Percentage Yield and Atom Economy – Revision Pack (C3)

Percentage Yield:

Percentage yield is a way of comparing amount of product made (actual yield) to amount expected (predicted yield).

You want a high percentage yield so that no reactants are wasted.

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

- 100% Yield means that no product has been lost
- 0% Yield means that all of the product has been lost

Reasons for not getting expected mass:

- Loss when filtering
- Loss when transferring liquids
- Loss when evaporating
- Not all the reactant was made into a product

Atom Economy:

The atom economy of a chemical reaction is a measure of the amount of starting materials that become ***useful products***.

Inefficient, wasteful processes have low atom economies; atoms are wasted not made into useful products. .

Efficient processes have high atom economies, and are important for **sustainable development**, as they use fewer natural resources and create less waste. A high atom economy also means that there are less unwanted products made.

BASIC SUMMARY: **Atom economy is a way of measuring the amount of atoms that are wasted when manufacturing a chemical**

$$\text{Atom Economy} = \frac{\text{Mr of desired product}}{\text{Sum of Mr of all products}} \times 100$$

- 100% atom economy means that all of the reactant was converted into the desired product
- 0% atom economy means that all of the product has been lost

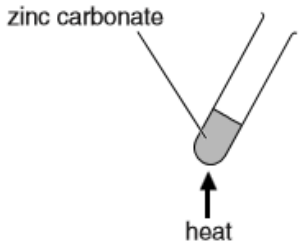
PPQ(1):

9

Section B – Module C3

5 Michael investigates the decomposition of zinc carbonate, $ZnCO_3$.

Look at the apparatus he uses.



Michael predicts that he should make 0.58 g of zinc oxide.

Michael actually makes 0.50 g of zinc oxide.

Calculate his **percentage yield**.

.....

.....

..... **[2]**

OCR Gateway Paper May 2012 B3 C3 P3

PPQ(2):

6 Aspirin is a medicine used to control pain.

Look at the equations. They show how aspirin can be made.

salicylic acid + ethanoyl chloride → aspirin + hydrogen chloride

$C_7H_6O_3$ + C_2H_3OCl → $C_9H_8O_4$ + HCl

Look at the table. It shows some information about the compounds involved in making aspirin.

Compound	Formula	Relative formula mass
salicylic acid	$C_7H_6O_3$	138
ethanoyl chloride	C_2H_3OCl	78.5
aspirin	$C_9H_8O_4$	180
hydrogen chloride	HCl	36.5

(a) Calculate the **atom economy** of this reaction.

.....

.....

.....

answer = ... % **[2]**

(b) A company is making a new medicine.

They want the atom economy to be as high as possible.

Explain why.

.....

.....

..... **[2]**

OCR Gateway January 2013 B3 C3 P3

(Refer to 'New Drugs' Revision pack for part b)

PPQ(3):

7 Milk of magnesia is an antacid that helps to relieve indigestion.

Milk of magnesia contains magnesium hydroxide, $Mg(OH)_2$.

A pharmaceutical company makes magnesium hydroxide using the following reaction

$$MgCl_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaCl$$

The sodium chloride, $NaCl$, made is a **waste product**.

Look at the table of relative formula masses.

Substance	Relative formula mass, M_r
$MgCl_2$	95
NaOH	40
$Mg(OH)_2$	58
$NaCl$	58.5

(a) Calculate the **atom economy** for the manufacture of magnesium hydroxide.

.....

.....

.....

atom economy = ... % **[2]**

(b) John is a scientist working for the pharmaceutical company.

He predicts that he should make 35 g of magnesium hydroxide.

He actually makes 21 g.

Calculate his **percentage yield** of magnesium hydroxide.

.....

.....

.....

percentage yield = ... % **[2]**

OCR Gateway June 2013 B3 C3 P3

PPQ(4):

11 Hydrogen peroxide has the molecular formula H_2O_2.

Hydrogen peroxide can be manufactured by reacting barium peroxide, BaO_2, with sulfuric acid, H_2SO_4.

$$BaO_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O_2$$

Barium sulfate, $BaSO_4$, is a waste product.

Look at the table of relative formula masses, M_r.

formula	relative formula mass, M_r
BaO_2	169
H_2SO_4	98
$BaSO_4$	233
H_2O_2	34

(a) Show that the **atom economy** for the reaction is 12.7%.

.....

.....

..... **[1]**

(b) A factory makes 18 tonnes of hydrogen peroxide.

Phil predicts the factory should make 20 tonnes of hydrogen peroxide.

Calculate the **percentage yield** of hydrogen peroxide.

.....

.....

.....

percentage yield = ... % **[2]**

(c) The manufacture of hydrogen peroxide from barium peroxide is **not sustainable**.

