



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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0620/41

May/June 2022

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

- 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.

- 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 list of substances is shown.

aluminium oxide	carbon dioxide	chlorine	diamond	ethanol
glucose	iron(III) oxide	limestone	nitrogen	oxygen

Answer the questions using the list of substances.

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

State which of the substances:

(a) is a reactant in photosynthesis

..... [1]

(b) is the main constituent of bauxite

..... [1]

(c) are **two** products of fermentation

..... and [2]

(d) is used as a fuel

..... [1]

(e) is a gas used to convert iron into steel

..... [1]

(f) is a greenhouse gas

..... [1]

(g) is a gas that is approximately 78% of clean, dry air

..... [1]

(h) is a form of carbon.

..... [1]

[Total: 9]

- 2 (a) Atoms are made of protons, neutrons and electrons. Atoms of the same element are known as isotopes.

(i) Complete the table.

particle	relative charge	relative mass
electron		$\frac{1}{1840}$
neutron		
proton	+1	

[2]

- (ii) $^{24}_{12}\text{Mg}$ and $^{25}_{12}\text{Mg}$ are isotopes of magnesium.

Complete the table to show the numbers of electrons, neutrons and protons in these isotopes of magnesium.

isotope	number of electrons	number of neutrons	number of protons
$^{24}_{12}\text{Mg}$			
$^{25}_{12}\text{Mg}$			

[2]

- (iii) Explain why magnesium ions have a charge of 2+.

.....
 [1]

- (b) Mg^{2+} ions have the electronic structure 2,8.

Give the formula of the following particles which have the same electronic structure as Mg^{2+} ions.

- a cation (positive ion)

.....

- an anion (negative ion)

.....

- an atom

.....

[3]

[Total: 8]

3 This question is about sodium and compounds of sodium.

(a) (i) Describe the bonding in a metallic element such as sodium.

You may include a diagram as part of your answer.

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

(ii) Describe how solid sodium conducts electricity.

..... [1]

(b) Some properties of sodium chloride are shown:

- melting point of 801 °C
- non-conductor of electricity when solid
- conductor of electricity when molten
- soluble in water.

(i) Name the type of bonding in sodium chloride.

..... [1]

(ii) Explain why sodium chloride conducts electricity when molten.

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

- (c) A student determines the concentration of a solution of dilute sulfuric acid, H_2SO_4 , by titration with aqueous sodium hydroxide, NaOH .

step 1 25.0 cm³ of 0.200 mol/dm³ NaOH is transferred into a conical flask.

step 2 Three drops of methyl orange indicator are added to the conical flask.

step 3 A burette is filled with H_2SO_4 .

step 4 The acid in the burette is added to the conical flask until the indicator changes colour. The volume of acid is recorded. This process is known as titration.

step 5 The titration is repeated several times until a suitable number of results is obtained.

- (i) Name the piece of apparatus used to measure exactly 25.0 cm³ of 0.200 mol/dm³ NaOH in **step 1**.

..... [1]

- (ii) State the colour change of the methyl orange indicator in **step 4**.

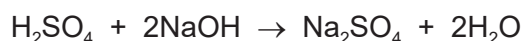
from to [1]

- (iii) State how the student decides that a suitable number of results have been obtained.

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

- (iv) 20.0 cm³ of H_2SO_4 reacts with 25.0 cm³ of 0.200 mol/dm³ NaOH .

The equation for the reaction is shown.



Calculate the concentration of H_2SO_4 using the following steps.

- Calculate the number of moles in 25.0 cm³ of 0.200 mol/dm³ NaOH .

..... mol

- Determine the number of moles of H_2SO_4 that react with the NaOH .

..... mol

- Calculate the concentration of H_2SO_4 .

..... mol/dm³
[3]

[Total: 12]

4 This question is about compounds of sulfur.

(a) Sulfuric acid, H_2SO_4 , is manufactured using the Contact process. This manufacture involves four stages.

stage 1 Molten sulfur burns in air to produce sulfur dioxide.

stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide.

stage 3 Sulfur trioxide combines with concentrated sulfuric acid to form oleum, $\text{H}_2\text{S}_2\text{O}_7$.

stage 4 Oleum reacts to form concentrated sulfuric acid.

