



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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0620/41

May/June 2021

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 Give the name of the process that is used:

(a) to produce ammonia from nitrogen

..... [1]

(b) to separate nitrogen from liquid air

..... [1]

(c) to produce bromine from molten lead(II) bromide

..... [1]

(d) to separate an undissolved solid from an aqueous solution

..... [1]

(e) to produce amino acids from proteins

..... [1]

(f) to separate a mixture of amino acids.

..... [1]

[Total: 6]

2 Complete the table to:

- deduce the number of protons, electrons and neutrons in the magnesium atom and copper ion shown
- identify the atom or ion represented by the final row.

	number of protons	number of electrons	number of neutrons
$^{25}_{12}\text{Mg}$	12		
$^{65}_{29}\text{Cu}^{2+}$			36
	17	18	20

[Total: 5]

3 Potassium reacts with chlorine to form potassium chloride, KCl .

(a) Write a chemical equation for this reaction.

..... [2]

(b) Potassium chloride is an ionic compound.

Complete the diagram to show the electron arrangement in the outer shells of the ions present in potassium chloride.

Give the charges on both ions.



[3]

(c) Molten potassium chloride undergoes electrolysis.

(i) State what is meant by the term *electrolysis*.

.....
 [2]

(ii) Name the products formed at the positive electrode (anode) and negative electrode (cathode) when molten potassium chloride undergoes electrolysis.

anode

cathode

[2]

(d) Concentrated aqueous potassium chloride undergoes electrolysis.

(i) Write an ionic half-equation for the reaction at the negative electrode (cathode).

..... [2]

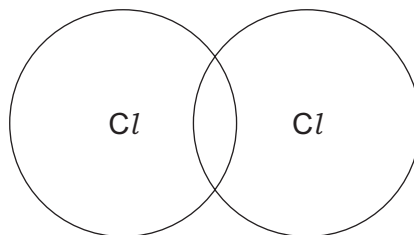
(ii) Name the product formed at the positive electrode (anode).

..... [1]

(iii) Name the potassium compound that remains in the solution after electrolysis.

..... [1]

- (e) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of chlorine, Cl_2 .
Show the outer electrons only.



[1]

- (f) The melting points and boiling points of chlorine and potassium chloride are shown.

	melting point / $^{\circ}\text{C}$	boiling point / $^{\circ}\text{C}$
chlorine	-101	-35
potassium chloride	770	1500

- (i) Deduce the physical state of chlorine at -75°C . Use the data in the table to explain your answer.

physical state

explanation

[2]

- (ii) Explain, in terms of structure and bonding, why potassium chloride has a much higher melting point than chlorine.

Your answer should refer to the:

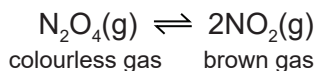
- types of particle held together by the forces of attraction
- types of forces of attraction between particles
- relative strength of the forces of attraction.

.....

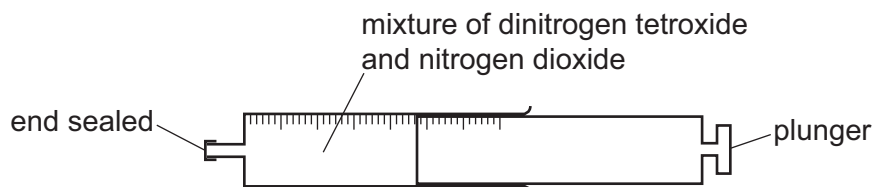
 [3]

[Total: 19]

- 4 Dinitrogen tetroxide, N_2O_4 , decomposes into nitrogen dioxide, NO_2 . The reaction is reversible.



A gas syringe containing a mixture of dinitrogen tetroxide and nitrogen dioxide gases was sealed and heated. After reaching equilibrium the mixture was a pale brown colour.

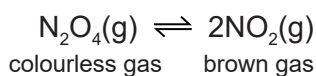


- (a) State what is meant by the term *equilibrium*.

.....

 [2]

- (b) The plunger of the gas syringe is pushed in. The temperature does not change. The mixture initially turns darker brown. After a few seconds the mixture turns lighter brown because the equilibrium shifts to the left.



- (i) Explain why the mixture initially turns darker brown.

..... [1]

- (ii) Explain why the position of equilibrium shifts to the left.

