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Examiners' Report
June 2018

GCE Chemistry 8CH0 02

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June 2018
Publications Code 8CH0_02_1806_ER

Introduction

Students appeared to have been quite well prepared for this paper; few blank answer spaces were seen, except in the latter parts of the paper where it seemed that some students may have been running out of time and were justifiably being more selective in the questions that they attempted. Just a few students also appeared to avoid the longer written questions, e.g. 6b, perhaps conscious that these questions may take longer, or possibly because they were less confident of their ability to score good marks where the quality of writing was also being assessed.

The paper had been deliberately ramped so that the more testing questions were placed towards the end of the paper.

One consistent feature was the poor layout of calculations. An appreciable number were so poorly laid out that it was sometimes difficult to award transferred error marks.

Some students failed to ensure that they had answered all parts of a question. For example, as part of Question 2 (b)(i), students were asked to calculate two mole quantities and then use their answers to decide which reactant was in excess. There are many routes to the final answer (the volume of gas produced), but marks were available for the intermediate stages. Those who chose to ignore the early part of the question and then used an unusual route to the final answer sometimes created difficulties in awarding transferred errors.

Question 2 (a) (i)

This was a relatively simple gas volume calculation, designed to give the students confidence with calculations at an early stage of the paper.

2 This question is about the molar volume of gases.

(a) (i) Calculate the volume of one mole of an ideal gas, **A**, at 60 °C and 500 kPa pressure. Give your answer to two significant figures and include units.

[The ideal gas equation is $pV = nRT$. Gas constant (R) = 8.31 J K^{-1} mol^{-1}]

(3)

60°C + 273 = 333K

n = 1

P = 500KPa

500000 Pa

500000V = 1 × 8.31 × 333

V = 5.53

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Examiner Comments

Final answers in cm^3, dm^3 or m^3 are acceptable but the number and units must correlate. Students were instructed to show all working so the conversion of °C to K and kPa to Pa were expected in the answers. If the pressure was not converted to Pa, the answer is in dm^3; this was acceptable. Those who left the conversion of °C to K as (60 +273) with no evaluation could score full marks for a correct answer but risked the loss of M1 if mistakes were made.

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Examiner Tip

The question specifically asks for 2 SF and units, there will be at least one mark for compliance with these instructions. The answer shown here is presented to 3 SF and has no units. M3 is lost for both reasons.

Question 2 (a) (ii)

This was another relatively simple calculation which should have required minimal time for a confident student.

Some students completed the more challenging section of the question; the determination of M_r, but then made no attempt to identify element X.

This response was awarded M1 but there was no attempt to deduce the identity of the element X, M2 was therefore not awarded.

(ii) At room temperature and pressure (r.t.p) another gas **B**, with formula XH_3, has a density of 1.42 g dm^{-3}.

Calculate the molar mass of the gas XH_3 and deduce the identity of the element X.

g/mol⁻¹

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

(2)

$d = \frac{m}{V}$

$\frac{1.42 g}{1 dm^{-3}} \times 24 dm^{-3} = 1.42 g$

$1.42 = \frac{m}{24}$

$m = 34.08$ g/mol⁻¹

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Examiner Comments

There are several mistakes in this response (as far as it goes). The final figure is presented as g/mol^{-1} which is incorrect (it should be g/mol or g mol^{-1}). There is also a units error in a previous line where 24 dm^{-3} should be 24 dm^{3}. These mistakes did not incur a penalty in this question because it was the number that was relevant.

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Examiner Tip

Ensure that you answer all parts of the question.

Take care with units, even when they are used at intermediate stages through a calculation.

Where a question specifies particular units, the final answer MUST be in those units. In such instances the units need not be given, it will be assumed that they will be as specified in the question. However, if units are given, they must be correct. If not, the mark for the final answer may not be awarded.

Question 2 (b) (i)

This question was very specific in its requirements. Students were instructed to calculate the moles of acid and sodium carbonate and use this information to decide which regent was in excess. A significant number of students did not calculate the moles of sodium carbonate. This created a problem for the student in deciding which reactant was in excess; it often followed that the evidence for the excess sodium carbonate was omitted.

Units were expected for the final answer. Where units are not specified by the question, it is expected that units will be given in the answer. In this question, some gave an answer in cm^3 (a familiar unit for many), but others in dm^3 (a logical consequence of the calculation), both were acceptable.

(i) Calculate the moles of hydrochloric acid and the moles of sodium carbonate used in this experiment.

Use your answers to decide which reactant is in excess.
Calculate the maximum volume of carbon dioxide which could be produced.

[Molar mass of Na_2CO_3 = 106.0 g mol^{-1}
Molar volume of gas = 24 000 cm^3 mol^{-1} at r.t.p.] **(5)**

$10 \div 1000 = 0.01\ dm^3$

moles = conc x vol
= 0.4 x 0.01
moles = 0.004

~~Moles = mass / RMM~~

moles = 0.242 ÷ 106
= 0.00228

The sodium carbonate is in excess.

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Examiner Comments

In this example, the first part of the question has been answered successfully. The moles of acid and the moles of sodium carbonate have been calculated and a decision made about the reactant in excess.

Neither moles calculation has been linked to a reactant and it has been left to the examiner to decide which reactant is linked to each calculation. There is no evidence to support the decision of the reactant in excess.

The second part of the question, the calculation of the volume of gas produced, has not been attempted.

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Examiner Tip

Use a few words to identify the steps in any calculation. In this example, only the numbers on the left indicate that this is the hydrochloric acid calculation. Similarly, the numbers to the right presumably indicate the sodium carbonate calculation.

In some calculations, the numbers may not give such clear-cut guidance. It is always advisable to identify any number processing so that transferred errors can be applied by the examiner.

Retain an adequate number of significant figures during the intermediate stages of a calculation. In this question, it is important to show more than 1 SF for the moles of sodium carbonate, (because comparison with the moles of sodium carbonate required by the acid were also expected).

Question 2 (b) (ii)

This question is based on practical work that the student is likely to have experienced.

Even if the student has not carried out the practical, it should still be possible to answer the question from the procedure described in the question.

(ii) The actual volume of carbon dioxide collected was less than calculated. Give **two** reasons for this.

(2)

There may have been a leak in the syringe.

They reaction may not have been completed.

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Examiner Comments

One mark was awarded for recognition that this is a rapid reaction and that gas will be lost before the delivery tube can be replaced.

Marks were not awarded for answers based on faulty equipment, i.e. leaks or syringe sticking etc.

The second mark requires the student to recall that carbon dioxide is sufficiently soluble in water to impact on the volume of gas collected.

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Examiner Tip

Even if the procedure described is unfamiliar to you, read it through carefully and try to understand each of the stages.

You should assume that all the equipment is in good working order unless the procedure indicates otherwise.

Question 3 (a)

M1: Problems included inverted expressions and the use of a + sign instead of a product.

M2: The units should be consistent with the expression as written.

kJ mol^{-1} was a relatively common error for the units.

3 This question is about the oxidation of ammonia.

One equation for the oxidation of ammonia is

$$4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$$

(a) Write the expression, including units, for the equilibrium constant K_c for this reaction.

(2)

Expression

$$\frac{[NH_3]^4\,[O_2]^3}{[N_2]^2\,[H_2O]^6}$$

Units $\frac{1}{dm^3\,mol^{-1}}$

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Examiner Comments

No marks were awarded for this answer.

The K_c expression has all the correct powers but it is inverted.

In this example, the units do not accord with the K_c expression as written. They would have been correct if the expression had not been inverted. However, they should still have been written in standard form, as mol dm^{-3}.

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Examiner Tip

Ensure that you write the K_c expression with the correct numerator and denominator. A + sign will never appear in a K_c expression. If it did, it would make it impossible to deduce the units.

The units are easily derived from the K_c expression by cancelling the powers.

Question 3 (b) (i)

This style of question is often best answered using an energy triangle. This makes it easy for the examiner to follow and allows transferred errors to be recognised easily.

(b) Nitric acid is made from ammonia. One of the stages in nitric acid production involves the oxidation of ammonia to produce nitrogen(II) oxide, NO. In this process, a mixture of ammonia and oxygen is passed over a platinum-rhodium catalyst. One manufacturer uses a pressure of 5 atm and a temperature of 850 °C. The equation for this reaction is different from that in 3(a).

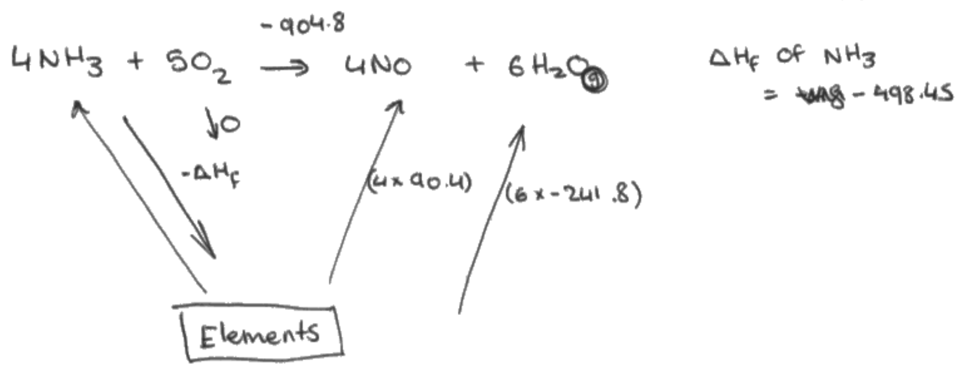
$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g) \qquad \Delta_r H = -904.8\,kJ\,mol^{-1}$$

(i) Use this equation, and the enthalpy changes of formation of nitrogen(II) oxide and water, to calculate the enthalpy change of formation of ammonia in kJ mol^{-1}. You may find it helpful to draw a Hess cycle first. You must show your working.

