AQA GCSE Combined Science - Trilogy | 8464

SPECIFICATION POINT 5.5.1.3

The energy change of reactions (HT only)

Mark schemes and examiner comments

Tier	**Higher**
Question groups	**5**
Available paper years	**2019–2025**

Using this booklet

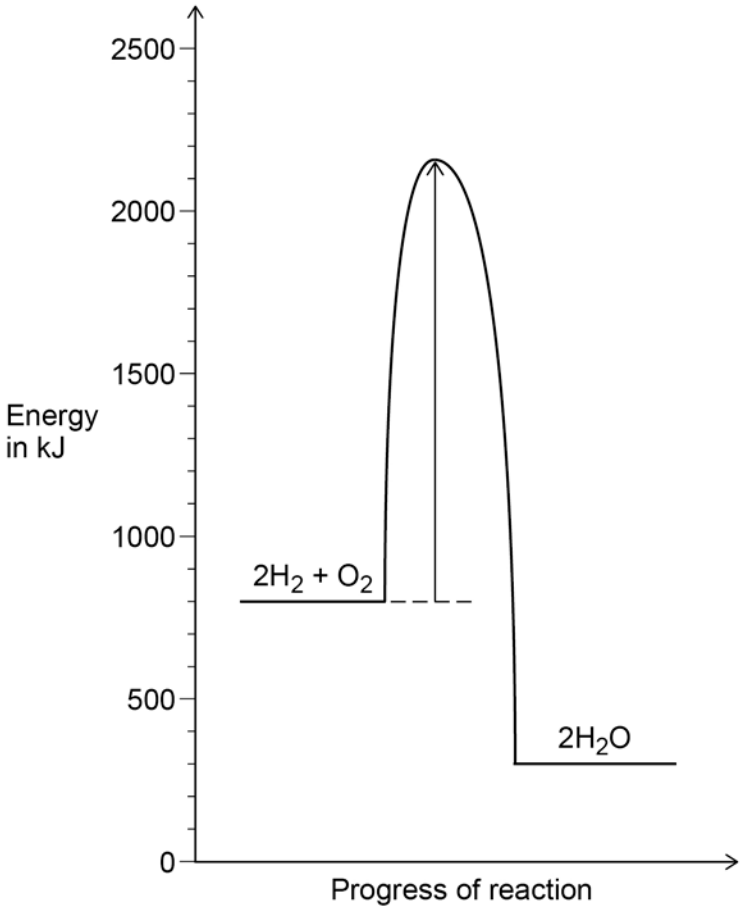
1. Booklet answer numbers match the question booklet.
2. Use the original question number within marking tables.
3. Examiner comments are included where available.

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.

5.5.1.3 The energy change of reactions (HT only)

Answer 01 · Mark scheme June 2019 | 8464/C/1H | Original Q3

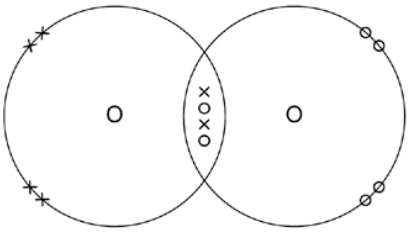
03.1	line from reactants to top of curve (i.e. from 800 to 2160)  ignore arrowheads	1	AO1 5.5.1.2

03.2		an answer of (–) 500 (kJ) scores **2** marks ignore sign		AO2 AO3 5.5.1.2
	reads levels of reactants (800 kJ) and products (300 kJ)		1	
	(800 – 300) = 500 (kJ)	allow correct subtraction of one incorrect value determined for the energy change	1	

5.5.1.3 The energy change of reactions (HT only)

Answer 01 · Mark scheme

June 2019 | 8464/C/1H | Original Q3

03.3		allow combination of circles, dots, crosses or e(–)		AO2 5.2.1.4
	two shared pairs in overlap		1	
	all non-bonding electrons in outer shell (4 electrons on each O atom)	ignore any inner shell electrons	1	
		 diagram scores 2 marks		