(i) Write a chemical equation for the reaction occurring in **stage 1**.

..... [1]

(ii) State the essential conditions that are necessary for **stage 2**. Write an equation for the chemical reaction that occurs.

.....

 [4]

(iii) Write a chemical equation for the reaction occurring in **stage 3**.

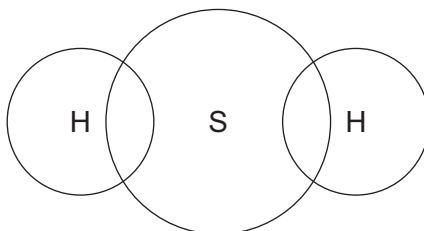
..... [1]

(iv) Name the substance that reacts with oleum in **stage 4**.

..... [1]

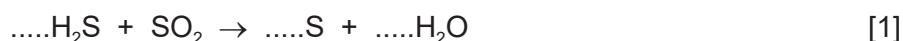
(b) Hydrogen sulfide has the formula H_2S .

(i) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of hydrogen sulfide. Show outer shell electrons only.



[2]

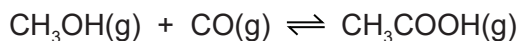
(ii) Balance the chemical equation for the reaction of hydrogen sulfide with sulfur dioxide shown.



[Total: 10]

- 5 Ethanoic acid is manufactured by the reaction of methanol with carbon monoxide.

An equilibrium mixture is produced.



- (a) State **two** characteristics of an equilibrium.

1

2 [2]

- (b) The purpose of the industrial process is to produce a high yield of ethanoic acid at a high rate of reaction.

The manufacture is carried out at a temperature of 300 °C.

The forward reaction is exothermic.

Use this information to state why the manufacture is **not** carried out at temperatures:

- **below** 300 °C

.....

- **above** 300 °C.

..... [2]

- (c) Complete the table using only the words *increases*, *decreases* or *no change*.

	effect on the rate of the forward reaction	effect on the equilibrium yield of CH ₃ COOH(g)
adding a catalyst		no change
decreasing the pressure		

[3]

- (d) Suggest which of the following metals is a suitable catalyst for the reaction. Give a reason for your answer.

aluminium

calcium

cobalt

magnesium

potassium

suitable catalyst

reason

[2]

- (e) Ethanoic acid is a member of the homologous series of carboxylic acids.

State the general formula of this homologous series.

..... [1]

- (f) Draw the structure of the carboxylic acid containing three carbon atoms. Show all of the atoms and all of the bonds.

[2]

- (g) When carboxylic acids react with alcohols, esters are produced.

The formula of ester **X** is $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOCH}_3$.

- (i) Name ester **X**.

..... [1]

- (ii) Give the name of the carboxylic acid and the alcohol that react together to produce ester **X**.

carboxylic acid

alcohol

[2]

- (h) Ester **Y** has the following composition by mass:

C, 48.65%; H, 8.11%; O, 43.24%.

Calculate the empirical formula of ester **Y**.

empirical formula = [3]

- (i) Ester **Z** has the empirical formula $\text{C}_2\text{H}_4\text{O}$ and a relative molecular mass of 88.

Determine the molecular formula of ester **Z**.

molecular formula = [1]

[Total: 19]

6 This question is about zinc and its compounds.

(a) Zinc is extracted from its ore which is mainly zinc sulfide, ZnS.

The steps for this extraction are shown.

step 1 Zinc sulfide is converted into zinc oxide.

step 2 The zinc oxide is then reduced to zinc in a furnace. The zinc formed becomes a gas.

step 3 The zinc gas is cooled to form molten zinc.

(i) Name the ore of zinc, which is mainly zinc sulfide.

..... [1]

(ii) Describe how zinc sulfide is converted into zinc oxide in **step 1**.

.....
 [1]

(iii) Name the reducing agent used in **step 2**.

..... [1]

(iv) Explain why the zinc forms a gas in **step 2** inside the furnace.

