



## Cambridge IGCSE™ (9–1)

CANDIDATE  
NAME

CENTRE  
NUMBER

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### CHEMISTRY

0971/31

Paper 3 Theory (Core)

May/June 2021

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.

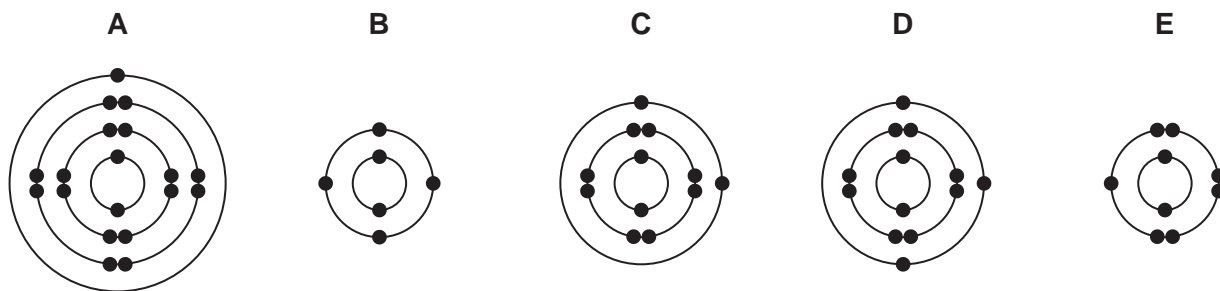
### INFORMATION

- 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 (a) The electronic structures of five atoms, **A**, **B**, **C**, **D** and **E**, are shown.



Answer the following questions about these electronic structures.  
Each electronic structure may be used once, more than once or not at all.

State which electronic structure, **A**, **B**, **C**, **D** or **E**, represents:

(i) an atom in Group II of the Periodic Table

..... [1]

(ii) an atom with a proton number of 13

..... [1]

(iii) an atom that forms a stable ion with a single negative charge

..... [1]

(iv) an atom of a non-metal that forms a giant covalent structure

..... [1]

(v) an atom of a metal used in food containers.

..... [1]

(b) Complete the table to show the number of electrons, neutrons and protons in the vanadium atom and calcium ion shown.

	number of electrons	number of neutrons	number of protons
$^{51}_{23}\text{V}$	23		
$^{48}_{20}\text{Ca}^{2+}$		28	

[3]

[Total: 8]

2 The table shows the masses of some of the ions in  $1000\text{ cm}^3$  of fruit juice.

name of ion	formula of ion	mass of ion in $1000\text{ cm}^3$ of fruit juice / mg
	$\text{NH}_4^+$	43
calcium	$\text{Ca}^{2+}$	79
chloride	$\text{Cl}^-$	135
lithium	$\text{Li}^+$	1
magnesium	$\text{Mg}^{2+}$	80
nitrate	$\text{NO}_3^-$	35
phosphate	$\text{PO}_4^{3-}$	120
potassium	$\text{K}^+$	575
sodium	$\text{Na}^+$	120
	$\text{SO}_4^{2-}$	105

(a) Answer these questions using only the information in the table.

(i) State which negative ion has the highest mass in  $1000\text{ cm}^3$  of fruit juice.

..... [1]

(ii) Give the formulae of the ions in ammonium sulfate.

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

(iii) Calculate the mass of sodium ions in  $200\text{ cm}^3$  of fruit juice.

mass = ..... mg [1]

(b) Describe a test for lithium ions.

test .....

observations .....

[2]

(c) Ions of the element potassium, K, are present in most fertilisers.

State the names of two **other** elements that are in most fertilisers.

1 .....

2 .....

[2]

(d) Orange juice is acidic.

Draw a circle around the pH of orange juice.

pH 4                  pH 7                  pH 10                  pH 13                  [1]

(e) Some soils are acidic.

Give the names of **two** compounds that are used to make soils less acidic.

1 .....

2 .....

[2]

(f) Hydrogen chloride is an acidic gas produced when concentrated hydrochloric acid evaporates.

(i) Describe the arrangement and separation of the molecules in hydrogen chloride gas.

arrangement .....

