

Examiners' Report
January 2012

GCE Chemistry 6CH02 01

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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. With a mean score of 14.2/20, Section A was clearly accessible to almost all candidates. In Section 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 of the candidate's responses. Candidates showed a good understanding of the core concepts underlying chemical calculations and there was an improvement in the use of significant figures. 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 quality of the diagrams in 22(f)(ii) was typically rather poor. Candidates were most comfortable when dealing with questions that mainly required repetition of learned material and questions requiring them to demonstrate their understanding, notably the organic mechanism question, proved much more challenging. The practical dimension of this paper still seemed to surprise many candidates.

Question 18 (a)

There were many excellent answers to this question demonstrating a clear understanding of the nature of the intermolecular forces involved and the factors which affect their magnitude. Problems arose where candidates failed to distinguish clearly between intramolecular bonds and intermolecular forces and some clearly believed that boiling molecular substances involves the breaking of covalent bonds. Another area of difficulty was in identifying the relevant particles with many references to bromide and iodide ions and to the electronegativity of ions and of molecules.

SECTION B

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

18 The boiling temperatures of some hydrides are given below.

Compound	Boiling temperature / K
HF	293
HCl	188
HBr	206
HI	238
H ₂ O	373

*(a) Explain, by comparing the forces involved, why HI has a higher boiling temperature than HBr.

(3)

- HI has a greater number of electrons because Iodine has a greater Ar than Bromine.
- Greater Van der Waals forces between HI
- Greater induced dipole between molecules of HI
Greater distortion of electron cloud.



ResultsPlus Examiner Comments

This candidate correctly identifies the main intermolecular force involved and the factor which determines the magnitude of the force in these examples. Strictly speaking, van der Waals forces is a general term that encompasses London forces *and* permanent dipole interactions but its use was allowed for London forces in the mark scheme. Note that the candidate only makes two points so scores two marks.



ResultsPlus Examiner Tip

Make sure that the number of points in your answer corresponds to the total marks available.

SECTION B

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

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HI	238
H ₂ O	373

*(a) Explain, by comparing the forces involved, why HI has a higher boiling temperature than HBr.

(3)

HI has a higher boiling ~~temp~~^{temperature} than HBr because it has more electrons than Bromine and therefore has a greater number of dispersion forces strengthening the H-I bond. - The more electrons it has, the stronger the dispersion forces and therefore



ResultsPlus Examiner Comments

This candidate gets off to a good start with the first three lines of the answer but then spoils the answer by confusing the intermolecular forces and the covalent bond.



ResultsPlus Examiner Tip

Great care is needed with this type of question where incorrect statements can negate correct answers.

SECTION B

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

18 The boiling temperatures of some hydrides are given below.

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HCl	188
HBr	206
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*(a) Explain, by comparing the forces involved, why HI has a higher boiling temperature than HBr.

(3)

The vander waal's and/or London forces present in the HI are much ~~higher~~ ^{stronger} than those in HBr. This is due to the increase in the ^{molecular} ~~atomic~~ size of ^{the anion from Br⁻ to I⁻} I. So, with an increasing size, it becomes easier to distort the electron cloud, this, therefore results in a stronger Vander waal's force



ResultsPlus Examiner Comments

This answer also starts well but the reference to the 'molecular size of the anion' reveals serious confusion about the nature of the particles present in these molecules.



ResultsPlus Examiner Tip

Understanding the distinction between the basic particles that make up chemical compounds (atoms, ions and molecules) is fundamental to answering this type of question.

Question 18 (b)

Generally this question was more accessible to candidates than 18(a) as most were aware that the main intermolecular force in HF is hydrogen bonding. It was generally appreciated that hydrogen bonding is a particularly strong intermolecular force but few candidates showed any awareness that in HCl the London forces are much larger than the permanent dipole-dipole interactions. As in 18(a) difficulties arose due to a lack of clarity about particles and where candidates failed to distinguish bonds and intermolecular forces. This led to discussions about the electronegativity of molecules and ions. There were many answers that included detailed explanations about the formation of hydrogen bonds which were not required by the question.

* (b) Explain, by comparing the types of forces involved, why HF has a higher boiling temperature than HCl. *because of this*

(3)
HF has hydrogen bonding due to "F" being extremely electronegative. Hydrogen bonds are stronger than dipole-dipole bonds. Therefore requiring more energy to boil the HF. HCl doesn't have hydrogen bonding only dipole-dipole bonds. Therefore a lower boiling point.



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Examiner Comments

This candidate makes four good points but note the incorrect statement that HCl has *only* dipole-dipole bonds.



ResultsPlus
Examiner Tip

The use of the phrase 'dipole-dipole bonds' is technically correct but it is generally a good idea to refer to intermolecular interactions as *forces* to make clear the distinction between these and ionic or covalent bonds. The exception to this is, of course, the hydrogen *bond*.

*(b) Explain, by comparing the types of forces involved, why HF has a higher boiling temperature than HCl.

(3)
Flouride ~~to~~ ion is the most electronegative element. This electronegativity enables it to bond tightly to the hydrogen ion. The polar bonds bonds formed enable HF to form hydrogen bonds which further enhance its strength.



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Examiner Comments

There are some typical confusions in this response, notably the reference to the fluoride *ion* being the most electronegative *element* and the suggestion that HF is ionically bonded.



ResultsPlus

Examiner Tip

Only atoms have electronegativity.

*(b) Explain, by comparing the types of forces involved, why HF has a higher boiling temperature than HCl.

(3)
As HF has hydrogen bonding which is much stronger than ~~then~~ the London forces in HCl, hence HF has higher Boiling temperature



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Examiner Comments

There are only two statements in this answer that can gain credit, the final phrase being just a re-statement of part of the question. Thus, although both are fully correct, the maximum score is 2.



ResultsPlus

Examiner Tip

Do match your answer to the marks available.

*(b) Explain, by comparing the types of forces involved, why HF has a higher boiling temperature than HCl.

This is because there ~~is~~ ^{is} hydrogen bonding present in the HF molecule. ~~so it has~~ Whereas the HCl molecule has weak London forces (weak intermolecular forces) present in it. The hydrogen bonding in HF makes ~~it~~ the HF molecules have very strong bonds and these are very hard to break. This is why HF has a higher boiling point. The weak HCl bonds are easier to break, which is why it has a low boiling point compared to HF. (3)



ResultsPlus

Examiner Comments

The use of the word 'bonds' in the latter half of the question introduces an ambiguity about the forces under discussion that weakens the answer.



ResultsPlus

Examiner Tip

Do read through your answers to check that the meaning of what you have written is clear and is what you want to convey.

