Edexcel

AS Chemistry

Questions and Answers

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Introduction

The new Edexcel specification for AS chemistry will be examined for the first time in 2009. This CD contains samples of questions that might be asked in the examinations, together with the sort of answers that an A-grade candidate should give. There is also important advice about how examinations should be tackled and examples of common mistakes made by candidates who achieve low grades. These questions with their answers provide a useful resource in the important matter of examination technique, as well as helping to clarify chemical ideas.

The questions given here are not balanced in each unit in terms of type of question or level of demand — they are not intended to typify real papers, only the sort of questions that could be asked.

The answers are those that examiners would expect from a grade-A candidate. They are not 'model answers' to be regurgitated without understanding. There are also examples of common errors that candidates make and which lead them away from the top grade.

In answers that require more extended writing, it is usually the ideas that count rather than the form of words used. The principle is that correct and relevant chemistry scores.

Below you will find important advice on how to cope with answer papers that are marked online and some information on marking exams and how this differs from the marking of homework.

The new specification

There are some significant differences in question style between previous examinations and the new ones. You should bear these differences in mind if you have to work through past papers based on the previous specification.

Multiple-choice questions

Multiple-choice questions have been re-introduced by Edexcel for first examination in 2009. These questions need to be read *carefully*; it is important not to jump to a conclusion about the answer too quickly. You need to be aware that one of the options may be a 'distracter'. For example, in a question having a numerical answer of –600 kJ mol^{-1}, a likely distracter would be +600 kJ mol^{-1}.

Some questions require you to think on paper — there is no demand that the working for multiple-choice questions be carried out in your head. Space is provided on the question paper for rough working. It is not marked, so do not write anything that matters in this space because the examiner will not see it.

Multiple-choice answers are machine-marked. For each question there are four suggested answers, A, B, C and D. You select the *best* answer by putting a cross in the box beside the letter of your choice. If you change your mind, you should put a horizontal line through the box and then indicate your alternative choice. Selecting more than one option does not earn any marks.

The Unit 1 and 2 examinations each have 20 multiple-choice questions, and these should take you no more than 20 minutes. Examination papers are often written on the basis of approximately 1 mark a minute.

Contemporary contexts

Chemistry questions often involve contexts, i.e. a particular area of chemistry is linked to an industrial process or a feature of everyday life. A context question may ask you to read a passage and then examine the underlying chemistry. It is not a simple comprehension exercise. The chemistry behind the context must be known, including any equations. It is in your answers to such questions that your quality of written communication will be assessed.

Context questions appear in Unit 2 at AS and Unit 4 at A2.

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How science works (HSW)

Although billed as new in this specification, HSW is not really new. It involves using theories and models, posing questions that can be answered scientifically, carrying out practical investigations and being able to use scientific terminology properly. All these skills have featured in previous specifications, but in the new one the role of HSW in assessment and its proportion in an examination paper are specified. It is unlikely that you would notice any difference between HSW questions and questions on similar topics from past papers.

An example of HSW involves the shapes of molecules in Unit 2. This uses the idea of minimising repulsions between the electron pairs about a given atom. In a molecule, a carbon atom having four electron pairs has a molecular shape that puts these pairs as far apart as possible, so that if all the bonds are single bonds the molecule is tetrahedral, like methane or carbon tetrachloride. This idea can be extended to predicting the shapes of other molecules. Therefore, it can be classified as HSW because it is a general theory that enables predictions to be made.

HSW includes:

- the assessment of risk in experiments, and understanding the difference between risk and hazard
- considering the way in which science is communicated and how the quality of the work is judged by other scientists (peer review)
- green chemistry; particularly the efforts to make chemical processes less hazardous and more efficient both in terms of the proportion of the atoms started with that finish up in the product (atom economy) and in terms of lower energy consumption

The examinations

The AS written examination papers (Unit 1 and Unit 2) are marked out of 80.

Unit 1 has two sections:

- Section A — multiple-choice questions, each with a choice of four answers
- Section B — a mixture of short-answer and extended-answer questions. This section looks similar to the papers in the previous modular tests, where the more extended writing is about 4 or 5 marks-worth of material.

Unit 2 has three sections:

- Section A — multiple-choice questions as in Unit 1
- Section B — a mixture of short-answer and extended-answer questions. These questions can include analysis and evaluation of practical work.
- Section C — questions using a contemporary context. An example is the industrial use of chlorine, which could cover the chemistry of the element, methods of finding the amount of chlorine in a solution by titration and a consideration of chlorofluorocarbons and their environmental effects. These questions can include the analysis and evaluation of practical work.

Marking examinations: Edexcel on-line marking (ePEN)

It is important to understand how examinations are marked, because it affects how you must present your answers. As the examiner reads your answer, decisions have to be made — is this answer worth the mark? Those who think that these decisions are always easy 'because science is right or wrong' have misunderstood the nature of marking and the nature of science.

Your job is to give the *clearest possible answer* to the question asked, in such a way that your chemical understanding is made obvious to the examiner. In particular, you must not expect the examiner to guess what is in your head; you can be judged only by what you write.

Not all marking is the same

The marking of homework or other school work is not the same as the marking of examinations. Teachers marking their students' work are engaging in formative assessment and their comments are geared towards helping students to improve their understanding of chemistry.

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It will include suggestions for improving understanding, which are far more important than the mark awarded, as is any discussion resulting from the work. An examination is a summative assessment; candidates have no opportunity to improve, so the mark is everything. This is why questions that are designed to improve your understanding of chemistry during the course are not of the same style as questions used to test that understanding at the end of a course.

You should not regard examination questions and answers as chemical education; they are an attempt to test whether you have acquired that education through the influence of your teachers and your own reading. Chemical education is designed to make you into a competent chemist rather than one who can simply regurgitate 'model answers' with no underlying understanding. If you do the necessary work throughout the course, the examination content should look after itself. What you need is the right answering technique.

Because examination answers cannot be discussed, you must make your answers as clear as possible. Do not expect examiners to guess what is in your head. This is one reason why you are expected to show working in calculations, for example. It is especially important to *think before you write*. You are given a reasonable amount of space in which to write your answer. However, differing handwriting size, false starts and crossings-out, and a tendency to repeat the question mean that this space is never exactly right for all candidates. The best advice is that *before you begin your answer you must have a clear idea of how it will end*. There is neither time nor space for subsequent editing. It is a good plan to practise putting your answer into a list of the points you wish to make, and then join them up into coherent sentences. You can also leave them as a list and still earn marks for good quality of written communication.

