

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- Show all your working in calculations and include units where appropriate.

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, including your use of grammar, punctuation and spelling.
- There is a Periodic Table on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Good luck with your examination.

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SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☐.

If you change your mind, put a line through the box ☐ and then mark your new answer with a cross ☐.

- 1 The numbers of subatomic particles present in four species **W**, **X**, **Y** and **Z** are given in the table.

Species	Number of protons	Number of neutrons	Number of electrons
W	19	20	18
X	19	20	19
Y	20	20	18
Z	20	22	20

Which of these species are isotopic?

- ☐ **A** **W** and **X**
- ☐ **B** **W** and **Y**
- ☐ **C** **X** and **Z**
- ☐ **D** **Y** and **Z**

(Total for Question 1 = 1 mark)

- 2 Iodine exists as one isotope with mass number 127.

Chlorine exists as two isotopes with mass numbers 35 and 37.

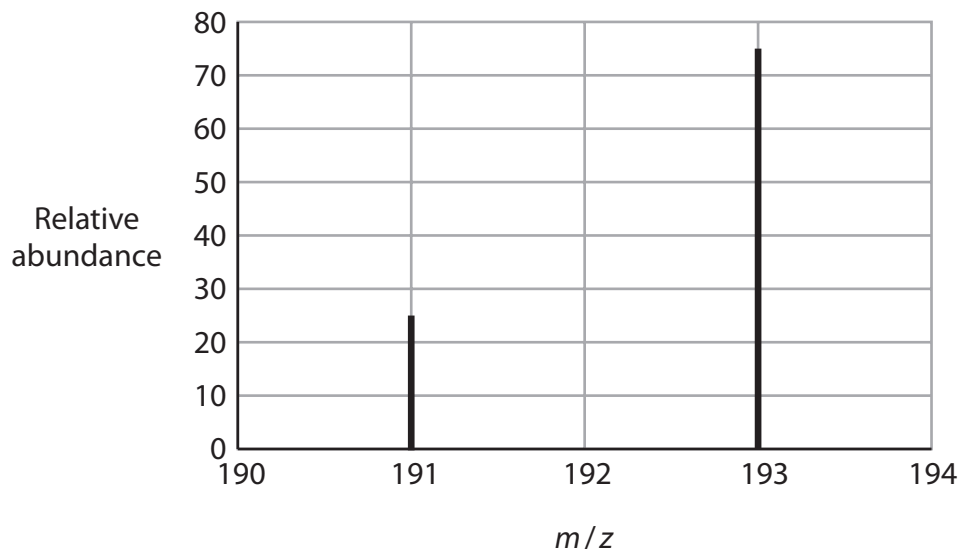
How many molecular ion (ICl_3^+) peaks are there in the mass spectrum of ICl_3 ?

- ☐ **A** 2
- ☐ **B** 3
- ☐ **C** 4
- ☐ **D** 5

(Total for Question 2 = 1 mark)



- 3 The mass spectrum of a sample of an element has only two peaks.



What is the approximate relative atomic mass of the element in this sample?

- ☐ A 191.5
- ☐ B 192.0
- ☐ C 192.5
- ☐ D 193.0

(Total for Question 3 = 1 mark)

- 4 Which equation represents the **second** ionisation energy of magnesium?

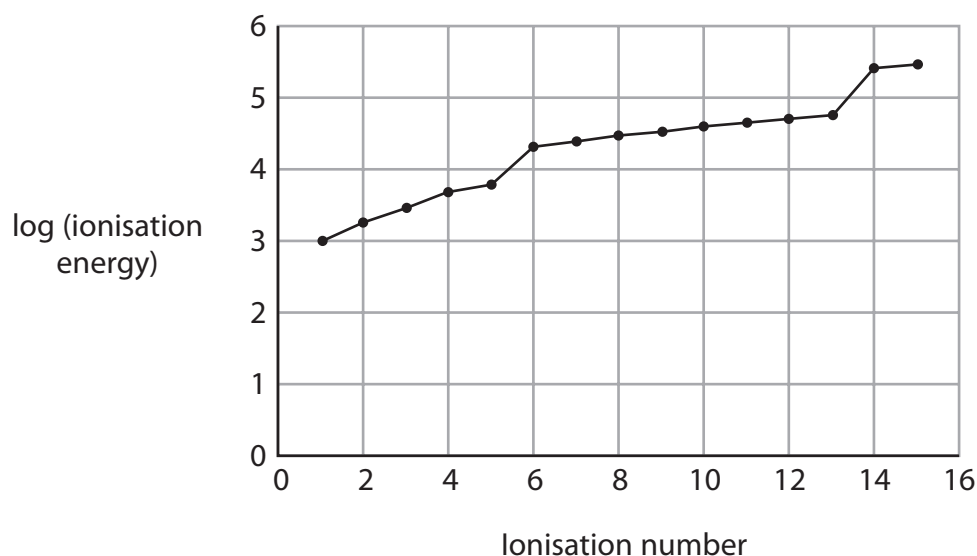
- ☐ A $\text{Mg(g)} \rightarrow \text{Mg}^{2+}(\text{g}) + 2\text{e}^{-}$
- ☐ B $\text{Mg}^{+}(\text{g}) \rightarrow \text{Mg}^{2+}(\text{g}) + \text{e}^{-}$
- ☐ C $\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{s}) + 2\text{e}^{-}$
- ☐ D $\text{Mg}^{+}(\text{s}) \rightarrow \text{Mg}^{2+}(\text{s}) + \text{e}^{-}$

