



Cambridge IGCSE™ (9–1)

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CHEMISTRY**0971/41**

Paper 4 Theory (Extended)

May/June 2024**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.

2

1 Name the process that is used to:

(a) convert sulfur dioxide into sulfur trioxide in the manufacture of sulfuric acid

..... [1]

(b) obtain water from aqueous sodium chloride

..... [1]

(c) extract aluminium from purified bauxite

..... [1]

(d) separate petroleum into useful substances

..... [1]

(e) produce ethanol from aqueous glucose

..... [1]

(f) manufacture alkenes and hydrogen from large alkane molecules

..... [1]

(g) separate a mixture of soluble coloured substances.

..... [1]

[Total: 7]

2 Complete Table 2.1.

Table 2.1

atom or ion	number of protons	number of electrons	number of neutrons
${}^{37}_{17}\text{Cl}$		17	
${}^{63}_{29}\text{Cu}^+$			34
	16	18	17

[5]

3 This question is about the elements sodium and fluorine and the compound sodium fluoride.

(a) Sodium reacts with fluorine to form sodium fluoride.

Write a symbol equation for this reaction.

..... [2]

(b) Some properties of sodium, fluorine and sodium fluoride are shown in Table 3.1.

Table 3.1

	melting point /°C	boiling point /°C	conduction of electricity when solid	conduction of electricity in aqueous solution
sodium	98	883	good	
fluorine	–220	–188	poor	
sodium fluoride	993	1695	poor	good

(i) Explain why sodium conducts electricity when it is a solid.

..... [1]

(ii) Complete the dot-and-cross diagram in Fig. 3.1 of a molecule of fluorine.

Show outer shell electrons only.

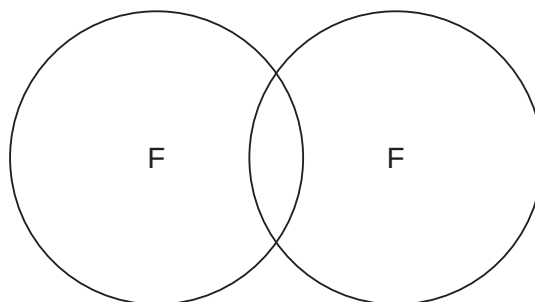


Fig. 3.1

[2]

(iii) Deduce the physical state of fluorine at –200 °C. Use the data in Table 3.1 to explain your answer.

physical state

explanation

.....

[2]

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

.....

.....

.....

.....

..... [3]

- (c) Dilute aqueous sodium fluoride undergoes electrolysis.

Hydrogen is produced at the cathode.

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

.....

.....

..... [2]

- (ii) Write an ionic half-equation for the production of hydrogen at the cathode.

..... [2]

[Total: 14]

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

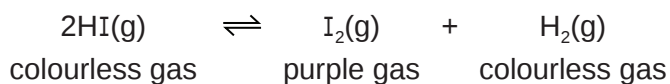


Fig. 4.1 shows a gas syringe containing a mixture of hydrogen iodide, iodine and hydrogen gases. The gas syringe is sealed and the mixture is heated to 300°C. The mixture of gases reaches equilibrium and is purple.

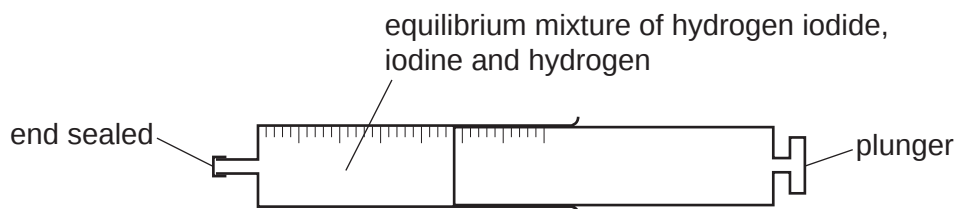


Fig. 4.1

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

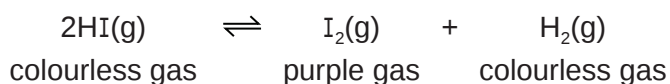
.....

 [2]

- (b) The pressure of the mixture is increased. All other conditions stay the same. 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 mixture of gases turns darker purple.