..... [1]

- (c) The forward reaction is endothermic.

- (i) State what happens to the position of equilibrium when the temperature of the mixture is increased.

..... [1]

- (ii) State what happens to the rate of the forward reaction and the rate of the backward reaction when the temperature of the mixture is increased.

rate of the forward reaction

rate of the backward reaction

[2]

[Total: 7]

5 This question is about salts.

(a) Salts that are insoluble in water are made by precipitation.

- Lead(II) iodide, PbI_2 , is insoluble in water.
- All nitrates are soluble in water.
- All sodium salts are soluble in water.

You are provided with solid lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2$, and solid sodium iodide, NaI .

Describe how you would make a pure sample of lead(II) iodide by precipitation.

Your answer should include:

- practical details
- a chemical equation for the precipitation reaction.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

(b) Nitrates decompose when heated.

(i) When hydrated zinc nitrate is heated, oxygen gas is given off.

Describe a test for oxygen.

test

observations

[2]

(ii) Complete the equation for the decomposition of hydrated zinc nitrate.



(c) Some sulfates are hydrated.

When hydrated sodium sulfate crystals, $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$, are heated, they give off water.



A student carries out an experiment to determine the value of x in $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$.

step 1 Hydrated sodium sulfate crystals are weighed.

step 2 The hydrated sodium sulfate crystals are then heated.

step 3 The remaining solid is weighed.

(i) Describe how the student can check that all the water has been given off.

.....

.....

..... [2]

- (ii) In an experiment, 1.61 g of $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$ is heated until all the water is given off. The mass of Na_2SO_4 remaining is 0.71 g.

$[M_r: \text{Na}_2\text{SO}_4, 142; \text{H}_2\text{O}, 18]$

Determine the value of x using the following steps.

- Calculate the number of moles of Na_2SO_4 remaining.

..... mol

- Calculate the mass of H_2O given off.

..... g

- Calculate the number of moles of H_2O given off.

..... mol

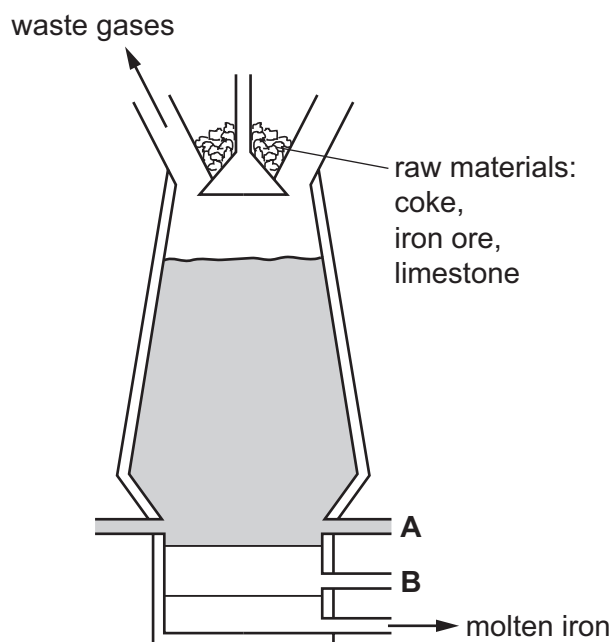
- Determine the value of x .

$x = \dots\dots\dots$
[4]

[Total: 15]

6 This question is about iron.

(a) Iron is extracted from its main ore in a blast furnace.



(i) Name the main ore of iron used in the blast furnace.

..... [1]

(ii) Name the substance that enters the blast furnace at **A**.

..... [1]

(iii) Name the substance that leaves the blast furnace at **B**.

..... [1]

(iv) Give **two** reasons for using coke in the blast furnace.

1

2

[2]

(b) Another ore of iron is iron pyrites, FeS_2 . Iron pyrites contains the positive ion, Fe^{2+} .

Deduce the formula of the negative ion in FeS_2 .

..... [1]

(c) Iron is a transition element.

A list of properties of iron is shown.

- Iron is a good conductor of electricity.
- Iron forms soluble salts.
- Iron forms coloured compounds.
- Iron has variable oxidation states.
- Iron acts as a catalyst.
- Iron forms a basic oxide.

(i) Give **two** properties from the list in which iron differs from Group I elements.

