

Candidate Name

Candidate Number

Centre Name

Centre Number

Paper 1: Chemistry
(2 hours)

For Examination June 2023

It is necessary to respond on the answer sheets provided alongside this question paper. Additionally, you must have a soft pencil (preferably of type B or HB), a clean eraser and a dark blue or black pen.

INSTRUCTIONS:

- You must write your name, candidate number, centre name and centre number on the answer sheets in the designated spaces.
- Objective section consists of 25 questions, and it is essential that you attempt all of them.
- Each question has four options labelled A, B, C, and D. Select the option that you think is correct. Mark it on the multiple choice answer sheet using a soft pencil.
- Attempt all the questions from subjective section using a dark blue or black pen.
- It is important to follow the instructions provided on the answer sheets.
- Do not use correction fluid.
- Avoid writing on any bar codes.

INFORMATION:

- This paper has a total of 110 marks.
- In objective section there are 25 questions, each carries one mark. There is no negative marking for incorrect responses.
- In subjective section, 45 marks are for extended theory and 30 marks for practical component.
- The number of marks assigned for every question or its parts is indicated within brackets []

The Periodic Table of Elements

		Group															
1	2											13	14	15	16	17	18
		<div style="border: 1px solid black; padding: 5px; display: inline-block;"> Key atomic number name atomic symbol relative atomic mass </div>															
		<div style="border: 1px solid black; padding: 5px; display: inline-block;"> 1 H hydrogen 1.0 </div>															
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminum 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs cesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —
87 Fr francium —	88 Ra radium —	89–103 actinoids	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganesson —

lanthanoids

57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium —	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
89 Ac actinium —	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium —	94 Pu plutonium —	95 Am americium —	96 Cm curium —	97 Bk berkelium —	98 Cf californium —	99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —	102 No nobelium —	103 Lr lawrencium —

actinoids

Instructions: Answer **all** the questions in the space provided.

Question 1

Iron and cobalt are adjacent elements in the Periodic Table. Iron has three main naturally occurring isotopes, cobalt has one.

(a) Explain the meaning of the term *isotope*.

.....
.....
..... [2]

(b) The most common isotope of iron is ^{56}Fe ; the only naturally occurring isotope of cobalt is ^{59}Co .

Use the *periodic table* to complete the table below to show the atomic structure of ^{56}Fe and of ^{59}Co .

	number of		
isotope	protons	neutrons	electrons
^{56}Fe			
^{59}Co			

[3]

(c) A sample of iron has the following isotopic composition by mass.

isotope mass	54	56	57
% by mass	5.84	91.68	2.17

(i) Define the term *relative atomic mass*.

.....
.....
.....
.....

(ii) By using the data above, calculate the relative atomic mass of iron to **three** significant figures.

[5]

[Total: 10]

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Question 2

Sulphur and its compounds are found in volcanoes, in organic matter and in minerals.

Hydrogen sulphide, H_2S , is a foul-smelling compound found in the gases from volcanoes. Hydrogen sulphide is covalent, melting at $-85\text{ }^\circ\text{C}$ and boiling at $-60\text{ }^\circ\text{C}$.

(a) (i) Draw a 'dot-and-cross' diagram to show the structure of the H_2S molecule.

(ii) Predict the shape of the H_2S molecule.

.....

(iii) Oxygen and sulphur are both in Group VI of the Periodic Table.

Suggest why the melting and boiling points of water, H_2O , are much higher than those of H_2S .

.....

.....

..... [4]

(b) Hydrogen sulphide burns with a blue flame in an excess of oxygen to form sulphur dioxide and water.

(i) Write a balanced equation for the complete combustion of H_2S .

.....

(ii) What is the change in the oxidation number of sulphur in this reaction?

from to

(iii) What volume of oxygen, measured at room temperature and pressure, is required for the complete combustion of 8.65 g of H_2S ? Give your answer to two decimal places.

(c) Hydrogen sulphide is a weak diprotic (dibasic) acid. Its solution in water contains HS^- and a few S^{2-} ions.

(i) What is meant by the term *weak acid*?

.....
.....

(ii) Write an equation, with state symbols, for the **first** ionisation of H_2S when it dissolves in water.

