Examiners' Report
June 2012

GCE Chemistry 6CH02 01

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June 2012

Publications Code US031857

Introduction

This paper tested a wide range of Unit 2 material and provided good opportunities for candidates to show their knowledge and understanding of the Chemistry covered by the Specification. There was no evidence that candidates were short of time.

The mean percentage scores in the multiple-choice section were higher than for the paper as a whole due to the presence of a number of readily accessible questions (over three-quarters of candidates gave the correct response for the following questions (in order of accessibility): 10, 5, 2(a), 9, 12, 1(a), 3). Only one question proved particularly challenging. This was Question 4, the test for iodine, for which just over a third of the candidates gave the right response, almost all the rest giving a halide test.

Question 11, the decomposition of carbonates, was the next most difficult question (correctly answered by just over half the candidates). Despite the relatively high mean mark, the scores on the multiple-choice section appeared to correlate well with overall achievement and gave good discrimination particularly at the E grade boundary.

In Sections B and C, candidates generally set out their work clearly and made sensible use of the space provided, although, in some cases, there was wasteful repetition both of the statements in the question and in the candidates' responses. Space allocation was only an issue in Question 20(b)(ii) where many candidates wrote far more than was needed. While many candidates used scientific vocabulary with skill and accuracy, there remain a significant number whose use of basic chemical terms appeared to lack an appreciation of their precise meaning; for example terms such as atom, ion and molecule can be taken by some candidates as interchangeable. The ability to write correct, balanced equations remains the preserve of the better candidates. Many candidates showed a poor understanding of the application of error / uncertainty theory to experimental situations and the typical understanding of environmental aspects of chemistry was perfunctory. The standard of the answers in Section C would have improved if more candidates had read the passage with due care.

Question 17 (a) (i)

While most candidates scored well on this question, appreciating that more ozone must be formed and that the increase in temperature favours the endothermic side of the equilibrium, there was a good deal of imprecise language even when both marks were awarded. For example, candidates frequently referred to 'the reaction' being endothermic, ignoring the reverse process. There were many elaborate discussions of the reaction 'absorbing the heat' and of the effect of temperature on the rate of the reaction which gained no marks.

17 (a) Ozone, O_3, is formed when oxygen is exposed to ultraviolet (UV) radiation or to an electric discharge. Ozone is a blue gas whereas oxygen is colourless. When the two gases are mixed, an equilibrium is established as shown in the following equation.

$$3O_2(g) \rightleftharpoons 2O_3(g) \qquad \Delta H = +143 \text{ kJ mol}^{-1}$$

(i) When the temperature of the pale blue equilibrium mixture is increased at constant volume, the colour darkens. Explain this observation in terms of the changes to the equilibrium.

(2)

The colour darkens as the equilibrium moves to the right hand side to counteract the increase in temperature.

ResultsPlus
Examiner Comments

The reference to counteracting the increase in temperature focuses incorrectly on a mechanism to explain Le Chatelier's Principle rather than the key point which is the endothermicity of the forward reaction.

ResultsPlus
Examiner Tip

With two marks available for this item, two points are essential.

(2)

As the right to left reaction is exothermic and produces a colourless gas. This means when the temperature is increased, the equilibria will attempt to do the opposite endothermic reaction to the left. This reaction takes in the excess heat and produces more blue gas.

ResultsPlus
Examiner Comments

This response is contradictory referring to the reaction to the left being both exothermic and endothermic.

ResultsPlus
Examiner Tip

Do check your answers carefully.

The equilibrium is moving in the endothermic direction (to the right) and so ozone is being produced at a greater rate, causing the colour to darken.

ResultsPlus
Examiner Comments

This is clearly a question about equilibrium so the mention of rate is superfluous.

ResultsPlus
Examiner Tip

Do try to keep to the point in your answers.

(2)

It is an endothermic reaction, when temperature is increased, it would favour a forward reaction to the right. The rate of reaction would be increased and the mixture would become darker. Yield of RHS (product) will be increased.

ResultsPlus
Examiner Comments

The forward reaction is indeed endothermic but the reverse reaction is, of course, exothermic so the language here is imprecise.

(2)

Because the reaction is endothermic when the temperature increases the ~~eqqa~~ equilibrium will shift to the endothermic side, also the rate will increase and so more $2O_{3(g)}$

ResultsPlus
Examiner Comments

Just more ozone or O_3(g) is much better than 'more $2O_3$(g)', as coefficients belong only in the equation.

Question 17 (a) (ii)

The effect of pressure on equilibrium was more clearly understood than the effect of temperature. A surprisingly common error was to omit the observation required by the question; candidates also referred to a blue gas being formed, ignoring the clue in 17(a)(i) indicating the best way to describe the change in appearance. Some candidates focused on explaining Le Chatelier's Principle in terms of absorbing the increase in pressure rather than describing the effect.

(ii) State and explain what you would **see** if the pressure of the system at equilibrium were increased.

(2)

If the pressure increased the system would become darker in colour (more O_3 produced) as there are less gas molecules on the right side.

ResultsPlus
Examiner Comments

This response gets straight to the point and scores full marks.

ResultsPlus
Examiner Tip

Less refers to amounts and fewer to number.

(ii) State and explain what you would **see** if the pressure of the system at equilibrium were increased.

(2)

The mixture would get a darker blue. This is because the system will respond to the increase in pressure by increasing the rate of the reaction which produces fewer moles of gas. There are fewer moles of gas on the right, so more ozone molecules will be produced.

ResultsPlus
Examiner Comments

The rate of reaction is irrelevant here and risks the second mark.

(ii) State and explain what you would **see** if the pressure of the system at equilibrium were increased.

↑ P = + -
↓ P = - +

(2)

when pressure is increased the reaction with fewer gas molecules is favoured, Hence the forward reaction is favoured as it has 2 gas molecules ~~whereas~~ whereas the backward reaction ~~has~~ produces 3 gas molecules.

ResultsPlus
Examiner Comments

Unfortunately this candidate fails to answer the question fully as there is no observation.

(ii) State and explain what you would **see** if the pressure of the system at equilibrium were increased.