.....
 [1]

- (c) The temperature of the mixture of gases is decreased. All other conditions stay the same.

The mixture of gases turns lighter purple.

State what can be deduced about the forward reaction from this information.

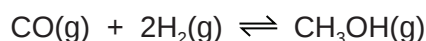
..... [1]

- (d) Deduce the oxidation number of iodine, I, in:

HI

I₂ [2]

- (e) Methanol is manufactured by reacting carbon monoxide with hydrogen.



The rate of formation of methanol increases when a catalyst is used.

- (i) Choose from the list the element that is most likely to be used as the catalyst.

Draw a circle around your chosen answer.

calcium carbon copper sodium sulfur [1]

- (ii) State the effect on the position of equilibrium when a catalyst is used.

..... [1]

- (iii) State the effect that a catalyst has on the activation energy, E_a , of a reaction.

..... [1]

[Total: 10]

5 (a) Lead(II) bromide, PbBr_2 , is an insoluble salt and is made by precipitation.

(i) Name **two** aqueous solutions that produce a precipitate of lead(II) bromide when they are mixed.

1

2 [2]

(ii) Describe how to produce a pure sample of lead(II) bromide from the mixture of aqueous solutions in (a)(i).

.....

..... [2]

(iii) Write an ionic equation for the precipitation reaction which produces lead(II) bromide. Include state symbols.

..... [3]

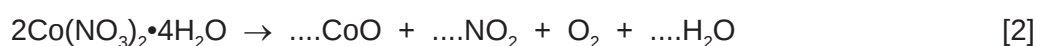
(b) When iron(II) sulfate crystals are heated strongly, sulfur dioxide gas is given off.

Describe a test for sulfur dioxide gas.

test

observations [2]

(c) Complete the equation for the thermal decomposition of hydrated cobalt(II) nitrate.



(d) Hydrated cobalt(II) sulfate, $\text{CoSO}_4 \cdot x\text{H}_2\text{O}$, produces water when it is heated.



A student does an experiment to determine the value of x in $\text{CoSO}_4 \cdot x\text{H}_2\text{O}$.

step 1 The student weighs a sample of hydrated cobalt(II) sulfate.

step 2 The student heats the sample of hydrated cobalt(II) sulfate.

step 3 The student weighs the remaining solid after heating.

(i) Describe what else the student should do to ensure that **all** the water has been given off. No other substances are required.

.....

 [2]

(ii) In an experiment, 1.405 g of $\text{CoSO}_4 \cdot x\text{H}_2\text{O}$ is heated until all the water is given off.

The mass of CoSO_4 that remains is 0.775 g.

[M_r : CoSO_4 , 155; H_2O , 18]

Determine the value of x using the following steps.

- Calculate the number of moles of CoSO_4 that remains.

..... 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: 17]

6 This question is about metals.

(a) Fig. 6.1 shows a blast furnace used to extract iron from its ore.

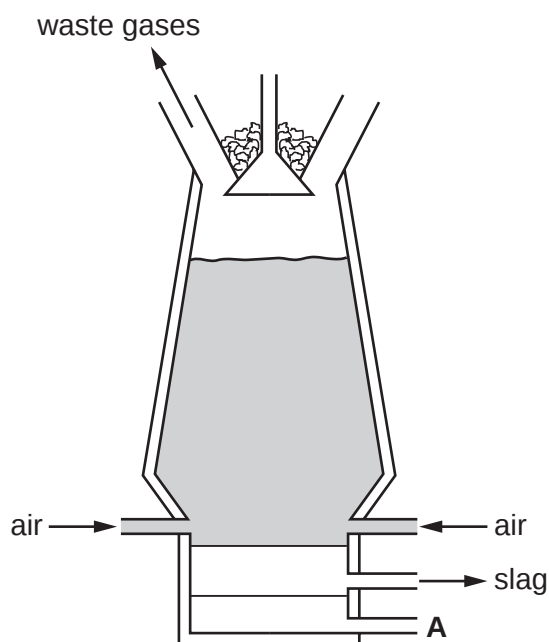


Fig. 6.1

(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) Slag is produced from an impurity in iron ore.

Name the impurity in iron ore that is converted into slag.

