



Cambridge IGCSE™ (9–1)

CANDIDATE
NAME

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CHEMISTRY

0971/42

Paper 4 Theory (Extended)

October/November 2021

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.



2

1 This question is about states of matter.

(a) Complete the table, using ticks (✓) and crosses (✗), to describe the properties of gases, liquids and solids.

state of matter	particles are touching	particles have random movement	particles are regularly arranged
gas			
liquid			
solid			

[3]

(b) Substances can change state.

(i) Boiling and evaporation are two ways in which a liquid changes into a gas.

Describe **two** differences between boiling and evaporation.

1

2 [2]

(ii) Name the change of state when:

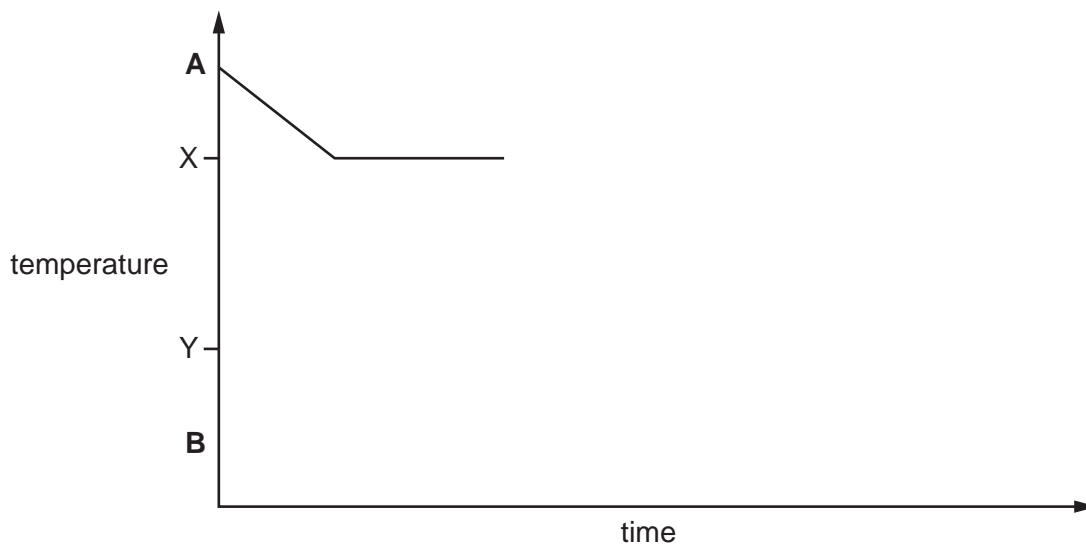
• a gas becomes a liquid

• a solid becomes a gas. [2]

3

- (c) A substance boils at temperature X and melts at temperature Y.

Complete the graph to show the change in temperature over time as the substance cools from temperature A to temperature B.



[2]

- (d) A solution is a mixture of a solute and a solvent.

(i) Name the process when a solid substance mixes with a solvent to form a solution.

..... [1]

(ii) Name the type of reaction when two solutions react to form an insoluble substance.

..... [1]

[Total: 11]

2 Acids are important laboratory chemicals.

(a) Some acids completely dissociate in water to form ions.

(i) State the term applied to acids that completely dissociate in water.

..... [1]

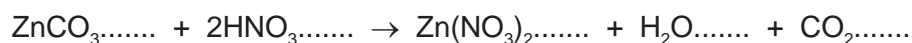
(ii) Complete the equation to show the complete dissociation of sulfuric acid in water.



(iii) State the colour of methyl orange in sulfuric acid.

..... [1]

(b) The equation for the reaction between powdered zinc carbonate and dilute nitric acid is shown.



(i) Complete the equation by adding state symbols. [2]

(ii) A student found that 2.5 g of zinc carbonate required 20 cm³ of dilute nitric acid to react completely.

Calculate the concentration of dilute nitric acid using the following steps:

- calculate the mass of 1 mole of ZnCO₃

..... g

- calculate the number of moles of ZnCO₃ reacting

..... moles

- determine the number of moles of HNO₃ reacting

..... moles

- calculate the concentration of HNO₃.

..... mol/dm³
[4]

[Total: 10]

5

3 Atoms contain protons, neutrons and electrons.

(a) Complete the table to show the relative mass and the relative charge of a proton, a neutron and an electron.

	relative mass	relative charge
proton		
neutron		
electron	$\frac{1}{1840}$	

[3]

(b) The table shows the number of protons, neutrons and electrons in some atoms and ions.

Complete the table.