5.5.1.3 The energy change of reactions (HT only)

Answer 01 · Mark scheme

03.4	(bonds broken) ((4×463) + (2×138) =) **2128** (bonds made) ((4×463) + (496) =) **2348** (energy change = bonds broken – bonds made) (2128 – 2348 =) (–) **220** (kJ) **alternative approach:** (bonds broken) (2× (O–O) = (2×138) =) **276** (1) (bonds made) (1× (O=O) =) **496** (1) (energy change = bonds broken – bonds made) (276 – 496 =) (–) **220** (kJ) (1)	an answer of (–) 220 (kJ) scores **3** marks an incorrect answer for one step does **not** prevent allocation of marks for subsequent steps ignore energy change sign allow correct calculation using incorrect values from step 1 and/or step 2	1 1 1	AO2 5.1.1.1 5.5.1.1 5.5.1.3

Total			**8**

5.5.1.3 The energy change of reactions (HT only)

Answer 01 · Mark scheme

June 2019 | 8464/C/1H | Original Q3

Question	Answers	Extra information	Mark	AO / Spec. Ref.

5.5.1.3 The energy change of reactions (HT only)

Answer 02 · Mark scheme

November 2021 | 8464/C/1H | Original Q7

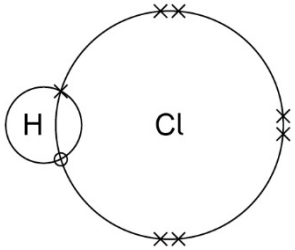
Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.1	particles collide		1	AO3 5.5.1.2
	(but at room temperature) particles have insufficient energy **or** (but) have energy less than the activation energy (so collisions are not successful)		1	
07.2	2120 (kJ/mol)		1	AO3 5.5.1.2 5.5.1.3
07.3		allow C–C for **X**		AO2 5.5.1.3
	(bonds broken = (8 × 410) + 2 **X** + (5 × 500) = 5780 + 2 **X**	allow (bonds broken = (8 × 410) + (5 × 500) = 5780	1	
	(bonds formed = (6 × 740) + (8 × 460) = 8120		1	
	(bonds broken – bonds formed = energy released) (5780 + 2 **X**) – 8120 = – 1640	allow correct use of incorrect values from step 1 and/or step 2	1	
	(2 **X** =) 700	allow correct use of incorrect value from step 3	1	
	(**X** =) 350 (kJ/mol)		1	
Total			**8**	

5.5.1.3 The energy change of reactions (HT only)

Answer 03 · Mark scheme

June 2022 | 8464/C/1H | Original Q6

Question 6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	one shared pair in overlap 6 non-bonding electrons in outer shell of chlorine	allow any combination of circles, dots, crosses or $e^{(-)}$ do **not** accept extra electron(s) on outer shell of hydrogen ignore any inner shell electrons an answer of  scores **2** marks	1 1	AO1 5.1.2.6 5.2.1.4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.2	completely ionises in aqueous solution	allow completely dissociates in aqueous solution	1	AO1 5.4.2.5

5.5.1.3 The energy change of reactions (HT only)

Answer 03 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.3	fizzing / effervescence **or** magnesium disappears		1	AO3 5.4.2.5
	at a greater rate with a strong acid	allow converse with weak acid allow for **2** marks strong acid has a greater temperature increase	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.4	(pH) decreases	allow pH is lower	1	AO1
	by (a unit of) 2		1	AO2 5.4.2.5

5.5.1.3 The energy change of reactions (HT only)

Answer 03 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.5	(bonds broken = (4 × 413) + C=C + 431 =) 2083 + **C=C**		1	AO2 5.5.1.3
	(bonds made = (346 + 339 + (5 × 413) =) 2750		1	
	(energy released = bonds made – bonds broken =) 56 = 2750 – [2083 + C=C]	allow correct use of incorrect value(s) from step 1 and / or step 2	1	
	(C=C) = 611 (kJ/mol)		1	