$\Delta_f H\,(NO(g)) = +90.4\,kJ\,mol^{-1}$

$\Delta_f H\,(H_2O(g)) = -241.8\,kJ\,mol^{-1}$

(3)



4x + 0 − 904.8 = −1089.2
4x + 0 = −1089.2 + −904.8

4x + 0 = −1993.8
x = −1993.8 / 4   x = −498.45

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Examiner Comments

This answer has utilised an energy triangle but the student seems unsure of the direction of the arrows and this has created problems in the calculation.

In this example M1 is awarded for the correct summation of the enthalpy changes of formation for the products.

Unfortunately M2 is then lost, probably as a result of the confusion with arrow directions in the cycle.

M3 is awarded for a TE from the incorrect M2. The student has divided by 4 for the 4 moles of ammonia.

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Examiner Tip

Sketch an energy cycle to help you apply Hess's Law. Ensure that your arrow directions are consistent with the sign of the data written next to them.

In this example, the student has written 'Elements' as the third part of the cycle. It takes only seconds to write the correct species and you are less likely to make mistakes.

M3 is awarded for a TE. The calculation is laid out sufficiently clearly that the error with the signs is easily identified.

Question 3 (b) (ii)

In general, students either knew how to answer this question, or they had little idea.

Atom economy is expressed as a percentage. Some omitted the conversion to a percentage.

(ii) Calculate the atom economy by mass for the formation of NO in this reaction.
Give your answer to an appropriate number of significant figures.

(2)

$$\frac{4 \times (14 + 16)}{(4 \times (14 + 16)) + (6 \times ((1 \times 2) + 16))}$$

$$\frac{120}{120 + 108} = 0.5263157895$$

$\therefore 0.526$ (3 SF)

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Examiner Comments

In this example, the student clearly knows what is meant by atom economy and has completed the more difficult part of the answer. However, one mark is then lost because the decimal should be converted to a percentage.

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Examiner Tip

Ensure that you know exactly what is meant by the term 'atom economy'.

The question specifies 'an appropriate number of significant figures'. Look at the number of significant figures in the data to judge the number expected in the answer. Two or three SF were expected here.

Question 3 (c) (i)

(c) In fact, this oxidation to form nitrogen(II) oxide is an equilibrium reaction.

(i) Explain the effect, if any, of increasing pressure on the equilibrium **yield** of NO in this reaction.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

9 10

(2)

Increasing the pressure would cause an ~~increa~~ decrease in the yield of NO in this reaction. This is because there are more moles on the RHS (10) than on the left (9) so more ~~successful~~ frequent collisions would occur on the RHS ($NO + H_2O$) resulting in a higher chance of $NH_3 + O_2$ being formed

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Examiner Comments

This question produced some answers that were contradictory and were therefore awarded no marks. e.g. a correct answer in terms of number of moles and the effect on the position of equilibrium but then saying that this would increase the yield. Or answers that correctly identified a decrease in yield but also said that the equilibrium position would move to the right

M2 is not awarded because there is no reference to the equilibrium. The argument in terms of number of moles of reactant and products is correct but not applied to the equilibrium.

There are no contradictory statements in this answer; if there were, no marks could have been awarded.

The reference to the increased frequency of collisions is correct, but not the answer to this question.

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Examiner Tip

Read your finished answer through carefully to ensure that there are no contradictory statements. It is a common error to confuse left and right when under pressure in an exam.

Question 3 (c) (ii)

(ii) Explain the effect, if any, of an increase in pressure on the **rate** of this reaction.

(2)

The rate of reaction would increase if the pressure increased as the gas ~~particles~~ molecules are ~~[illegible]~~ more likely to collide due to an increased number of gas particles in a fixed ~~smaller~~ volume of space. More particles ~~[illegible]~~ can therefore collide with enough activation energy. The ~~number~~ number of collisions increases.

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Examiner Comments

M1 required a recognition of the increased number of particles in a given volume when pressure is increased.

M2: Rate depends on the frequency of collisions, not just the number of collisions. 'More likely to collide' is not quite the same as collision frequency.

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Examiner Tip

Note that higher pressure results in more particles (molecules) in a given volume (3 dimensional), not area (which is 2 dimensional).

Rate depends on the frequency of collisions, not the number of collisions (which will increase with time).

Question 3 (c) (iii)

A heterogeneous catalyst is in a different state to the reactants. References to the products were ignored here.

The rates of the forward and reverse reaction are increased *to the same extent*, but this qualification was not required in order to award M2.

(iii) The platinum-rhodium catalyst used in this reaction is a **heterogeneous** catalyst. State what is meant by the term 'heterogeneous' and why a catalyst has no effect on the yield of the products in the reaction.

(2)

Heterogeneous ~~mean~~ catalyst is a catalyst that is in a different phase / state from the other elements in the reaction

→ Platinum-rhodium is metal and so solid when the elements are gaseous

→ a catalyst only increases the rate of the forward and backwards reaction equally not the yield.

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Examiner Comments

For M1, this answer is not correct. The catalyst is in a different state to the reactants. The use of 'elements' is not correct because one of the reactants here is a compound. The candidate may have been thinking of the Haber process in which the reactants are indeed elements.

M2 - A good answer that recognises that the rates of both the forward and reverse reactions will increase to the same extent (equally).

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Examiner Tip

A heterogeneous catalyst is in a different state to the reactants. Do not include the products.

To appreciate the effect of the catalyst on both the forward and reverse reactions, think of a reaction profile diagram.

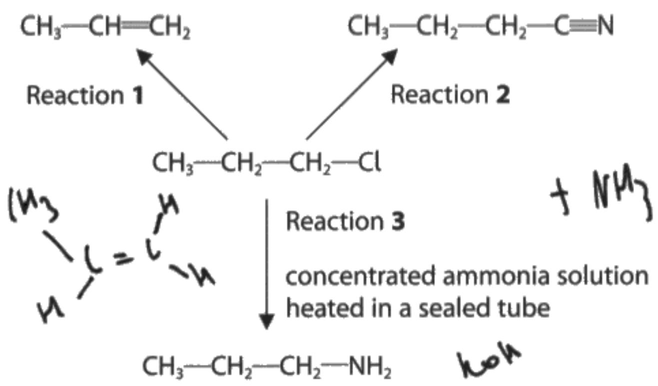
Question 4 (a) (i)

M1 was awarded for the correct reagent. M2 for the correct conditions (heating and ethanolic).

M1 was dependent on M2 except for a 'near miss' with the reagent, e.g. use of just OH^-.

4 This question concerns halogenoalkanes.

(a) 1-chloropropane can react to form organic products as shown in the reaction scheme:



(i) State the reagent and conditions used in Reaction **1**.

(2)

Ethanolic KOH and Sulfuric acid

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Examiner Comments

In this example, the M1 mark for the (correct) reagent, KOH, has been negated by the use of an acid, which would neutralise the KOH.

M2 cannot be awarded for a 'near miss' with the KOH because there is no mention of heating.

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Examiner Tip

Ensure that your answer does not contain any unintended contradictions. If in doubt, leave it out.

Question 4 (a) (ii)

M1 was awarded for the correct reagent. Conditions, if given, were ignored. Just 'cyanide' or the formula of the cyanide ion were not sufficient.

(ii) Identify a suitable reagent for Reaction **2** and include a reason why this is a particularly useful type of reaction in organic chemistry.

(2)

Reagent cyanide

Reason It contains the $C\equiv N$ group

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Examiner Comments

'Cyanide' alone is too generalised for M1. Not every cyanide is suitable.

A reassuring number of students recalled the importance of this reaction as a means of extending the carbon chain.

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Examiner Tip

A question that asks for a reagent will generally require the name of a compound.

Question 4 (a) (iii)

The question carried the word 'heated' and 'sealed' in bold to emphasise the need to address both of these two matters.

The mark allocation is also a good indication that two ideas will be required for a complete answer.

(iii) Explain why, in Reaction **3**, the reactants are **heated** in a **sealed** container.

(2)

heated in asealed container to increase temperature and pressure as the reaction has a high activation energy

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Examiner Comments

Students were not expected to be familiar with the chemical reactions described in this question. It was therefore expected that the application of basic principles of chemistry would provide adequate answers.

Heating would indeed raise the pressure in a sealed container of fixed volume but this does not directly answer the question of why reactions are heated.

The products are not central to the answer. It was expected that students would recall that one of the reactants, ammonia, is a gas at r.t.p and it would therefore be lost from an unsealed container.

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Examiner Tip

Heating certainly does raise the temperature, so ask yourself, 'why are reactions heated?'.

Why would a container be sealed? Usually to prevent the contents escaping. So the next question is, 'what is contained that might escape?' Ammonia is the obvious answer.

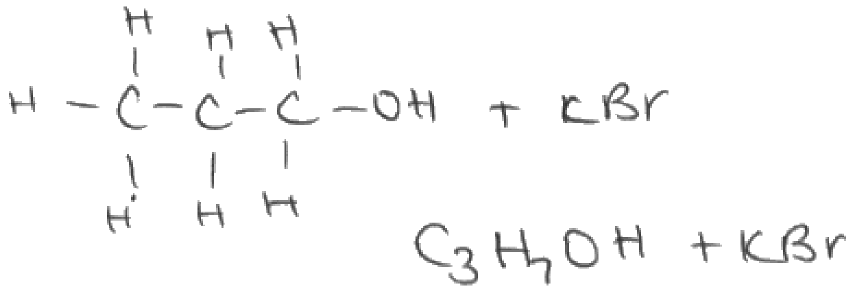
Question 4 (a) (iv)

Additional inorganic products were ignored.

The formula C_3H_7OH was not accepted because this would include the branched chain isomer.

(iv) Write the structural formula of the product that will be formed if 1-chloropropane is refluxed with **aqueous** potassium hydroxide solution.