..... [3]

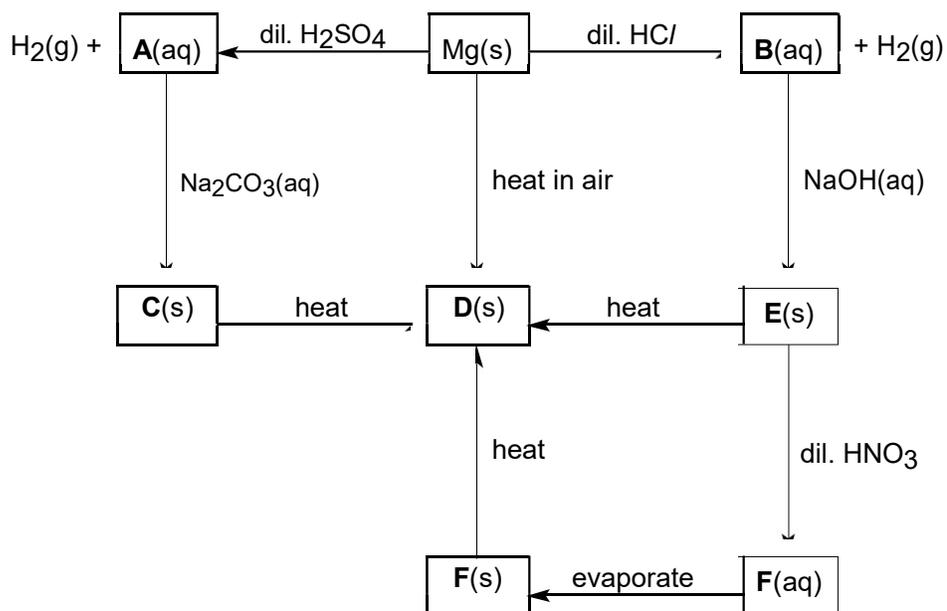
[Total: 12]

Question 3

Magnesium is the eighth most common element in the Earth's crust.

The metal is widely used in alloys which are light and strong.

Some reactions of magnesium and its compounds are shown in the reaction scheme below.



(a) Identify, by name or formula, compounds **A** to **F**.

A

B

C

D

E

F

[6]

(b) (i) Construct balanced equations for the following reactions.

magnesium to compound **A**

.....

compound **C** to compound **D**

.....

compound **F** to compound **D**

.....

(ii) Suggest a balanced equation for the effect of heat on compound **E**.

..... [4]

(c) i) Complete the electronic configuration of the magnesium atom.

..... [1]

ii) Complete the electronic configuration of the chlorine atom.

..... [1]

iii) Write the equation, including state symbols, for the reaction between chlorine and magnesium.

..... [2]

(iv) Name the kind of bonding that is present in magnesium chloride.

..... [1]

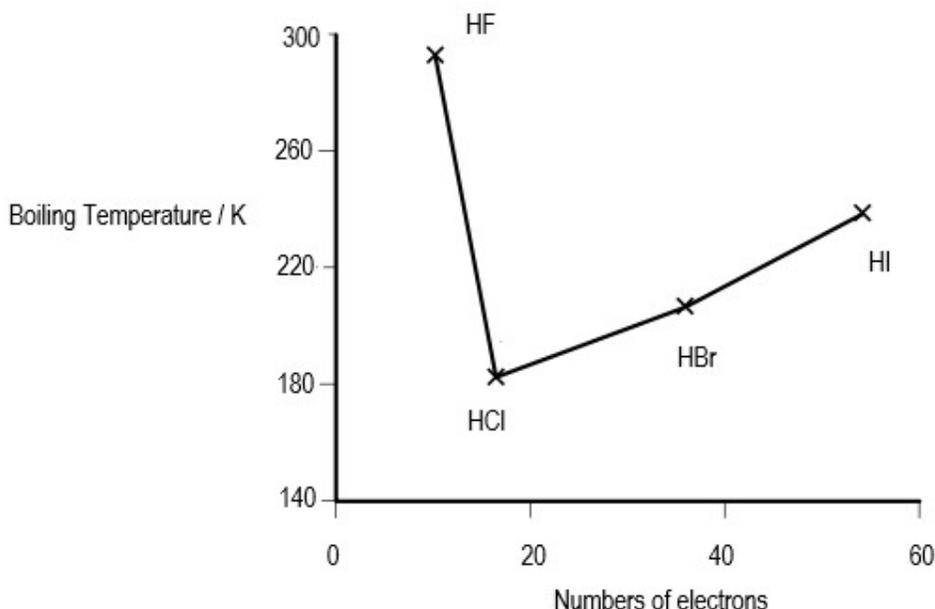
(v) Draw a diagram (using either crosses or dots) to show the bonding in magnesium chloride. Include ALL the electrons in each species and the charges that are present.

