Higher Chemistry: Unit 2 – Chemical Changes and Structure

Revision of Calculations – Getting the most from reactants

Learning Outcomes

The lesson will help you revise the following topics

1. Excess Calculations
2. Molar Volume
3. Percentage Yield and Atom Economy

Success Criteria

You will have been successful in this lesson if you:

1. Read the summary given (do not copy these notes – you already have notes for this)
2. Watch the links provided
3. Complete questions provided
4. EXTENSION: There is a further reading section to help you gain more depth of understanding for this section. There are also suggested questions for you to try from the blue book of revision questions.

If you have any questions about the content of this lesson, you should ask your class teacher either through your class MS team or via email. The teams will be monitored through the week and someone will get back to you as soon as they can.

Links to Prior Knowledge

You may wish to revise the following to help you understand this lesson:

Higher chemistry – Chemistry in Society – Getting the Most from Reactants

You may wish to have a copy of the data booklet handy for this lesson. Download or print a copy of the Higher Chemistry Data Booklet from MS Teams or the SQA website - https://www.sqa.org.uk/sqa/files_ccc/ChemistryDataBooklet_NewH_AH-Sep2016.pdf

You do not need to copy the notes below. You will have been given notes on these topics by your teacher. Have those notes to hand and use these worked examples to help refresh your memory of how to answer the calculations shown.

WATCH – Miss Adam's Chemistry YouTube channel

Miss Adam's Chemistry YouTube channel has videos explaining all of the parts of the chemistry higher course: For a recorded lesson on the following calculations, watch the videos below:

- Excess Calculations - https://youtu.be/hsjlVg5rkmM
- Molar Volume - https://youtu.be/dCqYTPNp2Y0
- Comparing gas volumes - https://youtu.be/PmxxLlSvleY
- Percentage Yield - https://youtu.be/sp3Yg1sX_Rc
- Atom Economy - https://youtu.be/qeF7fPTMgkI

Getting the most from reactants

For each of the following topics you should:

1. Read through your notes on the topic and the worked examples given by your teacher
2. Follow through the worked examples
3. Try the rest of the questions and check your answers

1. Excess Calculations

WORKED EXAMPLE:

12.5g of sodium reacts with 100cm^3 of 2moll^{-1} sulfuric acid.

$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2$

Show, by calculation, that sulfuric acid is the limiting reactant.

Step 1 – Calculate the number of moles you HAVE of each reactant

Number of moles of Na: n = m/gfm = 12.5/23 = 0.543

Number of moles of H_2SO_4: n = c x v = 2 x 0.1 = 0.2

Step 2 – compare number moles you HAVE with the number of moles you would NEED

Mole ratio = 2 mole Na : 1 mole H_2SO_4

HAVE 0.543 : 0.2 **HAVE**

0.272 **NEED** (0.543 ÷ 2)

Step 3 – make a statement comparing HAVE and NEED to show the LIMITING REACTANT

We **HAVE less** H_2SO_4 than we **NEED**. Therefore H_2SO_4 **is the limiting reactant.**

(If asked for the quantity of a product, it is the limiting reactant which is used)

Alternatively, if asked for the reactant in excess you could say:

*We **HAVE more** Na than we **NEED**. Therefore Na **is in excess.***

Now try the practice questions below.

Excess Calculations Practice

1. Show by calculation which reactant is in limiting reactant if 25cm^3 of 0.5 moll^{-1} of hydrochloric acid was neutralised by 38cm^3 of 0.35 moll^{-1} of sodium hydroxide?

   $HCl + NaOH \rightarrow NaCl + H_2O$

2. Show by calculation which reactant is in excess when 0.1 moles of hydrogen is burned with 0.1 moles of oxygen.

   $2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O$

3. Show by calculation which reactant is the limiting reactant when 5g of methane is burned in 0.8 moles of oxygen.

$CH_{4(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\ H_2O_{(l)}$

4. Show by calculation which reactant is the limiting reactant when 8g of sodium reacts with 10g of chlorine gas.

$2\ Na + Cl_{2\,(g)} \rightarrow 2\ NaCl$

5. Show by calculation which reactant is in excess when 0.4g of magnesium reacts with 250cm^3 of 2 moll^{-1} sulfuric acid.

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

6. Calculate the mass of calcium nitrate produced when 29.6g calcium hydroxide is neutralised with 400cm^3 of 1.5 moll^{-1} nitric acid.
(HINT: Work out what's in excess first and use the limiting reactant to calculate the product)

$Ca(OH)_2 + 2\ HNO_3 \rightarrow Ca(NO_3)_2 + 2\ H_2O$

7. $5N_2O_4(l) + 4CH_3NHNH_2(l) \rightarrow 4CO_2(g) + 12H_2O(l) + 9N_2\,(g)\ \ \Delta H = -5116$ kJ

Calculate the energy released when 2 moles of each reactant are mixed and ignited.

8. Excess iron was added to 100cm^3 to 1.0 mol l^{-1} copper(II) sulfate solution releasing 3.1 kJ of energy.

$Fe(s) + CuSO_4(aq) \rightarrow Cu\,(s) + FeSO_4\,(aq)$

Calculate the enthalpy change, in kJ mol^{-1} for the above reaction?