(2)

The colour would darken, as there are more moles and therefore a higher pressure on the left of the equation, where the gas is colourless, so to try to restore the conditions of equilibria, the reaction would shift to the side of lower pressure.

ResultsPlus
Examiner Comments

The candidate confuses pressure and number of moles and thereby loses the second mark.

ResultsPlus
Examiner Tip

Attempts to explain Le Chatelier in terms of absorbing heat or reducing pressure will rarely gain marks.

(ii) State and explain what you would **see** if the pressure of the system at equilibrium were increased.

(2)

The colour will ~~get~~ darken.

~~Bea~~ Because the reaction tends to reduce number of gas molecules from left to right, so presure is reduced from left to right. Once pressure increases, the equilibrium will shift to right to reduce pressure, so more O_3 is,

ResultsPlus

Examiner Comments

Again, the response in terms of what the reaction is 'trying to do' fails to score the second mark.

Question 17 (a) (iii)

There were many excellent answers to this item but a significant number of candidates failed to appreciate that the question was about dynamic equilibrium. Some focused on the last sentence and deduced (incorrectly) that the ^{18}O was acting as a catalyst while others produced elaborate mechanisms for the formation of O_3 containing the isotope.

(iii) A small amount of oxygen gas containing the isotope ^{18}O is added to the equilibrium mixture. After a few hours, ozone containing ^{18}O is detected. Given that the equilibrium position is **not** affected, explain this observation.

(1)

~~$O_3 + {}^{18}O \rightleftharpoons 2O_2$~~ some of the ^{18}O reacts with the ozone and oxygen already present.

$^{18}3O_2 \rightleftharpoons 2{}^{18}O_3$ then $^{18}O_3 \rightarrow 2{}^{18}O_2 + {}^{18}O$ then $^{18}O + O_2 \rightarrow O_3$ with ^{18}O and original O2 combined.

ResultsPlus

Examiner Comments

The attention of the candidate is directed towards the mechanism of the process. The answer does not address the main point of this whole section which is to do with the characteristics of equilibrium systems.

(1)

~~^{18}O does not react to form ozone as product + does not interfere with reaction. ^{18}O split equally between both sides.~~

^{18}O reacts to form ozone but this means ~~eq~~ no longer in equilibrium so ^{18}O goes to left hand side again after ~~some~~ some time to return to ~~~~ equilibrium – seen after a few hours.

ResultsPlus
Examiner Comments

Despite the clear statement in the question that the equilibrium is unaffected, the candidate insists on assuming that the position of equilibrium has changed.

ResultsPlus
Examiner Tip

Take note of all the information provided in the question.

(1)

Because the ^{18}O ~~acco~~ acted like a catalyst. It was present in both foward and backward reaction, meaning equilibrium couldn't have got affected.

ResultsPlus
Examiner Comments

Instead of answering the question this candidate offers an explanation for the equilibrium position being unaffected.

Question 17 (b)

The first three steps of the calculation were familiar ground for most candidates who tackled them confidently; the most common errors were the omission of the factor of a thousand in 17(b)(i) and the use of a further division by two in 17(b)(iii). The conversion of moles to volume proved more demanding with some candidates failing to appreciate that the successive stages in the calculation were linked and started a new calculation for 17(b)(iv), often dividing 100 by 0.024. The scaling calculation in 17(b)(v) also caused difficulties with the omission of the division by 100 being a common error. Some candidates showed a lack of awareness of the significance of the numerical values here and gave answers well in excess of a million. Most candidates were able to score the first mark in 17(b)(vi), usually by reference to the calculation of a mean value but the distinction between reliability and accuracy was not clearly understood and the importance of relating the answer to the specific question was often not appreciated.

(b) The concentration of ozone in the atmosphere may be determined by bubbling air through a solution of acidified potassium iodide. Iodine is formed in solution, the concentration of which may be determined by titration with a solution of sodium thiosulfate of known concentration. The equations for the reactions are

$$O_3 + 2I^- + 2H^+ \rightarrow O_2 + H_2O + I_2 \qquad \text{Equation 1}$$

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-} \qquad \text{Equation 2}$$

In an experiment to determine the concentration of ozone in a sample of air, 100 m^3 of air was bubbled through 100 cm^3 of a solution containing an excess of acidified potassium iodide.

The resulting solution was titrated against a solution of sodium thiosulfate of concentration 0.0155 mol dm^{-3}. The volume of sodium thiosulfate solution required for complete reaction was 25.50 cm^3.

(i) Calculate the number of moles of sodium thiosulfate that react. (1)

$\frac{0.0155}{1000} \times 25.50 = 3.9525 \times 10^{-4}$ moles

(ii) Calculate the number of moles of iodine that reacted with the sodium thiosulfate. (2)

2:1 ratio

$\frac{3.9525 \times 10^{-4}}{2} = 1.97625 \times 10^{-4}$

(iii) Use equation 1 to deduce the number of moles of ozone that reacted with the acidified potassium iodide. (1)

1:1 ratio

$\therefore 1.97625 \times 10^{-4}$

(iv) Calculate the volume of ozone, measured in m^3, present in the original sample of air. Assume that all gas volumes were measured at room temperature and pressure and that the molar volume of any gas under these conditions is $0.024\ m^3\ mol^{-1}$.

(1)

1.97625×10^{-4} in $100\ m^3$ of air

~~1.97625×10^{-6} in 1~~

$1.97625 \times 10^{-4} \times 0.024 = 4.743 \times 10^{-6}\ m^3$

(v) Calculate the concentration of ozone in the sample of air in units of parts per million (ppm) by volume.

(1)

$4.743 \times 10^{-6}\ m^3$ in $100\ m^3$ of air

$\times 10{,}000$

~~$= 4.743 \times 10^{4}$ ppm~~ 0.04743 ppm

(vi) A student suggested that the $100\ cm^3$ of acidified potassium iodide should be divided into four portions before the titration. Explain how this change increases the reliability and decreases the accuracy of the experiment.

(3)

Increases reliability Because he will have 4 seperate titres e can therefore take a mean from all of them, making his result more reliable.

Decreases accuracy The degree of error in the volume measurement is greater since you measure 4 volumes out instead of just 1 volume like with $100cm^3$. This increses the overall error of the experiment making it less accurate because there is error each time a volume is measured.

