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CHEMISTRY **0620/41**

Paper 4 Theory (Extended) **October/November 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.

[Turn over

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1 A list of chemical and physical processes, **A** to **H**, is shown.

A combustion
B diffusion
C melting
D neutralisation
E photosynthesis
F reversible reaction
G roasting
H thermal decomposition

Answer the following questions about processes **A** to **H**.
Each letter may be used once, more than once or not at all.

State which of the processes **A** to **H**:

(a) happens when an acid reacts with an alkali

..... [1]

(b) reaches a position of equilibrium

..... [1]

(c) involves particles changing from fixed positions to being mobile, but still touching

..... [1]

(d) are physical changes

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

(e) is caused by gas particles colliding with each other.

..... [1]

[Total: 5]

2 This question is about atomic structure and the Periodic Table.

(a) Define the term nucleon number.

..... [1]

(b) State the connection between the number of occupied electron shells in an atom and the period number of that element.

..... [1]

(c) Write the electronic configuration of the following atom and ion.

$^{28}_{14}Si$ .....

$^{37}_{17}Cl^-$ .....

[2]

(d) Complete Table 2.1.

Table 2.1

atom or ion	number of protons	number of neutrons	number of electrons
$^{23}_{11}Na$	11		
$^{19}_{9}F^-$	9	10	
	31	38	28

[5]

(e) A sample of thallium, T*l*, contains two isotopes, ^{203}T*l* and ^{205}T*l*.

(i) Define the term isotopes.

.....

..... [2]

(ii) The relative abundance of ^{203}T*l* : ^{205}T*l* is in the ratio 3 : 7.

Calculate the relative atomic mass of thallium in the sample to **one** decimal place.

relative atomic mass = ... [2]

(iii) Suggest why these two isotopes have identical chemical properties.

..... [1]

[Total: 14]

3 Copper(II) sulfate has the formula $CuSO_4$. Aqueous copper(II) sulfate is a blue solution.

A sample of aqueous copper(II) sulfate is made by adding excess copper(II) oxide, CuO, to hot dilute sulfuric acid, H_2SO_4.

(a) Complete the symbol equation for this reaction. Include state symbols.

$$CuO(.....) + H_2SO_4(.....) \rightarrow CuSO_4(.....) + ...(l)$$

[2]

(b) State **one** observation which shows that copper(II) oxide is added in excess.

..... [1]

(c) Describe how aqueous copper(II) sulfate can be separated from the reaction mixture.

..... [1]

(d) Crystals of hydrated copper(II) sulfate can be obtained from aqueous copper(II) sulfate by crystallisation.

(i) State what is meant by the term hydrated.

..... [1]

(ii) Write the formula of hydrated copper(II) sulfate.

..... [1]

(iii) Describe how this crystallisation is done.

.....

.....

..... [2]

(e) Aqueous copper(II) sulfate undergoes electrolysis using graphite electrodes.

(i) State why aqueous copper(II) sulfate conducts electricity.

..... [1]

(ii) Give **two** reasons why the electrodes are made of graphite.

1 .....

2 .....
[2]

(iii) Describe how the appearance of the electrolyte changes during the electrolysis of aqueous copper(II) sulfate.

..... [1]

(iv) Describe what is seen at the cathode during the electrolysis of aqueous copper(II) sulfate.

..... [1]

(v) Write the ionic half-equation for the reaction at the anode.

..... [3]

(vi) State **two** differences seen if the electrolysis is repeated using copper electrodes instead of graphite electrodes.

1 .....

2 .....
[2]

[Total: 18]

4 When magnesium nitrate is heated strongly, magnesium oxide is formed.

(a) The equation for this reaction is shown.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

(i) State the change in oxidation number of nitrogen, N, in this reaction.

from ..... to ..... [2]

(ii) Identify the element which is oxidised in this reaction.

..... [1]

(iii) Calculate the volume of NO_2 gas, at r.t.p., formed when 7.40 g of $Mg(NO_3)_2$ is heated.

Use the following steps.

- Calculate the M_r of $Mg(NO_3)_2$.

.....

- Calculate the number of moles of $Mg(NO_3)_2$ used.

..... mol

- Determine the number of moles of NO_2 formed.

..... mol

- Calculate the volume of NO_2 gas, in cm^3, at r.t.p.

..... cm^3
[4]

(b) Magnesium oxide, MgO, is an ionic compound.

Complete the dot-and-cross diagram in Fig. 4.1 of the ions in magnesium oxide.

Give the charges on each of the ions.

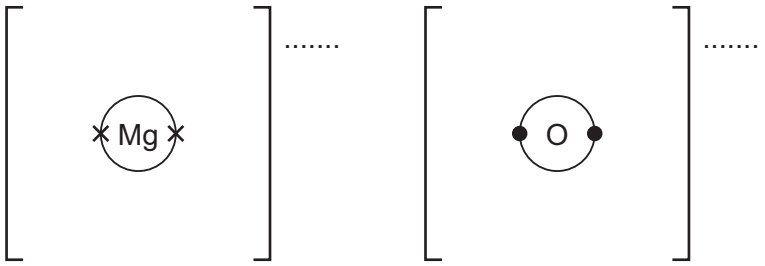

Fig. 4.1

[3]

(c) Oxygen is a covalent molecule.