Question 18 (c)

There were many good answers to this question although too many candidates suggested that the individual hydrogen bond in water was stronger than that in hydrogen fluoride. Other candidates attempted to hedge their bets by referring to the stronger London forces in water. A surprising number of candidates explained that the different numbers of hydrogen bonds in the two molecules was due to the fluorine atom having fewer lone pairs than the oxygen atom. As elsewhere in question 18 there was confusion about the particles present.

(c) Suggest why H₂O has a higher boiling temperature than HF.

(1)

H₂O can form two hydrogen bonds within itself due to the presence of two highly electronegative oxygen atoms, but HF can form only one hydrogen bond. so more energy is required to break the greater extent of hydrogen bonding in H₂O than that of HF.

(Total for Question 18 = 7 marks)



ResultsPlus

Examiner Comments

It is hard for an examiner to consider the reference to two oxygen atoms in water as just a slip.



ResultsPlus

Examiner Tip

Do read through your answers!

(c) Suggest why H₂O has a higher boiling temperature than HF.

(1)

H₂O has two bonds of hydrogen with one highly electronegative element (oxygen) whereas HF only has one. Therefore more energy is needed to break the bonds in H₂O hence forming a higher boiling temperature need.



ResultsPlus

Examiner Comments

This is an all too typical confusion of covalent bonds and intermolecular forces. The candidate may know the correct answer but what is written is ambiguous.

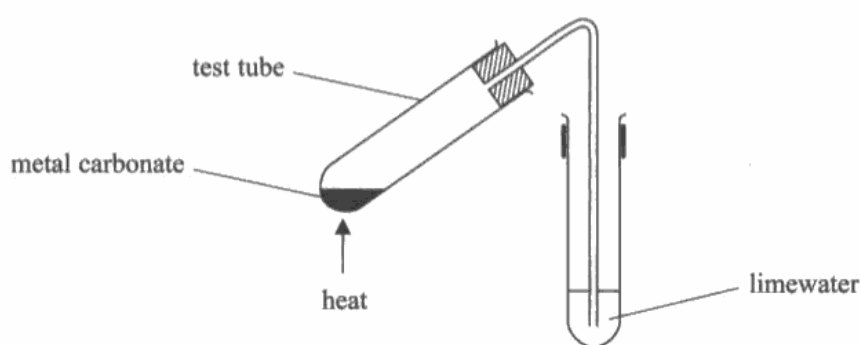
Question 19 (a) (i)

The first half of question 19 was intended to test the practical understanding of candidates by considering an experiment that could easily be carried out in a school laboratory. However, many candidates envisaged experimental methods that were far too complex, such as monitoring the mass of the carbonate or the degree of cloudiness of the lime water.

19 The carbonates of Group 2 in the Periodic Table decompose on heating to form the corresponding metal oxide and carbon dioxide. A general equation for the reaction is



The thermal stability of these carbonates can be compared in the laboratory using the apparatus in the diagram below. The test tube on the left contains a sample of a metal carbonate and the tube on the right contains limewater.



(a) (i) State the measurement that you would make in this experiment.

(1)

Volume of CO₂ gas produced



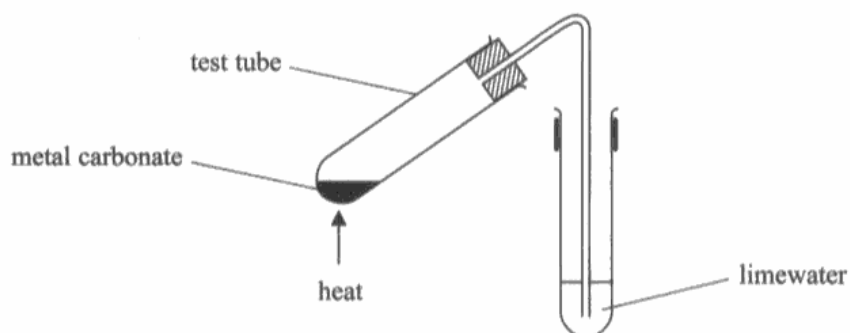
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Examiner Comments

The answer bears little relation to the apparatus in the diagram.

19 The carbonates of Group 2 in the Periodic Table decompose on heating to form the corresponding metal oxide and carbon dioxide. A general equation for the reaction is




The thermal stability of these carbonates can be compared in the laboratory using the apparatus in the diagram below. The test tube on the left contains a sample of a metal carbonate and the tube on the right contains limewater.



(a) (i) State the measurement that you would make in this experiment.

(1)

Change in mass of solid

 **ResultsPlus**
Examiner Comments
A typical incorrect answer.

Question 19 (a) (ii)

The idea of controlling key variables to ensure a 'fair test' should be well established with candidates but many slipped into reliance on generalities such as repeating experiments and using the same apparatus. It was of some concern that quite a few candidates envisaged measuring out the solid carbonate by volume or even referred to constant *concentration* of the solid. The best answers were clearly based on careful consideration of the experiment described in the question.

(ii) Suggest **three** ways to make sure that, when carrying out this experiment, the thermal stabilities of the different carbonates are compared fairly. (3)

1. Amount of metal carbonate
2. Use same temperature for each experiment
3. Use identical test tube for each metal carbonate



ResultsPlus Examiner Comments

The first point is careless; the candidate probably intends to say 'fixed amount' but has not done so.

The second point shows some understanding of what is required but ignores the practical dimension of this question; the candidate needs to consider how temperature would be kept constant.



ResultsPlus Examiner Tip

Bear in mind that your understanding of practical chemistry will be tested on the theory papers.

Make sure that your meaning is clear in your answers.

(ii) Suggest **three** ways to make sure that, when carrying out this experiment, the thermal stabilities of the different carbonates are compared fairly. (3)

1. Repeat the experiment
2. Use same amount of carbonates in each experiment
3. Use the same heating process.



ResultsPlus Examiner Comments

Once again a candidate shows an appreciation of the need to heat the carbonates in a consistent way but fails to describe how this will be achieved.

Question 19 (b) (ii)

Most candidates appreciated that this was a question about polarising power and polarisation with many excellent answers. The mark most likely to be lost was that for identifying the species (or bond) being polarised; sometimes this was omitted although a number of candidates thought the cation was polarised. As elsewhere in this paper candidates lost marks through slipshod use of terminology, for example referring to ions or even atoms rather than cations. Weaker candidates gave often extensive answers discussing shielding and bond strength without managing to touch on relevant or correct chemistry.

(b) (i) State the trend in the thermal stability of the metal carbonates as the group is descended.