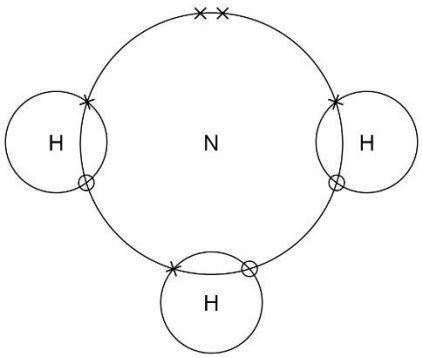
Total Question 6		**11**

5.5.1.3 The energy change of reactions (HT only)

Answer 04 · Mark scheme

June 2024 | 8464/C/1H | Original Q5

Question 5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1		allow any combination of circles, dots, crosses or $e^{(-)}$ ignore any inner shell electrons on nitrogen		AO1 5.2.1.4
	one shared pair of electrons in each overlap		1	
	2 non-bonding electrons on the outer shell of nitrogen	do **not** accept non-bonding electrons on hydrogen	1	
		an answer of  scores **2** marks		

5.5.1.3 The energy change of reactions (HT only)

Answer 04 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.2	(M_r NH_3 = 14 + (3 × 1) =) 17		1	AO2 5.3.1.1 5.3.2.2
	$\left(\text{moles } NH_3 = \frac{25}{17}\right)$ = 1.47 (mols)	allow correct use of incorrectly determined M_r of NH_3	1	
	(moles H_2 = 1.47 × $\frac{3}{2}$) = 2.205 (mols)	allow correct use of an incorrectly calculated value of moles of NH_3	1	
	(mass H_2 = 2.205 × 2) = 4.41 (g)	allow 4.4117647 (g) correctly rounded to at least 2 significant figures allow correct use of an incorrectly calculated value of moles of H_2	1	
	alternative approach (2 × M_r NH_3 = 17 × 2 =) 34 (1) 6 g H_2 → 34 g NH_3 (1) $\frac{6}{34}$ × 25 (g) H_2 → 25 g NH_3 (1) 4.41 (g H_2 → 25 g NH_3) (1)	allow correct use of an incorrectly calculated value of 2 × M_r NH_3		

5.5.1.3 The energy change of reactions (HT only)

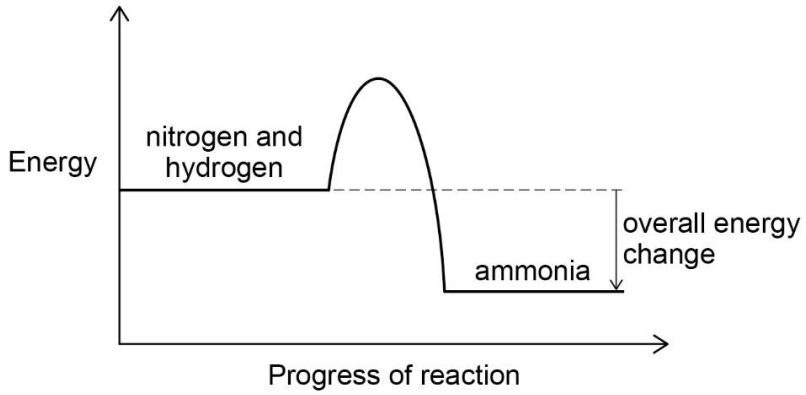
Answer 04 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.3	(bonds broken =) 945 + 3**X**		1	AO2 5.5.1.1 5.5.1.3
	(bonds made = 6 × 391 =) 2346		1	
	(energy released = bonds made – bonds broken =) 93 = 2346 – [945 + 3**X**]	allow correct use of incorrectly determined value(s) of bonds broken and/or bonds formed	1	
	(3**X** =) 1308 (kJ/mol)		1	
	(**X** =) 436 (kJ/mol)	allow correct use of an incorrectly determined value for 3**X**	1	

