AQA GCSE Chemistry | 8462

SPECIFICATION POINT 4.3.3.2

Atom economy

Mark schemes and examiner comments

Tier	**Higher**
Question groups	**9**
Available paper years	**2008–2025**

Using this booklet

1. Booklet answer numbers match the question booklet.
2. Use the original question number within marking tables.
3. Examiner comments are included where available.

Name: _____ **Date:** _____

Where a precise marking extract is unavailable, the full source document is included in an appendix. Any missing mark scheme is explicitly identified.

4.3.3.2 Atom economy

Answer 01 · Mark scheme

June 2008 | CHY2H | Original Q8 | Legacy

question	answers	extra information	mark
8(a)	25.4(%)	correct answer with **or** without working accept 25(%) accept 25.433……..(%) allow 26(%) for **1** mark if incorrect answer **1** mark for identification of 44 as M_r of useful product **or** 173 as total M_r of reactants / products	2
8(b)	any **two** sensible ideas from eg: • no / less waste • less materials / reactants needed / used • fewer / no environmental problems **or** less / no pollution • better for sustainable development / resources running out • more useful use of atoms • less purification / separation of products owtte	ignore references to energy / cheaper / profit / cost / efficient	2

Question 8 continued on next page…

COMPONENT NUMBER: CHY2H

COMPONENT NAME: Additional Science / Chemistry

STATUS: Final

DATE: June 2008

Question 8 continued...

question	answers	extra information	mark
8(c)	increase yield more (gaseous) reactant molecule than (gaseous) product molecule owtte	owtte accept more molecules on left hand side **or** converse accept Le Chatelier based answers for second mark ignore rate of reaction	1 1
8(d)	reduce yield **or** less product owtte	allow no yield ignore waste / less efficient	1
Total			**7**

4.3.3.2 Atom economy

Answer 02 · Mark scheme

Question 6

question	answers	extra information	mark
6(a)	any **two** from: • heat water / make steam / boil water **or** heat / steam used in stage 1 • carbon dioxide from stage 3 used in stage 7 / to make urea • nitrogen and / or hydrogen recycled (owtte) • ammonia and / or carbon dioxide <u>recycled</u> (owtte)	allow reused instead of recycled in correct context allow unreacted material / gas recycled from stage 5 (to 4) allow unreacted material / gas recycled from stage 8 (to 7) NB if neither of the last two points are awarded unreacted material recycled = **1** mark	2
6(b)	any **one** from: • fertiliser / fertilise / fertile • provide nitrogen • any idea of faster / better / helps growth of crop • greater yield of crop • helps proteins / amino acids to form in plants owtte	ignore cost ignore neutralisation / minerals / to treat plants / photosynthesis allow give plants nutrients allow provides nitrate	1
6(c)	3	allow correct multiples eg $2CH_4 + 2H_2O \rightarrow 2CO + 6H_2$	1
6(d)(i)	(forward reaction is) exothermic / gives out heat	accept Le Chatelier based answers accept reverse argument eg because at high temperature the ammonia would decompose	1

Question 6 continues on the next page...

CHY2H

Question 6 continued

question	answers	extra information	mark
6(d)(ii)	reaction is too slow / takes too long **or** to make the reaction fast(er)	allow answers that imply increased rate eg more collisions / particles have more energy allow catalyst works better ignore optimum condition / compromise type answers ignore yield	1
6(e)	sulfuric / H_2SO_4	accept sulphuric	1
6(f)(i)	3400	correct answer gains all **3** marks with or without working if answer incorrect: 1700 with or without working or 6000 × (34/60) gains **2** marks **or** 6800 gains **2** marks with or without working **or** moles of urea = 6000/60 = 100 gains **1** mark moles of ammonia needed = 200 gains **1** mark **or** 6000 × (17/60) gains **1** mark **or** (2×17) → 60 gains **1** mark **or** 34 → 60 gains **1** mark	3

Question 6 continueson the next page

4.3.3.2 Atom economy

CHY2H

Question 6 continued

question	answers	extra information	mark
6(f)(ii)	76.9	correct answer gains **2** marks with or without working. allow 77 or 76.923… allow 76 **or** 0.77 **or** 0.76923 for **1** mark if answer incorrect allow **1** mark for **either** identifying the mass of the useful product **or** the total M_r of reactants – this can be awarded from the numbers in the calculation: M_r of useful product = 60 M_r of reactants = 78 **or** (2×17)+44 **or** 60 +18 60/78 × 100 gains **1** mark	2
Total			**12**