Read the paper through

Now that examinations are answered on the question paper and offer no choice of questions, the instruction to 'read the paper through in its entirety before starting to write' seems to have declined in importance. Candidates are, unsurprisingly, eager to get on and write something, but you should be patient.

Reading the paper through gives an opportunity for the brain to do some subconscious processing while the conscious mind is busy directing the writing. You need to have an idea of what is around the corner and what dangers to avoid. This technique becomes more important the more chemistry you know, since the A2 papers increasingly expect you to make links between different areas of the specification and to acquire synoptic understanding. These links can be made by the brain in the background during an exam while you are writing other answers. Do not underestimate the value of reading the whole paper through *before* you start to write.

Online marking: how to avoid common pitfalls

- **Do *not* write in any colour other than black. This is now an exam board regulation.**
- **Do *not* write outside the space provided without saying, *in that space*, where the remainder of the answer can be found.**

Edexcel scripts are marked online, so few examiners handle the original paper script. The process is as follows:

- The exam paper is divided into items, usually a single part of a question. These items are also called clips.
- The items are set up so that they display on screen, with check-boxes for the score and various buttons to allow the score to be submitted or for the item to be processed in some other way.
- Your written paper is scanned; from that point your paper is only handled electronically. Your answers are tagged with an identity number and each item becomes part of a pool.
- It is impossible for examiners to identify a centre or a candidate from any of the information supplied.
- Examiners mark items over about 3 weeks.

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- They are instructed on how to apply the marking scheme and are tested to make sure that they know what is required and can mark the paper fairly.
- Examiners are monitored throughout the marking period. They are prevented from marking an item if they do not achieve the necessary standard of accuracy; defective marking is re-marked.
- Examiners mark items, not whole scripts. Depending on the length of an item, between 20 and 50 examples are marked and then the examiner moves on to another item. This style of marking means that your paper could be marked by as many as 20 different people.
- Items are allocated to examiners randomly, so generally they do not see more than one item from a given candidate.

It is important to avoid the following potential pitfalls:

- Do *not* write in any colour other than black or blue. The scans are black-and-white, so any colour used simply comes out black — unless you write in red, which does not come out at all. The scanner cannot see red (or pink or orange) writing. If, for example, you want to highlight different areas under a graph, or distinguish lines on a graph, you must use a different sort of shading rather than a different colour.
- Do *not* write too small. Because the answer appears on a screen, the definition is slightly degraded. In particular, very small numbers used for powers of 10 can be difficult to see. The original paper script can be checked but it takes a long time to get hold of it.
- Do *not* write in pencil. Faint writing does not scan well.
- Do *not* write outside the space provided without saying, *within that space*, where the remainder of the answer can be found. Examiners only have access to the items they are marking; they cannot see the rest of your script. So if you carry on your answer elsewhere but do not tell the examiner within the clip that he can see that it exists, it will *not* be marked. Although the examiner cannot mark the out-of-clip work, the paper will be referred to the Principal Examiner for marking.
- Do *not* use asterisks or arrows as a means of directing examiners to out-of-clip items. Explain in words. Examiners cannot be expected to guess what the asterisks mean.
- *Do not* write across the centre fold of the paper from the left-hand to the right-hand page. A strip about 8 mm wide is lost when the papers are guillotined for scanning.
- Do *not* repeat the question in your answer. For example, the answer to the question 'Define the first ionisation energy of calcium' is 'The energy change per mole for the formation of unipositive ions from isolated calcium atoms in the gas phase' or, using an equation, 'The energy change per mole for $Ca(g) \rightarrow Ca^{+}(g) + e^{-}$'. Do *not* start by writing 'The first ionisation energy for calcium is defined as...' because this will take up most of the space available for the answer. Examiners know what the question is — you do not need to repeat it.

Rod Beavon

Rod Beavon is Head of Science at Westminster School, London and Chief Examiner for Edexcel A-Level Chemistry. The questions presented here are a sample of those that will appear in the new Unit Guides for the 2008 Edexcel specification.

For further questions and answers, with examiner comments, and specific content guidance on each unit, see our *Student Unit Guides* for Edexcel AS Chemistry (available from Autumn 2008). For more information and to order copies online, visit **www.philipallan.co.uk**, or contact Bookpoint on 01235 827720.

Edexcel AS Chemistry Student Unit Guides
978-0-340-95012-8 Edexcel AS Chemistry Unit 1: The Core Principles of Chemistry
978-0-340-94818-7 Edexcel AS Chemistry Unit 2: Applications of the Core Principles of Chemistry

Unit 1: Multiple-choice questions

Each question or incomplete statement is followed by four suggested answers, A, B, C or D. Select the *best* answer in each case. The answers are given, with some commentary, after Question 10.

1 The definition of the mole is

- ☐ **A** the number of atoms in exactly 12 grams of the isotope $^{12}_{6}C$
- ☐ **B** the number of molecules in 24 dm^3 of a gas at 273 K and 1 atm
- ☐ **C** the number of molecules in 24 dm^3 of a gas at room temperature and 1 atm
- ☐ **D** the amount of any substance containing the same number of elementary entities as there are atoms in exactly 12 grams of the isotope $^{12}_{6}C$

2 Which of the following equations is associated with the definition of the standard enthalpy of formation of carbon monoxide?

- ☐ **A** $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$
- ☐ **B** $C(graphite) + \frac{1}{2}O_2(g) \rightarrow CO(g)$
- ☐ **C** $C(s) + O(g) \rightarrow CO(g)$
- ☐ **D** $C(g) + \frac{1}{2}O_2(g) \rightarrow CO(g)$

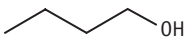
3 If the average C–H bond enthalpy is $+x$, which of the following represents a process with enthalpy change $+4x$?

- ☐ **A** $C(g) + 4H(g) \rightarrow CH_4(g)$
- ☐ **B** $CH_4(g) \rightarrow C(g) + 4H(g)$
- ☐ **C** $CH_4(g) \rightarrow C(g) + 2H_2(g)$
- ☐ **D** $C(s) + 2H_2(g) \rightarrow CH_4(g)$

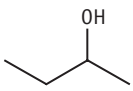
4 The elements of group 1 (Li–Cs) are very electropositive because

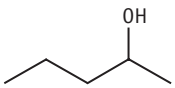
- ☐ **A** they all have small atomic radii
- ☐ **B** they all have low first ionisation energies
- ☐ **C** their ions all have a high charge density
- ☐ **D** they all have high second ionisation energies

5 The structure of butan-2-ol is represented by the skeletal formula

- ☐ **A** 

- ☐ **B**

- ☐ **C** 

- ☐ **D** 

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6 Which of processes A–D is a propagation step in the reaction between chlorine and methane in the presence of ultraviolet light?