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Examiner Comments

This candidate completes the calculations perfectly and gains the first mark in 17(b)(vi). However, the attempt to explain the decrease in accuracy implies that the more frequently a quantity is measured the less accurate it becomes. This was a common misconception based on the principle that errors are (approximately) summative.

(b) The concentration of ozone in the atmosphere may be determined by bubbling air through a solution of acidified potassium iodide. Iodine is formed in solution, the concentration of which may be determined by titration with a solution of sodium thiosulfate of known concentration. The equations for the reactions are

$$O_3 + 2I^- + 2H^+ \rightarrow O_2 + H_2O + I_2 \qquad \text{Equation 1}$$

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(i) Calculate the number of moles of sodium thiosulfate that react.

(1)

$0.0155 \times \frac{25.5}{1000} = 3.9525 \times 10^{-4}$

$= 3.95 \times 10^{-4}$ mol.

(ii) Calculate the number of moles of iodine that reacted with the sodium thiosulfate.

(2)

$\frac{3.9525 \times 10^{-4}}{2} = 1.97625 \times 10^{-4}$

$= 1.98 \times 10^{-4}$ mol.

(iii) Use equation 1 to deduce the number of moles of ozone that reacted with the acidified potassium iodide.

(1)

3.95×10^{-4} mol

(iv) Calculate the volume of ozone, measured in m^3, present in the original sample of air. Assume that all gas volumes were measured at room temperature and pressure and that the molar volume of any gas under these conditions is 0.024 $m^3\ mol^{-1}$.

(1)

$3{\cdot}9525 \times 10^{-4} \quad \times 0{\cdot}024$

$= 9{\cdot}486 \times 10^{-6}\ m^3$

(v) Calculate the concentration of ozone in the sample of air in units of parts per million (ppm) by volume.

(1)

$$\frac{9{\cdot}486 \times 10^{-6}}{100} \times \frac{10{,}000}{10{,}000}$$

$= 0{\cdot}09486$

$= 0{\cdot}0949$ ppm.

(vi) A student suggested that the 100 cm^3 of acidified potassium iodide should be divided into four portions before the titration. Explain how this change increases the reliability and decreases the accuracy of the experiment.

(3)

Increases reliability More repeats can be carried out, and the mean can be calculated.

ResultsPlus
Examiner Comments

The candidate scored the first three marks but gave the incorrect ratio of ozone to iodine. The most common error was to halve the amount of iodine calculated in 17(a)(ii) but here it is doubled. The next two calculation marks were awarded as the incorrect value from 17(a)(iii) is correctly processed. The candidate made no attempt at the final question.

ResultsPlus
Examiner Tip

Avoid leaving an answer blank.

(b) The concentration of ozone in the atmosphere may be determined by bubbling air through a solution of acidified potassium iodide. Iodine is formed in solution, the concentration of which may be determined by titration with a solution of sodium thiosulfate of known concentration. The equations for the reactions are

$$O_3 + 2I^- + 2H^+ \rightarrow O_2 + H_2O + I_2 \qquad \text{Equation 1}$$

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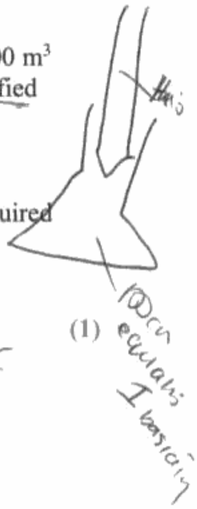

(i) Calculate the number of moles of sodium thiosulfate that react.

(1)

$\frac{25.50}{1000} \times 0.0155$ $\qquad$ $\frac{V}{1000} \times conc$

Ans = 0.00039525 mol

(ii) Calculate the number of moles of iodine that reacted with the sodium thiosulfate.

I_2 : 1mio
1 : 2
÷2 $\quad$ ÷2

(2)

$\frac{1}{2} \times 0.00039525$

Ans = 0.000197625 mol I_2

(iii) Use equation 1 to deduce the number of moles of ozone that reacted with the acidified potassium iodide.

O_3 : I_2
1 : 1

(1)

Ans 0.000197625 mol

(iv) Calculate the volume of ozone, measured in m^3, present in the original sample of air. Assume that all gas volumes were measured at room temperature and pressure and that the molar volume of any gas under these conditions is 0.024 m^3 mol^{-1}.

(1)

~~[illegible]~~ 0.000~~8~~197625 mol in 100m^3 $\times$ 0.024 ÷100

~~÷100 1.97625 $\times 10^{-6}$ mol in dm^3~~ $\times$ 0.024

~~Ans 4.743 $\times 10^{-8}$~~ Ans 4.743 $\times 10^{-6}$ m^3

dm^3 m 24

(v) Calculate the concentration of ozone in the sample of air in units of parts per million (ppm) by volume.

(1)

4.743 $\times 10^{-6}$ ppm

100m^3 y * 1000 000 dm^3 100cm = 1m

(vi) A student suggested that the 100 cm^3 of acidified potassium iodide should be divided into four portions before the titration. Explain how this change increases the reliability and decreases the accuracy of the experiment.

(3)

Increases reliability This is because the student would repeat the experiment and get more titres and can then calculate an ~~average~~ mean titre.

Decreases accuracy The acidified potassium iodide being divided in four portions would mean the titres (the sodium thiosulphate required) would be a smaller volume so percentage error would increase so hence accuracy decreases.

ResultsPlus
Examiner Comments

This response makes all the essential points in 17(b)(vi).

(b) The concentration of ozone in the atmosphere may be determined by bubbling air through a solution of acidified potassium iodide. Iodine is formed in solution, the concentration of which may be determined by titration with a solution of sodium thiosulfate of known concentration. The equations for the reactions are

$$O_3 + 2I^- + 2H^+ \rightarrow O_2 + H_2O + I_2 \qquad \text{Equation 1}$$

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The resulting solution was titrated against a solution of sodium thiosulfate of concentration 0.0155 mol dm^{-3}. The volume of sodium thiosulfate solution required for complete reaction was 25.50 cm^3.

