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CHEMISTRY **0620/42**

Paper 4 Theory (Extended) **February/March 2026**

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. Do **not** use correction fluid or tape.
- 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.

DC (SL/TC) 355339/7

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1 The symbols of elements with atomic numbers 21 to 30 are shown in Table 1.1.

Table 1.1

atomic number	21	22	23	24	25	26	27	28	29	30
symbol of element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn

Answer the following questions using only the symbols of the elements in Table 1.1.

The symbol of each element can be used once, more than once or not at all.

Give the symbol of the element that:

(a) is the catalyst in the Haber process

..... [1]

(b) is used to galvanise iron objects

..... [1]

(c) has a blue anhydrous chloride used to detect the presence of water

..... [1]

(d) is the catalyst used in the reaction of alkenes with hydrogen

..... [1]

(e) forms a green precipitate when aqueous sodium hydroxide is added to an aqueous solution of its ions which dissolves in excess aqueous sodium hydroxide

..... [1]

(f) forms an ion that has 24 electrons and a 3+ charge

..... [1]

(g) forms brass when mixed with copper.

..... [1]

[Total: 7]

2 Aluminium and indium are elements in Group III of the Periodic Table.

(a) Aluminium is extracted from its purified main ore. The purified ore is mainly aluminium oxide. During this extraction process aluminium oxide is broken down into its elements.

(i) Name the main ore of aluminium.

..... [1]

(ii) Name the process in which aluminium oxide is broken down into its elements.

..... [1]

(iii) Name the substance which is added to aluminium oxide to reduce the operating temperature of this process.

..... [1]

(b) Aluminium oxide reacts with both acids and bases to form salts.

(i) State the type of oxide that reacts with both acids and bases.

..... [1]

(ii) State the name and give the formula of the salt formed when aluminium oxide reacts with dilute hydrochloric acid.

name .....

formula .....

[2]

(c) The salt formed when aluminium oxide reacts with aqueous sodium hydroxide is sodium aluminate, $NaAlO_2$.

(i) Complete the equation for the reaction of aluminium oxide with aqueous sodium hydroxide by inserting the missing formula and balancing the equation.

$$Al_2O_3 + ...NaOH \rightarrow .....NaAlO_2 + ...$$

[2]

(ii) Write the formula of the anion in $NaAlO_2$.

..... [1]

(d) Indium has an atomic number of 49.

(i) State the number of occupied electron shells in an atom of indium.

..... [1]

(ii) A sample of indium contains two isotopes, ^{113}In and ^{115}In.

Complete Table 2.1 to show the number of protons and the number of neutrons in one atom of each isotope of indium.

Table 2.1

isotope	number of protons	number of neutrons
^{113}In		
^{115}In		

[2]

(iii) Table 2.2 shows the relative abundances of the two isotopes in the sample of indium.

Table 2.2

isotope	^{113}In	^{115}In
relative abundance	1	19

Calculate the relative atomic mass of this sample of indium to **one** decimal place.

relative atomic mass = ... [2]

[Total: 14]

3 The salt sodium chloride, NaC*l*, can be prepared in the laboratory by different methods.

method 1 Burning sodium metal is placed into a gas jar of chlorine gas. Solid sodium chloride is formed.

$$2Na + Cl_2 \rightarrow 2NaCl$$

method 2 Dilute hydrochloric acid is added to a known volume of aqueous sodium hydroxide in the presence of an indicator until a neutral solution is formed.

(a) (i) State the colour of the flame sodium metal burns with before it is placed into the chlorine gas in method 1.

..... [1]

(ii) State the colour of the chlorine gas before the burning sodium metal is added to it in method 1.

..... [1]

(iii) Calculate the mass of sodium chloride formed when excess burning sodium metal is placed into 960 cm^3 of chlorine gas at room temperature and pressure in method 1.

mass = ... g [3]

(b) (i) Write the ionic equation which represents the neutralisation reaction that takes place in method 2.

..... [1]

(ii) Name a suitable indicator to use in method 2.

..... [1]

(iii) Name the experimental technique used in method 2.

..... [1]

(c) In Figure 3.1, complete the dot-and-cross diagram of the ions in sodium chloride.

Give the charges on the ions.

Figure 3.1

[3]

(d) Molten and aqueous sodium chloride are separately electrolysed using inert electrodes.

(i) Name a suitable inert non-metal electrode and a suitable inert metal electrode.

non-metal electrode .....

metal electrode .....

[2]

(ii) Complete Table 3.1 to show the name of the product formed at the cathode during the electrolysis of different forms of sodium chloride.

