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Examiners' Report June 2022

IAL Chemistry WCH12 01

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Introduction

This paper was accessible to many candidates, and it provided them with the opportunity to demonstrate their knowledge and understanding of the key concepts in Unit 2. Some candidates were very well-prepared for the examination and lost just a few marks from slips, but others seemed unfamiliar with some of the topics and did not understand the basic chemical concepts in this Unit.

The mean mark for the multiple choice questions was 12.66. The most difficult question was 10b, with less than half of candidates scoring the mark, and the most straightforward question was 12, with most of the candidates scoring the mark.

For the successful candidates they:

- read the questions carefully and answered the questions as they were set
- understood and used correct scientific terminology
- could apply their knowledge to new situations
- could carry out familiar and unfamiliar calculations.

Some answers were of a lower standard than previous years.

Those less successful candidates:

- did not read the questions carefully and gave answers that were related to the topic being tested but did not answer the question
- did not use correct scientific terminology
- were not familiar with all the topics in Unit 2.

Question 15 (a)

Some candidates had a sound understanding of the thermal decomposition of Group 2 carbonates and scored full marks on this item. However, there were many who seemed unfamiliar with this concept and thought that magnesium carbonate was more stable to heat than calcium carbonate. A few candidates thought that the magnesium and calcium ions had different charges and a few thought they had just one positive charge. Some candidates had a little understanding but lost marks by using incorrect terminology. For example, they stated that magnesium has a smaller atomic radius than calcium, instead of referring to the Group 2 cations and others thought that the ionic bond between the cation and anion was polarised.

15 This question is about calcium carbonate, $CaCO_3$.

(a) Calcium carbonate decomposes on heating.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Explain why calcium carbonate decomposes at a higher temperature than magnesium carbonate, in terms of the charge and size of the cations.

(3)

As it goes down the group, thermal stability of the group 2 metal carbonates increases. ~~Since~~ As it goes down the group the size of cation is larger, which makes polarising the anion, carbonate, easier. Hence, more energy is required to break down $CaCO_3$ ~~the~~ than $MgCO_3$.

ResultsPlus
Examiner Comments

This response shows that the candidate has some knowledge about thermal decomposition of carbonates. The size of the cation does increase down the group, and it is the carbonate ion that is polarised. However, the charge density decreases down the group, so the calcium ion causes less polarisation than the magnesium ion. This response scored 2 marks.

ResultsPlus
Examiner Tip

The more the carbonate ion is polarised, the weaker the carbon-oxygen bonds are and the less thermally stable the carbonate is.

Question 15 (b)(i)

Candidates needed to read this question carefully and think about what they were asked to do to achieve 3 marks. Most candidates treated this as a theoretical calculation and did not think about the practical aspect that the gas syringe can be used to measure a maximum volume of 100 cm^3 of gas. It is usual to round values such as 16.667 to 16.7, however, if that volume of hydrochloric acid was used, the volume of carbon dioxide would be greater than 100 cm^3, so in this question the best answer was 16.6 cm^3. The examiners decided to allow 16.7 cm^3 on this occasion as it would produce 100.2 cm^3 of gas and as the measurements on a gas syringe is in 1 cm^3 divisions, this would not be noticeably higher than 100 cm^3, however, rounding to 17 cm^3 was not awarded the mark. Some candidates used fractions in their answers and that is acceptable for the intermediate steps, but the final answer should always be evaluated to a decimal with an appropriate number of significant figures as measuring instruments do not have divisions in fractions. Candidates should also consider the correct units to write with their answer. In this question, the answer could be given in cm^3 or dm^3 provided the number and unit matched, however, incorrect units such as cm^{-3} and dm^{-3} lost the last mark.

(b) Calcium carbonate reacts with dilute hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

A student determines the initial rate of this reaction by collecting the carbon dioxide in a gas syringe and measuring the volume at regular time intervals.

(i) The gas syringe can measure a maximum of 100 cm³ of gas.

Calculate the **maximum** volume of 0.500 mol dm^{-3} hydrochloric acid that can be added to excess calcium carbonate at room temperature and pressure (r.t.p.) without exceeding the measurable volume of the gas syringe.

[Molar volume of gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(3)

V of CO_2 : 100 cm^3

mole of CO_2 : $100/24000$ = $\frac{1}{240}$ mole

CO_2 : HCl = 1 : 2

mole of HCl : $\frac{1}{240} \times 2 = \frac{1}{120}$ mole

volume of HCl : $\frac{1}{120} \div 0.5 = \frac{1}{60} = 0.01667$

0.017 dm^3

ResultsPlus Examiner Comments

It is acceptable to leave fractions in the intermediate steps in calculations, as in this response. However, the final answer should always be evaluated and given to an appropriate number of significant figures.

This candidate has rounded up their final answer to 0.017 dm^3 of acid. This volume of acid would produce 102 cm^3 of carbon dioxide and the gas syringe can only measure a maximum of 100 cm^3 of gas, so this response scored 2 marks.

ResultsPlus Examiner Tip

Always check that your final answer agrees with the information given in the question.

(b) Calcium carbonate reacts with dilute hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

A student determines the initial rate of this reaction by collecting the carbon dioxide in a gas syringe and measuring the volume at regular time intervals.

(i) The gas syringe can measure a maximum of 100 cm^3 of gas.

Calculate the **maximum** volume of 0.500 mol dm^{-3} hydrochloric acid that can be added to excess calcium carbonate at room temperature and pressure (r.t.p.) without exceeding the measurable volume of the gas syringe.

[Molar volume of gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(3)

$n(CO_2) = \frac{100}{24000}$

$= 0.0041666$ mol

$n(HCl) = 2 \times 0.0041666$ mol

$= 0.008333$ mol

Max vol of HCl $= \frac{0.00833}{0.500}$

$= 0.0166$ dm^3

$= 16.66$ cm^3

$= 16.6$ cm^3 (Round down 3sf)

ResultsPlus
Examiner Comments

This is an excellent answer that scored 3 marks. In most of the calculations, a number such as 16.667 can be rounded to 16.7 cm^3. However, in this calculation the best answer is to round it down to 16.6 cm^3.

This candidate has read the question carefully and realised that any volume of hydrochloric acid greater than the calculated value will produce more than 100 cm^3 of gas, which is more than the measurable volume of the gas syringe.