(1)



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Examiner Comments

This answer is rescued by the inclusion of a displayed formula. The C_3H_7OH on its own would not have been sufficient.

The inclusion of the inorganic product (KBr) is ignored. The question is clearly focused on the organic product since it asks for a structural formula.

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Examiner Tip

The question asks for the structural formula so it is obvious that the organic molecule is required. The KBr would not be present in this form anyway because it is an aqueous solution.

If a structural formula is required, it is clear that a (partial) molecular formula (such as the C_3H_7OH shown in this example) would (on its own) be inadequate.

Question 5 (a) (iii)

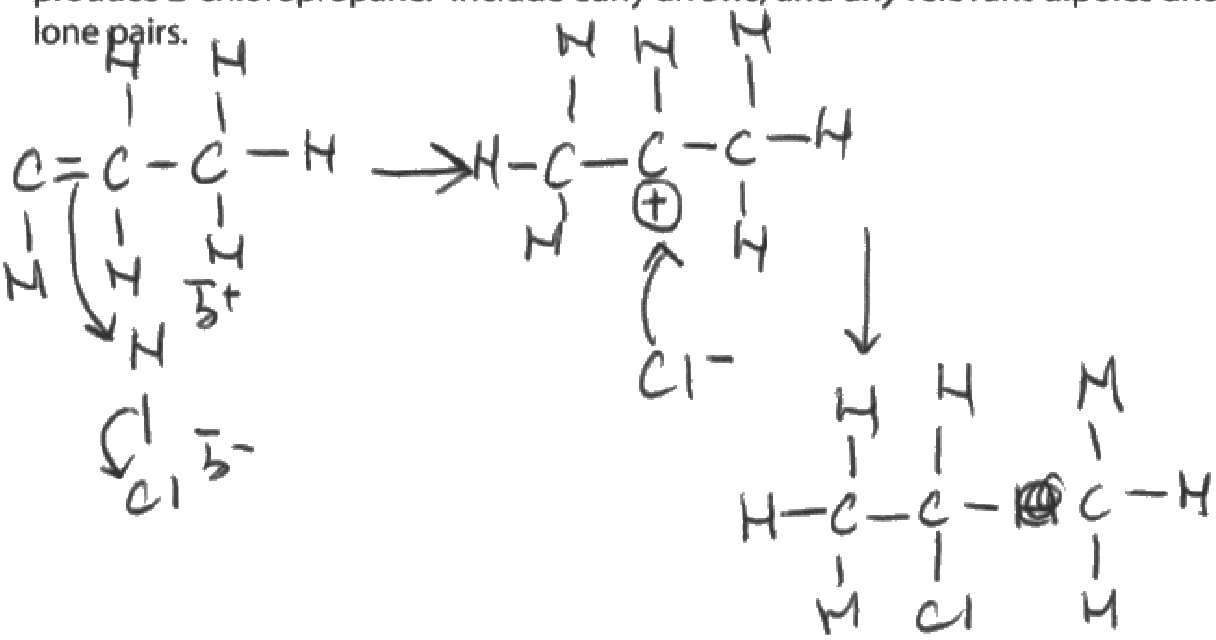
There were frequent casual errors in the response to this question. Missing H atoms and 5-bonded carbon atoms were all too frequent.

Occasionally, HBr was used in place of HCl and, in some instances, the halogen changed part-way through the mechanism.

The mechanism requested is for the production of 2-chloropropane. There is no credit for including the mechanism for 1-chloropropane as well.

(iii) Draw the mechanism for the reaction of propene with hydrogen chloride to produce 2-chloropropane. Include curly arrows, and any relevant dipoles and lone pairs.

(4)



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Examiner Comments

M1 is not awarded. There are two mistakes: an H atom missing from the starting alkene, and a 5-bonded C.

M2 is awarded. The relevant curly arrow is shown and starts from the H-Cl bond. The dipole is shown, however, the depiction of the 'delta' on the chlorine is not well drawn and could easily be mistaken for a negative sign (which would lose the mark).

M3 is awarded for a correct carbocation intermediate.

M4 is not awarded. The lone pair of electrons is not shown.

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Examiner Tip

Carefully check your starting molecule, any intermediate and the product for any missing H atoms or pentavalent carbons.

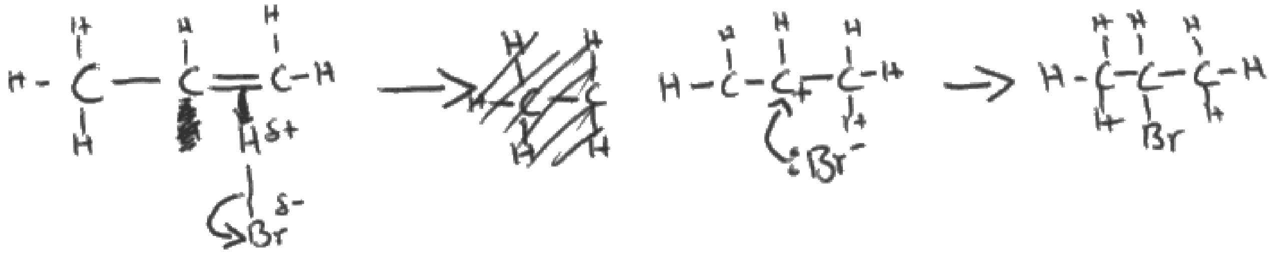
Take care with these mechanism drawings, a stray horizontal line might be mistaken for a negative charge.

For M4, the curly arrow **must** start from the lone pair.

Always include the organic product in your drawing, together with any other inorganic product (ions etc). There are no additional products to be included in this reaction.

(iii) Draw the mechanism for the reaction of propene with hydrogen chloride to produce 2-chloropropane. Include curly arrows, and any relevant dipoles and lone pairs.

(4)



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Examiner Comments

The curly arrow from the double bond to the delta+ H is unclear. Is it crossed out? What is its direction?

The student has used HBr instead of HCl. This will be penalised only once.

There is an H atom missing from the intermediate

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Examiner Tip

If you make so many alterations to your answer that any part of it becomes unclear, draw it out again.

Question 5 (b) (i)

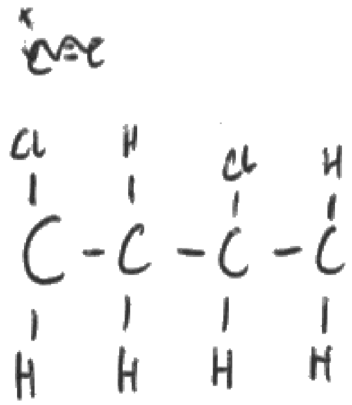
The diagram must show two repeat units and be fully displayed.

The question asked for two repeat units. It is therefore important to show how the two units are connected, and how they would connect to more units.

(b) The halogenoalkane chloroethene is used to make the important polymer poly(chloroethene), PVC.

(i) Draw a **displayed** formula of two repeat units of poly(chloroethene).

(1)



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Examiner Comments

In this example, both end carbon atoms have only three bonds. The bonds to the next units must be shown.

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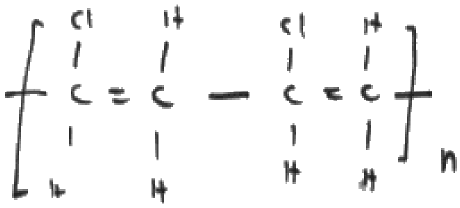
Examiner Tip

Ensure that every carbon atom has 4 bonds.

(b) The halogenoalkane chloroethene is used to make the important polymer poly(chloroethene), PVC.

(i) Draw a **displayed** formula of two repeat units of poly(chloroethene).

(1)



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Examiner Comments

The brackets can be ignored but the inclusion of the double bonds is incorrect.

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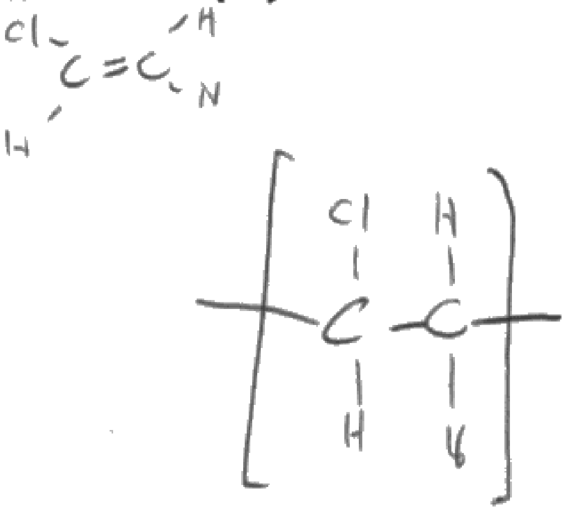
Examiner Tip

There are 5 bonded carbons here. Clearly wrong.

(b) The halogenoalkane chloroethene is used to make the important polymer poly(chloroethene), PVC.

(i) Draw a **displayed** formula of two repeat units of poly(chloroethene).

(1)



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The diagram of the original alkene can be ignored; it will be assumed that it is there as part of the preparation for the correct answer.

The response does not show **two** repeat units so the mark was not awarded.

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Examiner Tip

Even if a '2' had been included as a subscript behind the brackets, the mark would still not have been awarded. Two units must be shown (as required by the question).

Question 5 (b) (ii)

The question was specifically related to PVC. It was not sufficient to give answers that related to the incineration of polymers in general.

M2 was dependent on M1. Thus broad generalisations about acid rain or the effect on the ozone layer did not gain a mark unless connected to chlorinated products.

(ii) Some polymers are disposed of by incineration. Ignoring any economic considerations, explain why incineration is **not** a suitable method for the disposal of poly(chloroethene).

