

**Cambridge IGCSE™ (9–1)**CANDIDATE
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CHEMISTRY**0971/31**

Paper 3 Theory (Core)

May/June 2022**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 **20** pages. Any blank pages are indicated.

1 (a) A list of symbols and formulae is shown.

CaO
 CH₄
 C₂H₄
 C₂H₆
 Cl⁻
 Cu²⁺
 H₂
 He
 K⁺
 N₂
 Na⁺
 SO₂

Answer the following questions using these symbols or formulae.
 Each symbol or formula may be used once, more than once or not at all.

State which symbol or formula represents:

- (i) a compound produced by the thermal decomposition of calcium carbonate
 [1]
- (ii) a positive ion that gives a blue-green colour in a flame test
 [1]
- (iii) an element used as a fuel
 [1]
- (iv) the monomer used to produce poly(ethene)
 [1]
- (v) an ion formed when an atom gains an electron.
 [1]

(b) Complete the table to show the relative charges of a proton, a neutron and an electron.

type of particle	relative charge
proton	+1
neutron	
electron	

[2]

3

- (c) Choose the two correct statements about nitrogen.
Tick (✓) **two** boxes.

Nitrogen molecules are monoatomic.

All nitrogen atoms have seven protons.

Nitrogen atoms cannot be split into simpler substances by chemical means.

All nitrogen atoms have 14 neutrons.

Nitrogen is 21% of clean, dry air.

[2]

[Total: 9]

2 The table shows the masses of some ions in a 1000 cm^3 sample of toothpaste.

name of ion	formula of ion	mass of ion in 1000 cm^3 of toothpaste/g
	NH_4^+	0.2
calcium	Ca^{2+}	1.2
	Cl^-	0.9
fluoride	F^-	1.4
magnesium	Mg^{2+}	2.0
phosphate	PO_4^{3-}	24.4
sodium	Na^+	28.1
sulfate	SO_4^{2-}	9.2
tin(II)	Sn^{2+}	0.2
zinc	Zn^{2+}	0.1

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

(i) State which negative ion has the lowest mass in 1000 cm^3 of toothpaste.

..... [1]

(ii) Name the compound that contains NH_4^+ and Cl^- ions.

..... [1]

(iii) Calculate the mass of phosphate ions in 250 cm^3 of toothpaste.

mass = g [1]

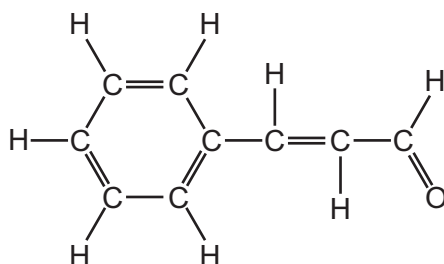
(b) Describe a test for sulfate ions.

test

observations

[2]

- (c) Toothpaste also contains cinnamal.
The structure of cinnamal is shown.



Deduce the formula of cinnamal to show the number of atoms of carbon, hydrogen and oxygen.

..... [1]

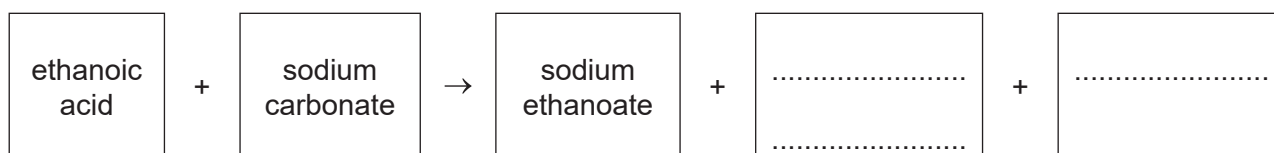
- (d) Cinnamal can be oxidised to a carboxylic acid.

- (i) Draw the structure of a carboxylic acid functional group to show all of the atoms and all of the bonds.

[1]

- (ii) Ethanoic acid is a carboxylic acid.
Ethanoic acid reacts like a typical acid.