- ☐ **A** $\bullet CH_3 + Cl\bullet \rightarrow CH_3Cl$
- ☐ **B** $CH_4 + Cl\bullet \rightarrow CH_3Cl + H\bullet$
- ☐ **C** $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
- ☐ **D** $CH_4 + Cl\bullet \rightarrow \bullet CH_3 + HCl$

7 Ethoxyethane, usually known as ether, is often used to extract organic compounds from aqueous solution. Which of its properties A–D does *not* favour its selection for this use?

- ☐ **A** it dissolves most organic compounds easily
- ☐ **B** it is immiscible with water
- ☐ **C** its air/vapour mixture is explosive
- ☐ **D** it is inert to most types of reaction

8 In an experiment to measure the enthalpy of neutralisation of hydrochloric acid, 25.0 cm^3 of hydrochloric acid containing 0.050 mol of HCl was reacted with 25.0 cm^3 of sodium hydroxide solution of the same concentration in an expanded polystyrene cup. The temperature rise was 13.7°C. The heat capacity of the solution is 4.2 $J\,g^{-1}\,°C^{-1}$ and the density is 1.00 $g\,cm^{-3}$. What is the enthalpy of neutralisation of hydrochloric acid (to 3 s.f.)?

- ☐ **A** –57.5 $kJ\,mol^{-1}$
- ☐ **B** +57.5 $kJ\,mol^{-1}$
- ☐ **C** –28.8 $kJ\,mol^{-1}$
- ☐ **D** –2.88 $kJ\,mol^{-1}$

9 The use of large amounts of disposable poly(alkene) packaging has been criticised because

- ☐ **A** a large amount of fossil fuel is burnt during its manufacture
- ☐ **B** the combustion of poly(alkene)s produces dangerous fumes
- ☐ **C** poly(alkene)s degrade to produce toxic materials
- ☐ **D** a large amount of fossil fuel is converted to the necessary monomers, such as ethene

10 The set of ions in which the members all have the same electron configuration is

- ☐ **A** Fe^{2+}, Fe^{3+}
- ☐ **B** N^{3-}, O^{2-}, F^{-}
- ☐ **C** $SO_4^{2-}, SeO_4^{2-}, TeO_4^{2-}$
- ☐ **D** F^{-}, C^{-}, Br^{-}

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Answers

1 D The general definition of the mole does not refer just to atoms. Therefore, the definition is **D**, with the proviso that 'the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles' (International Committee for Weights and Measures, 1971 and 1980). Option **A** is a statement related to the value of the Avogadro constant.

2 B This answer makes clear that the most stable form of the element carbon under standard conditions is graphite. This makes option **B** better than **A**, which is nearly right. This shows why you must read the questions carefully and not make up your mind too soon.

3 B The bond enthalpy relates to the energy change in the production of atoms, so isolated atoms must be the product if all four bonds in methane are broken.

4 B The low ionisation energies mean that this endothermic change can be recovered from the bonding produced when the cation and the anion attract one another. Options **A** and **C** are both the opposite of the truth, but **D** is true. Some of the incorrect answers to a question can be statements that in themselves are true. This is a common source of error in multiple-choice papers.

5 C The chain contains four carbon atoms with the –OH group on the second carbon. Formula A is butan-1-ol, and B and D are isomers of the 5-carbon alcohol pentanol.

6 D A propagation step must produce a radical for every radical that is used, so **B** could be an answer. However, answers do have to correspond with what actually happens in the universe.

7 C This is a **hazard** which must be overcome if ether is to be used. The **risk** from its explosive nature depends on how the ether is used. Using a fume cupboard and ensuring there are no naked flames are obvious solutions. There may be other less hazardous solvents that could be used instead.

8 A $\Delta H = \dfrac{-50.0\,\text{g} \times 4.2\,\text{J g}^{-1}\,^{\circ}\text{C}^{-1} \times 13.7\,^{\circ}\text{C}}{0.050\,\text{mol}}$

$= -57\,540\,\text{J mol}^{-1}$ or $-57.5\,\text{kJ mol}^{-1}$ to the required 3 s.f.

The other values are distracters arising from common errors in this type of calculation. The value is negative because the temperature has risen, so the reaction must be exothermic.

9 D None of A–C is true.

10 B All these ions have the electronic configuration $1s^2\,2s^2\,2p^6$, i.e. that of neon.

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Unit 1: Structured questions

Responses to questions with longer answers may have an examiner's comment, preceded by the icon *e*. Some of the comments highlight common errors made by candidates who produce work of C-grade standard or lower.

Question 11

Crude oil contains a large proportion of alkanes, which form a homologous series.

a (i) Explain the meaning of the term homologous series, using the alkanes as your example. (2 marks)

(ii) Alkanes exhibit structural isomerism. Draw the structural formulae of the three structural isomers of the alkane C_5H_{12}. (3 marks)

b Methane reacts with chlorine in the presence of ultraviolet light to give chloromethane and hydrogen chloride:

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

(i) What type of reaction is this? (1 mark)

(ii) The first step of the mechanism involves homolytic fission. Explain the meaning of the term homolytic fission. (1 mark)

(iii) Give the mechanism for the reaction between methane and chlorine, making clear which are the initiation, propagation and termination steps. (6 marks)

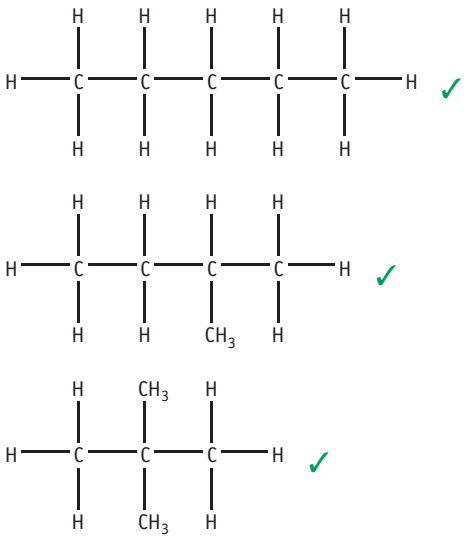
Total: 13 marks

Answers to Question 11

a (i) A series of compounds having the same general formula, in this case C_nH_{2n+2} ✓, and showing similar chemical properties ✓.

e The general formula is necessary to relate the answer to alkanes, as specified in the question. If asked about a particular type of compound, make sure that your answer is specific, not general.