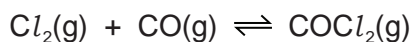
atom or ion	number of protons	number of neutrons	number of electrons
${}_{16}^{32}\text{S}$			
${}_{19}^{39}\text{K}^+$			
	35	44	36

[5]

[Total: 8]

6

- 4 Chlorine reacts with carbon monoxide to produce phosgene gas, $\text{COCl}_2(\text{g})$. A catalyst is used.



The reaction is exothermic.

- (a) Explain why the reaction is exothermic in terms of the energy changes of bond breaking and bond making.

.....

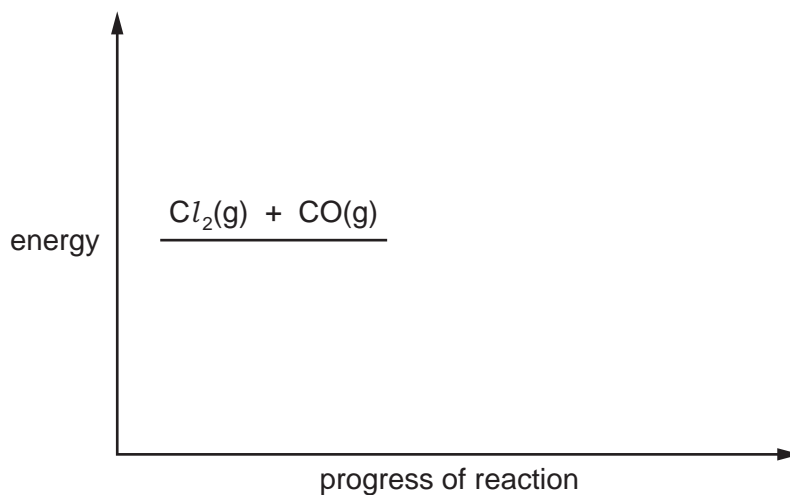
.....

..... [3]

- (b) (i) Complete the energy level diagram for this reaction.

On your diagram show:

- the product of the reaction
- an arrow representing the energy change, labelled ΔH
- an arrow representing the activation energy, labelled A.



[3]

- (ii) State why a catalyst is used.

..... [1]

(c) Describe and explain the effect, if any, on the position of equilibrium when:

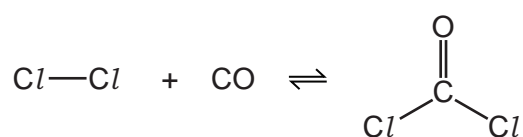
(i) the pressure is increased

.....
 [2]

(ii) the temperature is increased.

.....
 [2]

(d) The reaction between chlorine and carbon monoxide can be represented as shown.



When one mole of chlorine reacts with one mole of carbon monoxide, 230 kJ of energy is released.

Some bond energies are shown in the table.

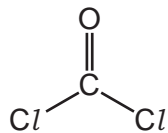
bond	bond energy in kJ/mol
Cl-Cl	240
C=O	745
C-Cl	400

Use the information to calculate the energy of the bond between the C and the O in carbon monoxide, CO.

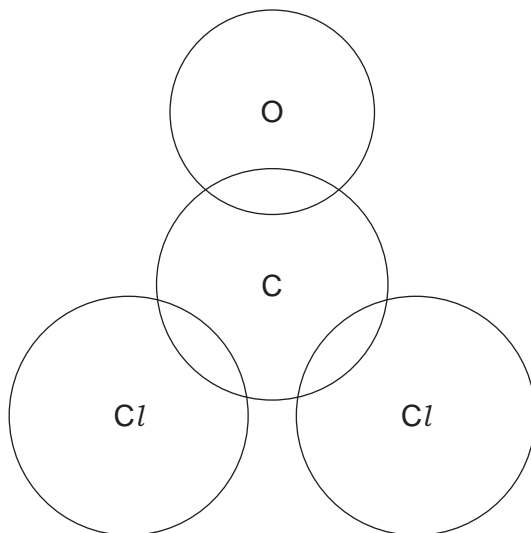
bond energy in carbon monoxide, CO = kJ/mol [3]

8

(e) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of COCl_2 .



Show outer electrons only.



[3]

[Total: 17]

5 Iron is a transition element. Potassium is a Group I element.

(a) Iron and potassium have the same type of bonding.

Name and describe the type of bonding in these two elements.

name

description

.....

.....

.....

[4]

(b) Transition elements and Group I elements have some similar physical properties.

They can both:

- be hammered into a shape
- conduct electricity
- be stretched into wires.

(i) Name the term used to describe the ability of elements to be hammered into a shape.

..... [1]

(ii) Describe what happens to the particles in iron when it is hammered into a shape.

.....

..... [1]

(iii) Suggest why copper, rather than other transition elements, is used for wires which conduct electricity.

..... [1]

(c) Transition elements are harder and stronger than Group I elements.

Describe how **two** other **physical** properties of transition elements are different from those of Group I elements.

