Applied Science - Brushing Up Your Knowledge!

This work is designed to help you prepare for the first topics you will encounter in Applied Science. A good understanding of these topics is vital as it underpins everything you will learn about.

Many of the topics we cover below will be familiar to you from GCSE but at Level 3 you need to be able to apply your knowledge quickly and so the following sections are to help you boost your existing knowledge and to allow you to tackle exam questions of these types without worry.

Work your way through the pack, reading the information and examples carefully before you attempt the questions. You will need to bring the complete booklet to your first Applied Science lesson.

Chemical Formula

Table of common ions:

1+	1-	2+	2-	3+
Lithium Li^+	Chloride Cl^-	Magnesium Mg^{2+}	Sulphate SO_4^{2-}	Aluminium Al^{3+}
Sodium Na^+	Bromide Br^-	Calcium Ca^{2+}	Carbonate CO_3^{2-}	Iron III Fe^{3+}
Potassium K^+	Iodide I^-	Zinc Zn^{2+}	Oxide O^{2-}	
Silver Ag^+	Hydroxide OH^-	Copper Cu^{2+}	Sulphide S^{2-}	
Ammonium NH_4^+	Nitrate NO_3^-	Lead Pb^{2+}		
Hydrogen H^+	Hydrogencarbonate HCO_3^-	Iron II Fe^{2+}		

Writing a chemical formula – the rules!

- Ionic compounds are neutral, so the number of positively charged ions and negatively charged ions in a formula must always be equal.
- Charges are never written in a chemical formula.
- The number of ions in a formula is written after the symbol and below the line, eg. $MgCl_2$ is made of 1 Mg ion and 2 Cl ions.
- Some ions contain more than one atom, such as NO_3^-. If you more than one of these ions in a formula, brackets must be used, eg. $(NO_3)_2$.

Now use these rules to work out the formulae of the following compounds:

1)	calcium bromide	………………	11)	hydrogen bromide	………………
2)	aluminium fluoride	………………	12)	barium iodide	………………
3)	potassium sulphide	………………	13)	zinc sulfate	………………
4)	magnesium nitrate	………………	14)	ammonium carbonate	………………
5)	silver nitrate	………………	15)	iron (III) hydroxide	………………
6)	ammonium chloride	………………	16)	lithium oxide	………………
7)	copper carbonate	………………	17)	sodium sulfate	………………
8)	iron (II) sulfate	………………	18)	calcium hydroxide	………………
9)	iron (III) sulfate	………………	19)	potassium hydrogencarbonate	………………
10)	copper oxide	………………	20)	aluminium oxide	………………

Balancing Equations

Balancing chemical equations is the stepping stone to using equations to calculate masses in chemistry. The guidelines are:

- Calculate how many atoms of each type of are on either side of the equation
- If it is the same then it is balanced – job done.
- If it is not the same then the quantities of each part of the equation may need to be changed to make them balance. You can only change quantities by using a large number in front of the reactant or product and NOT small subscript numbers in the formula as the FORMULA MUST stay the SAME. (start with the elements that are not balanced first but remember you change the quantity of every atom in the molecule)
- Keep doing this until the numbers of each type of atom are the same on either side
- Check and make sure that these numbers are the smallest ratio they can be.

NB – Atoms cannot be created or destroyed so what you have at the beginning, you must have at the end.

