AQA GCSE Chemistry | 8462

SPECIFICATION POINT 4.10.4.1

The Haber process

Mark schemes and examiner comments

Tier	**Higher**
Question groups	**18**
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.

4.10.4.1 The Haber process

Answer 01 · Mark scheme January 2008 | CHY2H | Original Q7 | Legacy

(c)	7		1
(d)(i)	steeper line from around the same starting point and left of the points levelling off at 99	allow crosses if they are fully correct for **1** mark accept short level line at 99 ± ½ square	1 1
(d)(ii)	any **three** from: • particles / molecules / atoms/ ions have more energy • move faster • collide <u>more</u> often **or** <u>more</u> chance of collisions **or** bump into each other <u>more</u> • collide with <u>more</u> force / energy **or** <u>more</u> particles have the activation energy **or** <u>more</u> collisions result in reaction **or** <u>more</u> collisions are successful	 allow given / gain / get energy ignore move about more ignore vibrate more / faster ignore collide quicker / faster	3
total			8

4.10.4.1 The Haber process

CHY2H

Question 2

question	answers	extra information	mark
(a)	any **one** from: • they are made of layers • atoms / ions / particles / layers (of atoms) can slide over each other	do **not** accept line / rows / lattice	1
(b)	any **one** from: • smaller / tiny **or** very small • correct size range 1 to 100 nanometres • a few hundred atoms in size	do **not** allow small alone if they state smaller and give a size outside range ignore size if it is less than 20,000	1
(c)	harder plus **one** from: • so does not wear as quickly / erode as quickly • less vulnerable to damage owtte • because they have a high surface area to volume ratio **or** stronger (1) plus **one** from: (1) • less likely to break / do not break • not as vulnerable to damage owtte • do not bend out of shape • because they have a high surface area to volume ratio	 ignore corrode harder to wear down = **1** mark accept withstand pressure harder and stronger alone gains **1** mark	1 1
total			4

4.10.4.1 The Haber process

Answer 01 · Mark scheme

CHY2H

Question 3

question	answers	extra information	mark
(a)	N_2O		1
(b)	13.8 to 14	gains full marks without working if answer incorrect 13 gains **1** mark **or** 14/101 × 100 gains **1** mark	2
total			3

4.10.4.1 The Haber process

CHY2H

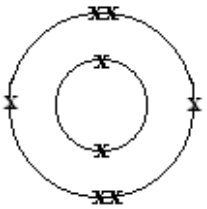
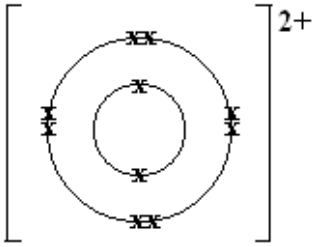
Question 4

question	answers	extra information	mark
(a)	electric current / electricity		1
	plus **one** from:		1
	• is passed through ionic compound / substance / electrolyte • passed through molten/aqueous compound / substance	must be linked to electricity allow liquid compound / substance do **not** allow solution / liquid alone	
	• causing decomposition	accept split up / breakdown / breaking up owtte ignore separated accept elements are formed ignore new substances form	
(b)	hydrogen	accept H_2 do **not** accept H / H^2	1
(c)	one electron from each atom	accept each carbon is bonded to three other carbon atoms leaving one (unbonded) electron owtte	1
	is delocalised / free (to move)	must be linked to electrons answers of delocalised / free electrons only, gains **1** mark accept each carbon is bonded to three other carbon atoms leaving delocalised / free electrons = **2** marks **maximum 1** mark if graphite described as a metal / giant ionic lattice	1
total			5

4.10.4.1 The Haber process

CHY2H

Question 5

question	answers	extra information	mark
(a)	any **one** from: • gives out heat / energy • transfers energy from a substance to the surroundings • ΔH / energy change / enthalpy change is negative	accept releases / gives off owtte ignore references to light	1
(b)	$2Mg + O_2 \rightarrow 2MgO$	accept correct multiples / fractions	1
(c)		electrons do not need to be paired accept dots / circles / e instead of crosses do **not** allow 2.6 without diagram	1
(d)		electrons do not need to be paired allow without brackets must have the charge accept dots / circles / e instead of crosses ignore extra empty outer shells ignore nucleus do **not** allow $[2.8]^{2+}$ without diagram	1

continued…

4.10.4.1 The Haber process

CHY2H

Question 5 continued…

question	answers	extra information	mark
(e)	oppositely charged (ions / atoms)	allow positive and negative(ions / atoms)	1
	(they) attract	must be in correct context accept held by electrostatic forces ignore ionic bonding **maximum 1** if they refer to intermolecular forces / attractions / covalent bonds	1
(f)	magnesium chloride	accept $MgCl_2$ (if correctly written)	1
total			7