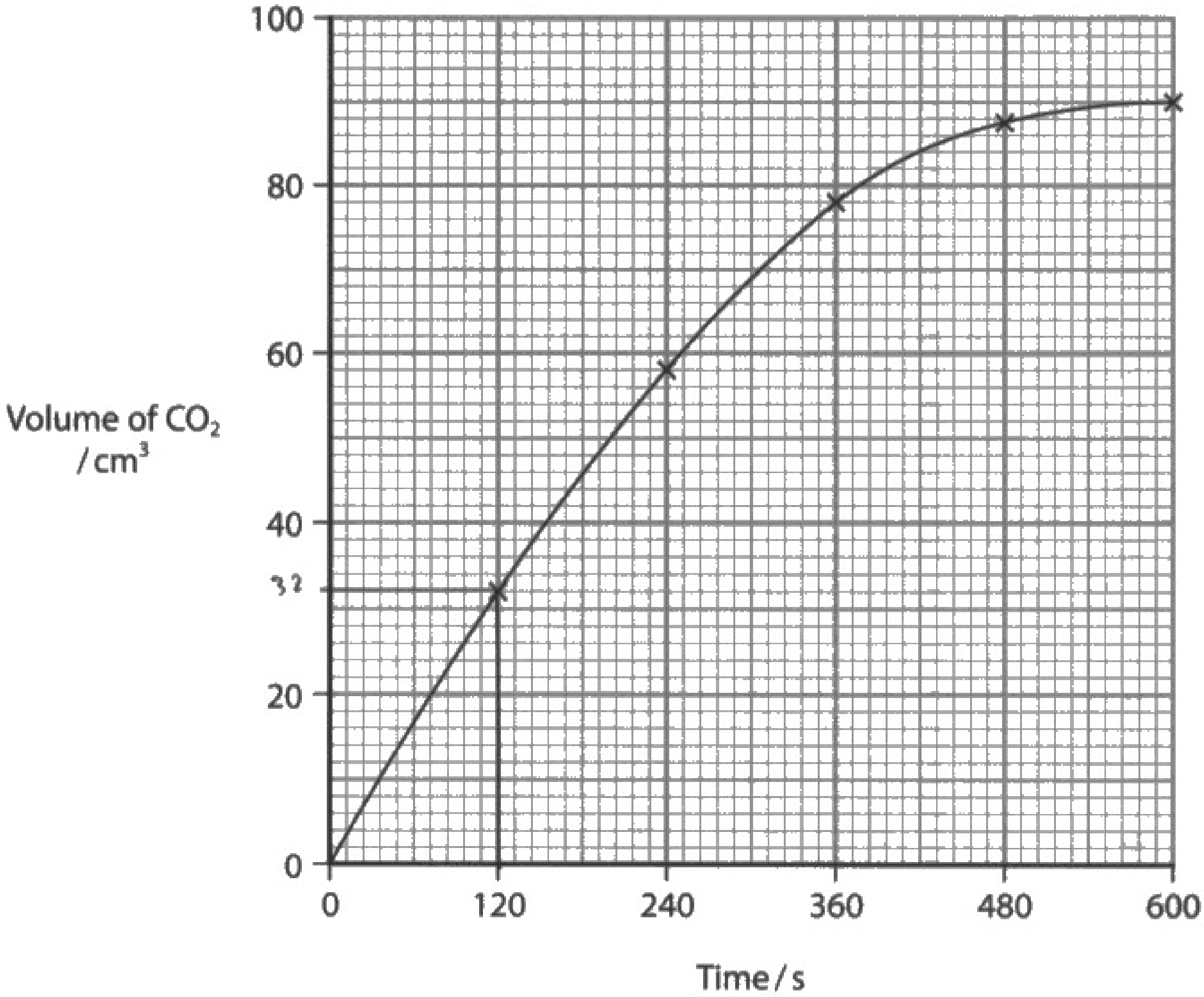
ResultsPlus
Examiner Tip

Read the question carefully and check to make sure that you have understood what you are being asked to calculate.

Question 15 (b)(ii)

Many candidates did not realise that they needed to draw a tangent to the curve at t=0 to calculate the initial rate of reaction. Some candidates drew a tangent at a different time. The majority could calculate a value for the initial rates and almost all achieved the mark for the correct units.

(ii) The results of the student's experiment are shown on the graph.



Calculate the initial rate of this reaction.
You **must** show your working on the graph.
Include units in your answer.

$\frac{32}{120} = 0.27\ cm^3 s^{-1}$

(3)

ResultsPlus
Examiner Comments

This is an example of a common response that scored 2 marks.

The candidate has just selected a point on the curve and divided the volume by time. They have also given the correct units. In order to improve their score, they should have drawn a tangent to the curve when t = 0 and calculated the gradient.

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Examiner Tip

Revise how to draw tangents to curves and calculate gradients.

Question 15 (b)(iii)

Every combination of increase, decrease and stay the same were seen as answers to this question. It was disappointing that candidates did not know that when the concentration of acid is halved, the initial rate of reaction would halve and so would the volume of carbon dioxide as there are half the number of hydrogen ions present.

(iii) The student repeats the experiment but uses hydrochloric acid with a concentration of 0.250 mol dm^{-3}. All other variables are kept the same.

State what would happen to the initial rate of reaction and the final volume of carbon dioxide collected.

(1)

Initial rate of reaction

The initial rate of reaction would decrease

Final volume of carbon dioxide collected

The final volume of carbon dioxide would be the same.

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Examiner Comments

This candidate has deduced that the initial rate of reaction would decrease when the concentration of hydrochloric acid decreases. However, the final volume of carbon dioxide cannot be the same if there are fewer moles of hydrochloric acid to react with the calcium carbonate.

No mark was awarded as both parts of the answer had to be correct for the mark.

In this question, the concentration of hydrochloric acid was halved, so the best answer would have stated that the initial rate of reaction halves and the volume of carbon dioxide halves.

ResultsPlus
Examiner Tip

Revise what happens to the rate of reaction and the amount of product formed when factors such as concentration, temperature and surface area of a solid are changed.

Question 16 (a)

Many candidates showed that they did not understand the meaning of the term 'electronegativity' and there was considerable confusion with electron affinity and ionisation energy. Many candidates scored the first mark for knowing that the atomic radius of the halogens increases down the group, although some wrote about ions. However, only a small minority wrote about the power of the nucleus to attract the bonding pair of electrons in a covalent bond, with the majority discussing the ability to attract the outer shell electrons or the ability to gain or lose electrons.

16 This question is about the halogens and some of their compounds.

(a) Descending the group from fluorine to iodine, the electronegativity of the atoms decreases even though their nuclear charge increases.

Explain the trend in electronegativity.

(2)

As you go down the group, the atomic radius increases so does shielding effect. Hence, these two factors outweigh the increasing nuclear charge and so the electronegativity decreases.

ResultsPlus
Examiner Comments

This response scored 1 mark for the atomic radius increases down the group. However, they have not related this to their understanding of electronegativity so cannot score the second mark.

ResultsPlus
Examiner Tip

Revise the meaning of the important terms in the specification, such as electronegativity.

16 This question is about the halogens and some of their compounds.

(a) Descending the group from fluorine to iodine, the electronegativity of the atoms decreases even though their nuclear charge increases.

Explain the trend in electronegativity.

(2)

Outer electrons are further away from the nucleus going down the group hence they experience less attraction to the nucleus. Thus the pair of electrons in a bond would be less attracted to the nucleus. The effects of increased distance from nucleus is greater than increased nuclear charge.

ResultsPlus
Examiner Comments

This is an example of a good answer that scored 2 marks. This candidate understands that electronegativity is the ability of an atom to attract the pair of electrons in a covalent bond.

ResultsPlus
Examiner Tip

Many candidates were confused between electronegativity and electron affinity. Make sure that you know the difference between these two terms.

Question 16 (b)

The majority of candidates could work out the oxidation numbers of iodine in the three species, although some thought it would be – 5 for I^- as they did not realise they should work it out for each individual ion. Many candidates struggled to explain why the reaction is not disproportionation as they frequently used incorrect terminology, such as compound. Some candidates thought that iodine was only being oxidised or only reduced and a few tried to explain why it was disproportionation. Candidates could have approached this question by stating that iodine is in two different species in the reactants or that only one species containing iodine is produced.

(b) Iodate(V) ions, IO_3^-, react with iodide ions in acid solution.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

Explain, in terms of the oxidation numbers of iodine in the three species, why this is **not** a disproportionation reaction.

(2)

Iodine goes from +5 to 0. $IO_3^- \rightarrow 3I_2$
Iodine goes from −1 to 0. $5I^- \rightarrow 3I_2$
Both a reduced. No element is simultaneasly oxidised and reduced

ResultsPlus Examiner Comments

This response scored 1 mark for the oxidation numbers of iodine. No mark is awarded for a reason why this is not a disproportionation reaction because they have stated that both species are reduced. The iodine in the iodate(V) ion is reduced as its oxidation number decreases but the oxidation number of the iodide ion increases so it has been oxidised.

ResultsPlus Examiner Tip

Revise how oxidation and reduction are related to changes in oxidation numbers.

(b) Iodate(V) ions, IO_3^-, react with iodide ions in acid solution.

I = +5 I = -1 I=0

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

I=+5 ; O=0 ~~I=-1~~ +1 I = O O = -2 ; H = +1

Explain, in terms of the oxidation numbers of iodine in the three species, why this is **not** a disproportionation reaction.

(2)

Iodine is reduced from (+5 in IO_3^- to 0 in I_2) and is oxidised from -1 in $5I^-$ to 0 in $3I_2$. It is not a disproportionation reaction because it didn't occur to the iodine in the same species, it occured to differnt reactants

ResultsPlus
Examiner Comments

This is an example of a good answer that scored 2 marks. This candidate showed that they understand the meaning of the term disproportionation.

ResultsPlus
Examiner Tip

Revise disproportionation and make sure that you fully understand when it can and cannot occur.

Question 16 (c)

It was disappointing to see that only a small minority of candidates were familiar with the reactions between hydrogen halides and concentrated sulfuric acid so knew the products formed. A common error was to include sulfur and that was incorrect as it is not a compound, and it does not have sulfur in its lowest oxidation state.

(c) Hydrogen bromide and hydrogen iodide reduce sulfuric acid.

