Inorganic Chemistry
Writing (Net Ionic) Equations for Various Reactions

On the AP examination you will encounter a question in which you will be required to write *net ionic equations* for various reactions. In past years, students have been required to choose 5 of 8 reactions. Some of the reactions you will undoubtedly recognize; others you will not! Hopefully, at least of them will be familiar to you!

On the examination you will be given reactions that actually occur - you will not be required to figure out whether or not the reaction actually works, as you did in 'Introductory' Chemistry. You will be required to write equations in *ionic form* - i.e. for **ionic compounds** you write the **anions (-)** and **cations (+)** as separate entities. You also omit the *spectator ions* - those ions that do not take part in the reaction. You wrote several different types of net ionic equations in 'INTRODUCTORY' Chemistry. On this handout, an attempt has been made to summarize the most important types of reactions. **It will not be possible, or useful, for you to learn dozens of specific reactions. Learn the general reactions, and figure out the specifics on the examination!**

<u>FOR THE EXAMINATION YOU WILL NEED TO KNOW:</u>

<u>Formulae For Common Ions</u>
Refer to the *Table of Ionic Charges* - hopefully all the *polyatomic ions* that you will encounter on the examination are on this chart.
Refer also to the *Table of Standard Reduction Potentials*, which you will be given on the examination.

<u>Formulae For Common Acids</u>
Again, refer to the *Table of Ionic Charges*

<u>General Solubility Rules</u>
Refer to the *Solubility Table* - you will need to know the general "trends".

<u>ON THIS HAND-OUT REFERENCE IS MADE TO:</u>
ELEMENTS - both **metals** and **non-metals**
ACIDS - both **dilute** and **concentrated**
BASES - **soluble metal hydroxides** (NaOH and KOH being the most common, by far)
- **soluble carbonates** (Na_2CO_3 and K_2CO_3 being the most common)
- an aqueous solution of **ammonia**, $NH_3(aq)$

SALTS - **ionic** compounds that are neither acids nor bases. In general, **MX**, where **M** is a **metal** and **X** is an **anion** such as Cl^-, So_4^{2-}, PO_4^{3-}
WATER
OXIDES
PEROXIDES
COMBUSTION REACTIONS
REDOX REACTIONS

Precipitation (Double Displacement) Reactions

If you have **two salts** reacting, and a reaction occurs, the chances are excellent that it will be a *precipitation (double displacement)* reaction.

The precipitate will, obviously, be the *insoluble* salt.

Example

Write the *net ionic* equation for the reaction that occurs when an aqueous solution of silver nitrate is added to an aqueous solution of copper(II) chloride.

Answer **$Ag^{+}(aq)$ + $Cl^{-}(aq)$ ---> $AgCl(s)$**

Refer back to the hand-out on *precipitation reactions* which you were given in Term 2.

There could be **two** precipitates, as is the case when an aqueous solution of copper(II) sulphate is added to an aqueous solution of barium hydroxide (**Both** copper(II) hydroxide **and** barium sulphate are **insoluble**)

$Cu^{2+}(aq)$ + $SO_4^{2-}(aq)$ + $Ba^{2+}(aq)$ + $2OH^{-}(aq)$ ---> $Cu(OH)_2(s)$ + $BaSO_4(s)$

Single Displacement Reactions

In 'INTRODUCTORY' Chemistry, you did two "types" of *single displacement* reactions:

METAL ATOM + METAL ION

Example

Write the *net ionic* equation for the *single displacement* reaction that occurs when aluminum is placed in an aqueous solution of copper(II) sulphate

Answer $2Al(s)$ + $3Cu^{2+}(aq)$ ---> $2Al^{3+}(aq)$ + $3Cu(s)$

Use the E^{o} table provided on the examination to assist you with these equations!

HALOGEN MOLECULE + HALIDE ION

Example

Write the *net ionic* equation for the *single displacement* reaction that occurs when chlorine gas is bubbled into an aqueous solution of potassium iodide

Answer $Cl_2(g)$ + $2I^{-}(aq)$ ---> $2Cl^{-}(aq)$ + $I_2(aq)$

Again, use the E^{o} table provided on the examination to assist you with these equations!

Reactions of Metals

WITH NON-METALS

Most metals can be made to react with most common non-metals (excluding the Noble gases); heat is usually required, however.