(i) Calculate the number of moles of sodium thiosulfate that react.

(1)

0.0155 × 0.0255

~~= 0.000395 moles~~

= 0.0003953 moles

(ii) Calculate the number of moles of iodine that reacted with the sodium thiosulfate.

(2)

1:2

0.0003953 ÷ 2 = 0.0001976 moles

(iii) Use equation 1 to deduce the number of moles of ozone that reacted with the acidified potassium iodide.

(1)

1:1

= 0.0001976 moles

(iv) Calculate the volume of ozone, measured in m^3, present in the original sample of air. Assume that all gas volumes were measured at room temperature and pressure and that the molar volume of any gas under these conditions is $0.024\ m^3\ mol^{-1}$.

(1)

0.024 ; ~~0.0001976~~

$0.024 \times 0.0001976 = 4.72 \times 10^{-6}\ m^3$

(v) Calculate the concentration of ozone in the sample of air in units of parts per million (ppm) by volume.

(1)

$4.72 \times 10^{-6} \times$ ~~10000~~ 1000,000

~~= 0.0472 ppm~~ = 4.72 ppm

(vi) A student suggested that the $100\ cm^3$ of acidified potassium iodide should be divided into four portions before the titration. Explain how this change increases the reliability and decreases the accuracy of the experiment.

(3)

Increases reliability It means that the experiment can be repeated to get four different results, so that any anomalies can be identified.

Decreases accuracy Because a smaller value of volume is used, the percentage error in the readings would be greater, so the results would be less accurate.

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Examiner Comments

The mark in 17(b)(iv) is lost because of a transcription error (4.72 rather than 4.742) and in (b)(v) the factor of 1/100 has been omitted.
The candidate gains a mark for the general statement on the increase in percentage error.

ResultsPlus

Examiner Tip

It is important to relate your answer to the specific case in the question. So in 17(b)(vi) a further mark was available for specifying the volume that was decreased.

Question 17 (c)

Many candidates scored full marks for this straightforward question, although there were some that were unaware that the oxidation number of an element in its elementary state is always zero. The most common incorrect suggestion as to the role of the ozone in the reaction was to describe its part in absorbing UV radiation from the sun.

(c) Give the oxidation numbers of oxygen in equation 1, shown below. Hence state the role of ozone in this reaction.

(3)

$$O_3 + 2I^- + 2H^+ \rightarrow O_2 + H_2O + I_2$$

Oxidation number of O 0 0 -2

Role of ozone oxidising agent

ResultsPlus
Examiner Comments

A perfect answer.

(c) Give the oxidation numbers of oxygen in equation 1, shown below. Hence state the role of ozone in this reaction.

(3)

$$O_3 + 2I^- + 2H^+ \rightarrow O_2 + H_2O + I_2$$

Oxidation number of O 0 0 -2

Role of ozone To block ~~absorb~~ UV radiation.

ResultsPlus
Examiner Comments

A failure to read the question properly costs a mark.

Question 17 (d)

This question proved unexpectedly difficult for candidates who were all too often distracted by their knowledge of the role of ozone in the upper atmosphere and the effect that chlorine compounds can have in the depletion of the ozone layer in the upper atmosphere. In this, the distinction between highly reactive chlorine and long-lived chlorine compounds like CFCs was lost. The need for candidates to consider each question in its specific context cannot be emphasised too strongly.

(d) Ozone is used as an alternative to chlorine to disinfect flood damaged buildings, to remove residual smoke odours from fires and in the treatment of drinking water. Suggest one advantage of using ozone rather than chlorine, given that chlorine and ozone are both toxic.

(1)

flamable

O_3 is stable and Cl_2 is ~~flamable~~ which may causes fire

ResultsPlus
Examiner Comments

This response suggests it was just a wild guess and shows a disappointing lack of knowledge of chlorine chemistry.

ResultsPlus
Examiner Tip

There is a common sense element to this type of question in which the candidate is required to apply general and chemical knowledge to a specific, but unfamiliar, situation.

(d) Ozone is used as an alternative to chlorine to disinfect flood damaged buildings, to remove residual smoke odours from fires and in the treatment of drinking water. Suggest one advantage of using ozone rather than chlorine, given that chlorine and ozone are both toxic.

(1)

ozone can break down to form oxygen molecules and free radicals whereas chlorine breaks down to form chlorine free radicals which are ~~dangeo~~ dangerous and harmful

ResultsPlus
Examiner Comments

This response shows a failure to appreciate the distinction between the chemistry that occurs in the high energy environment of the upper atmosphere and that which occurs under normal conditions.

(d) Ozone is used as an alternative to chlorine to disinfect flood damaged buildings, to remove residual smoke odours from fires and in the treatment of drinking water. Suggest one advantage of using ozone rather than chlorine, given that chlorine and ozone are both toxic.

(1)

Ozone can be changed into oxygen (O_2) which isn't harmful to humans. This is better than having risks of being intoxicated

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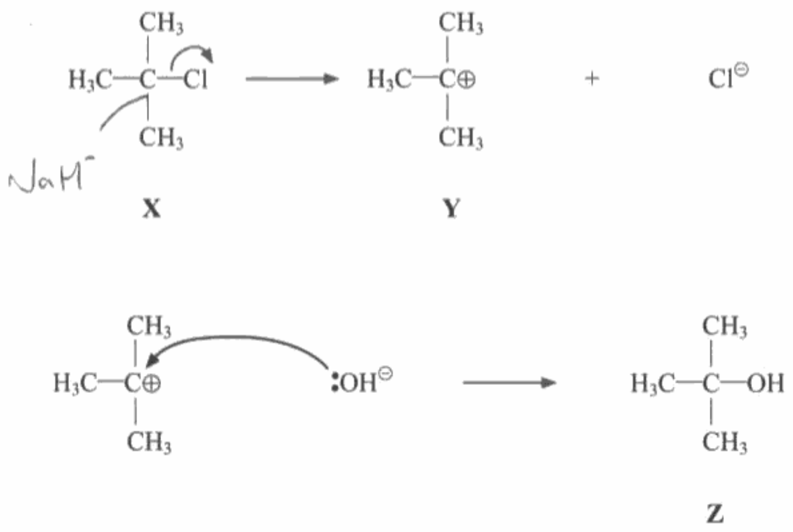
Examiner Comments

The first sentence gains the mark and the misuse of the word 'intoxicated' may be safely ignored.