[3]

[Total: 18]

Question 4

The graph below shows the boiling temperature of various group 7 (halide) hydrides.



(a) i) Identify the type of intermolecular force that results in an unusually high boiling temperature of hydrogen fluoride.

..... [1]

ii) State and explain whether the electronegativity of fluorine is less than, similar to, or greater than, that of bromine.

..... [1]

Using this information, explain why hydrogen fluoride can form the type of intermolecular force identified in (a) i) but hydrogen bromide is unable to do so.

.....
.....
.....
.....

[2]

(iii) Predict what the boiling temperature of hydrogen fluoride would be, if there was the absence of the type of intermolecular force named in (a)(i).

..... [1]

Propanone, CH_3COCH_3 , is a useful solvent for removing organic substances from glassware in laboratories.

(iv) Why is propanone an ideal solvent to dissolve a wide range of substances?

.....
.....
.....

[1]

(v) Propanone specifically has the ability to remove both octane and water from glassware.

For each of these two substances, identify the strongest intermolecular force produced with propanone and the part of the propanone molecule that is involved.

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.....
.....

[2]

[Total: 8]

Question 5

Calcium oxide, otherwise known as quicklime, is produced from calcium carbonate, using thermal decomposition.

(a) (i) Explain what is meant by the term thermal decomposition.

.....
.....
.....

[2]

ii) Write an equation for the thermal decomposition of calcium carbonate, including state symbols.

.....
.....

[1]

- iii) Other Group 2 carbonates are also known to undergo thermal decomposition. Provide a description and explanation for the trend in the thermal stability of carbonates down Group 2.

.....

.....

.....

.....

.....

.....

[3]

b) A student conducts an experiment and measures 0.121 g of an impure sample of quicklime. They then dissolve the sample in 50.0 cm³ of hydrochloric acid (which has a concentration of 0.100 mol dm⁻³). The excess hydrochloric acid is titrated against sodium hydroxide solution (which also has a concentration of 0.100 mol dm⁻³, and 18.0 cm³ was exactly needed to neutralise all of the acid. The indicator used in the experiment methyl orange.

- i) What colour would you expect the indicator to be at the end-point of this titration?

.....

[1]

- ii) Calculate the number of moles of hydrochloric acid that reacted overall with the sodium hydroxide solution.

.....

[1]

- iii) Calculate the number of moles of hydrochloric acid originally added to the quicklime. Use your answer and the one from (b) ii) to calculate the number of moles of quicklime that has reacted with the hydrochloric acid.

.....

[2]

iv) Calculate the percentage purity of the sample of quicklime. Provide your answer to **three** significant figures.

.....
.....
.....
.....
.....

[2]

c) i) Describe how to carry out a flame test on the impure sample of quicklime to confirm that the sample contains calcium ions.

.....
.....
.....
.....
.....
.....

[3]

ii) If the flame test gave a green colour, as well as an expected brick red flame colour, which Group 2 metal is also likely to be present as well?

.....

[1]

[Total: 16 marks]

Question 6

This question is about the reactions and properties of some halogenoalkanes.

- (a) List the reagents and conditions that are required to convert the following halogenoalkanes into the named product.

- (i) 1-bromobutane converted into butan-1-ol

.....
.....

[2]

- (ii) 1-iodobutane converted into butylamine

.....
.....

[2]

- (iii) 2-chloropropane converted into propene

.....
.....

[2]

- (b) Chloroethane can be prepared by reacting ethanol with potassium chloride in the presence of concentrated sulfuric acid.

Explain why a similar reaction which uses concentrated sulfuric acid and potassium iodide should not be used to prepare iodoethane.

.....
.....

[2]

- (c) Two gaseous halogenoalkanes that are commonly used to extinguish fires have the structural formulae CF_2ClBr and CF_3CHF_2 .

- (i) State the systematic name of CF_2ClBr .

[1]

.....
.....