The reaction is usually a *synthesis*: METAL + NON-METAL ---> SALT

With oxygen **oxide** is formed

With halogens metal **halide** is formed

(When a metal with variable oxidation numbers, such as iron which exists both as Fe^{2+} and Fe^{3+}, reacts with such things as oxygen and halogens, the compounds formed tend to be the ones in which the metal has the **higher** oxidation number. Thus, iron forms $FeCl_3$ when it reacts with chlorine, and Fe_3O_4 when it reacts with oxygen).

With nitrogen difficult to accomplish, but alkali metals and Mg from IIA form **nitrides** (in which the nitrogen is **N^{3-}** ion)
(e.g. Mg + N_2 ---> Mg_3N_2)

With hydrogen Group IA and IIA elements react with hydrogen to form metal **hydrides** (in which the hydrogen exists as **H^{-}** ion)
(e.g. $2Na$ + H_2 ---> $2NaH$)

WITH WATER

If the metal reacts with pure water, the reaction can be summarized as:

METAL + WATER ---> METAL HYDROXIDE + HYDROGEN

(Remember that *alkali metal* hydroxides are **soluble**, and the M^+ and OH^- ions will be written separately) E.g. $2K + 2H_2O \longrightarrow 2K^+ + 2OH^- + H_2$

WITH DILUTE SOLUTIONS OF STRONG ACIDS (excluding HNO_3)

If a metal reacts with a dilute solution of acids such as HCl and H_2SO_4, the reaction that occurs can be summarized as:

METAL + ACID ---> SALT + HYDROGEN

(The salt formed is usually soluble and, consequently, the ions are written separately)

E.g. $Mg + 2H^+ \longrightarrow Mg^{2+} + H_2$

WITH DILUTE NITRIC ACID

HNO_3 is a powerful oxidizing agent, and this is why it is usually employed in reactions.

Some examples you should know are:

Copper + dilute HNO_3

$$3Cu + 8HNO_3 \longrightarrow 3\,Cu(NO_3)_2 + 2NO(g) + 4H_2O$$

Or, in *net ionic* form....

$$3Cu(s) + 8H^+(aq) + 2NO_3^-(aq) \longrightarrow 3Cu^{2+}(aq) + 2NO(g) + 4H_2O$$

WITH CONCENTRATED ACIDS

There are, obviously, numerous different reactions involving concentrated solutions of strong acids. Unfortunately, they do not follow any general patterns, and are difficult to summarise. **You should, however, be aware of the following:**

Copper + concentrated HNO_3

$$Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2NO_2(g) + 2H_2O$$

Alternatively, in *net ionic* form...

$$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \longrightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O$$

Copper +concentrated sulphuric acid

$$Cu + 2H_2SO_4 \longrightarrow CuSO_4 + SO_2 + 2H_2O$$

Alternatively, in *net ionic* form...

$$Cu(s) + 4H^+(aq) + SO_4^{2-}(aq) \longrightarrow Cu^{2+}(aq) + SO_2(g) + 2H_2O$$

Reactions of Non-metals

WITH METALS

This has already been discussed under "metals".

WITH OTHER NON-METALS

Most non-metals can be made to react with other non-metals (excluding the Noble gases); heat is usually required, however.

The reaction is usually a *synthesis*:

NON-METAL$_1$ + NON-METAL$_2$ ---> COVALENT COMPOUND

With oxygen covalent **oxide** is formed (S forms SO_2, P forms P_4O_{10})

With halogens covalent **halide** is formed

With hydrogen Covalent **hydrides** are formed. E.g. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Reactions of Acids

NEUTRALIZATION REACTIONS

Reaction with Hydroxides

ACID + HYDROXIDE ---> SALT + WATER

The *net ionic* equation for an acid/hydroxide neutralization usually come down to:

$$H^+(aq) + OH^-(aq) \text{ ---> } H_2O$$

The salt formed is usually **soluble**, and the ions involved ar, therefore, *spectator ions*.
It is, however, possible to have **both** a *neutralization* reaction **and** a *precipitation* reaction occurring, as is the case when barium hydroxide solution is added to sulphuric acid:

$$Ba^{2+}(aq) + 2OH^-(aq) + 2H^+(aq) + SO_4^{2-}(aq) \text{ ---> } BaSO_4(s) + 2H_2O$$