..... [1]

(iv) Name **two** substances that react together to produce the high temperature in the blast furnace.

..... and [1]

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

1

2

[2]

11

(b) Zinc is produced from zinc oxide in a furnace.

The zinc is produced as a gas. It then forms molten zinc.

(i) Suggest why the zinc produced inside the furnace is a gas.

..... [1]

(ii) State the name of the physical change that occurs when gaseous zinc is converted into molten zinc.

..... [1]

(c) Zinc is used to coat iron to prevent rusting.

(i) Name the process used to coat iron with zinc as a method of rust prevention.

..... [1]

(ii) When the zinc coating is scratched, the iron underneath does not rust.

Explain why the iron underneath the zinc does **not** rust.

.....

..... [2]

(d) Zinc oxide neutralises both acids and bases.

(i) State the general name given to oxides that neutralise both acids and bases.

..... [1]

(ii) When zinc oxide neutralises aqueous sodium hydroxide, sodium zincate is formed.

The formula of the zincate ion is ZnO_2^{2-} .

Deduce the formula of sodium zincate.

..... [1]

(iii) Name the zinc compound that forms when zinc oxide neutralises dilute sulfuric acid.

..... [1]

[Total: 14]

7 Many organic compounds contain carbon and hydrogen only.

(a) (i) Organic compound **A** has the following composition by mass.

C, 82.76%; H, 17.24%

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

empirical formula = [3]

(ii) Compound **B** has the empirical formula CH_2 and a relative molecular mass of 70.

Determine the molecular formula of compound **B**.

molecular formula = [1]

(b) Fig. 7.1 shows a section of polymer **Q**.

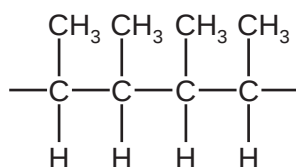


Fig. 7.1

- Draw the displayed formula of the monomer that forms polymer **Q**.

- Name the monomer used to form polymer **Q**.

..... [3]

13

- (c) Propene, C_3H_6 , can be produced by heating $C_{11}H_{24}$. The products of the reaction are propene, hydrogen and one other product in a 1 : 1 : 1 mole ratio.

Complete the symbol equation for this reaction.



- (d) Carboxylic acids and esters contain carbon, hydrogen and oxygen only.

An ester **X** and a carboxylic acid **Y** both contain 3 carbon atoms.

X and **Y** have the same molecular formula.

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

..... [1]

- (ii) Esters are made by the reaction between carboxylic acids and alcohols.

Ester **X** is methyl ethanoate.

Name the carboxylic acid and the alcohol used to make methyl ethanoate.

carboxylic acid

alcohol [2]

- (iii) Draw the displayed formula of carboxylic acid **Y**. Name the carboxylic acid.

name [2]

[Total: 13]

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The Periodic Table of Elements

Group																					
I	II											III	IV	V	VI	VII	VIII				
		Key atomic number atomic symbol name relative atomic mass												1Hhydrogen1							
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	57–71lanthanoids		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 —	86Rn radon —			
87Fr francium —	88Ra radium —	89–103actinoids		104Rf rutherfordium —	105Db dubnium —	106Sg seaborgium —	107Bh bohrium —	108Hs hassium —	109Mt meitnerium —	110Ds darmstadtium —	111Rg roentgenium —	112Cn copernicium —	113Nh nihonium —	114Fl flerovium —	115Mc moscovium —	116Lv livemorium —	117Ts tennessine —	118Og oganesson —			
lanthanoids		57La lanthanum 139	58Ce cerium 140	59Pr praseodymium 141	60Nd neodymium 144	61Pm promethium —	62Sm samarium 150	63Eu europium 152	64Gd gadolinium 157	65Tb terbium 159	66Dy dysprosium 163	67Ho holmium 165	68Er erbium 167	69Tm thulium 169	70Yb ytterbium 173	71Lu lutetium 175					
actinoids		89Ac actinium —	90Th thorium 232	91Pa protactinium 231	92U uranium 238	93Np neptunium —	94Pu plutonium —	95Am americium —	96Cm curium —	97Bk berkelium —	98Cf californium —	99Es einsteinium —	100Fm fermium —	101Md mendelevium —	102No nobelium —	103Lr lawrencium —					

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