4.3.3.2 Atom economy

Answer 03 · Mark scheme

June 2018 | 8462/1H | Original Q2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	FeS_2	do **not** accept equations	1	AO2 4.2.1.3
02.2	26 30 26	must be this order	1 1 1	AO2 4.1.1.4 4.1.1.5
02.3	any **two** from: • iron has a high(er) melting / boiling point • iron is dense(r) • iron is hard(er) • iron is strong(er) • iron is less reactive • iron has ions with different charges • iron forms coloured compounds • iron can be a catalyst	allow the converse statements for sodium allow transition metal for iron allow Group 1 metal for sodium ignore references to atomic structure ignore iron rusts allow iron is less malleable / ductile allow specific reactions showing difference in reactivity allow iron is magnetic	2	AO1 4.1.2.5 4.1.3.1 4.1.3.2

4.3.3.2 Atom economy

Answer 03 · Mark scheme

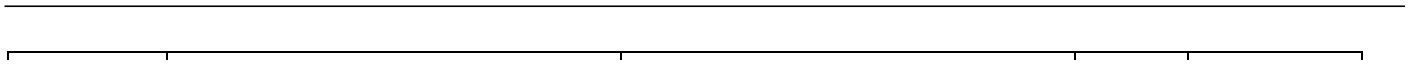
June 2018 | 8462/1H | Original Q2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.4	carbon is more reactive (than nickel) (so) carbon will displace / replace nickel (from nickel oxide) **or** (so) carbon will remove oxygen (from nickel oxide)	allow converse allow (so) nickel ions gain electrons allow (so) carbon transfers electrons to nickel (ions)	1 1	AO1 4.4.1.2 4.4.1.3
02.5	(total M_r of reactants =) 87 (percentage atom economy) $= \frac{59}{87} \times 100$ = 67.8 (%)	an answer of 67.8 (%) scores **3** marks an answer of 67.8160919 (%) or correctly rounded answer to 2, 4 or more sig figs scores **2** marks an incorrect answer for one step does **not** prevent allocation of marks for subsequent steps allow (percentage atom economy) $= \frac{59}{\text{incorrectly calculated } M_r} \times 100$ allow an answer from an incorrect calculation to 3 sig figs	1 1 1	AO2 4.3.3.2
Total			**11**	

4.3.3.2 Atom economy

Answer 03 · Mark scheme

June 2018 | 8462/1H | Original Q2



4.3.3.2 Atom economy

Answer 04 · Mark scheme

June 2019 | 8462/2H | Original Q10

Question 10

Question	Answers	Extra information	Mark	AO / Spec. Ref.
10.1	$\frac{6}{34} \times 100$	an answer of 17.6470588 (%) correctly rounded to at least 2 significant figures scores **2** marks	1	AO2 4.3.3.2
	= 17.6 (%)	allow 17.6470588 (%) correctly rounded to at least 2 significant figures	1	
10.2	higher yield (of hydrogen or carbon monoxide or product)	allow converse arguments in terms of higher pressure ignore references to rate allow more hydrogen or more carbon monoxide or more product allow equilibrium moves to the right allow equilibrium moves in the forward direction	1	AO2 4.6.2.4 4.6.2.7
	(because) fewer moles / molecules / particles on left hand side **or** (because) more moles / molecules / particles on right hand side	allow (because) the reverse reaction produces fewer moles / molecules / particles **or** allow (because) the forward reaction produces more moles / molecules / particles do **not** accept fewer / more atoms	1	
10.3	no effect (on yield of hydrogen)	allow position of equilibrium unaffected by pressure ignore references to rate of reaction	1	AO2 4.6.2.7