Reaction with Carbonates

ACID + CARBONATE ----> SALT + WATER + CARBON DIOXIDE

The *net ionic* equation for an acid/carbonate neutralization very often comes down to:

$$2H^+(aq) + CO_3^{2-}(aq) \text{----> } H_2O + CO_2(g)$$

T his is the equation of the carbonate used is in aqueous solution. It could, however, be in solid form, as is the case if a (weak) acid is added to a kettle to dissolve the solid **scale** ($CaCO_3$) that often builds up inside it:

$$CaCO_3(s) + 2H^+(aq) \text{ ----> } Ca^{2+}(aq) + H_2O + CO_2(g)$$

Also check to see if the salt formed is *soluble* or *insoluble*. Both of the above equations assume that the salt formed is **soluble**.

Reaction with Metals

METALS WITH DILUTE SOLUTIONS OF STRONG ACIDS (excluding HNO_3)

If a metal reacts with a dilute solution of acids such as HCl and H_2SO_4, the reaction that occurs can be summarised as:

METAL + ACID ---> SALT + HYDROGEN

e.g. $Mg(s) + 2H^+(aq) \text{ ---> } Mg^{2+}(aq) + H_2(g)$

(The salt formed is usually soluble and, consequently, the ions are written separately)

METALS WITH DILUTE NITRIC ACID

HNO_3 is a powerful oxidising agent, and this is why it is usually employed in reactions.

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$$3Cu + 8HNO_3 \text{ ---> } 3\,Cu(NO_3)_2 + 2NO(g) + 4H_2O$$

Alternatively, in *net ionic* form....

$$3Cu(s) + 8H^+(aq) + 2NO_3^-(aq) \text{ ----> } 3Cu^{2+}(aq) + 2NO(g) + 4H_2O$$

METALS WITH CONCENTRATED ACIDS

There are, obviously, numerous different reactions involving concentrated solutions of strong acids. Unfortunately, they do not follow any general patterns, and are difficult to summarise. **You should, however, be aware of the following:**

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Alternatively, in *net ionic* form...

$$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \text{ ----> } Cu^{2+}(aq) + 2NO_2(g) + 2H_2O$$

Copper +concentrated sulphuric acid

$$Cu + 2H_2SO_4 \text{ ---> } CuSO_4 + SO_2 + 2H_2O$$

Alternatively, in *net ionic* form...

$$Cu(s) + 4H^+(aq) + SO_4^{2-}(aq) \text{ ----> } Cu^{2+}(aq) + SO_2(g) + 2H_2O$$

Reactions with Metallic Oxides

Since ionic oxides are **basic**, a **neutralization** reaction will occur when an ionic oxide reacts with a base (**salt** and **water** being formed).

Example

Write the *net ionic equation* for the reaction of solid magnesium oxide with dilute sulphuric acid

Answer: $\mathbf{MgO(s) + 2H^{+}(aq) \dashrightarrow Mg^{2+}(aq) + H_2O}$

Miscellaneous Reactions Involving Acids

Preparation of chlorine gas

Conc. HCl + MnO_2: $MnO_2(s) + 4\,HCl \dashrightarrow MnCl_2(aq) + Cl_2 + 2\,H_2O$

Or, in *net-ionic* form...... $MnO_2 + 4H^+ + 2Cl^- \dashrightarrow Mn^{2+} + Cl_2 + 2H_2O$

Conc. HCl + $KMnO_4$: $2KMnO_4(s) + 16\,HCl \dashrightarrow 2\,KCl(aq) + 2\,MnCl_2(aq) + 5\,Cl_2 + 8\,H_2O$

Or, in *net ionic* form..... $2KMnO_4 + 16H^+ + 10Cl^- \dashrightarrow 2K^+ + 2Mn^{2+} + 5Cl_2 + 8H_2O$

Reactions of Hydroxides

REACTION WITH ACIDS

ACID + HYDROXIDE ----> SALT + WATER

The *net ionic* equation for an acid/hydroxide neutralization usually come down to:

$\mathbf{H^{+}(aq) + OH^{-}(aq) \longrightarrow H_2O}$

The salt formed is usually **soluble**, and the ions involved are, therefore, *spectator ions*.