(1)

Increases

*(ii) Explain this trend in stability.

(3)

as the cation increases in size there is less distortion on the anion as there is more shielding. The less distortion there is on the anion the ~~greater the~~ more stable it is. So as you go down the group ~~the cation~~ there is less distortion so it gets more stable

(Total for Question 19 = 8 marks)



ResultsPlus
Examiner Comments

This answer covers the essential points although it does not make it absolutely clear that the cation is responsible for polarising the anion.

(b) (i) State the trend in the thermal stability of the metal carbonates as the group is descended.

(1)

The thermal stability ~~decreases~~ ^{increases} :

*(ii) Explain this trend in stability.

(3)

- Thermal stability of a metal depends on its polarising power.
- As you go down the group the ionic radius increases and so the cations of group two become less electronegative and so are less polar.
- The cations ability to ~~polarise~~ ^{distort} the electron cloud of the carbonate ion decreases down the group and hence thermal stability increases down the group.

(Total for Question 19 = 8 marks)



ResultsPlus
Examiner Comments

There are the elements of a good answer here, particularly the final bullet point, but note the errors and imprecision that mar the first two points. In the first point the candidate refers to the thermal stability of the metal and 'its' polarising power. In the second point the candidate writes 'ion' rather than 'cation' and then refers to the electronegativity of the cations.

(b) (i) State the trend in the thermal stability of the metal carbonates as the group is descended.

(1)

Ans. bi) As the group is descended, thermal stability of the metal carbonates ~~increases~~ decreases.

*(ii) Explain this trend in stability.

(3)

Ans. ii). Beryllium carbonate decomposes much more ^{slowly} ~~efficiently~~ than ~~calcium~~ magnesium or calcium carbonate do. As we have kept the temperature constant in this experiment, we measure the time taken for each ^{metal} carbonate to decompose. Therefore, as the group is descended, the time taken ~~increases~~ ^{decreases}, which means that the thermal stability also ~~increases~~ ^{decreases}. This is because the size of the ionic radii increases down the group, making the metals more reactive and so they easily bond with the carbonate ion. This means when heat is provided to this molecule, because of the weak bonds, they decompose much more quickly.

(Total for Question 19 = 8 marks)

Therefore beryllium and magnesium carbonate are more stable than Barium carbonate.



ResultsPlus

Examiner Comments

This is a weak answer but it is worth noting the inappropriate use of specific group II elements in a question that clearly refers to general trends and the extensive references to the experimental results which gain no credit.

(b) (i) State the trend in the thermal stability of the metal carbonates as the group is descended.

(1)

Increases

*(ii) Explain this trend in stability.

(3)

down the group cation size increases
the charge is same which is +2, so ~~the~~
~~decreasing the~~ the charge density decrease
decreasing the polarising power so
less distortion for the cloud of
electron



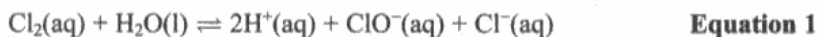
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Examiner Comments

The final mark cannot be awarded here because the candidate does not identify the electron cloud that is referred to.

Question 20 (a) (i-ii)

Most candidates were able to complete this calculation correctly although some failed to use the correct volume in 20(a)(i) and others did not use the appropriate stoichiometric ratio in 20(a)(ii).

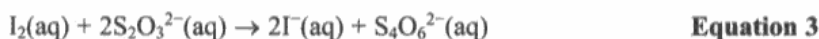
20 Chlorine disinfectants are essentially solutions containing chlorine molecules and chlorate(I) ions in an equilibrium summarised by the equation



The chlorine content of a disinfectant was determined using the following procedure.

1. 10.0 cm^3 of the disinfectant was transferred to a 250 cm^3 volumetric flask.
2. Approximately 20 cm^3 of nitric acid and 20 cm^3 potassium iodide solution (both in excess) were added to the volumetric flask.
3. The solution in the volumetric flask was made up to the mark with distilled water and then mixed thoroughly.
4. 10.0 cm^3 portions of the solution in the volumetric flask were titrated against a solution of sodium thiosulfate, concentration $0.109 \text{ mol dm}^{-3}$. Starch solution was added near the end-point of the titration and the mean (average) titre was 27.35 cm^3 .

The equations for the reactions involved in this procedure are



- (a) (i) Calculate the number of moles of sodium thiosulfate used in the titration.

$$\begin{aligned} \text{the number of moles of sodium thiosulfate} &= 0.109 \times \frac{27.35}{1000} \quad (2) \\ &= \frac{2.98115 \times 10^{-3}}{1} \\ &= 2.98 \times 10^{-3} \end{aligned}$$

- (ii) Calculate the number of moles of iodine, I_2 , that reacted in the titration (step 4).

$$\begin{aligned} \therefore \text{I}_2 : \text{S}_2\text{O}_3^{2-} &= 1:2 \quad (1) \\ \therefore \text{the number of moles of I}_2 &= \frac{2.98 \times 10^{-3}}{2} = 1.49 \times 10^{-3} \end{aligned}$$

- (iii) Hence state the number of moles of chlorine, Cl_2 , in 10.0 cm^3 of the solution in the volumetric flask.

$$\text{the number of moles of Cl}_2 = 1.49 \times 10^{-3} \times 2 \times 1000 \times 10 = 29.80 \text{ mole mol} \quad (1)$$



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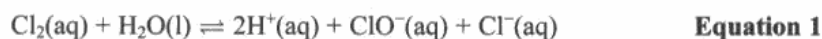
The response to 20(a)(iii) is not just incorrect but is unreasonably large.



ResultsPlus Examiner Tip

Do consider your answers to numerical questions from a common sense perspective. 30 mol of a substance dissolved in 10 cm^3 of solution is so obviously impossible that it should prompt a review of the calculation.

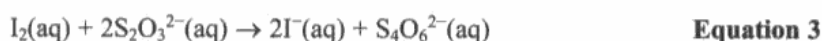
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2. Approximately 20 cm^3 of nitric acid and 20 cm^3 potassium iodide solution (both in excess) were added to the volumetric flask.
3. The solution in the volumetric flask was made up to the mark with distilled water and then mixed thoroughly.
4. 10.0 cm^3 portions of the solution in the volumetric flask were titrated against a solution of sodium thiosulfate, concentration $0.109 \text{ mol dm}^{-3}$. Starch solution was added near the end-point of the titration and the mean (average) titre was 27.35 cm^3 .

