Cambridge Assessment International Education

Cambridge IGCSE™ (9–1)

CANDIDATE NAME									
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0123456789

CHEMISTRY **0971/03**

Paper 3 Theory (Core) **For examination from 2023**

SPECIMEN PAPER **1 hour 15 minutes**

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.

This document has **16** pages. Any blank pages are indicated.

1 Fig. 1.1 shows the electronic configurations of five atoms, **A**, **B**, **C**, **D** and **E**.

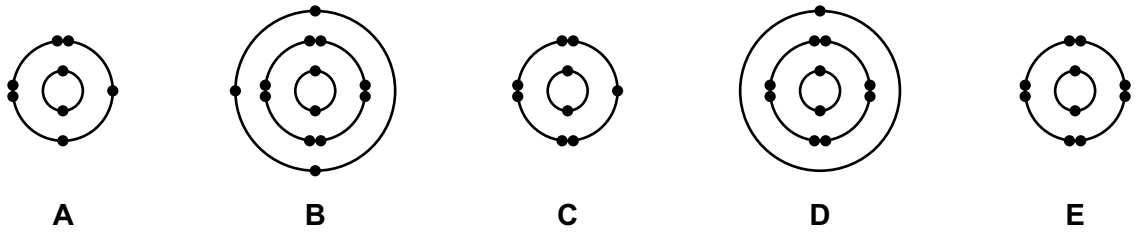

Fig. 1.1

(a) Answer the following questions.

Each letter may be used once, more than once or not at all.

Give the letter of the atom, **A**, **B**, **C**, **D** or **E**, that:

(i) is in Group III of the Periodic Table

..... [1]

(ii) has 13 protons

..... [1]

(iii) is a noble gas

..... [1]

(iv) forms a stable ion with a single negative charge.

..... [1]

(b) Complete Table 1.1 to show the number of electrons, neutrons and protons in the sulfur atom and oxide ion.

Table 1.1

	number of electrons	number of neutrons	number of protons
$^{34}_{16}S$	16		
$^{18}_{8}O^{2-}$		10	

[3]

[Total: 7]

2 **(a)** Table 2.1 shows the mass of ions present in a 100 cm^3 sample of milk.

Table 2.1

ion	formula of ion	mass of ion in 100 cm^3 milk / mg
calcium	Ca^{2+}	125
chloride	Cl^-	120
magnesium	Mg^{2+}	12
negative ions of organic acids		160
phosphate	PO_4^{3-}	95
potassium	K^+	140
sodium	Na^+	58
sulfate	SO_4^{2-}	30

(i) Calculate the mass of calcium ions present in a 20 cm^3 sample of this milk.

mass of calcium ions = ... mg [1]

(ii) Identify the positive ion present in the highest concentration in the 100 cm^3 sample of milk.

..... [1]

(iii) Complete Fig. 2.1 to show the electronic configuration of a potassium ion.

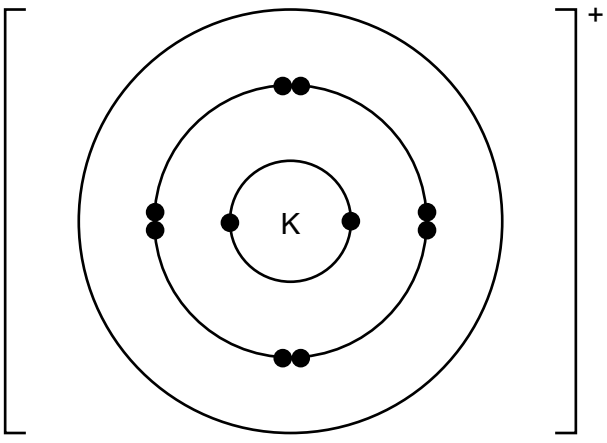

Fig. 2.1 [1]

(iv) Describe a test for chloride ions.

test .....

positive result .....
[2]

(v) Explain why the solutions used in qualitative chemical tests are made using distilled water and **not** tap water.

.....

..... [1]

(b) Which one of these salts is soluble in water?

Tick **one** box.

barium sulfate ☐

calcium carbonate ☐

ammonium sulfate ☐

iron(II) hydroxide ☐

[1]

(c) One of the organic acids present in milk is lactic acid.
The displayed formula of lactic acid is shown in Fig. 2.2.

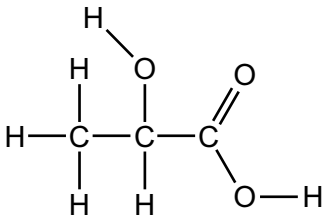

Fig. 2.2

(i) Draw a circle around the carboxylic acid functional group on the structure. [1]

(ii) Deduce the molecular formula of lactic acid.