4.10.4.1 The Haber process

CHY2H

Question 6

question	answers	extra information	mark
(a)	**Compound A** any **one** from: • sodium bromide • potassium bromide • ammonium bromide • hydrogen bromide • any metal bromide except silver and lead. **Compound B** silver nitrate	accept correct formulae accept silver sulfate	1 1
(b)	the silver compound will decompose / silver ions be reduced to silver (owtte)	accept film would darken owtte accept any idea of light changing silver bromide / silver ions / silver nitrate / silver sulfate allow 'forms a black solid' / it would turn black	1
(c)	precipitation	accept descriptions of precipitation reactions accept double decomposition accept precipitate do **not** allow displacement	1
(d)	electrons are gained	 the second mark **must** be linked to electrons accept it / silver / silver ions gains electrons for **both** marks ignore references to oxygen	1 1
total			6

4.10.4.1 The Haber process

CHY2H

Question 7

question	answers	extra information	mark
(a)	1213.8 to 1214.3 correct answer not given then check working 1) moles of N_2 = $\frac{1000}{28}$ = 35.7 mol 2) moles of NH_3 = 2 × (answer from (1)) = 71.4 mol 3) mass of NH_3 = (answer from 2) × 17 = 71.4 × 17 = 1214 g **or** • 28g of N_2 → 34g of NH_3 • 1g of N_2 → $\frac{34}{28}$ = 1.214g NH_3 • 1000 g of N_2 → 1000 × 1.214 = 1214g **or** • $1000 \times \frac{34}{28}$ **or** **other correct methods**	gains **3** marks without working **1** mark for each correct step do **not** penalise rounding errors in this part **1** mark for each correct step do **not** penalise rounding errors in this part allow error carried forward eg gains **2** marks if correct answer not given $1000 \times \frac{28}{34}$ gains **1** mark, **2** marks if correctly calculated (823.5g) $1000 \times \frac{28}{17}$ gains **1** mark if calculated correctly (1647.05g) look for the key ideas in the methods above	3

continued…

CHY2H

Question 7 continued…

question	answers	extra information	mark
(b)	25 / 25.035 **or** ecf from (a)	gains **2** marks even when there is no working incorrect answer then 304/(their answer from (a)) × 100 gains **1** mark	2
	or using figures from part (b)		
	27.6 / 28	gains **2** marks even when there is no working accept 27 for **1** mark if answers incorrect then304/1100 × 100 gains **1** mark	
(c)(i)	increase yield		1
	reaction is exothermic		1
	or		
	allow decreased yield because rate of reaction is slower / fewer collisions for **2** marks	**must** get both points for **2** marks	
(c)(ii)	increase yield		1
	plus **one** from: • more (gaseous) reactant molecules than (gaseous) product molecules (owtte) • increased rate of reaction / more collisions	accept greater volume on the left than the right owtte	1

continued…

CHY2H

Question 7 continued…

question	answers	extra information	mark
(d)	any **one** from: **economic** • large town provides workforce • workers do not have to travel far to the factory. (owtte) • transport infrastructure already in place for large town. (owtte) • factory brings prosperity to town (owtte) • factory provides employment • reduced tourism • reduction in local house prices • any other sensible economic factor linked to town		1
	any **one** from: **safety** • <u>escape</u> of dangerous / harmful chemicals / gases (owtte) • <u>danger</u> of increased traffic • risk of explosion.(owtte) /danger of high pressure • consequences of an accident could be severe if the town is close • any other sensible safety idea	do **not** allow polluting gases unqualified	1

continued…

4.10.4.1 The Haber process

CHY2H

Question 7(d) continued…

question	answers	extra information	mark
	any **one** from: **environmental** • factory might be unsightly (owtte) • screening of factory (owtte) • loss of habitats (owtte) • plant trees/ hedges etc on and around plant site • pollution of water / air / soil could harm plants / animals **or** noise pollution • CO_2 is produced by burning fuels / heating • CO_2 causes global warming / any effect of global warming • eye sore • any other sensible environmental factor	must be explained	1
total			12