Complete the dot-and-cross diagram in Fig. 4.2 of a molecule of oxygen.
The inner shells have been drawn.

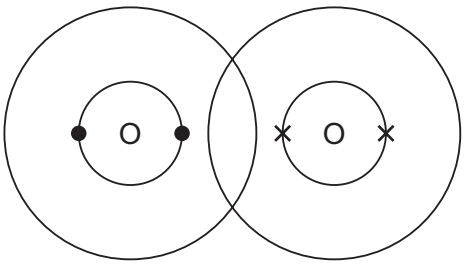

Fig. 4.2

[2]

[Total: 12]

5 Hydrogen is the first element of the Periodic Table.

(a) Hydrogen is used in fuel cells to produce electricity in vehicles.

(i) Name the substance which combines with hydrogen in a fuel cell.

..... [1]

(ii) Give **one** advantage and **one** disadvantage of using fuel cells instead of gasoline in vehicle engines.

advantage .....

disadvantage .....

[2]

(b) Hydrogen gas can be made from petroleum by a two-step procedure.

step 1 Petroleum is separated into different components.

step 2 Large molecules obtained in **step 1** are converted into smaller molecules including hydrogen gas.

(i) Name the process used in **step 1**.

..... [1]

(ii) Name the process used in **step 2**.

..... [1]

(c) Organic compounds contain hydrogen atoms.

Calculate the number of hydrogen atoms in 44.0 g of the ester methyl propanoate, $CH_3CH_2COOCH_3$.

One mole of $CH_3CH_2COOCH_3$ contains 6.02×10^{23} molecules.

Give your answer in standard form.

number of hydrogen atoms = ... [4]

(d) For each of the homologous series shown, name a member that contains **six** hydrogen atoms.

- alkanes .....
- alkenes .....
- alcohols .....
- carboxylic acids .....

[4]

(e) Unsaturated alkenes are converted into saturated alkanes by reaction with hydrogen gas.

(i) State why alkenes and alkanes are hydrocarbons.

..... [1]

(ii) State why alkenes are unsaturated.

..... [1]

(iii) Name the catalyst needed to convert alkenes into alkanes.

..... [1]

(iv) Explain why the conversion of alkenes into alkanes is an addition reaction.

..... [1]

[Total: 17]

6 Natural polyamides are polymers made from amino acid monomers.

(a) State the type of polymerisation reaction that occurs when natural polyamides form.

..... [1]

(b) State the term given to natural polyamides.

..... [1]

(c) An amino acid is represented as shown in Fig. 6.1.

Fig. 6.1

Complete Fig. 6.2 to show the general structure of an amino acid.

Show all of the atoms and all of the bonds in the functional groups.

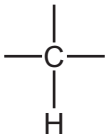

Fig. 6.2

[3]

(d) Three different amino acids are represented as shown in Fig. 6.3.

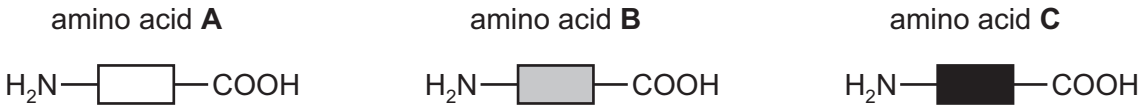

Fig. 6.3

Complete the diagram in Fig. 6.4 to show the part of the structure of the natural polyamide that forms when the three amino acids, **A**, **B** and **C**, combine.
Show all of the atoms and all of the bonds in the linkages.

Fig. 6.4

[3]

(e) A mixture of the three amino acids, **A**, **B** and **C**, can be separated and the amino acids identified using paper chromatography.

Complete the equation for R_f.

R_f =

[2]

(f) A sample of the mixture of the three amino acids, **A**, **B** and **C**, is placed onto the baseline and a chromatogram is allowed to develop as shown in Fig. 6.5.

The finished chromatogram is shown in Fig. 6.6.

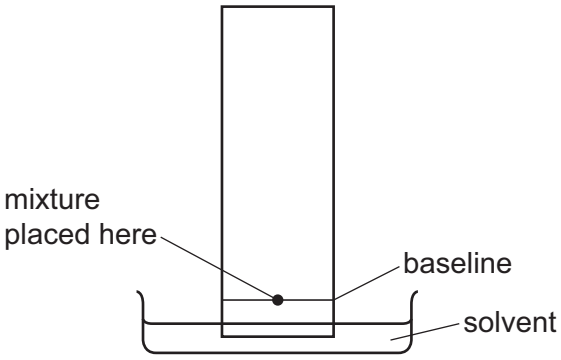

Fig. 6.5

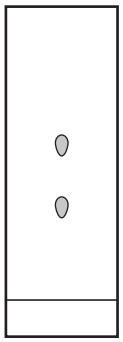

Fig. 6.6

The amino acids, **A**, **B** and **C**, are colourless. Water is used as the solvent.

(i) Explain why the baseline is drawn in pencil.

..... [1]

(ii) State the type of substance used to make the colourless amino acids visible on the chromatogram in Fig. 6.6.

..... [1]

(iii) Explain why in Fig. 6.6 only **two** spots are seen from the mixture of three amino acids.

.....

..... [1]

(iv) Suggest how the experiment can be changed to separate all three amino acids.

..... [1]

[Total: 14]

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The Periodic Table of Elements

Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group 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.).