(Total for Question 4 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.



- 5 The graph shows log (ionisation energy) against ionisation number for the successive ionisations of an element.



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In this element, how many quantum shells contain electrons, and how many electrons are in the outer quantum shell?

	Number of quantum shells containing electrons	Number of electrons in the outer quantum shell
☐ A	3	2
☐ B	3	5
☐ C	5	2
☐ D	5	5

(Total for Question 5 = 1 mark)

- 6 Which ion has the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$ in its ground state?

- ☐ A Al^{3+}
- ☐ B Cl^-
- ☐ C N^{3-}
- ☐ D Na^+

(Total for Question 6 = 1 mark)



7 What is the relative formula mass of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$?

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0]

- ☐ A 106
- ☐ B 142
- ☐ C 263
- ☐ D 286

(Total for Question 7 = 1 mark)

8 Which of these isoelectronic ions has the **largest** radius?

- ☐ A Na^+
- ☐ B Mg^{2+}
- ☐ C O^{2-}
- ☐ D F^-

(Total for Question 8 = 1 mark)

9 Which ion is the most polarisable?

- ☐ A Mg^{2+}
- ☐ B Ca^{2+}
- ☐ C Cl^-
- ☐ D I^-

(Total for Question 9 = 1 mark)

10 Which substance has a giant lattice of atoms?

- ☐ A diamond
- ☐ B ice
- ☐ C poly(ethene)
- ☐ D sodium chloride

(Total for Question 10 = 1 mark)



11 Which compound has bonds that are the most polar?

- ☐ A H_2O
- ☐ B H_2S
- ☐ C NH_3
- ☐ D PH_3

(Total for Question 11 = 1 mark)

12 Which molecule is planar?

- ☐ A CF_4
- ☐ B C_2F_4
- ☐ C PF_5
- ☐ D SF_6

(Total for Question 12 = 1 mark)

13 When $\text{C}_{20}\text{H}_{42}$ is cracked, each molecule produces one molecule of ethene, one molecule of butane and two molecules of hydrocarbon **E**.

What is the molecular formula of **E**?

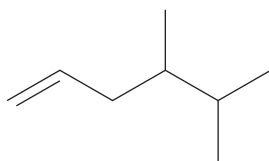
- ☐ A C_7H_{13}
- ☐ B C_7H_{14}
- ☐ C $\text{C}_{14}\text{H}_{26}$
- ☐ D $\text{C}_{14}\text{H}_{28}$

(Total for Question 13 = 1 mark)

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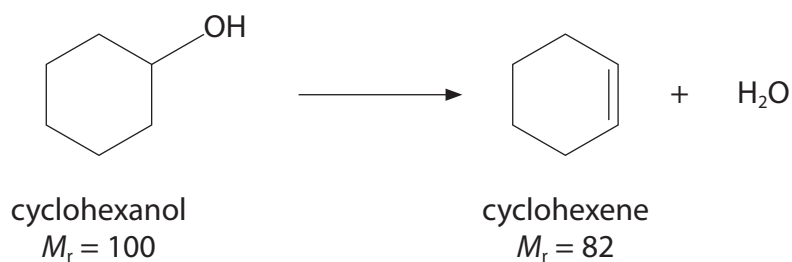
14 What is the systematic name of this compound?



- ☐ A 1,1,2-trimethylpent-4-ene
- ☐ B 2,3-dimethylhex-5-ene
- ☐ C 4,5-dimethylhex-1-ene
- ☐ D 4,5,5-trimethylpent-1-ene

(Total for Question 14 = 1 mark)

15 Cyclohexene may be prepared by the dehydration of cyclohexanol.



What mass of cyclohexene can be made from 12.5 g of cyclohexanol if the yield is 51.2%?