4.10.4.1 The Haber process

Answer 02 · Mark scheme January 2010 | CHY2H | Original Q6 | Legacy

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

4.10.4.1 The Haber process

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**

4.10.4.1 The Haber process

Answer 03 · Mark scheme

June 2010 | CHY2H | Original Q1 | Legacy

Question 1

question	answers	extra information	mark
1(a)(i)	(nitrogen) + hydrogen → ammonia	accept H_2 and NH_3 ignore incorrect symbols ignore balancing	1
1(a)(ii)	any **one** from: • catalyst • to speed up the reaction • lower activation energy	 ignore causes reaction ignore heat / reference to particles 	1
1(a)(iii)	any **two** from: • cooled • ammonia condenses / turns into liquid • nitrogen and hydrogen do not condense / turn into liquid **or** nitrogen and hydrogen stay as gases	it = ammonia ignore references to boiling point if no marks awarded accept pass through / separated in condenser **or** unreacted nitrogen and hydrogen / gases recycled for **1** mark	2

Question 1 continues on the next page

4.10.4.1 The Haber process

CHY 2H

Question 1 continued

question	answers	extra information	mark
1(b)	80	correct answer with or without working gains **2** marks ignore units if answer incorrect, evidence of correct working gains **1** mark eg 14 + (4 x 1) + 14 + (3 x 16) (= 70) **or** 2N + 4H +30	2
1(c)	fertiliser is **C** evidence of correct working	 examples of minimum correct working: 39/101 **or** 14/101 **or** 38.61/100 **or** 13.86/100	1 1
Total			**8**

4.10.4.1 The Haber process

Answer 03 · Mark scheme

June 2010 | CHY2H | Original Q1 | Legacy

CHY 2H

4.10.4.1 The Haber process

Answer 04 · Mark scheme

June 2011 | CHY2H | Original Q7 | Legacy

Question 7

question	answers	extra information	mark
7(a)(i)	nitrogen – air	accept atmosphere	1
	hydrogen – north sea gas / natural gas / methane / CH_4	accept water / (crude) oil / coal / hydrocarbons / brine	1
7(a)(ii)	• high temperature gives a low yield	allow converse throughout	1
	• because reaction is exothermic	must be linked to first bullet point	1
	• but at low temperatures the rate is (too) slow		1
		if no other marks awarded accept 450°C is a compromise between yield and rate **or** 450°C gives a reasonable yield in a reasonable time for **1** mark	
7(a)(iii)	nitric (acid)	accept HNO_3	1
7(b)	Ammonia / Haber process can be used to make fertiliser		1
	with a specified economical reason eg raw materials for Haber process readily available eg transport costs are lower or no need to import eg Haber process is a continuous process	ignore employment / labour costs	1
Total			**8**

The AQA UMS Conversion Calculator is available on the Results statistics page of the AQA Website

4.10.4.1 The Haber process

Answer 05 · Mark scheme

Question 3

question	Answers	extra information	Mark
3(a)(i)	M_r of NH_3 = 17 **or** 2 (moles of) NH_3 = 34 **or** 14 → 17 **or** 28 → 34	correct answer with or without working gains **3** marks accept correct rounding of intermediate answers can be credited from correct substitution from step 2	1
	(28/34) x 6.8 **or** (14/17) x 6.8	allow ecf from step 1	1
	= 5.6	allow ecf from step 1	1
3(a)(ii)	61.8	accept 61.76 **or** 62 **or** 61.76… correct answer with or without working gains **2** marks if answer is not correct evidence of 4.2 / 6.8 x 100 gains **1** mark if answer not correct 0.618 or 0.62 gains **1** mark	2
3(a)(iii)	reaction is reversible	accept reaction reaches equilibrium allow reaction does not reach completion ignore some is lost	1
3(b)	3 bonding pairs	do **not** accept extra electrons on hydrogen	1
	1 lone pair	accept 2 non-bonding electrons on outer shell of nitrogen	1
3(c)(i)	hydroxide / OH^-	accept phonetic spelling	1

Question 3 continues on the next page

4.10.4.1 The Haber process

Question 3 continued

question	Answers	extra information	Mark
3(c)(ii)	neutralisation	accept acid-base allow exothermic	1
3(c)(iii)	nitric (acid)	allow HNO_3 ignore incorrect formula	1
3(c)(iv)	$(NH_4)_2SO_4$	allow $(NH_4^+)_2SO_4^{2-}$	1
Total			**12**

4.10.4.1 The Haber process

Answer 06 · Mark scheme

June 2013 | CH3HP | Original Q6 | Legacy

Question 6

question	Answers	extra information	Mark
6(a)	air		1
6(b)	recycle (unreacted) nitrogen and hydrogen	allow re-use allow N_2 and H_2	1 1
6(c)	$N_2 + 3H_2 \rightarrow 2NH_3$	allow correct multiples	1
6(d)	 because a higher temperature would reduce (equilibrium) yield because a lower temperature would reduce rate	allow converse arguments ignore references to compromise allow higher temperature favours backward reaction	 1 1
6(e)(i)	(energy of) reactants greater than (energy of) products	allow converse allow (overall) energy decreases allow energy required to break bonds is less than the energy released making bonds	1
6(e)(ii)	line starting and finishing at same levels but with lower peak		1
Total			8