Identify, by name or formula, the **compound** produced containing sulfur with its lowest oxidation number in that reaction.

(1)

Hydrogen halide	Compound produced with the lowest oxidation number of sulfur
HBr	Sulfur Dioxide
HI	Sulfur

SO_2
HBr
Br
SO_2
S
H_2S
-2

ResultsPlus
Examiner Comments

No mark was awarded for this answer. Sulfur dioxide is the compound with the lowest oxidation number of sulfur formed from hydrogen bromide. However, sulfur is not a compound and hydrogen sulfide is formed from hydrogen iodide and the sulfur has an oxidation number of – 2 in that compound.

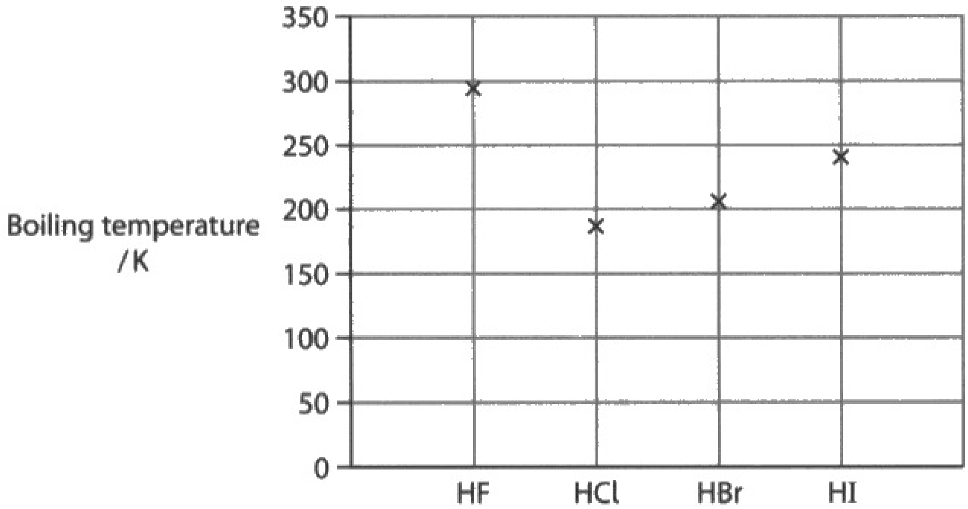
ResultsPlus
Examiner Tip

Read the question carefully and pay particular attention to any words in bold. In this question, only compounds were acceptable as answers.

Question 16 (d)

This question was answered well by many candidates, showing that they know the intermolecular forces that exist between the hydrogen halides and could compare their strengths. Some candidates did not make clear comparisons, for example, just stating that hydrogen bonds are strong will not be awarded a mark, whereas stating that hydrogen bonds are stronger than London forces will receive credit. A few candidates thought that all of the hydrogen halides had hydrogen bonding and a few thought that it is the hydrogen-halogen bonds that are broken.

(d) The graph shows the boiling temperatures of the hydrogen halides.



Explain the trend in the boiling temperatures of the hydrogen halides.

(4)

* HF > HI > HBr > HCl } In order of increasing Boiling temperature.

HF has hydrogen Bonding which is the strongest intermolecular force so more energy is required to break the strong hydrogen bonding between HF.

• HI, HBr and HCl are have london forces, As you go down group 7, Mr increases and so increase in number of electrons = more london forces and so more energy required to break the Bond.

* Also with increasing Mr, Bond enthalpy Decreases and with decrease in bond enthalpy the C-X (↓ halogen) Bond is weaker so its easier to break. C-I is the weakest and C-Cl is the strongest, so more heat energy required to break C-Cl so lower Boiling temperature

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Examiner Comments

This candidate started with a very good answer by identifying the correct intermolecular forces and comparing their strengths. However, they then discuss bond enthalpies and how these are related to breaking covalent bonds. When substances with small molecules are boiled, it is the intermolecular forces that are overcome and **not** the covalent bonds that are broken. This part of the answer is incorrect and negates the mark for identifying London forces so 3 marks were awarded.

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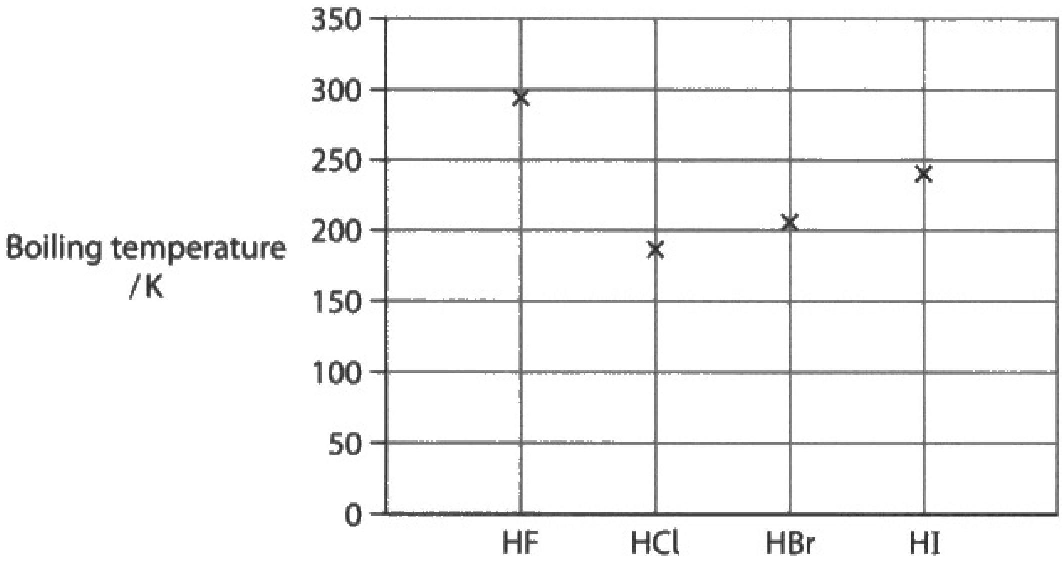
Examiner Tip

Revise the types of intermolecular forces or bonds that are overcome when different types of substances melt or boil.

(d) The graph shows the boiling temperatures of the hydrogen halides.



Explain the trend in the boiling temperatures of the hydrogen halides.

(4)

HF has the highest boiling temperature since it has london forces and hydrogen bonds. Hydrogen bonds are the strongest intermolecular forces.

HCl, HBr, HI all only have london forces. However, boiling temperature increases down ~~G7~~ hydrogen halides from HCl onwards.

Also, down the group the elements have ~~more~~ a higher Mr so they have more electrons, thus gradually increasing.

Overall, the trend decreases then increases.

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Examiner Comments

This response scored 3 marks. The candidate has identified the hydrogen bonds between hydrogen fluoride molecules and that these are the strongest type of intermolecular force. They have identified the London forces between the hydrogen halides and stated that the number of electrons increases down the group. However, they have not linked the increasing number of electrons to the increasing strength of the London forces so could not score full marks.

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Examiner Tip

Re-read your answers to check that you have answered in detail and made any essential links to complete an explanation.

Question 16 (e)

Some candidates gave clear answers to this calculation and explained their working. Others wrote a jumble of numbers without any words so made it difficult for examiners to award them any marks. Many candidates worked out the number of moles of silver chloride but quite a lot were unable to proceed any further. Some candidates just worked out 0.098 divided by 0.226 as a percentage as they did not understand how to carry out this calculation.

(e) A sample of seawater was evaporated to dryness.

The solid residue was weighed, then dissolved completely in deionised water.

Excess aqueous silver nitrate was added to the solution.
All the chloride ions in the seawater formed a precipitate of silver chloride.

$$Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$$

0.226 g

The precipitate was filtered, washed, dried and weighed.

Results:

Mass of solid residue from seawater = 0.098 g

Mass of silver chloride precipitate = 0.226 g

Calculate the percentage, by mass, of chloride ions in the solid residue.

[Assume silver chloride is the only precipitate.]

