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Examiners' Report
June 2015

IAL Chemistry WCH04 01

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June 2015

Publications Code IA041109

Introduction

This was the fourth session of the International Advanced Level Chemistry Unit 4 paper. The specification and style of examination paper are exactly the same as the 6CH04 paper, so the candidates had plenty of opportunity to work through past papers to develop their examination technique.

Successful candidates:

- read the questions carefully and addressed all parts of the question in their answer;
- used scientific terminology correctly;
- completed calculations correctly;
- gave concise but detailed explanations where required;
- understood the mechanism for the reaction between 1-bromopropane and hydroxide ions;
- used the information given in the question and thought about the chemistry involved;
- wrote balanced equations;
- selected correct data from the Data Booklet;
- checked their work, particularly in calculations, to avoid careless errors such as missing or incorrect signs or units.

Less successful candidates:

- did not read the questions carefully and assumed the answer required was the same as in a past paper;
- made careless errors in calculations and did not think about the chemistry involved to realise that their answer could not be correct;
- did not express their understanding clearly when explaining concepts;
- did not use all the information given in the questions to help them in their answers;
- did not write balanced equations;
- did not understand the use of curly arrows and a transition state in an organic mechanism;
- were unable to select correct data from the Data Booklet.

The majority of candidates were proficient in carrying out calculations and just made an occasional careless slip. In future, candidates need to concentrate on expressing their ideas clearly and concisely when explaining chemical concepts.

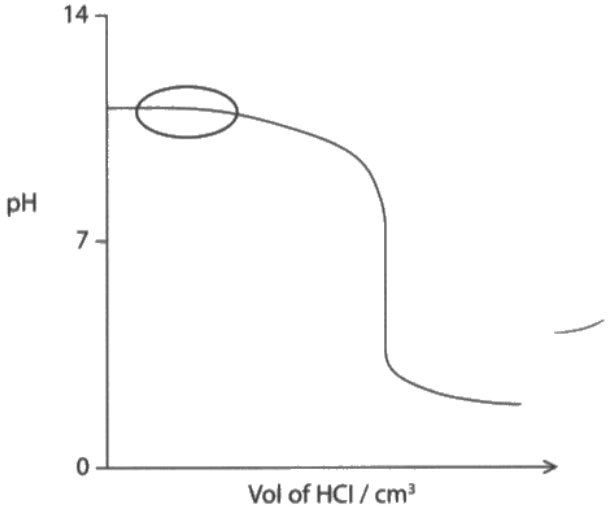
Question 13 (a) (i)

Many candidates realised that a buffer solution was present in the ringed region on the titration curve. However, many just wrote a generic definition of a buffer solution and did not explain that the added H^+ ions were reacting with ammonia in the particular solution in the question. A few candidates assumed that the buffer solution was formed from the more usual weak acid and conjugate base that they have studied. Although ionic equations were not required, they would have helped some candidates to score an extra mark or two.

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

13 A student carried out a titration by adding 0.0540 mol dm^{-3} hydrochloric acid to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution. A sketch graph of pH against volume of hydrochloric acid added is shown below.



(a) *(i) Name the type of solution formed in the region ringed on the sketch graph and explain its chemical behaviour.

(3)

It is a buffer solution. It resists any small change in pH as there is a reservoir of the acid and base to replenish the lost H^+ ions

ResultsPlus
Examiner Comments

This response scored 1 mark for identifying a buffer solution.

The candidate wrote the general definition of a buffer solution but this did not score any marks here as they should have applied it to this particular buffer solution involving ammonia and ammonium ions.

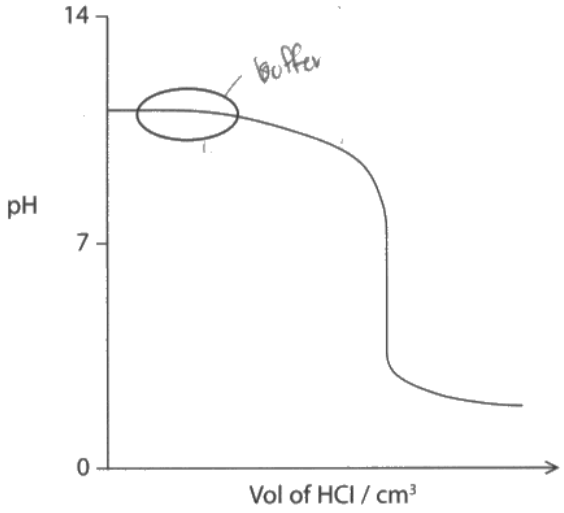
ResultsPlus
Examiner Tip

When you are given a specific example of a reaction, always write about that in your answer rather than giving a general description of the type of reaction.

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

13 A student carried out a titration by adding 0.0540 mol dm^{-3} hydrochloric acid (strong acid) to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution (weak alkali). A sketch graph of pH against volume of hydrochloric acid added is shown below.



(a) *(i) Name the type of solution formed in the region ringed on the sketch graph and explain its chemical behaviour.

(3)

The solution formed is buffer solution.

The buffer solution formed is alkali buffer which ~~resists~~ changes of pH from weak alkali and conjugate acid, ~~ammonia~~ it resists changes of pH of solution when small amount of acid is added into its. As it ~~can~~ reacts, with acid, its concentration remains unchanged and resists change in pH.

ResultsPlus

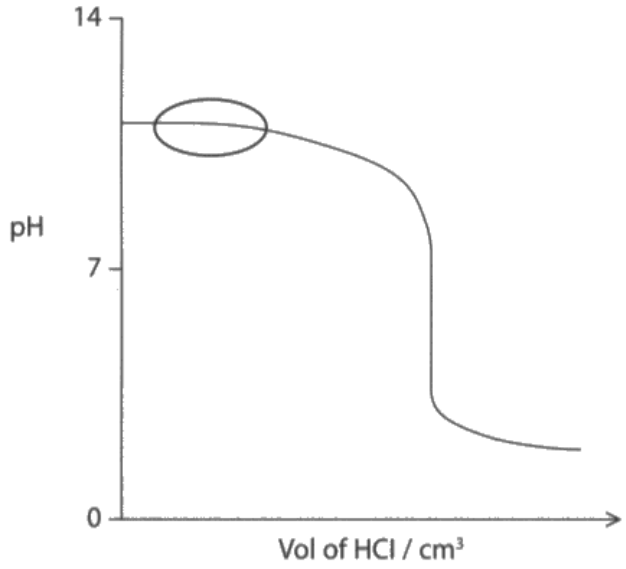
Examiner Comments

This answer scored 2 marks. The candidate has identified that a buffer solution is present and that it consists of a weak alkali with its conjugate acid. However, they have not explained why the addition of more acid causes little change in the pH.

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

13 A student carried out a titration by adding 0.0540 mol dm^{-3} hydrochloric acid to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution. A sketch graph of pH against volume of hydrochloric acid added is shown below.



(a) *(i) Name the type of solution formed in the region ringed on the sketch graph and explain its chemical behaviour.

(3)

Alkali-Buffer solution is formed. When NH_3 (weak base) reacts with HCl (strong acid), NH_3 then forms a strong conjugate acid. This produces a reservoir of conjugate acid and NH_3. This resists change in pH by large amounts if Acid or alkali is added in small amounts. NH_3 reacts with acid, which alkali reacts conjugate acid reacts base. (NH_4^+)

ResultsPlus
Examiner Comments

This is a good answer that scored all 3 marks.

ResultsPlus
Examiner Tip

Always write about the particular reaction in the question, as in this example.

Question 13 (a) (ii)

The majority of candidates scored 1 mark for identifying that ammonium ions are present at the equivalence point or for stating that this is a reaction between a strong acid and a weak alkali. Far fewer candidates realised that the ammonium ions react with water to produce H^+ ions that make the solution acidic. Full marks were awarded for the correct ionic equation. A few candidates were unable to write the correct formulae for ammonia or ammonium ions.

*(ii) Explain why the pH at the equivalence point of this titration is less than 7. Include an ionic equation in your answer.

(3)

~~$NH_3 + H^+ \longrightarrow NH_4^+$~~

$NH_3 + H^+ \rightleftharpoons NH_4^+$

$HCl \longrightarrow H^+ + Cl^-$

~~#~~ Hydrochloric acid fully ionizes in the solution to give H^+.

H^+ is accepted by weak base, NH_3 to form NH_4^+.

NH_3 is ~~slightly~~ ionized partially in the solution.

ResultsPlus
Examiner Comments

This candidate scored 1 mark for identifying that ammonium ions are present at the equivalence point.

ResultsPlus
Examiner Tip

Ammonium reacts with water to form H_3O^+ ions and these make the solution acidic. This could be shown in an ionic equation.

*(ii) Explain why the pH at the equivalence point of this titration is less than 7. Include an ionic equation in your answer.

(3)

All of the ammonia is converted to its conjugate acid, NH_4Cl which in aqueous conditions dissociates as such:

$NH_4^+(aq) \rightarrow NH_3(aq) + H^+$

to donate protons, hence decreasing pH of the solution (ell than 7.

ResultsPlus
Examiner Comments

This response scored 2 marks as the ammonium ions have been identified and an ionic equation showing the formation of H^+ ions has been given. To score the third mark, the candidate would need to mention that the ammonium ions react with water.

*(ii) Explain why the pH at the equivalence point of this titration is less than 7. Include an ionic equation in your answer.

(3)

$HCl + NH_3 \rightarrow NH_4Cl + H_2O$

$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

Since more of H_3O^+ ions are produced the pH is less than 7.

ResultsPlus
Examiner Comments

The first equation shows that ammonium chloride is formed at the equivalence point. It is not balanced, but that does not matter in this response as this candidate scored 3 marks for the ionic equation between ammonium ions and water.

ResultsPlus
Examiner Tip

Learn why some salt solutions are not neutral.