..... [1]

(v) State the name of the physical change occurring when zinc gas is converted into molten zinc.

..... [1]

(b) Zinc sulfate crystals, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, are hydrated.

Zinc sulfate crystals are made by reacting zinc carbonate with dilute sulfuric acid.

The equation for the overall process is shown.



step 1 Large pieces of solid zinc carbonate are added to dilute sulfuric acid until the zinc carbonate is in excess. This forms aqueous zinc sulfate.

step 2 The excess zinc carbonate is separated from the aqueous zinc sulfate.

step 3 The aqueous zinc sulfate is heated until a saturated solution is formed.

step 4 The saturated solution is allowed to cool and crystallise.

step 5 The crystals are removed and dried.

- (i) In **step 1**, zinc carbonate is in excess when no more zinc carbonate dissolves.

State one **other** observation that indicates the zinc carbonate is in excess in **step 1**.

..... [1]

- (ii) Name a different substance, other than zinc carbonate, that can be added to dilute sulfuric acid to produce aqueous zinc sulfate in **step 1**.

..... [1]

- (iii) **Step 1** is repeated using powdered zinc carbonate instead of large pieces.

All other conditions are kept the same.

The rate of reaction increases.

Give a reason why the rate of reaction increases. Explain your answer in terms of particles.

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

- (iv) Suggest what is observed when the solution is saturated in **step 3**.

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

- (v) The formula of zinc sulfate crystals is $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$.

Give the formula of the solid formed if the crystals are heated to dryness in **step 3**.

..... [1]

[Total: 11]

7 The Periodic Table can be used to classify elements.

(a) Group I elements react with cold water to form alkaline solutions.

(i) Place the Group I elements caesium, lithium, potassium, rubidium and sodium in their order of reactivity with water.

Put the most reactive element first.

most reactive
→
 least reactive

--	--	--	--	--

[1]

(ii) Name the alkaline solution formed when caesium reacts with cold water.

..... [1]

(b) Group I elements have lower melting points than transition elements.

Describe one **other** difference in the **physical** properties of Group I elements and transition elements.

..... [1]

(c) Group VII elements are known as the halogens.

Astatine is below iodine in Group VII.

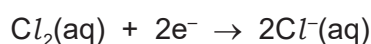
Predict the physical state of astatine at room temperature and pressure.

..... [1]

(d) Some Group VII elements react with aqueous solutions containing halide ions.

When aqueous chlorine is added to aqueous potassium bromide a reaction occurs.

The ionic half-equations for the reaction are shown.



(i) Describe the colour change of the solution.

original colour of potassium bromide solution

final colour of reaction mixture

[2]

(ii) Identify the species that is oxidised.

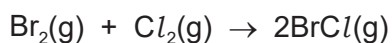
Explain your decision.

species oxidised

explanation

[2]

(e) Bromine monochloride, BrCl , is made by the reaction between bromine and chlorine. The chemical equation is shown.



bond	bond energy in kJ/mol
Br–Br	190
Cl–Cl	242
Br–Cl	218

Calculate the overall energy change for the reaction using bond energies.

Use the following steps.

- Calculate the total amount of energy required to break the bonds in 1 mole of $\text{Br}_2(\text{g})$ and 1 mole of $\text{Cl}_2(\text{g})$.

..... kJ

- Calculate the total amount of energy released when the bonds in 2 moles of $\text{BrCl}(\text{g})$ are formed.

..... kJ

- Calculate the overall energy change for the reaction.