(3)

Cl⁻ Mr : 35.5

AgCl → $\frac{0.226}{143.4}$

Mr = 107.9 + 35.5
= 143.4

mole : 1.5760×10^{-3}

1 : 1

x : 1.5760×10^{-3}

x = 1.5760×10^{-3}

Cl = $1.5760 \times 10^{-3} \times 35.5$

mass = 0.05595 g

% = $\frac{0.05595}{0.226} \times 100\%$

% by mass = 27.76%

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Examiner Comments

This response scored 2 marks. The candidate has calculated the number of moles of silver chloride and the mass of chloride ions in the solid residue. However, when attempting to calculate the percentage, by mass, of chloride ions, they have divided by the mass of silver chloride precipitate instead of the mass of solid residue from the seawater.

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Examiner Tip

Always check to make sure that you are using the correct values from the data given in the question.

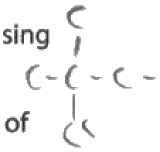
Question 17 (a)

Most candidates were able to classify the two halogenoalkanes correctly. Some thought that bromocyclohexane was tertiary and a few classified them as secondary and primary alcohols.

Question 17 (b)

Many candidates struggled to understand how to answer this question. Many of them knew that the structure and the halogen would both affect the rate of hydrolysis but they did not realise that these were opposing factors, so it is not possible to predict the relative rates. Most candidates knew that 2-chloro-2-methylpropane is a tertiary compound, but they did not all make the comparison that it would hydrolyse faster than 1-iodobutane, which is primary. Similarly, many candidates knew that iodocompounds would hydrolyse faster but they did not link this to the lower C-I bond enthalpy. Many candidates described the practical details for this experiment, which was not relevant to this question.

(b) Samples of 1-iodobutane and 2-chloro-2-methylpropane were hydrolysed using aqueous silver nitrate in ethanol.



Explain whether or not it is possible to predict the relative rate of hydrolysis of these two compounds.

(3)

No, it's not : ~~since~~

First, ~~the~~ the halogen present are different, we need to make sure they are the same type of halogenoalkane. ~~Either~~ ~~(or)~~ However, 1-iodobutane is a primary halogenoalkane whereas ~~2-(or)~~ 2-chloro-2-methylpropane is a tertiary halogenoalkane.

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Examiner Comments

This candidate knows the two factors that can influence the rate of hydrolysis of halogenoalkanes. However, they have just stated the factors and not how they affect the rate. The answer could be improved by stating that tertiary halogenoalkanes react at a faster rate than primary halogenoalkanes.

ResultsPlus
Examiner Tip

This question is asking for an explanation, so it is important to include reasons in your answer and not just facts.

(b) Samples of 1-iodobutane and 2-chloro-2-methylpropane were hydrolysed using aqueous silver nitrate in ethanol.

Explain whether or not it is possible to predict the relative rate of hydrolysis of these two compounds.

(3)

It is possible to predict the rate of hydrolysis. The time taken for the silver halide precipitate to form can be measured. ~~and it can be used.~~ 2-chloro 2methyl propane is a tertiary halogenoalkane, and so the rate of hydrolysis will be very fast. 1-iodo butane is a primary halogenoalkane, which will result in a slower ~~rate~~ rate. However the C-I ~~bond enth~~ bond is weaker compared to the C-Cl bond and so the time difference will not be too ~~big~~ large.

ResultsPlus
Examiner Comments

This response shows that the candidate knows the two factors that can influence the rates of hydrolysis of halogenoalkanes so has scored 2 marks. However, they have not appreciated that when the different structures are considered, 2-chloro-2-methylpropane will react the fastest but when different halogens are present, 1-iodobutane will react the fastest so it is not possible to predict the relative rates.

ResultsPlus
Examiner Tip

When there are two factors to consider, start by looking at them separately then decide if they both have the same effect or, as in this question, they have opposing effects.

Question 17 (c)(i)

Most candidates realised that a gas would escape if the mixture was heated under reflux, but only a small number realised that ammonia is a gas at room temperature and so it would escape. Many candidates just wrote generally about 'the products escaping' but that was not sufficient. Some candidates mentioned safety issues.

(c) Butylamine is formed when 1-bromobutane reacts with excess concentrated alcoholic ammonia.

$$CH_3CH_2CH_2CH_2Br + 2NH_3 \rightarrow CH_3CH_2CH_2CH_2NH_2 + NH_4Br$$

(i) Give a reason why this reaction should be carried out by heating the reactants in a sealed tube rather than heating under reflux.

(1)

Some of the product could escape in the ~~refux~~ reflux reaction as it ~~[illegible]~~ is not sealed

ResultsPlus Examiner Comments

This candidate has the right idea about using a sealed tube to prevent the escape of something during heating under reflux. However, they have stated that the product could escape. The products are butylamine and ammonium bromide and neither of these is highly volatile. One of the reactants, ammonia, is a gas at room temperature so it could escape.

ResultsPlus Examiner Tip

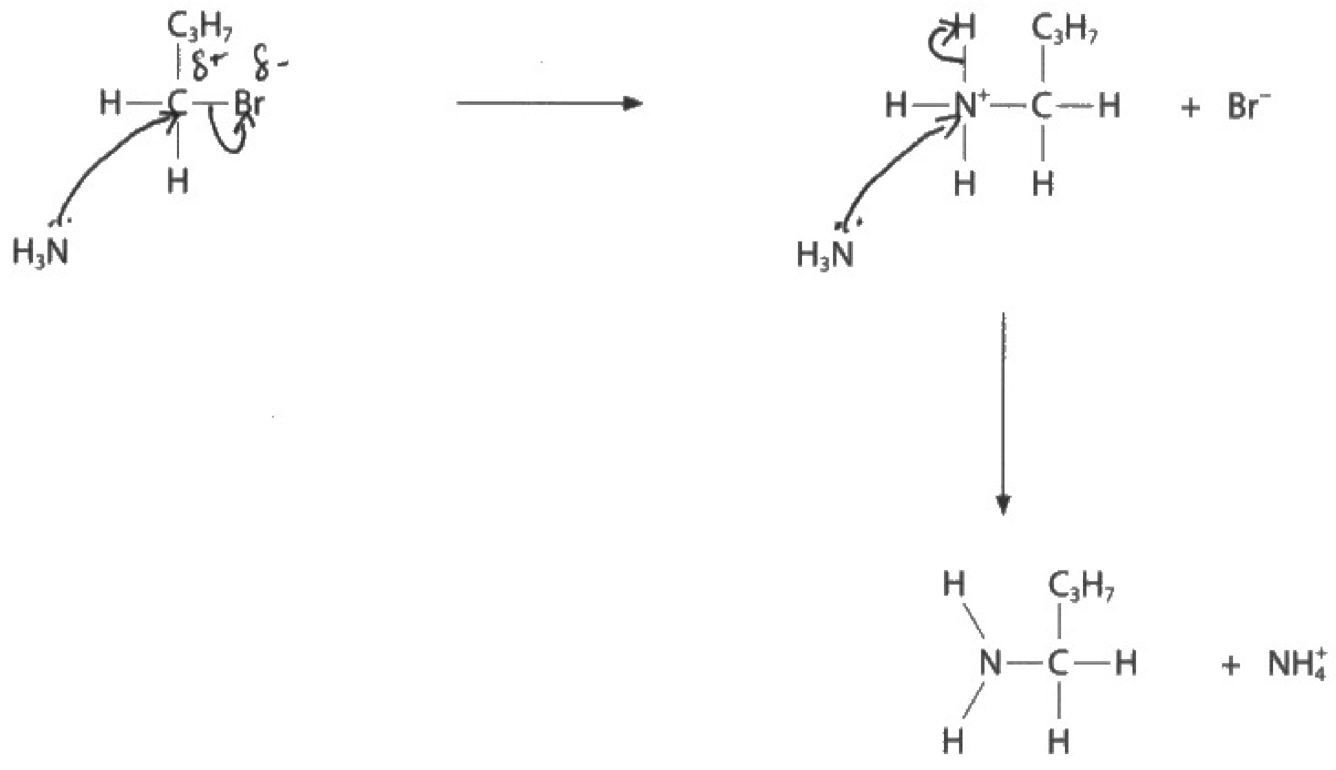
Always identify a particular reactant or product that could escape when heating under reflux.

Question 17 (c)(ii)

This mechanism is on the specification but tends to be less well-known than some of the others. Most candidates scored the first two marks, although some added a negative charge to ammonia or showed the lone pair on H instead of N. A much smaller number could work out how the molecule of ammonia was involved in removing H^+ from the intermediate and there were many curly arrows pointing in the wrong direction. Many students would benefit from a review of mechanisms in organic chemistry to ensure that they understand the meaning of a curly arrow and where it can start and finish.