(2)

Because incineration of polymers produces harmful chemicals such as carbon monoxide, sulfurdioxide and Nitroegen oxides. Carbon monoxide is very toxic and sulfur dioxide causes acid rain ~~and~~ as well as nitrogen oxides. These chemicals can also cause smog.

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Examiner Comments

This response typifies generalisations that would apply to the incineration of most polymer materials.

The question is about PVC and it was expected that students would focus on the presence of chlorine and predict the presence of chlorinated products.

Appreciable quantities of chlorine gas are unlikely to be present in the incineration products but were allowed because chlorine may be present in small quantities.

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Examiner Tip

Read the question carefully. The question asks about PVC and your answer should focus on the particular problems associated with the incineration of this polymer. HCl would be a likely product. Avoid chlorine radicals as a product, their lifetime would be very short.

(ii) Some polymers are disposed of by incineration. Ignoring any economic considerations, explain why incineration is **not** a suitable method for the disposal of poly(chloroethene).

(2)

Incineration is not a suitable method for the dispoal of poly(chloroethane) because it produces toxic gases such as hydrogen chloride and also releases greenhouse gases such as carbon dioxide which leads to global warming

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Examiner Comments

This response has identified HCl as a possible product and correctly recognised that it is toxic. The final part of the answer is more generalised and would not, on its own, have scored M2. However, it is not incorrect.

Question 5 (b) (iii)

This question required students to recognise that chloroethane will be a carcinogenic gas at room temperature, and to suggest an appropriate precaution.

Keeping below 260 K is not a reasonable suggestion because many of its reactions would be carried out at higher temperatures. The compound would still be carcinogenic as a liquid.

A 'mask' on its own was an inadequate answer. Many simple face masks are designed to filter out solids; they allow gases to pass through freely.

(iii) Chloroethene has a boiling temperature of 260 K and is known to be carcinogenic. Use these facts to state **one** precaution that chemists should take when using this compound.

(1)

If heating the chloroethene to 260 and above make sure no one is in the room and none of it can escape the room.

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Examiner Comments

It would be difficult to do anything with the chemical if no-one was allowed near it! This is not a reasonable precaution.

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Examiner Tip

Think carefully about precautions. Chemists will usually use a lab coat, gloves and eye protection, so it is unlikely that a question will ask specifically about these three items.

will be released into the air. (Chlorine compounds will be toxic).

(iii) Chloroethene has a boiling temperature of 260 K and is known to be carcinogenic. Use these facts to state **one** precaution that chemists should take when using this compound.

(1)

Should not be touched with bare skin so they should wear a lab coat and gloves and safety goggles.

ResultsPlus
Examiner Comments

These precautions are too generalised and indicate that the student has not thought about the particular requirements of this chemical.

ResultsPlus
Examiner Tip

It is likely that you will need the information given in the question, in this case the information about the boiling point and the carcinogenic nature.

Question 5 (c) (i)

M1: This question required the candidate to discuss why a temperature below 50°C is **not** used. Simply, the rate of reaction will be (too) low. Discussions concerning the increased yield at lower temperatures would favour the use of low temperatures.

M2: Temperatures above 80°C are not used because the yield would be lower for this exothermic reaction. The exothermic nature of the forward reaction is essential to the answer.

Reverse arguments in terms of the endothermic nature of the reverse reaction were also accepted.

Answers relating to the possibility of other products at higher temperatures were rarely seen.

(c) Chloroethene can be manufactured by a two-stage process.

(i) In stage 1, chlorine is reacted with ethene at a temperature between 50 °C and 80 °C

$$Cl_2 + CH_2{=}CH_2 \rightleftharpoons CH_2Cl{-}CH_2Cl \qquad \Delta H = -178\,kJ\,mol^{-1}$$

Give **one** reason why a temperature below 50 °C and **another** reason, apart from costs, why a temperature above 80 °C would not be used for this process.

(2)

Below 50°C the reaction will be happening too slow to meet demands. Above 80°C the equilibrium of the exact reaction will shift to the left in order to counteract the increase, so the yield (of products) will be too low to meet demands again.

ResultsPlus
Examiner Comments

M1 The response correctly identifies the rate as (too) slow below 50°C.

The discussion of temperatures above 80°C is correct as far as it goes, but it does not link the lower yield to the exothermic nature of the forward reaction. M2 was not awarded.

ResultsPlus
Examiner Tip

Any response to a question about a reaction in equilibrium should include the word 'equilibrium' in the answer.

Be careful with the quality of your writing. You may be able to read it but can the examiner? Many people experience a deterioration in the quality of their writing when under exam pressure. Can yours still be read easily?

The quality of the writing in this response is not helpful. The 50^{o}C is reasonably clear but the figure that is assumed to be 80^{o}C looks more like 60^{o}C.

Question 6 (a) (i)

The two marks for this response were awarded independently.

Simple inspection of the organic reactant and the product showed that hydrogen had been added, so M1 should have been easily obtainable.

6 This question is about the synthesis and reactions of butane-1,4-diol.

(a) Butane-1,4-diol can be synthesised from but-2-ene-1,4-diol, by reaction with a reagent, **B**.

but-2-ene-1,4-diol butane-1,4-diol

(i) Identify reagent **B** and state suitable conditions for this reaction.

(2)

Use a nickel catalyst and a high temperature

ResultsPlus
Examiner Comments

The reagent has not been identified.

Since M2 is not dependent on M1, the identification of a nickel catalyst gets M2.

ResultsPlus
Examiner Tip

Although the molecules involved are unfamiliar to the student, simple inspection shows that two hydrogen atoms have been added across the double bond of the starting molecule. It follows that the reagent is probably hydrogen gas, H_2.

Do not be put off by the introduction of unfamiliar molecules. Just look for the functional groups and apply your knowledge as if it were a simple molecule.

Question 6 (a) (iii)

(iii) Name **one** other commercially important product that can be manufactured by this type of reaction with the alkene group.

(1)

Ethene

ResultsPlus
Examiner Comments

Ethene could be reduced to ethane using this reaction. The question asks for the product so ethene is incorrect.

Additionally, ethane is not manufactured commercially by this reaction. As a precursor to other reactions ethene is much too useful to be reduced back to ethane.

Ethane is more economically manufactured during the processing of crude oil.

ResultsPlus
Examiner Tip

Read the question carefully, in this question it is the product that must be identified.

Margarine and (butter substitute) spreads are manufactured commercially using this reaction. Butter itself is not reduced commercially.

Question 6 (b)

This is a longer answer question where marks are awarded for key points and for 'reasoning' which involves the continuity of the answer. Bad chemistry may be penalised in the reasoning.

Some candidates included extensive details of the oxidation of the diol to the dioic acid. This was not required and the question does not ask for this procedure.

*(b) Butane-1,4-diol can be oxidised to form butanedioic acid. The molecular formula of butanedioic acid is $C_4H_6O_4$ and it is a solid at room temperature.

Describe how you would make 250 cm^3 of a solution of butanedioic acid with an accurately known concentration of approximately 0.0500 mol dm^{-3}.
Butanedioic acid is sufficiently soluble in water to achieve this concentration.

[Molar mass of butanedioic acid = 118 g mol^{-1}] concentration = moles / volume **(6)**

You could ~~use~~ measure a specific amount of butanedioic acid using a measuring scale. You need a conical flask with a mark at 250 cm^3. ~~To~~ ~~make~~ ~~a~~ ~~c~~

You need 1.475 g of $C_4H_6O_4$. Accurately try to weigh 1.475g of $C_4H_6O_4$ on the measuring scale. Put the $C_4H_6O_4$ inside the conical flask. You can then fill it with water till it reaches the 250 cm^3 mark making sure you mix the solution.

$118 \times \underline{0.0125} = 1.475\ g$

ResultsPlus
Examiner Comments

Only IP1 is awarded here for specifying, correctly, the mass of acid to be weighed out.

The weighing itself is not awarded a mark (IP2) because there is insufficient weighing procedure detail.

IP3 is not awarded because the water used is not distilled.

There is nothing that could be awarded for IP4, IP5 or IP6.

ResultsPlus
Examiner Tip

Read the question carefully. Do not use your valuable time writing details of something that is not required. This question asks how a standard solution of the acid would be made, not about the oxidation of the diol.

Minor details like the use of **distilled** water are important in this style of question. It is better to include too much detail rather than too little.

Although two pages were provided for the answer, full marks can be scored using relatively few lines.

*(b) Butane-1,4-diol can be oxidised to form butanedioic acid. The molecular formula of butanedioic acid is $C_4H_6O_4$ and it is a solid at room temperature.

Describe how you would make 250 cm^3 of a solution of butanedioic acid with an accurately known concentration of approximately 0.0500 mol dm^{-3}.
Butanedioic acid is sufficiently soluble in water to achieve this concentration.

[Molar mass of butanedioic acid = 118 g mol^{-1}]

(6)

(calculation: $n = \frac{250}{1000} \times 0.05 = 0.0125$ mass = $0.0125 \times 118 = 1.475$g)

Weigh by difference the mass of 1.475g of butanedioic acid powder and empty this into a ~~beaker~~ 250 ~~100~~ cm^3 beaker. Add 50cm^3 of distilled water and stir until all solid is dissolved.
Using a funnel, pour the solution into a 250cm^3 ~~volumetric~~ volumetric flask. Rinse beaker and funnel with distilled water and add rinsings to ~~conical~~ volumetric flask. Top up to 250 cm^3 ~~of distill~~ using distilled water. Put a stopper. Invert to mix.

ResultsPlus
Examiner Comments

IP1 is awarded for the correctly calculated mass.

IP2 is not awarded. 'Weigh by difference' lacks sufficient detail.

IP3 is awarded. The key words are beaker, distilled water and dissolve.

IP4 is awarded. Volumetric flask is mentioned. Here it is also used correctly but for **this** mark scheme, it would be awarded the mark even if used inappropriately.