(ii)



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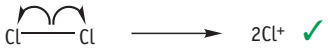
b (i) (Free) radical substitution ✓

(ii) Breaking a covalent bond so that one electron goes to each of the two species formed, which are radicals ✓

(iii) Initiation:



✓

Propagation:

$CH_4 + Cl\bullet \rightarrow \bullet CH_3 + HCl$ ✓

$\bullet CH_3 + Cl_2 \rightarrow CH_3Cl + Cl\bullet$ ✓

Termination:

$2Cl\bullet \rightarrow Cl_2$ ✓

$Cl\bullet + \bullet CH_3 \rightarrow CH_3Cl$ ✓

$2 \bullet CH_3 \rightarrow C_2H_6$ ✓

Question 12

a State Hess's law. (2 marks)

b Define the term standard enthalpy of combustion, making clear the meaning of 'standard' in this context. (3 marks)

c The equation for the combustion of ethanol in air is:

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

Calculate the enthalpy change for this reaction using the average bond enthalpy values given in the table. (3 marks)

Bond	Average bond enthalpy/ kJ mol^{-1}	Bond	Average bond enthalpy/ kJ mol^{-1}
C–H	+412	C–C	+348
C–O	+360	O–H	+463
O=O	+496	C=O	+743

Total: 8 marks

Answers to Question 12

a The heat energy/enthalpy change in a chemical reaction is independent of the route used to go from the reagents to the products ✓ provided that the initial and final states are the same ✓.

e The term *energy* change alone should not be used — this refers to a reaction at constant volume, not constant pressure.

b The heat energy change per mole ✓ for the complete combustion of a substance in excess oxygen ✓ at 1 atm pressure and stated temperature ✓.

e In practice, quoting the temperature as 298 K would also gain credit, but this temperature is not part of the definition of the standard state. *Heat* energy change, not energy change alone, is important. The energy change for a reaction is given the symbol ΔU and is measured at constant volume, not constant pressure.

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c There is no standard notation for the average bond enthalpy. Using D(X–X) to represent it for the X–X bond:

ΔH = (sum of bond energies of reagents) – (sum of bond energies of the products) ✓

= [5D(C–H) + D(C–O) + D(C–C) + D(O–H) + 3D(O=O)] – [4D(C=O) + 6D(O–H)] ✓

= [(5 × 412) + 360 + 348 + 463 + (3 × 496)] – [(4 × 743) + (6 × 463)]

= –1031 kJ mol^{-1} ✓

e Note that brackets are used to separate the enthalpy values for each type of bond. The absence of such working is characteristic of C-grade answers and is a high-risk strategy. If the answer only is shown and it is wrong, you cannot get marks for the intermediate steps.

Additionally it is important to be able to see the chemical background to the calculation. Examiners are better disposed towards candidates whose work is transparent.

Be careful to choose the correct values — for example, candidates often use the C–O bond strength for the C=O bond.

This method is the same as adding up the energies of the bonds broken, and of those made, and then ΔH = (energy of bonds broken) – (energy of bonds made).

Question 13

a (i) Complete the electronic configuration of a sulfur atom: $1s^2$…. (1 mark)

(ii) State the number of neutrons in the nucleus of an atom of ^{32}S. (1 mark)

b (i) Define the term first electron affinity. (2 marks)

(ii) The following equation represents the change occurring when the second electron affinity of sulfur is measured:

$$S^-(g) + e^- \rightarrow S^{2-}(g)$$

Explain why the second electron affinity of an element is always endothermic. (2 marks)

Total: 6 marks

Answers to Question 13

a (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ ✓

(ii) 32 – 16 = 16 ✓

e This question requires you to use the periodic table that is provided with all question papers. It is a way of finding out whether you know what the terms atomic number and mass number mean.

b (i) The energy change for the addition of one electron to each atom in 1 mole of atoms ✓ in the gas phase ✓.

e This could also be answered by means of one statement with an equation:
The energy change per mole ✓ for the process:
$X(g) + e^- \rightarrow X^-(g)$ ✓

b (ii) The negative electron is being added to a negative ion ✓ and the two negative charges repel ✓.

e Succeeding electron affinities are also positive (endothermic); in practice, simple ions of charge greater than 3– are not seen.

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Question 14

a When a sample of copper is analysed using a mass spectrometer, its atoms are ionised, accelerated, and then separated according to their mass/charge (*m/e*) ratio.

- **(i)** Explain how the atoms of the sample are ionised. (2 marks)
- **(ii)** State how the resulting ions are accelerated. (1 mark)
- **(iii)** State how the ions are separated according to their *m/e* values. (1 mark)

b For a particular sample of copper, two peaks were obtained in the mass spectrum, showing an abundance of 69.10% at *m/e* 63 and 30.90% at *m/e* 65.

- **(i)** Give the formula of the species responsible for the peak at *m/e* 65. (1 mark)
- **(ii)** State why two peaks, at *m/e* values of 63 and 65, were obtained in the mass spectrum. (1 mark)
- **(iii)** Calculate the relative atomic mass of this sample of copper to three significant figures, using the data given above. (2 marks)

Total: 8 marks

Answers to Question 14

a (i) Fast-moving *or* energetic electrons strike the atoms ✓ removing electrons from the sample atoms, forming positive ions ✓.

e The copper sample is placed on a heated probe; although the vapour pressure of copper is small, the number of atoms volatilised at the low pressure in the mass spectrometer is large enough to be detected.

(ii) In an electric *or* electrostatic field ✓

(iii) By a magnetic field ✓

b (i) $^{65}Cu^{+}$ ✓

e Many candidates forget to include the essential positive charge when giving the formulae of the ions detected by a mass spectrometer.

(ii) Because naturally occurring copper contains two isotopes of mass 63 and 65 ✓

(iii) Relative atomic mass $= \dfrac{(63 \times 69.10) + (65 \times 30.90)}{(69.10 + 30.90)}$ ✓

$= 63.6$ ✓

e The question asks for *three* significant figures. If you write 63.618 or 63.62, you will not score the mark. This is a silly way to lose marks.