The equations for the reactions involved in this procedure are



(a) (i) Calculate the number of moles of sodium thiosulfate used in the titration.

$$n = \frac{c \times V}{1000} = \frac{0.109 \times 27.35}{1000} = \underline{\underline{2.98115 \times 10^{-3} \text{ moles}}} \quad (2)$$

(ii) Calculate the number of moles of iodine, I_2 , that reacted in the titration (step 4).

$$\frac{2.98115 \times 10^{-3}}{2} = \underline{\underline{1.490575 \times 10^{-3} \text{ moles}}} \quad (1)$$

(iii) Hence state the number of moles of chlorine, Cl_2 , in 10.0 cm^3 of the solution in the volumetric flask.

(1)

$$\underline{\underline{1.490575 \times 10^{-3} \text{ moles}}}$$



ResultsPlus Examiner Comments

This is a fully correct answer but it should not be necessary to write down so many significant figures.



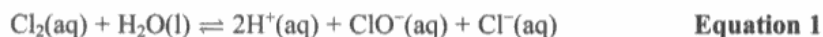
ResultsPlus Examiner Tip

In multi-step calculations retain the intermediate values in your calculator but round the answers that you write down.

Question 20 (a) (iv)

This calculation caused considerable difficulties. Most candidates realised that the answer to 20(a)(iii) needed to be multiplied by 100 but few appreciated that a further factor of 25 was needed to produce the final answer. Some candidates gave, without comment, answers that were clearly of the wrong order of magnitude.

20 Chlorine disinfectants are essentially solutions containing chlorine molecules and chlorate(I) ions in an equilibrium summarised by the equation



The chlorine content of a disinfectant was determined using the following procedure.

1. 10.0 cm³ of the disinfectant was transferred to a 250 cm³ volumetric flask.
2. Approximately 20 cm³ of nitric acid and 20 cm³ potassium iodide solution (both in excess) were added to the volumetric flask.
3. The solution in the volumetric flask was made up to the mark with distilled water and then mixed thoroughly.
4. 10.0 cm³ portions of the solution in the volumetric flask were titrated against a solution of sodium thiosulfate, concentration 0.109 mol dm⁻³. Starch solution was added near the end-point of the titration and the mean (average) titre was 27.35 cm³.

The equations for the reactions involved in this procedure are



(a) (i) Calculate the number of moles of sodium thiosulfate used in the titration.

$$\frac{\text{volume} \times \text{concentration}}{1000} = \frac{27.35 \times 0.109}{1000} = 0.00298 \text{ mol}^{(2)}$$

(ii) Calculate the number of moles of iodine, I₂, that reacted in the titration (step 4).

$$\frac{0.00298 \text{ mol}}{2} = 0.00149 \text{ mol} \quad (1)$$

(iii) Hence state the number of moles of chlorine, Cl₂, in 10.0 cm³ of the solution in the volumetric flask.

$$\frac{0.00149 \text{ mol}}{2} = 0.000745 \text{ mol} \quad (1)$$

(iv) Calculate the concentration of chlorine, in mol dm^{-3} , in the **original** disinfectant.

(2)

$$\frac{0.00149}{10} \times 1000 = 0.149 \text{ mol dm}^{-3}$$

$$\frac{\text{volume} \times \text{concentration}}{1000} = \text{moles} \qquad \frac{\text{moles} \times 1000}{\text{volume}}$$

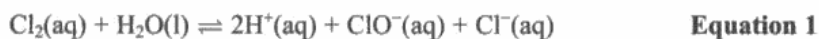
$$\frac{0.00149 \times 1000}{10} = 0.149 \text{ mol dm}^{-3}$$



ResultsPlus
Examiner Comments

This is a typical answer gaining one mark out of two.

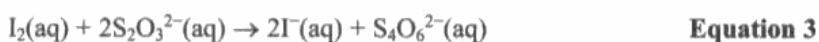
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3. The solution in the volumetric flask was made up to the mark with distilled water and then mixed thoroughly.
4. 10.0 cm³ portions of the solution in the volumetric flask were titrated against a solution of sodium thiosulfate, concentration 0.109 mol dm⁻³. Starch solution was added near the end-point of the titration and the mean (average) titre was 27.35 cm³.

The equations for the reactions involved in this procedure are



- (a) (i) Calculate the number of moles of sodium thiosulfate used in the titration. (2)

$$c = \frac{n}{v} = 0.109 = \frac{n}{27.35/1000}$$

$$n = 3.99 \text{ moles}$$

- (ii) Calculate the number of moles of iodine, I₂, that reacted in the titration (step 4). (1)

$$\frac{3.99}{2} = 1.995 \text{ moles}$$

- (iii) Hence state the number of moles of chlorine, Cl₂, in 10.0 cm³ of the solution in the volumetric flask. (1)

$$1.995 \text{ moles}$$

- (iv) Calculate the concentration of chlorine, in mol dm⁻³, in the original disinfectant. (2)

$$c = \frac{n}{v} = \frac{1.995}{0.01} = 199.5 \text{ mol dm}^{-3}$$



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Examiner Comments

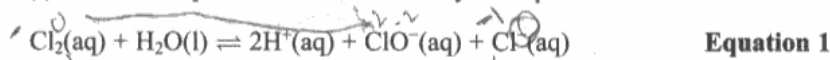
An impossibly large answer.



ResultsPlus
Examiner Tip

This is an answer that should prompt a review of the calculation that produced it.

- 20 Chlorine disinfectants are essentially solutions containing chlorine molecules and chlorate(I) ions in an equilibrium summarised by the equation

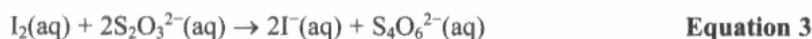


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- 10.0 cm³ portions of the solution in the volumetric flask were titrated against a solution of sodium thiosulfate, concentration 0.109 mol dm⁻³. Starch solution was added near the end-point of the titration and the mean (average) titre was 27.35 cm³.

$\frac{27.35}{1000} = 0.02735$

The equations for the reactions involved in this procedure are



- (a) (i) Calculate the number of moles of sodium thiosulfate used in the titration. (2)

$$\frac{0.109 \times 0.02735}{1000} = 2.98115 \times 10^{-6} \text{ moles of Sodium thiosulfate in the titration.}$$

- (iv) Calculate the concentration of chlorine, in mol dm⁻³, in the **original** disinfectant. (2)

$$C = \frac{n \times 1000}{V} = \frac{1.490575 \times 10^{-8} \times 1000}{0.25} = 5.9623 \times 10^{-5} \text{ mol dm}^{-3}$$



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Examiner Comments

This answer is impossibly small.