Question 18 (a) (i)

Most candidates scored both marks on this question, although many were allowed despite minor inaccuracies such as the use of an incorrect order of substituents, the omission of hyphens and the insertion of spaces. The most common error was to attempt to name the carbocation, **Y**, rather than the alcohol, **Z**.

18 The steps below show the reaction mechanism for the reaction of a halogenoalkane with sodium hydroxide in aqueous solution to form an alcohol.



(a) (i) Name **X** and **Z**.

(2)

X 2-methyl -2chloro propane

Z 2methyl - propan-2-ol

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Examiner Comments

This answer scored both marks despite the incorrect order of substituents, the missing hyphens and the space between the 'chloro' and the 'propane'.

Question 18 (a) (ii)

The use of skeletal formulae is improving and most candidates scored this mark.

(ii) Draw the **skeletal** formula of **X**.

(1)

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Examiner Comments

Carbon atoms do not appear in skeletal formulae.

(ii) Draw the **skeletal** formula of **X**.

(1)

ResultsPlus
Examiner Comments

Atoms other than carbon need to have a definite bond showing how they are joined to the carbon atom.

Question 18 (a) (iii)

Z was generally recognised as a tertiary alcohol. The use of abbreviations (most usually 3º) was not penalised but should be avoided.

(iii) What type of alcohol is **Z**?

(1)

Tertiary / 3°

ResultsPlus
Examiner Comments

This scores the mark but the abbreviation should be avoided.

Question 18 (b) (i)

Both marks were usually scored on this question.

(b) (i) Name the mechanism and type of reaction shown above.

(2)

nucleophilic substitution. Sn2

ResultsPlus
Examiner Comments

If additional information is included in an answer it must be correct and, in this case, S_N2 cost a mark.

Question 18 (b) (ii)

While the great majority of candidates appreciated that the arrows represented the movement of electrons, a significant number failed to specify that the arrows in the mechanism indicated an electron pair. Given that the mechanism showed two distinct operations, there was no scope to give credit for answers focusing on heterolytic fission, which is, in any case, the outcome of the movement of the electron pair.

Question 18 (b) (iii)

Identifying the number of electrons in the valence shell of the carbocation proved a challenge, with many candidates believing that a lone pair or a single electron were present as well as the three bonding pairs. Marks were also lost through inaccurate use of terms to describe the bonding electron pairs, by references to repulsion between the methyl groups and through confusion between the ideas of maximum separation and minimum repulsion. Quite a number of candidates discussed the stability of the carbocation rather than its shape.

*(iii) Suggest the shape of the intermediate **Y**. Explain your answer.

(3)

~~pyramidal as~~ trigonal planar to provide maximum separation ~~electrons between electrons~~ between bonded pairs of electrons

ResultsPlus
Examiner Comments

This answer is a little too terse; the number of bonding pairs must be specified.

*(iii) Suggest the shape of the intermediate **Y**. Explain your answer.

(3)

Pyramidal because the central carbon has a lone pair of electrons which ~~xxx~~ repels the other methyl groups and moves them closer together.

ResultsPlus

Examiner Comments

The number of electron pairs in the valence shell is incorrect and the error is compounded by reference to the lone pair repelling the methyl groups.

*(iii) Suggest the shape of the intermediate **Y**. Explain your answer.

(3)

~~Tra~~ trigonal planar.

The carbon ($C^{\oplus}$) is attracted to three methyl groups which are repeling each other as ~~mo~~ much as possible. To minimise the repulsion, the angle between the methyl groups will ~~be~~ change from 90° to 120°

ResultsPlus

Examiner Comments

The wide range suggested for the bond angle contradicts the trigonal planar shape. Despite the reference to the mutual repulsion of the methyl groups, the 'minimum repulsion' mark is still awarded.

*(iii) Suggest the shape of the intermediate **Y**. Explain your answer.

(3)

The shape would be trigonal planar due to the fact that the 3 bonds would repel each other to be as far apart as possible and since there are no other electrons on the carbocation then there wouldn't be any othe forces of repulsion

ResultsPlus
Examiner Comments

This candidate describes repulsion between the bonds rather than the electron pairs and refers to a position of 'no repulsion' rather than 'minimum repulsion'.

ResultsPlus
Examiner Tip

Understanding the correct technical terms and using them appropriately are critical factors in examination success.

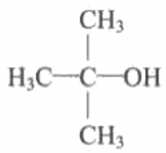
Question 18 (b) (iv)

Most candidates recognised the reaction as elimination and the alternatives had the appearance of wild guesses. Those who knew the reaction generally knew the product also although not invariably. A common error was to have a pentavalent carbon in the product structure.

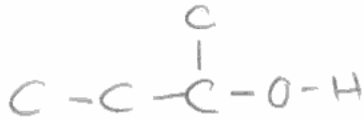
Question 18 (c)

The oxidation products of the different types of alcohols seemed well-known and the loss of marks was generally due to elementary errors in writing the formulae such as omitting atoms or presenting the same structure in a different orientation as a distinct isomer. In general, candidates seemed less fluent with abbreviated structural formulae than with displayed formulae and often preferred the latter.

(c) The alcohol **Z** (shown below) resists oxidation. However, **Z** has three structural isomers which are readily oxidized. On complete oxidation, one isomer forms a ketone and the other two isomers form carboxylic acids.