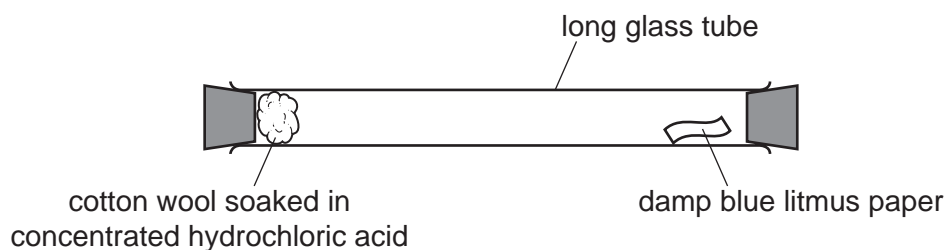
.....

separation .....

.....

[2]

(ii) A long glass tube is set up as shown.



At first, the blue litmus paper does not turn red.

After a short time, the litmus paper turns red.

Explain these observations using the kinetic particle model.

.....

.....

.....

.....

..... [3]

[Total: 15]

3 The table shows some properties of four Group I elements.

element	melting point /°C	boiling point /°C	atomic radius /nm
sodium	98	883	0.191
potassium	63	760	
rubidium	39		0.250
caesium	29	671	0.272

(a) (i) Complete the table by predicting:

- the boiling point of rubidium
- the atomic radius of potassium.

[2]

(ii) Describe the trend in the melting point of the Group I elements down the group.

..... [1]

(iii) Deduce the physical state of potassium at 60°C.  
Explain your answer.

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

(b) Caesium is a radioactive element with a proton number of 55.

(i) Define proton number.

..... [1]

(ii) State **one** industrial use of radioactive isotopes.

..... [1]

(c) Sodium hydride, NaH, reacts with iron(III) oxide.

(i) Balance the equation for this reaction.



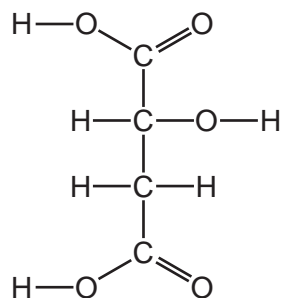
(ii) Explain how this equation shows that iron(III) oxide is reduced.

..... [1]

[Total: 10]

6

4 The structure of malic acid is shown.



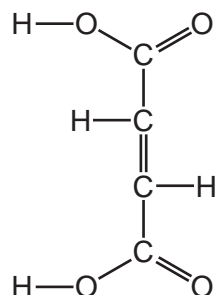
(a) (i) On the structure draw a circle around the alcohol functional group. [1]

(ii) Deduce the formula of malic acid to show the number of carbon, hydrogen and oxygen atoms.

..... [1]

(b) When malic acid is heated it forms compound F.

The structure of compound F is shown.



Explain why compound F is described as unsaturated.

..... [1]

(c) Compound F can form polymers.

(i) State the meaning of the term *polymer*.

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

(ii) State the name of the polymer formed when ethene is polymerised.

..... [1]

(d) Ethanoic acid is a carboxylic acid.

