NATIONAL 5 CHEMISTRY

FORMULAE AND CALCULATIONS

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Formula Mass

Formula mass is the total mass of all the different parts of a chemical formula.

- Use the relative atomic masses listed in your data book
- Use the 'Ls' !

Example
Calculate the formula mass of $MgCl_2$

$MgCl_2$

$2 \times 35.3 = 71$
$1 \times 24.5 = 24.5$

95.5

Tip – remember that formula mass has no units.

Calculate the formula mass of each of the following:

a) NaOH
b) H_2O
c) $AlBr_3$
d) Calcium sulphide
e) Magnesium sulphate
f) Lithium phosphide
g) Potassium phosphate
h) Dinitrogen trioxide

Tip – remember to use the valency swap over rule when writing chemical formulae. Don't forget that you don't use this rule when dealing with prefixes like di and tri.

Gram Formula Mass – The Mole

The mass of one mole of a substance is equal to the gram formula mass of that substance (the formula mass in grams).

To calculate the mass of 1 mole of a substance first calculate the formula mass then add the unit 'g' for grams.

Example
Calculate the mass of 1 mole of aluminium oxide.

First you need the correct chemical formula – use the valency swap over rule:

	Al	O
Valency	3	2
Swap	2	3
Formula	Al_2O_3	

Now calculate the gram formula mass:

Al_2O_3

3 x 16 = 48
2 x 27 = 54

102g

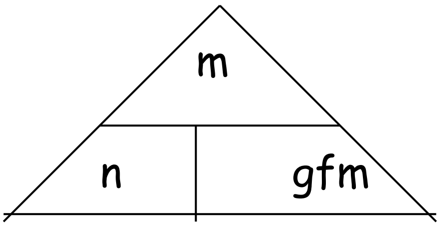
Tip – don't forget to add the unit 'g' to your answer.

Calculate the mass of 1 mole of each of the following:

a) Magnesium hydroxide
b) Potassium permanganate
c) Ammonium nitrate
d) Aluminium phoshate
e) Calcium nitride
f) Boron tribromide
g) Phosphorus pentachloride
h) Iron (III) sulphide
i) Copper (I) bromide
j) Lead (II) iodide

Tip – don't forget to add the unit 'g' to your answer.

Mole Calculations involving Masses of solids



m = the mass of the substance given in the question

n = number of moles

gfm = the mass of 1 mole of the substance

Example

How many moles are present in 25g of $CaCO_3$? $n = \frac{m}{gfm}$

n = ?

m = 25g

gfm = 100g

$CaCO_3$

3 x 16 = 48

1 x 12 = 12

1 x 40 = 40

100g

$n = \frac{m}{gfm} = \frac{25}{100} = 0.25$ moles

1. Calculate the mass of one mole of each of the following substances:

a) Bromine, Br_2 b) Zinc carbonate, $ZnCO_3$

c) Ammonium nitrate d) Iron (III) sulphate

e) Carbon tetrahydride f) Butene

2. Calculate the mass of each of the following:

a) 4 moles of water b) 3 moles of ammonia

c) 2.5 moles of ammonium carbonate

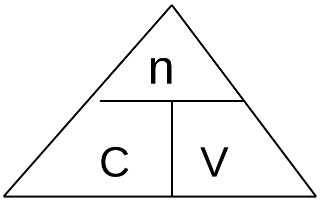
d) 4 moles of Silicon tetrachloride

3. Calculate the number of moles in each of the following:

a) 100g of magnesium nitride b) 90g of ethane

c) 22g of carbon dioxide d) 127g of iodine

Mole Calculations involving Solutions – Volumes and Concentrations



n = number of moles
c = concentration in moles per litre mol l^{-1}
v = volume in litres

Example
Calculate the number of moles present in $500cm^3$ of NaCl of concentration 0.5 mol l^{-1}.

n = c x v
= 0.5 x 0.5
= 0.25 mol

Tip – remember to convert cm^3 *to litres by dividing by 1000.*

1. Calculate the concentration of the following solutions in mol l^{-1}.

a) 0.25 moles of sodium hydroxide dissolved in 500 cm^3 of water.
b) 6 moles of potassium bromide dissolved in 3 litres of solution.
c) 0.4 moles of sodium nitrate dissolved in 100 cm^3 of solution.