- ☐ A 5.25 g
- ☐ B 6.40 g
- ☐ C 7.80 g
- ☐ D 10.25 g

(Total for Question 15 = 1 mark)

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16 Which of these gases occupies 6.0 dm^3 at room temperature and pressure (r.t.p.)?

[molar volume of gas at r.t.p. = $24.0 \text{ dm}^3 \text{ mol}^{-1}$]

A_r values: He = 4.0 C = 12.0 N = 14.0 O = 16.0]

- ☐ A 2.0 g of helium
- ☐ B 4.0 g of oxygen
- ☐ C 11.0 g of carbon dioxide
- ☐ D 14.0 g of nitrogen

(Total for Question 16 = 1 mark)

17 An oxide of lead contains 90.7% by mass of lead.

What is the formula of this oxide?

[A_r values: O = 16.0 Pb = 207.2]

- ☐ A PbO
- ☐ B PbO₂
- ☐ C Pb₂O₃
- ☐ D Pb₃O₄

(Total for Question 17 = 1 mark)

18 Propane burns completely in oxygen as shown.



100 cm^3 of propane was mixed with 600 cm^3 of oxygen and the mixture was ignited.

What is the **total** volume, in cm^3 , of the gas mixture at the end of the reaction?
All gas volumes were measured at room temperature and pressure.

- ☐ A 300
- ☐ B 400
- ☐ C 700
- ☐ D 800

(Total for Question 18 = 1 mark)



19 Which aqueous solution contains the greatest number of **ions**?

- ☐ A 200 cm³ of 1.5 mol dm⁻³ MgCl₂
- ☐ B 400 cm³ of 0.8 mol dm⁻³ MgSO₄
- ☐ C 500 cm³ of 1.0 mol dm⁻³ NaCl
- ☐ D 1000 cm³ of 0.25 mol dm⁻³ Na₂SO₄

(Total for Question 19 = 1 mark)

20 A sample of seawater with a mass of 1 kg contains 6×10^{-9} g of gold.

How many atoms of gold, to one significant figure, are there in 1 g of this seawater?

[A_r value: Au = 197 Avogadro constant = 6×10^{23} mol⁻¹]

- ☐ A 2×10^{10}
- ☐ B 4×10^{12}
- ☐ C 2×10^{13}
- ☐ D 4×10^{15}

(Total for Question 20 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS



SECTION B

Answer ALL the questions.

Write your answers in the spaces provided.

21 Heptane, C_7H_{16} , is an alkane found in crude oil.

(a) Heptane can undergo incomplete combustion.

(i) Give a reason why incomplete combustion sometimes occurs.

(1)

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(ii) Write the equation for the incomplete combustion of heptane, forming carbon monoxide and water as the **only** products.
State symbols are not required.

(1)

(b) Heptane is reformed into branched-chain and cyclic hydrocarbons that are used in petrol.

(i) Draw the **skeletal** formulae of a branched-chain alkane and a cycloalkane, each containing **seven** carbon atoms.

(2)

Branched-chain alkane

Cycloalkane

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- (ii) Write the equation for the reforming of heptane into a cycloalkane.
Use molecular formulae.

(1)

- (iii) Give a reason for adding cycloalkanes to petrol.

(1)

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(c) Heptane, C_7H_{16} , reacts with chlorine in the presence of ultraviolet radiation.

(i) State the type and mechanism of this reaction.

(2)

(ii) Give the mechanism for the reaction to produce $C_7H_{15}Cl$, $C_{14}H_{30}$ and HCl as the **only** products.

Include the name of each of the steps in your mechanism.

Curly half-arrows are **not** required.

(7)

(Total for Question 21 = 15 marks)