(ii) Complete the mechanism for this reaction by adding curly arrows, and any relevant lone pairs and dipoles.

(4)



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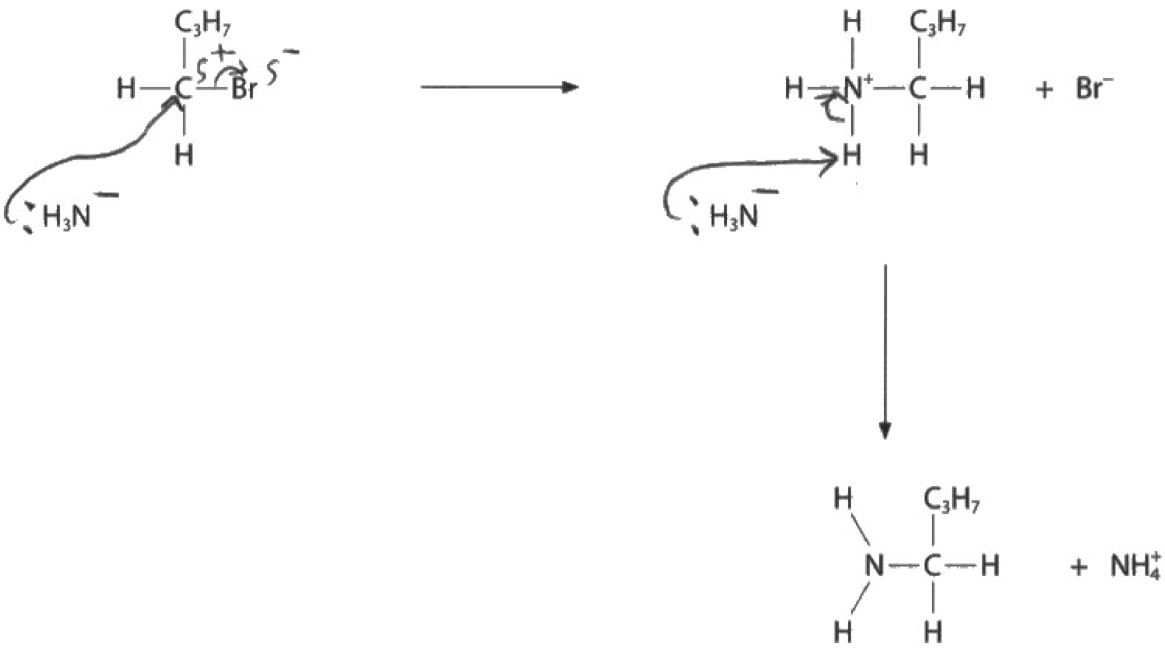
This mechanism scored 2 marks for the curly arrows, lone pair and correct dipole on the structure on the left. The curly arrow should start from the lone pair on the NH_3 attacking the intermediate, but it is joining to H^+ to form the NH_4^+ ion so it should be pointing to a hydrogen atom and not the nitrogen. The final curly arrow should be pointing from the N-H bond towards the nitrogen atom.

ResultsPlus Examiner Tip

Think carefully about where curly arrows end. Remember that they represent the movement of a pair of electrons.

(ii) Complete the mechanism for this reaction by adding curly arrows, and any relevant lone pairs and dipoles.

(4)



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Examiner Comments

This mechanism scored 3 marks. The first curly arrow is incorrect as it starts from a lone pair on a hydrogen atom instead of the nitrogen atom. This would form a C-H bond instead of the N-C bond shown in the intermediate. The candidate has also added a negative charge to the ammonia molecule which is incorrect. The dipole on the C-Br bond and curly arrow are both correct. The candidate has made the same error with the lone pair and negative charge on the NH_3 attacking the intermediate, so they have not been penalised again and have been given the mark for the curly arrow pointing to the hydrogen atom. The final curly arrow is correct.

ResultsPlus
Examiner Tip

Think carefully about which atom in a molecule will have a lone pair of electrons and do not add incorrect charges to neutral molecules.

Question 17 (d)

Many candidates seemed unfamiliar with the concept of a limiting reagent in calculations and would benefit from carrying out more calculations like this. Most candidates scored a mark for calculating the number of moles of each of the reagents but many thought that the mass of product would be related to the amount of sulfuric acid as that was present in the largest amount. Some candidates were unsure what to do next and some added all the moles of reactants together and others took an average. Those who chose ethanol as the limiting reagent usually completed the calculation correctly and scored 3 marks.

(d) Bromoethane is prepared by reacting ethanol with potassium bromide and concentrated sulfuric acid.

$$C_2H_5OH + KBr + H_2SO_4 \rightarrow C_2H_5Br + KHSO_4 + H_2O$$

Calculate the maximum mass of bromoethane that could be prepared from 4.65 g of ethanol, 14.90 g of potassium bromide and a solution containing 16.35 g of H_2SO_4.

[A_r values: H = 1.0 C = 12.0 O = 16.0 S = 32.1 K = 39.1 Br = 79.9]

(3)

$C_2H_5OH + KBr + H_2SO_4 \rightarrow C_2H_5Br + KHSO_4 + H_2O$

4.65g   14.90g   16.35g   → x

$n(C_2H_5OH) = \frac{4.65}{12+12+6+16} = 0.101086957$ ← smallest

$n(KBr) = \frac{14.90}{39.1+79.9} = 0.125210084\ldots$ ← excess

$n(H_2SO_4) = \frac{16.35g}{2+32.1+(4\times16)} = 0.16$ ← excess

$\therefore C_2H_5OH : C_2H_5Br$

1 : 1

$0.101086957 : 0.101086957 \times (2+5+79.9)$

$= 8.784456563$

$\approx 8.78g$

ResultsPlus
Examiner Comments

This candidate has made a good attempt at this calculation and scored 2 marks. They have calculated the number of moles of each reactant and realised that ethanol is present in the smallest amount so the number of moles of bromoethane formed cannot be larger than this. Unfortunately they have calculated the molar mass of bromoethane incorrectly by using 2 instead of 24 for the two carbon atoms so they did not score the final mark.

ResultsPlus
Examiner Tip

The relative atomic masses were given in this question so check to make sure that you have used them correctly. Many questions do not include relative atomic masses but they can always be found on the periodic table on the back page of the exam paper.

(d) Bromoethane is prepared by reacting ethanol with potassium bromide and concentrated sulfuric acid.

$$C_2H_5OH + KBr + H_2SO_4 \rightarrow C_2H_5Br + KHSO_4 + H_2O$$

Calculate the maximum mass of bromoethane that could be prepared from 4.65 g of ethanol, 14.90 g of potassium bromide and a solution containing 16.35 g of H_2SO_4.

[A_r values: H = 1.0 C = 12.0 O = 16.0 S = 32.1 K = 39.1 Br = 79.9]

(3)

C_2H_5OH

m = 4.65 g

$n = \frac{4.65}{2(12)+5+16+1}$

= 0.101 mol

↑ limiting reagent

KBr

m = 14.9 g

$n = \frac{14.9}{39.1+79.9}$

= 0.125 mol

H_2SO_4

m = 16.35 g

$n = \frac{16.35}{2+32.1+4(16)}$

= 0.167 mol

C_2H_5Br

n = 0.101 mol

m = 0.101 × (2(12) + 5 + 79.9)

= 11.0 g (3 s.f.)

ResultsPlus
Examiner Comments

This is an example of an excellent answer that scored 3 marks. This candidate has clearly identified which is the limiting reagent as it is present in the least amount.

ResultsPlus
Examiner Tip

Revise how to carry out calculations where you have to identify the limiting reagent.

Question 17 (e)

This was a straightforward extended open response and the candidates who had revised the two reactions were able to score high marks. Unfortunately, many candidates seemed unfamiliar with the reactions so were unable to make much progress. A few candidates did not include equations in their answers, even though this was specified in the question, and some wrote unbalanced equations. The most common points missing from answers were the recognition that the hydroxide ion is acting as a base in ethanolic solution and identification of propan-2-ol formed from 2-bromopropane.

*(e) The reaction between 2-bromopropane and potassium hydroxide takes place under two different conditions:

- in aqueous solution
- in ethanolic solution.

Compare and contrast these two reactions.