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2. Molar Volume

WORKED EXAMPLE:

Example 1 - Mass / Volume Calculation:

Calculate the volume of sulfur dioxide produced when 13g of sulfur is burned in excess oxygen. (Take the molar volume of a gas to be 24 litres.)

$S + O_2 \rightarrow SO_2$

1 mol S $\rightarrow$ 1 mol SO_2

32.1 g $\rightarrow$ 24 l

1 g $\rightarrow$ $\frac{24}{32.1}$

13 g $\rightarrow$ $\frac{24}{32.1}$ x 13 = 9.72 litres

Example 2 - Gas to Gas calculation with **excess reactant**.

Calculate the **volume and composition** of the gas mixture when 600cm^3 of hydrogen reacts with 300cm^3 of nitrogen.

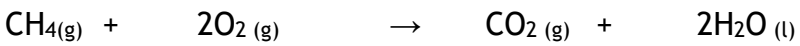
$3H_2$ +	N_2 $\rightarrow$	$2NH_3$
3 moles	1 mole	2 moles
3 volumes	1 volume	2 volumes
600 cm^3	300 cm^3 **HAVE**	
	200 cm^3 **NEED**	
	N_2 is in **excess by 100cm^3**	
		400cm^3 ammonia is made (600 x $\frac{2}{3}$)

At the end of the reaction **100cm^3 of nitrogen and 400cm^3 ammonia** would be present.

Now try the practice questions below.

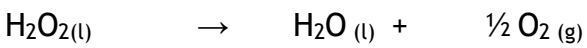
Molar Volume Calculations Practice

1. Calculate the volume of carbon dioxide produced when 5g of methane is burned in excess oxygen. (Assume molar volume = 22 litres)



$CH_{4(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{\,(l)}$

2. Calculate the volume of oxygen produced when 26.7 kg of hydrogen peroxide decomposes. (Assume molar volume = 25 litres)



$H_2O_{2(l)} \rightarrow H_2O_{\,(l)} + \frac{1}{2}\,O_{2\,(g)}$

3. Calculate the volume of nitrogen dioxide produced when 250cm^3 of nitrogen reacts with excess oxygen.

$N_2 + 2O_2 \rightarrow 2NO_2$

4. 500cm^3 of hydrogen was burned in 325cm^3 of oxygen. What gas was in excess?

$H_{2\,(g)} + \frac{1}{2}\,O_{2\,(g)} \rightarrow H_2O_{\,(l)}$

5. 100cm^3 of propene was burned in 800cm^3 of oxygen.

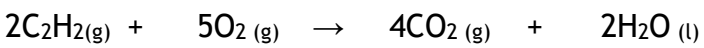
$C_3H_{6(g)} + 4\frac{1}{2}O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 3H_2O_{\,(l)}$

a) What gas was in excess?

b) What volume of carbon dioxide was produced?

c) What will be the total volume and composition of the resulting gas mixture?

6. What is the total volume and composition of the gas mixture when 100 cm^3 of ethyne is burned in 500 cm^3 of oxygen?



$2C_2H_{2(g)} + 5O_{2\,(g)} \rightarrow 4CO_{2\,(g)} + 2H_2O_{\,(l)}$

ethyne

4. Percentage Yield and Atom Economy

WORKED EXAMPLE:

Percentage Yield

Using the following equation, calculate the **percentage yield** of propanol when **25kg of propene reacts** with excess water **producing 31kg of propanol.**

$C_3H_6 + H_2O \rightarrow C_3H_7OH$

Step 1: Theoretical yield calculation

C_3H_6	→	C_3H_7OH
1 mole	→	1 mole
42 g	→	60 g
1 g	→	$\frac{60}{42}$
25 kg	→	$\frac{60}{42}$ x 25 = **35.71** kg = **THEORETICAL YIELD**

Step2: percentage yield calculation

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

$$= \frac{31}{35.71} \times 100 = \mathbf{87\%}$$

WORKED EXAMPLE:

Atom Economy

Calculate the atom economy for the following reaction for the production of iron.

	Fe_2O_3 +	3CO	→	2Fe +	$3CO_2$
Mass of 1 mole =	=159.6g	=28g		=55.8g	44g

$$\text{\% atom economy} = \frac{(2 \times 55.8)}{(159.6 + (3 \times 28))} \times 100$$

$$= \frac{111.6}{243} \times 100 = 46\%$$

Percentage Yield and Atom Economy Calculations Practice

1. In the reaction vessel, ethanol is produced in an exothermic reaction.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

(a) If 1·64 kg of ethanol (relative formula mass = 46) is produced from 10·0 kg of ethene (relative formula mass = 28), calculate the percentage yield of ethanol.

(b) Calculate the atom economy for the production of ethanol.