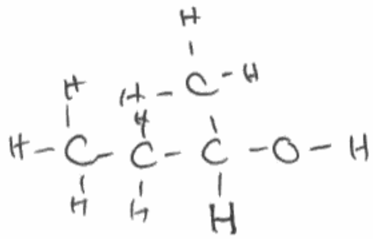


Z



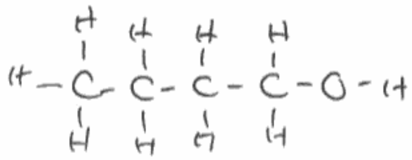
(i) Draw the structural formula of the isomer of **Z** that forms a ketone.
(1)

$CH_3CH_2CH(CH_3)OH$

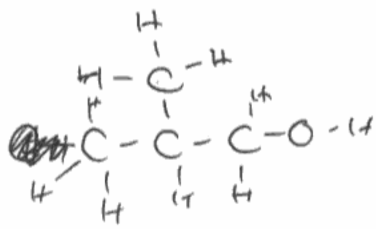


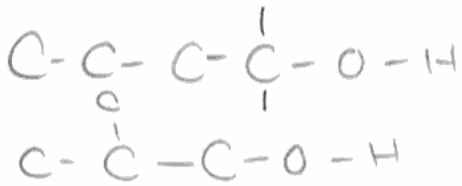
(ii) Draw the structural formulae of the isomers of **Z** that form carboxylic acids.
(2)

1. $CH_3CH_2CH_2CH_2OH$



2. $CH_3CH(CH_3)CH_2OH$





(Total for Question 18 = 15 marks)

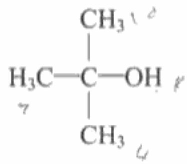
ResultsPlus
Examiner Comments

In a fairly typical response the candidate gives both displayed and structural formulae. In the latter, the use of brackets is slightly unconventional.

ResultsPlus
Examiner Tip

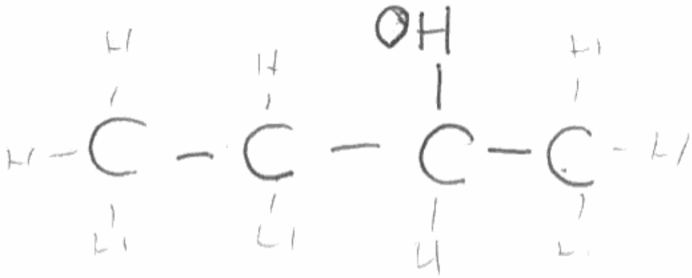
Do bear in mind that when multiple answers are given, all must be correct.

(c) The alcohol **Z** (shown below) resists oxidation. However, **Z** has three structural isomers which are readily oxidized. On complete oxidation, one isomer forms a ketone and the other two isomers form carboxylic acids.



Z

(i) Draw the structural formula of the isomer of **Z** that forms a ketone. Seconday
(1)

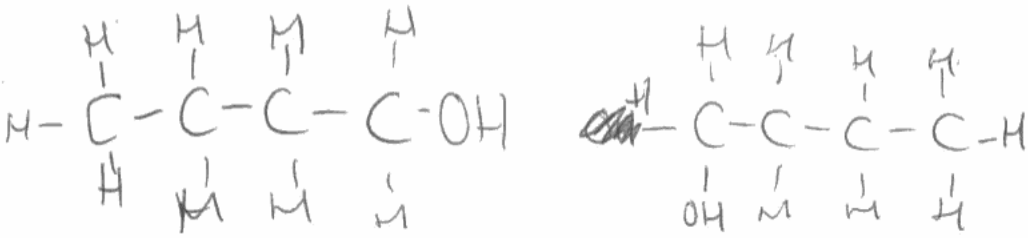


$CH_3C(OH)HCH_2$
CH_3

(ii) Draw the structural formulae of the isomers of **Z** that form carboxylic acids. primary
(2)

$CH_3CH_2CH_2CH_2(OH)$

$CH_2(OH)CH_2CH_2CH_3$

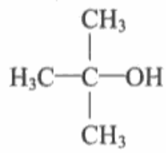


(Total for Question 18 = 15 marks)

ResultsPlus
Examiner Comments

In the first structure the carbon is clearly bonded to the hydrogen on the OH group and therefore the mark was not awarded. In part (ii) the same structure is repeated, it is just oriented differently.

(c) The alcohol **Z** (shown below) resists oxidation. However, **Z** has three structural isomers which are readily oxidized. On complete oxidation, one isomer forms a ketone and the other two isomers form carboxylic acids.



Z

(i) Draw the structural formula of the isomer of **Z** that forms a ketone.

(1)

$CH_3CH_2CH(OH)CH_3$

(ii) Draw the structural formulae of the isomers of **Z** that form carboxylic acids.

(2)

$CH_3CH_2CH_2CH_2(OH)$

$CH_3CH(CH_3)CH_2(OH)$

ResultsPlus

Examiner Comments

This response scored full marks but the brackets around the OH in (c)(ii) are unusual.

Question 19 (a) (i)

The formula of potassium nitrite was not well known and there were frequent examples of KNO or even KN in the equation. In both 19(a)(i) and 19(a)(ii) candidates included oxygen as a reactant; this was not penalised if the overall equation was balanced but candidates at this level should appreciate the distinction between heating and burning.

19 Metal nitrates decompose on heating. Potassium nitrate, KNO_3, decomposes to form potassium nitrite and oxygen, whereas calcium nitrate, $Ca(NO_3)_2$, decomposes to form calcium oxide, nitrogen dioxide and oxygen.

(a) Write equations for the decomposition of each of these metal nitrates. State symbols are **not** required.

(2)

(i) Potassium nitrate

$\cancel{2KNO_3 \rightarrow KNO\ 2KN + 3O_2}$

$\cancel{2\ KNO}\ KNO_3 \rightarrow KNO + O_2$

ResultsPlus
Examiner Comments

This response shows two fairly typical incorrect responses, one has been crossed out.

Question 19 (a) (ii)

The equation for the decomposition of calcium nitrate was more likely to be correct than that for potassium nitrate. The formulae of the products were better known and the most common problem was in balancing the equation.

(ii) Calcium nitrate

$Ca(NO_3)_2 \rightarrow CaO + NO_2 + O_2.$

ResultsPlus
Examiner Comments

There is no evidence of even an attempt to balance the equation.

ResultsPlus
Examiner Tip

Straightforward equations are usually worth just one mark so species and balancing must be correct.

(ii) Calcium nitrate

$2Ca(NO_3)_2 \rightarrow 2CaO + 2NO_2 + 3O_2$

ResultsPlus
Examiner Comments

This is an example of a common, incorrect response.