5.5.1.3 The energy change of reactions (HT only)

Answer 04 · Mark scheme

June 2024 | 8464/C/1H | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.4	correct shape for exothermic reaction with the product line below the level of the reactants line		1	AO2
	labelled horizontal lines for reactants and product	labelled horizontal lines for nitrogen and hydrogen and ammonia	1	AO1
	labelled overall energy change		1	AO1 5.5.1.2
	an answer of  scores **3** marks			

Total Question 5	14

5.5.1.3 The energy change of reactions (HT only)

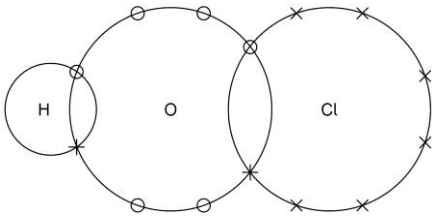
Answer 05 · Mark scheme

June 2025 | 8464/C/1H | Original Q5

Question 5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	(hydrogen chloride) g / (g) **and** (water) l / (l) **and** (hydrochloric acid) aq / (aq)		1	AO2 5.2.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.2	3.16×10^{-4} (mol/dm^3)		1	AO2 5.4.2.5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.3		allow any combination of x, O, $e^{(-)}$, ● for electrons		AO2 5.2.1.1 5.2.1.4
	1 pair of electrons in both overlaps		1	
	4 non-bonding electrons on oxygen atom **and** 6 non-bonding electrons on chlorine atom	do **not** accept non-bonding electrons on hydrogen	1	
		an answer of  scores **2** marks		

5.5.1.3 The energy change of reactions (HT only)

Answer 05 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.4	a weak acid partially ionises in an aqueous solution (so) produces a lower concentration of hydrogen ions		1 1	AO1 5.4.2.4 5.4.2.5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.5	(bonds broken = (4 × 413) + 243 =) 1895 (bonds made = (3 × 413) + 346 + 432 =) 2017 (energy change = 1895 − 2017 =) (−) 122 (kJ/mol) **alternative approach** (bonds broken = 413 + 243 =) 656 (1) (bonds made = 346 + 432 =) 778 (1) (energy change = 656 − 778 =) (−) 122 (kJ/mol) (1)	allow correct use of an incorrectly determined value for bonds broken and / or bonds made allow correct use of an incorrectly determined value for bonds broken and / or bonds made	1 1 1	AO2 5.5.1.3

Total Question 5	9

5.5.1.3 The energy change of reactions (HT only)

Answer 01 · Examiner comments — June 2019 | 8464/C/1H | Original Q3

Question 3

This was the first question not common with the Foundation tier. There was a ramping of demand through the question from standard demand (03.1) to standard/high demand (03.2) then to high demand (03.3 and 03.4).

03.1 A good proportion of students correctly identified the activation energy. Common errors included arrows pointing to the maximum of the energy diagram or to a section of the line leading to the peak.

03.2 Students were very good at determining the overall energy change; nearly three-quarters of all students gained full marks. Those students who selected one value of either the reactants or products from the graph gained credit for a correct subtraction of their values.

03.3 Students provided a wide range of responses for the dot-and-cross diagram of oxygen. Half of all students appreciated the number of electrons involved in bonding and non-bonding. A number of students did not appreciate that oxygen always has two sharing pairs of electrons; in this case a double bond results between the two atoms. Others who added 4 electrons for a double bond often still added 3 other non-bonding pairs on each O atom.

03.4 This question discriminated very well where two-fifths of students gained all three marks for an answer of (–) 220 kJ.

Many students presented their working clearly. This allowed examiners to identify where any errors had been made which allowed access to the final marking point (MP3); a subtraction of bonds made (their MP2) from bonds broken (their MP1).

Answer 01 · Examiner comments — June 2019 | 8464/C/1H | Original Q3

Common mistakes centred on using an O-O value when an O=O bond strength should have been used and not taking into account the stoichiometry of the equation.