10.4	an answer of 2.25 scores **3** marks 350 (°C) and 285 (atmospheres) = 63 (%) **and** 450 (°C) and 200 (atmospheres) = 28 (%) $\frac{63}{28}$ = 2.25 (times greater)	 allow a value between 62 (%) and 64 (%) inclusive allow a correct expression using incorrectly determined value(s) for percentage yield allow a correct calculation using incorrectly determined value(s) for percentage yield correctly evaluated and rounded to at least 2 significant figures	 1 1 1	AO2 4.10.4.1
10.5	any **one** from: • the energy costs would be high(er) • the equipment would need to be strong(er) • high(er) pressures are (more) dangerous	allow converse arguments in terms of low(er) pressure ignore energy / cost unqualified allow the equipment would be (more) expensive (to build / maintain) allow (more) dangerous because (greater) risk of explosion	1	AO1 4.10.4.1
10.6	higher temperatures produce a lower (percentage) yield (of ammonia)	allow converse allow correct reference to shift in equilibrium ignore references to pressure	1	AO2 4.6.2.6 4.10.4.1
10.7	world population has increased any **one** from: • demand for fertiliser has increased • increased demand for other specified ammonia-based products e.g. nitric acid, drugs, dyes, explosives	 allow more food needed	1 1	AO3 AO1 4.10.4.1 4.10.4.2
Total			**12**	

4.3.3.2 Atom economy

Answer 05 · Mark scheme

November 2020 | 8462/1H | Original Q3

Question 3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	(total) mass before = 156.76 (g) **and** (total) mass after = 156.76 (g) **or** increase in mass of beaker **A** and contents = 29.96 (g) **and** decrease in mass of beaker **B** and contents = 29.96 (g) (so) the mass of products equals the mass of the reactants **or** (so) there is no change in mass during the reaction	allow 78.26 + 78.50 = 156.76 **and** 108.22 + 48.54 = 156.76 allow 108.22 – 78.26 = 29.96 **and** 48.54 – 78.50 = – 29.96 allow (so) no atoms were lost or made during the reaction	1 1	AO2 AO1 4.3.1.1
03.2	filter / filtration	allow a description of filtration	1	AO2 4.1.1.2
03.3	sodium nitrate (solution) **or** silver nitrate (solution) **or** sodium iodide (solution)	allow correct formulae allow sodium / nitrate / silver / iodide ions	1	AO2 4.1.1.2
03.4	to remove / evaporate the water	allow to dry (the solid)	1	AO3 4.1.1.2

Answer 05 · Mark scheme

Question 3 continued

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.5	(total M_r = 170 + 150) = 320	allow (235 + 85) = 320	1	AO2 4.3.3.2
	(% atom economy =) $\frac{235}{320} \times 100$	allow correct use of incorrectly calculated total M_r	1	
	= 73.4375 (%)		1	
	= 73.4 (%)	allow an answer correctly calculated to 3 significant figures from an incorrect percentage calculation which uses the values in the question	1	
03.6	any **one** from: • for sustainable development • for economic reasons • to produce a high(er) percentage of useful product	allow to reduce waste	1	AO1 4.3.3.2
Total			**10**	

4.3.3.2 Atom economy

Answer 06 · Mark scheme

November 2021 | 8462/1H | Original Q3

Question 3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	(3 × M_r H_2O = 3 × (2 + 16) =) 54 (A_r **R** = 150 – 54 =) 96 **alternative approach**: (M_r **R**O_3 = 150 – 6 =) 144 (1) (A_r **R** = 144 – (3 × 16) =) 96 (1)	 ignore units ignore units	1 1	AO2 4.3.1.1 4.3.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.2	**(R** =) molybdenum / Mo	allow ecf from question **03.1**	1	AO3 4.1.1.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.3	(total M_r of reactants) = 163 (% atom economy =) $\frac{119}{163}$ (×100) = 73 (%)	 allow correct use of an incorrectly calculated value of total M_r allow 73.00613 (%) correctly rounded to at least 2 significant figures	1 1 1	AO2 4.3.1.2 4.3.3.2

Question 3 continued

Question	Answers	Mark	AO/ Spec. Ref
03.4	**Level 2:** Some logically linked reasons are given. There may also be a simple judgement.	3-4	AO3 4.4.1.3
	Level 1: Relevant points are made. They are not logically linked.	1–2	
	No relevant content	0	
	Indicative content • carbon and iron are the cheapest reactants • hydrogen is the most expensive reactant • separating solid products is expensive • separating solid products is time consuming • in method 1, tungsten needs to be separated from tungsten carbide • in method 1, some tungsten is lost as tungsten carbide • in method 1, the carbon dioxide produced will escape • in method 2, the water vapour produced will escape • in method 2, no separation of solids is needed • in method 3, tungsten needs to be separated from iron oxide		