It is, however, possible to have **both** a *neutralization* reaction **and** a *precipitation* reaction occuring, as is the case when barium hydroxide solution is added to sulphuric acid:

$\mathbf{Ba^{2+}(aq) + 2OH^{-}(aq) + 2H^{+}(aq) + SO_4^{2-}(aq) \dashrightarrow BaSO_4(s) + 2H_2O}$

REACTION WITH NON-METALLIC (COVALENT) OXIDES AND WITH AMPHOTERIC OXIDES

Since covalent oxides are **acidic**, a **neutralization** reaction will occur when a covalent oxide reacts with a base (**salt** and **water** being formed).

Example

Write the *net ionic equation* for the reaction of sulphur dioxide gas with sodium hydroxide solution

Answer: $\mathbf{SO_2(g) + 2OH^{-}(aq) \dashrightarrow SO_3^{2-}(aq) + H_2O}$

MISCELLANEOUS REACTIONS INVOLVING NaOH AND KOH

KOH(aq) and Hydrogen Sulphide (H_2S) gas

Hydrogen Sulphide is a *weak acid*, therefore **neutralization** occurs

$\mathbf{H_2S(g) + 2OH^{-}(aq) \dashrightarrow S^{2-}(aq) + 2H_2O}$ (K^+ ions are *spectator*)

Cl_2(g) and cold, dilute NaOH

$\mathbf{Cl_2(g) + 2OH^{-}(aq) \longrightarrow OCl^{-}(aq) + Cl^{-}(aq) + H_2O}$

Reactions of Oxides

You have already learned that **metals tend to form ionic *oxides* that are *basic*; whereas non-metals tend to form covalent oxides that are *acidic*. Aluminum, chromium and zinc form *amphoteric* oxides.**

REACTIONS OF IONIC (BASIC) OXIDES

Decomposition

Most ionic oxides are very stable, but the oxides of metals low in the Activity Series do decompose on heating. For example: **$2Ag_2O \text{ ---->} 4Ag + O_2$**

Reaction With Water

Most ionic oxides are insoluble in water, but those that do dissolve (oxides of Group IA & IIA metals) form OH^- ions:

Examples: **$Na_2O(s) + H_2O \text{ --->} 2Na^+(aq) + 2OH^-(aq)$**
$CaO(s) + H_2O \text{ --->} Ca^{2+}(aq) + 2OH^-(aq)$

Reaction With Acids

Since ionic oxides are **basic**, a **neutralization** reaction will occur when an ionic oxide reacts with a base (**salt** and **water** being formed).

Example

Write the *net ionic equation* for the reaction of solid magnesium oxide with dilute sulphuric acid

Answer: **$MgO(s) + 2H^+(aq) \text{ --->} Mg^{2+}(aq) + H_2O$**

Reaction With Carbon

When the oxide is heated with carbon, the carbon will often **reduce** the oxide to the **pure metal**. This is often the way a metal is extracted from its ore.

For example: **$2PbO(s) + C(s) \text{ --->} 2Pb(s) + CO_2(g)$**

Reaction With Hydrogen

When the oxide is heated with hydrogen gas, the hydrogen will often **reduce** the oxide to the **pure metal**.

For example: **$CuO(s) + H_2(g) \text{ --->} Cu(s) + H_2O(g)$**

REACTIONS OF COVALENT (ACIDIC) OXIDES

Reaction With Water

Covalent oxides usually dissolve in water and, when they do so, an **acid** is formed.

Examples: **$SO_3(g) + H_2O \text{ --->} SO_4^{2-}(aq) + 2H^+(aq)$** (sulphuric acid)
$CO_2(g) + H_2O \text{ --->} CO_3^{2-}(aq) + 2H^+(aq)$ (carbonic acid)
$P_2O_5(g) + 3H_2O \text{ --->} PO_4^{3-}(aq) + 6H^+(aq)$ (phosphoric acid)

Reaction With Bases

Since covalent oxides are **acidic**, a **neutralization** reaction will occur when a covalent oxide reacts with a base (**salt** and **water** being formed).

Example

Write the *net ionic equation* for the reaction of sulphur dioxide gas with sodium hydroxide solution

Answer: **$SO_2(g) + 2OH^-(aq) \text{ --->} SO_3^{2-}(aq) + H_2O$**

REACTIONS OF AMPHOTERIC OXIDES

Amphoteric oxides (such as Al_2O_3, Cr_2O_3 and ZnO) do not dissolve in water but, since they are amphoteric, they react with **acids** and with **bases**.