IP5 is awarded for the addition of washings to the volumetric flask.

IP6 is not awarded. There is no mention of a 'mark' for the topping up procedure. The correct inversion procedure is used to mix the contents of the volumetric flask.

ResultsPlus
Examiner Tip

The omission of minor details, e.g. a description of the weighing procedure and 'topping up to the mark' have cost this response two marks. In other respects, this is a clear, concise account illustrating that extensive writing is not always necessary to score the indicative points.

It was the omission of sufficient detail in the weighing procedure that was the most frequent error.

*(b) Butane-1,4-diol can be oxidised to form butanedioic acid. The molecular formula of butanedioic acid is $C_4H_6O_4$ and it is a solid at room temperature.

Describe how you would make 250 cm³ of a solution of butanedioic acid with an accurately known concentration of approximately 0.0500 mol dm⁻³. Butanedioic acid is sufficiently soluble in water to achieve this concentration.

[Molar mass of butanedioic acid = 118 g mol⁻¹]

(6)

First of all we calculate the mas s we need of the butanedioic acid so:

moles of bútanedioic acid = 0,0500 mol dm⁻³ · 250 · 10⁻³ dm³ = 0,0125 mol

mass ($C_4H_6O_4$) = 0,0125 mol · 118 g mol⁻¹ = = 1,48 g

So we need 1,48 g of $C_4H_6O_2$. We take some ~~solid~~ butanedioic acid and we weight it with a balance until we reached ~~a~~ the wanted mass.

We take take a volumetrice flask and we add the butanedioic acid in it and then we wash the container that held $C_4H_6O_4$ with pure water and put the washings ~~back~~ in the volumetric flask.

~~We put~~ Then we ~~put~~ fill the volumetric flask with pure water until we reach the line on the flask that indicate that we reached 250 cm³.

We put a stopper at the top of the flask and we shake it to mix the ~~put~~ pure water with ~~the~~ the butanedioic acid ~~to~~ ~~bave~~ to have the wanted solution.

ResultsPlus
Examiner Comments

IP1 is awarded. An appropriate mass of the dioic acid has been calculated. Here the mass is expressed to 2 dp but this is acceptable.

IP2 is not awarded. The weighing procedure lacks detail.

IP3 is not awarded. There is no mention of dissolving.

IP4 is awarded for the mention of the volumetric flask.

IP5 is awarded because washings have been added to the volumetric flask.

IP6 is awarded because the procedure includes topping up to the mark and shaking the flask to mix. (In practice, inverting is more effective than shaking.)

ResultsPlus
Examiner Tip

Include as much minor detail as you have time for. Some detail may be extraneous but it is better to include too much rather than too little.

Question 7 (a) (i)

7 This question is about the titration of a weak acid with a strong base.

(a) A standard solution of ethanedioic acid, which is a weak, diprotic acid, can be used to determine the concentration of a sodium hydroxide solution. 25.0 cm^3 of the ethanedioic acid solution, with concentration 3.80 g dm^{-3}, was pipetted into a conical flask. A few drops of indicator solution were added. The ethanedioic acid was titrated with the sodium hydroxide solution which was in the burette. The titration was repeated and the following results were obtained.

[Molar mass of ethanedioic acid = 90.0 g mol^{-1}]

	Titration 1	Titration 2	Titration 3	Titration 4
Final reading / cm^3	18.00	17.60	35.30	27.70
Initial reading / cm^3	0.00	0.00	17.60	10.05
Titre / cm^3	18.00	17.60	17.70	17.65
Titre used to find the mean titre (✓)			✓	✓
			Mean titre / cm^3	17.55

(i) In the appropriate row, tick (✓) those titre values that should be used to find the mean, and use these titres to calculate it.
Write the value of the mean titre in the box provided in the table of results.

(2)

ResultsPlus
Examiner Comments

Only 2 of the 3 appropriate titres have been ticked, so M1 was not awarded.

M2 was still available for the mean of 17.70 and 17.65. In this example, 17.55 is not a correct calculation of the mean for the ticked titres, so M2 was not awarded.

ResultsPlus
Examiner Tip

Titres that are given to 2 d.p. should have a mean to the same number of d.p. In this example, the correct mean would have been 17.68, not 17.675

Question 7 (a) (ii)

More advanced studies would demand a specific indicator for a weak acid/strong base titration. But at this stage, students have probably encountered only phenolphthalein and methyl orange.

Any indicator was allowed but not universal indicator or litmus.

Minor errors in spelling were allowed, (particularly for phenolphthalein).

(ii) Ethanedioic acid is a weak acid. Name a suitable indicator for this titration and state the colour change at the end-point.

(2)

Name of indicator ....

Colour change at the end-point from colourless to pale-pink

ResultsPlus
Examiner Comments

M2 depends on M1. No indicator was suggested therefore no mark can be awarded for a colour change (which, in this example, would be correct for phenolphthalein).

In this example, the titration procedure appears to have been understood sufficiently to give the correct colours of phenolphthalein in acid and at the end point of the titration.

ResultsPlus
Examiner Tip

It is meaningless to give a colour change without naming the indicator.

(ii) Ethanedioic acid is a weak acid. Name a suitable indicator for this titration and state the colour change at the end-point.

(2)

Name of indicator Phenylphthaleine

Colour change at the end-point from Colourless to pink

ResultsPlus
Examiner Comments

This spelling of phenolphthalein is sufficiently incorrect that the mark was not awarded. Phenyl and phenol are different.

However, M2 (for the colour change) was awarded as a near miss with M1.

ResultsPlus
Examiner Tip

Learn how to spell phenolphthalein.

Note that the colour change is to the colour at the end point, **not** the colour in alkaline solution.

Question 7 (a) (iii)

(iii) The equation for the reaction of ethanedioic acid with sodium hydroxide is

$$C_2H_2O_4 + 2NaOH \rightarrow C_2O_4Na_2 + 2H_2O$$

Calculate the concentration of the sodium hydroxide solution, in mol dm^{-3}.
Give your answer to **three** significant figures.

(4)

moles of acid $= 0 \cdot 042 \times \frac{25}{1000}$

$= 1.05 \times 10^{-3}$ moles

$3.80 \text{ g dm}^{-3} = 0.042 \text{ mol dm}^{-3}$

moles of NaOH $= 2.11 \times 10^{-3}$

concentration $= \frac{2.11 \times 10^{-3}}{17.65 \div 1000}$

$= 0.120 \text{ mol dm}^{-3}$

ResultsPlus
Examiner Comments

Some stages of the calculation have been omitted in this answer.

The figure 0.042 is written to only 2 SF but more figures must have been held on the calculator to get a final answer that is correct to 3 SF (as required).

The answer is presented to 3 SF, as stipulated in the question.

The question states that the concentration should be given in mol dm^{-3}. So units are not essential in the final answer (although many students will give them). However, if given, they must be correct.

ResultsPlus
Examiner Tip

It is useful to retain more SF in the intermediate stages of a calculation than you need for the final answer. If more SF are not written down but retained on a calculator, and you get the correct final answer, you may still get full marks. But if the final answer is incorrect, you could lose a mark for rounding early or truncating a figure.

(iii) The equation for the reaction of ethanedioic acid with sodium hydroxide is

25·0cm³

$$C_2H_2O_4 + 2NaOH \rightarrow C_2O_4Na_2 + 2H_2O$$

3·80gdm⁻³

Calculate the concentration of the sodium hydroxide solution, in mol dm^{-3}.
Give your answer to **three** significant figures.

(4)

3·80 ÷ 90 = 0.0422

n = cv

n = 0·0422 × 25/1000

n = 0·5921 ← moles of $C_2H_2O_4$

0.5921 × 2 = 1·184 ← moles of 2NaOH.

ResultsPlus
Examiner Comments

M1 was awarded for the division by 90 (conversion to moles).

M2 is incorrect, the answer is 1.0556 not 0.5921

M3 can be awarded for the x2. There is sufficient to make it clear that this is a conversion from moles of acid to moles of NaOH.

M4 is not awarded. No attempt to convert moles to concentration

ResultsPlus
Examiner Tip

The calculation shows sufficient SF to retain accuracy.

There is an error in calculation of n, (possibly a wrong button on the calculator).

However, the calculation is laid out sufficiently clearly for a TE to be awarded in the last line.

Question 7 (b) (i)

(b) The uncertainty in each burette reading is $\pm 0.05\,cm^3$. The uncertainty in the pipette volume is $\pm 0.06\,cm^3$.

(i) Calculate the percentage uncertainties for titre 4, and the pipette volume.

(2)

$$\frac{\pm 0.05 \times 2}{17.63} \times 100$$

$$= 0.57\%$$

ResultsPlus
Examiner Comments

This calculation is not identified as the burette uncertainty or the pipette uncertainty. It has been left to the examiner to deduce from the figures that this is probably the burette calculation.

The second figure in the answer is probably a 7, so this was given BoD.

There is no calculation of pipette uncertainty.

ResultsPlus
Examiner Tip

It takes only a second or two to label this as the burette (calculation).

Similarly, the 7 in the final answer appears to have been changed from another figure. It takes only a second or so to write is again, clearly.

The +/- in the numerator might be taken for a 1 at first glance. Why not write it more clearly?

(b) The uncertainty in each burette reading is ±0.05 cm^3. The uncertainty in the pipette volume is ±0.06 cm^3.

(i) Calculate the percentage uncertainties for titre 4, and the pipette volume.

(2)

$$\frac{2 \times 0.05}{25} \times 100$$

pipette = 0.45%

$$\frac{2 \times 0.05}{17.65} = 0.567\%$$

ResultsPlus
Examiner Comments

The burette calculation is not identified. The examiner is left to deduce that, since the first calculation is labelled 'pipette', the second is probably the burette calculation.