Complete the word equation for the reaction of ethanoic acid with sodium carbonate.



[2]

[Total: 9]

3 This question is about halogens and halogen compounds.

(a) Deduce the number of electrons, neutrons and protons in one atom of the isotope of chlorine shown.



number of electrons

number of neutrons

number of protons

[3]

(b) State why chlorine is used in water treatment.

..... [1]

(c) Aqueous chlorine reacts with aqueous potassium iodide.

(i) Complete the chemical equation for this reaction.



(ii) Explain in terms of the reactivity of the halogens why aqueous iodine does **not** react with aqueous potassium chloride.

.....

..... [1]

(d) The table shows some properties of four halogens.

halogen	melting point /°C	boiling point /°C	density of liquid at boiling point in g/cm ³
fluorine	-220	1.51
chlorine	-101	-35
bromine	-7	59	3.12
iodine	114	184	4.93

(i) Complete the table by predicting:

- the boiling point of fluorine
- the density of liquid chlorine at its boiling point.

[2]

(ii) Predict the physical state of chlorine at -105°C.
Give a reason for your answer.

.....

..... [2]

[Total: 11]

4 This question is about acids and bases.

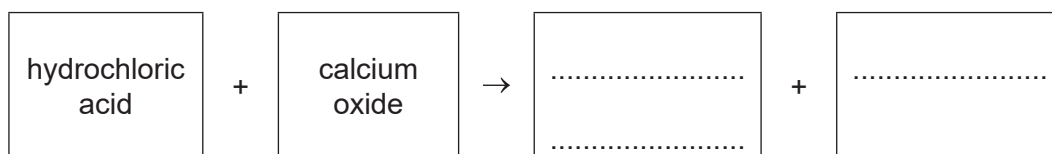
(a) Describe the colour of methyl orange in acidic and alkaline solutions.

in acidic solution

in alkaline solution

[2]

(b) Complete the word equation for the reaction of hydrochloric acid with calcium oxide.



[2]

(c) Calcium oxide is lime.

Give **one** use of lime.

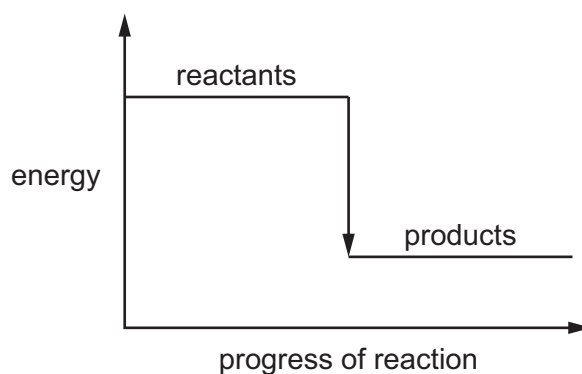
..... [1]

(d) The reaction of hydrochloric acid with calcium oxide is exothermic.

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

..... [1]

(ii) The energy level diagram for the reaction of hydrochloric acid with calcium oxide is shown.



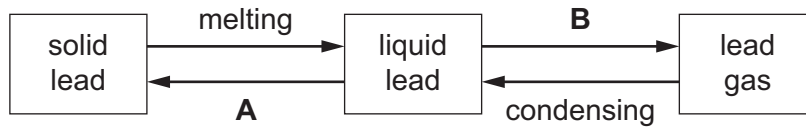
Explain how the energy level diagram shows that this reaction is exothermic.

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

[Total: 7]

5 This question is about Group IV elements and their compounds.

(a) The changes of state of lead are shown.



Name the changes of state represented by **A** and **B**.

A

B

[2]

(b) Use the kinetic particle model to describe the differences between liquid lead and lead gas in terms of:

- the separation of the particles

.....

.....

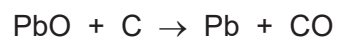
- the motion of the particles.

.....

.....

[4]

(c) Lead is extracted from lead(II) oxide by heating with carbon.