Explain why.

.....

..... **[1]**

[Total: 4]

OCR Gateway January 2012 C1 C2 C3

PPQ(5):

13 Fertilisers and medicines are useful chemicals.

Ammonium sulfate is used as a fertiliser.

Ammonium sulfate is made by reacting ammonia with dilute sulfuric acid.

(b) Alex makes some ammonium sulfate in a laboratory.

(i) Alex predicts he should make 8.0 g of ammonium sulfate.

He actually makes 6.0 g.

Show, by calculation, that his **percentage yield** of ammonium sulfate is 75%.

.....

.....

..... **[2]**

OCR Gateway May 2012 C1 C2 C3

PPQ(6):

14

SECTION C – Module C3

10 Stowmarket Synthetics manufacture ethanoic acid, $C_2H_4O_2$, by two different processes.

Process **1** $C_2H_6O + O_2 \rightarrow C_2H_4O_2 + H_2O$

Process **2** $CH_4O + CO \rightarrow C_2H_4O_2$

Look at the table of relative formula masses.

Compound	Formula	Relative formula mass, M_r
ethanol	C_2H_6O	46
oxygen	O_2	32
ethanoic acid	$C_2H_4O_2$	60
water	H_2O	18
methanol	CH_4O	32
carbon monoxide	CO	28

(b) Stowmarket Synthetics know that the **atom economy** of a process is important.

Water is a waste product in process **1**.

Show that the atom economy for making ethanoic acid by process **1** is 77%.

.....

.....

..... **[2]**

15

(c) Stowmarket Synthetics also know that the **percentage yield** of a process is important.

The factory uses 5.2 tonnes of methanol in process **2**.

A scientist predicts they should make 9.8 tonnes of ethanoic acid.

They actually make 9.5 tonnes of ethanoic acid.

Show that the percentage yield of ethanoic acid is 97%.

.....

.....

.....

..... **[2]**

(d) Look at the table.

It gives information about the atom economy and percentage yield for making ethanoic acid.

Process	Atom economy (%)	Percentage yield (%)
1	77	85
2	100	97

Process **2** has a higher atom economy and a higher percentage yield.

(i) Explain one advantage, other than cost, of a very high atom economy.

.....

..... **[1]**

(ii) Explain one advantage, other than cost, of a very high percentage yield.

.....

..... **[1]**

OCR Gateway January 2013 C1 C2 C3

(b) Magnesium nitrate is made by a neutralisation reaction.

Look at the equation for the reaction.

$$2HNO_3 + MgO \rightarrow Mg(NO_3)_2 + H_2O$$

Water is a waste product.

Show that the atom economy for the reaction is 89% and explain why it is important that the atom economy for a reaction is as high as possible.

The relative atomic masses (A_r) for H = 1, N = 14, O = 16 and Mg = 24.

The quality of written communication will be assessed in your answer to this question.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

OCR Gateway May 2013 C1 C2 C3

Mark Schemes:

PPQ(1):

	86% (2) but $\frac{0.50}{0.58}$ x 100 or (actual yield / predicted yield) x 100 (1)	2	**allow** 86.2 (%) / 86.21 (%) 86.0 (%) or 86.206897(%) = (1)

PPQ(2):

Question			Answer	Marks	Guidance
6	(a)		83.1 (%) scores (2) if answer incorrect for one mark: $\frac{180 \times 100}{216.5}$ or $\frac{M_r \text{ of desired products} \times 100}{\text{sum of } M_r \text{ of all products}}$ or $\frac{M_r \text{ of desired products} \times 100}{\text{sum of } M_r \text{ of all reactants}}$ or $\frac{180 \times 100}{138 + 78.5}$ or $\frac{M_r \text{ of desired products}}{\text{sum of } M_r \text{ of all reactants}}$ or $\frac{180}{138 + 78.5}$ or $\frac{M_r \text{ of desired products}}{\text{sum of } M_r \text{ of all products}}$ or $\frac{180}{180 + 36.5}$	2	**allow** 83 / any number of decimal places if rounded correctly eg 83.141 (2) but if rounded incorrectly eg 83.140 (1)
	(b)		**any two from:** idea of reduce production of unwanted products / ORA (1) idea of making the process (more) sustainable (1) maximise profit (1)	2	**allow** to make only wanted products / less waste product **ignore** reduce waste reactants **ignore** reduce waste unqualified **ignore** references to the environment **ignore** unqualified references to cost **allow** qualified reference to cost eg it costs less for raw materials / cost less in disposing waste **allow** help profits

PPQ(3):

