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CHEMISTRY **0620/42**

Paper 4 Theory (Extended) **February/March 2025**

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 **12** pages.

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1 Using numbers only, state the:

(a) percentage of oxygen in clean, dry air ..... [1]

(b) typical operating temperature, **in °C**, used in the Haber process ..... [1]

(c) number of atoms in a diatomic molecule ..... [1]

(d) maximum number of electrons in the second electron shell of an atom ..... [1]

(e) number of hydrogen atoms in an alkane with 7 carbon atoms ..... [1]

(f) number of particles in **one** mole, in standard form. ..... [1]

[Total: 6]

2 This question is about ionic compounds.

(a) State what is meant by the term ionic bond.

.....

..... [2]

(b) Potassium sulfide, K_2S, is an ionic compound.

Complete the dot-and-cross diagram in Fig. 2.1 of the ions in potassium sulfide.

Show the charges on the ions.

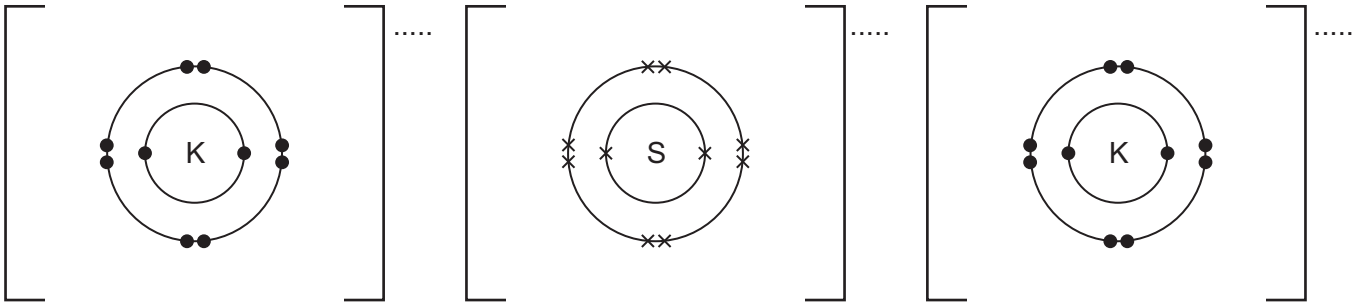


Fig. 2.1

[3]

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(c) Ionic compounds form giant ionic lattices.

(i) Fig. 2.2 shows part of the giant ionic lattice structure of sodium chloride.

Complete the diagram in Fig. 2.2 to show the ions present. Use '+' for sodium ions and '–' for chloride ions. One chloride ion has been completed for you.

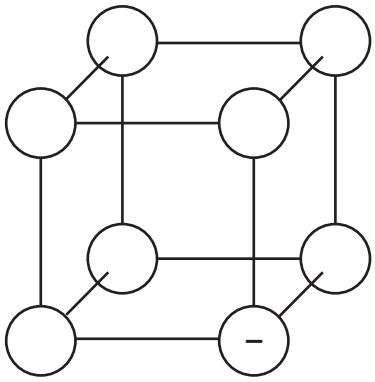


Fig. 2.2

[2]

(ii) State the name given to any positive ion.

..... [1]

(d) Ionic compounds can be decomposed by the passage of an electric current using inert electrodes.

(i) State the name of this process.

..... [1]

(ii) Write the ionic half-equation for the reaction which takes place at the anode when **molten** potassium bromide, KBr, is decomposed by the passage of an electric current.

..... [2]

(iii) Name the products and state the observations at the negative and positive electrodes when **dilute aqueous** potassium bromide, KBr, is decomposed by the passage of an electric current.

product at the negative electrode

.....

observations at the negative electrode

.....

products at the positive electrode

..... and .....

observations at the positive electrode

.....

[5]

[Total: 16]

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3 The halogens are a group of elements in the Periodic Table.

Chlorine is a member of this group.