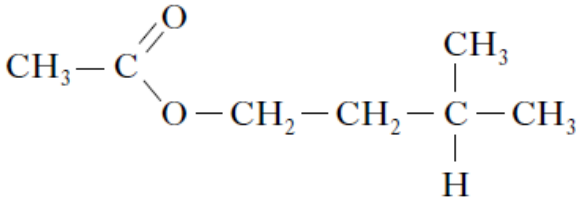
2. Hydrogen fluoride gas is manufactured by reacting calcium fluoride with concentrated sulphuric acid.

$$CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$$

(a) If 15 tonnes of hydrogen fluoride is produced from 55 tons of calcium fluoride, calculate the percentage yield of the hydrogen fluoride.

(b) Calculate the atom economy for the production of hydrogen fluoride.

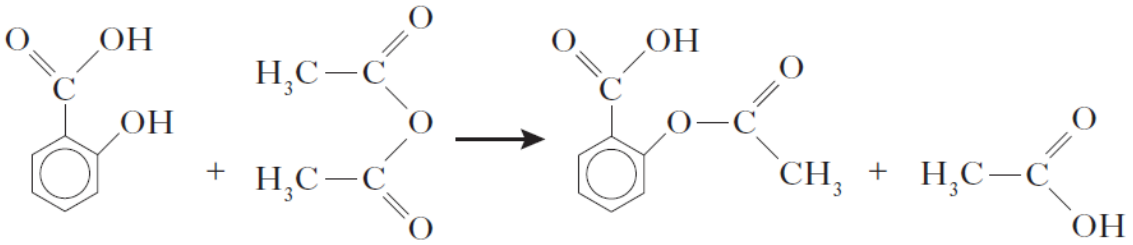
3. One of the chemicals released in a bee sting is an ester that has the structure shown.



(a) If there is a 65% yield, calculate the mass of ester produced, in grams, when 4·0 g of the alcohol reacts with a slight excess of the acid.
(Mass of one mole of the alcohol = 88 g;
mass of one mole of the ester = 130 g)

(b) Calculate the atom economy for the production of the ester. (You will need to calculate the gfm of the acid used)

4. Aspirin, a common pain-killer, can be made by the reaction of salicylic acid with ethanoic anhydride.



$C_7H_6O_3$	$C_4H_6O_3$	$C_9H_8O_4$	$C_2H_4O_2$
salicylic acid	ethanoic anhydride	aspirin	ethanoic acid
mass of one mole = 138 g	mass of one mole = 102 g	mass of one mole = 180 g	mass of one mole = 60 g

(*a*) Calculate the atom economy for the formation of aspirin using this method.

Show your working clearly.

(b) In a laboratory preparation of aspirin, 5·02 g of salicylic acid produced 2·62 g of aspirin.

Calculate the percentage yield of aspirin.

Show your working clearly.

Answers to the exercises above can be found at the end of this document

WATCH - Miss Adam's Chemistry YouTube channel

Miss Adam's Chemistry You Tube channel has videos explaining all of the calculations above and many more. Visit the higher playlist and select any video on a topic you need more help with:

https://www.youtube.com/playlist?list=PLpeedPxQgHa3oIN5_t_Ab70Ttd9CQW38U

Learning Outcomes

You should have now revised:

1. Excess Calculations
2. Molar Volume
3. Percentage Yield and Atom Economy

Further Reading

To learn more about proteins, try the following online resources:

BBC Bitesize: https://www.bbc.co.uk/bitesize/guides/z8fvvcw/revision/1

Read prevision pages (optional) and **TRY THE END TOPIC TEST**

Scholar: Log in through GLOW

Higher Chemistry → Chemistry in Society → Topic 1

Read through the exercises and **TRY THE END TOPIC TEST**

Evans2 chem web: https://www.evans2chemweb.co.uk/login/index.php#

Username: snhs password: giffnock

Select any teacher → revision material → CfE Higher → Unit 3: Chemistry in Society → Getting the most from reactants

EXTENSION WORK

Use the online learning link above if you would like to extend your knowledge on this topic. For more practise questions, use your Revision Questions for Higher Chemistry "Blue book":

Molar Volume of Gases	page 76
The idea of excess	page 81
Percentage Yield	page 93
Atom Economy	page 95

Check your answers to the exercises above

Excess

1. NaOH is the limiting reactant
2. O_2 is in excess
3. CH_4 is the limiting reactant
4. Cl_2 is the limiting reactant
5. H_2SO_4 is in excess
6. $Ca(OH)_2$ is in excess; 49.2 g calcium nitrate is produced.
7. 2046.4 kJ
8. 31 kJ mol^{-1}

Molar Volume

1. 6.88 l
2. 9816.18 l
3. 500cm^3
4. O_2 is in excess
5. a. O_2 is in excess
   b. 300 cm^3 CO_2
   c. 300 cm^3 CO_2 , 350 cm^3 O_2 = 650 cm^3
6. Composition = 200 cm^3 CO_2, 250 cm^3 O_2

Percentage Yield and Atom Economy

1. A. Theoretical = 16.43 kg, % = 9.98% B. 100%
2. A. Theoretical = 28.17 tonnes, % = 53.25% B. 22.71%
3. A. Theo = 5.91 g, Actual = 3.84 g B. 87.84%
4. A. 75% B. Theo = 6.55 g, % = 40%