1

2 [2]

(ii) Give **two** properties from the list in which iron is similar to Group I elements.

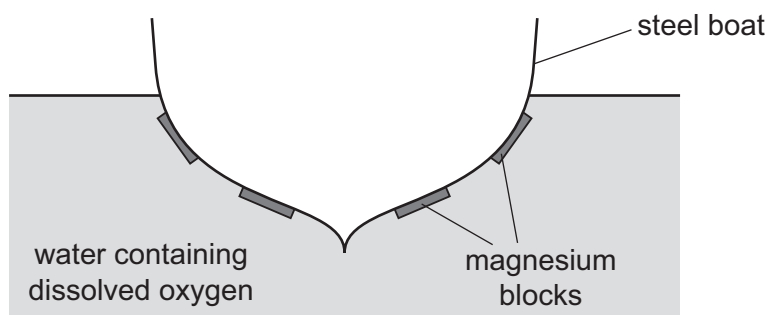
1

2 [2]

(d) Steel consists mainly of iron.

Iron forms rust when it reacts with water and oxygen.

Magnesium blocks can be attached to the bottom of steel boats. The magnesium does not completely cover the steel.



(i) Explain how the magnesium blocks prevent iron from rusting.

.....

 [2]

- (ii) Explain why replacing the magnesium blocks with copper blocks will **not** prevent the bottom of the boat from rusting.

.....

..... [1]

[Total: 13]

7 Many organic compounds contain carbon, hydrogen and oxygen only.

(a) An organic compound **V** has the following composition by mass.

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

Calculate the empirical formula of compound **V**.

empirical formula = ... [3]

(b) Compound **W** has the empirical formula CH_4O and a relative molecular mass of 32.

Calculate the molecular formula of compound **W**.

molecular formula = ... [1]

(c) Compounds **X** and **Y** have the same general formula.

X and **Y** are both carboxylic acids.

Compound **X** has the molecular formula $\text{C}_2\text{H}_4\text{O}_2$.

Compound **Y** has the molecular formula $\text{C}_4\text{H}_8\text{O}_2$.

(i) Deduce the general formula of compounds **X** and **Y**.

..... [1]

- (ii) Draw the structure of compound Y. Show all of the atoms and all of the bonds.

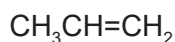
Name compound Y.

name [3]

- (iii) Give the name used to describe a 'family' of similar compounds with the same general formula, similar chemical properties and the same functional group.

..... [1]

- (d) Propene is an unsaturated hydrocarbon. The formula of propene is shown.



- (i) State the colour change observed when propene is added to aqueous bromine.

from to [1]

- (ii) Propene can be produced by cracking long chain alkanes.

Pentadecane, $\text{C}_{15}\text{H}_{32}$, is cracked to produce an alkane and propene in a 1 : 2 molar ratio.

Complete the chemical equation for this reaction.

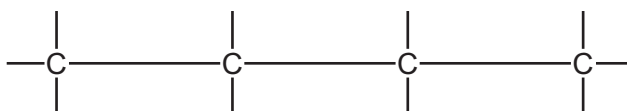


- (iii) Propene can be converted into poly(propene).

Name the type of polymerisation that occurs when propene is converted into poly(propene).

..... [1]

- (iv) Complete the diagram to show a section of poly(propene).



[2]

[Total: 15]

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The Periodic Table of Elements