Answer 02 · Examiner comments — November 2021 | 8464/C/1H | Original Q7

Question 7 (standard / high and high demand)

07.1 One mark was gained by approximately one fifth of students, usually for stating that particles collide. Very few appreciated that at room temperature the particles had insufficient energy to react.

07.2 Approximately two thirds of students gained this mark. They were able to deduce the trend in increase of energy released as the number of carbon atoms increased.

07.3 Approximately one third of students were able to score at least one mark but only a small number scored all five marks. Students had to calculate the energy required to break all bonds and also the energy released when all bonds are formed. However, many made mistakes in these calculations. Few then were able to subsequently evaluate the difference in bonds broken (including the two C-C bonds), bonds made, and the energy released (1640 kJ/mol).

Concluding Remarks

The demand of this paper was similar to those previously set for this specification. Students should note that two-mark questions, for example, require two answer points.

15% of marks are based upon the required practical activities; students should question 'what and why' is happening in each step of these procedures. Answers should be chemically accurate, e.g. crystals are produced from salt solutions when the solution is heated (partially evaporated to produce a more concentrated solution) and then left to crystallise, rather than implying that 'all the water was evaporated'.

In chemistry 20% are marks are for questions assessing mathematical skills. In these questions, students should show their working for each step. If an error is made, such as an incorrect evaluation of values in the question, credit is awarded for each correct step shown. In **01.5** not all students used all the data provided to evaluate the relative atomic mass, a weighted mean of the mass numbers. In **04.4** most students calculated the percentage and mass of the other elements. Fewer were able to use the ratio of percentages to evaluate the mass of iron. In **06.4** students found difficulty in converting moles to a formula or to simple whole number ratios in equations. In **07.3** the displayed formula was provided to help students calculate the energy required to break all the bonds and the energy released when all the bonds are formed. Many failed to link the energy released as the difference in bonds broken (including the two C-C bonds) and bonds made.

5.5.1.3 The energy change of reactions (HT only)

Answer 02 · Examiner comments

November 2021 | 8464/C/1H | Original Q7

Mark Ranges and Award of Grades

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

5.5.1.3 The energy change of reactions (HT only)

Answer 03 · Examiner comments

June 2022 | 8464/C/1H | Original Q6

Question 6 (Standard, standard/high and high demand)

06.1 Two third of students correctly drew a dot and cross diagram for hydrogen chloride. The most common mark was for the two shared electrons in the overlap between the atoms. Many did not show that there are six unshared electrons.

06.2 Less than 10% were able to state what is meant by the term strong acid. Many omitted ‘in aqueous solution’.

06.3 40% of students gained 1 mark usually for referring to an observation when magnesium reacts with a strong acid and a weak acid. The second mark was for a comparison of the rates of reaction between magnesium and the two acids, with few students being able to develop their response to give this.

06.4 Nearly 40% of students gained 1 mark usually for stating that the pH decreases when the concentration was increased. However very few recognised that pH was related to the power of 10, so when the concentration of hydrochloric acid is increased by a factor of 100 then the pH will decrease by 2.

06.5 Many students were good at calculating the energy changes for bonds broken and bonds made, however then went on to simply subtract these two numbers without taking into account the C=C bond energy. Many students kept their working to a minimum which often did not help them score. This question discriminated well with better responses showing clear working where the energy released was equated to the difference between the bonds made and the bonds broken.

Answer 04 · Examiner comments

Question 5 (standard/high & high demand)

05.1 Around two-thirds of students were able to complete the dot and cross diagram for an ammonia molecule.

Some students gained just 1 mark for correctly adding either three shared pairs of electrons or two non-bonding electrons on the outer shell of nitrogen, or included non-bonding electrons on hydrogen, so were not able to access mark point 2.

05.2 In this reacting mass calculation students were asked to calculate the mass of hydrogen needed to produce 25 g of ammonia. As always, a number of approaches were taken and students who showed their working often gained credit even after making errors. More than half of students scored at least 1 mark.