Include equations for the reactions.
Detailed mechanisms of these reactions are **not** required.

(6)

When 2-bromopropane reacts with aqueous potassium hydroxide, an alcohol forms which is propan-2-ol and KBr as a side product.

$C_3H_7Br + KOH_{(aq)} \rightarrow C_3H_7OH + KBr$

when 2-bromopropane reacts with ethanolic potassium hydroxide, an alkene forms which is propene and KBr and water as side products.

$C_3H_7Br + KOH_{(eth.)} \rightarrow C_3H_6 + KBr + H_2O$

KBr is produced in both reactions. On the other hand, H_2O is produced in only one (ethanolic KOH).

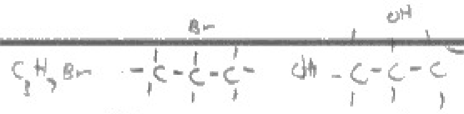
ResultsPlus Examiner Comments

This candidate has made a good start to this extended open response by comparing the products that are formed and writing equations for the two reactions. They have been awarded 3 Indicative Points, which equates to 2 marks and 1 mark for structure and lines of reasoning, giving a total of 3 marks.

The answer could be improved by giving more detail about the reactions, for example, the type of reagent used, the type of reactant and by giving a similarity.

ResultsPlus Examiner Tip

The question asks you to compare and contrast the two reactions so you must include at least one similarity and one difference.



*(e) The reaction between 2-bromopropane and potassium hydroxide takes place under two different conditions:

- in aqueous solution   substitution   propan-2-ol   water + heat OH^- acts as nucleophile
- in ethanolic solution.   ~~alkene~~ propene + KBr + H_2O elimination   ethanol + heat

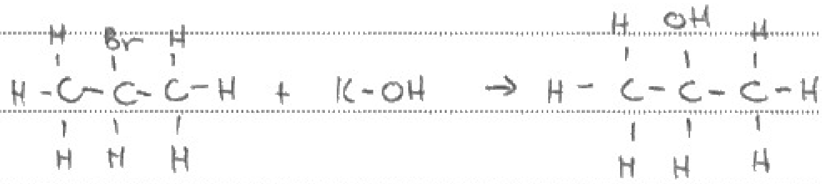
Compare and contrast these two reactions.   KOH acts as base

Include equations for the reactions.
Detailed mechanisms of these reactions are **not** required.

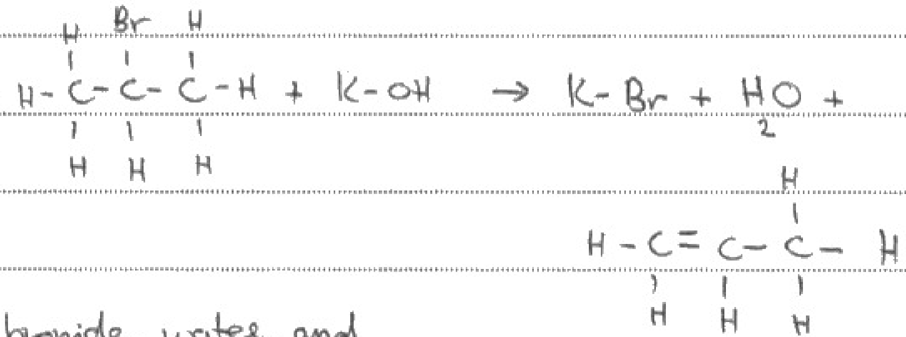
(6)

in aqueous solution, a substitution reaction occurs because OH^- ion acts as a nucleophile.

in ethanolic solution, an elimination reaction occurs because OH^- ion acts as a base.

aqueous solution : 

forms propan-2-ol

ethanolic solution : 

forms potassium bromide, water, and propene.

both reactions require heating.

ResultsPlus
Examiner Comments

This is a very good answer that scored 5 marks. The candidate has given 5 Indicative Points, which equates to 3 marks and they have been awarded 2 marks for structure and lines of reasoning as the answer clearly compares and contrasts the two reactions. The only error is that the first equation is unbalanced.

ResultsPlus
Examiner Tip

Remember to check that all equations are balanced, including those written in the extended open response.

Question 18 (a)(i)

It was disappointing that many candidates did not know the temperature and pressure for standard conditions. Many gave incorrect temperatures, and the units were often incorrect for the pressure.

(a) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, of 2,2,4-trimethylpentane is −5461 kJ mol^{-1}.

(i) State the two standard conditions for this enthalpy change.

(1)

100 atm pressure & 298 K tenprature.

ResultsPlus Examiner Comments

This response scored 0. The temperature is correct, but the pressure is incorrect. Both temperature and pressure needed to be correct to award the mark.

ResultsPlus Examiner Tip

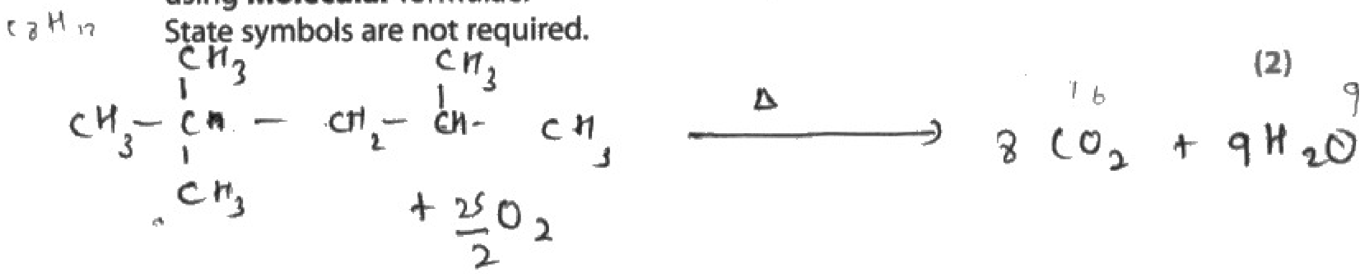
Learn the standard conditions used for enthalpy changes.

Question 18 (a)(ii)

Although many candidates were able to write the balanced equation for the complete combustion of 2,2,4-trimethylpentane, some ignored the instruction to use **molecular** formulae and drew a structural or displayed formula for the alkane. The candidates who did not use the molecular formula were able to access the mark for balancing the equation. Some candidates did not read the information in the question that this alkane is an isomer of octane, so the molecular formula must be C_8H_{18}, and some focussed on the 'pentane' part of the name and used C_5H_{12} so lost both marks.

(ii) Write the equation for the complete combustion of 2,2,4-trimethylpentane, using **molecular** formulae.
State symbols are not required.

(2)



ResultsPlus
Examiner Comments

This candidate has written a balanced equation, but they have ignored the question that asks them to use **molecular** formulae, so they scored 1 mark instead of 2.

ResultsPlus
Examiner Tip

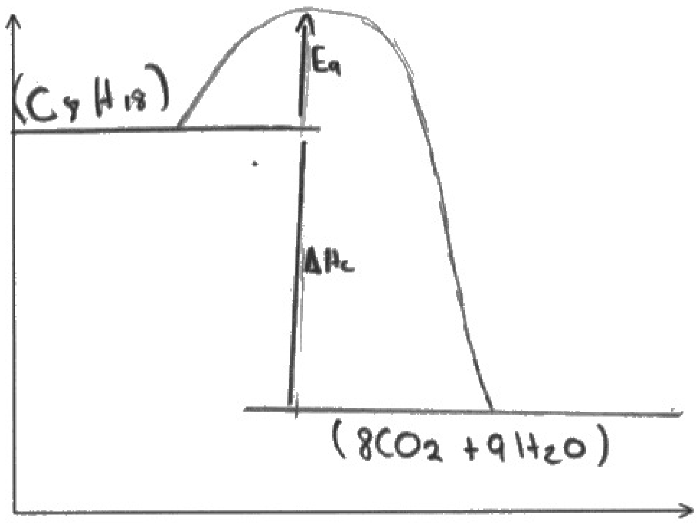
Read the questions carefully, particularly any words in bold.

Question 18 (a)(iii)

Although some excellent, clearly labelled enthalpy level diagrams were seen, there were a significant number of poor diagrams. Many candidates labelled the y axis as enthalpy change instead of just enthalpy and many drew careless arrows to represent the enthalpy change as the arrow did not start at the reactants level and finish at the products level. Some candidates just drew a line for ΔH , some labelled it as – ΔH and others drew a double-headed arrow.

