



Cambridge IGCSE™ (9–1)

CANDIDATE
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CHEMISTRY

0971/42

Paper 4 Theory (Extended)

October/November 2023

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.

1 Table 1.1 gives the electronic configurations of some atoms and ions, **A** to **G**.

Table 1.1

	electronic configuration
A	2,5
B	2,8
C	2,8,2
D	2,8,4
E	2,8,5
F	2,8,6
G	2,8,18,7

Answer the following questions about **A** to **G**.

Each letter may be used once, more than once or not at all.

State which of the atoms or ions, **A** to **G**, could be:

(a) a noble gas atom

..... [1]

(b) an atom of an element in Group VI

..... [1]

(c) an atom with an atomic number of 14

..... [1]

(d) atoms from the same group

..... and [1]

(e) a halogen atom

..... [1]

(f) an atom of an element which is a good conductor of electricity

..... [1]

(g) a stable ion of a Group V element

..... [1]

(h) an atom that forms an ion with a 2– charge.

..... [1]

[Total: 8]

2 Cobalt and copper are transition elements.

(a) Copper has two naturally occurring isotopes, ^{63}Cu and ^{65}Cu . Cobalt has only one naturally occurring isotope, ^{59}Co .

(i) Complete Table 2.1 to show the number of protons, neutrons and electrons in the ^{59}Co atom and the $^{65}\text{Cu}^{2+}$ ion.

Table 2.1

	^{59}Co	$^{65}\text{Cu}^{2+}$
protons		
neutrons		
electrons		

[3]

(ii) Table 2.2 shows the relative abundance of the two naturally occurring isotopes of copper.

Table 2.2

isotope	^{63}Cu	^{65}Cu
relative abundance	70%	30%

Calculate the relative atomic mass of copper to **one** decimal place.

relative atomic mass = [2]

(b) One physical property of transition elements such as copper and cobalt is that they are hard. Other metals such as lithium are softer.

State **two** other physical properties of copper and cobalt which are significantly different from lithium.

1

2

[2]

(c) Both copper and cobalt can form coloured compounds. Some of these compounds contain water of crystallisation.

(i) Define the term water of crystallisation.

.....
..... [2]

(ii) State the colour and formula of hydrated cobalt(II) chloride crystals.

colour

formula

[2]

(iii) State the colour change seen when a few drops of water are added to anhydrous copper(II) sulfate.

from to [2]

(iv) State how this colour change can be reversed.

..... [1]

[Total: 14]

3 Iron is manufactured in a blast furnace.

(a) Three of the starting materials added to the blast furnace are coke, iron ore and limestone.

Name the **other** starting material added to the blast furnace.

..... [1]

(b) The source of iron in the blast furnace is Fe_2O_3 . Fe_2O_3 is found in iron ore.

(i) Name the main ore of iron which contains Fe_2O_3 .

..... [1]

(ii) The iron in Fe_2O_3 is reduced by reaction with carbon monoxide. The unbalanced symbol equation is shown.

Complete the equation.

$\text{Fe}_2\text{O}_3 + \dots\text{CO} \rightarrow \dots\text{CO}_2 + \dots\text{Fe}$ [1]

(iii) State the change in oxidation number of iron in the reaction in (ii).

from to [2]

(iv) Explain how the change of oxidation number shows that iron has been reduced.

..... [1]

(c) The major impurity in iron ore is silicon(IV) oxide. Limestone is added to the blast furnace to remove this impurity.

Write two symbol equations to show how silicon(IV) oxide is removed. For each equation, state the type of chemical reaction that takes place.

equation 1

type of chemical reaction

equation 2

type of chemical reaction

[4]

(d) Iron is converted to steel by mixing it with carbon and other elements.

(i) State the term given to a substance which is a mixture of a metal and other elements.

..... [1]

(ii) Name **one** element, other than carbon, mixed with iron in the making of stainless steel.

..... [1]

(e) Preventing the rusting of steel is important.

State the chemical name of rust.