Question 13 (a) (iii)

Many candidates completed this calculation correctly and scored 4 marks. Most students received some credit for some correct work. A few candidates worked out the volume of acid used and then the moles of excess acid. Common incorrect answers included not converting the moles of excess acid into a concentration, just calculating the moles of acid used and converting that to pH and just calculating the pH of the original acid. All of these methods received some credit.

(iii) By considering the amount of excess acid remaining, calculate the pH of the solution formed when 40.0 cm^3 of 0.0540 mol dm^{-3} hydrochloric acid has been added to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution.

(4)

$K_a = \frac{[Cl^-][NH_4Cl^+]}{[HCl][NH_3]}$

moles of HCl = $0.0540 \times \frac{40}{1000}$

= 2.16×10^{-3}

moles of $NH_{3(aq)}$ = $\frac{25}{1000} \times 0.024$

= 6×10^{-4}

~~$K_a = [Cl^-][NH_4Cl^+]$~~

ResultsPlus

Examiner Comments

This candidate was awarded 1 mark for calculating the initial concentrations of ammonia and hydrochloric acid.

ResultsPlus

Examiner Tip

Even if you cannot complete a calculation, at least start it using the information given in the question and you will receive some credit.

(iii) By considering the amount of excess acid remaining, calculate the pH of the solution formed when 40.0 cm^3 of 0.0540 mol dm^{-3} hydrochloric acid has been added to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution.

(4)

~~excess acid = 40 − 25 = 15.0 cm^3~~

~~Cancels with Cl^- = 25.0 cm^3~~

mol of HCl = $\frac{40.0 \times 0.0540}{1000} = 2.16 \times 10^{-3}$ mol

mol of NH_3 = $\frac{25.0 \times 0.0240}{1000} = 6 \times 10^{-4}$ mol

excess mol of HCl = $2.16 \times 10^{-3} - 6 \times 10^{-4}$

= 1.56×10^{-3} mol

$[H^+]$ (in 1 dm^3) = $\frac{1.56 \times 10^{-3}}{65.0} = 2.4 \times 10^{-5}$ mol/dm^3

pH = $-\log [2.4 \times 10^{-5}]$

= 4.6

ResultsPlus

Examiner Comments

This response scored 3 marks.

The candidate has calculated the initial moles of ammonia and hydrochloric acid for the first mark. The second mark was awarded for calculating the moles of excess hydrochloric acid. The candidate has tried to calculate the new concentration of H^+ ions but has forgotten to multiply their fraction by 1000, so they have lost the third mark. However, they have been given the fourth mark for calculating pH from their concentration of H^+ ions.

(iii) By considering the amount of excess acid remaining, calculate the pH of the solution formed when 40.0 cm^3 of 0.0540 mol dm^{-3} hydrochloric acid has been added to 25.0 cm^3 of 0.0240 mol dm^{-3} ammonia solution.

(4)

mol of HCl added = $\frac{40}{1000} \times 0.054 = 2.16 \times 10^{-3}$ mol

mol of NH_3 = $\frac{25 \times 0.024}{1000} = 6 \times 10^{-4}$ mol

excess acid = $(2.16 \times 10^{-3}) - (6 \times 10^{-4})$

$= 1.56 \times 10^{-3}$ mol

total concentration = $\frac{65}{1000}$ dm^3

$\frac{1.56 \times 10^{-3} \text{ mol}}{0.065} = 0.024$ mol dm^{-3}

pH = $-\log(0.024) = 1.62$

ResultsPlus
Examiner Comments

This is a good example of a response that scored 4 marks. The candidate has explained their working clearly, so if they had made a slip, they could still have been awarded some marks.

ResultsPlus
Examiner Tip

Always show your working in calculations.

Question 13 (b)

The majority of candidates scored 2 marks for showing that the pH of water is 6.13 at 373 K, with just a small number who omitted the second step. The second part of the question proved to be much more challenging for many students as they just looked at the pH value, saw that it was less than 7 so deduced that water is acidic. If they had looked carefully at their calculation in (b)(i), they would have seen that they had assumed that the concentrations of H^+ and OH^- ions are equal, so the solution is still neutral. It was very surprising to see that a small number of students thought that water was alkaline.

(b) (i) Show, using the data below, that the pH of water at 373 K is 6.13.

- $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
- $K_w = 5.50 \times 10^{-13}$ mol^2 dm^{-6} at 373 K

(2)

$K_w = [H^+][OH^-]$ $\quad [H^+] = [OH^-]$

$\therefore K_w = [H^+]^2$

$[H] = \sqrt{5.5 \times 10^{-13}} = 6.129$

(ii) At 373 K, is water neutral, acidic or alkaline? Explain your answer.

(2)

It is acidic since there are more H^+.

It is acidic as the pH is below 7.

There are slightly more H^+ ions than OH^- in the water.

ResultsPlus
Examiner Comments

This answer scored 1 mark for (b)(i).

The candidate has shown part of the calculation for the pH of water, but has omitted to show that it is necessary to use pH = -log[H^+], so the second mark was not awarded.

Water is not acidic so no marks were awarded for (b)(ii).

ResultsPlus
Examiner Tip

In questions that involve proving an answer, it is essential to show every step of your working.

Water is always neutral as [H^+] = [OH^-].

However, the value of the pH of water does change as the temperature changes as K_w changes and the concentrations of the ions changes.

(b) (i) Show, using the data below, that the pH of water at 373 K is 6.13.

- $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
- $K_w = 5.50 \times 10^{-13}$ mol^2 dm^{-6} at 373 K

(2)

$K_w = [H^+][OH^-]$

$5.50 \times 10^{-13} = [H^+][OH^-]$

concentration of $[OH^-] = 7.42 \times 10^{-7}$

$\frac{5.5 \times 10^{-13}}{7.42 \times 10^{-7}} = [H^+]$

$[H^+] = 7.413 \times 10^{-7}$

$pH = -\log[H^+] = -\log[7.413 \times 10^{-7}] = 6.13$

(ii) At 373 K, is water neutral, acidic or alkaline? Explain your answer.

(2)

Neutral, as the Kw increase to keep it constant the pH and pOH both increase so the effects of each would cancel out. So water remains Neutral at 373k.

ResultsPlus
Examiner Comments

This candidate scored 2 marks for (b)(i) as they have shown both steps in the calculation of the pH of water.

In (b)(ii), they scored 1 mark for recognising that the water is neutral, but there is not enough explanation for the second mark.

(b) (i) Show, using the data below, that the pH of water at 373 K is 6.13.

- $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
- $K_w = 5.50 \times 10^{-13}$ mol^2 dm^{-6} at 373 K

(2)

$K_w = [H^+][OH^-]$

$5.50 \times 10^{-13} = x^2$

$x = 7.42 \times 10^{-7}$

$x = [H^+] = [OH^-]$

$pH = -\log [H^+]$

$pH = -\log(7.42 \times 10^{-7})$

$pH = 6.13$

(ii) At 373 K, is water neutral, acidic or alkaline? Explain your answer.

(2)

Water is neutral because the concentration of H^+ ions is equal to the concentration of OH^- ions.

ResultsPlus

Examiner Comments

This is a good answer that scored 2 marks for (b)(i) and 2 marks for (b)(ii). The candidate has used the information from (b)(i) to deduce that water is neutral.

Question 14 (a)

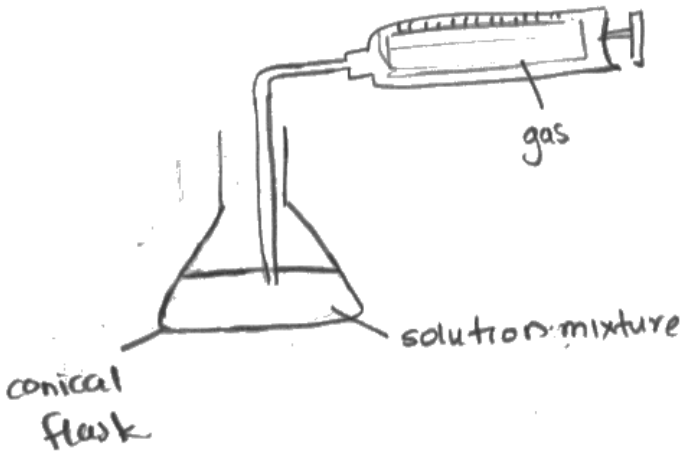
The majority of candidates were able to describe a suitable method to determine the rate of reaction. Most of them collected the gas in a gas syringe or an upturned measuring cylinder over water, but a few did describe measuring mass loss. A few candidates tried to collect the gas at the same time as measuring the mass. There were a few poor diagrams of apparatus that would not work and these did lose a mark, for example, delivery tubes not ending under the upturned measuring cyliner or no bung on the flask.

14 The kinetics of the reaction below was investigated in a series of experiments.

$$\mathbf{A} + \mathbf{B} \xrightarrow{\text{catalyst } \mathbf{X}} \mathbf{C} + \mathbf{D} \quad \Delta H \text{ is positive}$$

(a) Compound **C** is a gas, whereas compounds **A**, **B** and **D** are in solution. Outline a method that could be used to investigate the rate of the reaction. You may wish to draw a diagram.

(3)



Use a syringe to find the volume of the gas and the rate of reaction. Take a ~~sample~~ solution of ~~compound~~ A in a flasks and add ~~compou~~ solution B into it. Then the gas will be collected in the syringe.

ResultsPlus
Examiner Comments

This response scored 1 mark for the gas syringe. This apparatus would not work as there is no bung on the flask so the gas would escape. The delivery tube is also in the solution in the flask so the gas would not get through it, even if there was a bung. The candidate has mentioned measuring the volume of gas but not time.

ResultsPlus
Examiner Tip

Check that the apparatus in your diagrams would work.