M1 is awarded for the burette uncertainty.

M2: The pipette uncertainty is incorrect. A pipette is read only once so the uncertainty is not doubled.

ResultsPlus
Examiner Tip

Identify your calculations.

(b) The uncertainty in each burette reading is ±0.05 cm³. The uncertainty in the pipette volume is ±0.06 cm³.

(i) Calculate the percentage uncertainties for titre 4, and the pipette volume.

(2)

titre 4

$\frac{0.05}{17.65} \times 100 \times 2 = 0.56\%$

pipette

$\frac{0.06}{25} \times 100 = 0.24\%$

ResultsPlus
Examiner Comments

Both calculations are clearly identified. The pipette calculation is correct and is awarded 1 mark.

However, the answer for the Titre 4 calculation has been incorrectly rounded. 0.567% rounds to 0.57%, not 0.56%

ResultsPlus
Examiner Tip

Take care with rounding. In **this** question an answer to 1, 2 or 3 SF was acceptable, but when rounding, the rounding must be correct.

For the titre 4 uncertainty, an answer to 1 SF is 0.6%

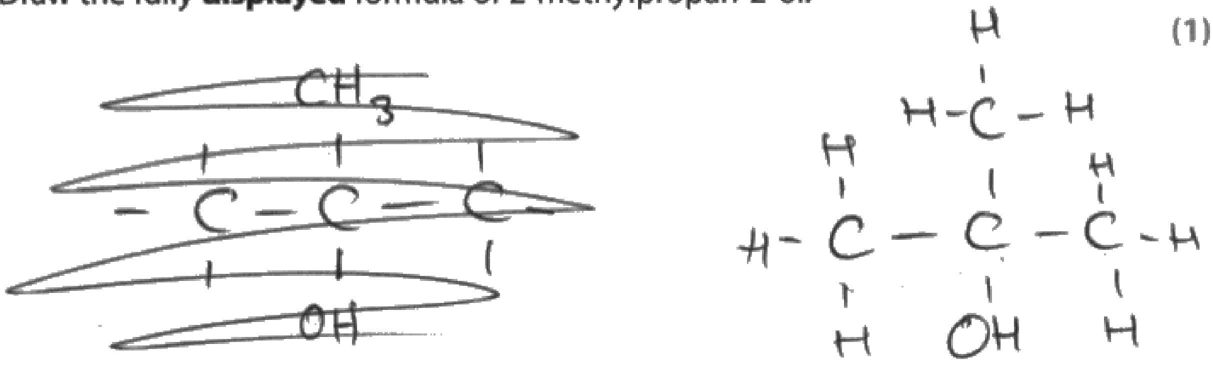
Question 8 (a)

This question tested the ability to draw a fully displayed formula.

8 This question is about 2-methylpropan-2-ol.

(a) Draw the fully **displayed** formula of 2-methylpropan-2-ol.

(1)



ResultsPlus
Examiner Comments

All three methyl groups are fully displayed.

The alcohol group is not displayed but this was allowed **for this paper.**

The bond from the central C atom to the alcohol group is poorly positioned. It should be clearly shown as a C-O bond. However, this was not penalised **in this paper**.

In general, where the OH group is positioned vertically above or below the central carbon, a certain amount of leniency is allowed for the positioning of the C-O bond. If the OH group is written in a horizontal position, more care must be taken. If the bonding to the OH group is drawn as C-H-O or C-HO, the mark will not be awarded.

ResultsPlus
Examiner Tip

If a displayed formula is required, it **must** be displayed. A structural or partially structural formula will not score the mark.

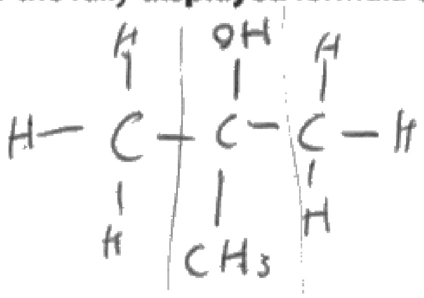
If the formula is an alcohol, it is better to show the bond to the alcohol group as a clear C-O bond and also to show the O-H bond.

For a displayed formula, ensure that alkyl groups, e.g. the methyl groups in this example, are also fully displayed.

8 This question is about 2-methylpropan-2-ol.

(a) Draw the fully **displayed** formula of 2-methylpropan-2-ol.

(1)



C_4H_9OH

ResultsPlus
Examiner Comments

In this example, one of the methyl groups is not displayed. The mark was not awarded.

The bond between the central C atom and the OH group is also poorly positioned (it should go to the O atom, not somewhere between the O and the H). However this was not penalised **in this paper.**

The non-displayed formula at the bottom left would have been ignored (assumed to be working towards the final answer). However, it should have been crossed out (with a single line through) to avoid any confusion.

ResultsPlus
Examiner Tip

For a fully displayed formula, all atoms and bonds should be shown.

Question 8 (b) (i)

This question required application of the basic principles of fragmentation in a mass spectrometer, in an unfamiliar situation.

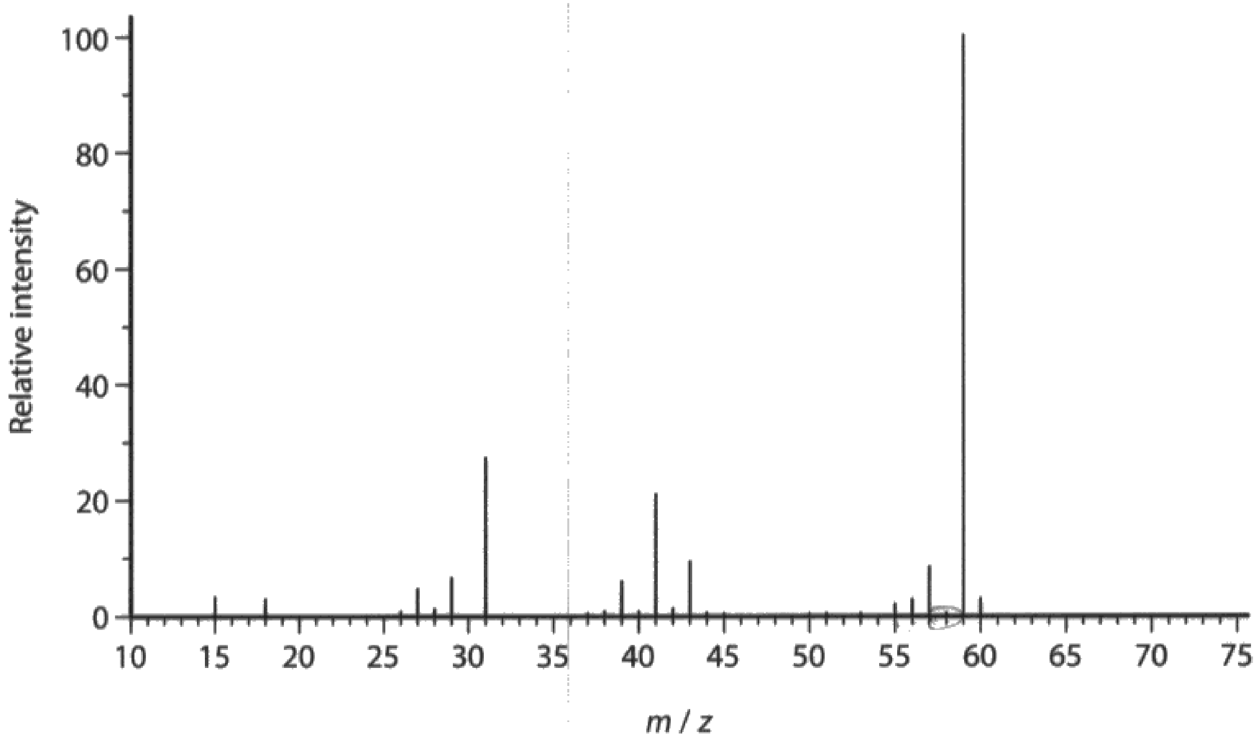
Fragmentation of either the molecule or the molecular ion were acceptable answers.

A good answer would conclude that *all* of the molecules/molecule ions must have fragmented.

Students were informed that there is no molecular ion peak, so arguments based on a very small number of molecular ions were not allowed.

Another response suggested that all molecular ions were 2+, hence halving the m/z ratio. This would be unlikely but showed a better understanding of the workings of the mass spectrometer.

(b) The mass spectrum of 2-methylpropan-2-ol is shown.



(i) The relative molecular mass of 2-methylpropan-2-ol is 74. Give a possible reason why there is no molecular ion peak in the mass spectrum of 2-methylpropan-2-ol.

(1)

There is no isotope of 2-methylpropan present.

ResultsPlus
Examiner Comments

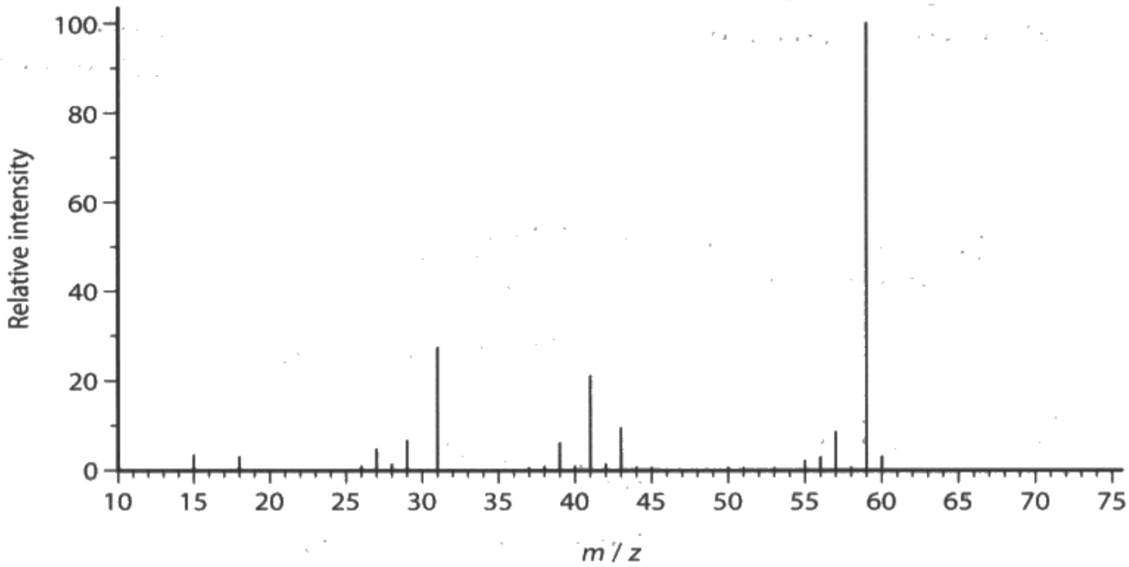
This response appears to confuse isotope analysis with the fragmentation of an organic molecule.