1

2

[2]

(d) Chemical properties of some Group I elements are shown in the table.

element	reaction with cold water	reaction with oxygen	flame test colour
lithium	<ul style="list-style-type: none"> steadily effervesces forms a colourless solution 	very slowly forms an oxide layer	red
sodium	<ul style="list-style-type: none"> strongly effervesces forms a colourless solution 	slowly forms an oxide layer	
potassium	<ul style="list-style-type: none"> very strongly effervesces forms a colourless solution 	quickly forms an oxide layer	
rubidium			ruby red

(i) Add to the table:

- the flame test colours for sodium and potassium
- the predicted reactions of rubidium with water and with oxygen.

[4]

(ii) Name the gas produced when Group I elements react with water.

..... [1]

(iii) Name the solution formed when potassium reacts with water.

..... [1]

(iv) Predict the pH of the colourless solution formed when potassium reacts with water.

..... [1]

(v) Write the chemical equation for the reaction of sodium with oxygen.

..... [2]

(e) Iron is a typical transition element. It is the catalyst used in the Haber process.

(i) Write the equation for the reaction that occurs in the Haber process.

..... [2]

(ii) State the temperature and pressure used in the Haber process. Include units.

temperature

pressure

[2]

[Total: 22]

6 Ethanol, C_2H_5OH , belongs to the homologous series called alcohols.

(a) Write the general formula of alcohols.

..... [1]

(b) Explain why ethanol **cannot** be described as a hydrocarbon.

..... [1]

(c) Ethanol can be manufactured from different substances by reaction with steam or by fermentation.

(i) Give the formula of the substance which reacts with steam to form ethanol.

..... [1]

(ii) Name a substance which will undergo fermentation to form ethanol.

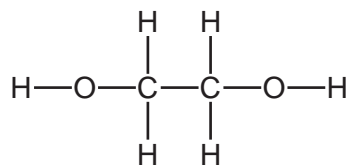
..... [1]

(d) Ethanol is a fuel.

Write the chemical equation for the complete combustion of ethanol.

..... [2]

(e) Ethane-1,2-diol has two alcohol functional groups.



One molecule of ethane-1,2-diol will react with two molecules of ethanoic acid to form molecule **X**.

X has two ester functional groups and a molecular formula of $\text{C}_6\text{H}_{10}\text{O}_4$.

(i) State the empirical formula of **X**.

..... [1]

(ii) Draw the structure of **X**.

Show all of the atoms and all of the bonds.

[2]

(iii) Name the **other** substance formed in this reaction.

..... [1]

(f) Each alcohol functional group in ethane-1,2-diol reacts with acidified potassium manganate(VII) to form a different organic compound, **Y**.

(i) Name the functional groups formed in **Y**.

..... [1]

(ii) Draw the structure of **Y**.

Show all of the atoms and all of the bonds.

[1]

[Total: 12]

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The Periodic Table of Elements

		Group															
I	II	III	IV	V	VI	VII	VIII										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Li lithium 7	Be beryllium 9	B boron 11	C carbon 12	N nitrogen 14	O oxygen 16	F fluorine 19	Ne neon 20										
11	12	13	14	15	16	17	18										
Na sodium 23	Mg magnesium 24	Al aluminium 27	Si silicon 28	P phosphorus 31	S sulfur 32	Cl chlorine 35.5	Ar argon 40										
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K potassium 39	Ca calcium 40	Sc scandium 45	Ti titanium 48	V vanadium 51	Cr chromium 52	Mn manganese 55	Fe iron 56	Co cobalt 59	Ni nickel 59	Cu copper 64	Zn zinc 65	Ga gallium 70	Ge germanium 73	As arsenic 75	Se selenium 79	Br bromine 80	Kr krypton 84
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb rubidium 85	Sr strontium 88	Y yttrium 89	Zr zirconium 91	Nb niobium 93	Mo molybdenum 96	Tc technetium —	Ru ruthenium 101	Rh rhodium 103	Pd palladium 106	Ag silver 108	Cd cadmium 112	In indium 115	Sn tin 119	Sb antimony 122	Te tellurium 128	I iodine 127	Xe xenon 131
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs caesium 133	Ba barium 137	lanthanoids	Hf hafnium 178	Ta tantalum 181	W tungsten 184	Re rhenium 186	Os osmium 190	Ir iridium 192	Pt platinum 195	Au gold 197	Hg mercury 201	Tl thallium 204	Pb lead 207	Bi bismuth 209	Po polonium —	At astatine —	Rn radon —
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr francium —	Ra radium —	actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Lv livermorium —	Ts tennessine —	Og oganesson —	—

Key

atomic number
atomic symbol
name
relative atomic mass

1
H
hydrogen
1

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 dm³ at room temperature and pressure (r.t.p.).