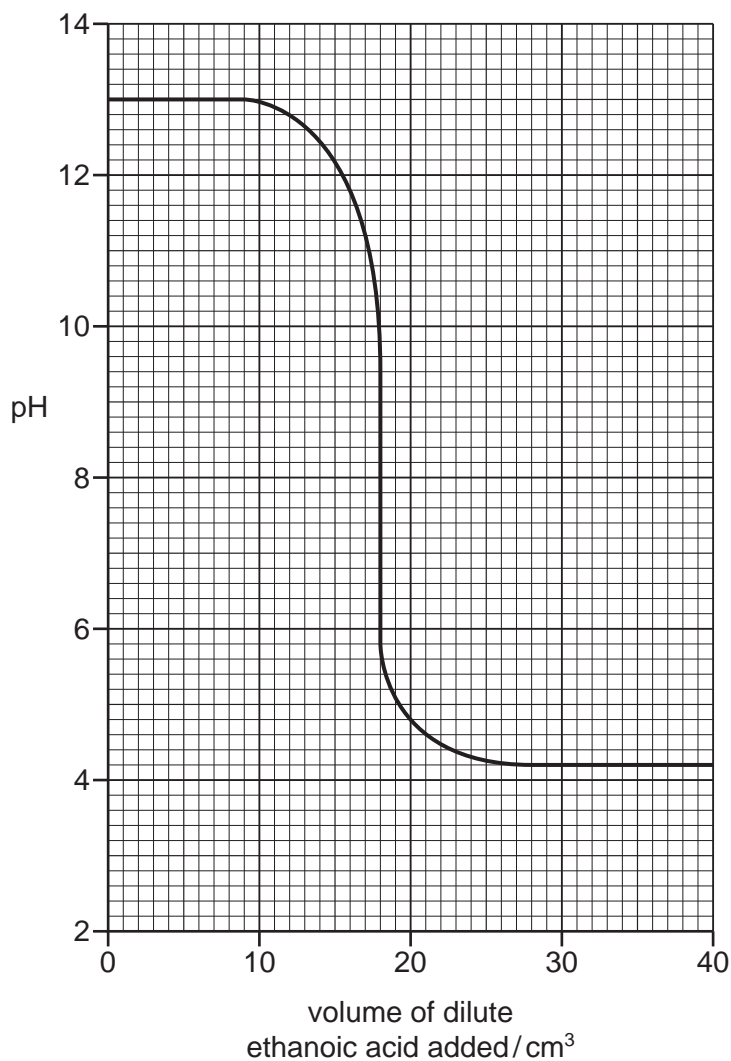
Describe the observations made when dilute ethanoic acid reacts with:

magnesium .....

litmus solution. ....

[2]

(e) The graph shows how the pH changes when dilute ethanoic acid is added slowly to aqueous sodium hydroxide.



(i) Deduce the pH of the aqueous sodium hydroxide before the addition of dilute ethanoic acid.

pH = ..... [1]

(ii) Deduce the volume of dilute ethanoic acid added when the pH is neutral.

..... cm<sup>3</sup> [1]

[Total: 10]

5 (a) Calcium oxide is made by the thermal decomposition of calcium carbonate.

(i) State the meaning of the term *thermal decomposition*.

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

(ii) Describe a test for calcium ions.

test .....

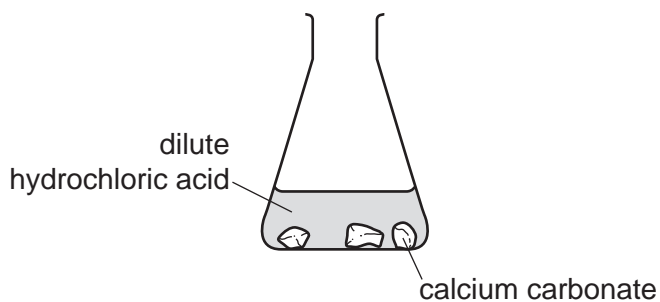
observations .....

[2]

(b) Carbon dioxide is produced when dilute hydrochloric acid reacts with calcium carbonate.



(i) Complete the diagram to show how to measure the volume of carbon dioxide produced during this reaction.



[2]



(ii) Describe the effect of each of the following on the rate of reaction of dilute hydrochloric acid with calcium carbonate.

- The concentration of hydrochloric acid is decreased.

All other conditions stay the same.

.....

- The temperature is increased.

All other conditions stay the same.

.....

[2]

(c) Carbon dioxide is also formed when the hydrocarbon  $C_3H_8$  is completely combusted.

(i) State the meaning of the term *hydrocarbon*.

.....

..... [2]

(ii) The hydrocarbon  $C_3H_8$  is called propane.

Name the homologous series that propane belongs to.

..... [1]

(iii) Name two substances formed by the incomplete combustion of propane.

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

[Total: 13]

6 This question is about water.

(a) The water in rivers often contains pollutants such as acids.

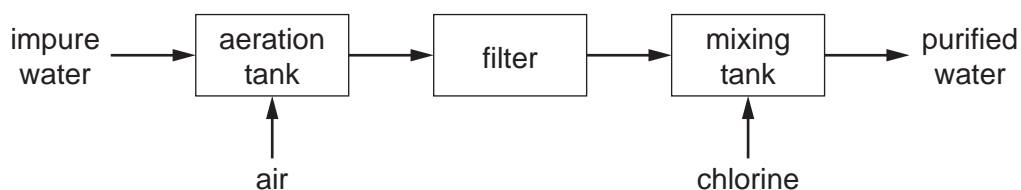
Describe how universal indicator paper can be used to determine the pH value of the water.