..... [1]

[Total: 9]

3 A coloured crystal of cobalt(II) chloride is placed at the bottom of a beaker containing water.

Colour spreads throughout the water over time. Fig 3.1 shows the spread of colour after two days.

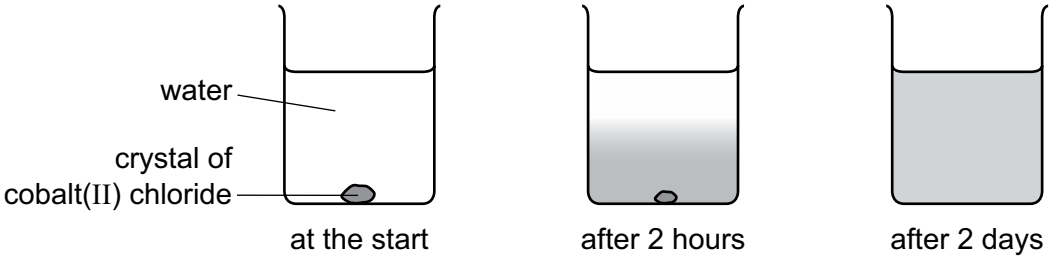

Fig. 3.1

(a) Explain these observations.

.....

.....

.....

.....

..... [3]

(b) Cobalt(II) chloride can be used to test for the presence of water.

$$CoCl_2 + 6H_2O \rightleftharpoons CoCl_2 \cdot 6H_2O$$

anhydrous cobalt(II) chloride — hydrated cobalt(II) chloride

(i) State the meaning of the symbol ⇌.

..... [1]

(ii) State the colour change when water is added to anhydrous cobalt(II) chloride.

from ……..……. to ……..……..... [2]

(c) **(i)** Table 3.1 compares the reactivity of cobalt with that of three other metals.

Table 3.1

metal	reactivity with cold water	reactivity with steam
barium	reacts rapidly	
cobalt	no reaction	reacts slowly when heated
magnesium	reacts very slowly	reacts rapidly
zinc	no reaction	reacts easily when heated

Use this information to put the four metals in order of their reactivity. Put the least reactive metal first.

least reactive ⟶ most reactive

[2]

(ii) State the boiling point of pure water at room temperature and pressure.

..... °C [1]

(d) Cobalt is a transition element. Lithium is a Group I element.

Describe **two** ways in which the properties of cobalt differ from those of lithium.

1 .....

2 .....

[2]

(e) When cobalt(II) oxide, CoO, is heated in air an oxide with the formula Co_3O_4 is formed.

Balance the equation for this reaction.

$$\text{.....}\ CoO + O_2 \rightarrow 2Co_3O_4$$ [1]

(f) When the oxide Co_3O_4 is heated in hydrogen, cobalt metal is formed.

$$Co_3O_4 + 4H_2 \rightarrow 3Co + 4H_2O$$

Explain how this equation shows that Co_3O_4 is reduced.

.....

..... [1]

[Total: 13]

4 A student investigates the reaction of small pieces of zinc with dilute sulfuric acid at 20 °C. The zinc is in excess.

(a) Fig. 4.1 shows the volume of hydrogen gas released as the reaction proceeds.