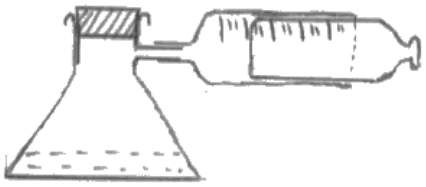
14 The kinetics of the reaction below was investigated in a series of experiments.

$$\mathbf{A} + \mathbf{B} \xrightarrow{\text{catalyst } \mathbf{X}} \mathbf{C} + \mathbf{D} \quad \Delta H \text{ is positive}$$

(a) Compound **C** is a gas, whereas compounds **A**, **B** and **D** are in solution. Outline a method that could be used to investigate the rate of the reaction. You may wish to draw a diagram.

(3)

Collecting volume of gas in gas tube



Because one of the products is gas. We can ~~use~~ collect volume of gas to know ~~to~~ rate of reaction. Known amounts of reactants added and volume collected is noted. Repeat a couple of times and then calculate rate of reaction from known values.

ResultsPlus
Examiner Comments

This candidate has drawn an acceptable diagram and scored 2 marks. They have mentioned that they will measure the volume of gas but this is not sufficient. The question is about rate of reaction so the time must be measured as well.

ResultsPlus
Examiner Tip

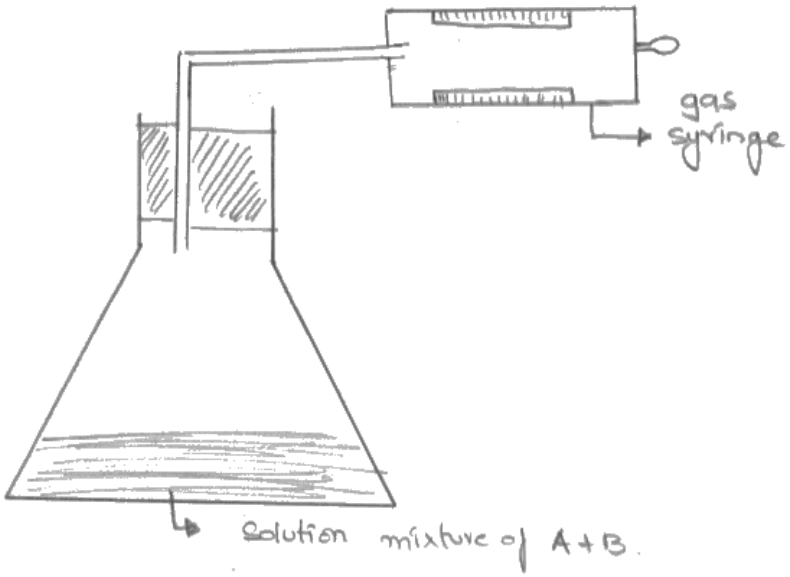
When describing an experiment, check to make sure that you have mentioned all the measurements that need to be taken.

14 The kinetics of the reaction below was investigated in a series of experiments.

$$A_{(aq)} + B_{(aq)} \xrightarrow{\text{catalyst } X} C_{(g)} + D_{(aq)} \quad \Delta H \text{ is positive}$$ endo

(a) Compound **C** is a gas, whereas compounds **A**, **B** and **D** are in solution. Outline a method that could be used to investigate the rate of the reaction. You may wish to draw a diagram.

(3)



Compound A and B is placed in a flask. The flask should be connected to a gas syringe (as shown). The volume of gas released should be recorded at regular time intervals. After attaining sufficient values of the volume of gas collected at regular time intervals a graph of volume of gas C against time should be plotted. ~~The gradient of the~~ The shape of the graph obtained from the result would tells us about the rate of reaction.

ResultsPlus
Examiner Comments

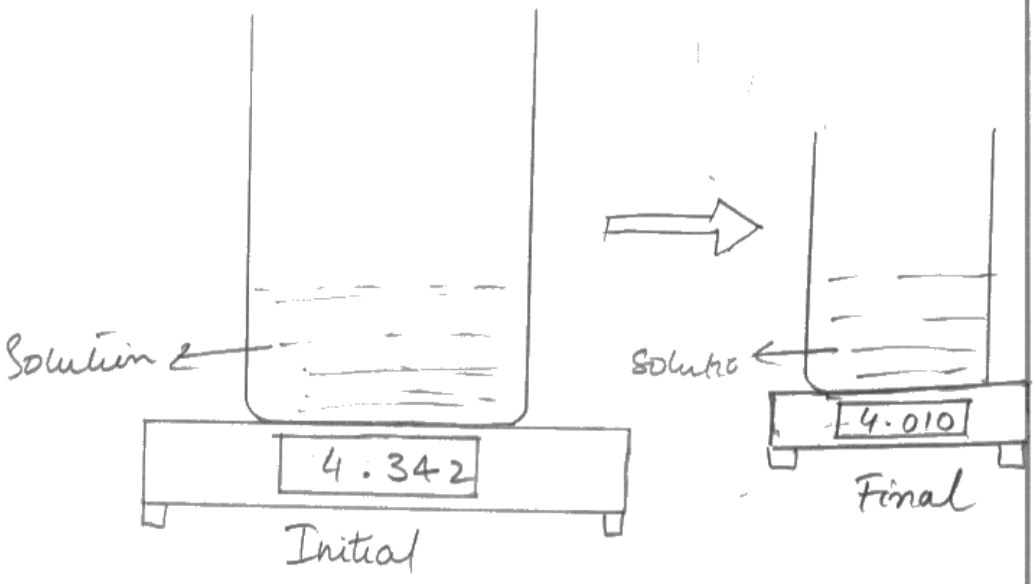
This is a good answer that scored 3 marks. The diagram shows apparatus that will work and both measurements have been stated.

14 The kinetics of the reaction below was investigated in a series of experiments.

$$\mathbf{A} + \mathbf{B} \xrightarrow{\text{catalyst } \mathbf{X}} \mathbf{C} + \mathbf{D} \quad \Delta H \text{ is positive}$$

(a) Compound **C** is a gas, whereas compounds **A**, **B** and **D** are in solution. Outline a method that could be used to investigate the rate of the reaction. You may wish to draw a diagram.

(3)



→ You could measure how rapidly or slowly the change in mass is occuring. If the mass decreases rapidly then the rate of reaction is fast. As C is a gas, and a product the mass has to decrease.

→ Measure the time it takes for the mass to reduce to a certain extent, eg, measure the time for every 0.05 g decrease in mass. Eventually the time will keep on increasing and at one time the mass will stop decreasing.

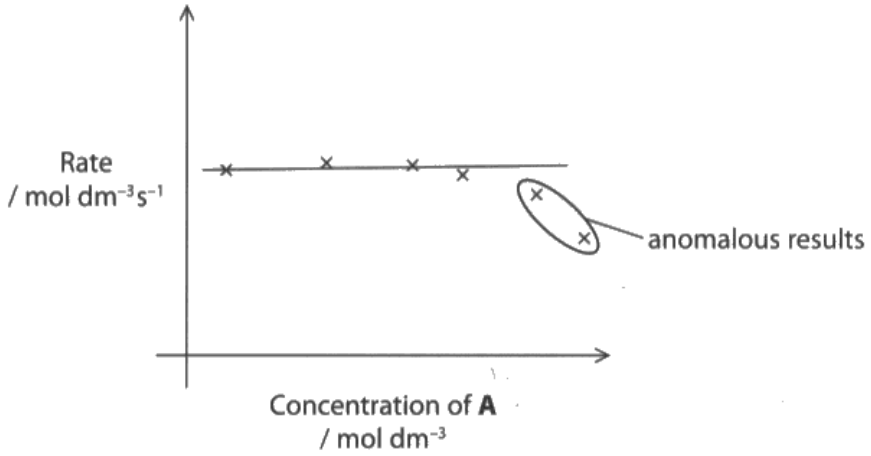
ResultsPlus
Examiner Comments

This is an alternative method for determining the rate of this reaction. This response also scored 3 marks.

Question 14 (b) (i)

This item was poorly answered as many candidates wrote general answers about experimental error which they were told not to include, rather than writing specifically about this reaction. Most candidates failed to recognise that the lower results were at higher concentrations of **A**. They could have written about the reaction being endothermic, the catalyst active sites being blocked or the greater loss of gas before the bung was placed in the flask at higher concentrations.

(b) The rate of the reaction was measured at several different initial concentrations of **A** in the presence of a large excess of compound **B** and a constant amount of catalyst **X**, to find the order of reaction with respect to **A**. The results are shown on the graph below.



(i) Suggest an explanation, other than experimental error, for the two anomalous results ringed.

(2)

The result was not accurate.
Instruments are poor.

ResultsPlus
Examiner Comments

This is an example of a vague answer that did not score any marks. These are results of the same method carried out but with different concentrations of **A** so you can assume the same measuring instruments are used in each experiment.

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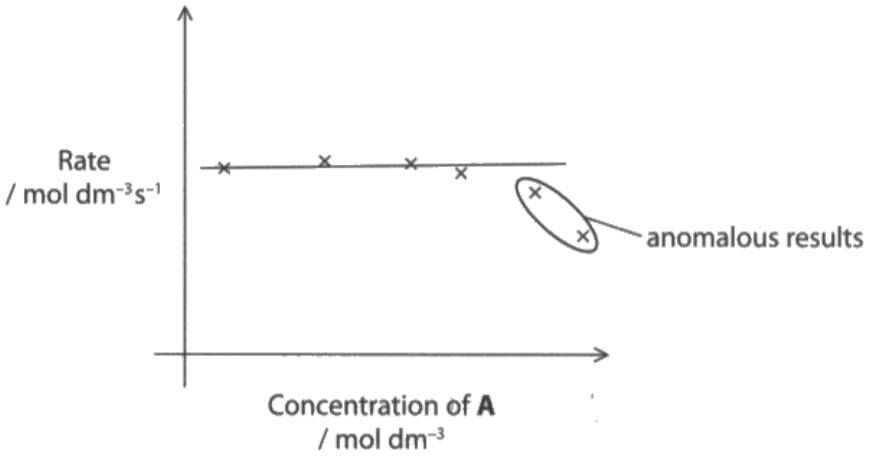
Examiner Tip

Try to give answers that are specifically related to the question. In this question, the anomalous results occur when there is a high concentration of **A** so try to think what effect this high concentration might have on the method.