.....

.....

..... [2]

(b) The diagram shows some of the stages in water treatment.



(i) Air is blown through the aeration tank.

Name the **two** gases that make up most of the air.

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

(ii) After aeration, the water still contains large insoluble particles.

The filter is made up of fine sand and stones.

Explain how the filter helps purify the water.

.....

.....

..... [2]

(iii) Explain why chlorine is used in water treatment.

..... [1]

(c) Anhydrous cobalt(II) chloride is used to test for water.

State the colour change in this test.

from ..... to ..... [2]

[Total: 9]

7 (a) Molten lead(II) bromide is electrolysed using carbon electrodes.

(i) State the products of this electrolysis at:

the negative electrode .....

the positive electrode. ....

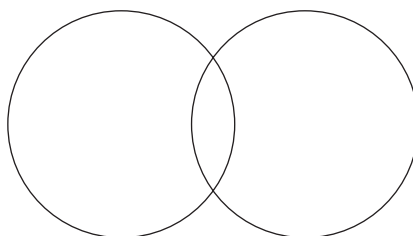
[2]

(ii) State the name of **another** substance which can be used as an inert electrode.

..... [1]

(b) When aqueous magnesium chloride is electrolysed using carbon electrodes, hydrogen gas is produced at the negative electrode.

Complete the dot-and-cross diagram to show the electron arrangement in one molecule of hydrogen.



[1]

[Total: 4]

8 This question is about elements in the Periodic Table.

(a) The table shows some properties of five elements, **P**, **Q**, **R**, **S** and **T**.

element	melting point /°C	density in g/cm <sup>3</sup>	electrical conductivity of the solid	atomic radius /nm
<b>P</b>	1535	7.86	very good	0.125
<b>Q</b>	-7	3.12	does not conduct	0.114
<b>R</b>	1495	8.90	very good	0.126
<b>S</b>	-157	0.0035	does not conduct	0.110
<b>T</b>	839	1.54	very good	0.174

Use only the elements shown in the table to answer this question.

State which two of the elements, **P**, **Q**, **R**, **S** and **T**, are covalent molecules.

Give **two** reasons for your answer.

elements ..... and .....

reason 1 .....

reason 2 .....

[3]

(b) Element **T** is on the left-hand side of the Periodic Table.

Suggest whether its oxide is acidic or basic.

Give a reason for your answer.

.....

..... [1]

(c) Krypton is an element in Group VIII of the Periodic Table.

Explain, using ideas about electronic structure, why krypton is unreactive.

.....

..... [1]

- (d) Sodium is an element in Group I of the Periodic Table. Iron is a transition element.

Iron has a higher melting point and higher boiling point than sodium.

Give **two** other ways in which the properties of transition elements differ from the properties of Group I elements.

1 .....

2 .....

[2]

- (e) The table compares the reactivity of four metals with dilute hydrochloric acid.

metal	reaction with dilute hydrochloric acid
calcium	reacts very rapidly
copper	no reaction
iron	reacts rapidly
nickel	reacts slowly

Put the four metals in order of their reactivity.

Put the least reactive metal first.

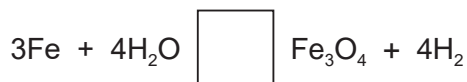
least reactive  $\longrightarrow$  most reactive

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[2]

- (f) Hot iron reacts with steam. The reaction is reversible.

Complete the equation by writing the symbol for a reversible reaction in the box.



[1]

- (g) Steel is an alloy of iron.

State the meaning of the term *alloy*.

..... [1]

[Total: 11]



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The Periodic Table of Elements