Group																		
I	II	Key										III	IV	V	VI	VII	VIII	
		1Hhydrogen1																
		atomic number atomic symbol name relative atomic mass																
3Li lithium 7	4Be beryllium 9											5B boron 11	6C carbon 12	7N nitrogen 14	8O oxygen 16	9F fluorine 19	2He helium 4	
11Na sodium 23	12Mg magnesium 24											13Al aluminium 27	14Si silicon 28	15P phosphorus 31	16S sulfur 32	17Cl chlorine 35.5	18Ar argon 40	
19K potassium 39	20Ca calcium 40	21Sc scandium 45	22Ti titanium 48	23V vanadium 51	24Cr chromium 52	25Mn manganese 55	26Fe iron 56	27Co cobalt 59	28Ni nickel 59	29Cu copper 64	30Zn zinc 65	31Ga gallium 70	32Ge germanium 73	33As arsenic 75	34Se selenium 79	35Br bromine 80	36Kr krypton 84	
37Rb rubidium 85	38Sr strontium 88	39Y yttrium 89	40Zr zirconium 91	41Nb niobium 93	42Mo molybdenum 96	43Tc technetium —	44Ru ruthenium 101	45Rh rhodium 103	46Pd palladium 106	47Ag silver 108	48Cd cadmium 112	49In indium 115	50Sn tin 119	51Sb antimony 122	52Te tellurium 128	53I iodine 127	54Xe xenon 131	
55Cs caesium 133	56Ba barium 137	57–71 lanthanoids		72Hf hafnium 178	73Ta tantalum 181	74W tungsten 184	75Re rhenium 186	76Os osmium 190	77Ir iridium 192	78Pt platinum 195	79Au gold 197	80Hg mercury 201	81Tl thallium 204	82Pb lead 207	83Bi bismuth 209	84Po polonium —	85At astatine —	
87Fr francium —	88Ra radium —	89–103 actinoids		104Rf rutherfordium —	105Db dubnium —	106Sg seaborgium —	107Bh bohrium —	108Hs hassium —	109Mt meitnerium —	110Ds darmstadtium —	111Rg roentgenium —	112Cn copernicium —		114Fl flerovium —		116Lv livermorium —		

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 —

actinoids

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



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NUMBER

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0620/43

May/June 2021

1 hour 15 minutes

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- 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 Give the name of the process that is used:

(a) to produce large molecules from monomers

..... [1]

(b) to separate oxygen from liquid air

..... [1]

(c) to make ethanol from glucose

..... [1]

(d) to separate water from aqueous sodium chloride

..... [1]

(e) to produce aluminium from aluminium oxide in molten cryolite

..... [1]

(f) to separate the products of hydrolysis of long chain carbohydrates

..... [1]

(g) to separate an aqueous solution from an undissolved solid.

..... [1]

[Total: 7]

2 Complete the table to:

- deduce the number of protons, electrons and neutrons in the boron atom and chloride ion shown
- identify the atom or ion represented by the final row.

formula	number of protons	number of electrons	number of neutrons
${}^{11}_5\text{B}$		5	
${}^{35}_{17}\text{Cl}^-$	17		
	24	21	30

[Total: 5]

3 Sodium reacts with fluorine to form sodium fluoride, NaF.

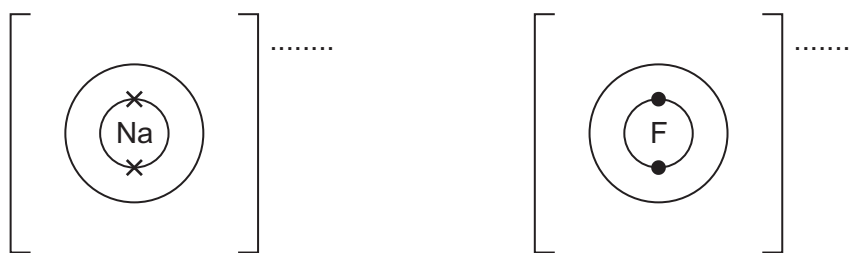
(a) Write a chemical equation for this reaction.

..... [2]

(b) Sodium fluoride is an ionic compound.

Complete the diagram to show the electron arrangement in the outer shells of the ions present in sodium fluoride.

Give the charges on both ions.



[3]

(c) Aqueous sodium fluoride undergoes electrolysis.

(i) State what is meant by the term *electrolysis*.

.....
 [2]

(ii) Name the products formed at the positive electrode (anode) and the negative electrode (cathode) when dilute aqueous sodium fluoride undergoes electrolysis.

anode

cathode

[2]

(d) Molten sodium fluoride undergoes electrolysis.

(i) Name the products formed at the positive electrode (anode) and the negative electrode (cathode) when molten sodium fluoride undergoes electrolysis.

anode

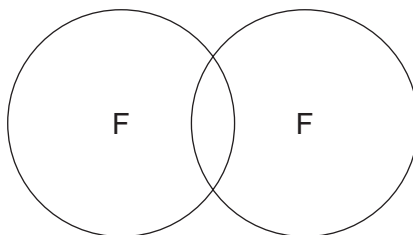
cathode

[2]

(ii) Write the ionic half-equation for the reaction at the negative electrode (cathode).