(iii) Draw a labelled enthalpy level diagram for the complete combustion of 2,2,4-trimethylpentane.

(2)



ResultsPlus Examiner Comments

This enthalpy level diagram has too many errors to score any marks.

The y axis should be labelled with enthalpy or energy.

If formulae are used as labels on the reactants line, they should be correct, and all reactants included.

There should not be an activation energy 'hump' although that was not penalised in this question.

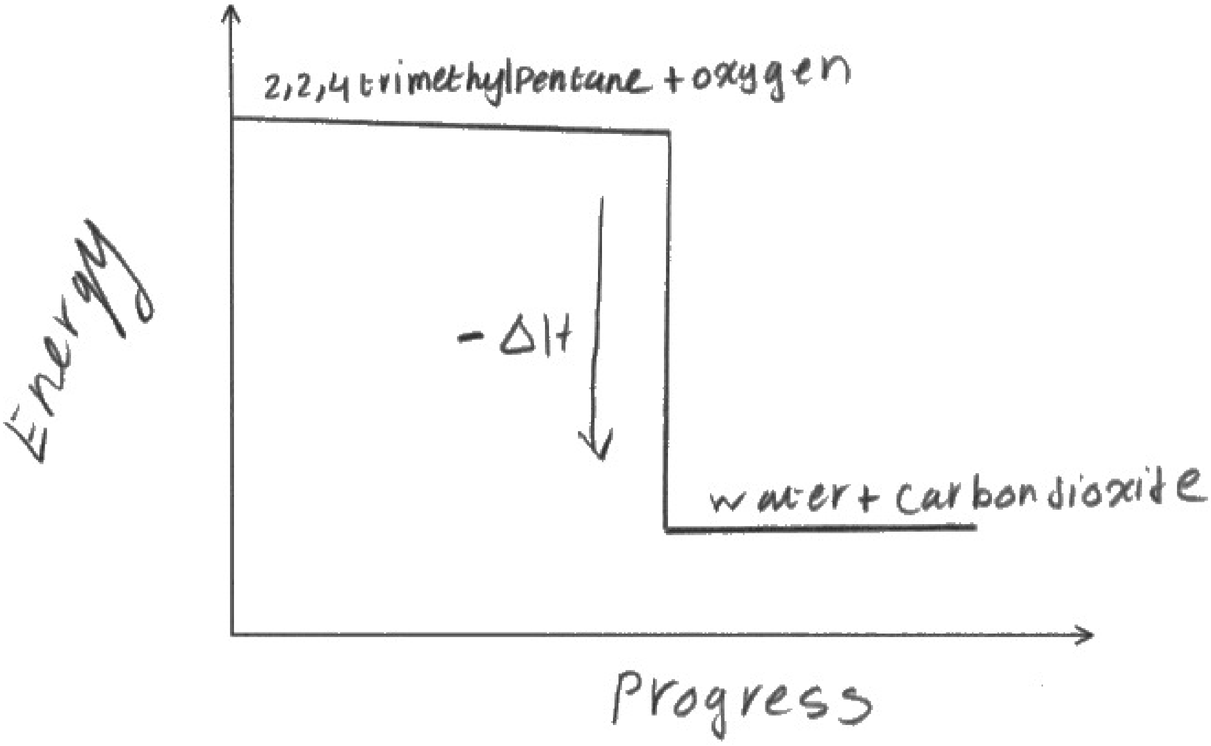
There is no arrowhead on the delta H line.

ResultsPlus Examiner Tip

Revise how to draw enthalpy level diagrams.

(iii) Draw a labelled enthalpy level diagram for the complete combustion of 2,2,4-trimethylpentane.

(2)



ResultsPlus
Examiner Comments

This candidate has made a good attempt at drawing an enthalpy level diagram. However, the arrow showing delta H is too short as it should start at the reactants level and finish at the products level. It should also not have a negative sign.

ResultsPlus
Examiner Tip

The arrows drawn on enthalpy level diagrams should start and finish at the correct levels.

Question 18 (a)(iv)

Candidates who looked carefully at the units of the quantities in the question and who could work out how to use the density to calculate mass, scored full marks on this question. Some candidates did not seem to understand that the unit for density shows them that density is equal to the mass divided by volume.

(iv) Calculate the heat energy released during the complete combustion of 1 dm^3 of 2,2,4-trimethylpentane.

[Density of 2,2,4-trimethylpentane = 0.692 g cm^{-3}]

(3)

Density = $\frac{m}{v}$.

m = 0.692 × 1000

= 692g.

Moles = $\frac{692}{114}$ =

= 6.07 moles

Q = mcΔT.

$\Delta_c H^{\circ}$ = −5461 kJ/mol

ΔH = $\frac{-5461}{}$ = $\frac{5461}{6.07}$ ∴ ΔH = 899.7 kJ/mol

Q = 692 × 4.18 ×

ResultsPlus
Examiner Comments

This response scored 2 marks.

The calculations to determine the mass of 2,2,4-trimethylpentane and the number of moles are correct. However, the heat energy released is the standard enthalpy change of combustion multiplied by the number of moles, not divided by the number of moles.

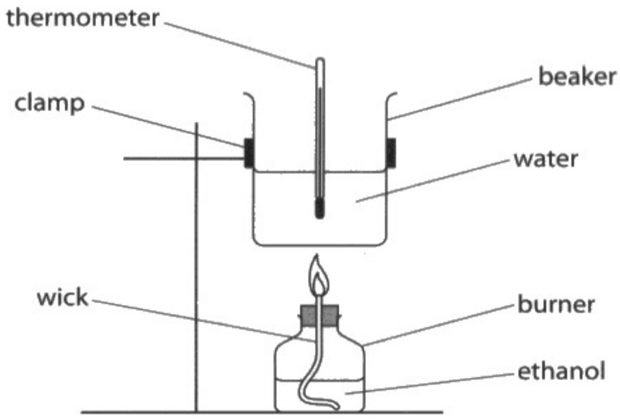
ResultsPlus
Examiner Tip

The standard enthalpy change of combustion is measured in kJ mol^{-1} so 6.07 mol of fuel will release a lot more energy than 1 mol.

Question 18 (b)(i)

Candidates were much more confident in the calculation in this question as it followed a familiar format for them. The common errors were just using the mass of ethanol to calculate the heat evolved or adding the mass of ethanol to the mass of water, converting the temperature rise to kelvin, omitting the minus sign to show that the reaction is exothermic and not giving the final answer to an appropriate number of significant figures.

(b) In an experiment to determine the enthalpy change of combustion of ethanol, C_2H_5OH, a student used the apparatus shown.



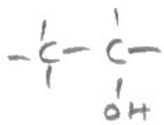
Results:

Mass of water = 100.0 g

Mass of ethanol used = 0.305 g

Temperature rise of water = 13.2 °C

C_2H_5OH



(i) Calculate the enthalpy change of combustion of ethanol.

Give your answer to an appropriate number of significant figures, and include a sign and units.

[Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}]

(4)

$Q = mc\Delta T$

$m = 100$

$c = 4.18$

$\Delta T = 13.2$

$Q = 100 \times 4.18 \times 13.2$

$= \frac{5517.6}{1000}$

$= 5.5176$ kJ

$\Delta H = \frac{-Q}{n}$

$n = \frac{m}{Mr}$

$= \frac{0.305}{46} = 6.63 \times 10^{-3}$

$\Delta H = \frac{-5.1576}{6.63 \times 10^{-3}}$

$= -777.87$ kJ/mol

ResultsPlus
Examiner Comments

This response scored the first two marks from the mark scheme for calculating the heat evolved and the number of moles of ethanol.

Unfortunately the candidate has written two digits (5 and 1) the wrong way around in the calculation of ΔH and they have not given their final answer to an appropriate number of significant figures.