Question 20 (b)

Most candidates showed a good general understanding of the term disproportionation but a lack of precision in the answers meant that relatively few were able to score full marks. In the general definition candidates frequently failed to appreciate that disproportionation involves changes in the oxidation state of a single *element* while, in the explanation of the specific example, all too frequently neither the oxidation and reduction processes nor the species involved were clearly identified.

(b) **Equation 1** is an example of a disproportionation reaction. Define the term 'disproportionation' and explain, by considering the relevant oxidation numbers, why this reaction is a disproportionation.

(3)

Disproportionation reaction is when a species is both reduced and oxidised in the same reaction. Cl_2 is 0 and its reduced to -1 in Cl^- and also oxidised to +1 in ClO^- .



ResultsPlus

Examiner Comments

The word species is not sufficient to gain the first mark but the subsequent explanation, despite its brevity, scores the two explanation marks.

(b) **Equation 1** is an example of a disproportionation reaction. Define the term 'disproportionation' and explain, by considering the relevant oxidation numbers, why this reaction is a disproportionation.

(3)

In a same reaction taking place in a chemically closed system a simultaneous occurring of both oxidation and reduction of the same species is known as "disproportionation". Cl_2 reduces to give Cl^- and Cl oxidize to give Cl^+



ResultsPlus

Examiner Comments

The use of Cl^+ , either as a shorthand for 'chlorine in oxidation state +1' or in place of ClO^- , is very dubious.



ResultsPlus

Examiner Tip

It is best to use the full formula of the species *and* to state the oxidation number, remembering to include the sign.

(b) **Equation 1** is an example of a disproportionation reaction. Define the term 'disproportionation' and explain, by considering the relevant oxidation numbers, why this reaction is a disproportionation.

(3)

Disproportionation reaction occurs when the same reactant gets oxidised and reduced simultaneously. In reaction 1, chlorine gets reduced from 0 to -1 chlorine gets oxidised from 0 to +1.



ResultsPlus

Examiner Comments

Despite a good general understanding, imprecision cost this candidate two marks. The use of 'reactant' rather than 'element' loses the definition mark and the failure to identify the species formed in the disproportionation costs the second mark.

(b) **Equation 1** is an example of a disproportionation reaction. Define the term 'disproportionation' and explain, by considering the relevant oxidation numbers, why this reaction is a disproportionation.

(3)

Disproportionation means one element is both oxidised and reduced. Oxidation number of chlorine in Cl_2 is 0. In Cl^- , oxidation number is -1. So chlorine is reduced. In ClO^- , oxidation number of chlorine is +1. So ~~at~~ hence chlorine is oxidised.



ResultsPlus

Examiner Comments

An excellent answer.

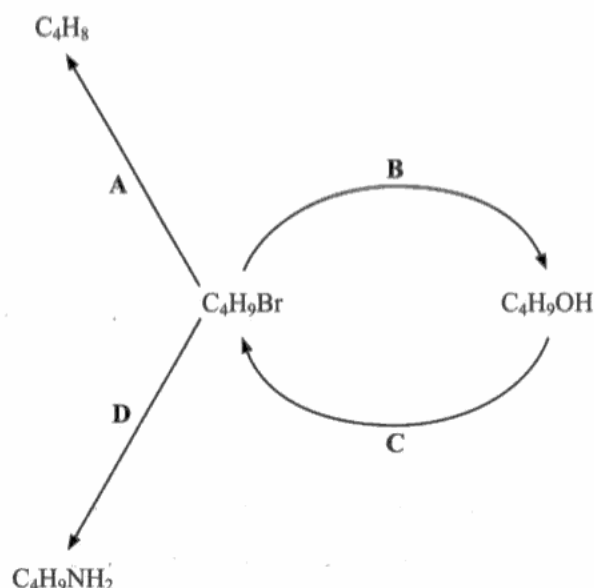
Question 20 (c)

It is important in an iodine-thiosulfate titration to add the starch solution very close to the end-point, so the *pale* in pale yellow is important.

Question 21 (a)

This question tested knowledge of the reagents and essential conditions for some basic organic reactions; these were generally well-known but a lack of precision often resulted in the loss of marks.

21 Halogenoalkanes are important intermediates in organic chemistry. The scheme below summarises some important reactions of a halogenoalkane.



(a) Identify the reagents and any specific conditions required for the reactions in the diagram. (You may assume that a suitable temperature is maintained in each reaction.)

(4)

- A Reagent - alcoholic NaOH; condition - heating under reflux
- B Reagent - aqueous NaOH; condition - heat
- C Reagent - Red phosphorus and bromine; condition - heat
- D Reagent - alcoholic ammonia; condition - heating and sealed apparatus



ResultsPlus
Examiner Comments

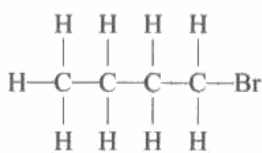
A perfect answer.

Question 21 (b) (ii)

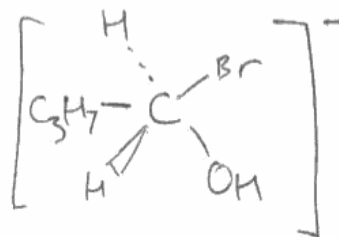
This question proved very challenging. While most candidates were able to draw the tertiary carbocation, many assumed that the formation of the primary alcohol proceeded via a primary carbocation and those who were aware of the the S_N1 mechanism were often unable to draw the transition state correctly. Some candidates simply described the S_N1 and S_N2 mechanisms without attempting to answer the actual question.

* (ii) Reaction B can proceed via two possible reaction mechanisms, depending on the structure of the original compound. For each of the two isomers of C_4H_9Br shown below, draw the structure of the intermediate or transition state which is formed during the reaction. Explain in each case why the specified structure is more favourable.