(ii) Calcium nitrate

$O_2 + Ca(NO_3)_2 \longrightarrow CaO + 2NO_2 + 2O_2$

ResultsPlus
Examiner Comments

There is oxygen on the left-hand side of this equation although the question is about heating.

ResultsPlus
Examiner Tip

Heating alone does not involve combination with oxygen.

Question 19 (b)

While the appearance of nitrogen dioxide was well known, very few candidates realised that the calcium nitrate would melt on heating.

(b) State **two** things that you would **see** when anhydrous calcium nitrate is heated. (2)

The calcium nitrate would melt into a liquid from a solid and brown gas is given off.

ResultsPlus
Examiner Comments

This is an example of a rare, excellent answer.

Question 19 (c)

While there were many excellent answers to this question, there were also a great number of poor responses which covered almost every conceivable error.

The chemistry required often seemed to be understood but not communicated unambiguously. The most common issue was the precise identification of the relevant particles. The terms atom and ion were often used as if they were synonymous and there were frequent references to the charge density and polarizing power of atoms, molecules and compounds. Many candidates believed that, because the potassium ion had a smaller charge, it also had a smaller radius. A significant group of answers offered an explanation in terms of the different numbers of nitrate ions in the two compounds.

*(c) Explain why potassium nitrate and calcium nitrate decompose to form different products.

(3)

because Ca has a small radius ~~Ka~~ and a larger charge than potassium. This means that ~~potassium~~ Calcium has a larger polarising ability than ~~Ca~~ potassium. Potassium has only +1 charge, therefore it can distort the N-O enough to make an oxide. Where as Ca has the ability to distort the N-O bond ~~and~~ make and split the ~~Oxide~~ Oxygen to make ~~a~~ CaO

ResultsPlus
Examiner Comments

This response illustrates the most common error from candidates who had a basic understanding of the Chemistry but failed to score full marks: the terms atom and ion are not distinguished.

ResultsPlus
Examiner Tip

Clarify the difference between the various particles (atom, ion and molecule) and think carefully before deciding which one to use.

Question 20 (a) (i)

The idea of greenhouse gases trapping IR radiation was well-known but the point that this radiation emanated from the surface of the Earth was often omitted. Weaker candidates suggested that greenhouse gases absorbed UV radiation from the sun.

Fuels of the Future

Concerns about the future availability of fossil fuels, and the fact that their combustion produces greenhouse gases, have led to a search for alternative sources of energy. A great deal of attention has been directed at developing the use of hydrogen as a fuel. Since the only product of its combustion is water, hydrogen is considered to be a clean fuel.

However, the use of hydrogen has major drawbacks. The small size of the hydrogen molecule means that it is difficult to prevent leaks and, to store enough to provide a reasonable amount of fuel for a car, hydrogen must be compressed to around 700 atmospheres. Furthermore, the main source of hydrogen is currently fossil fuels such as methane, which is combined with steam in a series of reactions to form carbon dioxide and hydrogen.

One suggested alternative to hydrogen is ammonia. Ammonia, which is obtained by combining nitrogen and hydrogen at temperatures around 450 °C and pressures of about 150 atmospheres, also has serious disadvantages: it is a toxic, corrosive and pungent gas which is difficult to ignite.

However, burning ammonia produces only nitrogen and water and it is relatively easy to liquefy, having a boiling temperature of just −33 °C. Furthermore, the technology works: ammonia was used as a fuel for Belgian buses in the Second World War and, in 2007, the 'NH3 Car' project based in Ann Arbor, Michigan, used a mixture of ammonia and petrol to fuel a 2500 mile journey, from Detroit to San Francisco, in a modified pickup truck.

(a) (i) Explain the term **greenhouse gas**.

(2)

A gas which is polar and absorbs infra red radiation in the atmosphere to ~~create~~ create a layer ~~trap the~~ around Earth trapping heat.

ResultsPlus
Examiner Comments

The interaction of the molecule with IR radiation is well understood but the candidate fails to identify the source of this radiation.

(a) (i) Explain the term **greenhouse gas**.

(2)

greenhouse gases are compounds which enter the upper troposphere and block infra-red radiation from escaping the atmosphere increasing global temperatures

ResultsPlus

Examiner Comments

Again the second marking point is missed.

(a) (i) Explain the term **greenhouse gas**.

(2)

greenhouse gases are those that traps infrared rays from the sun inside the atmosphere, making the earth get warmer.

ResultsPlus

Examiner Comments

The candidate incorrectly identifies the source of the IR radiation as the sun.

Question 20 (a) (ii)

Most candidates knew that the absorption of IR radiation depends on a change in polarity when a molecule vibrates and that water was a polar molecule. Some candidates were aware that water is a greenhouse gas but then simply described the trapping of heat rather than the feature of the molecule that made this possible. Some confused the absorption of the IR frequencies and the reflection of radiation by clouds.

*(ii) State and explain whether or not water (in the gaseous state) is a greenhouse gas.

(2)

Water vapour is a greenhouse gas because it contains 2 elements - Hydrogen & water. Because the bonds between hydrogen and water are polar, ~~&~~ the bonds absorb infra-red radiation, making it a greenhouse gas

ResultsPlus
Examiner Comments

The consistent use of 'water' instead of oxygen costs a mark.

ResultsPlus
Examiner Tip

Do read through what you have written.

Question 20 (a) (iii)

Despite the products of the reaction being mentioned in the passage, organic compounds, such as methanol and methanal, were frequently seen instead of carbon dioxide. There were a surprising number of responses which gave non-existent compounds as products or used CH_3 as the formula of methane. Even when the reactants and products were correct, balancing the equation proved a challenge for many candidates.

(iii) Write the equation for the formation of hydrogen from methane and steam.
State symbols are **not** required.

(2)

$$CH_4 + H_2O \rightarrow CH_3OH + H_2$$

ResultsPlus
Examiner Comments

With methanol as a product, there is no credit for the balanced equation.

Question 20 (a) (iv)

This question proved difficult for candidates to interpret and many tended to put forward generalised responses such as atom economy or global warming without any attempt to relate these concepts to the specific situation. Some did appreciate that hydrogen would be obtained from the water as well as from the methane but those that mentioned the production of carbon dioxide from the combustion of methane rarely mentioned the idea of carbon capture.