(b) The rate of the reaction was measured at several different initial concentrations of **A** in the presence of a large excess of compound **B** and a constant amount of catalyst **X**, to find the order of reaction with respect to **A**. The results are shown on the graph below.



(i) Suggest an explanation, other than experimental error, for the two anomalous results ringed.

(2)

The concentration of A is high that the room temperature is not high enough. The reaction is endothermic.

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Examiner Comments

This candidate has scored a mark for realising that the reaction is endothermic is an important factor here. You were told that the reaction is endothermic at the start of question 14. To score the second mark, you would need to state the effct of this on the rate of reaction.

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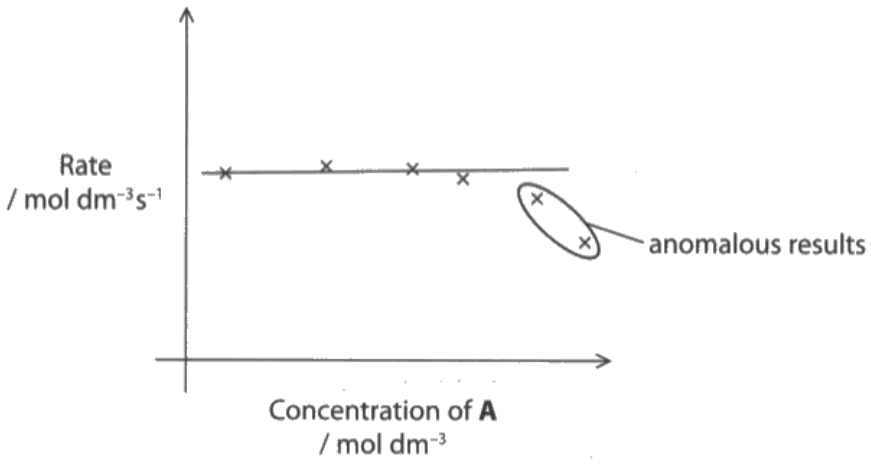
Examiner Tip

Use all of the information given in the question.

(b) The rate of the reaction was measured at several different initial concentrations of **A** in the presence of a large excess of compound **B** and a constant amount of catalyst **X**, to find the order of reaction with respect to **A**. The results are shown on the graph below.



(i) Suggest an explanation, other than experimental error, for the two anomalous results ringed.

(2)

All active sites of X are saturated, so the reaction is less catalysed and rate decrease to form the 2 outliers.

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Examiner Comments

This is a good answer that scored 2 marks. This candidate has realised that if there is a high concentration of **A** it is possible that all of the active sites on the catalyst are blocked so this will decrease the rate.

Question 14 (b) (ii)

Nearly all candidates scored at least one mark for this question for recognising that the reaction is zero order. A few candidates did not explain their answer clearly enough to score the second mark.

(ii) What is the order of reaction with respect to **A**? Justify your answer.

(2)

Zero order reaction since graph shows a straight line

ResultsPlus
Examiner Comments

This candidate has scored 1 mark for identifying zero order. The 'graph is a straight line' is not sufficient for the second mark, as a first order reaction would also have a straight line. If the candidate had included 'horizontal line', they would have scored the second mark.

ResultsPlus
Examiner Tip

Think carefully about the use of 'straight line'. It could be horizontal, vertical or at any angle.

(ii) What is the order of reaction with respect to **A**? Justify your answer.

(2)

~~orde~~ order with respect to A is zero. As the concentration increases rate ~~is~~ has no change. Straight horizontal line no change in rate.

ResultsPlus
Examiner Comments

This is a good answer that scored 2 marks as the order is correct and so is the reason.

Question 14 (c)

Many candidates scored full marks for all parts of (c). A few candidates did not give precise answers to (i) so lost a mark. Generally the orders of reaction with respect to **B** and **X** were correct and explained clearly. A few thought that when the concentration of **B** triples and the rate increases by a factor of 9, it is third order with respect to **B**. A few gave inaccurate reasons such as stating when the concentration of **B** is double, the rate increases by a factor of 4, even though there were no experiments that showed this. A few assumed that as **X** is a catalyst, it must be zero order. A few candidates tried to use experiments 3 and 4 to deduce the order with respect to **X** but as its concentration was not changing, the order could not be deduced. The rate equation and calculation of the rate constant were nearly always correct, although some candidates were unable to work out the correct units.

(ii) What is the order of reaction with respect to **A**? Justify your answer.

(2)

Zero order. Same rate at different concentrations.

(c) In a second series of experiments, further data were collected using a different method. These results are summarised in the table below.

Experiment	Initial concentration / mol dm^{-3}			Rate / mol dm^{-3} s^{-1}
	A	**B**	**X**	
1	0.010	0.025	0.100	0.0025
2	0.010	0.075 ×1·3	0.100	0.0225 ×1·3
3	0.010	0.100	0.200	0.0800
4	0.020	0.100	0.200	0.0800

(i) Give **one** reason why obtaining these further data may be considered useful.

(1)

Specific values are recorded for each experiment.

(ii) State the order with respect to **B** and hence deduce the order with respect to **X**. Explain how you arrived at your answers. Include appropriate experiment numbers in your explanation.

(4)

B => Exp. 1 and 2.

B x 3, R x 9

doubles so 2nd order.

$[B]^2$

X => Exp. 2 and 3.

X x 2, R x 3.

0 order.

$[X]^0$

(iii) Use your answers to (b)(ii) and (c)(ii) to give the rate equation for the reaction.

(1)

$R = k[A]^0[B]^2[X]^0$

$R = k[B]^2$

(iv) Use your answer from (c)(iii) and appropriate data from **Experiment 3** in the table, to calculate the value of the rate constant, *k*.
Include units in your answer.

(2)

$R = k[B]^2$

$0.0025 = k[0.025]^2$

$0.0025 = 0.000625k$

$k = 4 \text{ mol}^2\text{dm}^{-6}$

ResultsPlus
Examiner Comments

(i) This answer is too vague so no mark awarded.

(ii) The order with respect to **B** is correct and there is an explanation but the order with respect to **X** is incorrect, so 2 marks awarded.

(iii) The rate equation is correct for the orders stated by the candidate so scored 1 mark.

(iv) The candidate has used the result of experiment 1 instead of experiment 3 to calculate the rate constant and this was allowed on this occasion. However, the units are incorrect so 1 mark awarded.

(ii) What is the order of reaction with respect to **A**? Justify your answer.

(2)

The order of the reaction with respect to A is zero order. Because according to the graph as the concentration of A is changed the rate does not change it remains the same.

(c) In a second series of experiments, further data were collected using a different method. These results are summarised in the table below.

Experiment	Initial concentration / mol dm^{-3}			Rate / mol dm^{-3} s^{-1}
	A	**B**	**X**	
1	0.010	0.025	0.100	0.0025
2	0.010	0.075	0.100	0.0225
3	0.010	0.100	0.200	0.0800
4	0.020	0.100	0.200	0.0800

(i) Give **one** reason why obtaining these further data may be considered useful.

(1)

It's useful because it makes the experiment reliable and valid.

(ii) State the order with respect to **B** and hence deduce the order with respect to **X**. Explain how you arrived at your answers. Include appropriate experiment numbers in your explanation.

(4)

For B: Considering experiment 1 and 2. Concentrations of A and X were kept constant. Concentration of B was trebled. As a result rate increased by 3^2. Therefore 'B' is a second order reaction with respect to B.

For X: 'X' is zero order with respect to 'X' because X is a catalyst and concentration of a catalyst has no effect on the rate of reaction. only the Presense of a catalyst has an effect on the rate of reaction.

(iii) Use your answers to (b)(ii) and (c)(ii) to give the rate equation for the reaction.

(1)

Rate = $k[A]^0[B]^2[X]^0$

(iv) Use your answer from (c)(iii) and appropriate data from **Experiment 3** in the table, to calculate the value of the rate constant, *k*.
Include units in your answer.

(2)

$0.0800 = k(0.010)^0 \times (0.100)^2 \times ((0.200)^0$

$0.0800 = 0.01k$

$k = \frac{0.0800}{0.01}$

$= 8$ ~~s^{-1}~~ $8\ mol\ dm^3\ s^{-1}$ //

ResultsPlus
Examiner Comments

(i) Correct for 1 mark.

(ii) Correct for 4 marks.

(iii) Correct for 1 mark.

(iv) The value is correct and scored 1 mark, but the unit is incorrect.

ResultsPlus
Examiner Tip

Always checks units carefully for rate constants and equilibrium constants.

Question 14 (d)

This question tested the ability of candidates to apply their knowledge of a mechanism. There were more than two acceptable correct features and incorrect features but a minority of candidates scored 4 marks. Some candidates did not understand the meaning of the curly arrows and others were not familiar with the transition state in this mechanism.

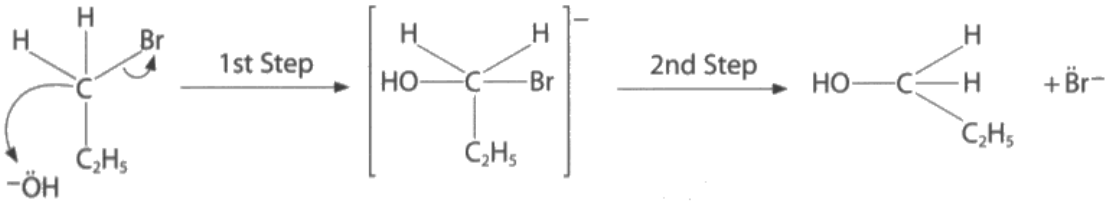
(d) A student carried out an investigation into the kinetics of the reaction between 1-bromopropane and hydroxide ions. A summary of the student's findings is shown below.

Kinetics Investigation - Summary of Key Findings

Reaction is second order overall and is known as S_N2.
Both 1-bromopropane and the hydroxide ions are involved in the slow step of this two-part reaction.