4.10.4.1 The Haber process

Answer 07 · Mark scheme June 2014 | CH3HP | Original Q5 | Legacy

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
5(a)	$2NH_3$	allow NH_3 with incorrect or missing balancing for **1** mark *allow multiples*	2	2 / 3.5.1b	E
5(b)(i)	200		1	3 / 3.5	G
5(b)(ii)	rate of reaction (too) slow	*allow converse* ignore references to yield / *cost*	1	2 / 3.5.1f/h	E
5(b)(iii)	400		1	2 / 3.5	A
5(b)(iv)	lower yield	*allow converse* accept shifts equilibrium to left allow favours the backward reaction allow favours side with *more* (gaseous) molecules allow lower rate	1	2 / 3.5.1g/h	E
5(c)	(gases) cooled *ammonia* liquefied	*it = ammonia* accept *ammonia* condensed accept ammonia cooled below boiling point for **2** marks	 1 1	1 / 3.5.1b	E
Total			**8**		

4.10.4.1 The Haber process

Answer 07 · Mark scheme

June 2014 | CH3HP | Original Q5 | Legacy



4.10.4.1 The Haber process

Answer 08 · Mark scheme

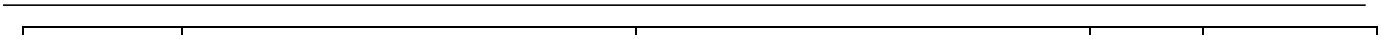
June 2015 | CH3HP | Original Q1 | Legacy

Question	Answers	Extra information	Mark	AO / Spec. Ref.
1(a)	Li **and** K	either order allow lithium **and** potassium	1	**AO1** 3.1.3.a
1(b)	Fe	allow iron	1	**AO1** 3.5.1.b
1(c)	N **and** As	either order allow nitrogen **and** arsenic	1	**AO2** 3.1.2.b
1(d)	Cu	allow copper	1	**AO1** 3.1.3.d
Total			**4**	

4.10.4.1 The Haber process

Answer 08 · Mark scheme

June 2015 | CH3HP | Original Q1 | Legacy



4.10.4.1 The Haber process

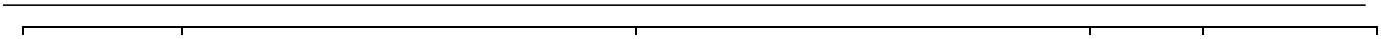
Answer 09 · Mark scheme June 2015 | CH3HP | Original Q6 | Legacy

Question	Answers	Extra information	Mark	AO / Spec. Ref.
6(a)(i)	nothing can enter **and** nothing can leave the reaction	allow sealed reaction vessel	1	**AO1** 3.5.1.c
6(a)(ii)	forward and backward reactions have same rate so there is no (overall) change in quantities of reactants and products	 allow concentrations of reactants and products	1 1	**AO1/ AO2** 3.5.1.c
6(b)(i)	natural gas	allow methane / CH_4 allow fossil fuels / hydrocarbons allow water	1	**AO1** 3.5.1.a
6(b)(ii)	provides an alternative reaction pathway which has a lower activation energy	 ignore references to collisions	1 1	**AO1** 3.3.1.h
6(b)(iii)	the amount (of ammonia) increases the equilibrium moves to the side (of the equation) with fewer (gaseous) molecules / moles	allow yield increases allow it favours the forward reaction	1 1	**AO1/ AO2** 3.5.1.d/g
6(c)(i)	vertical arrow from reactants to maximum		1	**AO2** 3.3.1.e
6(c)(ii)	(energy of) products higher than (energy of) reactants	allow converse	1	**AO2** 3.3.1.d
6(c)(iii)	amount of hydrogen iodide decreases equilibrium moves in the direction of the endothermic reaction	 allow it favours the forward reaction	1 1	**AO1/ AO2** 3.5.1.d/e
Total			**12**	