Those who answered with a moles method usually scored 4 marks for the correct answer, 3 marks for 2.94 g (because they missed the molar ratio) or 1 mark for determining the M_r of ammonia.

Those who used a ratio method usually either scored 4 marks for the correct answer or 1 mark for $2 \times M_r$ of ammonia; few showed clear working to gain either marking point 2 or marking point 3.

05.3 In this question students were asked to calculate the bond energy for the H—H bond. The working for breaking bonds needed to show that the values 945 and 3*X* have been added together.

Many students were good at calculating the energy changes for bonds broken but went on to simply subtract the bond breaking value from the bond making value without taking into account the H—H bond energy. In the reaction more energy was released than was needed to break existing bonds so this value, 93 kJ/mol, needed to be correctly used in the next stage of the calculation before the H—H bond energy was determined by dividing by 3.

This question differentiated well, with higher-attaining students showing clear working where they equated the energy released to the difference between the bonds made and the bonds broken.

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5.5.1.3 The energy change of reactions (HT only)

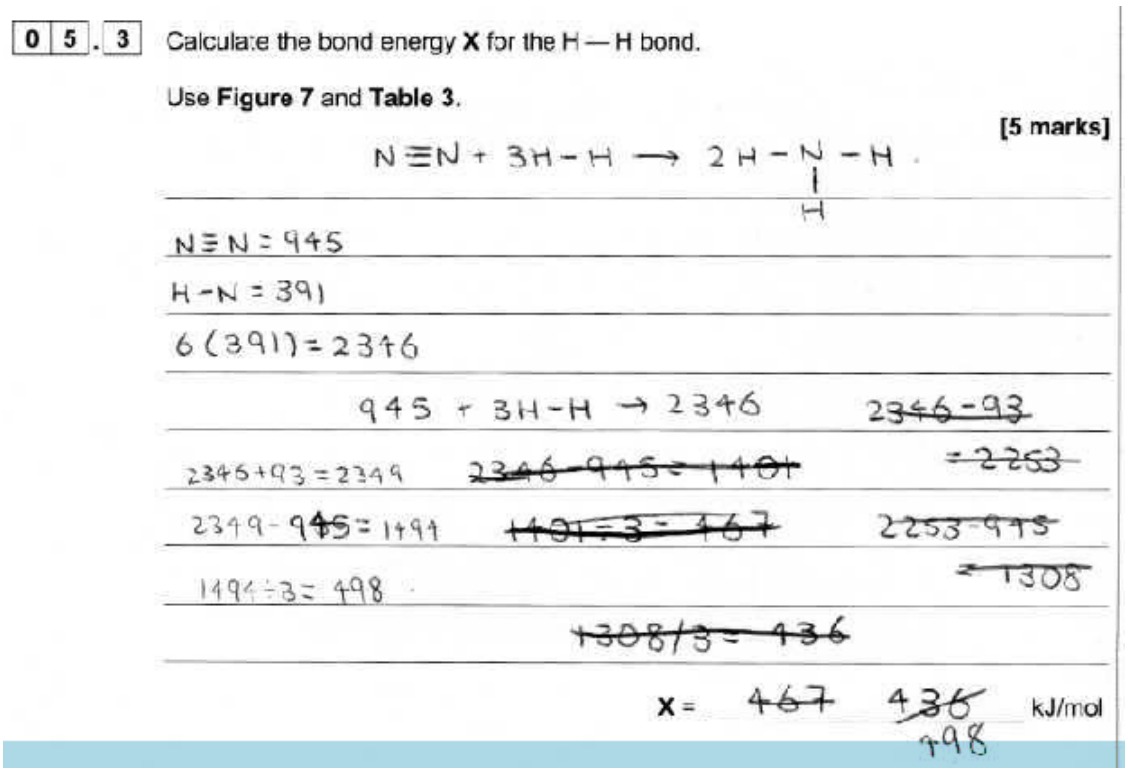
Answer 04 · Examiner comments

June 2024 | 8464/C/1H | Original Q5

0 5 . 3 Calculate the bond energy **X** for the H — H bond.