..... [1]

(f) Steel can be coated with zinc to prevent rusting. This provides both a barrier method and sacrificial protection.

(i) State the term used for coating steel with zinc.

..... [1]

(ii) Describe another barrier method for preventing rusting.

..... [1]

(iii) Explain how zinc provides sacrificial protection.

..... [2]

[Total: 17]

4 This question is about lead(II) chloride, PbCl_2 .

(a) A student prepares a sample of insoluble lead(II) chloride, PbCl_2 , by mixing aqueous solutions of **two** salts in a beaker.

(i) Identify **two** soluble salts suitable for making lead(II) chloride when mixed together.

.....
.....

[2]

(ii) Write the ionic equation for the formation of lead(II) chloride by mixing aqueous solutions.

Include state symbols.

.....

[3]

(iii) List the steps the student should take in preparing a pure sample of lead(II) chloride from the mixture in the beaker.

.....
.....
.....

[3]

(b) The student carries out an electrolysis experiment on molten lead(II) chloride using the apparatus shown in Fig. 4.1. Chlorine gas forms at the anode and escapes from the apparatus.

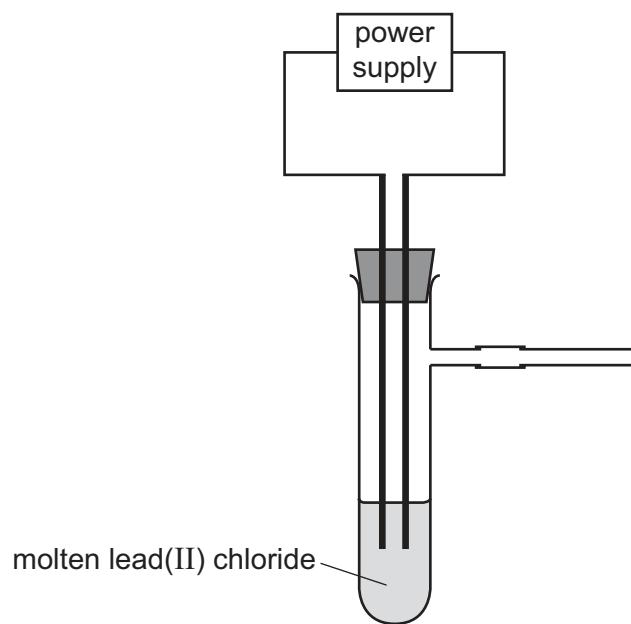


Fig. 4.1

(i) Explain why lead(II) chloride needs to be molten before it will conduct electricity.

..... [1]

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

..... [2]

(iii) State the test for chlorine gas.

test

observations

[2]

(iv) Describe what is observed at the cathode.

..... [1]

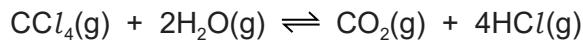
[Total: 14]

5 Chemical reactions can involve transfer of thermal energy.

(a) State the term used for the transfer of thermal energy during a reaction.

..... [1]

(b) Tetrachloromethane gas, $\text{CCl}_4(\text{g})$, reacts with steam as shown.



The reaction is reversible. The forward reaction is exothermic.

(i) State what happens, if anything, to the rate of the forward reaction if the concentration of CCl_4 is increased.
Explain your answer in terms of collision theory.

.....
.....
.....
..... [3]

(ii) State what happens to the position of equilibrium, if anything, when the pressure is increased.
Explain your answer.

..... [2]

(iii) Fig. 5.1 shows an incomplete reaction pathway diagram for the forward reaction.