2. Calculate the volume of solution that would produce each of the following:

a) A 2 mol l^{-1} solution containing 6 mol of sulphuric acid.
b) 1 mol of hydrochloric acid in a 1 mol l^{-1} solution.
c) 1.5 mol of nitric acid contained in a 2 mol l^{-1}solution.
d) A 2.4 mol l^{-1} solution containing 0.6 mol of potassium iodide.

3. Calculate the number of moles of solute present in each of the following solutions:

a) 2 litres of 1 mol l^{-1} sodium hydroxide.
b) 0.25 litres of 3 mol l^{-1} ammonia.
c) 250 cm^3 of 2 mol l^{-1} lithium nitrate.
d) 500 cm^3 of 0.1 mol l^{-1} potassium iodide.

Tip – remember to convert cm^3 *to litres by dividing by 1000.*

Mole Calculations – Combining Masses, Volume and Concentration

1. Calculate the concentration of the following solutions:

a) 222g of calcium chloride in 4 litres of solution.
b) 20.2g of potassium nitrate in 250 cm^3 of solution.
c) 4g of sodium hydroxide in 250 cm^3 of solution.
d) 1.49g of ammonium phosphate in 20 cm^3 of solution.

2. Calculate the mass of solute present in each of the following solutions:

a) 1 litre of 1 mol l^{-1} Na_2CO_3
b) 2.5 litres of 4 mol l^{-1} calcium hydroxide.
c) 500 cm^3 of 5 mol l^{-1} H_2SO_4
d) 100 cm^3 of 0.01 mol l^{-1} sodium hydroxide.

Calculations from Balanced Equations

Example
Calculate the mass of hydrogen produced when 12g of magnesium reacts with excess hydrochloric acid.

- First you need the balanced equation

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

- Now identify the substances referred to in the question – the substance you need to calculate a value for and the substance for which some numerical information is given.

$$\bigcirc\!\!\!\!\!\!Mg\ + 2HCl \rightarrow MgCl_2 + \bigcirc\!\!\!\!\!\!H_2$$

- Write the mole ratio

1 mole Mg $\rightarrow$ 1 mole H_2

- Calculate the number of moles of Mg in the reaction using
  $n = \frac{m}{gfm} = \frac{12}{24.5} = 0.49$ moles

- Use the mole ratio to work out the number of moles of hydrogen that will be produced

1 mole Mg → 1 mole H_2

So 0.49 moles Mg → 0.49 moles H_2

Now that you know the number of moles of H_2 that would be produced you can calculate the mass using m = n x gfm
=0.49 x 2
= 0.98g

1. Calculate the mass of tin that would be produced from 7.55g of SnO_2 in the following reaction:

$$SnO_2 + 2H_2 \rightarrow Sn + 2H_2O$$

2. Calculate the mass of iron produced from 10g of iron (III) oxide in the following reaction:

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

3. What mass of carbon dioxide is formed when 64g of methane burns completely in air?

4. Calculate the mass of ethanol, C_2H_5OH, needed to produce 25 moles of water during combustion of the fuel.

Calculations based on Titrations

The results of a titration between an acid and an alkali can be used to calculate an unknown concentration of either the acid or the alkali.

Example
The average volume of hydrochloric acid needed to neutralise 25.0 cm^3 of 1 mol l^{-1} sodium hydroxide solution is 22.4 cm^3. Calculate the concentration of the acid.

- You need the balanced equation for the reaction

$$HCl + NaOH \rightarrow NaCl + H_2O$$

- Now write the mole ratio

$$1 \text{ mole HCl} \rightarrow 1 \text{ mole NaOH}$$

- Now you need to know how many moles of sodium hydroxide you had in your reaction mixture

$$\begin{aligned} n &= c \times v \\ &= 1 \times 0.025 \\ &= 0.025 \text{ moles sodium hydroxide} \end{aligned}$$

- Using the mole ratio work out the number of moles of hydrochloric acid that must be present

1:1 ratio therefore 0.025 moles acid present

- Now you can calculate the concentration of the acid using

$$C = \frac{n}{V} = \frac{0.025}{0.0224} = 1.12 \text{ mol l}^{-1}$$

1. In a titration, 10 cm^3 of sodium hydroxide solution of concentration 0.2 mol l^{-1} was neutralised by 25 cm^3 of dilute hydrochloric acid. Calculate the concentration of the acid.

