembering that in order to form a Noble Gas Configuration, **Metals tend to <u>LOSE</u> electrons to Non-Metals**, and **Non-Metals tend to <u>GAIN</u> electrons from Metals**.
  - $Mg - 2e^- \longrightarrow Mg^{2+}$
  - $Al - 3e^- \longrightarrow Al^{3+}$
  - $N + 3e^- \longrightarrow N^{3-}$
  - $O + 2e^- \longrightarrow O^{2-}$
  - $F + 1e^- \longrightarrow F^{1-}$

<u>Precipitation Reactions</u>

- A Precipitation Reaction is a Double Displacement Reaction in which one of the products is a solid.

<u>Reduction Reactions</u>

- When a substance gains electrons, then this is called a Reduction Reaction. The GCSE mnemonic is
  O **O**xidisation
  I **I**nvolves
  L the **L**oss of Electrons.
  R **R**eduction
  I **I**nvolves
  G the **G**ain of Electrons.

<u>Redox (REDuction-OXidisation = REDOX) or Electron Transfer Reactions</u>

- In a REDOX reaction, both a Reduction Reaction and an Oxidisation Reaction occur simultaneously.

- It is possible to start with one of the simpler reactions in Chemistry (say the reaction between Sodium and Oxygen) to demonstrate the mechanics of such reactions. The reaction that takes place between Sodium and Oxygen can be stated as
  Sodium + Oxygen —> Sodium Oxide [= Na_2O or $(Na^+)_2(O^{2-})_1$]

- Clearly, there are two transactions involved viz.
  A) each Sodium atom loses one electron (giving, from OILRIG, an **Oxidisation** reaction)
  $Na - e^- \longrightarrow Na^+$ (one half-equation), and
  B) each Oxygen atom gains two electrons (giving a **Reduction** reaction)
  $O + 2e^- \longrightarrow O^{2-}$ (a second half-equation)
  and each of these two statements is called a "half-equation" (because each statement represents only one half of the total transaction involved).

- However, an equation using these half-equations would not balance because each Sodium atom is giving up one electron, whereas each Oxygen atom requires two electrons to become O^{2-}! Therefore, in order for the half-equations to give a balanced full ionic equation, the Sodium half-equation needs to be multiplied by "2" to give

	A)	2Na	–	$2e^-$	—>	$2Na^+$ and
+	B)	O	+	$2e^-$	—>	O^{2-} which can now be added up to give

= $2Na + O$ —> $(Na^+)_2(O^{2-})_1$ but this equation is *Chemically* unacceptable!

- This equation is unacceptable because Oxygen has diatomic molecules therefore the equations (A) + (B) should have read

  A) 2Na - $2e^-$ —> $2Na^+$

  B) O_2 + $4e^-$ —> $2O^{2-}$

  therefore (A) must now be multiplied by "2", and (A) + (B) added together would now give

  A) 4Na - $4e^-$ —> $4Na^+$

  B) O_2 + $4e^-$ —> $2O^{2-}$

  = 4Na + O_2 —> $4Na^+ + 2O^{2-}$ = $2[(Na^+)_2(O^{2-})_1]$ = $2Na_2O$

  or **4Na + O_2 —> $2Na_2O$**

  .... and we have now identified the ***molar/stoichimetric*** ratio for the reaction!

NB Getting the same number of electrons in each half-equation **IS THE KEY** to doing ionic half-equations. THAT is the essential part of the exercise because it is that which unifies the two half-equations. One half-equation must generate the same number of electrons as the other half-equation needs to complete its reaction.

Synthesis or Combination Reactions

- A Synthesis/Combination reaction takes the form **A + B —> AB** . Possibly the most common type of Synthesis reaction is an Oxidisation Reaction e.g.

- The most common of these is the oxidisation of Iron into "rust". Most metals will oxidise (will react with Oxygen) to form an Oxide of the metal. However, once some metals have become coated with a protective outer layer of the Oxide of the metal, then no further Oxidisation can occur e.g. when aluminium becomes coated with Al_2O_3, then the outer coating stops any further oxidisation of the pure metal.

$$4Al\ (s)\ +\ 3O_2\ (g)\ \longrightarrow\ 2Al_2O_3\ (s)$$

There are many other sorts of reactions, but this Blog serves as an introduction to the subject of "Types of Reactions".