Describe how this equation shows that lead(II) oxide is reduced.

.....

..... [1]

(d) Lead is a pollutant of the air.

(i) State **one** source of lead in the air.

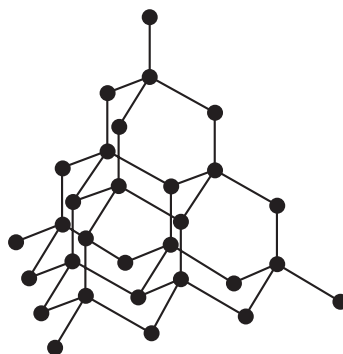
..... [1]

(ii) State **one** adverse effect of lead on health.

..... [1]

(e) Diamond is a form of carbon.

The structure of diamond is shown.



(i) Choose the word which best describes the structure of diamond.

Draw a circle around your chosen answer.

giant **ionic** **metallic** **simple** [1]

(ii) Name the type of bonding in diamond.

..... [1]

(iii) Give **one** use of diamond.

..... [1]

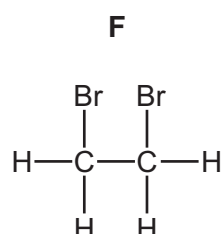
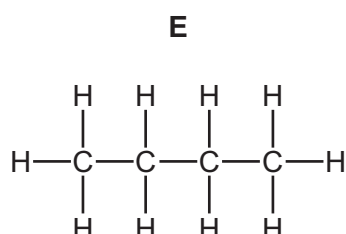
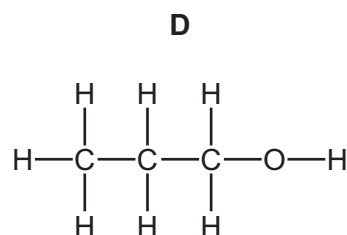
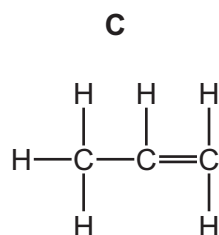
(iv) Deduce the electronic structure of carbon.

Use the Periodic Table to help you.

..... [1]

[Total: 13]

- 6 (a) The structures of four organic compounds, **C**, **D**, **E** and **F**, are shown.



Answer the following questions about these compounds.
Each compound may be used once, more than once or not at all.

State which compound, **C**, **D**, **E** or **F**:

- (i) decolourises aqueous bromine [1]
- (ii) is an alcohol [1]
- (iii) is unsaturated [1]
- (iv) is in the same homologous series as ethane. [1]
- (b) Petroleum is a mixture of hydrocarbons which can be separated into fractions with different boiling points.

Name the method used to separate these fractions.

..... [1]

- (c) Complete the table to show the name and uses of some petroleum fractions.

name of fraction	use of fraction
refinery gas	
gasoline	
	waxes and polishes

[3]

(d) Some hydrocarbons are formed by the process of cracking.

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

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

(ii) Describe the conditions needed for cracking.

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

[Total: 12]

7 This question is about zinc and compounds of zinc.

(a) Zinc is a metal.

Give **three** physical properties of metals.

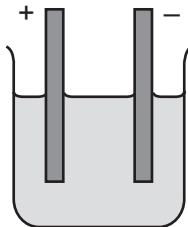
- 1
- 2
- 3 [3]

(b) Zinc reacts with phosphorus to form zinc phosphide, Zn_3P_2 .

Complete the equation for this reaction.



(c) Molten zinc chloride is electrolysed.
The incomplete apparatus is shown.



(i) Complete the diagram by:

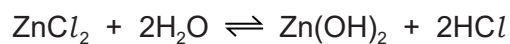
- completing the circuit to show the wires and power pack
- labelling the anode. [2]

(ii) Name the products formed at each electrode.

positive electrode

negative electrode [2]

(d) Zinc chloride reacts with water as shown. The solution formed is acidic.



(i) State the meaning of the symbol \rightleftharpoons .

..... [1]

(ii) Choose the pH value which is acidic.