Use **Figure 7** and **Table 3**.

[5 marks]



This student gained 3 marks for 498 kJ/mol. They gained the first 2 marks for calculating the energy to break bonds and the energy released when bonds are made but did not then include the value of 93 so were unable to gain the next 2 marks. They then correctly divided 1494 by 3 to determine the average H—H bond energy so gained the final mark.

The student has made three attempts at the calculation, two of which they have crossed out. In the middle they did not use the value of 93, which gave a common incorrect answer of 436; this answer would have also scored 3 marks. On the right (also crossed out) they used the value of 93 correctly to give the correct answer of 436, which would have scored all 5 marks.

05.4 This question was well answered with approximately 20% of students gaining 3 marks, 40% gaining 2 marks and 20% of students gaining 1 mark.

Those students who gained 2 marks usually either drew the arrow indicating the overall energy change incorrectly or completed a correct profile for an endothermic reaction.

When 1 mark was scored this was usually for the correct shape for an exothermic reaction but labels for reactants and/or product were omitted and the arrow indicating the overall energy change was incorrect. On this occasion any sort of arrow was allowed accompanied with the label for the overall energy change, and ΔH is an equivalent response for the label.

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Answer 05 · Examiner comments

Question 5 (Standard/High and High demand)

05.1 The state symbols for hydrogen chloride gas and water were well known but aqueous for hydrochloric acid was not. Some students mixed up l and aq. Most students correctly use lower case letters.

05.2 Few students gained this high demand mark. Those students who gained the mark often wrote down a few words next to the values given in the question, e.g. 'add 1, divide by 10' or 'concentration increases by factor of 10, pH decreases by 1'. Numerous students multiplied by 10 rather than dividing and many struggled to evaluate data in standard form.

05.3 More than half of students gained two marks for completing the dot and cross diagram. When 1 mark was gained it was usually for 1 pair of electrons in both overlaps with extra non-bonding electrons on hydrogen or incorrect numbers of non-bonding electrons on the oxygen atom and/or the chlorine atom.

05.4 Very few gained both marks. Students had to explain why a weak acid has a higher pH than a strong acid of the same concentration. Most answers were in terms of a pH comparison. Lots of students did not achieve MP1 by not using the full definition including in aqueous solution. For MP2 many students said there were less H^+ ions omitting reference to concentration or number per unit volume.

05.5 Many students were able to calculate the energy changes for bonds broken and for bonds made and then subtracted the latter value from the former. The value of bonds broken was less than bonds made so the overall energy change was a negative number. Those students who miscounted the bonds broken or made, could not gain MP1 and/or MP2 but were still able to access MP3 by evaluating their own figures correctly.

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5.5.1.3 The energy change of reactions (HT only)

Answer 05 · Examiner comments June 2025 | 8464/C/1H | Original Q5

0 5 . 5 Hydrogen chloride is produced in the reaction between methane and chlorine.

Figure 6 represents the equation for the reaction.

Figure 6

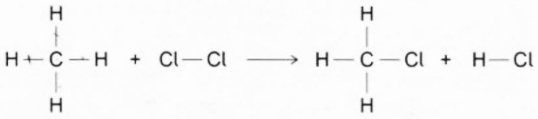


Table 4 shows the bond energies.

Table 4

Bond	C — H	Cl — Cl	C — Cl	H — Cl
Bond energy in kJ/mol	413	243	346	432

Calculate the overall energy change for the reaction.

[3 marks]

reactants	Products
413 x 4 = 1652	1 x 346 = 346
243 x 2 = 486	413 x 3 = 1239
total = 1652 + 486 =	432 x 1 = 432
2138 − 2017 = 121	total = 2346 + 1239 + 432 = 2017

Overall energy change = 121 kJ/mol

This student has broken 2× Cl—Cl bonds (not 1×) for the reactants so is not awarded MP1. They then correctly subtract the correct value for bond making (2017) so MP2 and MP3 are credited.

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