(ii) Draw the skeletal formula of CF_3CHF_2 .

[1]

.....
.....

(iii) Suggest TWO reasons why these compounds can help put out fires.

[2]

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.....

iv) Explain why fire retardants containing halogenoalkanes are being phased out.

Suggest a reason why the scientific community still supports the use of compounds containing CF_3CHF_2 .

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[3]

[Total: 15 marks]

Question 7

Group 2 elements share numerous common chemical properties.

- 1) a) Calcium reacts in cold water more quickly than magnesium because more energy is required to remove the outer electrons in magnesium. However, this occurs even though calcium atoms have a greater nuclear charge.

Explain why more energy is required to remove the outer electrons in magnesium than in calcium.

.....
.....
..... [2]

- b) 0.001 mol of strontium reacts with an excess of cold water. When the reaction is complete a colourless solution is seen.

Construct the equation for the reaction of strontium with cold water. You must include state symbols.

..... [2]

- c) 0.005 mol of calcium and 0.005 mol of strontium are added separately to two beakers. Each beaker contains 100 cm³ of cold water.
At the end of each reaction a white solid and a colourless solution are seen in both beakers.

Predict which element, calcium or strontium, produces the solution that is more alkaline. Explain your answer.

.....
.....
..... [2]

- 2) Element **X** is a known metal. **X** reacts with oxygen to form a black solid oxide. The oxidation state of **X** in this oxide is +2. The carbonate of **X**, **XCO₃**, is a green solid. It decomposes on heating to form the oxide and a colourless gas.

- (a) From the information given, state two similarities and one difference that metal **X** and its compounds have with Group 2 metals and their compounds.

similarity 1

.....

similarity 2

.....

difference 1

.....

[3]

(b) Write the expected formula of the oxide of X.

..... [1]

(c) Write an equation for the reaction of XCO_3 as it is heated.

..... [1]

[Total: 11 marks]

Question 8

The feasibility of a chemical reaction depends on the standard Gibbs free energy change, ΔG^\ominus . This is dependent on the standard enthalpy and entropy changes, and the temperature.

a) i) State and explain whether the following processes will lead to an increase or decrease in entropy.

the reaction of magnesium with hydrochloric acid entropy change

explanation [1]

ii) the dissolving of solid potassium chloride in water entropy change

explanation [1]

iii) the condensing of water from steam entropy change

explanation [1]

iv) Magnesium carbonate can be decomposed on heating.



Standard entropies are shown in Table 1.

Table 1

substance	$\text{MgCO}_3(\text{s})$	$\text{MgO}(\text{s})$	$\text{CO}_2(\text{g})$
$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$	+65.7	+26.9	+214

Calculate ΔG^\ominus for this reaction at 298 K.
Show your working.

$\Delta G^\ominus = \dots\dots\dots \text{kJ mol}^{-1}$ [3]

(b) Explain why this reaction is feasible only at high temperatures.

.....
..... [1]

(c) Table 2 lists values of solubility products, K_{sp} , of some Group 2 carbonates.

Table 2

	solubility product in water at 298 K, $K_{sp} / \text{mol}^2 \text{dm}^{-6}$
MgCO ₃	1.0×10^{-5}
CaCO ₃	5.0×10^{-9}
SrCO ₃	1.1×10^{-10}

Deduce the trend in the solubility of the Group 2 carbonates down the group. Justify your answer using the data given.

.....
..... [1]

d)(i) Write an equation to show the equilibrium for the solubility product of MgCO₃. Include state symbols.

..... \rightleftharpoons [1]

ii) With reference to your equation in (d)(i), suggest what is observed when a few cm³ of concentrated Na₂CO₃(aq) are added to a saturated solution of MgCO₃. Explain your answer.

.....
.....
..... [2]

iii) Use the data in Table 2 to calculate the solubility of MgCO₃ in water at 298 K, in g dm⁻³. Show your working.

solubility of MgCO₃ = g dm⁻³ [2]

e) Describe and explain the variation in the thermal stabilities of the carbonates of the Group 2 elements.

.....
.....
.....
.....
..... [3]

[Total: 16 marks]

Question 9

Compare and explain the relative acidities of butanoic acid, ethanol, ethanoic acid and water.

..... > > >
most acidic least acidic
.....
.....
.....
.....
.....
..... [4]

[Total: 4 marks]

End of Paper