Suggested Mechanism

The hydroxide ions react with the 1-bromopropane as below.



Use your knowledge of the mechanism of nucleophilic substitution reactions to suggest **two** features of the summary, including the student's mechanism, that you think are correct and **two** features you think are incorrect.

(4)

Two features you think are correct.

- The curly arrows have been drawn correctly
- Lone pairs ~~labb~~ labelled correctly.

Two features you think are incorrect.

Reaction is first order overall

Hydroxide not present in the rate determining step because it is not in the rate equation.

ResultsPlus
Examiner Comments

This candidate has not scored any marks.

'The curly arrows have been drawn correctly' would have scored a mark if it had referred to the curly arrow from the C-Br bond towards the Br or, which is correct. The other curly arrow from C to OH is incorrect.

ResultsPlus
Examiner Tip

Learn the mechanisms in the specification carefully and make sure you understand what they represent.

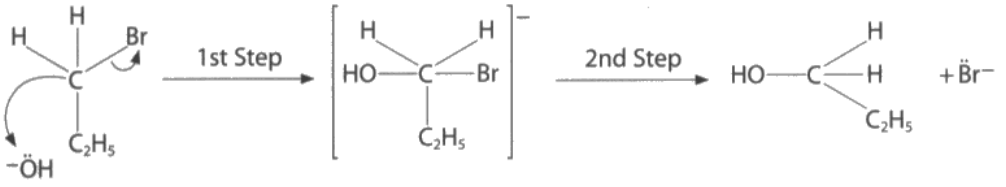
(d) A student carried out an investigation into the kinetics of the reaction between 1-bromopropane and hydroxide ions. A summary of the student's findings is shown below.

Kinetics Investigation - Summary of Key Findings

Reaction is second order overall and is known as S_N2.
Both 1-bromopropane and the hydroxide ions are involved in the slow step of this two-part reaction.

Suggested Mechanism

The hydroxide ions react with the 1-bromopropane as below.



Use your knowledge of the mechanism of nucleophilic substitution reactions to suggest **two** features of the summary, including the student's mechanism, that you think are correct and **two** features you think are incorrect.

(4)

Two features you think are correct.

The reaction is second order overall and is known as ~~SN~~ S_N2.
Both 1-bromopropane and the hydroxide ions are involved in the slow step, is also correct.

Two features you think are incorrect.

The arrow from C to -ÖH is in-correct.
The arrow from C to Br is incorrect.

ResultsPlus
Examiner Comments

This response scored 1 mark for the correct S_N2 reaction. The candidate has realised that the arrow from the C to the OH is incorrect but needed to state that it should be in the opposite direction to score a mark.

ResultsPlus
Examiner Tip

When you identify an incorrect feature, also state what is needed to correct it.

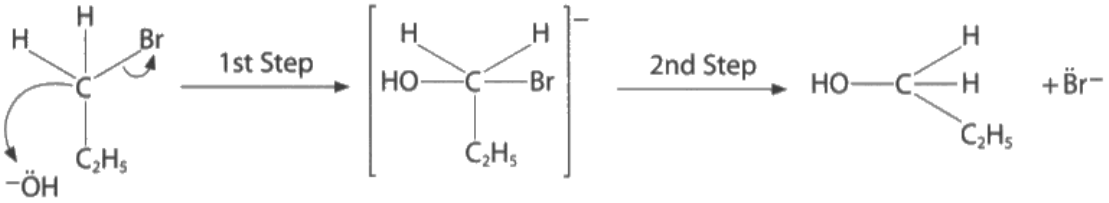
(d) A student carried out an investigation into the kinetics of the reaction between 1-bromopropane and hydroxide ions. A summary of the student's findings is shown below.

Kinetics Investigation - Summary of Key Findings

Reaction is second order overall and is known as S_N2.
Both 1-bromopropane and the hydroxide ions are involved in the slow step of this two-part reaction.

Suggested Mechanism

The hydroxide ions react with the 1-bromopropane as below.



Use your knowledge of the mechanism of nucleophilic substitution reactions to suggest **two** features of the summary, including the student's mechanism, that you think are correct and **two** features you think are incorrect.

(4)

Two features you think are correct.

The reaction involves substitution, as is shown.
After step 1, the whole compound made is negatively charged.

Two features you think are incorrect.

Carbon can only bond with 4 atoms but after 1st step 5 bonds are shown.
The charge on the carbocation is not shown.

ResultsPlus
Examiner Comments

This candidate has scored 2 marks for the charge being correct and that carbon cannot form 5 bonds.

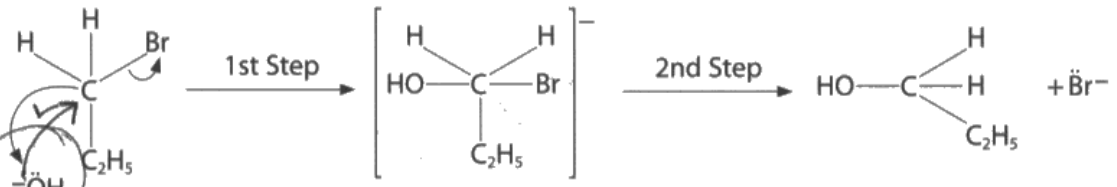
(d) A student carried out an investigation into the kinetics of the reaction between 1-bromopropane and hydroxide ions. A summary of the student's findings is shown below.

Kinetics Investigation - Summary of Key Findings

Reaction is second order overall and is known as S_N2.
Both 1-bromopropane and the hydroxide ions are involved in the slow step of this two-part reaction.

Suggested Mechanism

The hydroxide ions react with the 1-bromopropane as below.



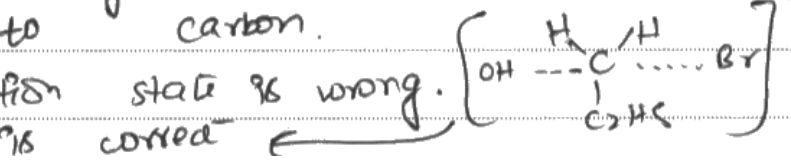
Use your knowledge of the mechanism of nucleophilic substitution reactions to suggest **two** features of the summary, including the student's mechanism, that you think are correct and **two** features you think are incorrect.

(4)

Two features you think are correct.

Reaction is going to follow SN2 mechanism. Both OH^- and the halogenoalkane are involved in the rate determining step. Sign above the transition state is correct (-ve).

Two features you think are incorrect.

SN2 is a one step reaction, not 2. curly arrow shown from C to O(:)H is wrong. curly arrow should be from (:)OH to carbon. transition state is wrong. This is correct ←  -1

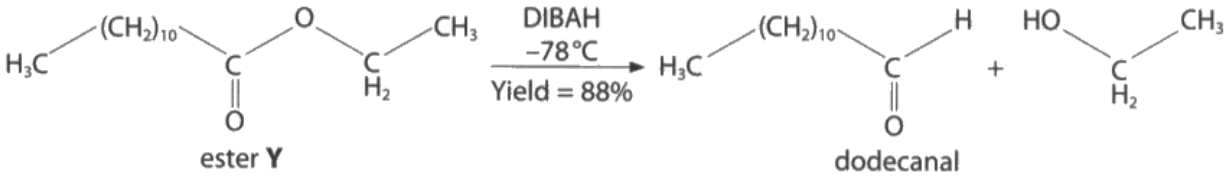
ResultsPlus
Examiner Comments

This candidate has explained two correct features and two incorrect features so has scored 4 marks.

Question 15 (a)

There were many correct answers for the name of the ester but a significant number of candidates did not use the information given in the question or were careless.

15 Aldehydes can be synthesised in the laboratory by the reaction of esters with the reagent diisobutylaluminiumhydride (DIBAH), which acts as a source of hydride ions. An example is shown below.



ester **Y** dodecanal

(a) Give the systematic name of ester **Y**.

(1)

ethyl decanoate

ResultsPlus
Examiner Comments

This is an example of one of many different incorrect answers. This candidate has missed out the do- in front of decanoate so has not scored a mark.

ResultsPlus
Examiner Tip

Use the information given in the question. The ester forms ethanol, so the name must start with ethyl. Dodecanal is also formed so the second part of the name is dodecanoate.

Question 15 (b)

The majority of candidates could apply their knowledge to this question and deduce that DIBAH is a reducing agent. Some incorrect answers included: oxidising agent, catalyst and hydrating agent.

(b) DIBAH acts as a source of hydride ions. What type of reagent is DIBAH?

(1)

~~acidic~~ reducing agent

ResultsPlus
Examiner Comments

There were many correct answers scoring 1 mark.

(b) DIBAH acts as a source of hydride ions. What type of reagent is DIBAH?

(1)

Nucleophile

ResultsPlus
Examiner Tip

This was another acceptable answer.

Question 15 (c)

Very few candidates could apply their knowledge of aldehydes to this reaction and many vague answers were seen here. Common incorrect answers included references to rate and yield.

(c) Suggest why the reaction is kept at –78 °C.

(1)

To avoid hydrolysis of the ester.

ResultsPlus
Examiner Comments

There were many incorrect answers to this question, such as this one here.

(c) Suggest why the reaction is kept at –78 °C.

(1)

- The esters and the DIBAH are volatile.

ResultsPlus
Examiner Comments

This is another common incorrect answer.

ResultsPlus
Examiner Tip

Aldehydes are often volatile, but not when there are twelve carbon atoms in the molecules.

(c) Suggest why the reaction is kept at –78 °C.

(1)

~~In order to make sure that~~ Above this temperature the ~~ketone~~ aldehyde will further reduce to a primary alcohol

ResultsPlus
Examiner Comments

This is a rare example of a correct answer.

ResultsPlus
Examiner Tip

Although you have not come across this particular reaction, you can apply your knowledge of aldehydes here. You know that carefully controlled conditions are needed to oxidise a primary alcohol to an aldehyde. The same applies for the reduction process. If the temperature is not kept low enough, the aldehyde will undergo further reduction to produce a primary alcohol.