..... [1]

- (e) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of fluorine, F_2 .
Show the outer electrons only.



[1]

- (f) The melting points and boiling points of fluorine and sodium fluoride are shown.

	melting point / $^{\circ}\text{C}$	boiling point / $^{\circ}\text{C}$
fluorine	-220	-188
sodium fluoride	993	1695

- (i) Deduce the physical state of fluorine at -195°C . Use the data in the table to explain your answer.

physical state

explanation

.....

[2]

- (ii) Explain, in terms of structure and bonding, why sodium fluoride has a much higher melting point than fluorine.

Your answer should refer to the:

- types of particle held together by the forces of attraction
- types of forces of attraction between particles
- relative strength of the forces of attraction.

.....

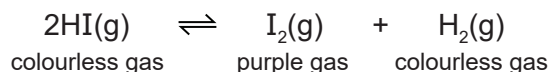
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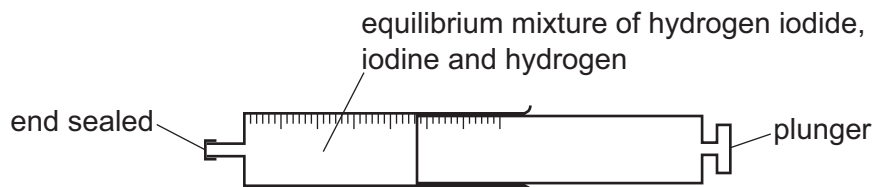
..... [3]

[Total: 18]

- 4 Hydrogen iodide, HI, decomposes into iodine and hydrogen. The reaction is reversible.



A gas syringe containing a mixture of hydrogen iodide, iodine and hydrogen gases was sealed. After reaching equilibrium the mixture was a pale purple colour.



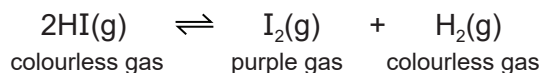
- (a) State what is meant by the term *equilibrium*.

.....

 [2]

- (b) The plunger of the gas syringe is pushed in. The position of equilibrium does not change. The colour of the gaseous mixture turns darker purple.

The temperature remains constant.



- (i) Explain why the position of equilibrium does **not** change.

..... [1]

- (ii) Suggest why the colour of the gaseous mixture turns darker purple even though the position of equilibrium does not change.

..... [1]

- (c) The forward reaction is endothermic.

- (i) State what happens to the position of equilibrium when the temperature is decreased.

.....
 [1]

- (ii) State what happens to the rate of the forward reaction and the rate of the backward reaction when the temperature of the mixture is decreased.

rate of the forward reaction

rate of the backward reaction

[2]

[Total: 7]

5 This question is about salts.

- (a)** Salts that are soluble in water can be made by the reaction between insoluble carbonates and dilute acids. Zinc sulfate is soluble in water.

You are provided with solid zinc carbonate, ZnCO_3 , and dilute sulfuric acid, H_2SO_4 .

Describe how you would make a pure sample of zinc sulfate crystals.

Your answer should include:

- practical details
- how you would make sure that all the dilute sulfuric acid has reacted
- a chemical equation for the reaction.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

- (b)** Some sulfates decompose when heated.

When hydrated iron(II) sulfate is heated strongly, sulfur dioxide gas is given off.

- (i)** Describe a test for sulfur dioxide.

test

observations

[2]

- (ii)** Complete the equation for the decomposition of hydrated iron(II) sulfate.



(c) Some chlorides are hydrated.

When hydrated barium chloride crystals, $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$, are heated they give off water.



A student carries out an experiment to determine the value of x in $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

step 1 Hydrated barium chloride crystals are weighed.

step 2 The hydrated barium chloride crystals are then heated.

step 3 The remaining solid is weighed.

(i) Describe how the student can be sure that all the water is given off.

.....

 [2]

(ii) In an experiment, 4.88 g of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$ is heated until all the water is given off. The mass of BaCl_2 remaining is 4.16 g.

[M_r : BaCl_2 , 208; H_2O , 18]

Determine the value of x using the following steps.

- Calculate the number of moles of BaCl_2 remaining.

..... mol

- Calculate the mass of H_2O given off.

..... g

- Calculate the number of moles of H_2O given off.