4.10.4.1 The Haber process

Answer 09 · Mark scheme

June 2015 | CH3HP | Original Q6 | Legacy



4.10.4.1 The Haber process

Answer 10 · Mark scheme June 2016 | CH2HP | Original Q2 | Legacy

Question	Answers	Extra information	Mark	AO / SpecRef
2(a)	endothermic		1	AO1 2.5.1d
2(b)	82 (%)	correct answer with working gains **3** marks if 17 or 34 not shown in working **max 2** marks accept 82.4 accept 82.35 to full calculator display (82.35294...) correctly rounded to at least 2 sf if no answer or incorrect answer, then (M_r =) 17 gains **1** mark **or** 14/17 gains **2** marks **OR** ($2M_r$ =) 34 gains **1** mark **or** 28/34 gains **2** marks **OR** 14/their M_r shown gains **1** mark **or** correct calculation of 14/their M_r gains **2** marks	3	AO2 2.3.3a, 2.3.1f
2(c)(i)	7 / seven		1	AO1 2.6.2d
2(c)(ii)	$H^+ + OH^- \rightarrow H_2O$		1	AO1 2.6.2e
2(c)(iii)	ammonium chloride	allow NH_4Cl ignore an incorrect formula	1	AO1 2.6.2b

Question 2 continues on the next page

Question 2 continued

Question	Answers	Extra information	Mark	AO / SpecRef
2(d)			6	2AO2 / 4AO3 2.6.2c

Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information on page 5 and apply a 'best-fit' approach to the marking.

0 marks	Level 1 (1–2 marks)	Level 2 (3–4 marks)	Level 3 (5–6 marks)
No relevant content.	Suggestion with a reference to a graph.	Suggestion with reasons referring to more than one graph.	Suggestion with reasons from all three graphs, and linking of ideas which may explain a compromise.

Examples of chemistry points made in response:
A reasonable suggested amount of fertiliser would be in the region of 200 kg (per ha). Accept any suggestion from about 180 kg (per ha) to 500 kg (per ha).

Yield:
- Using fertiliser improves yield.
- Yield improved most up to about 200 kg (per ha) of fertiliser.
- Yield only increased slightly above about 200 kg (per ha).

Profit:
- About 200 kg of fertiliser gives the most profit.
- Above about 200 kg (per ha) of fertiliser profit declines.

Run off:
- Run off is at low levels until about 300 kg (per ha) of fertiliser.
- Above about 300 kg (per ha) of fertiliser, run off increases.

Examples of linking of ideas:
- Overall 200 kg gives high crop yield and most profit.
- In conclusion 200 kg gives high crop yield and low run off.
- 200 kg gives most profit and low run off.

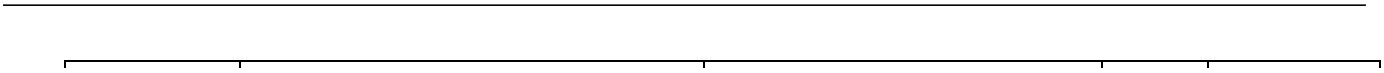
Examples of compromise:
- Profits go down after about 200 kg (per ha) of fertiliser because cost of fertiliser is not covered by increased yield.
- 200 kg gives the highest profit although it is not the highest yield.
- 500 kg gives the best yield but has the most runoff.

Total			13

4.10.4.1 The Haber process

Answer 10 · Mark scheme

June 2016 | CH2HP | Original Q2 | Legacy



4.10.4.1 The Haber process

Answer 11 · Mark scheme June 2016 | CH3HP | Original Q6 | Legacy

Question	Answers	Extra information	Mark	AO / SpecRef
6(a)(i)	natural gas	allow fossil fuels / biogas generator	1	AO1 3.5.1a
6(a)(ii)	air contains oxygen this would react with / oxidise the hydrogen	 allow this would react with / oxidise the iron ignore nitrogen	1 1	AO3 3.5.1b
6(a)(iii)	cooled ammonia condenses / liquefies (so can be separated) nitrogen and hydrogen (remain as gases and) are returned to the reactor	 allow recycled	1 1 1	AO1 3.5.1b
6(b)(i)	200 °C **and** 1000 atmospheres		1	AO3 3.5.1b
6(b)(ii)	the reaction is reversible forward reaction is exothermic so increased temperature lowers the yield of ammonia a lower temperature would decrease rate of reaction a higher pressure would increase the yield of ammonia because the forward reaction produces the least number of (gaseous) molecules / moles higher pressures would involve high cost / energy	allow stated as equilibrium or forward / backward reaction anywhere in answer allow converse allow converse allow converse ignore risk / explosion	1 1 1 1 1	3AO1 / 2AO3 3.5.1d,e,f,g,h
Total			**12**	