For example: **$Al_2O_3(s) + 6H^+(aq) \text{ ---->} 2Al^{3+}(aq) + 3H_2O$**
$Al_2O_3(s) + 2OH^-(aq) \text{ ---->} 2AlO_2^-$ $(aq) + H_2O$

Reactions of Peroxides

A **peroxide** can be distinguished from the "normal" oxide by the fact that it contains more oxygen than "normal". Peroxides actually contain the **O-O bond**.

Decomposition

Peroxides are not particularly stable, and they decompose when heated gently.

For example: $Na_2O_2(s) \longrightarrow Na_2O(s) + \frac{1}{2}O_2(g)$

$H_2O_2(l) \longrightarrow H_2O(l) + \frac{1}{2}O_2(g)$

Note that the decomposition of H_2O_2 can be **catalysed** by the addition of powdered **solid manganese dioxide (MnO_2)** or **$KMnO_4$.**

Reaction With Water

When solid sodium peroxide is added to water, the following reaction occurs:

$$Na_2O_2(s) + 2\,H_2O \longrightarrow 2Na^+(aq) + 2OH^-(aq) + H_2O_2(l)$$

Reactions of Water

REACTION WITH METALS

If the metal reacts with pure water, the reaction can be summarised as:

METAL + WATER ---> METAL HYDROXIDE + HYDROGEN

(Remember that *alkali metal* hydroxides are **soluble**, and the M^+ and OH^- ions will be written separately) E.g. $Ca + 2H_2O \longrightarrow Ca^{2+} + 2OH^- + H_2$

REACTION OF METAL OXIDES

Most ionic oxides are insoluble in water, but those that do dissolve (oxides of Group IA & IIA metals) form OH^- ions:

Examples: $Na_2O(s) + H_2O \longrightarrow 2Na^+(aq) + 2OH^-(aq)$

$CaO(s) + H_2O \longrightarrow Ca^{2+}(aq) + 2OH^-(aq)$

REACTION OF METAL PEROXIDES

When solid sodium peroxide is added to water, the following reaction occurs:

$$Na_2O_2(s) + 2\,H_2O \longrightarrow 2Na^+(aq) + 2OH^-(aq) + H_2O_2(l)$$

REACTION OF NON-METAL OXIDES

Covalent oxides usually dissolve in water and, when they do so, an **acid** is formed.

Examples: $SO_3(g) + H_2O \longrightarrow SO_4^{2-}(aq) + 2H^+(aq)$ (sulphuric acid)

$CO_2(g) + H_2O \longrightarrow CO_3^{2-}(aq) + 2H^+(aq)$ (carbonic acid)

REACTION OF METAL HYDRIDES

Metal hydrides react with water to give hydroxides and hydrogen gas.

For example: $NaH(s) + H_2O \longrightarrow Na^+(aq) + OH^-(aq) + H_2(g)$

Reactions of Ammonia

An aqueous solution of ammonia consists of the following equilibrium mixture:

$$NH_3(aq) \;+\; H_2O \;\text{<---->}\; NH_4^+(aq) \;+\; OH^-(aq)$$

AMMONIA IS A WEAK BASE, SINCE IT CONTAINS THE OH^- ION

Ammonia will undergo the "hydroxide **neutralization** reactions" mentioned earlier, but remember it is a **weak** base.

COMPLEX ION FORMATION

In Term 1 you found that $NH_3(aq)$ would dissolve a white ppt. of AgCl(s) due to the formation of a **complex ion.** The equation for the reaction is:

$$AgCl(s) \;+\; 2NH_3(aq) \;\text{--->}\; Ag(NH_3)_2^+(aq) \;+\; Cl^-(aq)$$

PRECIPITATION REACTIONS

Since most **hydroxides are insoluble**, and an aqueous ammonia solution **contains OH^- ions**, numerous salts will form precipitates when mixed with aqueous ammonia solution.