Question 20 (a) (v)

The mark for this item proved readily accessible, most often when it was appreciated that generating very high pressure requires high energy. However, there were many responses that did little more than reiterate the question, referring to the high cost of the high pressure or the equipment used without any explanation for these being so expensive.

(v) Storing hydrogen at a pressure of 700 atmospheres is a disadvantage to its use as a fuel because of the costs involved. Suggest why using such high pressures is so expensive.

(1)

its so expensive because it means a lot of equipment and would be needed to work ~~the~~ constantly.

ResultsPlus
Examiner Comments

This answer typifies the rather vague generalisations used by some candidates.

ResultsPlus
Examiner Tip

Try to relate your answers in this type of question to the specific matter under consideration.

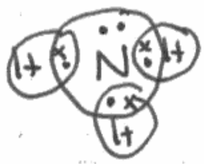
Question 20 (b) (i)

The dot and cross diagram for ammonia was completed competently by the majority of candidates although some of the diagrams showed the bonding electrons in an unusual orientation and others showed two separate electrons rather than a lone pair. The mark was most frequently lost by omitting the lone pair altogether.

(b) (i) Draw a dot and cross diagram for ammonia, showing the outer electrons only.

(1)

NH_3.



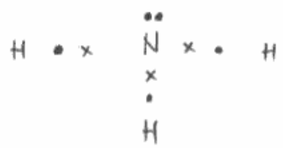
ResultsPlus

Examiner Comments

This is an example of a typical, correct response.

(b) (i) Draw a dot and cross diagram for ammonia, showing the outer electrons only.

(1)



ResultsPlus

Examiner Comments

This is an unusual way to represent shared pairs of electrons and is not recommended.

Question 20 (b) (ii)

This question covered very familiar concepts and attracted many well-prepared answers that were both concise and accurate. There were also the usual errors associated with descriptions of intermolecular forces, the most significant of these being the confusion between covalent bonds and intermolecular forces. A recurring misconception was that the presence of a lone pair of electrons was a sufficient condition for the formation of hydrogen bonds.

Question 20 (c) (i)

Despite the combustion products of ammonia being stated in the passage, many alternatives were given, the most common being one of the oxides of nitrogen and, more surprisingly, carbon dioxide. A few equations showed atomic nitrogen as a reactant and there were a small number of Haber process equations. Even when the species were correct or acceptable, balancing the equation proved beyond some candidates.

(c) (i) Write the equation for the combustion of ammonia. State symbols are **not** required.

(2)

$$2NH_3 + \tfrac{7}{2}O_2 \rightarrow 2NO_2 + 3H_2O$$

ResultsPlus
Examiner Comments

Nitrogen dioxide was a popular choice of product; there was no credit for balancing this equation.

ResultsPlus
Examiner Tip

Do read the passage carefully and make use of the information in it.

Question 20 (c) (ii)

These two marks proved fairly easy to obtain although the scoring points were often accompanied by irrelevant material. Despite the instructions in the question, there was a good deal of discussion about the enthalpies of combustion and possible environmental factors.

Question 20 (c) (iii)

Candidates who appreciated the practical aspect of this question usually gained the mark but there were still many who looked for some broader, environmental explanation.

(iii) The fact that ammonia has a pungent smell is listed as a disadvantage of its use as a fuel. Suggest why this might also be an advantage.

(1)

if there is a fuel leak it would be easy to find.

ResultsPlus
Examiner Comments

The idea of detecting a fuel leak was spotted by most candidates.

Question 20 (c) (iv)

The idea of facilitating the ignition of ammonia was not difficult, providing the passage had been read carefully, but many responses assumed that the range of the vehicle would be increased by mixing the ammonia with petrol.

(iv) Suggest why ammonia was mixed with petrol in the 'NH3 Car' project.

(1)

petrol will help ~~comb~~ combust ammonia.

ResultsPlus
Examiner Comments

This response gained a mark, but only just. The quality of the language could be improved.

ResultsPlus
Examiner Tip

Do read what you have written and try to ensure that your answer conveys the meaning that you want it to.

(iv) Suggest why ammonia was mixed with petrol in the 'NH3 Car' project.

(1)

It ~~'~~ helps prevent knocking.

ResultsPlus

Examiner Comments

This type of response, mentioning something to do with internal combustion in hope rather than expectation, was typical of candidates who had apparently not read the passage with sufficient care.

ResultsPlus

Examiner Tip

Section C is not intended as a comprehension exercise but the answers to some of the questions will be found through close reading.

(iv) Suggest why ammonia was mixed with petrol in the 'NH3 Car' project.

(1)

So it would work in the modified engine. To help the NH_3 ignite.

To reduce toxicity.

ResultsPlus

Examiner Comments

The correct answer is here but so are two incorrect suggestions. This type of list response should be avoided unless you are confident that all the answers are right.

Question 20 (c) (v)

This question was often interpreted as requiring a choice between hydrogen and ammonia despite the fact that ammonia is manufactured from hydrogen. Correct responses were based on the fact that hydrogen is manufactured from fossil fuels and very few candidates mentioned the idea of using renewable energy to extract hydrogen from water.

(v) State, with a reason, whether hydrogen or ammonia can currently be considered to be long term replacements for fossil fuels.

(1)

They can be considered but realistically, no, as the 'NH_3 car' project shows they still relied on petrol and both fuels have too many disadvantages and don't work well enough.

ResultsPlus
Examiner Comments

In this response there is no analysis, just some vague generalisations.

(v) State, with a reason, whether hydrogen or ammonia can currently be considered to be long term replacements for fossil fuels.

(1)

Ammonia. ~~Be~~ Because it does not come from fossil fuels, ~~it~~ - it is a renewable resource + will not run out. & like hydrogen,

ResultsPlus
Examiner Comments

This is a typical response comparing the two fuels and depending on the false proposition that ammonia is a renewable fuel.

Paper Summary

Candidates are advised to take note of the following in order to improve their performance in this paper:

- practise writing chemical equations
- read carefully the passage at the start of Section C
- read through what you have written and check that it answers the question in the way that you intend.

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