4.10.4.1 The Haber process

Answer 12 · Mark scheme June 2017 | CH3HP | Original Q6 | Legacy

Question	Answers	Extra information	Mark	AO / Spec. Ref.
6(a)(i)	natural gas or water / steam	allow methane / crude oil / petroleum ignore processes	1	**AO1** 3.5.1a
6(a)(ii)	cool to any temp in the range -33 to -196 °C because (at this temperature) ammonia becomes a liquid **or** ammonia condenses		1 1	**AO1** **AO3** 3.5.1b
6(b)(i)	81(kJ)	ignore sign ((4 x 391 + 160) =) 1724 for 1 mark, and ((2 x 432 + 941) =) 1805 for 1 mark correct subtraction using one correct value for 1 mark	3	**AO2** 3.3.1f
6(b)(ii)	because energy taken in to break bonds is less than energy given out when bonds form	allow converse	1 1	**AO1** 3.3.1e,f
Total			**8**	

4.10.4.1 The Haber process

Answer 13 · Mark scheme

June 2018 | 8462/2H | Original Q3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	hydrogen	allow H_2	1	AO1 4.10.4.1
03.2	450 °C 200 atm / atmospheres	allow values in the range 400– 500 °C allow values in the range 150– 250 atm / atmospheres allow **1** mark if both values within range but no units given	1 1	AO1 4.10.4.1
03.3	ammonia has a higher boiling point	allow the other gases have lower boiling points ignore references to melting point	1	AO3 4.10.4.1

4.10.4.1 The Haber process

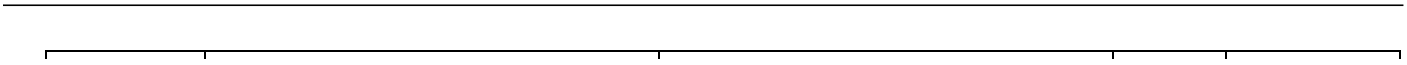
Answer 13 · Mark scheme June 2018 | 8462/2H | Original Q3

Question	Answers		Mark	AO / Spec. Ref.
03.4	**Level 3:** Relevant points (reasons / causes) are identified, given in detail and logically linked to form a clear account.		5–6	AO2
	Level 2: Relevant points (reasons / causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.		3–4	AO1
	Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.		1–2	AO1
	No relevant content		0	
	Indicative content **changes** • carbon dioxide has decreased • oxygen has increased **processes** • volcanic activity released water vapour • the water vapour condensed to form oceans • carbon dioxide dissolved in oceans • carbonates produce sediments • carbon locked up in sedimentary rocks • algae and plants evolved / appeared • algae / plants absorbed carbon dioxide • by photosynthesis • which also released oxygen • carbon locked up in fossil fuels			4.9.1.2 4.9.1.3 4.9.1.4
03.5	any **one** from: • occurred 4.6 billion years ago • limited or no evidence	allow any indication of billions of years allow limited or no proof ignore there was nobody there	1	AO1 4.9.1.2
Total			**11**	

4.10.4.1 The Haber process

Answer 13 · Mark scheme

June 2018 | 8462/2H | Original Q3



4.10.4.1 The Haber process

Answer 14 · Mark scheme

June 2019 | 8462/2H | Original Q10

Question 10

Question	Answers	Extra information	Mark	AO / Spec. Ref.
10.1	$\frac{6}{34} \times 100$ = 17.6 (%)	an answer of 17.6470588 (%) correctly rounded to at least 2 significant figures scores **2** marks allow 17.6470588 (%) correctly rounded to at least 2 significant figures	1 1	AO2 4.3.3.2
10.2	higher yield (of hydrogen or carbon monoxide or product) (because) fewer moles / molecules / particles on left hand side **or** (because) more moles / molecules / particles on right hand side	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 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 1	AO2 4.6.2.4 4.6.2.7
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

4.10.4.1 The Haber process

Answer 14 · Mark scheme

June 2019 | 8462/2H | Original Q10

10.4	350 (°C) and 285 (atmospheres) = 63 (%) **and** 450 (°C) and 200 (atmospheres) = 28 (%) $\frac{63}{28}$ = 2.25 (times greater)	an answer of 2.25 scores **3** marks 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**	

4.10.4.1 The Haber process

Answer 15 · Mark scheme

November 2021 | 8462/2H | Original Q5

Question 5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	ammonium phosphate potassium nitrate		1 1	AO2 4.10.4.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.2	(nitric acid) calcium nitrate (phosphoric acid) (calcium) triple superphosphate **or** calcium dihydrogenphosphate		1 1	AO1 4.10.4.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.3		allow converse for laboratory process ignore references to cost / energy		AO3 4.10.4.2
	(industrial process) (is) large(er) scale	ignore large mass produced	1	
	(is) quicker		1	
	(is a) continuous process	allow does not need to be repeated	1	
	reasoned judgement		1	

