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CHEMISTRY **0620/41**

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.

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1 Name the process that is used to:

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

..... [1]

(b) obtain water from aqueous sodium chloride View solution

..... [1]

(c) extract aluminium from purified bauxite View solution

..... [1]

(d) separate petroleum into useful substances View solution

..... [1]

(e) produce ethanol from aqueous glucose View solution

..... [1]

(f) manufacture alkenes and hydrogen from large alkane molecules View solution

..... [1]

(g) separate a mixture of soluble coloured substances.

..... [1]

[Total: 7]

View solution

2 Complete Table 2.1.

View solution

Table 2.1

atom or ion	number of protons	number of electrons	number of neutrons
$^{37}_{17}Cl$		17	
$^{63}_{29}Cu^{+}$			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.

View solution

Write a symbol equation for this reaction.

..... [2]

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

View solution

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.

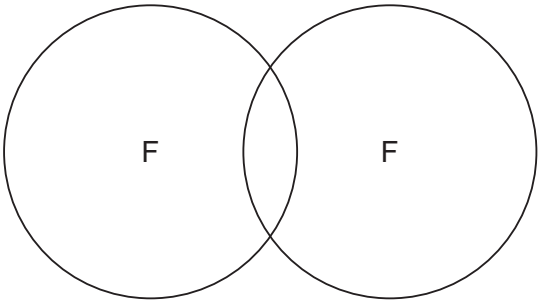

Fig. 3.1

[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]

View solution

(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]

View solution

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

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

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.

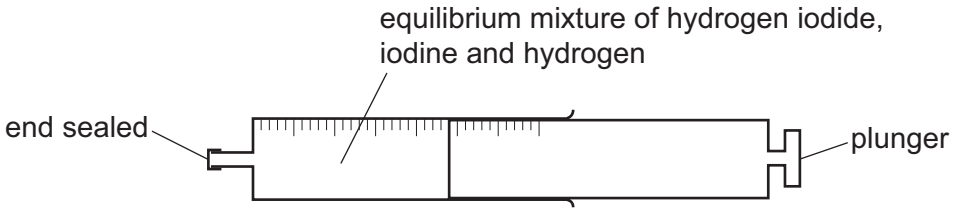

Fig. 4.1

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

View solution

.....

.....

..... [2]

(b) The pressure of the mixture is increased. All other conditions stay the same. The position of equilibrium does **not** change.

View solution

The colour of the gaseous mixture turns darker purple.

The temperature remains constant.

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

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

.....

..... [1]

(ii) Suggest why the colour of the mixture of gases turns darker purple.

View solution

.....

..... [1]

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(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]

View solution

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

HI .....

I_2. .....

[2]

View solution

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

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

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]

View solution

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

..... [1]

[Total: 10]

View solution

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.

View solution

Describe a test for sulfur dioxide gas.

test .....

observations .....
[2]

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

$$2Co(NO_3)_2 \bullet 4H_2O \rightarrow \ldots.CoO + \ldots.NO_2 + O_2 + \ldots.H_2O$$ [2]

View solution

(d) Hydrated cobalt(II) sulfate, $CoSO_4 \cdot \mathbf{x}H_2O$, produces water when it is heated.

View solution

$$CoSO_4 \cdot \mathbf{x}H_2O(s) \rightarrow CoSO_4(s) + \mathbf{x}H_2O(g)$$

A student does an experiment to determine the value of **x** in $CoSO_4 \cdot \mathbf{x}H_2O$.

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 $CoSO_4 \cdot \mathbf{x}H_2O$ is heated until all the water is given off.

View solution

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.

View solution

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

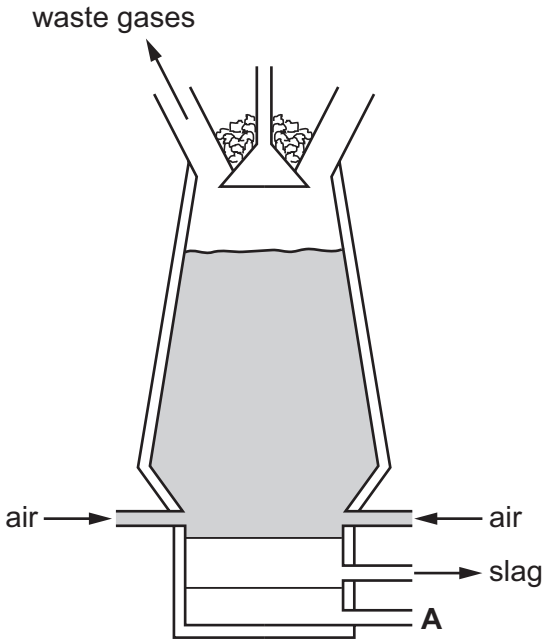

Fig. 6.1

(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]

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

View solution

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.

View solution

(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.

View solution

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

.....

..... [2]

(d) Zinc oxide neutralises both acids and bases.

View solution

(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.

View solution

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]

View solution

7 Many organic compounds contain carbon and hydrogen only.

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

View solution

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.

View solution

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

molecular formula = ... [1]

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

View solution

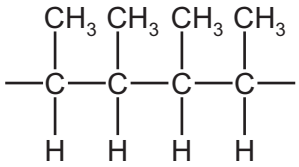

Fig. 7.1

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

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

.....
[3]

(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.

View solution

Complete the symbol equation for this reaction.

$$C_{11}H_{24} \rightarrow C_3H_6 + H_2 + ...$$ [1]

View solution

(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]

View solution

(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]

View solution

(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
							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	9 F fluorine 19	10 Ne neon 20
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 –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

Key

atomic number
atomic symbol
name
relative atomic mass

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
actinoids	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 dm^3 at room temperature and pressure (r.t.p.).