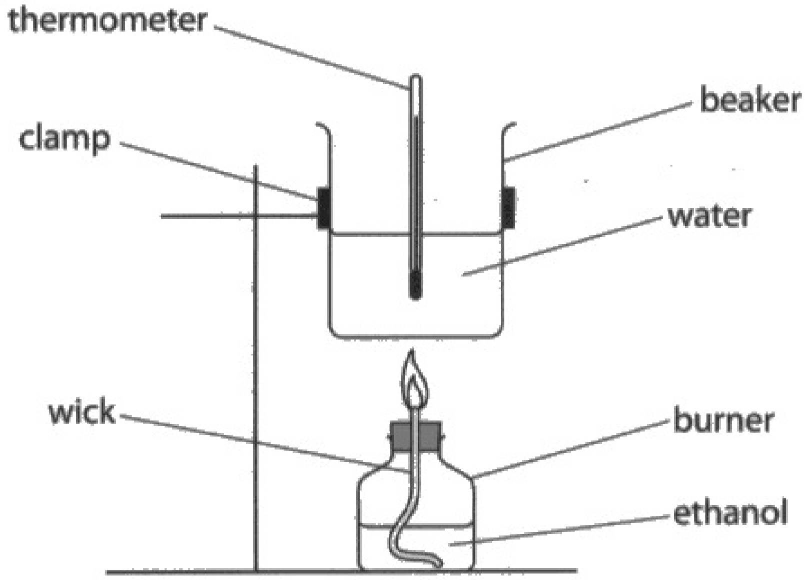
ResultsPlus
Examiner Tip

Check that you have copied numbers correctly.

Check whether the question asks you to give your answer to a particular number of significant figures or an appropriate number of significant figures. You will lose a mark if you do not follow the instructions in the question.

(b) In an experiment to determine the enthalpy change of combustion of ethanol, C_2H_5OH, a student used the apparatus shown.

(12x2)+5+17 =
46



Results:

Mass of water = 100.0 g

Mass of ethanol used = 0.305 g

$\frac{0.305}{46} = 6.63 \times 10^{-3}$ mol

Temperature rise of water = 13.2 °C

(i) Calculate the enthalpy change of combustion of ethanol.

Give your answer to an appropriate number of significant figures, and include a sign and units.

[Specific heat capacity of water = $4.18\,J\,g^{-1}\,°C^{-1}$]

(4)

$Q = m \times c \times \Delta T$

$Q = 100 \times 4.18 \times 13.2 = 5517.6$ J

5.5176 KJ

$\frac{5.5176\,KJ}{6.63 \times 10^{-3}\,mol} = 832.2$

832 KJ mol^{-1}

ResultsPlus
Examiner Comments

This response scored 3 marks. The candidate carried out the calculation correctly but omitted to include the minus sign in the final answer.

ResultsPlus
Examiner Tip

Remember that a ΔH value for an exothermic reaction should have a negative sign and ΔH for an endothermic reaction should have a positive sign.

Question 18 (b)(ii)

It was disappointing that many candidates were unable to calculate the percentage uncertainty in the temperature rise. Some forgot that there are two temperature measurements so they should multiply their answer by two, however, a significant number rounded 0.75758 to 0.75% and lost the mark.

(ii) The uncertainty in each thermometer reading is ±0.05 °C.

Calculate the percentage uncertainty in the temperature rise in this experiment.

(1)

$$\frac{2 \times 0.05}{13.2} \times 100$$

0.75 %

ResultsPlus Examiner Comments

This was a common response that scored 0. The full answer is 0.75758 and the candidate has rounded it incorrectly to 0.75%.

ResultsPlus Examiner Tip

Think carefully about how to round your final answer. Don't just leave off the final digits from your calculator.

Question 18 (b)(iii)

Most candidates knew two reasons for the difference between the data book value and the experimental value, with incomplete combustion and heat loss to the surroundings being the most common reasons seen. Some candidates gave answers that were too general to score marks, such as experimental error. A few candidates referred to mean bond enthalpies, which were not relevant to this question and a few were confused between incomplete combustion and the idea that not all of the ethanol was burned.

(iii) The student looked in a data book and found the actual value for the standard enthalpy change of combustion of ethanol was more exothermic than the experimental value obtained.

Give **two** reasons for the difference between the data book value and the experimental value, other than referring to standard conditions.

(2)

Some heat is not transferred to the water, they transferred to the air and some ethanol is not burnt.

ResultsPlus
Examiner Comments

This response scored 1 mark for the idea of heat loss to the surroundings.

The idea that 'some ethanol is not burned' will not make any difference to the calculated enthalpy change as the mass of ethanol burned will be lower. Many candidates think this is the same as incomplete combustion, where carbon and/or carbon monoxide would be formed.

ResultsPlus
Examiner Tip

Revise the meaning of incomplete combustions.

Question 18 (c)

This style of question involving the use of bond enthalpies was less familiar to candidates but those who worked through the equations in a logical order to identify the bond enthalpies of different bonds, generally scored 3 marks. Some candidates did not know how to start this question and they need to review the concept of bond enthalpies to understand what they represent.

(c) The enthalpy changes for the conversion of four compounds in the gas phase into their constituent atoms are shown.

$H_2O(g) \rightarrow 2H(g) + O(g)$ $\Delta_r H = +928\ kJ\ mol^{-1}$

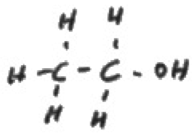
$CH_4(g) \rightarrow C(g) + 4H(g)$ $\Delta_r H = +1740\ kJ\ mol^{-1}$

$CH_3OH(g) \rightarrow C(g) + 4H(g) + O(g)$ $\Delta_r H = +2105\ kJ\ mol^{-1}$

$C_2H_5OH(g) \rightarrow 2C(g) + 6H(g) + O(g)$ $\Delta_r H = +3322\ kJ\ mol^{-1}$

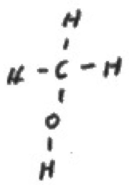
Calculate the bond enthalpy of the C—C bond, in $kJ\ mol^{-1}$.
You **must** show your working.

(3)

→ ~~[crossed out]~~  → + 3322 kJ /mol.

→ 2 → O-H bonds → + 928 | 1 O-H bond enthalpy = 464 kJ /mol

→ 4 → C-H bonds → 1740 | 1 → C-H bond = $\frac{1740}{4}$ = 435 kJ /mol.

→  → one C-O bond = 2105 - [[3 x 435] + 464] = 336 kJ /mol

→ ΔH for one C-C bond = 3322 - [(5 x 435) + 336 + 464]

= 3322 - 2975

= +347 kJ /mol

ResultsPlus
Examiner Comments

This is an example of a good response that scored 3 marks. The candidate has set out their working clearly and logically.

ResultsPlus

Examiner Tip

Examiners will find it easier to award you marks if they can follow your working, so write a few words to explain each step.

Question 18 (d)

This was a straightforward question on the effect of increasing the pressure on an industrial process at equilibrium and many candidates scored both marks. However, some spent time writing about the effect of temperature and/or a catalyst, when these were not required. Some candidates omitted to state what would happen to the equilibrium yield of ethanol.

(d) Ethanol can be manufactured by reacting ethene with steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta_r H = -45\ \text{kJ mol}^{-1}$$

This reaction is usually carried out in industry at 300 °C and 70 atm pressure using a catalyst.

Explain the effect on the equilibrium position and the equilibrium yield of ethanol if the reaction is carried out at 300 °C and 200 atm pressure.

(2)

The forward reaction is exothermic, so temperature has to be low. However, low temperature decrease rate of reaction. Catalyst allow the temperature to be low by finding an alternative pathway. High pressure will increase the yield and increase rate of reaction.

ResultsPlus
Examiner Comments

This response scored 0. The candidate has spent time writing about a change in temperature and the effect of a catalyst, neither of which was needed to answer this question. The candidate has written that high pressure will increase the yield, but this needed to be included with a comment about the position of equilibrium shifting to the right.

ResultsPlus
Examiner Tip

Read the question carefully and don't spend time writing about points that are irrelevant to the question.

Paper Summary

Based of their performance on this paper, candidates are offered the following advice:

- read the question carefully and use the information in it to help you to answer the question
- after you have written your answer, re-read the question and your answer to ensure that you have fully answered the question
- learn the meanings of as many of the key scientific words in each topic as possible and use them correctly e.g. atom, ion and molecule
- explain your working in each step of a calculation
- always evaluate the final answer in a calculation as a decimal and give it to an appropriate number of significant figures, with units if applicable
- make sure that you understand how to work out which is the limiting reagent in a calculation
- revise all the organic reactions in this Unit so that you can state the reagents, conditions, types of reaction and write equations
- when you are asked to make a comparison, use adjectives such as larger, stronger and faster followed by than …

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