Total			8

4.10.4.1 The Haber process

Answer 16 · 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

4.10.4.1 The Haber process

Answer 16 · 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	

4.10.4.1 The Haber process

Answer 16 · 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**

4.10.4.1 The Haber process

Answer 17 · Mark scheme

Question 2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	to recycle (remaining) nitrogen and hydrogen	allow to recycle unreacted gases allow to return nitrogen and hydrogen to the reactor	1	AO1 4.10.4.1

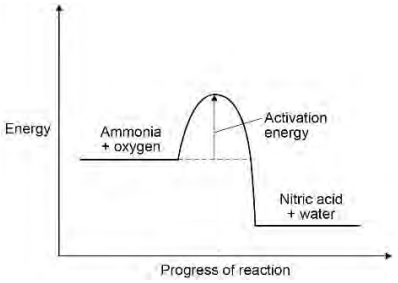
Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.2	iron	allow Fe	1	AO1 4.6.1.4 4.10.4.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.3	(test) glowing splint (result) (splint) relights	 MP2 is dependent upon MP1 being awarded	 1 1	AO1 4.8.2.2

4.10.4.1 The Haber process

Answer 17 · Mark scheme

June 2024 | 8462/2H | Original Q2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.4	labelled vertical arrow from dotted line to peak ammonia **and** oxygen on left **and** nitric acid **and** water on right	ignore arrow heads allow NH_3 for ammonia allow O_2 for oxygen allow HNO_3 for nitric acid allow H_2O for water an answer of  scores **2** marks	1 1	AO2 4.6.1.4 4.10.4.1 4.10.4.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.5	the line would reach a higher peak		1	AO1 4.6.1.4 4.10.4.1 4.10.4.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.6	fertilisers	allow explosives allow sports injury packs	1	AO3 4.10.4.1 4.10.4.2

Total Question 2	8

Answer 18 · Mark scheme

June 2025 | 8462/2H | Original Q9

Question 9

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.1	the forward reaction is endothermic		1	AO2 4.6.1.3 4.6.2.4 4.6.2.6
	(so high temperature) shifts the equilibrium (position) to the right		1	
	(which) increases the yield (of products)	allow (and a high temperature) increases the rate of reaction	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.2		allow converse		AO2 4.6.2.4 4.6.2.7
	(low pressure) shifts the equilibrium (position) to the right		1	
	(because) there are more moles on the right	allow (because) there are more molecules on the right	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.3	no effect on equilibrium position		1	AO3 4.6.1.4 4.6.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.4	(volume ~) $\frac{50 \times 100}{80}$	allow a value in the range 78.0 to 80.0 for percentage of nitrogen	1	AO2 4.9.1.1 4.10.4.1
	~ 62.5 (dm^3)		1	

4.10.4.1 The Haber process

Answer 18 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.5	(the reaction mixture is) cooled		1	AO1 4.10.4.1
	(so that) ammonia condenses / liquefies		1	
	(but) nitrogen **and** hydrogen are gases		1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
09.6	any **three** from: • nitrogen is an abundant gas (in the air) • the use of nitrogen releases fewer greenhouse gases • the nitrogen released replaces that used to make ammonia • natural gas is a finite resource • (the use of hydrogen / methane releases) carbon dioxide which contributes to climate change	allow nitrogen is renewable allow (the use of hydrogen / methane releases) carbon dioxide contributes to global warming	3	AO3 4.10.1.1 4.10.4.1

Total Question 9	14

4.10.4.1 The Haber process

Answer 13 · Examiner comments

June 2018 | 8462/2H | Original Q3

Question 3 (standard demand)

03.1 80% of students realised that the other gas used in the Haber process is hydrogen.

03.2 44% of the students knew the temperature and pressure used in the process. This was made even more challenging as they had to give the correct units as well.

03.3 32% of students could explain why only the ammonia, and not the other gases, turn into a liquid: because its boiling point is higher.

03.4 This was an 'extended response', 'level marked' question. There were three levels and the command word was 'explain'. The question was marked holistically. Students were given information about the current atmosphere of Venus, believed to be similar to that on the early Earth, and the Earth's atmosphere today.

Generally, a level 1 response used the percentages given to say in which direction the amounts of these gases had moved. Level 2 moved beyond this, giving an explanation in terms of one process, such as photosynthesis or dissolving in oceans. Level 3 responses usually gave more than one process, for example both of the processes mentioned above.