Question 15

a (i) Describe one piece of evidence for the nature of the bonding in sodium chloride. (2 marks)

(ii) Explain, in terms of its bonding and structure, why the melting temperature of sodium chloride is high. (3 marks)

b Explain, in terms of its structure and bonding, why aluminium is a good conductor of electricity. (3 marks)

c Draw a dot-and-cross diagram for iodine, I_2, showing the outer electrons only. (2 marks)

Total: 11 marks

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Answers to Question 15

a (i) *Either:* electron diffraction ✓ shows zero electron density between the sodium and the chlorine ✓.
Or: molten sodium chloride will conduct electricity ✓ giving sodium at one electrode and chlorine at the other ✓.

(ii) Sodium chloride has a lattice ✓ of oppositely charged ions ✓ with strong attractions throughout the lattice ✓.

e The extension of the attractions throughout the lattice is important. No pairs of ions can be selected over any other pair; the attraction is uniform throughout the crystal. There are also repulsions in the lattice between ions of the same charge; the attraction is a net attraction.

b Metal ions are in a lattice ✓ bonded by attraction to delocalised electrons ✓. Mobile electrons enable conduction ✓.

e Make sure that you say that the electrons are mobile. Just saying that they form a 'sea' is not enough. It is also important to say that the electrons are attracted to the ions.

c

e Share pair ✓
3 lone pairs on each iodine atom ✓

The dot-and-cross diagram can use all dots or all crosses because all electrons are the same.

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Unit 2: Multiple-choice questions

Each question or incomplete statement is followed by four suggested answers, A, B, C or D. Select the *best* answer in each case. The answers are given, with some commentary, after Question 10.

1 Deuterium oxide, D_2O, is water that contains the stable hydrogen isotope ^2H, usually shown as D. When dissolved in deuterium oxide, ethanol undergoes the following reaction:

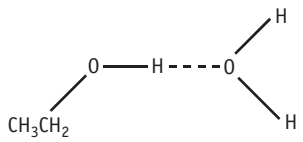
$$CH_3CH_2OH + D_2O \rightleftharpoons CH_3CH_2OD + HOD$$

The best way of showing that this reaction has occurred is

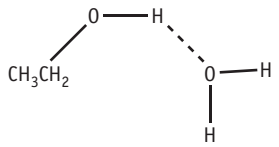
- ☐ **A** by testing the product with phosphorus pentachloride and not getting steamy fumes
- ☐ **B** by determining the mass spectrum of the mixture and showing peaks at *m/e* values of 20 and 46
- ☐ **C** by fractionally distilling the mixture and determining the amount of CH_3CH_2OD using a Geiger counter
- ☐ **D** by determining the mass spectrum of the mixture and showing peaks at *m/e* values of 19 and 47

2 Which of A–D represents most accurately the hydrogen bonding that occurs between ethanol and water?

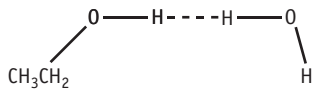
☐ **A**



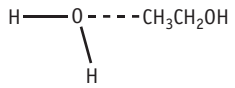
☐ **B**



☐ **C**



☐ **D**



3 A catalyst increases the rate of a chemical reaction by

- ☐ **A** lowering the activation energy for the reaction
- ☐ **B** giving the reacting molecules more energy so more of them collide successfully per unit time
- ☐ **C** providing an alternative pathway with an activation energy that is lower than that of the uncatalysed reaction
- ☐ **D** providing a surface on which the reactants can combine

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4 The shape of an ammonia molecule is

- ☐ **A** trigonal planar with three electron pairs around the nitrogen atom
- ☐ **B** tetrahedral with four electron pairs around the nitrogen atom
- ☐ **C** pyramidal with four electron pairs around the nitrogen atom
- ☐ **D** square planar with four electron pairs around the nitrogen atom

5 Radium occurs below barium in group 2. On the basis of the trends in the chemistry of group 2, which of the following statements is true?

- ☐ **A** radium sulfate is more soluble in water than magnesium sulfate
- ☐ **B** radium hydroxide is more soluble in water than calcium hydroxide
- ☐ **C** radium carbonate is more easily decomposed by heating than magnesium carbonate
- ☐ **D** radium carbonate is very soluble in water

6 A nucleophile is a species

- ☐ **A** that donates an electron pair
- ☐ **B** that accepts an electron pair
- ☐ **C** that must be negatively charged
- ☐ **D** that has a single unpaired electron

7 When iron(II) sulfate is oxidised by potassium manganate(VII), the iron(II) ions are oxidised to iron(III), and the manganate(VII) ions are reduced to Mn(II).

50.0 cm^3 of acidified iron(II) sulfate solution of concentration 0.0200 mol dm^{-3} is completely oxidised by x cm^3 of potassium manganate(VII) of concentration 0.0200 mol dm^{-3}. What is the value of x?

- ☐ **A** 10.0
- ☐ **B** 25.0
- ☐ **C** 50.0
- ☐ **D** 200.0

8 Which anions that contain chlorine are produced when chlorine gas is passed into cold, dilute sodium hydroxide solution?

- ☐ **A** Cl^-, ClO_3^-
- ☐ **B** OCl^-, Cl^-
- ☐ **C** ClO_3^-, ClO_4^-, Cl^-
- ☐ **D** ClO_3^-, OCl^-

9 An alcohol with the formula C_3H_8O is heated under reflux with an acidified solution of potassium dichromate. The organic product has the formula $C_3H_6O_2$. Which of the following statements is true?

- ☐ **A** the alcohol is a primary alcohol and it has been oxidised to an aldehyde
- ☐ **B** the alcohol is a secondary alcohol and it has been oxidised to a ketone
- ☐ **C** the alcohol is a primary alcohol and it has been oxidised to a carboxylic acid
- ☐ **D** the alcohol is a tertiary alcohol

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10 It is suggested that IR spectroscopy can be used to show that an alcohol has been oxidised to a ketone by comparing the IR spectra of the alcohol and its oxidation product. Which of the following statements is true?