Draw a circle around your chosen answer.

pH 3 pH 7 pH 9 pH 14 [1]

(e) A compound of zinc has the formula $\text{ZnC}_4\text{H}_{10}$.

Complete the table to calculate the relative molecular mass of $\text{ZnC}_4\text{H}_{10}$.

atom	number of atoms	relative atomic mass	
zinc	1	65	$1 \times 65 = 65$
carbon		12	
hydrogen		1	

relative molecular mass = [2]

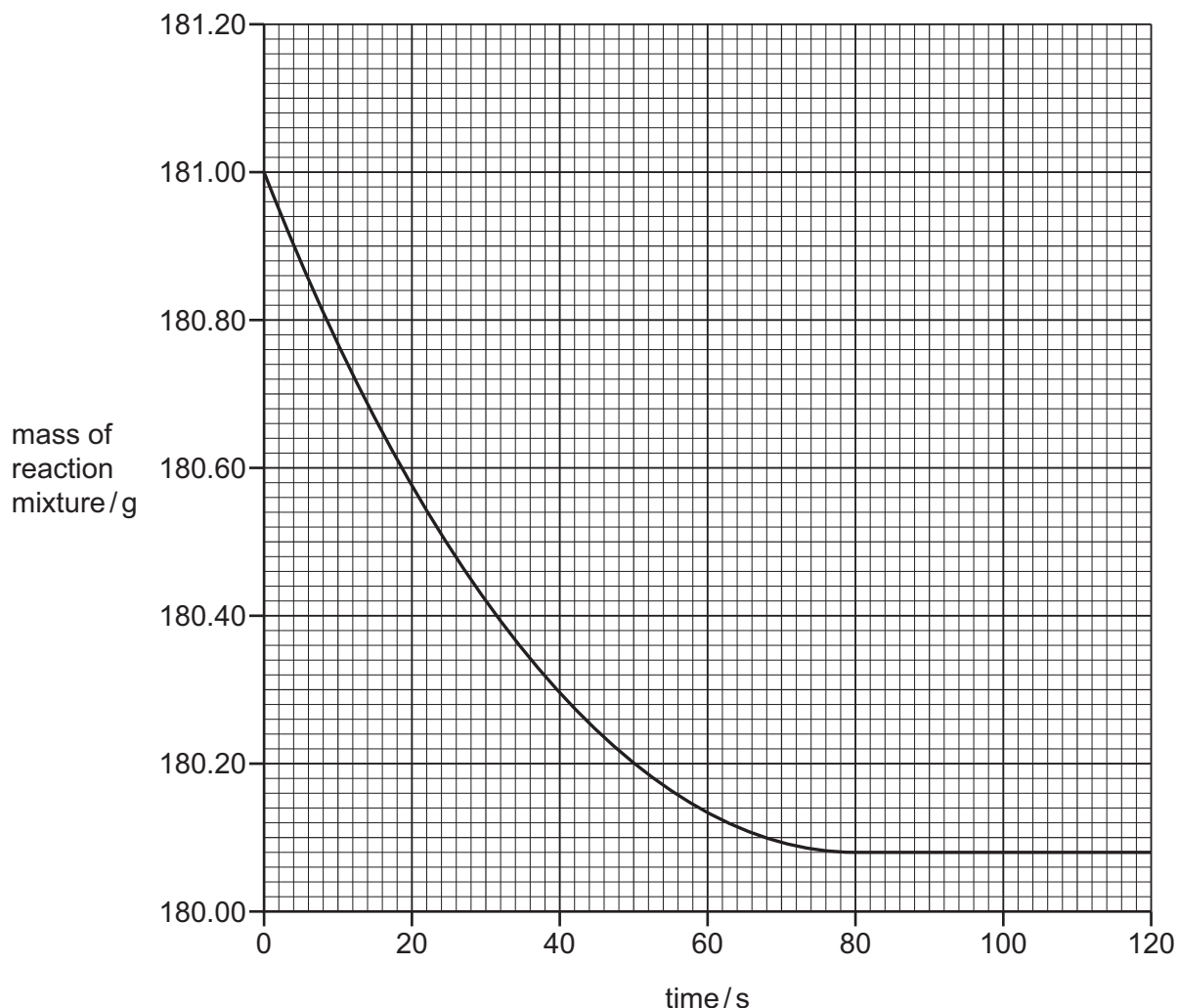
[Total: 13]

- 8 A student investigates the reaction of large pieces of copper(II) carbonate with dilute hydrochloric acid. The hydrochloric acid is in excess.