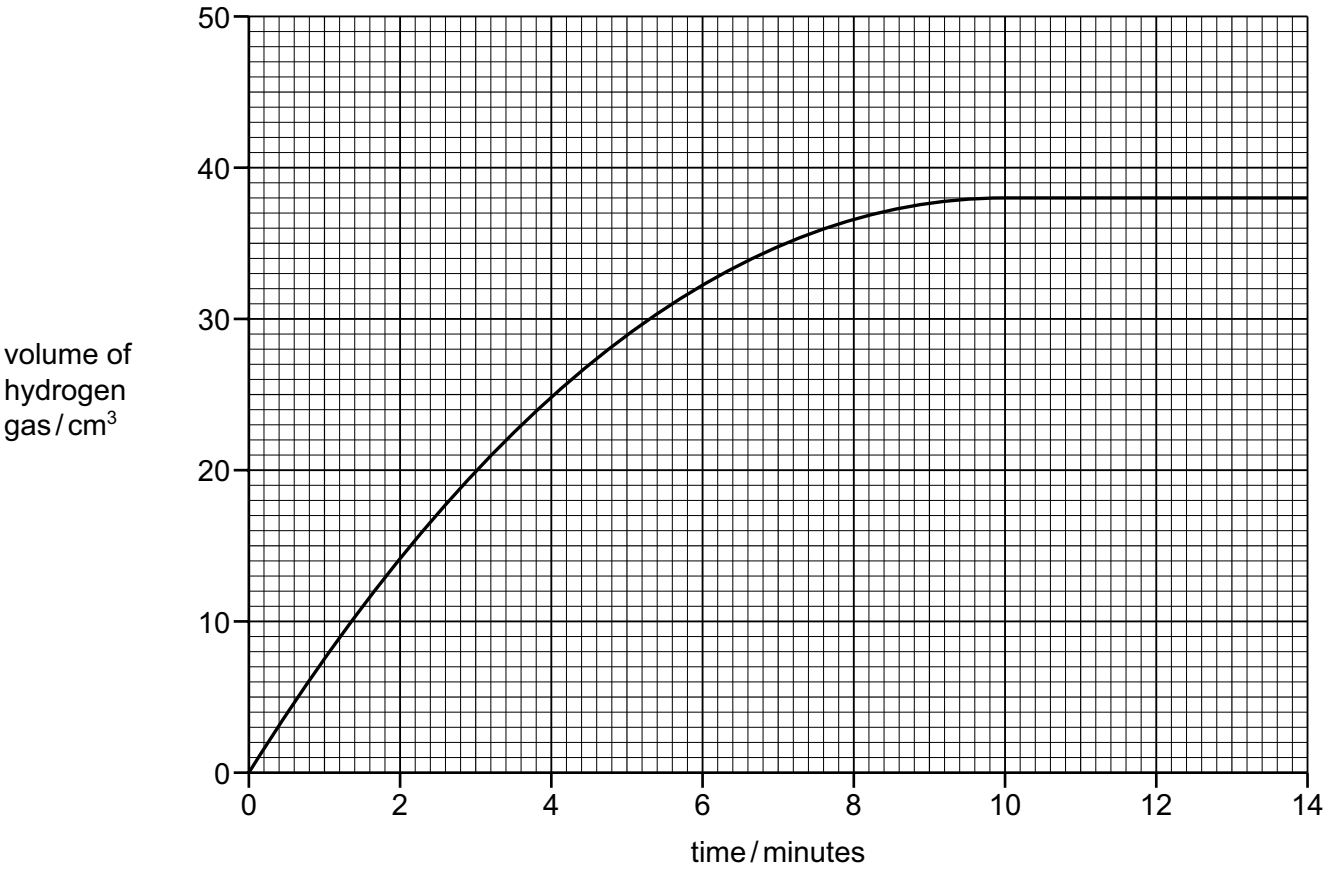

Fig. 4.1

(i) Suggest why the volume of hydrogen gas stays the same after 10 minutes.

.....

..... [1]

(ii) Deduce the time taken from the start of the experiment to collect 20 cm^3 of hydrogen gas.

..... [1]

(iii) The student repeats the experiment at 30 °C.

All other conditions stay the same.

Draw a line **on the grid** in Fig. 4.1 to show how the volume of hydrogen gas changes with time when the reaction is carried out at 30 °C. [2]

(b) The student repeats the experiment using zinc powder instead of small pieces of zinc.

Describe how the rate of reaction differs when zinc powder is used.

Give a reason for your answer.

.....

.....

..... [2]

(c) Sulfuric acid is a compound.

(i) Define the term compound.

.....

..... [1]

(ii) State the formula of the ion that is present in an aqueous solution of all acids.

..... [1]

(iii) A few drops of the indicator methyl orange are added to aqueous dilute sulfuric acid.

State the colour change observed.

from orange to ..... [1]

(iv) The formula of sulfuric acid is H_2SO_4.

Complete Table 4.1 to calculate the relative molecular mass of sulfuric acid.

Table 4.1

atom	number of atoms	relative atomic mass	
hydrogen	2	1	$2 \times 1 = 2$
sulfur			
oxygen			

relative molecular mass = ... [2]

[Total: 11]

5 Table 5.1 shows the properties of four substances.

Table 5.1

substance	boiling point	electrical conductivity of solid	electrical conductivity when molten	density in g / cm^3
aluminium	high	conducts	conducts	2.70
diamond				3.51
potassium bromide	high	does not conduct	conducts	2.75
sulfur	low	does not conduct		2.07

(a) Complete Table 5.1 to show the electrical conductivity of solid diamond and molten sulfur. [2]

(b) State **one** piece of evidence from Table 5.1 that shows that sulfur is a simple molecular substance.