		Group																
I	II	III	IV	V	VI	VII	VIII											
		1 <b>H</b> hydrogen 1							2 <b>He</b> helium 4									
3 <b>Li</b> lithium 7	4 <b>Be</b> beryllium 9	<b>Key</b> atomic number atomic symbol name relative atomic mass						9 <b>F</b> fluorine 19	10 <b>Ne</b> neon 20									
11 <b>Na</b> sodium 23	12 <b>Mg</b> magnesium 24	13 <b>Al</b> aluminium 27	14 <b>Si</b> silicon 28	15 <b>P</b> phosphorus 31	16 <b>S</b> sulfur 32	17 <b>Cl</b> chlorine 35.5	18 <b>Ar</b> argon 40											
19 <b>K</b> potassium 39	20 <b>Ca</b> calcium 40	21 <b>Sc</b> scandium 45	22 <b>Ti</b> titanium 48	23 <b>V</b> vanadium 51	24 <b>Cr</b> chromium 52	25 <b>Mn</b> manganese 55	26 <b>Fe</b> iron 56	27 <b>Co</b> cobalt 59	28 <b>Ni</b> nickel 59	29 <b>Cu</b> copper 64	30 <b>Zn</b> zinc 65	31 <b>Ga</b> gallium 70	32 <b>Ge</b> germanium 73	33 <b>As</b> arsenic 75	34 <b>Se</b> selenium 79	35 <b>Br</b> bromine 80	36 <b>Kr</b> krypton 84	
37 <b>Rb</b> rubidium 85	38 <b>Sr</b> strontium 88	39 <b>Y</b> yttrium 89	40 <b>Zr</b> zirconium 91	41 <b>Nb</b> niobium 93	42 <b>Mo</b> molybdenum 96	43 <b>Tc</b> technetium —	44 <b>Ru</b> ruthenium 101	45 <b>Rh</b> rhodium 103	46 <b>Pd</b> palladium 106	47 <b>Ag</b> silver 108	48 <b>Cd</b> cadmium 112	49 <b>In</b> indium 115	50 <b>Sn</b> tin 119	51 <b>Sb</b> antimony 122	52 <b>Te</b> tellurium 128	53 <b>I</b> iodine 127	54 <b>Xe</b> xenon 131	
55 <b>Cs</b> caesium 133	56 <b>Ba</b> barium 137	57–71 lanthanoids	72 <b>Hf</b> hafnium 178	73 <b>Ta</b> tantalum 181	74 <b>W</b> tungsten 184	75 <b>Re</b> rhenium 186	76 <b>Os</b> osmium 190	77 <b>Ir</b> iridium 192	78 <b>Pt</b> platinum 195	79 <b>Au</b> gold 197	80 <b>Hg</b> mercury 201	81 <b>Tl</b> thallium 204	82 <b>Pb</b> lead 207	83 <b>Bi</b> bismuth 209	84 <b>Po</b> polonium —	85 <b>At</b> astatine —	86 <b>Rn</b> radon —	
87 <b>Fr</b> francium —	88 <b>Ra</b> radium —	89–103 actinoids	104 <b>Rf</b> rutherfordium —	105 <b>Db</b> dubnium —	106 <b>Sg</b> seaborgium —	107 <b>Bh</b> bohrium —	108 <b>Hs</b> hassium —	109 <b>Mt</b> meitnerium —	110 <b>Ds</b> darmstadtium —	111 <b>Rg</b> roentgenium —	112 <b>Cn</b> copernicium —	114 <b>Fl</b> flerovium —	116 <b>Lv</b> livermorium —					

lanthanoids	57 <b>La</b> lanthanum 139	58 <b>Ce</b> cerium 140	59 <b>Pr</b> praseodymium 141	60 <b>Nd</b> neodymium 144	61 <b>Pm</b> promethium —	62 <b>Sm</b> samarium 150	63 <b>Eu</b> europium 152	64 <b>Gd</b> gadolinium 157	65 <b>Tb</b> terbium 159	66 <b>Dy</b> dysprosium 163	67 <b>Ho</b> holmium 165	68 <b>Er</b> erbium 167	69 <b>Tm</b> thulium 169	70 <b>Yb</b> ytterbium 173	71 <b>Lu</b> lutetium 175
actinoids	89 <b>Ac</b> actinium —	90 <b>Th</b> thorium 232	91 <b>Pa</b> protactinium 231	92 <b>U</b> uranium 238	93 <b>Np</b> neptunium —	94 <b>Pu</b> plutonium —	95 <b>Am</b> americium —	96 <b>Cm</b> curium —	97 <b>Bk</b> berkelium —	98 <b>Cf</b> californium —	99 <b>Es</b> einsteinium —	100 <b>Fm</b> fermium —	101 <b>Md</b> mendelevium —	102 <b>No</b> nobelium —	103 <b>Lr</b> lawrencium —

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