- ☐ **A** the alcohol has been oxidised to a ketone if the broad O–H absorption at about 3300 cm^{-1} in the alcohol spectrum is replaced by a narrow C=O absorption at about 1700 cm^{-1} in the product spectrum
- ☐ **B** the alcohol has been oxidised to a ketone if the narrow O–H absorption at 3300 cm^{-1} in the alcohol spectrum is replaced by a broad C=O absorption at about 1700 cm^{-1} in the product spectrum
- ☐ **C** you cannot tell whether the alcohol has been oxidised to a ketone because these compounds do not absorb in the IR part of the spectrum
- ☐ **D** you cannot tell whether the alcohol has been oxidised to a ketone because both ketones and aldehydes give an IR absorption at around 1700 cm^{-1}

Answers

1 D The two peaks mentioned are due to the presence of CH_3CH_2OD and HOD, which would not have been formed in the absence of any reaction. The suggestion for the use of a Geiger counter (option **C**) might be chosen by students who think that the word 'isotope' is synonymous with 'radioactive'.

2 A In a hydrogen bond, the hydrogen atom forms a bridge between two electronegative atoms; in this case, both are oxygen. However the hydrogen bond is also linear: O–H-----O is, therefore, a more accurate representation than the diagram shown in option **B**.

3 C The essential feature of a catalyst is that it changes the mechanism of a reaction to one that has lower activation energy than the uncatalysed reaction. The activation energy for a particular reaction mechanism is intrinsic to that mechanism and cannot be changed. Option **D** is often true, but does not apply to all catalysts.

4 C The nitrogen atom in ammonia has three bond pairs and one lone pair. The basis of its shape is the (nearly) tetrahedral arrangement of these electron pairs, but the name of its shape is defined by the atom centres and is pyramidal.

5 B The solubility of the hydroxides of group 2 metals in water increases with increasing atomic mass of the metal (i.e. down the group). All the other suggestions are opposite to the actual trends in the group.

6 A All nucleophiles donate an electron pair, but they do not have to be negatively charged. Both water and ammonia are nucleophilic reagents.

7 A Oxidation of Fe^{2+} to Fe^{3+} is a one-electron change; reduction of MnO_4^- to Mn^{2+} is a five-electron change. The concentrations of the solutions are the same, so the volume of manganate(VII) solution required is one-fifth that of the iron(II) solution.

8 B The ionic equation for the reaction is $Cl_2 + 2OH^- \rightarrow Cl^- + OCl^- + H_2O$. The chlorine has disproportionated. The answer would be **A** if the sodium hydroxide solution had been hot, since OCl^- ions disproportionate on heating to chloride ions and chlorate(V) ions.

9 C Since the only product options for alcohol oxidation are aldehydes, ketones (both with only one oxygen atom) and carboxylic acids, the latter must be the product.

10 D The O–H absorption is broad and the C=O absorption is narrow, so **A** is true; but the point is that aldehydes and ketones cannot be distinguished by their C=O peaks.

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Unit 2: Structured questions

Responses to questions with longer answers may have an examiner's comment, preceded by the icon *e*. Some of the comments highlight common errors made by candidates who produce work of C-grade standard or lower.

Question 11

The catalysed reaction between sulfur dioxide and oxygen is a dynamic equilibrium:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

a Explain what is meant by dynamic equilibrium. (2 marks)

b In the table below, state the effect on this reaction of increasing the temperature and of increasing the pressure.

	Effect on the rate of the reaction	**Effect on the position of equilibrium**
Increasing the temperature		
Increasing the pressure	Stays the same	

(3 marks)

c This reaction is one of the steps in the industrial production of sulfuric acid. The normal operating conditions are a temperature of 450°C, a pressure of 2 atm and the use of a catalyst. Justify the use of these conditions:

(i) temperature of 450°C (2 marks)

(ii) pressure of 2 atm (2 marks)

(iii) catalyst (1 mark)

d Name the catalyst used. (1 mark)

Total: 11 marks

Answers to Question 11

a The forward and backward reactions are occurring at the same rate ✓, so there is no net change in composition ✓.

e The first mark is for *dynamic* and the second for *equilibrium*.

b

	Effect on the rate of the reaction	**Effect on the position of equilibrium**
Increasing the temperature	Increases ✓	Moves to the left ✓
Increasing the pressure	Stays the same	Moves to the right ✓

e The equilibrium mixture does not *move* in a physical sense. The terms are used as shorthand — 'moves to the right' means that the concentrations of the substances on the right-hand side of the equation (the products, conventionally) increase.

The effect of an increase in pressure on the rate of a heterogeneously catalysed reaction is negligible. The reactants have a strong affinity for the surface of the catalyst. At all pressures (other than extremely low), the catalyst surface, which is where the reaction

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occurs, is saturated with the reactants and so increasing the pressure makes no difference. This point is commonly misunderstood.

e The equilibrium composition changes in a way that *tends* to oppose the imposed change. For example, increasing the temperature causes more energy to be absorbed, but this does not bring the temperature down again. The changes are to the *equilibrium* conditions — the alteration in composition has no effect on the conditions that are externally imposed.

c (i) The temperature needs to be high to give an acceptable rate but low to achieve an acceptable yield ✓; the temperature used is therefore a compromise *or* the temperature is the optimum for the catalyst used ✓.

(ii) High pressure increases the yield but is not necessary since an acceptable yield is obtainable at low pressures; *or* you need a high enough pressure to drive the gases through the catalyst bed(s) ✓; an increase in pressure would increase yield but this would not offset the increase in costs ✓.

e The yield is high because, in practice, four catalyst beds are used at different temperatures and these are efficient enough at low pressure. High-pressure sulfur trioxide is extremely corrosive. The use of high pressure would also cause the sulfur dioxide to liquefy in those parts of the plant that are at low temperature. The biggest cost in using high pressure is the cost of fuel for compressing the gases.

(iii) Increases reaction rate ✓

e The implication from a cost–yield viewpoint is that the rate becomes acceptable at a lower temperature than would otherwise be the case.

d Vanadium(V) oxide ✓ *or* vanadium pentoxide

e Platinum can be used in the laboratory, but it is not used industrially, so it is not an acceptable answer.

Question 12

The rate of a chemical reaction increases as the temperature is increased.