Question 15 (d)

The majority of candidates could calculate the correct mass of dodecanal. The most common error was not using the 88% yield. A few candidates rounded the moles of ester from 0.02307 to 0.02 and lost a mark. Candidates should keep all significant figues in their calculator for each stage and give their final answer to at least 2 significant figures.

(d) The overall yield for this process is 88%.

Calculate the mass, in g, of dodecanal that would be formed from 5.26 g of the ester **Y**.

[Molar masses / g mol^{-1}: ester **Y** = 228; dodecanal = 184]

(3)

moles of ester Y = $\frac{5.26}{228}$ = 0.0231

ratio 1 : 1

~~0.0231 moles~~

$\frac{n}{5.26} \times 100 = 88$

$n = 4.6288$ g //

(Total for Question 15 = 6 marks)

ResultsPlus
Examiner Comments

This response scored 1 mark for calculating the moles of ester Y.

In the second step shown, they have calculated 88% of the mass of ester, but this is not worthy of credit as it is just the first step of an alternative method.

(d) The overall yield for this process is 88%.

Calculate the mass, in g, of dodecanal that would be formed from 5.26 g of the ester **Y**.

[Molar masses / g mol^{-1}: ester **Y** = 228; dodecanal = 184]

(3)

moles of ester Y = $\frac{5.26}{228}$ = 0.0231

ratio 1 : 1

~~0.0231 moles~~

$\frac{n}{5.26} \times 100 = 88$

$n = 4.6288$ g //

ResultsPlus
Examiner Comments

This response scored 2 marks.

The candidate worked out the moles of ester Y that were used and then the theoretical mass of dodecanal produced. However, they omitted to use the overall yield of 88%.

ResultsPlus
Examiner Tip

Check to make sure that you have used all the data given in the question.

(d) The overall yield for this process is 88%.

Calculate the mass, in g, of dodecanal that would be formed from 5.26 g of the ester **Y**.

[Molar masses / g mol^{-1}: ester **Y** = 228; dodecanal = 184]

(3)

$n_{(ester\ Y)} = \frac{5.26}{228} = 0.023\ mol$

$0.023\ mol = \frac{m}{184} \quad m = 4.24$

$\%\ yield = \frac{m}{4.24} = 88\%$

$m = 4.24 \times \frac{88}{100} = 3.74\ g$

ResultsPlus
Examiner Comments

This is a good example of the calculation, with the working clearly explained. This response scored 3 marks.

ResultsPlus
Examiner Tip

Always show your working, as in this example.

Question 16 (a) (i)

The majority of candidates were able to suggest a method for purifying an oil, with recrystallisation being the most common incorrect answer.

16 Chemists in Asia have been investigating the use of a range of non-edible seeds to produce oil for bio-diesel production, instead of using edible oils. The oils are obtained by pressing the seeds to release the oil. The relatively impure oil is filtered, and then purified using an industrial version of a standard laboratory technique. The oil can then be converted to bio-diesel by the reaction with methanol in the presence of a suitable catalyst.

(a) (i) Suggest a 'standard laboratory technique' that could be used to purify the oil.

(1)

sep recrystallisation.

ResultsPlus
Examiner Comments

This was a common incorrect answer that did not score a mark.

ResultsPlus
Examiner Tip

Recrystallisation is used to purify solids. Oils are liquids.

16 Chemists in Asia have been investigating the use of a range of non-edible seeds to produce oil for bio-diesel production, instead of using edible oils. The oils are obtained by pressing the seeds to release the oil. The relatively impure oil is filtered, and then purified using an industrial version of a standard laboratory technique. The oil can then be converted to bio-diesel by the reaction with methanol in the presence of a suitable catalyst.

(a) (i) Suggest a 'standard laboratory technique' that could be used to purify the oil.

(1)

Fractional distillation

ResultsPlus
Examiner Comments

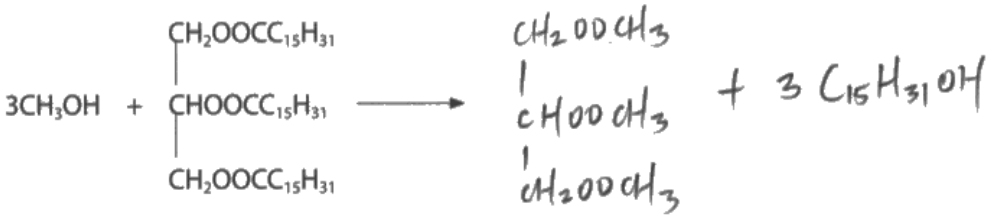
Distillation, fractional distillation, steam distillation and solvent extraction are all acceptable methods for purifying a liquid so this response scored 1 mark.

Question 16 (a) (ii)

This question was poorly answered by the majority of candidates. Many of them seemed unfamiliar with trans-esterification as they did not realise that propane-1,2,3-triol is one of the products so they were unable to work out the formula for the bio-diesel.

(ii) Complete the equation below for the formation of a bio-diesel from the reaction of an oil with methanol.

(2)



ResultsPlus
Examiner Comments

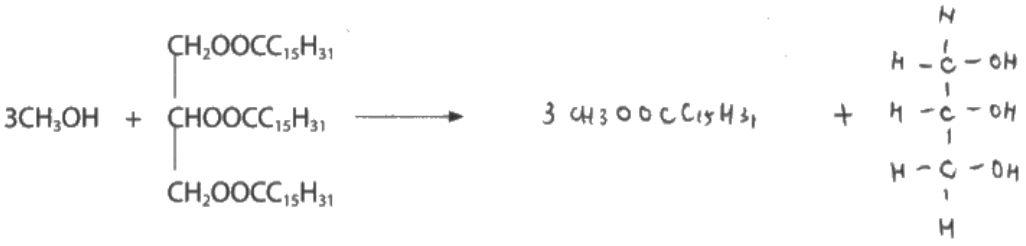
This is an example of one of the many incorrect answers that did not score a mark.

ResultsPlus
Examiner Tip

Learn how to write the equation for trans-esterification.

(ii) Complete the equation below for the formation of a bio-diesel from the reaction of an oil with methanol.

(2)



ResultsPlus
Examiner Comments

A correct equation that scored 2 marks.

ResultsPlus
Examiner Tip

A few candidates lost a mark by writing CH_2OH on the centre carbon atom in propane-1,2,3-triol. You will avoid making this type of slip if you draw the structure like the one in this example.

Question 16 (a) (iii)

There was a large number of different acid and bases catalysts acceptable here so the majority of candidates scored a mark. Common incorrect answers included catalysts that students have met in other reactions, such as nickel, iron and platinum.

(iii) Suggest a suitable catalyst for the reaction in (a)(ii).

(1)

(OH^-) NaOH (base Hydrolysis)

ResultsPlus
Examiner Comments

The majority of candidates gave a correct catalyst and scored 1 mark.

Question 16 (b)

The majority of candidates scored low marks for this question. They tended to repeat the information given rather than develop it into arguments showing whether it was an advantage or disadvantage. For example, many candidates wrote that samphire can be grown in marshy areas close to the coast. They did not receive any credit for this as that is given in the question. However, if they had extended this to say that this is an advantage as this land is unlikely to be used for growing other crops, they would have scored a mark. Many candidates wrote about processing the plants or seeds into bio-diesel and did not receive credit for this as the question asked about growing the plants. The most common points worthy of credit included: renewable, reduction in land available for growing crops, using samphire reduces availability as a food source.

*(b) Another source of oil currently being investigated for bio-diesel production is the edible plant known as samphire. It can be grown in marshy areas close to coastlines and is tolerant of salt.

Consider the advantages and disadvantages of growing both samphire and non-edible seeds as sources of vegetable oil.

Suggest, giving your reasons, which of the two sources would provide a potentially greener, more sustainable supply of bio-diesel.

(4)

In my opinion, growing samphire would provide a potentially greener, more sustainable supply of bio-diesel.
First of all, it is edible. When it is not used as fuel it can be a food source.
Second, it is tolerant of salt and can be grown close to coastlines, meaning it can be easily grown, so the supply of it should be more stable.

ResultsPlus
Examiner Comments

This candidate has written several points about samphire, but they are just repeating information that has been given in the question, so this response did not score any marks.

ResultsPlus
Examiner Tip

In this style of question, use the information you are given, but you need to develop arguments from it and not just repeat it.

*(b) Another source of oil currently being investigated for bio-diesel production is the edible plant known as samphire. It can be grown in marshy areas close to coastlines and is tolerant of salt.

Consider the advantages and disadvantages of growing both samphire and non-edible seeds as sources of vegetable oil.

Suggest, giving your reasons, which of the two sources would provide a potentially greener, more sustainable supply of bio-diesel.

(4)

~~Samphire is grown in a different area than samphire can be crops because they are edible~~. Both samphire and non-edible seeds are renewable, sources and they can offset carbon dioxide emissions. However, they need a large area for planting them and in the process of extracting oil, machinery ~~uses~~ used also producing carbon dioxide.

ResultsPlus
Examiner Comments

This response scored 1 mark for realising that samphire and non-edible seeds are renewable. There is nothing else worthy of credit.

ResultsPlus
Examiner Tip

The question asks for advantages and disadvantages of growing samphire and non-edible seeds so there were no marks awarded for processing them to produce bio-diesel.

*(b) Another source of oil currently being investigated for bio-diesel production is the edible plant known as samphire. It can be grown in marshy areas close to coastlines and is tolerant of salt.

Consider the advantages and disadvantages of growing both samphire and non-edible seeds as sources of vegetable oil.

Suggest, giving your reasons, which of the two sources would provide a potentially greener, more sustainable supply of bio-diesel.