2. 25 cm^3 of 0.5 mol l^{-1} potassium hydroxide solution was neutralised by 16 cm^3 of nitric acid. Calculate the concentration of the acid.

3. 40 cm^3 of 0.5 mol l^{-1} lithium hydroxide solution was neutralised by 30 cm^3 of sulphuric acid. Calculate the concentration of the sulphuric acid.

4.

Titre	**Volume acid at start (cm^3)**	**Volume acid at end (cm^3)**	**Volume acid used (cm^3)**
Rough	0.0	18.7	18.7
1	0.0	20.4	20.4
2	0.0	19.8	19.8
3	0.0	19.7	19.7

a. Calculate the average volume of acid needed to neutralise the alkali.

b. Why was the first titre not included when calculating the average volume?

c. Why was titre 2 not included in the calculation?
d. Why was the titration repeated?

e. 17.5cm^3 of sodium hydroxide of concentration 1 mol $l^{-1}$was neutralised by hydrochloric acid during the titration. Calculate the concentration of the acid.

Percentage Composition

Calculating the % composition of a compound is like calculating your % score in a test.

If you scored 18 / 20 in a test you would calculate your % as follows:

$$\frac{18}{20} \times 100 = 90\%$$

In chemistry we can find the percentage by mass of an element in its compound using the same method.
First we need to know the gram formula mass of the compound (this is like the total marks for the test). Then we use the mass of the particular element in the compound in the same way as your score in the test.

Example
Calculate the % by mass of sodium in sodium chloride.

First use the ‘Ls’ to work out the gfm of NaCl.

NaCl

Cl: 1 x 35.5 = 35.5
Na: 1 x 23 = 23
= 58.5g

Now we can use the mass of sodium in the gfm to work out the % mass of sodium in the compound.

$$\frac{23}{58.5} \times 100 = 39.3\%$$

Tip – if you are asked to calculate the ‘% composition’ of a compound instead of the’ % by mass’ of one element in the compound, you are being asked to work out the % of EVERY element in the compound and the total should add up to 100%

1. Calculate the percentage by mass of hydrogen in water.

2. Calculate the percentage by mass of copper in copper (II) oxide.

3. Calculate the percentage by mass of iron in Iron (III) oxide.

4. Calculate the percentage composition of carbon dioxide.

5. Calculate the percentage composition of zinc carbonate.

Calculating the Energy Released from Fuels

In this experiment you will probably have used a spirit burner to heat a specific volume of water using different alcohols as fuels. You will have measured the starting and final temperature of the water and the volume of water being heated.

You need to know

- The temperature rise in ^oC
- The mass of water heated in kg (remember that $1cm^3$ can be taken to have a mass of 1g)

You will also use the specific heat capacity of water, c, which you can find in the front of your National 5 data book.

A typical results table is shown below:

Initial temperature of the water (^oC)	23
Final temperature of the water (^oC)	31
Volume of water heated (cm^3)	100
Mass of fuel burned (g)	0.2

You will need to use the equation

$E = cm\Delta T$ where - E is the energy produced
- C is the specific heat capacity of water
- m is the mass of the water that is being heated NOT the mass of fuel burned
- ΔT is the CHANGE in the water temp

Tip – the results table includes the mass of fuel burned but this is an attempt to confuse you. Ignore it. You will not use it in your calculation.

Example

Use the results in the table on the previous page to calculate the energy produced by that fuel.

$$E = cm\Delta T$$
$$= 4.18 \times 0.1 \times 8$$
$$= 3.34\text{kJ}$$

The specific heat capacity of water from your data book.

The change in temperature of the water.

The mass of the water being heated ($100cm^3$ = 100g so 0.1kg)

The units of measurement of energy.

1. Calculate the energy, in kJ, when 0.1g of methanol is burned and raises the temperature of $100cm^3$ of water by 11 ^oC.

2. Calculate the energy, in kJ, when 0.5g of propanol heats 50 cm^3 of water from 25 ^oC to 43 ^oC.

3. The table below shows the results of an experiment in which butan-1-ol was burned and the heat transferred to 200 cm^3 of water. Calculate the energy produced by the fuel.

Initial temperature of the water (^oC)	19
Final temperature of the water (^oC)	37
Mass of fuel burned (g)	0.2

4. Calculate the temperature rise of 700 cm^3 of water which was heated by a fuel producing 20.5kJ of energy.