The absence of any peaks around 74 eliminates the possibility of a C13 answer, even if this was what the candidate had in mind.

ResultsPlus
Examiner Tip

The context of a question often gives a clue to the nature of the expected answer. This question is about an organic molecule so it is unlikely that it would include isotopic analysis.

(b) The mass spectrum of 2-methylpropan-2-ol is shown.



(i) The relative molecular mass of 2-methylpropan-2-ol is 74. Give a possible reason why there is no molecular ion peak in the mass spectrum of 2-methylpropan-2-ol.
(1)

The amount of 2-methyl propan - 2 - ol formed is very small. Too small to identify on the mass spectrum.

ResultsPlus
Examiner Comments

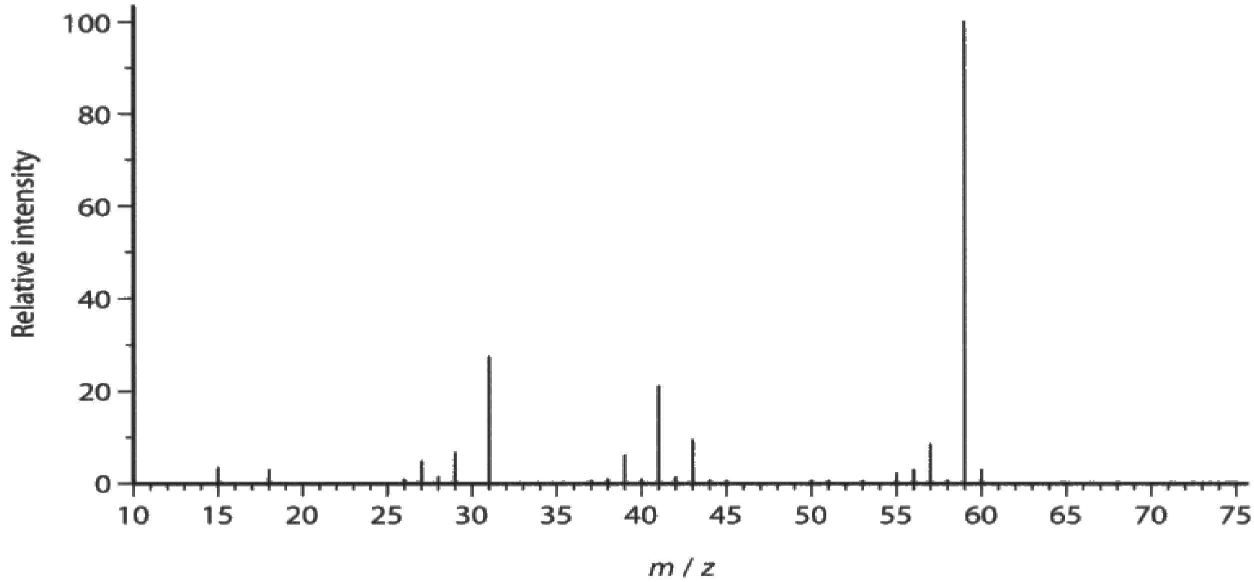
This answer assumes that the peak is there but small. It ignores the information given by the question, that there is no molecular ion peak.

The response also seems to assume that it is the molecule (not the ion) that is responsible for the molecular ion peak, and that the molecule is formed in the mass spectrometer.

ResultsPlus
Examiner Tip

Read the question carefully. In this example, it states that there is no molecular ion peak. So think of reasons why there are no molecular ions.

(b) The mass spectrum of 2-methylpropan-2-ol is shown.



(i) The relative molecular mass of 2-methylpropan-2-ol is 74. Give a possible reason why there is no molecular ion peak in the mass spectrum of 2-methylpropan-2-ol.

(1)

Only fragments of the alcohol were detected and not the whole ~~comp~~ ~~molecule~~ molecule

ResultsPlus
Examiner Comments

This response is almost correct but it still does not answer the question of why there is no molecular ion peak. It tells us that fragments only were detected.

It is not the molecule itself that is detected, it is the molecule ion.

ResultsPlus
Examiner Tip

Ensure that your response answers the question. This example indicates that the student may have known the answer to the question but has failed to communicate adequately.

Take care with the accuracy of your statements. The mass spectrometer detects ions not molecules.

Question 8 (b) (ii)

The question did not specify which particular type of formula was required so any type was acceptable. The positive charge on the ion was an essential requirement.

The majority of students presented their answers in a structural format, indicating that the correct answer had been deduced from fragmentation of the original molecule/ion.

(ii) Write the formula for a species that could be responsible for the peak at $m / z = 59$.
(1)

C = 12
H = 1
O = 16

C×3 = 36
H×6 = 6 } = 59
OH = 17

C_3H_6OH

ResultsPlus
Examiner Comments

This response included a scattering of working that the examiner is required to trawl through.

The formula presented would have been correct if a positive charge had been included. The hard work had been done!

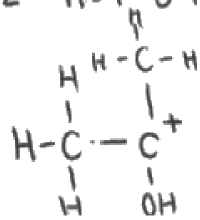
ResultsPlus
Examiner Tip

Mass spectrometers detect **ions**, so it is important to recognise that all the fragments are detected as **positive** ions.

(ii) Write the formula for a species that could be responsible for the peak at $m / z = 59$.

(1)

C = 12 H = 1 O-H = 17



$CH_3(CH_3)(OH)C^+$

ResultsPlus
Examiner Comments

The formula on the right is presented in an unusual and unconventional format. However, the formula is recognisable and the positive charge has been included so the mark is awarded.

Any doubts about the formula on the right are dispelled by the clear (partially) displayed formula (with correct charge) on the left.

ResultsPlus
Examiner Tip

Write structural formulae in a conventional format.

Question 8 (c) (i)

The responses to this question sometimes included a mass of figures followed by a final answer. It was often difficult to assign marks to transferred errors when the final answer was incorrect.

Many answers indicated a mechanical application of the figures for bond formation and bond breaking, and showed little appreciation that bond breaking is an endothermic process while bond formation is exothermic.

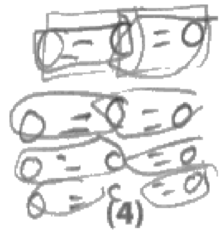
Common errors included the use of 4 C-C bonds and 10 C-H bonds. The bond enthalpies of the C-O and O-H bonds were also frequently omitted.

Very few answers included an energy cycle. A well-drawn energy cycle or the use of Hess's Law equation would have helped to convince the reader that the energy changes were understood.

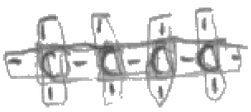
(c) The equation for the complete combustion of 2-methylpropan-2-ol is

$$C_4H_{10}O(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

(i) Using the bond enthalpies shown in the table, calculate a value for the enthalpy change, in kJ mol^{-1}, for the complete combustion of 2-methylpropan-2-ol.



(4)



Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C—H	413
C—O	358
O—H	464
O═O	498
C═O	805

O=O
O=O
O=O
O=O
O=O
O=O

10 × C–H
3 × C–C
1 × O=O
6 × O=O

413 × 10 = 4130
347 × 3 = 1041 +
498 × 1 = 498
498 × 6 = 2988

= 8657

8 × C=O
10 × O–H

8 × 805 = 6440

10 × 464 = 4640

= -11080

+ 8657 + − 11080
= − 2423

ResultsPlus
Examiner Comments

This response typifies many of those seen, but it is also clearer than some. More could have been done to explain the various steps in the calculation.

M1. 10 C-H bonds have been used (instead of the correct number, 9). The bond enthalpy of the C-O bond has been omitted. The bond enthalpy for a O=O bond has been mistakenly used instead of that for the O-H bond.

It would have been helpful if the proposed sum of the bond-breaking enthalpies for 2-methylpropan-2-ol had been shown as a number.

M2. The bond enthalpies for the 6 oxygens have been correctly calculated but it has been left for the examiner to check if this figure has been correctly added to the incorrect M1. It has!

M3. The bond formation enthalpies have been correctly summed and presented with a negative sign showing that this candidate appreciates that bond formation is exothermic.

M4 The mark is awarded for a correct transferred error. The units are not required (stated in the question).

ResultsPlus
Examiner Tip

It is helpful to the examiner if the maths is completed for intermediate stages in a calculation. If all the calculation is left to the end and a mistake is made resulting in an incorrect final answer, the examiner will attempt to find the mistake and award transferred error marks if appropriate. This may only be possible if your working is clear.

(c) The equation for the complete combustion of 2-methylpropan-2-ol is

$$C_4H_{10}O(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

(i) Using the bond enthalpies shown in the table, calculate a value for the enthalpy change, in kJ mol⁻¹, for the complete combustion of 2-methylpropan-2-ol.