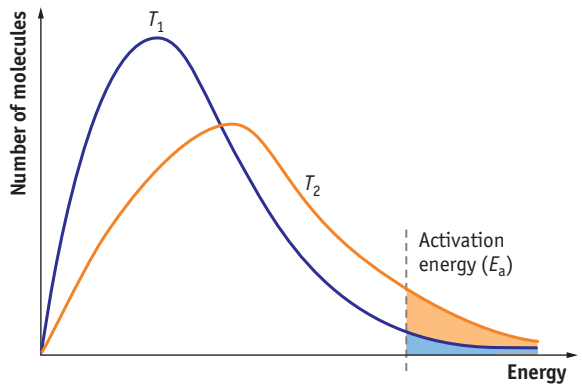
a Draw a diagram of the Maxwell–Boltzmann distribution of molecular energies at a temperature T_1 and at a higher temperature T_2. (3 marks)

b Use your diagram and the idea of activation energy to explain why the rate of a chemical reaction increases with increasing temperature. (4 marks)

Total: 7 marks

Answers to Question 12

a



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e Correctly labelled axes ✓; curve for T_1 skewed and correct shape within reason (starts at the origin and does not intercept the x-axis at high energy) ✓; curve for T_2 with peak to the right and lower ✓

The Maxwell–Boltzmann curve has a well-defined shape and you are expected to be able to reproduce it accurately. Common errors include drawing a curve that is symmetrical or a curve that either starts part way up the *y*-axis or intersects the *x*-axis. The Maxwell–Boltzmann curve is not like a normal distribution (bell) curve.

b E_a shown *on the diagram* well to the right of the peak ✓; area under the curve for energies above E_a is higher for T_2 than for T_1 ✓ so there is a *higher proportion of* successful ✓ collisions, since collision energy > E_a for these molecules ✓.

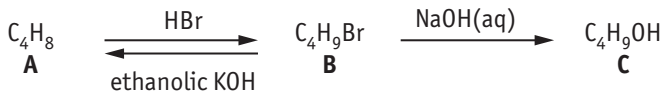
e The idea of *collision* energy is important, as is the ability to see kinetics in terms of particle interactions. If you do not refer to the diagram, you can earn a maximum of only 3 marks.

The *higher proportion of* successful collisions is an important, but subtle, point. It is not true to say, as many candidates do, that the number of collisions increases. Overall, the number of collisions leading to reaction for the same amount of product is the same. It is the *time* during which these collisions occur that matters. You could also say that the number of successful collisions *per unit time* increases.

Remember that your script is scanned before marking, so different colours cannot be distinguished and red is not picked up. When you shade the areas under the curves, you use different types of shading or hatching, not colours.

Question 13

Consider the following series of reactions, and then answer the questions that follow:



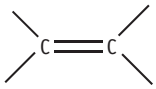
a (i) Compound A is an alkene that has two geometric isomers. Draw their structural formulae. (2 marks)

(ii) State the two features of the molecule that makes this isomerism possible. (2 marks)

(iii) Stating what you would see, give a simple chemical test for the functional group present in compound A. (2 marks)

(iv) What type of reaction is the conversion of compound A to compound B? (1 mark)

(v) Draw the mechanism for the reaction of compound A with hydrogen bromide. In your mechanism, the alkene (A) can be represented simply as:



(3 marks)

(vi) What type of reaction is the conversion of compound B to compound A? (1 mark)

b (i) The reaction of compound B to give compound C is a nucleophilic substitution. What is meant by the term nucleophile? (1 mark)

(ii) Give the full structural formula of compound C. (1 mark)

(iii) Give a simple chemical test for the functional group in compound C. Describe what you would see as a result of this test. (2 marks)

(iv) Give the full structural formula for the compound obtained by heating compound C with acidified potassium dichromate solution. (2 marks)

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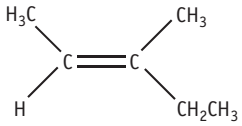
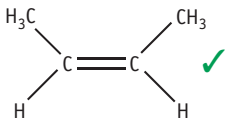
c The alkene 3-methylpent-2-ene has two geometric isomers. Giving your reasons, state whether the isomer shown below is the *E*-isomer or the *Z*-isomer. (2 marks)

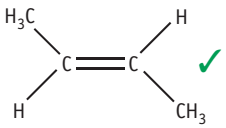


Total: 19 marks

Answers to Question 13

a (i)





e Each correct structure scores 1 mark.

(ii) Restricted (or no) rotation about the C=C bond ✓ and the two groups on a given carbon in the double bond are different ✓

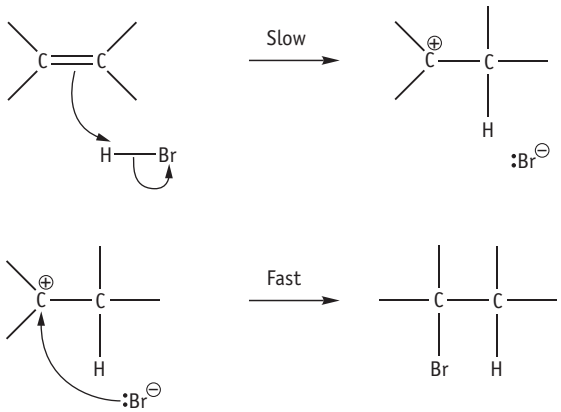
e The requirement that the groups on a given carbon must be different is often missed.

(iii) Bromine water ✓ is decolorised from yellow (or orange) to colourless ✓.

e Note the difference between *colourless* (no colour) and *clear*, which means see-through and can be any colour. Confusion between the two is common. The fail-safe answer to all questions involving colour changes is to give the starting and finishing colours.

(iv) Electrophilic addition ✓

(v)



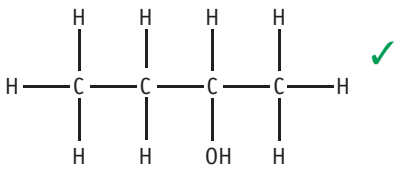
The marks are for the two arrows initially ✓, for the structure of the carbocation intermediate ✓, and for the arrow in the second step ✓ to give the product.

e The arrows show the movement of electron pairs and it is important to show their positions accurately. It is not *essential* to show the lone pair on the bromide ion, but it is better to include it because the lone pair makes the bromide a nucleophile. Similarly the labels 'slow' and 'fast' do not have to be added, but the statements are true so why not include them? Candidates seldom do — but it is knowledge of such details that indicates A-grade performance.

(vi) Elimination ✓

b (i) An electron-pair donor ✓

(ii)

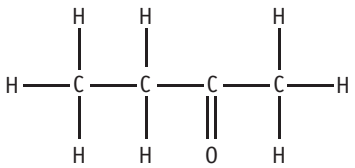


The use of 'full' in the question suggests that the displayed formula is the one to use — and it is the one to use if in any doubt. The hydroxyl group is generally accepted as shown, without the O–H bond being explicitly shown.