Question			Answer	Marks	Guidance
7	(a)		33(%) (2) **but** if correct answer not given, atom economy = $\frac{M_r \text{ of desired products}}{\text{sum of } M_r \text{ of all products}} \times 100$ **or** atom economy = $\frac{M_r \text{ of desired products}}{\text{sum of } M_r \text{ of all reactants}} \times 100$ **or** atom economy = $\frac{58}{175} \times 100$ scores (1)	2	**allow** full marks for correct answer even if equation for atom economy not stated **allow** 33.1% / 33.14% **allow** $\frac{58}{58 + 117}$ or $\frac{58}{58 + (2 \times 58.5)}$ (1)
	(b)		60(%) scores (2) **but** $\frac{\text{actual yield}}{\text{predicted yield}} \times 100$ (1) or $\frac{21}{35} \times 100$ scores (1)	2	**look for correct answer first**, 60(%) on own scores (2) unit not needed – **ignore** incorrect units **allow** $\frac{am}{pm} \times 100$ (1)

PPQ(4)

Question			Answer	Marks	Guidance
11	(a)		$\frac{34}{267}$ x 100 (1)	1	**allow** $\frac{34}{(233+34)}$ x100 / $\frac{34}{(98+169)}$ x 100 the mark is for the working out and not the answer
	(b)		$\frac{18}{20}\times100$ / $\frac{18}{20}$ (1) 90 (1)	2	**allow** $\frac{am}{pm}\times100$ for one mark if answer incorrect **allow** full marks for 90(%) with no working out
	(c)		because the atom economy is low / lots of atoms are wasted in the reaction (1)	1	**allow** lots of waste made / produces waste products / produces barium sulfate which is not used **not** reference to percentage yield
			Total	**4**	

PPQ(5):

(b)	(i)	percentage yield = $\frac{\text{actual yield}}{\text{predicted yield}}$ x 100 (1) **but** $\frac{6.0}{8.0}$ x 100 (2)	2	**allow** $\frac{\text{am}}{\text{pm}}$ x 100 (1) **or** $\frac{6.0}{8.0}$ = 0.75 (1) 0.75 x 100 (1) No mark for 75%

PPQ(6):

	(b)		atom economy = $\frac{60}{60+18}$ / $\frac{60}{46+32}$ / $\frac{60}{78}$ (1) **but** atom economy = $\frac{60}{60+18}$ x 100 / $\frac{60}{46+32}$ x 100 / $\frac{60}{78}$ x 100 (2)	2	**allow** atom economy formula in words for one mark i.e. atom economy = total Mr of desired products x 100 (1) total Mr of all products
	(c)		percentage yield = $\frac{9.5}{9.8}$ (1) **but** percentage yield = $\frac{9.5}{9.8}$ x 100 (2)	2	**allow** percentage yield formula in words for one mark e.g. percentage yield = actual yield x 100 predicted yield or percentage yield = am x 100 pm
	(d)	**(i)**	more sustainable / makes less or no **waste** products (1)	1	makes less waste is **not** sufficient **ignore** makes less products **ignore** it wastes less resources
		(ii)	less waste of reactants (1)	1	**allow** no need to recycle unreacted reactants **ignore** less waste / waste products **ignore** able to make more / more products made

PPQ(7):

Question			Answer	Marks	Guidance
	(b)		**Level 3 (5–6 marks)** **Calculates the atom economy for the given reaction** **AND** **Explains clearly why an industrial process should have as high an atom economy as possible.** Quality of written communication does not impede communication of the science at this level. **Level 2 (3–4 marks)** **Calculates the atom economy for the given reaction** **OR** **Gives at least two reasons why an industrial process should have as high an atom economy as possible.** Quality of written communication partly impedes communication of the science at this level. **Level 1 (1–2 marks)** **Gives a reason why an industrial process should have as high an atom economy as possible** **OR** **calculates the required formula masses of magnesium nitrate and water.** Quality of written communication impedes communication of the science at this level. **Level 0 (0 marks)** Insufficient or irrelevant science such as repeating the question. Answer not worthy of credit.	6	**This question is targeted at grades up to A*.** **Indicative scientific points may include:** **reasons for need for high atom economy:** • to reduce the production of unwanted products (makes less waste is **not** sufficient) • to make the process more sustainable • in this reaction water is the only unwanted product so the process is very green. **calculation of atom economy:** • recall $\text{atom economy} = \frac{\text{molecular mass of all of the desired products}}{\text{sum of all of the molecular masses of all of the products}} \times 100\%$ • formula mass of magnesium nitrate = 148 • formula mass of water = 18 • formula mass of all products = 166 • atom economy = 89%. **Use the L1, L2, L3 annotations in scoris; do not use ticks.**
			Total	**8**	