Total			**10**

4.3.3.2 Atom economy

Answer 07 · Mark scheme

June 2022 | 8462/2H | Original Q7

Question 7

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.1	(nitrogen) air (hydrogen) natural gas	allow atmosphere allow methane allow water / steam	1 1	AO1 4.10.4.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.2	there is only one product		1	AO2 4.3.3.2 4.10.4.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.3	(mixture is) cooled (so that only) ammonia liquefies	 allow (so that only) ammonia condenses	1 1	AO1 4.10.4.1

4.3.3.2 Atom economy

Answer 07 · Mark scheme

June 2022 | 8462/2H | Original Q7

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.4	scale labelled at 100, 200, 300 and 400 (atm)	allow scale labelled at 50, 150, 250 and 350 (atm)	1	AO2 4.10.4.1
	all five points plotted correctly	allow a tolerance of ± ½ a small square allow **1** mark for three / four points plotted correctly	2	
	line of best fit		1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.5 View with Figure 5	extrapolation to 500 atmospheres		1	AO2 4.10.4.1
	percentage value at 500 atmospheres	allow a tolerance of ± ½ a small square	1	

4.3.3.2 Atom economy

Answer 07 · Mark scheme

June 2022 | 8462/2H | Original Q7

Question	Answers	Mark	AO / Spec. Ref.
07.6	**Level 3**: Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.	5–6	AO1 4.6.1.3 4.6.1.4 4.6.2.6 4.6.2.7 4.10.4.1
	Level 2: Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.	3–4	
	Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.	1–2	
	No relevant content	0	
	Indicative content **rate** • higher temperature gives higher rate because of more frequent collisions • higher temperature gives higher rate because more particles have the activation energy • higher pressure gives higher rate because of more frequent collisions • use of catalyst gives higher rate because the activation energy is lowered **equilibrium** • higher temperature shifts the position of equilibrium to the left because reaction is exothermic • higher pressure shifts the position of equilibrium to the right because more molecules on left-hand side • use of catalyst has no effect on the position of equilibrium **other factors** • higher temperature (than 450°C) uses more energy so increases costs • higher pressure (than 200 atmospheres) uses more energy so increases costs • higher pressure (than 200 atmospheres) requires stronger reaction vessels so increases costs • use of a catalyst reduces energy costs **compromise** • the temperature chosen is a compromise between rate of reaction and position of equilibrium • the temperature chosen is a compromise between rate and cost • the pressure chosen is a compromise between yield / rate and cost		

Total Question 7		**17**

Answer 08 · Mark scheme

June 2023 | 8462/1H | Original Q9

Question 9

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.1	(substance reduced) Fe_2O_3 (reason) (Fe_2O_3) loses oxygen	allow iron oxide MP2 is dependent upon MP1 being awarded ignore Fe^{3+} gains electrons	1 1	AO2 4.4.1.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.2	$\frac{3}{2}$ × 12g		1	AO2 4.3.1.1 4.3.2.1 4.3.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.3	**A** loses electrons and $\mathbf{B}^+$ gains electrons		1	AO2 4.4.1.4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.4	**D**		1	AO3 4.4.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.5	(metal) **C** (explanation) aluminium forms ions with a charge 3+ (so) 3 nitrate ions are needed for 1 aluminium ion	 allow aluminium forms Al^{3+} (ions) allow (so) 3 nitrate ions are needed to balance the 3+ charge on 1 aluminium (ion)	1 1 1	AO3 4.4.1.2 4.4.3.3

4.3.3.2 Atom economy

Answer 08 · Mark scheme

June 2023 | 8462/1H | Original Q9

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.6	(percentage atom economy =) $\frac{A_r\mathbf{X}}{A_r\mathbf{X} + 54} \times 100 = 77.3$		1	AO2 4.3.3.2
	100 A_r**X** = 77.3 (A_r**X** + 54)	allow A_r**X** = 0.773 (A_r**X** + 54) allow correct use of an incorrectly determined value of the M_r of the non-useful reactant atoms	1	
	22.7 A_r**X** = 4174.2	allow 0.227 A_r**X** = 41.742	1	
	A_r**X** = 184	allow 183.8854626 correctly rounded to at least three significant figures	1	
	alternative approach 1: ($3M_r$ H_2O = (3 × 16) + (6 × 1) =) 54 **and** (percentage = 100 – 77.3 =) 22.7% (1)			
	(total M_r of reactants =) $\frac{100}{22.7} \times 54$ (1)	allow correct use of an incorrectly determined value for $3M_r$ H_2O and/or percentage of unwanted products		
	= 238 (1)			
	(A_r**X** = 238 – 54) **or** $\left(A_r\mathbf{X} = 238 \times \frac{77.3}{100}\right)$ = 184 (1)	allow correct use of an incorrectly determined value of total M_r of reactants and/or value for $3M_r$ H_2O allow 183.8854626 correctly rounded to at least three significant figures		