Many students talked only about the changes in the last few centuries, which was not what the question was asking. 47% of students were able to provide a level 3 response.

03.5 39% of students seemed aware of the timescale under consideration here, namely the atmosphere of billions of years ago, or that there was a lack of evidence or proof. Many merely asserted that there was no-one there (to make measurements).

4.10.4.1 The Haber process

Answer 15 · Examiner comments November 2021 | 8462/2H | Original Q5

Question 5 (standard / high and high demand)

05.1 Nearly four-fifths of students identified one salt, while more than a third worked out both.

05.2 Around two-thirds of students could identify calcium nitrate.

05.3 Two marks were usually easily scored, often for ideas relating to a quicker or continuous process. Four marks were almost never awarded, because students did not appear to appreciate the need for a reasoned judgement when the command word is 'evaluate'.

Answer 16 · 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.

4.10.4.1 The Haber process

Answer 16 · 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.

4.10.4.1 The Haber process

Answer 17 · Examiner comments June 2024 | 8462/2H | Original Q2

Question 2 (standard demand)

02.1 Around two-fifths of students gained credit on this question. Some students referred to both hydrogen and nitrogen gases being recycled or reused. A few referred to only one of the gases or unspecified unreacted gases.

A number of students referred to excess gases or gases alone. In addition, some students focused their answer on the condenser part of the flow chart and responded with the idea that uncondensed gases needed to be recycled.

02.2 This question was answered well by the majority of students, with roughly two-thirds of students gaining the mark.

02.3 Although this question was answered well, some students referred to a splint being lit initially and then blown out. These students did not often mention the splint was still glowing. The majority of students who stated glowing splint also gained the second marking point. Around three-quarters of students gained both marks; of those who did not, most described the test for hydrogen.

02.4 There were many variations of drawing the arrow for the activation energy. A number of students labelled the activation energy with abbreviations such as E_a. The majority of students correctly named the reactants and products and placed them above and below the lines, with a few using arrows to point out their positions. More than 60% of students gained both marks.

02.5 This multiple-choice question was well answered, with around 70% of students gaining credit. The most popular distractor was that the peak would be lower rather than higher.

02.6 This question was answered extremely well with fertiliser or NPK fertiliser. A small minority stated farming or agricultural use unqualified. Only a handful of students identified its use in explosives or sports injury packs.

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4.10.4.1 The Haber process

Answer 18 · Examiner comments

June 2025 | 8462/2H | Original Q9

Question 9

09.1 Three quarters of students scored at least one mark on this item. This was for either identifying the forward reaction as endothermic, or giving the allow statement for marking point 3, that a high temperature increases the rate. The answers for marking point 2 were often quite vague, talking about the reaction moving to the right-hand side, rather than the position of the equilibrium. Many students gave answers in terms of the Haber process, rather than the given reaction, so answers that suggest an increase in the yield of ammonia were incorrect.

09.2 Fewer than half of students scored either or both marks for this high demand item. The most common response was for identifying that the equilibrium position moved to the right, with far fewer giving the link to the number of molecules on either side of the equation. Many incorrect answers were seen in terms of rate of reaction, or because safety is a factor.

09.3 Two thirds of students correctly identified that catalysts have no effect on the position of the equilibrium.

09.4 It is quite rare to ask for an estimate in a calculation question and this was included because the percentage of nitrogen in the air is given as four fifths in the specification. Around 40% of students recognised that nitrogen makes up between

4.10.4.1 The Haber process

Answer 18 · Examiner comments June 2025 | 8462/2H | Original Q9

78 and 80% of the atmosphere, so would require between 62 and 65 dm^3 of air to produce 50 dm^3 of nitrogen. Where students did not score was because they did not know the percentage of nitrogen in the air.

09.5 Around half of students gained at least one mark on this item, usually for the idea that ammonia condenses. Far fewer students knew that this is done by cooling the mixture or that both nitrogen and hydrogen stay as gases and are recycled, many only mentioning recycling, which was given in the diagram.

09.6 Around two-thirds of students gained at least one mark for this high demand interpretation question. The most common answer was for linking carbon dioxide to climate change. Many students did not gain this mark as there was a need to mention that the production of hydrogen causes this, if further detail was given. Mant talked about hydrogen producing carbon dioxide, which is incorrect and did not gain credit. The next most common response was for the idea that nitrogen was abundant in the atmosphere.

4.10.4.1 The Haber process

Answer 18 · Examiner comments

June 2025 | 8462/2H | Original Q9

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results Statistics page of the AQA Website.