Example 1: Aqueous ammonia plus iron(III) chloride solution

$$Fe^{3+}(aq) \;+\; 3OH^-(aq) \;\text{--->}\; Fe(OH)_3(s)$$

Example 2: Aqueous ammonia and zinc iodide solution

$$Zn^{2+}(aq) \;+\; 2OH^-(aq) \;\text{--->}\; Zn(OH)_2(s)$$

AMMONIA ACTING AS A *LEWIS BASE*

Remember: a *Lewis base* is an electron pair donor

Write the equation for the reaction that occurs between ammonia and boron fluoride

Oxidation-Reduction (Redox) Reactions

REACTIONS INVOLVING Fe(II) AND Fe(III) IONS

In 'INTRODUCTORY' Chemistry you came across the following reactions:

$$Fe(s) \;+\; 2\,Fe^{3+}(aq) \;\text{--->}\; 3\,Fe^{2+}(aq)$$

$$Fe^{2+}(aq) \;+\; Cl_2(aq) \;\text{--->}\; Fe^{3+}(aq) \;+\; 2\,Cl^-(aq)$$

REACTIONS INVOLVING THE PERMANGANATE ION AND THE DICHROMATE ION

Two of the most common **oxidising agents** employed in the laboratory are **permanganate (MnO_4^-)** and **dichromate ($Cr_2O_7^{2-}$). The reduction half-equations are as follows:**

$$MnO_4^-(aq) \;+\; 8H^+(aq) \;+ 5e^- \;\text{--->}\; Mn^{2+}(aq) \;+\; 4H_2O$$

$$Cr_2O_7^{2-}(aq) \;+\; 14H^+(aq) \;+\; 6e^- \;\text{--->}\; 2Cr^{3+}(aq) \;+\; 7H_2O$$

If you come across reactions involving either permanganate or dichromate, it is safe to assume that they will be **redox reactions**, and that the MnO_4^- or $Cr_2O_7^{2-}$ ions will be **reduced**. Something else, obviously, will be **oxidised**. For example, Fe^{2+} could be oxidised to Fe^{3+} or Sn^{2+} could be oxidised to Sn^{2+}

Write net ionic equations for each of the following reactions

Iron(II) chloride solution reacting with an acidified solution of potassium permanganate

Tin(II) chloride solution reacting with an acidified solution of potassium dichromate

Combustion Reactions

ELEMENTS
Most elements undergo combustion to form **oxides**. The **synthesis** reaction can be summarised as: **ELEMENT + OXYGEN ---> OXIDE**

ORGANIC COMPOUNDS
Most organic compounds undergo combustion. You have encountered these combustion reactions several times before.
The **hydrogen** in the organic compound becomes **water**.
The **carbon** in the organic compound becomes **CO_2** when the combustion is **complete**, and either **CO** or **C** when the combustion is **incomplete**.
The **sulphur**, if it exists, becomes **$SO_2(g)$**.
The **nitrogen**, if it exists, becomes

METALLIC AND NON-METALLIC SULPHIDES
When a **metallic (or non-metallic) sulphide** is strongly heated in oxygen, both the metal (or non-metal) and the sulphur from the sulphide are **oxidised**. For example:

$$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$$
$$2Bi_2S_3 + 9O_2 \longrightarrow 2Bi_2O_3 + 6SO_2$$
$$2H_2S + 3O_2 \longrightarrow 2H_2O + 2SO_2$$
$$CS_2 + 3O_2 \longrightarrow CO_2 + 2SO_2$$

Reactions with Carbonates and Bicarbonates

HEATING CARBONATES AND BICARBONATES
Decomposition occurs. For example:

$$CuCO_3 \longrightarrow CuO + CO_2$$
$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$
$$(NH_4)_2CO_3 \longrightarrow 2NH_3 + CO_2 + H_2O$$

REACTIONS OF CARBONATES WITH DILUTE ACIDS
ACID + CARBONATE ----> SALT + WATER + CARBON DIOXIDE

The *net ionic* equation for an acid/carbonate neutralization very often comes down to:

$$2H^+(aq) + CO_3^{2-}(aq) \longrightarrow H_2O + CO_2(g)$$

T his is the equation of the carbonate used is in aqueous solution. It could, however, be in solid form, as is the case if a (weak) acid is added to a kettle to dissolve the solid **scale** ($CaCO_3$) that often builds up inside it:

$$CaCO_3(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + H_2O + CO_2(g)$$

Also check to see if the salt formed is *soluble* or *insoluble*. Both of the above equations assume that the salt formed is **soluble**.