(4)

An advantage of using samphire is that it can grow in marshy areas where humans do not grow crops, thereby conserving land. However since it is edible, humans eat it and therefore if samphire crops ~~will~~ are used for bio diesel ~~fuel~~, it is a reduction in food for humans which is a disadvantage. Non-edible seeds have the advantage in that humans do not consume it and therefore a reduction in their population due to ~~the~~ biofuel production would not affect humans. However a lot of land is needed to grow them which could be used to grow crops for human consumption. Therefore samphire would provide a greener, more sustainable supply of ~~bio oil~~ bio-diesel.

(Total for Question 16 = 8 marks)

ResultsPlus
Examiner Comments

This response scored 2 marks for:

- samphire can grow in areas where other crops do not grow
- use of samphire could cause a reduction in food supply
- the points made about non-edible seeds are the direct opposite of these for samphire so do not receive additional credit.

*(b) Another source of oil currently being investigated for bio-diesel production is the edible plant known as samphire. It can be grown in marshy areas close to coastlines and is tolerant of salt.

Consider the advantages and disadvantages of growing both samphire and non-edible seeds as sources of vegetable oil.

Suggest, giving your reasons, which of the two sources would provide a potentially greener, more sustainable supply of bio-diesel.

(4)

~~Non edible seeds is more sustainable than samphire.~~

Samphire can easily be grown without deforestation but as it is edible, usage of samphire contributes to the ~~long~~ shortage of food supply.

Non edible seeds in the other hand is a waste product from ~~edible~~ plants, so the usage of non-edible seeds reduce waste product. Hence ~~none~~ non-edible seeds is a more sustainable supply of bio-diesel.

(Total for Question 16 = 8 marks)

TOTAL FOR SECTION B = 47 MARKS

ResultsPlus
Examiner Comments

This response scored 3 marks.

The points worthy of credit were:

- growing samphire does not require deforestation
- using samphire will lead to a food shortage
- non-edible seeds are a waste product if not used to make bio-diesel.

Question 17 (a)

It was surprising to see a significant number of candidates who could not select the correct data from the Data Booklet. Some copied the numbers incorrectly, some read the data from the wrong substance and it was difficult to see where some of the data had come from. The majority of candidates were able to complete the calculations in (ii) and (iii) with the data they selected, although some omitted to use the stoichiometry of the reaction and some got the cycles the wrong way around. Many candidates were able to calculate the total entropy but some omitted to convert the two values to the same energy unit before adding them together. Many candidates did not mention the effect of increasing temperature on the standard entropy change of the system in (v).

17 Ethanoic acid, CH_3COOH, is a carboxylic acid with many uses, including as a food additive. It can be made by the reaction of butane with oxygen.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightleftharpoons 4CH_3COOH(l) + 2H_2O(l)$$

(a) (i) Use the Data Booklet to complete the table below.

(3)

	$CH_3CH_2CH_2CH_3(g)$	$O_2(g)$	$CH_3COOH(l)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−2876·5	0	−874·1	−241·8
$S^{\ominus}$ / J mol^{-1} K^{-1}	310·1	205	159·8	188·7

(ii) Use data from your table to calculate the standard enthalpy change, in kJ mol^{-1}, for this reaction.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightarrow 4CH_3COOH(l) + 2H_2O(l)$$

(2)

Std Enthalpy change = $[(2\times -241{\cdot}8) + (4\times -874{\cdot}1)] - [(2\times -2876{\cdot}5) + (5\times 0)]$

$= -3980 + 5733$

$= 1773\ kJ\ mol^{-1}$

(iii) Use data from your table to calculate the standard entropy change of the system, in J mol^{-1} K^{-1}, for the same reaction.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightarrow 4CH_3COOH(l) + 2H_2O(l)$$

(2)

Standard entropy of system = product − reactant

~~$= [(2\times -241{\cdot}8) + (4\times 159{\cdot}8)] - [(5\times 205) + (2\times 310{\cdot}1)]$~~

~~$= 155{\cdot}6 - 1645{\cdot}2$~~

~~$= -1489{\cdot}6 = -1490\ J\ mol^{-1}K^{-1}$~~

$= [(2\times 188{\cdot}7) + (4\times 159{\cdot}8)] - [(5\times 205) + (2\times 310{\cdot}1)]$

$= -628{\cdot}6\ JK^{-1}mol^{-1}$

(iv) Use your answer to (a)(ii) to calculate $\Delta S_{surroundings}$ and use this and your answer to (a)(iii) to calculate ΔS_{total} for the reaction at 298 K.

(3)

$\Delta S^{\ominus}_{surroundings} = \frac{-\Delta H}{T} = \frac{-(-2256.6) \times 1000}{298}$

$= +7572.5 \text{ J mol}^{-1}$

$\Delta S^{\circ}_{total} = \Delta S^{\circ}_{sys} + \Delta S^{\circ}_{surr}$

$= -866.2 + 7572.5$

$= 6706 \text{ J mol}^{-1} \text{ K}^{-1}$

(v) It was suggested that **increasing** the temperature of the reaction to more than 298 K would produce a greater yield of ethanoic acid.

Explain, in terms of the effect on ΔS_{system}, $\Delta S_{surroundings}$ and hence ΔS_{total}, whether this would be the case.

(3)

Increasing temperature of the reaction decreases ΔS°_{surr} because the reaction is exothermic. ΔS°_{sys} will remain same. ΔS°_{total} will decrease as ΔS°_{surr} is decreasing. As the entropy is decreasing, ~~react~~ more products are forming and more ethanoic acid will form as it is liquid and has lower entropy.

ResultsPlus
Examiner Comments

(i) Only 2 correct data values have been given, so 1 mark awarded.

(ii) Consequentially correct from incorrect data, so 2 marks awarded.

(iii) Consequentially correct from incorrect data, so 2 marks awarded.

(iv) 1 mark awarded. The candidate has not converted the enthalpy change into J mol^{-1} before calculating $\Delta S_{surroundings}$ and adding it to the ΔS_{system} value.

(v) No marks awarded as the answer is not correct from the negative value of $\Delta S_{surroundings}$.

ResultsPlus
Examiner Tip

Practise using the Data Booklet so that you can look up the required data.

17 Ethanoic acid, CH_3COOH, is a carboxylic acid with many uses, including as a food additive. It can be made by the reaction of butane with oxygen.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightleftharpoons 4CH_3COOH(l) + 2H_2O(l)$$

(a) (i) Use the Data Booklet to complete the table below.

(3)

	$CH_3CH_2CH_2CH_3(g)$	$O_2(g)$	$CH_3COOH(l)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−2876·5	0	−874·1	−241·8
$S^{\ominus}$ / J mol^{-1} K^{-1}	310·1	205	159·8	188·7

(ii) Use data from your table to calculate the standard enthalpy change, in kJ mol^{-1}, for this reaction.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightarrow 4CH_3COOH(l) + 2H_2O(l)$$

(2)

Std Enthalpy change = $[(2\times -241{\cdot}8)+(4\times -874{\cdot}1)] - [(2\times -2876{\cdot}5)+(5\times 0)]$

$= -3980 + 5733$

$= 1773\ kJ\ mol^{-1}$

(iii) Use data from your table to calculate the standard entropy change of the system, in J mol^{-1} K^{-1}, for the same reaction.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightarrow 4CH_3COOH(l) + 2H_2O(l)$$

(2)

Standard entropy of system = product − reactant

~~$= [(2\times -241{\cdot}8)+(4\times 159{\cdot}8)] - [(5\times 205)+(2\times 310{\cdot}1)]$~~

~~$= 155{\cdot}6 - 1645{\cdot}2$~~

~~$= -1489{\cdot}6 = -1490\ J\ mol^{-1}K^{-1}$~~

$= [(2\times 188{\cdot}7)+(4\times 159{\cdot}8)] - [(5\times 205)+(2\times 310{\cdot}1)]$

$= -628{\cdot}6\ J\ K^{-1}\ mol^{-1}$

(iv) Use your answer to (a)(ii) to calculate $\Delta S_{surroundings}$ and use this and your answer to (a)(iii) to calculate ΔS_{total} for the reaction at 298 K.

(3)

$\Delta S_{surroundings} = -\frac{\Delta H}{T} = -\frac{1773}{298} = -5.95$

$= -5949.66 \text{ J mol}^{-1} \text{ K}^{-1}$

ΔS_{total} = System + surroundings.

~~$\Delta S_{total} = -628.6 + (-5.95)$~~

~~$= -634.55$~~

$\Delta S_{total} = -628.6 - 5949.66$

$= -6578.3 \text{ J mol}^{-1} \text{ K}^{-1}$

(v) It was suggested that **increasing** the temperature of the reaction to more than 298 K would produce a greater yield of ethanoic acid.

Explain, in terms of the effect on ΔS_{system}, $\Delta S_{surroundings}$ and hence ΔS_{total}, whether this would be the case.

(3)

Increasing the temperature will decrease the value of $\Delta S_{surroundings}$ and the total entropy will also decrease.

ResultsPlus
Examiner Comments

(i) The enthalpy of formation of water is incorrect. The candidate has misread the Data Booklet and written down the value for HIO_3, which is on the line above water. 2 marks awarded.

(ii) Consequentially correct so 2 marks awarded.

(iii) Correct, so 2 marks awarded.

(iv) Consequentially correct, so 3 marks awarded.

(v) The effects of a higher temperature on $\Delta S_{surroundings}$ and ΔS_{total} are correct so 2 marks awarded. There is no mention of ΔS_{system} in the answer.

ResultsPlus
Examiner Tip

Check the values that you use from the Data Booklet. Some candidates used the enthalpy of formation for gaseous water instead of liquid water.

17 Ethanoic acid, CH_3COOH, is a carboxylic acid with many uses, including as a food additive. It can be made by the reaction of butane with oxygen.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightleftharpoons 4CH_3COOH(l) + 2H_2O(l)$$

(a) (i) Use the Data Booklet to complete the table below.