	alternative approach 2: ($3M_r$ H_2O = (3 × 16) + (6 × 1) =) 54 **and** (percentage = 100 – 77.3 =) 22.7% (1) $\left(\frac{1}{22.7} \times 54 =\right)$ 2.3788546 (1) 2.3788546 × 77.3 (1) = 184 (1)	allow correct use of an incorrectly determined value for $3M_r$ H_2O and/or percentage of unwanted products allow correct use of an incorrectly determined value for 1% of the total M_r of reactants allow 183.8854626 correctly rounded to at least three significant figures		

Total Question 9	**12**

4.3.3.2 Atom economy

Answer 09 · Mark scheme

June 2025 | 8462/1H | Original Q3

Question 3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	(substance reduced) SnO_2	allow tin oxide	1	AO2 4.4.1.1 4.4.1.3
	(reason) (SnO_2) loses oxygen	allow (tin oxide) loses oxygen MP2 is dependent upon MP1 being awarded	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.2	carbon is more reactive than tin	allow tin is less reactive than carbon	1	AO3 4.4.1.2 4.4.1.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.3	(total M_r = 128 + 12 =) 140	allow (total M_r = 112 + 12 + 16 =) 140	1	AO2 4.3.3.2
	(% atom economy =) $\frac{112}{140} \times 100$	allow correct use of an incorrectly determined total M_r	1	
	= 80 (%)		1	

4.3.3.2 Atom economy

Answer 09 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.4		allow the converse for potassium allow the transition metal for tungsten allow the Group 1 metal for potassium ignore references to atomic structure		
	any **two** from: tungsten • has a higher melting / boiling point • is denser • is harder • is stronger • is less reactive • has ions with different charges • forms coloured compounds • can be a catalyst	 allow is less malleable / ductile allow specific reactions showing difference in reactivity	2	AO1 4.1.2.5 4.1.3.1 4.1.3.2

4.3.3.2 Atom economy

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.5	(sum of relative formula masses on left hand side =) 232 + (3 × 2) = 238 (is equal to sum of relative formula masses on right hand side =) 184 + (3 × 18) = 238	allow (sum of relative formula masses on left hand side =) 232 + 6 = 238 allow (is equal to sum of relative formula masses on right hand side =) 184 + 54 = 238 if no other mark awarded, allow **1** mark for 232 + (3 × 2) = 184 + (3 × 18) **or** 232 + 6 = 184 + 54 **or** allow **1** mark for both sides = 238	1 1	AO2 4.3.1.1 4.3.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.6	for sustainable development **or** for economic reasons	allow to minimise use of limited resources allow to minimise use of energy allow to minimise waste ignore references to yield	1	AO1 4.3.3.2

Total Question 3	11

4.3.3.2 Atom economy

Answer 03 · Examiner comments

June 2018 | 8462/1H | Original Q2

Question 2 (standard demand)

02.1 Because the question asked for the formula rather than the empirical formula, an answer of Fe_9S_{18} was accepted. Even so, 51% of students could not count the atoms and produce a ratio of 1:2. A formula was required, not an equation which some students provided.

02.2 This was very well answered, with 88% of students achieving all three marks.

02.3 57% of students achieved both marks. However, some repeated information in the stem of the question, and some contradicted it by saying sodium is not a metal. Some gave differences in the structure of the atoms instead of differences in properties of the substances.

02.4 This was well answered, with 32% of students achieving one mark, and 57% achieving both.

A common error was to say that carbon is reacting with oxygen (it is not; it is reacting with nickel oxide to remove the oxygen). Those who tried to answer in terms of electron transfer often struggled to gain all the marks.

Answer 03 · Examiner comments

June 2018 | 8462/1H | Original Q2

02.5 This question was well answered, with 60% of students achieving all three marks. However, interpretation of calculator displays did cause a bit of trouble for some students. Some students lost the final mark because they gave an answer of 67.$\dot{8}$. This answer is neither correct (it is not 67.8888888…) nor to three significant figures (it is to an infinite number of significant figures). Some even recognised this latter point and rounded, incorrectly, to 67.9.