..... mol

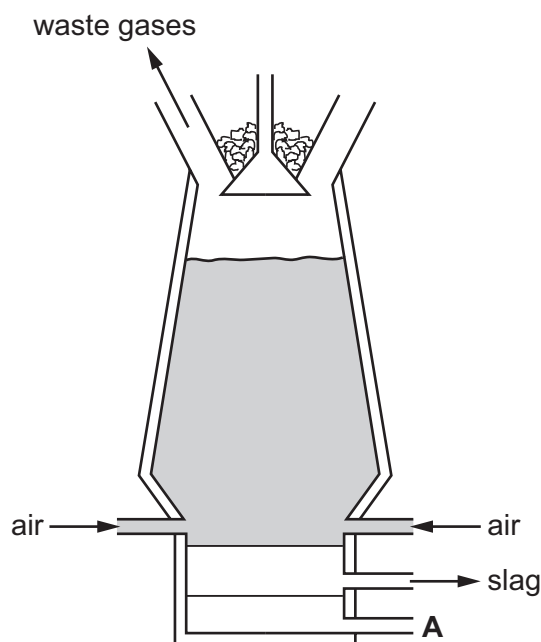
- Determine the value of x .

$x =$
 [4]

[Total: 15]

6 This question is about metals.

(a) Iron is extracted from its main ore in a blast furnace.



(i) Coke and iron ore are added at the top of the blast furnace.

Name one **other** substance that is added at the top of the blast furnace.

..... [1]

(ii) Name the substance that leaves the blast furnace at **A**.

..... [1]

(iii) Iron ore is mainly iron(III) oxide, Fe_2O_3 .

Name a substance that reduces iron(III) oxide to iron in the blast furnace.

..... [1]

(iv) Temperatures inside a blast furnace can reach 2000°C .

Name **two** substances that react together, in the blast furnace, to produce this high temperature.

..... [1]

(v) Name **two** waste gases that leave the blast furnace.

1

2

[2]

(b) Zinc is extracted from zinc blende.

(i) Name the main zinc compound that is present in zinc blende.

..... [1]

(ii) When zinc is extracted, it is formed as a gas.

The gaseous zinc is then converted into molten zinc.

State the name of this physical change.

..... [1]

(c) Name the alloy that contains zinc and copper only.

..... [1]

(d) Copper has the following properties.

- It has a high melting point.
- It has a high density.
- It is a good conductor of electricity.
- It has variable oxidation states.
- It forms a basic oxide.
- It forms soluble salts.

(i) Give **two** properties from the list in which copper differs from Group I elements.

1

2 [2]

(ii) Give **two** properties from the list in which copper is similar to Group I elements.

1

2 [2]

[Total: 13]

7 Many organic compounds contain carbon, hydrogen and oxygen only.

(a) An organic compound **R** has the following composition by mass.

C, 69.77%; H, 11.63%; O, 18.60%

Calculate the empirical formula of compound **R**.

empirical formula = ... [2]

(b) Compound **S** has the empirical formula CH_2O and a relative molecular mass of 60.

Calculate the molecular formula of compound **S**.

molecular formula = ... [2]

(c) Compounds **T** and **V** have the same molecular formula, $\text{C}_3\text{H}_6\text{O}_2$.

- Compound **T** is an ester.
- Compound **V** contains a -COOH functional group.

(i) State the name given to compounds with the same molecular formula but different structures.

..... [1]

(ii) Name the homologous series that **V** is a member of.

..... [1]

(iii) Draw a structure of compound **T**. Show all of the atoms and all of the bonds.

Name compound **T**.

name [3]

(iv) Draw the structure of compound **V**. Show all of the atoms and all of the bonds.

Name compound **V**.

name [2]

(d) Ethanol can be produced from long chain alkanes such as decane, $C_{10}H_{22}$, in a two-step process.



For each of the two steps:

- name the type of chemical reaction that occurs
- write a chemical equation.

step 1: decane to ethene

type of reaction

chemical equation

step 2: ethene to ethanol

type of reaction

chemical equation

[4]

[Total: 15]

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The Periodic Table of Elements

Group																		
I	II	1 Hhydrogen1										III	IV	V	VI	VII	VIII	
3 Li lithium 7	4 Be beryllium 9	Key atomic number atomic symbol name relative atomic mass										5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	2 He helium 4	
	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
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 —		