(3)

	$CH_3CH_2CH_2CH_3(g)$	$O_2(g)$	$CH_3COOH(l)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−126·5	0	−484·5	−230·1
$S^{\ominus}$ / J mol^{-1} K^{-1}	310·1	205	159·8	69·9

(ii) Use data from your table to calculate the standard enthalpy change, in kJ mol^{-1}, for this reaction.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightarrow 4CH_3COOH(l) + 2H_2O(l)$$

(2)

$((4\times-484.5) + (2\times-230.1)) - ((2\times-126.5) + (5\times0))$

$-2398.2 + 253$

$= -2145.2$ kJ mol^{-1} K^{-1} ~~$= -2.1$ kJ mol^{-1} K^{-1}~~

(iii) Use data from your table to calculate the standard entropy change of the system, in J mol^{-1} K^{-1}, for the same reaction.

$$2CH_3CH_2CH_2CH_3(g) + 5O_2(g) \rightarrow 4CH_3COOH(l) + 2H_2O(l)$$

(2)

$\Delta S^{\ominus} = (4\times159.8 + 2\times69.9) - (2\times310.1 + 5\times205)$

$= 779 - 1695.2$

$= -866.2$ ~~kJ~~ J mol^{-1} K^{-1}

(iv) Use your answer to (a)(ii) to calculate $\Delta S_{surroundings}$ and use this and your answer to (a)(iii) to calculate ΔS_{total} for the reaction at 298 K.

(3)

$\Delta S_{surr} = \frac{-\Delta H}{T}$ *

$\Delta S_{Total} = -866.2 + \frac{2145.2 \times 1000}{298}$

$= -859 \text{ Jmol}^{-} + 6332.5 \text{ J mol}^{-1}\text{k}^{-1}$ //

(v) It was suggested that **increasing** the temperature of the reaction to more than 298 K would produce a greater yield of ethanoic acid.

Explain, in terms of the effect on ΔS_{system}, $\Delta S_{surroundings}$ and hence ΔS_{total}, whether this would be the case.

(3)

Increasing the temperature would decrease $\Delta S_{surrounding}$. and as ΔH is negative and as ΔS_{system} too is negative, it would result in a decreased value of ΔS_{total}. Therefore the yield of ethanoic acid would be less. Suggestion is incorrect in this case.

ResultsPlus
Examiner Comments

This is a good response that scored full marks for each part.

Question 17 (b)

The vast majority of candidates scored a mark for this item. The preferred answer was the peak between 1725-1700 cm^{-1} for C=O. The O-H peak between 3300-2500 cm^{-1} was allowed, even though this would be due to the O-H bonds in water as well as in ethanoic acid. A few candidates quoted an incorrect range for the peaks and a small number did not quote a peak range, even though they were told to use the Data Booklet.

(b) Infrared spectroscopy can be used to follow the progress of reactions.

Using information from the Data Booklet, suggest one way this technique could be used to follow the progress of the reaction in (a) to produce ethanoic acid.

(1)

Peak would decrease as reaction progresses. End point will be reached when peak stops decreasing.

ResultsPlus
Examiner Comments

Some candidates did not give a wavenumber range for the peak so did not score a mark.

ResultsPlus
Examiner Tip

When you are asked to use the Data Booklet, you should quote the appropriate numbers from it.

(b) Infrared spectroscopy can be used to follow the progress of reactions.

Using information from the Data Booklet, suggest one way this technique could be used to follow the progress of the reaction in (a) to produce ethanoic acid.

(1)

It could follow the appearance of C=O bonds with a peak at 1725 - 1700 or a broad peak at 3500 - 2500 for O-H.

ResultsPlus
Examiner Comments

There were many correct answers for this item, such as this one that scored 1 mark. Only 1 of the peak ranges was needed to score the mark.

Question 17 (c)

Tha vast majority of candidates scored a mark for this item. There were a few answers that were not acceptable, such as, forms an ester and smells nice.

(c) Ethanoic acid is the food additive E260. Suggest the role it may have when added to foodstuffs.

(1)

It preservese the food.

ResultsPlus
Examiner Comments

There were many correct answers to this item, such as this one which scored 1 mark.

Question 17 (d) (i)

The vast majority of candidates were able to confirm the empirical formula for compound **Q**. A small number omitted the oxygen or rounded the moles too early, for example, 1.75 was rounded to 2 to give C_2H_3O.

(i) Use these data to confirm its empirical formula is $C_7H_{12}O_4$.

(3)

C	H
$\frac{52.5}{12}$	$\frac{7.5}{1}$
$\frac{4.375}{4.375}$	$\frac{7.5}{4.375}$
1 :	2

ResultsPlus
Examiner Comments

This candidate has omitted the oxygen, so has not scored any marks.

ResultsPlus
Examiner Tip

Read the question carefully. The empirical formula is given and shows oxygen as well as carbon and hydrogen. The percentage of oxygen was not given but it can be worked out by subtracting the percentages of carbon and hydrogen from 100.

(i) Use these data to confirm its empirical formula is $C_7H_{12}O_4$.

(3)

C H O

$\frac{52.5}{100} : \frac{7.5}{100} = \frac{40}{100}$ 40% oxygen.

$\frac{0.525}{0.075}, \frac{0.075}{0.075} \frac{0.4}{0.075}$

$= 7 \quad 1 \quad 5$.

ResultsPlus
Examiner Comments

This candidate has scored 1 mark for working out the percentage of oxygen. However, they have forgotten to calculate the moles of each element by dividing the percentages by the relative atomic masses before dividing by the smallest to work out the simplest ratio.

ResultsPlus
Examiner Tip

When you are asked to confirm something and your answer is not as expected, go back and check your working as you will have made an error somewhere.

(i) Use these data to confirm its empirical formula is $C_7H_{12}O_4$.

(3)

C H O

$\frac{52.5}{12} \quad \frac{7.5}{1} \quad \frac{40}{16}$

$\frac{4.375}{2.5} \quad \frac{7.5}{2.5} \quad \frac{2.5}{2.5}$

$\left(\frac{7}{4} \quad 3 \quad 1\right) \times 4$

$7 \quad 12 \quad 4$

$C_7H_{12}O_4$

ResultsPlus
Examiner Comments

There were many clear examples of working that scored 3 marks, such as this one.

Question 17 (d) (ii)

A large number of candidates scored the mark for this item. A few candidates thought that the base or highest peak would confirm the relative molecular mass, but the molecular ion peak is at the highest m/e value and is not necessarily the most abundant. Some candidates just stated that there would be a peak at m/e 160 but did not say that it was the highest m/e value or furthest to the right on the mass spectrum.

(ii) Explain how the mass spectrum of **Q** could be used to confirm that its relative molecular mass is 160.

(1)

It will have an m/e peak at 160.

ResultsPlus
Examiner Comments

This was a common response that did not score a mark. The response needed to indicate that this is the highest m/e value or corresponds to the molecular ion.

(ii) Explain how the mass spectrum of **Q** could be used to confirm that its relative molecular mass is 160.

(1)

$[C_7H_{12}O_4]^+$ the molecular ion peak which is the furthest to the right will show m/e = 160

ResultsPlus
Examiner Comments

There were many correct answers to this item, such as this one which scored 1 mark.

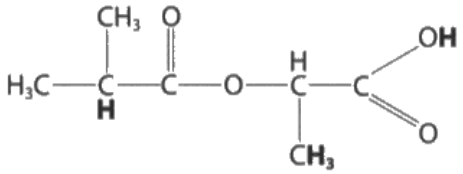
Question 17 (d) (iii)

It was surprising that a higher proprtion of candidates did not score full marks for this fairly straightforward question on an nmr spectrum. Almost all candidates could find the chemical shift for the COOH proton in the Data Booklet but only a small proportion looked up the correct value for the CH proton as they did not notice the adjacent C=O group. Some candidates did not understand that the relative area below the peak is related to the number of protons in the group and some did not understand the splitting pattern.

(iii) The table below summarises some information about parts of the nmr spectrum of compound **Q**.

Use the Data Booklet, and your knowledge of features in nmr spectra, to complete the table with respect to the features of compound **Q** shown in bold.

(4)



Feature of compound **Q**	Chemical shift / ppm for TMS	Splitting pattern	Relative area below peak
CH$_3$	0.1 – 1.9	doublet	1
CH	4.5-6.5	doublet	1
COOH	10-12	singlet	1

ResultsPlus
Examiner Comments

This response scored 1 mark for the correct chemical shift for the proton in COOH.

ResultsPlus
Examiner Tip

The CH and COOH protons have a relative area below the peak of 1, so the protons in CH_3 will have a relative peak area of 3.

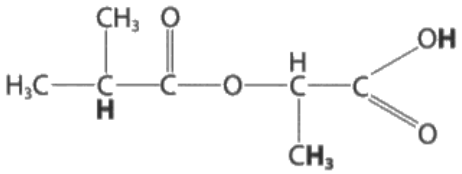
The CH proton has six protons on neighbouring carbon atoms so the peak will be split into 6+1 = 7.

The CH proton is adjacent to C=O and the Data Booklet shows the chemical shift is 1.8-3.0 ppm.

(iii) The table below summarises some information about parts of the nmr spectrum of compound **Q**.

Use the Data Booklet, and your knowledge of features in nmr spectra, to complete the table with respect to the features of compound **Q** shown in bold.

(4)



Feature of compound **Q**	Chemical shift / ppm for TMS	Splitting pattern	Relative area below peak
CH_3	0.1 – 1.9	doublet	3
CH	0.1 - 1.9	heplet => 7 peaks	1
COOH	10 - 12	singlet	1

ResultsPlus
Examiner Comments

This was a common answer that scored 3 marks. The chemical shift for the CH proton is incorrect as they have not noticed that it is adjacent to C=O.

Paper Summary

In order to improve their performance, candidates should:

- read the questions carefully and use all the information given;
- develop an argument from information given rather than just repeat it;
- check their answers to calculations to avoid careless errors;
- explain their answers clearly and concisely;
- write balanced equations;
- understand the different stages in a mechanism;
- select the correct data from the Data Booklet.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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with its registered office at 80 Strand, London WC2R 0RL.