Beginner level

1) $Ca + O_2 \rightarrow CaO$

2) $Na_2O + H_2O \rightarrow NaOH$

3) $Al + O_2 \rightarrow Al_2O_3$

4) $Na + Cl_2 \rightarrow NaCl$

5) $Na_2CO_3 \rightarrow Na_2O + CO_2$

6) $K + O_2 \rightarrow K_2O$

7) $C_4H_8 + O_2 \rightarrow CO_2 + H_2O$

8) $Fe_2O_3 + HCl \rightarrow FeCl_3 + H_2O$

9) $F_2 + KBr \rightarrow KF + Br_2$

10) $C_5H_{12} + O_2 \rightarrow CO_2 + H_2O$

11) $NH_3 + O_2 \rightarrow NO + H_2O$

12) $HNO_3 \rightarrow NO_2 + H_2O + O_2$

Intermediate Level

1) $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$

2) $NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

3) $FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$

4) $Al + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2$

5) $MgO + HNO_3 \rightarrow Mg(NO_3)_2 + H_2O$

6) $Ba(OH)_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O$

7) $Ca(OH)_2 + HNO_3 \rightarrow Ca(NO_3)_2 + H_2O$

8) $PCl_3 + H_2O \rightarrow P(OH)_3 + HCl$

9) $Cu + HNO_3 \rightarrow Cu(NO_3)_2 + H_2O + NO$

10) $Pb_3O_4 + HNO_3 \rightarrow Pb(NO_3)_2 + PbO_2 + H_2O$

Challenge

1) $Zn + HNO_3 \rightarrow Zn(NO_3)_2 + H_2$

2) $SO_2 + O_2 \rightarrow SO_3$

3) $C + CO_2 \rightarrow CO$

4) $Al(OH)_3 + HNO_3 \rightarrow Al(NO_3)_3 + H_2O$

5) $C_6H_{12} + O_2 \rightarrow CO_2 + H_2O$

6) $Br_2 + NaOH \rightarrow NaBr + NaOBr + H_2O$

7) $F_2 + KBr \rightarrow KF + Br_2$

8) $CuCO_3 \rightarrow CuO + CO_2$

9) $Li + O_2 \rightarrow Li_2O$

10) $Ba + H_2O \rightarrow Ba(OH)_2 + H_2$

The Mole

Counting atoms and molecules

Chemists are able to count atoms and molecules of different elements and compounds by weighing them. This is because atoms of different elements have different masses.
We call the mass of an atom, the **relative atomic mass, Ar.** This is defined as the average mass of all the atoms of an element relative to the mass of the carbon-12 isotope which is given exactly the mass of 12.

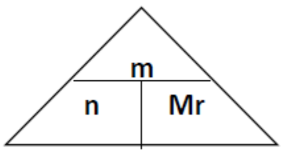
The mole is a number. It is equal to the number of atoms in 12g of the carbon 12 isotope. All relative atomic and molecular masses are compared to the mass of the carbon 12 isotope. So for all atoms and molecules, the atomic/molecular mass in grams always contains 1 mole of particles. This mass is often referred to as the **molar mass, relative atomic mass or relative molecular mass**.

The number of particles in one mole of a substance is called **Avogadro's Constant** and is equal to **6×10^{23}**.

Equal numbers of moles always contain the same number of particles and so the mole can be used as a link between chemical equations showing number of particles (stoichiometry) and reacting quantities (ie. masses of substances).

The link between mass and number of moles can be written as:

$$n = \frac{m}{Mr}$$



n = number of moles
m = mass in grams (g)
Mr = relative molecular mass

Formula mass

Work out the formula mass of the following:

a) F_2 ……………………………………………………………………………………………

b) Fe ……………………………………………………………………………………………

c) H_2SO_4 ……………………………………………………………………………………………

d) Al_2O_3 ……………………………………………………………………………………………

e) $Mg(OH)_2$ ……………………………………………………………………………………………

f) $Al(NO_3)_3$ ……………………………………………………………………………………………

g) $(NH_4)_2SO_4$……………………………………………………………………………………………

Moles Calculations

Exercise 1: Calculate the number of moles in the following:

a) 90 g of H_2O ....

....

b) 20 g of C_4H_{10} ....

....

c) 680 g of NH_3 ....

....

d) 100 g of O_2 ....

....

e) 1 kg of Al_2O_3 ....

....

f) 20 mg of Au ....

....

Exercise 2: Calculate the mass of the following:

a) 4 moles of N_2 ....

....

b) 0.1 moles of HNO_3 ....

....

c) 0.02 moles of K_2O ....

....

d) 2.5 moles of PH_3 ....

....

e) 0.40 moles of C_2H_5OH ....

....

f) 10 moles of $Ca(OH)_2$ ....

....

Reacting Masses

Try using what you know about moles to answer the following questions.

1) Aluminium is extracted from aluminium oxide as shown. Calculate the mass of aluminium that can be formed from 1020 g of aluminium oxide.

$2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2$

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....

....

2) Calculate the mass of oxygen needed to react 10 g of calcium to form calcium oxide.

$2\ Ca + O_2 \rightarrow 2\ CaO$

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3) What mass of propane could burn in 50 g of oxygen?

$C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

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....

4) What mass of ammonia can be made from 20 g of hydrogen?

$3\ H_2 + N_2 \rightarrow 2\ NH_3$

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....

5) What mass of sodium hydroxide is needed to neutralise 10 kg of sulfuric acid?

$H_2SO_4 + 2\ NaOH \rightarrow Na_2SO_4 + 2\ H_2O$

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6) What mass of carbon dioxide is formed when 10 g of copper carbonate decomposes on heating?

$CuCO_3 \rightarrow CuO + CO_2$

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Reacting Masses – Challenge

Try these as a bit more of a challenge:

1) Titanium is extracted from titanium chloride as shown. Calculate the mass of sodium needed to react with 10 g of titanium chloride. $TiCl_4 + 4 Na \rightarrow Ti + 4 NaCl$

....

....

....

2) Calculate the mass of oxygen needed to react 50 g of magnesium to form magnesium oxide. $2 Mg + O_2 \rightarrow 2 MgO$

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3) What mass of ethanol could burn in100 g of oxygen? $C_2H_5OH + 3 O_2 \rightarrow 2 CO_2 + 3 H_2O$

....

....

....

4) What mass of hydrogen is formed when 2 g of magnesium reacts with sulfuric acid? $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

....