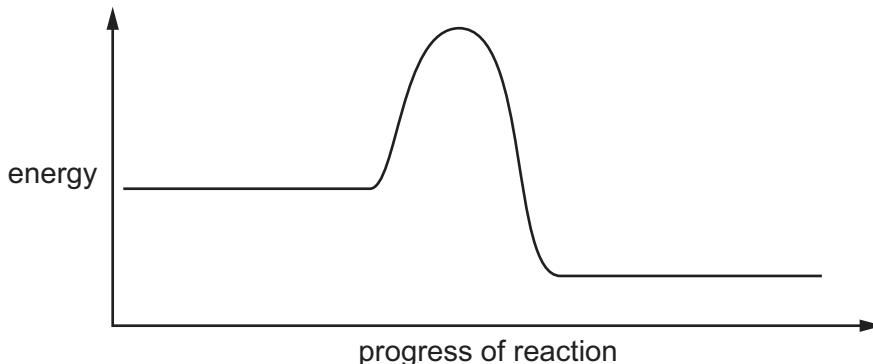
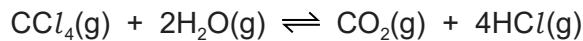


Fig. 5.1

On Fig. 5.1:

- insert the formulae of the reactants and products
- draw an arrow, labelled E_a , to show the activation energy
- draw an arrow, labelled ΔH , to show the transfer of energy in the reaction.

[3]

(iv) Define the term activation energy.

..... [2]

(v) State **one** way in which the activation energy of a reaction can be changed.

..... [1]

(c) The equation for the reaction between tetrachloromethane gas and steam can be represented as shown in Fig. 5.2.

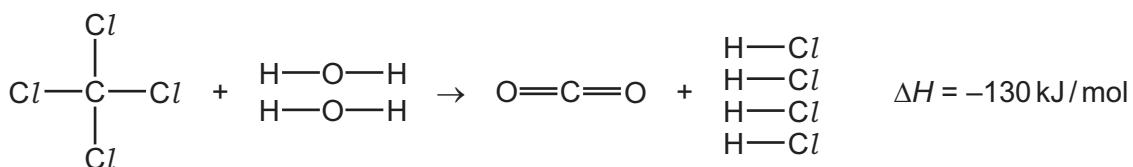


Fig. 5.2

Table 5.1 shows some bond energies.

Table 5.1

bond	C–Cl	H–O	C=O
bond energy in kJ/mol	340	460	805

Use the bond energies in Table 5.1 and the ΔH value for the reaction to calculate the H–Cl bond energy using the following steps.

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

..... kJ

- Calculate the energy released when the bonds in carbon dioxide form.

..... kJ

- Calculate the H–Cl bond energy.

..... kJ/mol
[4]

[Total: 16]

6 A homologous series is a family of organic compounds whose members have similar chemical properties.

(a) Give **two** characteristics that are the **same** for all members of a homologous series.

1

2

[2]

(b) In terms of structure, state how one member of a homologous series differs from the next member of that homologous series.

..... [1]

(c) **A**, **B** and **C** are organic compounds.

A has the molecular formula $C_{12}H_{24}$.

B has the name tetradecane.

C has three carbon atoms and is in the homologous series with the general formula $C_nH_{2n+1}COOH$.

(i) Name the homologous series each organic compound belongs to.

A

B

C

[3]

(ii) Name **C** and draw its displayed formula.

name

displayed formula

[2]

(d) Amino acids are a homologous series where each member has the general structure shown in Fig. 6.1.

The R side chain contains carbon and hydrogen atoms only.

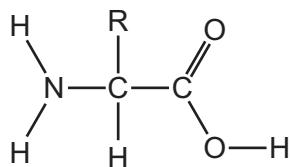


Fig. 6.1

(i) An amino acid has a relative molecular mass of 103.

Deduce the formula of the R side chain in this amino acid.

Show your working.

..... [2]

(ii) State the name given to the natural polyamides formed from amino acid monomers.