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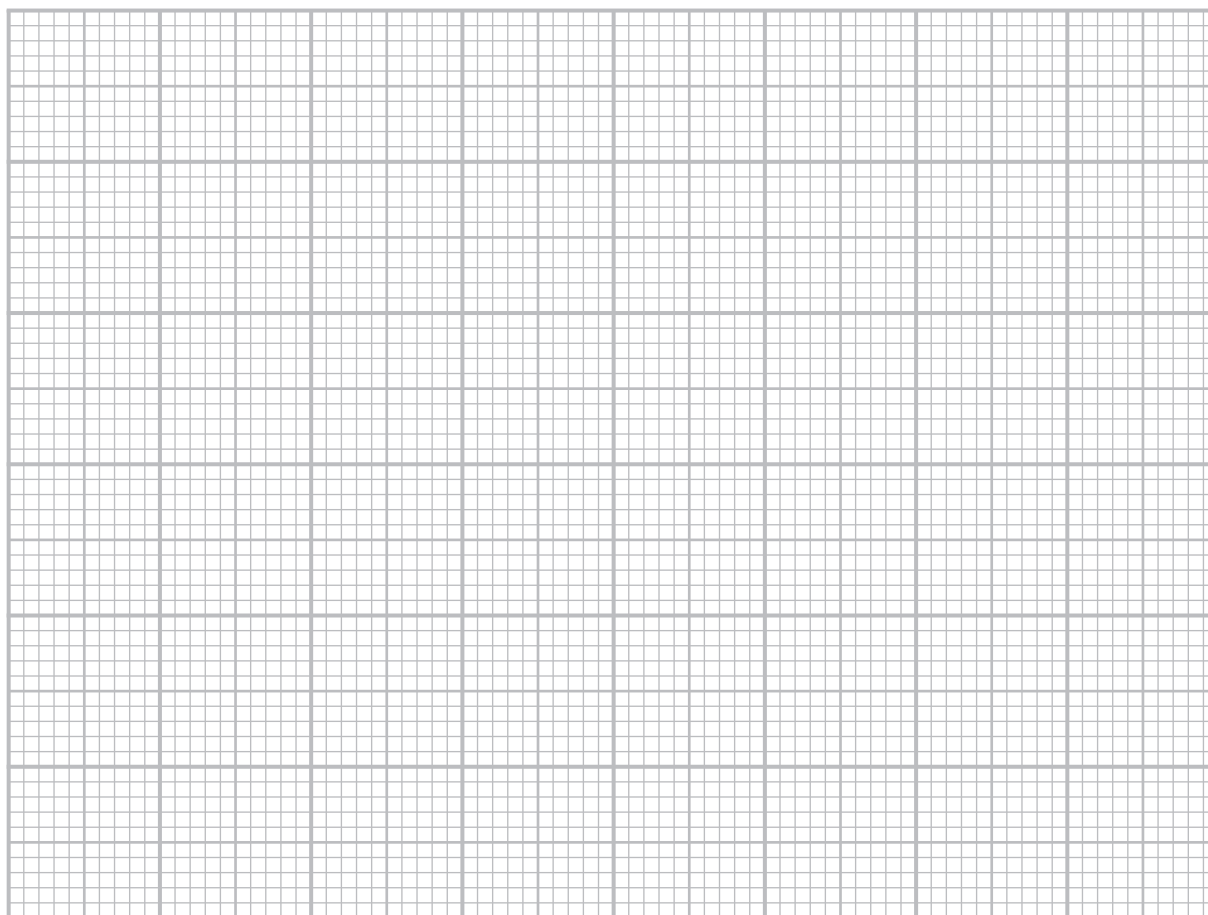
22 This question is about the elements in Period 3 of the Periodic Table, and some of their compounds.

(a) The atomic radii of six of the elements are given.

Symbol	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	15	16	17	18
Atomic radius / nm	0.191	0.160	0.130			0.102	0.099	0.095

(i) Plot a graph of atomic radius against atomic number.

(2)



(ii) Use the graph to estimate the atomic radius of silicon, Si.

(1)



- (iii) Suggest an explanation for the decrease in atomic radius as atomic number increases across a period.

(3)

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- (b) The melting temperatures of sodium, sodium chloride and chlorine are given in the table.

Complete the table to show the type of structure, the type of bond or force broken on melting and the particles involved.

(6)

Substance	Sodium	Sodium chloride	Chlorine
Melting temperature / °C	98	801	–101
Type of structure	giant		simple molecular
Type of bond or force broken on melting			
Particles involved			chlorine molecules



(c) Solid phosphorus(V) chloride contains PCl_4^+ ions.

(i) Draw a dot-and-cross diagram of a PCl_4^+ ion.

Show only outer shell electrons.

(1)

(ii) Predict the shape of a PCl_4^+ ion.

Justify your answer.