Table 3.1

form of sodium chloride	name of product formed at the cathode
molten	
dilute aqueous solution	
concentrated aqueous solution	

[3]

[Total: 16]

4 When hydrogen reacts with carbon dioxide in a sealed vessel at 130 °C using a suitable catalyst, methanol is produced.

The equation is shown.

$$3H_2(g) + CO_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -40\,kJ/mol$$

The activation energy, E_a, of the forward reaction is +220 kJ / mol.

(a) State how the information shows that this reaction is reversible and exothermic.

reversible .....

exothermic .....

[2]

(b) Complete Table 4.1 to show the effect, if any, for each change of condition.

Use only the words **increases**, **decreases** or **no change**.

Table 4.1

change of condition	effect on the concentration of methanol at equilibrium	effect on the rate of the forward reaction
temperature is decreased		
pressure in the reaction vessel is decreased		decreases
the catalyst is removed	no change	

[4]

(c) Figure 4.1 shows an incomplete reaction pathway diagram for the forward reaction.

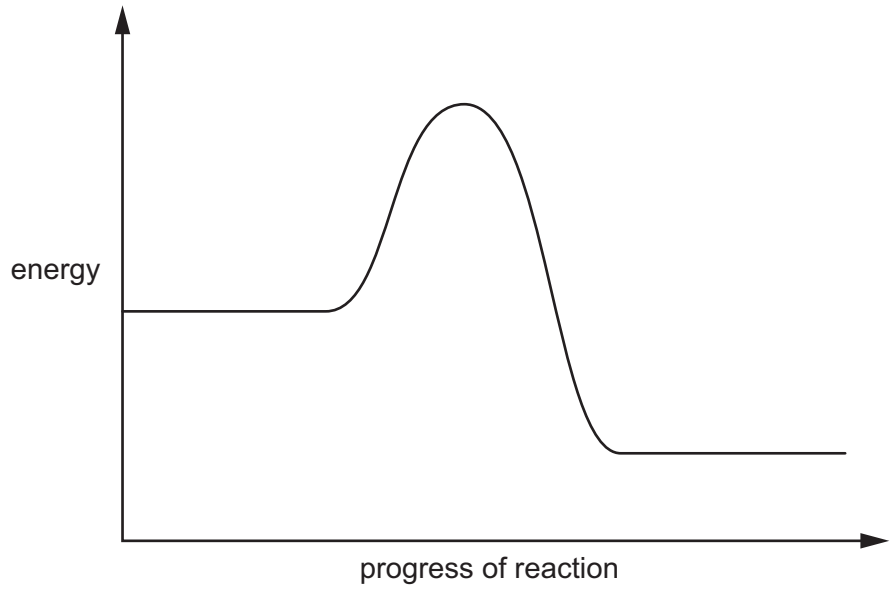

Figure 4.1

(i) Complete the reaction pathway diagram in Figure 4.1.

In your diagram, include:

- the formulas of the reactants and the products
- an arrow, labelled E_a, to show the activation energy of the forward reaction
- an arrow, labelled ΔH, to show the enthalpy change of the forward reaction.

[3]

(ii) Use Figure 4.1 and the information given to determine:

- the enthalpy change, in kJ / mol, of the reverse reaction

Include a sign with your answer.

..... kJ / mol

- the activation energy, in kJ / mol, of the reverse reaction.

Include a sign with your answer.

..... kJ / mol
[2]

(d) The equation for the reaction of hydrogen with carbon dioxide can be represented as shown in Figure 4.2.

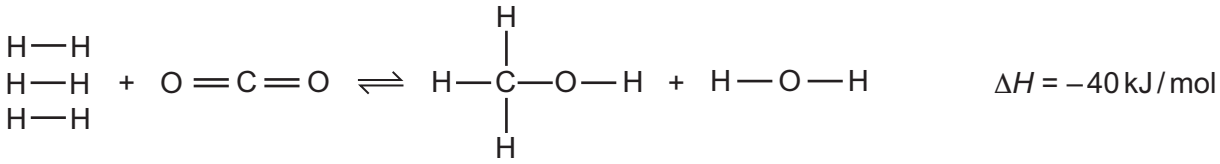

Figure 4.2

Table 4.2 shows some bond energies.

Table 4.2

bond	H–H	C=O	O–H	C–O
bond energy in kJ / mol	440	805	460	360

Use the bond energies in Table 4.2 and the value of ΔH for the forward reaction to calculate the C–H bond energy in kJ / mol.

Use the following steps.

- Calculate the energy needed to break the bonds in the reactants.

..... kJ

- Calculate the energy released when the bonds in water form.

..... kJ

- Calculate the bond energy of the C–H bond.

..... kJ / mol
[4]

(e) In Figure 4.3, complete the dot-and-cross diagram of a molecule of methanol.