(4)



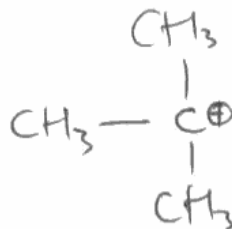
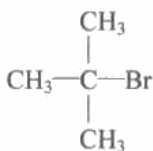
S_N2



Intermediate or transition state

••

Explanation because there isn't enough alkyl groups because of it being a primary haloalkane so it isn't strong enough to make a stable carbocation



Intermediate or transition state

••

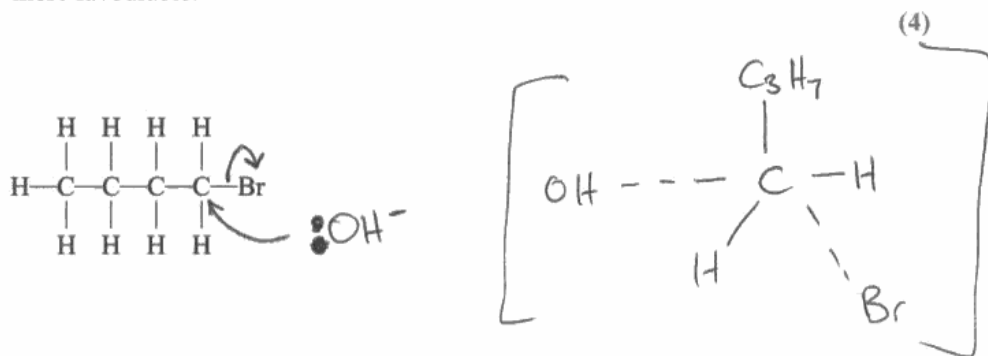
Explanation because it's a tertiary haloalkane there is 3 alkyl groups attached to the carbon meaning it is strong enough to form a stable carbocation



ResultsPlus
Examiner Comments

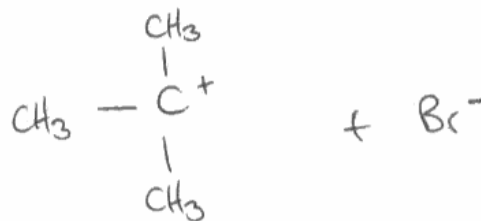
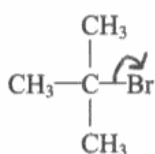
The S_N1 transition state is shown with five bonds to the central carbon rather than with the attacking OH^- and the leaving group Br^- both partially bonded to the central carbon atom. The candidate appreciates that the tertiary carbocation is more stable but the explanation of this is too confused to gain a further mark.

- *(ii) Reaction B can proceed via two possible reaction mechanisms, depending on the structure of the original compound. For each of the two isomers of C_4H_9Br shown below, draw the structure of the intermediate or transition state which is formed during the reaction. Explain in each case why the specified structure is more favourable.



Intermediate or transition state

Explanation SN_2 (2 species at beginning) due to being a primary halogenoalkane no shielding ~~is~~ \therefore reaction can occur in 1 step via a transition state.



Intermediate or transition state

Explanation SN_1 (1 species at beginning) due to being a tertiary halogenoalkane the methyl groups create a lot of shielding \therefore 2 steps required where a carbocation is formed



ResultsPlus
Examiner Comments

The transition state here has two errors: the hydrogen in the OH group is shown bonded to the central carbon and the transition state has no charge, the latter error was not penalised. The candidate has the idea that the methyl groups stabilise the tertiary carbocation but no real idea how this is effected.

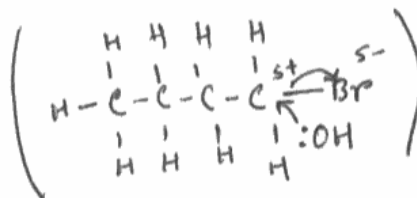
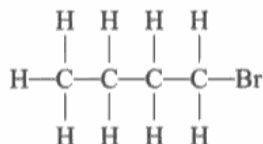


ResultsPlus
Examiner Tip

When writing equations involving ions, keep a check on the overall charge on the system, which must be constant.

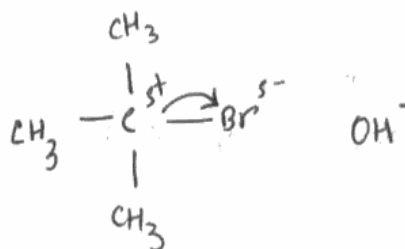
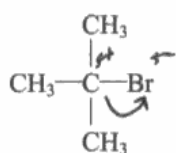
- * (ii) Reaction B can proceed via two possible reaction mechanisms, depending on the structure of the original compound. For each of the two isomers of C_4H_9Br shown below, draw the structure of the intermediate or transition state which is formed during the reaction. Explain in each case why the specified structure is more favourable.

(4)



Intermediate or transition state

Explanation Here there is plenty of space for the OH^- to attack and it does so because the carbon is not surrounded by methyl groups. This process can produce 1-bromobutane, 2-bromobutane.



Intermediate or transition state

Explanation Here the carbon is surrounded by 3 methyl groups so there is no space to attack the carbon. So the Br has to go first and then the OH^- can attack the carbon.

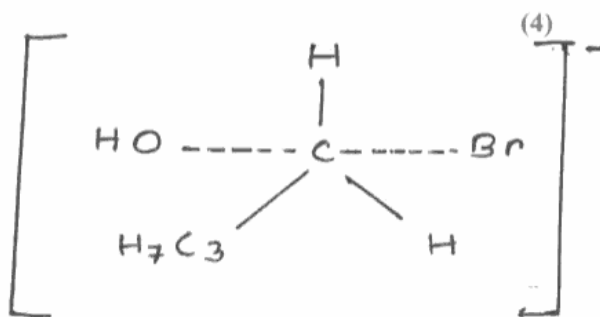
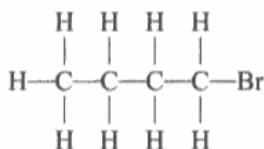
This process can only produce one type of bromobutane.



ResultsPlus
Examiner Comments

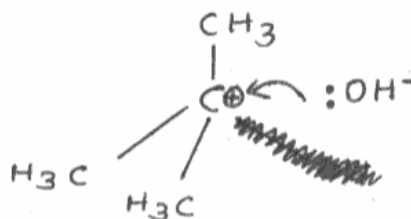
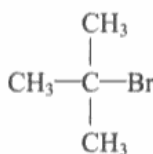
This candidate shows a reasonable understanding of the steric factors that influence the mechanism, the transition state and intermediate have not been drawn. This type of response showing the electron movements leading to the transition state and intermediate but not the actual species was quite common.

- * (ii) Reaction B can proceed via two possible reaction mechanisms, depending on the structure of the original compound. For each of the two isomers of C_4H_9Br shown below, draw the structure of the intermediate or transition state which is formed during the reaction. Explain in each case why the specified structure is more favourable.



Intermediate or transition state

Explanation The reaction goes through a transition state with no carbocation, since the carbocation formed would be a 1° or primary carbocation which is the least stable.



Intermediate or transition state

Explanation An intermediate is formed with a tertiary or 3° carbocation, since tertiary carbocations are the most stable. The electron-donating alkyl groups facilitate the heterolytic bond fission of the C-Br bond and the -OH^- nucleophile can attack the tertiary carbocation formed.