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5) What mass of aluminium reacts with 50 g of chlorine to form aluminium chloride? $2 Al + 3 Cl_2 \rightarrow 2 AlCl_3$

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Percentage Yields

Percentage Yield Calculations

We have seen how to work out how much **product should** be produced in a reaction using relative molecular mass (mole) calculations. This is called the **theoretical yield**. In reality, some product is always lost during the process of making the product so we never actually get the full amount. The amount of product actually made in an experiment is called the **actual yield**. We can calculate the actual yield as a percentage of the theoretical yield as follows:

$$\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Now try these:

1) Ammonia is made by reacting hydrogen with nitrogen. $3\ H_2 + N_2 \rightarrow 2\ NH_3$

a) Calculate the mass of ammonia that can be formed from 12 g of hydrogen.

....

....

....

b) 20 g of ammonia was formed in this reaction. Calculate the percentage yield..

....

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....

2) Iron is made by reduction of iron oxide with carbon monoxide. $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$

a) Calculate the mass of iron that can be formed from 100 g of iron oxide.

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b) 65 g of iron was formed in this reaction. Calculate the percentage yield.

....

....

3) Chlorine can be made by the electrolysis of sodium chloride solution. $2\ NaCl + 2\ H_2O \rightarrow 2\ NaOH + Cl_2 + H_2$

a) Calculate the mass of chlorine that can be formed from 50 g of sodium chloride.

....

....

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b) 25 g of chlorine was formed in this reaction. Calculate the percentage yield.

....

....

4) Chromium is a useful metal. It is extracted from chromium oxide by reaction with aluminium. $Cr_2O_3 + 2\ Al \rightarrow 2\ Cr + Al_2O_3$

a) Calculate the mass of chromium that can be formed from 1 kg of chromium oxide.

....

....

....

b) 600 g of chromium was formed in this reaction. Calculate the percentage yield.

....

....

5) Titanium is made by the reaction of titanium chloride with sodium. $TiCl_4 + 4\ Na \rightarrow Ti + 4\ NaCl$

a) Calculate the mass of titanium that can be formed from 10 kg of titanium chloride.

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c) 1950 g of titanium was formed in this reaction. Calculate the percentage yield.

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Percentage Composition

Sometimes the mass of an element in a compound can be given as a percentage. This can be worked out quite easily.

Example:
Calculate the % by mass of magnesium and oxygen in magnesium oxide.
[Ar (Mg) = 24, Ar (O) = 16]

(i) First work out the Relative molecular mass of magnesium oxide:

MgO Mr = 24 + 16 = 40

(ii) Next, work out how much of the total relative formula mass of the compound comes from each element:

Total mass = 40
Mass of magnesium = 24
Mass of oxygen = 16

(iii) Now, work out for each element the fraction of the total mass of the compound as a percentage:

$$\% \text{ composition} = \frac{\text{Mass of element}}{\text{Total mass of compound}} \times 100$$

So for Magnesium Oxide (MgO)
Magnesium = (24/40) x 100 = **60%**
Oxygen = (16/40) x 100 = **40%**

Now try these:

Calculate percentage by mass of the element shown in the following substances.

a) O in Fe_2O_3 ....

.... (1)

b) O in $MgSO_4.7H_2O$ ....

.... (1)

Do You Know Your Salt?

At A level we expect you to know the 3 reactions of acids that produce salts. In the space below, write out the general word equations for these reactions and then add an example of a specific reaction with an acid to get the salt.

____________+________________→_______________+________________

____________+________________→_______________+________________

____________+________________→_______________+________________

ACIDS

Substances that react with water to release H^+ ions.

Common acids

H_2SO_4	sulfuric acid
HCl	hydrochloric acid
HNO_3	nitric acid
H_3PO_4	phosphoric acid
CH_3COOH	ethanoic acid

BASES

Substances that react with acids to form a salt and water (& sometimes carbon dioxide as well)

Common bases

metal oxides,	e.g. CaO, Al_2O_3, Na_2O, CuO
metal hydroxides,	e.g. $Ca(OH)_2$, NaOH, KOH
metal carbonates,	e.g. $CaCO_3$, Na_2CO_3, $CuCO_3$

ALKALIS

These are a special type of base.

Substances that react with water to release OH^- ions.

Common alkalis

NH_3 ammonia

plus water soluble metal hydroxides:

NaOH	sodium hydroxide
KOH	potassium hydroxide
$Ca(OH)_2$	calcium hydroxide

SALTS

Ionic substances formed when acids react with bases

Common bases

sulfates	made from sulfuric acid
chlorides	made from hydrochloric acid
nitrates	made from nitric acid
phosphates	made from phosphoric acid
ethanoates	made from ethanoic acid
citrates	made from citric acid

Put the following substances into the correct boxes to show examples:

MgO	Na_2SO_4	KNO_3	HNO_3	K_2CO_3	LiOH	KCl	NaBr	Fe_2O_3	$NiCO_3$	HCl	K_2O	NH_3	CuO
$Ca(NO_3)_2$	$CuSO_4$	CH_3COOH	Al_2O_3	RbOH	AgCl	Na_3PO_4	zinc citrate	$ZnCO_3$	$PbBr_2$	H_2SO_4	Li_2CO_3	$Ba(OH)_2$	KI

Notes