(4)

Bond	Mean bond enthalpy / kJ mol⁻¹
C—C	347
C—H	413
C—O	358
O—H	464
O═O	498
C═O	805

$\Delta_c H^\ominus$

$C_4H_{10}O$ l) + $6O_2$ g) → $4CO_2$ (g) + $5H_2O$(l)

(347×4) + (413×10) + 464
= 1388 + 4130 + 464
= 5982
+ (6 × 498) = 2988
= 8970

(4×(358+498))
+ 5×
3424

5×464
= 2320

2988 − 3424 = −436 kJmol⁻¹

5982 − 3424
= −2558 kJmol⁻¹

ResultsPlus
Examiner Comments

Only M2 is awarded in this example.

M1 is not awarded. There are several mistakes; 4 C-C bonds, 10 C-H bonds and the bond enthalpy for the C-O bond has been omitted.

M2. However, these (incorrect) bonds have been summed which makes it easy for the examiner to check that the bond enthalpies for the oxygen have been calculated and added correctly. A TE mark is awarded.

M3 is not awarded. The bond enthalpies for the bond-making process have been calculated incorrectly, although they have correctly been given a negative sign.

M4 is not awarded. The figures used are not the sums of the bond enthalpies calculated earlier in the calculation so there is no possibility of a TE.

ResultsPlus
Examiner Tip

It is useful to complete calculations at each stage in a lengthy calculation. This makes it easier for the examiner to identify mistakes and award TE marks where appropriate.

(c) The equation for the complete combustion of 2-methylpropan-2-ol is

$$C_4H_{10}O(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

(i) Using the bond enthalpies shown in the table, calculate a value for the enthalpy change, in kJ mol⁻¹, for the complete combustion of 2-methylpropan-2-ol.

(4)

Bond	Mean bond enthalpy / kJ mol^{-1}
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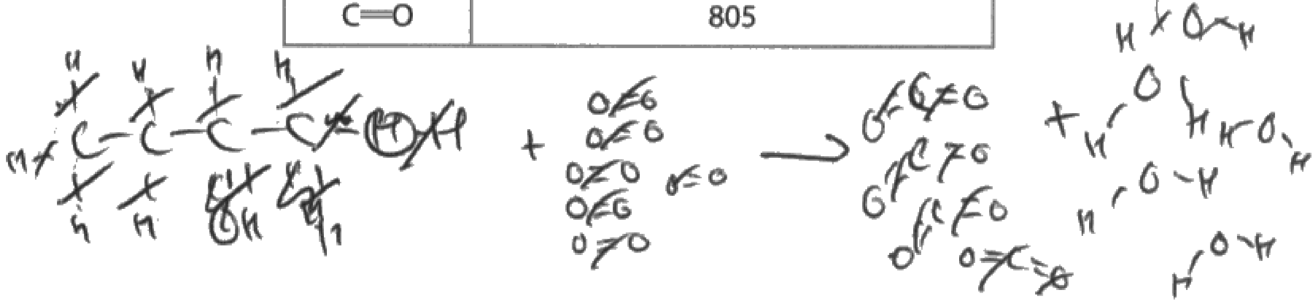

Bond breaking

9 x C-H = 3717

4 x C-C = 1388

1 x C-O = 358

1 x O-H = 464

6 x 498 = ~~2988~~

55 35

Bond making

8 x 805 = 6440

10 x 464 = 4640

-11 080

5535 - 11080 = -5545 kJmol

ResultsPlus
Examiner Comments

M1 is not awarded because 4 C-C bonds have been used.

M2. The bond enthalpies of the alcohol have not been summed separately. This makes it difficult to decide where the mistake lies. The sum of the first 4 numbers presented + 2988 does not equal 5535 so M2 cannot be awarded. If the first 4 numbers had been summed, it might have been possible to award a TE for M2. As written, it is impossible to know if the error is the in summation of the first 4 numbers or in the subsequent addition of the 2988.

M3 is awarded for a correct summation of the bonds formed. This has been correctly given a negative sign.

M4 is awarded for a transferred error. The figure 5535 is incorrect but the correct mathematical operation has been completed. Units were not required (specified by the question) but, if given, must be correct. Here the -1 of mol^{-1} is almost lost in the margin line on the question paper.

ResultsPlus
Examiner Tip

Explain what you are doing in calculations.

Be careful with units. If units are specified by the question, you must give the numerical answer in those units. It is not essential to write the units. If you choose to include the units, they must be correct.

If units are not specified by the question, it is essential that you give the correct units for your numerical answer.

Ensure your answer is within the designated area on the paper. There is a danger with writing answers that extend beyond the designated area for the response:

(i) It is possible that the examiner may not realise that there is more work elsewhere on the paper.

(ii) If part of the answer is written in the area of the paper trimmed off during scanning, the work may be lost irretrievably.

Question 8 (c) (ii)

M1 and M2 were marked independently.

(ii) 2-methylpropan-2-ol burns in air with a smoky flame. Explain how burning with a smoky flame affects the value of the experimentally determined enthalpy change of combustion.

(2)

Smoky flame means incomplete combustion. This means the experimental value is less than the actual value because energy is lost to producing other products.

ResultsPlus
Examiner Comments

M1 is awarded for the recognition of incomplete combustion.

M2. The 'value is less' is ambiguous.

ResultsPlus
Examiner Tip

Be clear about exothermic and endothermic enthalpy changes. To say that a negative number is lower does not make it clear if the number is more negative or less negative.

For an exothermic reaction, it is clearer to say that the number is more/less exothermic, or, more/less negative. Similar considerations apply for endothermic changes.

(ii) 2-methylpropan-2-ol burns in air with a smoky flame. Explain how burning with a smoky flame affects the value of the experimentally determined enthalpy change of combustion.

(2)

the actual value will be less [less negative] since other products are formed meaning it doesn't perform complete combustion

ResultsPlus
Examiner Comments

This response can be awarded both marks.

M1 is awarded because 'doesn't perform complete combustion' is equivalent to incomplete combustion.

M2 is awarded for the 'less negative' statement. Just 'less', on its own, would not have been awarded the mark.

ResultsPlus
Examiner Tip

Try to use the same words that you think will be in the Mark Scheme. In this example, 'doesn't perform complete combustion' could have been witten more concisely as 'incomplete combustion'.

Question 8 (c) (iii)

The discrepancy in this instance is explained by the difference in the states of water and 2-methylpropan-2-ol. Bond enthalpies refer to the gaseous state, whereas the equation shows water and 2-methylpropan-2-ol as liquids. There is a significant enthalpy change associated with changes of state, much larger than differences caused by the use of mean bond enthalpies.

will be less exothermic.

(iii) A Data Book value for the enthalpy change of combustion of 2-methylpropan-2-ol is -2643.8 kJ mol^{-1}. Give the main reason for the difference between this value and your answer to part 8(c)(i).

(1)

Bond enthalpies are for molecules in ~~g~~ a gaseous state however both water and 2-methylpropan-2-ol are liquids in this reaction.

ResultsPlus
Examiner Comments

This is a very clear answer, correctly stating that (Data Book) bond enthalpies refer to the gaseous state, whereas the equation, as written, includes water and 2-methylpropan-2-ol in the liquid state.

ResultsPlus
Examiner Tip

Sometimes the discrepancies can be explained by the fact that bond enthalpies are usually means. But always check the states in any situation where you have used bond enthalpies. The enthalpy changes involved in changes of state will be much greater than can be explained by the use of mean values.

(iii) A Data Book value for the enthalpy change of combustion of 2-methylpropan-2-ol is −2643.8 kJ mol^{-1}. Give the main reason for the difference between this value and your answer to part 8(c)(i).

(1)

In 8(c)(i) the mean bond enthalpies were used, and bond enthalpies differ between different chemical environments.

ResultsPlus
Examiner Comments

An example of a typical answer involving mean bond enthalpies. This is true, but the **main** reason for the difference is associated with the enthaply change involved in a change of state.

ResultsPlus
Examiner Tip

The difference between mean bond enthalpies and those specific to particular compounds can cause a small difference between a data book value and one calculated from mean bond enthalpies.

However, if changes of state are involved, the difference in the enthalpy changes is likely to be much larger.

Paper Summary

Based on the performance on this paper, students are offered the following advice:

- It is recommended that students should first attempt those questions where they feel most confident, for example, those who are confident with numbers might attempt the calculations first. If you can't answer a question, read it through then mark it in some way and come back to it later. The paper is designed to take the allocated time for those who are fully conversant with the course content. If you spend a long time struggling with a question that you can't do, you might run out of time.

- In many longer answers, particularly calculations, it is essential to show the intermediate stages. There will be marks available for transferred errors; if an error is made early in a calculation, transferred error marks can be awarded provided that the rest of the calculation can be followed. Ideally, students will include sufficient explanation for examiners to easily understand the logic. A scattering of numbers is almost impossible to follow and may gain little credit.

- Students should read through each question carefully and identify the key points. There is no credit for writing an extensive answer to a question that has not been asked. Furthermore, this will eat into time that should be spent on other parts of the paper. This was typified by some of the responses to Q6(b) in this paper; some students wrote extensively about the oxidation of the diol to an acid, but this was not required by the question.

- The response area in the answer booklet has been designed to be adequate for the expected answer. It is unlikely that students will need more than the designated space. However, should the need arise to continue the answer elsewhere, it is useful to put a note to that effect in the designated area on the answer space.

- Do not write outside the delineated box on the paper. There is a chance that any information written here will be lost and will not therefore be credited.

- Where you decide to change an answer, write the new answer first before you cross out the old answer. If an answer has to be crossed out, put a single line through it so that it is still legible. Do not scribble heavily though it. If an answer is crossed out but not replaced, the examiners will attempt to read the crossed out work

Grade Boundaries

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