The rate of reaction is found by measuring the mass of the reaction mixture as time increases.

The results are shown on the graph.



- (a) Deduce the mass of the reaction mixture at 30 s.

mass = g [1]

- (b) The experiment is repeated using smaller pieces of copper(II) carbonate.

All other conditions stay the same.

Draw a line **on the grid** to show how the mass of the reaction mixture changes as time increases. [2]

- (c) Describe the effect each of the following has on the rate of reaction of copper(II) carbonate with dilute hydrochloric acid.

All other conditions stay the same.

- The reaction is carried out in the presence of a catalyst.

.....

- The reaction is carried out using a lower concentration of hydrochloric acid.

.....

[2]

- (d) When 0.2g of copper(II) carbonate is used, 38 cm³ of carbon dioxide gas is produced.

Calculate the volume of carbon dioxide gas produced when 0.50g of copper(II) carbonate is used.

volume of carbon dioxide gas = cm³ [1]

[Total: 6]

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The Periodic Table of Elements

		Group							
I	II	III	IV	V	VI	VII	VIII		
3 Li lithium 7	4 Be beryllium 9	1 H hydrogen 1	5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20	2
11 Na sodium 23	12 Mg magnesium 24	Key atomic number atomic symbol name relative atomic mass							
19 K potassium 39	20 Ca calcium 40	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Al aluminium 27	32 Si silicon 28	33 P phosphorus 31
37 Rb rubidium 85	38 Sr strontium 88	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31
55 Cs caesium 133	56 Ba barium 137	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31
87 Fr francium —	88 Ra radium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	116 Lv livermorium —	117 Tl thallium 204	118 Xe xenon 131
57 La lanthanum 139	58 Ce cerium 140	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
89 Ac actinium —	90 Th thorium 232	94 Pu plutonium —	95 Am americium —	96 Cm curium —	97 Bk berkelium —	98 Cf californium —	99 Es einsteinium —	100 Fm fermium —	101 Md mendelevium —
		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
		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
		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
		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 —
		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
		71 Lu lutetium 175	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
		103 Lr lawrencium —	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —
		86 Rn radon —	87 Fr francium —	88 Ra radium —	89–103 actinoids	89 Ac actinium —	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238
		84 Kr krypton —	85 Rb rubidium 85	86 Sr strontium 88	87 Cs caesium 133	88 Ba barium 137	89 La lanthanum 139	90 Ce cerium 140	91 Pr praseodymium 141
		82 Xe xenon 131	83 Rb rubidium 85	84 Sr strontium 88	85 Cs caesium 133	86 Ba barium 137	87 Fr francium —	88 Ra radium —	89 Ac actinium —
		80 Br bromine 80	81 Rn radon —	82 Xe xenon 131	83 Kr krypton 84	84 Sr strontium 88	85 Rb rubidium 85	86 Cs caesium 133	87 Ba barium 137
		53 I iodine 127	54 Xe xenon 131	55 Cs caesium 133	56 Ba barium 137	57 La lanthanoids	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144
		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 La lanthanoids	58 Ce cerium 140
		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
		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
		32 S sulfur 32	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
		16 O oxygen 16	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
		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
		14 N nitrogen 14	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
		12 C carbon 12	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
		11 B boron 11	12 C carbon 12	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
		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

lanthanoids

actinoids

The volume of one mole of any gas is 24 dm³ at room temperature and pressure (r.t.p.).