(a) State the group number of the halogens.

..... [1]

(b) State how many halogens there are in this group.

..... [1]

(c) Suggest the identity of the halogen which:

(i) has the highest density

..... [1]

(ii) is the most reactive.

..... [1]

(d) State the name of the negative ions (anions) formed by halogens.

..... [1]

(e) State how many occupied electron shells there are in a bromine atom.

..... [1]

(f) Name the noble gas which has the same electronic configuration as a Br^- ion.

..... [1]

(g) Aqueous chlorine, Cl_2, reacts with aqueous potassium iodide, KI.
One of the products formed is iodine, I_2.

(i) Complete and balance the ionic equation for the reaction between Cl_2 and I^- ions.
State symbols are **not** required.

$$Cl_2 + ...I^- \rightarrow ..... + I_2$$

[2]

(ii) Explain why this reaction is defined as a redox reaction.

Give your answer in terms of electron transfer.

.....

..... [2]

(h) Give the colour and state of iodine at room temperature and pressure.

colour .....

state .....

[2]

[Total: 13]

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4 Carbonyl chloride, $COCl_2$, is manufactured by reacting carbon monoxide with chlorine.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -105 \text{ kJ/mol}$$

The process takes place in a closed system, and an equilibrium is reached.
The conditions for this process are 200 °C and 200 kPa.

(a) Explain what is meant by the term closed system.

..... [1]

(b) State what the symbol ΔH represents.

..... [1]

(c) State how the value of ΔH shows that the forward reaction is exothermic.

..... [1]

(d) Deduce the value of ΔH for the reverse reaction. Include a sign in your answer.

..... [1]

(e) Complete Table 4.1 to show the effect, if any, on the concentration of $COCl_2(g)$ at equilibrium when the following changes to the conditions are applied.

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

Table 4.1

change to conditions	effect on the concentration of $COCl_2(g)$ at equilibrium
the temperature is increased	
some CO is added	
the pressure is increased	
a catalyst is added	

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(f) The equation for the reaction can be represented as shown in Fig. 4.1.

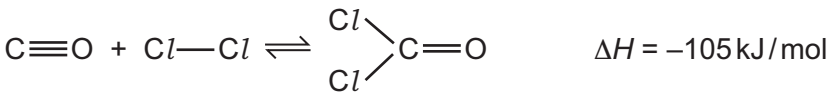


Fig. 4.1

Table 4.2 shows some bond energies.

Table 4.2

bond	C≡O	C*l*–C*l*	C–C*l*
bond energy in kJ / mol	1075	240	340

Use the bond energies in Table 4.2 and the value of ΔH for the reaction to calculate the bond energy, in kJ / mol, of the C=O bond.

Use the following steps.

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

..... kJ

- Calculate the energy released when the bonds in carbonyl chloride form.

..... kJ

- Calculate the bond energy of the C=O bond.

..... kJ / mol
[3]

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(g) Complete the dot-and-cross diagram in Fig. 4.2 of a molecule of carbonyl chloride.

Show outer shell electrons only.

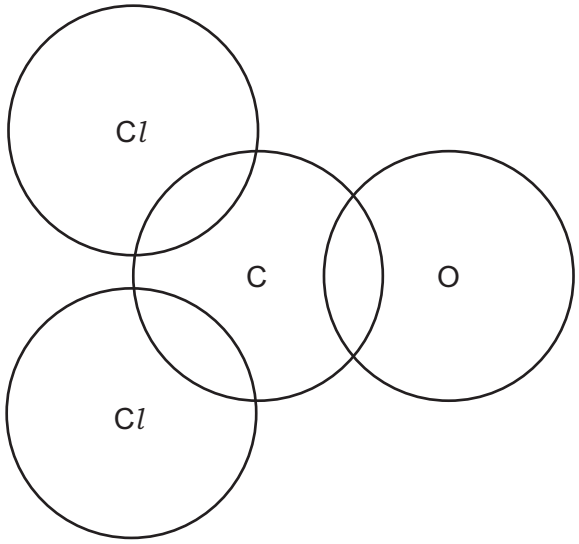


Fig. 4.2

[3]

[Total: 14]

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5 Manganese is the element with atomic number 25 in the Periodic Table.
Calcium is the element with atomic number 20 in the Periodic Table.