LIMEWATER REACTIONS

Limewater is a solution of $Ca(OH)_2$, and is employed as the usual test for CO_2 gas. When CO_2 is bubbled into limewater, it first turns "milky" due to the formation of a white ppt. of $CaCO_3$. If you keep bubbling the CO_2, however, the solution turns clear again since $Ca(HCO_3)_2(aq)$ is formed. The two equations are:

$$Ca(OH)_2(aq) + CO_2(g) \text{ ----> } CaCO_3(s) + H_2O$$
$$CaCO_3(s) + CO_2(g) + H_2O \text{ ----> } Ca(HCO_3)_2(aq)$$

Reactions for making some common gases in the laboratory

PREPARATION OF OXYGEN GAS BY HEATING POTASSIUM (OR SODIUM) CHLORATE

$$KClO_3(s) \text{ ----> } KCl(s) + 3O_2(g)$$

PREPARATION OF SULPHUR DIOXIDE BY REACTING COPPER WITH CONCENTRATED SULPHURIC ACID

$$Cu + 2H_2SO_4 \text{ ---> } CuSO_4 + SO_2 + 2H_2O$$

Or, written in *net ionic* form.....

$$Cu + 4H^+ + SO_4^{2-} \text{ ---> } Cu^{2+} + SO_2 + 2H_2O$$

PREPARATION OF CHLORINE GAS BY REACTING CONCENTRATED HYDROCHLORIC ACID EITHER WITH SOLID MANGANESE DIOXIDE OR WITH SOLID POTASSIUM PERMANGANATE

Conc. HCl + MnO_2: $MnO_2(s) + 4\,HCl \text{ ---> } MnCl_2(aq) + Cl_2 + 2\,H_2O$

Or, in *net-ionic* form...... $MnO_2 + 4H^+ + 2Cl^- \text{ ---> } Mn^{2+} + Cl_2 + 2H_2O$

Conc. HCl + $KMnO_4$: $KMnO_4(s) + 16\,HCl \text{ ---> } 2\,KCl(aq) + 2\,MnCl_2(aq) + 5\,Cl_2 + 8\,H_2O$

Or, in *net ionic* form..... $2KMnO_4 + 16H^+ + 10Cl^- \text{ ---> } 2K^+ + 2Mn^{2+} + 5Cl_2 + 8H_2O$

PREPARATION OF HYDROGEN SULPHIDE GAS BY REACTING A METALLIC SULPHIDE BY DILUTE HYDROCHLORIC OR SULPHURIC ACID

For example: $FeS(s) + 2H^+(aq) \text{ ----> } Fe^{2+}(aq) + H_2S(g)$

PREPARATION OF SOME OXIDES OF NITROGEN

Copper + dilute nitric acid

$$3Cu + 8HNO_3 \text{ ---> } 3\,Cu(NO_3)_2 + 2NO(g) + 4H_2O$$

Or, written in net ionic form.....

$$3Cu(s) + 8H^+(aq) + 2NO_3^-(aq) \text{ ----> } 3Cu^{2+}(aq) + 2NO(g) + 4H_2O$$

Copper + concentrated nitric acid

$$Cu + 4HNO_3 \text{ ---> } Cu(NO_3)_2 + 2NO_2(g) + 2H_2O$$

Or, written in net ionic form.....

$$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \text{ ----> } Cu^{2+}(aq) + 2NO_2(g) + 2H_2O$$

Miscellaneous Reactions

Making Sulphur Trioxide $2SO_2(g) + O_2(g) \text{ ----> } 2SO_3(g)$

Sodium Thiosulphate and Hydrochloric Acid
Remember the *reaction rate experiment*?
$S_2O_3^{2-}(aq) + 2H^+(aq) \text{ ----> } SO_2(g) + S(s) + H_2O$

Preparing Acetylene
Remember this one from Term 1?
$CaC_2(s) + H_2O \text{ ----> } CaO(s) + C_2H_2(g)$

Heating a hydrate
You did this several times in 'INTRODUCTORY' chemistry.
For example: $CuSO_4.5H_2O \text{ ----> } CuSO_4 + 5H_2O$

Ammonium thiocyanate solution and iron(III) chloride solution
Remember the reaction from Experiment 15 (Equilibrium)?
$Fe^{3+}(aq) + SCN^-(aq) \text{ ----> } FeSCN^{2+}(aq)$

Electrolysis Reactions
These will be covered in the final unit of the course. Do not despair, they are simple!!