4.3.3.2 Atom economy

Answer 05 · Examiner comments November 2020 | 8462/1H | Original Q3

Question 3 (standard demand)

03.1 Many students failed to recognise or state that a reaction was taking place, merely referring to changes in mass on mixing. Some did not use the data in the question, as was required. Many students appeared to confuse conservation of mass with conservation of energy.

03.2 Most students realised that filtration would obtain the solid. Crystallisation was a commonly seen incorrect response.

03.3 Many students gave the answer 'sodium' as opposed to sodium nitrate, sodium iodide or sodium ions. Dust and bacteria were not uncommon responses.

03.4 Many students did not realise that heating was simply to dry the silver iodide, by evaporating off the water from the previous step.

03.5 This calculation was well done, although some students added up all four values of M_r instead of just those of the reactants.

03.6 Most answered correctly in terms of profitability, or reduction of waste. There was some confusion between atom economy and percentage yield.

Answer 06 · Examiner comments November 2021 | 8462/1H | Original Q3

Question 3 (standard demand)

03.1 This was well answered by many students. A common error was to not multiply the relative formula mass of hydrogen by three, leading to an answer of 100.

03.2 This was well answered. Credit was given to those who applied an incorrect response to question **03.1** correctly. Some students gave an answer which corresponded to their answer to question **03.1** used as atomic number rather than relative atomic mass.

03.3 This was well answered, although a common error was to omit the carbon in calculating the total M_r of the reactants.

03.4 The best answers gave the pros and cons of each method and then gave a judgement. One misconception was that the iron oxide in method 3 could be sold. Many concentrated only on cost, and the number of by-products, rather than what those products were and how difficult or costly further separation would be. Few students used the information provided, that solid products have to be separated. A few very good students commented on the low atom economy that method 1 would give because of some tungsten being lost as tungsten carbide.

4.3.3.2 Atom economy

Answer 07 · Examiner comments

June 2022 | 8462/2H | Original Q7

Question 7 (Standard, standard/high and high demand)

07.1 This was well answered with around half of the students scoring both marks. Incorrect responses included the atmosphere being a source of the hydrogen as well as the nitrogen. There were far fewer responses stating that biogas of any kind was suitable for the large-scale production of ammonia than in previous years.

07.2 About 25% of the students scored this mark. 'No by-products' was seen quite often and others stated there were the same number of atoms on both sides, which just means that the equation is balanced, not necessarily that there is only 1 product.

07.3 Roughly 1 in 10 students gained both marks. Many scored the second mark, but far fewer the first. This was often due to imprecise language rather than misunderstanding, but many stated that 'ammonia is cooled'. The distinction between **all** the gases being cooled but only ammonia condensing is important. A large proportion did not mention cooling at all. Some negated the second mark by stating that ammonia has a lower boiling point than the other two gases.

4.3.3.2 Atom economy

Answer 07 · Examiner comments June 2022 | 8462/2H | Original Q7

07.4 Labelling the scale and the plotting of the given points was nearly always correct. Some did not label on the major gridlines, while a few got the scale completely wrong by labelling the major gridlines in multiples of 60 atmospheres, which did not match the pre-plotted points and therefore denied access to the plotting marks. Most students drew good best-fit curves, although some inappropriately drew a straight line. Over half of the students gained all four marks.

07.5 Most students extrapolated their line correctly and read off the value of the percentage at 500 atmospheres. About two-thirds of the students scored both marks.

07.6 This high demand extended response question gave students the opportunity to demonstrate their knowledge of collision theory, Le Chatelier's Principle and catalytic action in the context of the Haber Process.

More able students seemed to understand that they needed to consider cost implications. Explaining that a compromise is made in the choice of the temperature and the pressure was important in accessing Level 3.

The compromises made for temperature and pressure that were related to cost were more commonly stated than the compromise for temperature in relation to rate and position of equilibrium.

There was a high proportion of responses with additional material producing comprehensive, high-scoring responses. There were also a good number of weaker responses containing isolated statements, most commonly relating the conditions to rate, or more rarely position of equilibrium, but without explaining these relationships. Such responses were usually confined to Level 1. The ratio of Level 1:2:3 marks was roughly 40:20:20 with the remainder failing to gain any marks on this question.