(a) Complete Table 5.1 to show the number of protons, neutrons and electrons in the ^{55}Mn atom and the $^{42}Ca^{2+}$ ion.

Table 5.1

	^{55}Mn	$^{42}Ca^{2+}$
protons		
neutrons		
electrons		

[3]

(b) Manganese forms several oxides. The formulae of some of these oxides are shown.

MnO
Mn_2O_3
Mn_3O_4
MnO_2
Mn_2O_7

(i) Suggest why manganese is expected to form coloured oxides.

..... [1]

(ii) State which other property of manganese is shown by the formation of several oxides.

..... [1]

(iii) State the formula of manganese(II) oxide.

..... [1]

(c) Mn_3O_4 is found in an ore of manganese. Manganese metal can be extracted from Mn_3O_4 using aluminium as the reducing agent.

(i) Define the term reducing agent.

.....

..... [2]

(ii) Complete the symbol equation by inserting the formula of the missing product and balancing the equation.

$$.....Mn_3O_4 + ...Al \rightarrow ..... + ...Mn$$

[2]

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(d) MnO_2 reacts with dilute hydrochloric acid as shown in the equation.

$$MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$$

(i) Calculate the volume of chlorine gas formed, in cm^3, at r.t.p. when excess MnO_2 reacts with 50.0 cm^3 of 0.200 mol / dm^3 HCl.

Use the following steps.

- Calculate the number of moles of HCl used.

.....mol

- Determine the number of moles of Cl_2 formed.

.....mol

- Calculate the volume of Cl_2 formed.

..... cm^3
[3]

(ii) Describe a test for chlorine gas.

test .....

observations .....
[1]

(iii) Explain, in terms of collision theory, why decreasing the temperature decreases the rate of this reaction.

.....

.....

.....

.....

.....

..... [3]

[Total: 17]

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6 The structural formulae of two compounds, **A** and **B**, are shown.

A	B
$CH_2=CHCH_3$	$CH_3CH=CHCH_3$

A and **B** are members of the same homologous series.

(a) Give **two** reasons why the structural formulae of **A** and **B** show they are members of the same homologous series.

1 .....

2 .....

[2]

(b) Explain why **A** and **B** are both hydrocarbons.

..... [1]

(c) Write the symbol equation for the complete combustion of **A**.

..... [2]

(d) Deduce the empirical formula of **A**.

..... [1]

(e) Name compound **B**.

..... [1]

(f) A structural isomer of **B** is a member of the same homologous series.

Draw the displayed formula of this structural isomer of **B**.

[1]

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(g) Compound **B** reacts with aqueous bromine at room temperature to form product **C**. The equation is shown.

$$\underset{\textbf{B}}{CH_3CH{=}CHCH_3} + Br_2 \rightarrow \underset{\textbf{C}}{CH_3CHBrCHBrCH_3}$$

(i) State why this is an addition reaction.

..... [1]

(ii) Describe the colour change in aqueous bromine during this reaction.

from ..... to ..... [1]

(iii) Name product **C**.

..... [1]

(h) Under certain conditions, **one** mole of **B** reacts with oxygen to form **two** moles of carboxylic acid **D**.

Carboxylic acid **D** has **two** carbon atoms.

(i) Draw the displayed formula of carboxylic acid **D**.

[1]

(ii) Name carboxylic acid **D**.

..... [1]

(iii) Complete the symbol equation for this reaction.

$$CH_3CH{=}CHCH_3 + \text{.....} \rightarrow \text{.....}$$

[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.).

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