..... [1]

[Total: 11]

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The Periodic Table of Elements

		Group									
		I				II		III			
		1		2		3		4		5	
		H	He	Li	Be	Li	Be	Li	Be	Li	Be
Key		atomic number	atomic symbol	name							
		relative atomic mass									
1	2	3	4	5	6	7	8	9	10	11	12
Li	Be	Li	Be	Li	Be	Li	Be	Li	Be	Li	Be
lithium	beryllium	lithium	beryllium	lithium	beryllium	lithium	beryllium	lithium	beryllium	lithium	beryllium
7	9	7	9	7	9	7	9	7	9	7	9
Na	Mg	Na	Mg	Na	Mg	Na	Mg	Na	Mg	Na	Mg
sodium	magnesium	sodium	magnesium	sodium	magnesium	sodium	magnesium	sodium	magnesium	sodium	magnesium
23	24	11	12	11	12	11	12	11	12	11	12
K	Ca	K	Ca	K	Ca	K	Ca	K	Ca	K	Ca
potassium	calcium	potassium	calcium	potassium	calcium	potassium	calcium	potassium	calcium	potassium	calcium
39	40	19	20	19	20	19	20	19	20	19	20
Sc	Ti	Sc	Ti	Sc	Ti	Sc	Ti	Sc	Ti	Sc	Ti
scandium	titanium	scandium	titanium	scandium	titanium	scandium	titanium	scandium	titanium	scandium	titanium
45	48	20	21	20	21	20	21	20	21	20	21
Mo	Ru	Mo	Ru	Mo	Ru	Mo	Ru	Mo	Ru	Mo	Ru
molybdenum	ruthenium	molybdenum	ruthenium	molybdenum	ruthenium	molybdenum	ruthenium	molybdenum	ruthenium	molybdenum	ruthenium
96	101	43	44	43	44	43	44	43	44	43	44
Tc	Rh	Tc	Rh	Tc	Rh	Tc	Rh	Tc	Rh	Tc	Rh
technetium	rhodium	technetium	rhodium	technetium	rhodium	technetium	rhodium	technetium	rhodium	technetium	rhodium
—	103	—	103	—	103	—	103	—	103	—	103
Rb	Sr	Rb	Sr	Rb	Sr	Rb	Sr	Rb	Sr	Rb	Sr
rubidium	strontium	rubidium	strontium	rubidium	strontium	rubidium	strontium	rubidium	strontium	rubidium	strontium
85	88	37	38	37	38	37	38	37	38	37	38
La	Y	La	Y	La	Y	La	Y	La	Y	La	Y
lanthanoids	yttrium	lanthanoids	yttrium	lanthanoids	yttrium	lanthanoids	yttrium	lanthanoids	yttrium	lanthanoids	yttrium
137	89	56	57–71	56	57–71	56	57–71	56	57–71	56	57–71
Ba	Ca	Ba	Ca	Ba	Ca	Ba	Ca	Ba	Ca	Ba	Ca
barium	caesium	barium	caesium	barium	caesium	barium	caesium	barium	caesium	barium	caesium
133	133	87	88	87	88	87	88	87	88	87	88
Fr	Ra	Fr	Ra	Fr	Ra	Fr	Ra	Fr	Ra	Fr	Ra
francium	radium	francium	radium	francium	radium	francium	radium	francium	radium	francium	radium
—	—	—	—	—	—	—	—	—	—	—	—
Group		VII				VIII				I	
		VII				VIII				He	
		VII				VIII				helium	
		VII				VIII				4	
		VII				VIII				Neon	
		VII				VIII				20	
		VII				VIII				Ne	
		VII				VIII				He	
		VII				VIII				4	

16

57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Dy	66	Tb	67	Ho	68	Er	69	Tm	70	Yb	71	Lu		
	lanthanum		cerium		praseodymium		neodymium		promethium		samarium		euroium		gadolinium		dysprosium		terbium		holmium		erbium		thulium		ytterbium	173	lutetium	175	
139		140		141		144		—		150		152		157		159		163		159		165		167		169		173		—	103
89	Ac	90	Th	91	Pa	92	U	93	Pu	94	Am	95	Cm	96	Bk	97	Cf	98	Curium	99	Einsteinium	100	Fermium	101	Mendelevium	102	No	103			
	actinium		thorium		protactinium		uranium		neptunium		plutonium		americium		—		berkelium		—		—		—		—		—	—	—	—	—
—		232		231		238		—		—		—		—		—		—		—		—		—		—		—	—	—	—

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