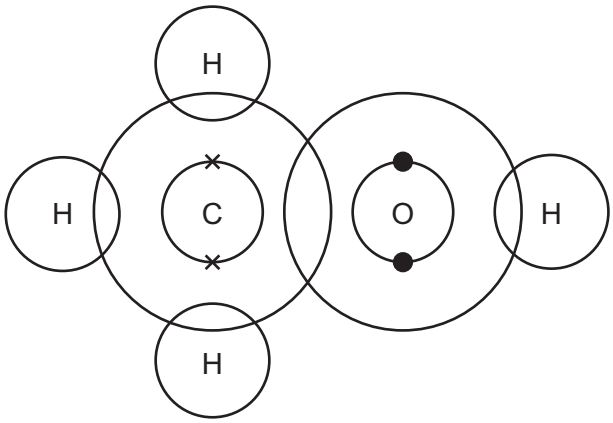

Figure 4.3

[3]

(f) Ethanol is a common fuel. Methanol can also be used as a fuel.

Complete and balance the symbol equation for the incomplete combustion of methanol, CH_3OH.

$$CH_3OH + ... \rightarrow CO + ...H_2O$$ [1]

[Total: 19]

5 **A**, **B**, **C** and **D** are the first four members of a family of organic compounds with similar chemical properties.

Table 5.1 gives either the molecular formula or the name of **A**, **B**, **C** and **D**.

Table 5.1

A	B	C	D
CH_2O_2	ethanoic acid	propanoic acid	butanoic acid

(a) State the term given to a family of organic compounds with similar chemical properties.

..... [1]

(b) Explain why members of a family of organic compounds show similar chemical properties.

..... [1]

(c) State the general formula of the family of organic compounds in Table 5.1.

..... [1]

(d) Complete Table 5.2.

Table 5.2

name of A	
structural formula of B	
molecular formula of C	
empirical formula of D	

[4]

(e) **C** is made by oxidation of an alcohol. The oxidising agent used has the formula $KMnO_4$.

(i) Name the alcohol which is oxidised to form **C**.

..... [1]

(ii) Give the chemical name of $KMnO_4$.

..... [1]

(iii) State the **two** conditions needed for the oxidation of the alcohol in **5(e)(i)** with $KMnO_4$.

1 .....

2 .....

[2]

(f) **D** reacts with ethanol to form an ester.

(i) State the type of catalyst needed for this reaction.

..... [1]

(ii) Complete the word equation for this reaction.

butanoic acid + ethanol ⇌ ..... + ...

[2]

(iii) Draw the displayed formula of the ester formed.

[2]

[Total: 16]

6 Polyamides are condensation polymers.
Proteins are natural polyamides formed from amino acid monomers.

Figure 6.1 shows part of the structure of a protein.

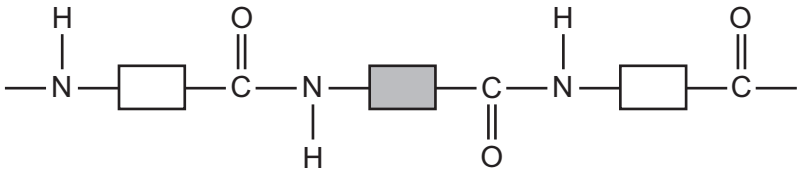

Figure 6.1

(a) Deduce the number of different types of amino acid monomers needed to make the part of the protein shown in Figure 6.1.

..... [1]

(b) Deduce the number of water molecules produced when the part of the protein shown in Figure 6.1 forms from amino acid monomers.

..... [1]

(c) Complete Figure 6.2 to show the general structure of an amino acid monomer.

R represents a side-chain.

Show all of the atoms and all of the bonds.

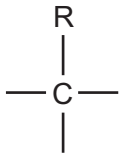

Figure 6.2

[3]

(d) Figure 6.3 shows part of the structure of a different polymer.

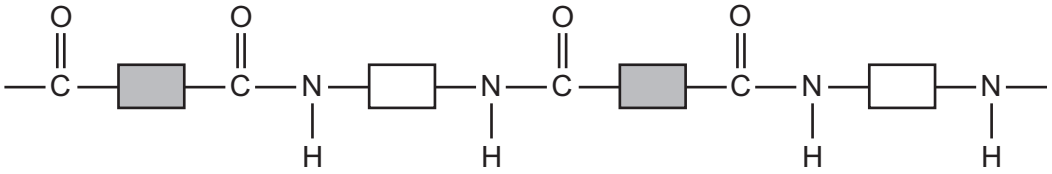

Figure 6.3

(i) Deduce the number of repeat units shown in Figure 6.3.

..... [1]

(ii) Name the **two** types of organic compounds needed to make the polymer shown in Figure 6.3.

1 .....

2 .....

[2]

[Total: 8]

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.).