..... [1]

(c) **(i)** State the meaning of the term ionic bonding.

.....

..... [2]

(ii) Identify which information in Table 5.1 shows that potassium bromide is an ionic compound.

.....

.....

..... [2]

(d) State the property of aluminium given in Table 5.1 which makes it suitable for the manufacture of aircraft.

..... [1]

(e) Molten potassium bromide can be electrolysed.

Predict the products of this electrolysis at:

the anode .....

the cathode. .....
[2]

[Total: 10]

6 Aqueous sodium hydroxide is a base.

(a) Complete this sentence about the different types of bases.

Bases are metal hydroxides or metal ..... [1]

(b) Describe the reaction of aqueous sodium hydroxide with:

- a named acid

.....

.....

.....

- an ammonium salt.

.....

.....

.....

[4]

(c) Ammonia is a soluble base.

Draw a circle around the pH value of aqueous ammonia.

pH 1 **pH 5** **pH 7** **pH 10** [1]

(d) Ammonia is used in the manufacture of nitrogen-containing fertilisers.

Which two of these compounds are present in fertilisers?

Tick **two** boxes.

copper(II) oxide ☐

potassium chloride ☐

sodium phosphate ☐

strontium fluoride ☐

sulfur dioxide ☐

[2]

(e) Bacteria in the soil convert ammonium compounds to oxides of nitrogen.
The oxides of nitrogen escape into the atmosphere.

(i) State one **other** source of oxides of nitrogen in the atmosphere.

..... [1]

(ii) Oxides of nitrogen contribute to photochemical smog.

Describe one **other** adverse effect of oxides of nitrogen on the environment.

..... [1]

[Total: 10]

7 **(a)** Table 7.1 shows some properties of some of the halogens.

Table 7.1

halogen	melting point / °C	boiling point / °C	colour
chlorine	−101	−35	yellow-green
bromine	−7		red-brown
iodine	+114	+184	grey-black
astatine	+302	+337	

Use the information in Table 7.1 to suggest:

- the colour of astatine .....
- the boiling point of bromine .....
- the state of iodine at 190 °C. .....

[3]

(b) Aqueous chlorine reacts with aqueous potassium bromide as shown.

$$Cl_2 + 2KBr \rightarrow Br_2 + 2KCl$$

(i) Name the salt formed in this reaction.

..... [1]

(ii) Explain why aqueous bromine does **not** react with aqueous potassium chloride.

.....

..... [1]

(iii) Complete the dot-and-cross diagram in Fig. 7.1 of a molecule of chlorine.

Show outer shell electrons only.

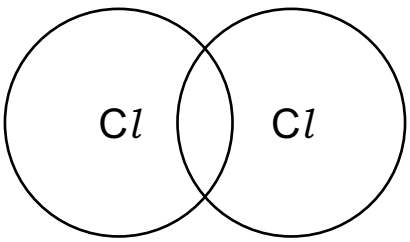

Fig. 7.1 [2]

[Total: 7]

8 Hydrogen is a fuel which can be obtained from water by electrolysis.

Refinery gas and petrol are fuels obtained by the fractional distillation of petroleum.

(a) (i) Complete the equation for the burning of hydrogen.

..... $H_2(g)$ + $O_2(g)$ → .....$H_2O(l)$ [1]

(ii) State the meaning of (g) and (l).

(g) .....

(l) .....
[2]

(iii) Thermal energy is released to the surroundings when hydrogen is burnt.

State the name of the type of reaction which transfers heat to the surroundings.

..... [1]

(b) Some cars use hydrogen–oxygen fuel cells as a source of energy.

Explain **one** advantage to the environment of using a hydrogen–oxygen fuel cell instead of a petrol engine.

.....

.....

..... [2]

(c) Refinery gas contains methane.

Methane is a gas which is responsible for climate change.

State **two** strategies to reduce the amount of methane entering the atmosphere.

1 .....

2 .....
[2]

(d) Petrol is a mixture of alkanes.

One of the alkanes in petrol is octane, C_8H_{18}.

Name the **two** products formed when octane is burnt in excess air.

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

(e) More petrol can be made by cracking less useful petroleum fractions.

(i) Define the term cracking.

.....

.....

..... [2]

(ii) Complete the equation for the cracking of dodecane, $C_{12}H_{26}$, to form ethene and one other hydrocarbon.

$$C_{12}H_{26} \rightarrow C_2H_4 + ...$$ [1]

[Total: 13]

The Periodic Table of Elements

Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group VIII
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	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 –

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	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 –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

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