(3)

Shape

Justification

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(Total for Question 22 = 16 marks)



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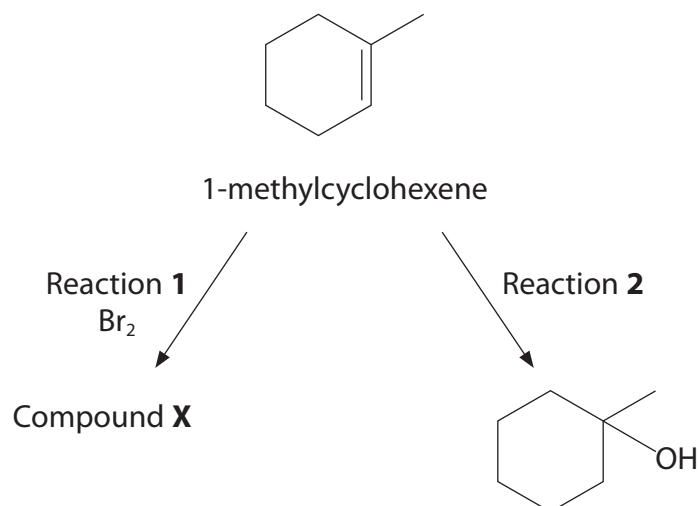
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Structure of geometric isomer 1	Structure of geometric isomer 2
Name of isomer 1	Name of isomer 2



(c) Two reactions of 1-methylcyclohexene are shown.



(i) Draw the **skeletal** formula of compound **X** formed in Reaction 1.

(1)

(ii) Give the reagent and condition needed for Reaction 2.

(2)

Reagent

Condition

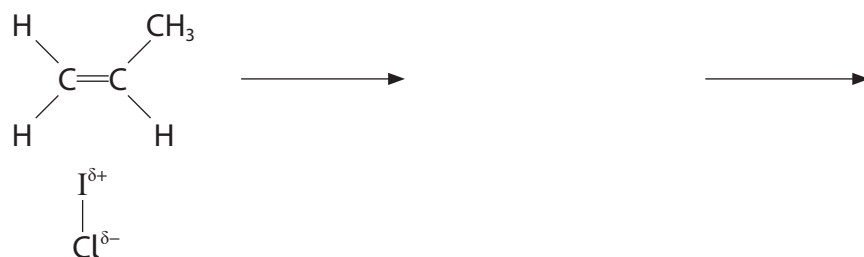


- (d) Iodine monochloride, ICl, reacts with alkenes in a similar way to hydrogen bromide.

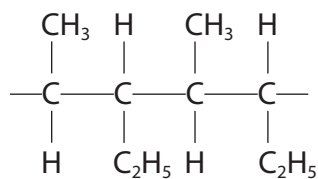
Complete the mechanism for the reaction of iodine monochloride with propene to form the **major** product.

Include curly arrows, the relevant lone pair and the structures of the intermediate and product.

(4)



- (e) A section of a polymer showing two repeat units is given.



Give the **name** of the monomer that forms this polymer.

(1)



- (f) 0.0100 mol of an alkene reacts completely with exactly 600 cm³ of hydrogen gas, measured at 298 K and 1.24×10^5 Pa pressure, to form an alkane.

Use the ideal gas equation to deduce the number of double bonds in **one** molecule of the alkene.

You **must** show your working.

$$[pV = nRT \quad R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}]$$

(4)

(Total for Question 23 = 16 marks)



24 This question is about iron and some of its compounds.

(a) Complete the table to show the numbers of subatomic particles in $^{56}\text{Fe}^{2+}$.

(1)

Number of protons	Number of neutrons	Number of electrons

(b) A sample of iron contains the following isotopes.

Isotope	Percentage abundance
^{54}Fe	5.84
^{56}Fe	91.68
^{57}Fe	2.17
^{58}Fe	0.31

Calculate the relative atomic mass of this sample of iron.
Give your answer to **three** significant figures.

(2)

(c) Magnesium reacts with aqueous iron(II) sulfate in a displacement reaction.

Write the **ionic** equation for this reaction.
Include state symbols.

(2)



(d) 25.00 g of a compound contains 6.98 g of iron and 6.03 g of sulfur.

The remaining mass is oxygen.

Calculate the **empirical** formula of this compound.

[A_r values: O = 16.0 S = 32.1 Fe = 55.8]

(3)



- (e) When 6.95 g of $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$ is heated, 2.00 g of iron(III) oxide, 0.80 g of sulfur dioxide and 1.00 g of sulfur trioxide are produced. The only other product is water.

Deduce the overall equation for the reaction using these data.
State symbols are not required.

You **must** show your working.

[A_r values: H = 1.0 O = 16.0 S = 32.1 Fe = 55.8]

(5)

(Total for Question 24 = 13 marks)

TOTAL FOR SECTION B = 60 MARKS
TOTAL FOR PAPER = 80 MARKS



The Periodic Table of Elements

[illegible]

* Lanthanide series

* Actinide series

Elements with atomic numbers 112-116 have been reported but not fully authenticated