ResultsPlus
Examiner Comments

The intermediates shown here are particularly well drawn and the candidate gains a further mark for noting the (greater) stability of the tertiary carbocation. However, while the candidate is aware that the methyl groups are important in determining the mechanism, their role in stabilising the carbocation is not made clear.

Question 21 (b) (iii)

This was a straightforward question with many correct answers. Although the question was worth just one mark, many candidates gave elaborate discussions involving electronegativity differences often without touching on the key point. There were a surprising number of responses which referred to the H—X rather than the C—X bond.

(iii) If C_4H_9I is used instead of C_4H_9Br in reaction D, the rate of formation of $C_4H_9NH_2$ increases. Explain why the rate of reaction increases.

(1)

The C-I bond is weaker than the C-Br bond, therefore will break easier, so that the reaction takes place quicker.



ResultsPlus
Examiner Comments

This answer is very much to the point.

(iii) If C_4H_9I is used instead of C_4H_9Br in reaction D, the rate of formation of $C_4H_9NH_2$ increases. Explain why the rate of reaction increases.

(1)

Because Br_2 is more reactive than I_2 is substitution reaction.



ResultsPlus
Examiner Comments

More particle confusion. Here the halogen molecules are involved.

(iii) If C_4H_9I is used instead of C_4H_9Br in reaction **D**, the rate of formation of $C_4H_9NH_2$ increases. Explain why the rate of reaction increases.

(1)

Iodine is a larger molecule, with large bond length and hence weaker than the bromoalkane, so it reacts easily. Thus rate of reaction increases.



ResultsPlus

Examiner Comments

The mark cannot be awarded here because it is far from clear that the candidate is referring to the relevant bond.

Question 21 (c)

While there were many excellent answers to this question, there was some confusion about how a refrigerant cools and a failure of common sense in choosing the properties that might be desirable in a refrigerant.

Question 22 (a)

While most candidates were able to write the correct balanced equation for this reaction, a significant minority could not.

Nitrogen monoxide is an unusual molecule both in its chemical structure (shown below) and in its impact on our lives.

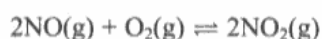


Nitrogen monoxide is an important chemical messenger in all mammals and, at appropriate concentrations, it is vital to life; however, at high concentrations in the body, it is extremely toxic.

Nitrogen monoxide is considered a dangerous atmospheric pollutant; it is involved in the formation of a range of toxic substances, including ozone, at low altitudes, and in the depletion of the ozone layer at high altitudes.

Nitrogen monoxide is formed by the direct combination of nitrogen and oxygen at high temperatures, a reaction that occurs naturally in lightning discharges, and as a by-product of the reactions in internal combustion and jet engines. Catalytic converters reduce nitrogen monoxide emissions from car engines by catalysing the reaction between nitrogen monoxide and carbon monoxide to form nitrogen and carbon dioxide.

The reactions of nitrogen monoxide which involve ozone in the atmosphere are summarised below.



When the ratio of nitrogen dioxide to nitrogen monoxide is high (> 3), the rate of formation of ozone is faster than its rate of removal. When the ratio is low (< 0.3), the reverse is true.

Ozone causes breathing difficulties, headaches, fatigue and can aggravate respiratory problems. The reaction of nitrogen monoxide with hydrocarbons can also produce other toxic compounds, such as aldehydes.

- (a) Write the equation for the formation of nitrogen monoxide from nitrogen and oxygen. State symbols are **not** required.



(1)



ResultsPlus
Examiner Comments

The most frequent error in answering this question was the use of atomic nitrogen; atomic oxygen was very rare.

SECTION C

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

22

Nitrogen monoxide is an unusual molecule both in its chemical structure (shown below) and in its impact on our lives.



Nitrogen monoxide is an important chemical messenger in all mammals and, at appropriate concentrations, it is vital to life; however, at high concentrations in the body, it is extremely toxic.

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Ozone causes breathing difficulties, headaches, fatigue and can aggravate respiratory problems. The reaction of nitrogen monoxide with hydrocarbons can also produce other toxic compounds, such as aldehydes.

- (a) Write the equation for the formation of nitrogen monoxide from nitrogen and oxygen. State symbols are **not** required.

(1)



ResultsPlus
Examiner Comments

Despite the instruction in the question, the candidate includes the state symbols. This does not affect the mark but is unnecessary.

Question 22 (b) (i)

Most candidates were familiar with the terms 'free radical' and homolytic fission.

Question 22 (c) (i-iii)


Fully correct answers to this sequence of questions were quite rare. Few candidates appreciated that unburnt fuel in vehicle exhaust emissions was the most likely source of hydrocarbons in the atmosphere and difficulties were exacerbated by poor use of language. Most candidates realised that the conversion of a hydrocarbon to an aldehyde was an oxidation reaction but there were also references to the (partial) oxidation of alcohols indicating that the question had not been fully understood. The skeletal formula question produced a range of answers. Common errors were the skeletal formula of ethanal and full structural formula of propanal.

(c) (i) Suggest the most likely source of the hydrocarbons that react with nitrogen monoxide to form toxic compounds. (1)

(ii) Suggest the type of reaction that is involved when a hydrocarbon is converted into an aldehyde. (1)

Oxidation

(iii) Draw the skeletal formula of the aldehyde with three carbon atoms. (1)



ResultsPlus Examiner Comments

The skeletal formula here scores the mark but it is preferable to indicate each carbon atom with an angle of about 90°.



ResultsPlus Examiner Tip

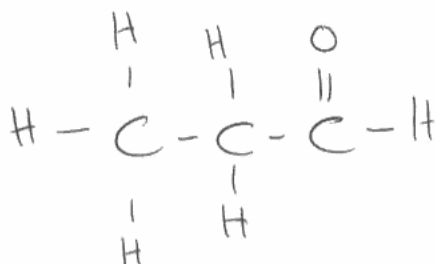
Many candidates find skeletal formulae difficult so it is well worth the time ensuring that you understand the principles and practising drawing examples.

(c) (i) Suggest the most likely source of the hydrocarbons that react with nitrogen monoxide to form toxic compounds. (1)

(ii) Suggest the type of reaction that is involved when a hydrocarbon is converted into an aldehyde. (1)

oxidation

(iii) Draw the **skeletal** formula of the aldehyde with three carbon atoms. (1)



ResultsPlus Examiner Comments

Skeletal is bold in the question but this is a full structural formula.

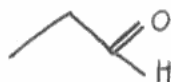
(c) (i) Suggest the most likely source of the hydrocarbons that react with nitrogen monoxide to form toxic compounds. (1)

alcohols

(ii) Suggest the type of reaction that is involved when a hydrocarbon is converted into an aldehyde. (1)

~~oxidation~~ substitution

(iii) Draw the **skeletal** formula of the aldehyde with three carbon atoms. (1)



ResultsPlus Examiner Comments

The inclusion of the hydrogen in the skeletal formula means the mark cannot be awarded.