..... kJ/mol
[3]

[Total: 11]

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The Periodic Table of Elements

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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 —	114 Fl flerovium —	116 Lv livermorium —	118 Og oganesson —	119 Uue unbinilium —	120 Uuh untrium —	121 Uut ununilium —	122 Uuq unquadium —	123 Uub unbium —	124 Uut ununilium —	125 Uuq unquadium —	126 Uub unbium —	127 Uut ununilium —	128 Uuq unquadium —	129 Uub unbium —	130 Uut ununilium —	131 Uuq unquadium —	132 Uub unbium —	133 Uut ununilium —	134 Uuq unquadium —	135 Uub unbium —	136 Uut ununilium —	137 Uuq unquadium —	138 Uub unbium —	139 Uut ununilium —	140 Uuq unquadium —	141 Uub unbium —	142 Uut ununilium —	143 Uuq unquadium —	144 Uub unbium —	145 Uut ununilium —	146 Uuq unquadium —	147 Uub unbium —	148 Uut ununilium —	149 Uuq unquadium —	150 Uub unbium —	151 Uut ununilium —	152 Uuq unquadium —	153 Uub unbium —	154 Uut ununilium —	155 Uuq unquadium —	156 Uub 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unbium —	472 Uut ununilium —	473 Uuq unquadium —	474 Uub unbium —	475 Uut ununilium —	476 Uuq unquadium —	477 Uub unbium —	478 Uut ununilium —	479 Uuq unquadium —	480 Uub unbium —	481 Uut ununilium —	482 Uuq unquadium —	483 Uub unbium —	484 Uut ununilium —	485 Uuq unquadium —	486 Uub unbium —	487 Uut ununilium —	488 Uuq unquadium —	489 Uub unbium —	490 Uut ununilium —	491 Uuq unquadium —	492 Uub unbium —	493 Uut ununilium —	494 Uuq unquadium —	495 Uub unbium —	496 Uut ununilium —	497 Uuq unquadium —	498 Uub unbium —	499 Uut ununilium —	500 Uuq unquadium —	501 Uub unbium —	502 Uut ununilium —	503 Uuq unquadium —	504 Uub unbium —	505 Uut ununilium —	506 Uuq unquadium —	507 Uub unbium —	508 Uut ununilium —	509 Uuq unquadium —	510 Uub unbium —	511 Uut ununilium —	512 Uuq unquadium —	513 Uub unbium —	514 Uut ununilium —	515 Uuq unquadium —	516 Uub unbium —	517 Uut ununilium —	518 Uuq unquadium —	519 Uub unbium —	520 Uut ununilium —	521 Uuq unquadium —	522 Uub unbium —	523 Uut ununilium 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unbium —	577 Uut ununilium —	578 Uuq unquadium —	579 Uub unbium —	580 Uut ununilium —	581 Uuq unquadium —	582 Uub unbium —	583 Uut ununilium —	584 Uuq unquadium —	585 Uub unbium —	586 Uut ununilium —	587 Uuq unquadium —	588 Uub unbium —	589 Uut ununilium —	590 Uuq unquadium —	591 Uub unbium —	592 Uut ununilium —	593 Uuq unquadium —	594 Uub unbium —	595 Uut ununilium —	596 Uuq unquadium —	597 Uub unbium —	598 Uut ununilium —	599 Uuq unquadium —	600 Uub unbium —	601 Uut ununilium —	602 Uuq unquadium —	603 Uub unbium —	604 Uut ununilium —	605 Uuq unquadium —	606 Uub unbium —	607 Uut ununilium —	608 Uuq unquadium —	609 Uub unbium —	610 Uut ununilium —	611 Uuq unquadium —	612 Uub unbium —	613 Uut ununilium —	614 Uuq unquadium —	615 Uub unbium —	616 Uut ununilium —	617 Uuq unquadium —	618 Uub unbium —	619 Uut ununilium —	620 Uuq unquadium —	621 Uub unbium —	622 Uut ununilium —	623 Uuq unquadium —	624 Uub unbium —	625 Uut ununilium —	626 Uuq unquadium —	627 Uub unbium —	628 Uut ununilium —	629 Uuq unquadium —	630 Uub unbium —	631 Uut ununilium —	632 Uuq unquadium —	633 Uub unbium —	634 Uut ununilium —	635 Uuq unquadium —	636 Uub unbium —	637 Uut ununilium —	638 Uuq unquadium —	639 Uub unbium —	640 Uut ununilium —	641 Uuq unquadium —	642 Uub unbium —	643 Uut ununilium —	644 Uuq unquadium —	645 Uub unbium —	

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
	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 dm³ at room temperature and pressure (r.t.p.).