(iii) Add phosphorus pentachloride ✓; steamy (acidic) fumes ✓

'Acid fumes' alone would not score because you cannot see that the fumes are acidic; nor are the fumes white, which is a common error.

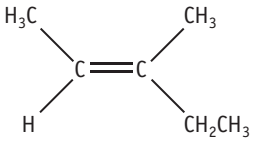
(iv)



✓✓

There is 1 mark for the structure being a ketone and 1 mark for it being the correct ketone.

c In the structure:



the methyl group on the left-hand carbon atom takes precedence and the ethyl group on the right-hand carbon takes precedence ✓; these are across the double bond, so the isomer is the *E*-isomer ✓ (*entgegen*).

Note that if this molecule is named using the *cis–trans* notation, it is the *cis*-isomer. The molecule is (*E*)-3-methylpent-2-ene.

In this question many of the parts depend on the previous part. So, if you think that compound A is but-1-ene, you might forget Markovnikoff's rule and think that compound B is a primary halogenoalkane and that compound C is a primary alcohol, which oxidises to an aldehyde or to a carboxylic acid. This would be taken into account in the mark scheme, so that marks could still be scored, even though an initial error had been made.

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Unit 2: Context question

In past context questions the context was often supplied as a short statement, rather than a longer passage. Note particularly that the passage gives the context but the question is about the chemistry; this is not a comprehension exercise. Extended writing is also required.

Question 14

The halogens, group 7, are important elements that are used widely. Chlorine is the most significant element in the maintenance of public health because of its use in the disinfection of water supplies. In early Victorian times, cholera was common in London and elsewhere and it was through proper sewage disposal and also the treatment of drinking water with chlorine that the disease was eliminated. Chlorine and its compounds are important as bleaches and disinfectants, and in the extraction of bromine. Halogenated compounds are used widely as anti-stick coatings, anaesthetics, flame-proofing agents, photographic chemicals, for the manufacture of window frames and piping and as intermediates in chemical synthesis in the pharmaceutical industry. The 1906 Nobel Prize in chemistry was awarded to Henri Moissan for his discovery, in 1886, of fluorine, the most reactive of all elements.

a Seawater contains aqueous bromide ions. During the manufacture of bromine, seawater is treated with chlorine gas and the following reaction occurs:

$$2Br^- + Cl_2 \rightarrow Br_2 + 2Cl^-$$

(i) Explain the term oxidation in terms of electron transfer. (1 mark)

(ii) Explain the term oxidising agent in terms of electron transfer. (1 mark)

(iii) State which of the elements, chlorine or bromine, is the stronger oxidising agent. Explain the importance of this in the extraction of bromine from seawater, as represented by the equation above. (2 marks)

b When sodium chlorate(I), NaClO, is heated, sodium chlorate(V) and sodium chloride are formed.

(i) Write the ionic equation for this reaction. (2 marks)

(ii) What type of reaction is this? (1 mark)

c During the process for the manufacture of iodine the following reaction occurs:

$$2IO_3^- + 5SO_2 + 4H_2O \rightarrow I_2 + 8H^+ + 5SO_4^{2-}$$

(i) State the oxidation numbers of sulfur in SO_2 and SO_4^{2-}. (2 marks)

(ii) Use your answer to part c(i) to explain whether SO_2 is oxidised or reduced in the above reaction. (2 marks)

(iii) Name a reagent that could be used to confirm that a solution contains iodine. State what you would see. (2 marks)

d Chlorofluorocarbons, or CFCs, have been used widely as refrigerants and in aerosol propellants. Their use is appealing because they are inert and non-toxic. However, their use is being discontinued because they are environmentally damaging. Explain the circumstances under which CFCs harm the environment. Illustrate your answer with suitable equations. (6 marks)

Total: 19 marks

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Answers to Question 14

a (i) Oxidation is electron loss ✓.

(ii) An oxidising agent gains electrons ✓.

(iii) Chlorine is the stronger oxidising agent ✓; it removes electrons from bromide ions ✓ to produce bromine.

e It is important to distinguish between bromine and bromide. Always make clear which species is under consideration. Similarly 'magnesium' is an element — if you mean 'magnesium ions' (Mg^{2+}), you must include the word 'ions'.

b (i) $3ClO^- \rightarrow 2Cl^- + ClO_3^-$

e There is 1 mark for the species and 1 mark for the balanced equation. Note that the question asks specifically for the ionic equation. The non-ionic version including the sodium might get 1 mark.

(ii) Disproportionation ✓

e It is true that this is also a redox reaction. However, it is a particular type of redox reaction and this is the more significant piece of information.

c (i) In SO_2 the oxidation number of sulfur is +4 ✓; in SO_4^{2-} it is +6 ✓.

e Note that there is no credit for showing any working because there is only 1 mark available for each answer. This is unlike other calculation-type questions in which there are often marks available for working, even if the answer is wrong.

(ii) Oxidised ✓ because the oxidation state of sulfur has increased ✓.

(iii) Starch ✓; it turns blue-black ✓.

e Starch-iodide paper should not be used in this test; the iodide ions could be oxidised to iodine by either chlorine or bromine, so starch-iodide paper turns blue-black with all the halogens. Starch turns blue-black only with iodine.

d —

e There are many answers to this question. Your answer should have six of the following scoring points (✓) written in a logical manner and in good English; at least one of the scoring points must be an equation. Quality of written communication is always assessed in the context question.

- CFCs are decomposed by ultraviolet light ✓ to give chlorine radicals.
- $CF_3Cl \rightarrow \bullet CF_3 + Cl\bullet$ ✓
- Chlorine radicals catalyse the decomposition of ozone ✓.
- One chlorine radical can destroy many ozone molecule ✓
- $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ ✓
- $ClO\bullet + O\bullet \rightarrow Cl\bullet + O_2$ ✓
- Ozone protects the surface of the Earth against harmful ultraviolet radiation ✓.
- Higher ultraviolet levels could increase the incidence of skin cancer ✓.
- CFC molecules absorb infrared radiation ✓ because their polarity alters when the bonds vibrate ✓.
- CFCs are, therefore, greenhouse gases ✓.

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e When answering questions about environmental matters such as the greenhouse effect, try to retain a sense of proportion. Many student answers are almost apocalyptic. This is not appropriate in a science examination. Remember that the science behind ozone depletion and the absorption of infrared radiation may be good, but the predictions of the long-term effects are controversial.

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