Question 22 (c) (iv)

There were many excellent answers to this question but some candidates failed to take account of the mark allocation and gave lengthy and elaborate responses while others ignored the word 'explain'.

(iv) By considering the equation



explain the effect of the reaction of hydrocarbons with nitrogen monoxide on the breakdown of ozone.

More depletion of ozone, more breakdown of the ozone. (1)



ResultsPlus Examiner Comments

This candidate has ignored the key word 'explain' in the question and simply given the outcome of the reaction between nitrogen monoxide and hydrocarbons.



ResultsPlus Examiner Tip

Make sure that you identify the command word in a question e.g. 'state', 'identify', 'define', 'explain'. These words indicate the required scope of the answer.

(iv) By considering the equation



explain the effect of the reaction of hydrocarbons with nitrogen monoxide on the breakdown of ozone.

Nitrogen monoxide attacks the ozone layer and produces more NO_2 gas, which is a greenhouse gas and causes global warming. (1)



ResultsPlus Examiner Comments

This response not only ignores the essential point required by the question but also brings in irrelevant reference to global warming.

Question 22 (d)

Most candidates referred to the effect of UV radiation but often without mentioning that its intensity would be greater at higher altitudes. Those candidates who discussed the effect of the reduced pressure on the equilibrium were more likely to gain both marks. A surprising number of candidates believed that nitrogen dioxide was too heavy a molecule to reach high altitudes.

(d) Suggest why the proportion of nitrogen dioxide might be reduced at high altitudes.

(2)

UV radiation acts upon it and turn it into $\text{NO}^{\cdot} + \text{O}^{\cdot}$
free radicals



ResultsPlus
Examiner Comments

A typical answer which makes good use of the material in the passage but fails to address the high altitude issue.



ResultsPlus
Examiner Tip

There were two marks for this item but the answer only makes one point.

(d) Suggest why the proportion of nitrogen dioxide might be reduced at high altitudes.

(2)

~~NO~~ NO_2 is heavy, so it would normally drop back to a lower level, hence at high altitudes NO_2 is reduced.



ResultsPlus
Examiner Comments

It was surprising to find this response at AS level but the idea that NO_2 is too heavy was by no means uncommon.

Question 22 (e)

Most candidates understood the role of ozone in absorbing UV radiation and why this is important but there were many examples of careless use of terminology. Common examples were the idea that UV radiation is reflected back into space or prevented from entering the atmosphere. Some candidates failed to identify the radiation as UV, referring to 'radiation' or 'light' or UV and IR; there were many references to global warming being caused by UV radiation.

In order to prevent too much ~~UV~~ ^{UV} light coming into the atmosphere, as ~~as this~~ Too much UV light may heat up the earths atmosphere causing global warming (4)



ResultsPlus
Examiner Comments

This response contains some typical confusion about the nature of the atmosphere and the mechanism of global warming.

Question 22 (f) (i)

Some candidates failed to balance this equation and there was more use of nitrogen atoms (as in 22(a)).

(f) (i) Write an equation for the reaction on a catalytic converter described in the passage. State symbols are **not** required.

(1)



ResultsPlus
Examiner Comments

A correct answer; using $\frac{1}{2}\text{N}_2$ is perfectly acceptable.

(f) (i) Write an equation for the reaction on a catalytic converter described in the passage. State symbols are **not** required.

(1)



ResultsPlus

Examiner Comments

Another fully correct answer, this time the coefficients have been scaled up to eliminate the fraction.

(f) (i) Write an equation for the reaction on a catalytic converter described in the passage. State symbols are **not** required.

(1)



ResultsPlus

Examiner Comments

Atomic nitrogen!

Question 22 (f) (ii)

Almost all candidates had the right idea in this question; there very few Maxwell-Boltzmann distribution curves. However, as elsewhere in the paper, marks were often lost due to a lack of precision. The main problems were incorrect or missing labels although there were also some endothermic systems drawn. Most examiners commented on the poor quality of the diagrams,

Question 22 (f) (iii)

This question was very well answered with the final marking point the one most likely to be lost.

Question 22 (g)

Candidates usually appreciated the importance of aircraft flying close to the ozone layer although it was often expressed with insufficient clarity, candidates frequently stating to the effect that 'aircraft fly higher than cars'. The second mark proved more difficult to gain with vague ideas such as the time that it would take the NO to reach the upper atmosphere being fairly typical. There was also much vague reference to 'emissions' and 'pollutants' and 'greenhouse gases'.

(g) Jet aircraft are considered a greater threat to the ozone layer than road vehicles.
Suggest an explanation for this.

(2)

Jets expell their the waste products directly in the air at high altitudes This means ozone is 'found' quicker by NOx & thus more ozone is affected, whereas in road vehicles the NO will have to travel to the upper atmosphere by the most will have dissipated.

(Total for Question 22 = 20 marks)



ResultsPlus

Examiner Comments

The idea of NO being 'dissipated' is sufficient to gain the second mark.

Suggest an explanation for this.

(2)

Jet aircraft release Nitrogen monoxide higher up in the atmosphere than car engines, so are more likely to damage Ozone. The nitrogen monoxide in car engines can decompose at a lower level in the atmosphere

(Total for Question 22 = 20 marks)



ResultsPlus

Examiner Comments

The ideas in this response lack sufficient precision ('higher up in the atmosphere than car engines') and development (what exactly does the last sentence mean?)



ResultsPlus

Examiner Tip

Do ensure that what you have written fully expresses what you want to say.

(g) Jet aircraft are considered a greater threat to the ozone layer than road vehicles.
Suggest an explanation for this.

(2)

because the Jet aircraft travels closer to
the Earth's atmosphere so the harmful gases or
greenhouse gases attack the ozone layer faster,
also Jet aircrafts may produce larger amounts.

(Total for Question 22 = 20 marks)



ResultsPlus

Examiner Comments

By including irrelevant reference to greenhouse gases and a dubious statement (jet aircraft fly closer to the Earth's atmosphere) this candidate is distracted from attempting the question properly.

Paper Summary

The number of marks for a question indicates the number of scoring points the examiner will be looking for and the number of lines shows the **maximum** likely length of a reasonable response. Use this information in framing your answers.

Do read your answers carefully and check that you have answered the question set by the examiner.

The 'theory' papers will all include questions that test practical knowledge and understanding.

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