4.3.3.2 Atom economy

Answer 08 · Examiner comments

June 2023 | 8462/1H | Original Q9

Question 9 (standard, standard/high and high demand)

09.1 Students found this question difficult, with only a tenth of students scoring both marks and not many more scoring one. Most students gave incorrect responses for the substance reduced: usually iron, but sometimes carbon. Those who gave the correct substance were usually able to give the correct reason in terms of loss of oxygen. It seems that students are so well versed in the definitions of redox in terms of electrons (as in question 09.3) that they have forgotten the simpler definitions in terms of gain or loss of oxygen.

09.2 Fewer than a third of students gave the correct answer, with all three distractors being very popular. This suggests a large degree of guessing rather than using the equation to work out the mole ratio of C:Fe as 3/2 and then multiply by 12 grams.

09.3 Over three-quarters of students could correctly apply their knowledge of redox in terms of electrons. By far the most common incorrect response was **A** gains electrons and $\mathbf{B}^+$ loses electrons.

09.4 Fewer than one in seven students answered this high demand question correctly, with the great majority giving metal **A** as the answer. It was necessary to realise that the greatest tendency to form positive ions means the most reactive metal. It was then necessary to work out from the three reactions in the table that **A** is more reactive than **B**, **C** is more reactive than **A**, and **C** is less reactive than **D**, making **D** the most reactive.

09.5 This question discriminated well. Over half of students scored at least one mark, with just over one in ten scoring all three.

Many students tried to answer in terms of the reactivity series. This was not possible, as insufficient detail was provided to identify any of the four metals. The formula of the nitrate ion was provided but was not referenced by the majority of students. The key to answering the question was in the formulae of the nitrates; aluminium forms an ion of charge 3+, so each ion requires three nitrate ions to balance the charge. Even when students got the basic idea, they often did not express themselves clearly enough, using phrases such as ‘aluminium has a 3+ charge’ rather than referring to an aluminium ion.

09.6 Those who understood the concept of atom economy were able to complete this difficult calculation successfully; over a fifth of students scored all four marks and two fifths scored at least one.

There were two main approaches. One was to substitute values into the atom economy expression, followed by successive rearrangements of the expression to give the value of A_r of **X**. A neater solution, used by students who had a good understanding of atom economy, was to realise that the remaining 22.7% was the total M_r of the waste atoms, ie 54, and then scale either to 100% and subtract the 54, or scale straight to 77.3%. Many students misunderstood the M_r of XO_3, thinking it meant the A_r of **X** times 48. Some also misunderstood $3H_2$ or $3H_2O$, giving various values for what should have been a total of 54 for the M_r of the waste atoms. Nevertheless, correct manipulation after these errors allowed access to 3 marks.

Answer 09 · Examiner comments

Question 3 (standard demand)

03.1 This was answered less successfully, with the majority of students choosing tin as the substance reduced. Tin is the product of the reduction, not the substance which is reduced. Those who did choose the correct substance, SnO_2, were usually able to give a correct reason; one in seven students were awarded both marks. Some tried to answer in terms of electrons, despite the instruction to answer in terms of oxygen. These answers did not gain credit for the second marking point.

03.2 Nearly three quarters of students managed to state succinctly that carbon is more reactive than tin or that tin is less reactive than carbon. However, some answers were vague and used the word 'it' which is problematic as there are three substances named in the question. 'Carbon is more reactive' is insufficient as we do not know what the reactivity is being compared to.

03.3 More than two thirds of students achieved full marks. Some did not calculate a total M_r but used the M_r of CdO instead; these answers were not creditworthy. Others added up all the M_r of reactants and products instead of just the reactants; these gained partial credit.

03.4 The question asked for two differences in properties, so comparative language was necessary (potassium is softer rather than potassium is soft). Three fifths of students scored both marks, choosing from differences in physical properties and properties exhibited by transition metals only. The most common type of error was to describe differences in atomic structure rather than differences in the properties of the metals in bulk.

03.5 The vast majority of students interpreted the equation correctly and showed that the total M_r on both sides was 238.

03.6 More than two thirds of students gave an acceptable response. Most of those who were awarded the mark answered in terms of economic reasons such as lowering the cost of the operation. Fewer answered in terms of sustainable development; of those who did, most referred to a high atom economy producing less waste. Some students confuse a high atom economy with a high yield; references to yield were ignored.