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CHEMISTRY

0620/41

Paper 4 Theory (Extended)

May/June 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.

1 Give the name of the process that is used:

(a) to produce ammonia from nitrogen

..... [1]

(b) to separate nitrogen from liquid air

..... [1]

(c) to produce bromine from molten lead(II) bromide

..... [1]

(d) to separate an undissolved solid from an aqueous solution

..... [1]

(e) to produce amino acids from proteins

..... [1]

(f) to separate a mixture of amino acids.

..... [1]

[Total: 6]

2 Complete the table to:

- deduce the number of protons, electrons and neutrons in the magnesium atom and copper ion shown
- identify the atom or ion represented by the final row.

	number of protons	number of electrons	number of neutrons
${}_{12}^{25}\text{Mg}$	12		
${}_{29}^{65}\text{Cu}^{2+}$			36
	17	18	20

[Total: 5]

3 Potassium reacts with chlorine to form potassium chloride, KCl .

(a) Write a chemical equation for this reaction.

..... [2]

(b) Potassium chloride is an ionic compound.

Complete the diagram to show the electron arrangement in the outer shells of the ions present in potassium chloride.

Give the charges on both ions.



[3]

(c) Molten potassium chloride undergoes electrolysis.

(i) State what is meant by the term *electrolysis*.

.....
 [2]

(ii) Name the products formed at the positive electrode (anode) and negative electrode (cathode) when molten potassium chloride undergoes electrolysis.

anode

cathode

[2]

(d) Concentrated aqueous potassium chloride undergoes electrolysis.

(i) Write an ionic half-equation for the reaction at the negative electrode (cathode).

..... [2]

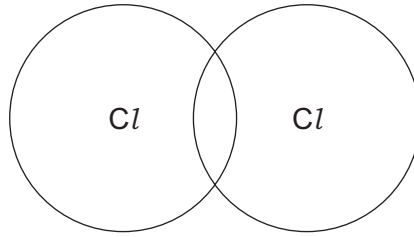
(ii) Name the product formed at the positive electrode (anode).

..... [1]

(iii) Name the potassium compound that remains in the solution after electrolysis.

..... [1]

- (e) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of chlorine, Cl_2 .
Show the outer electrons only.



[1]

- (f) The melting points and boiling points of chlorine and potassium chloride are shown.

	melting point /°C	boiling point /°C
chlorine	-101	-35
potassium chloride	770	1500

- (i) Deduce the physical state of chlorine at -75°C . Use the data in the table to explain your answer.

physical state

explanation

..... [2]

- (ii) Explain, in terms of structure and bonding, why potassium chloride has a much higher melting point than chlorine.

Your answer should refer to the:

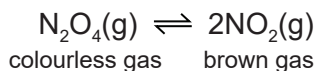
- types of particle held together by the forces of attraction
- types of forces of attraction between particles
- relative strength of the forces of attraction.

.....

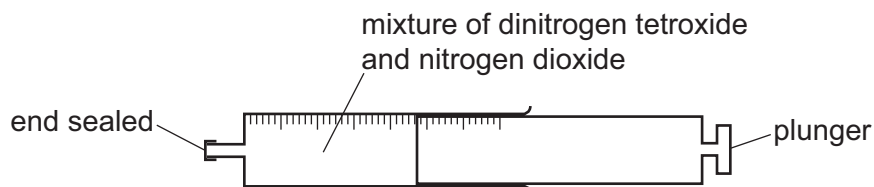
 [3]

[Total: 19]

- 4 Dinitrogen tetroxide, N_2O_4 , decomposes into nitrogen dioxide, NO_2 . The reaction is reversible.



A gas syringe containing a mixture of dinitrogen tetroxide and nitrogen dioxide gases was sealed and heated. After reaching equilibrium the mixture was a pale brown colour.

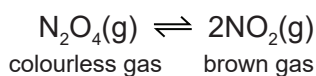


- (a) State what is meant by the term *equilibrium*.

.....

 [2]

- (b) The plunger of the gas syringe is pushed in. The temperature does not change. The mixture initially turns darker brown. After a few seconds the mixture turns lighter brown because the equilibrium shifts to the left.



- (i) Explain why the mixture initially turns darker brown.

..... [1]

- (ii) Explain why the position of equilibrium shifts to the left.

..... [1]

- (c) The forward reaction is endothermic.

- (i) State what happens to the position of equilibrium when the temperature of the mixture is increased.

..... [1]

- (ii) State what happens to the rate of the forward reaction and the rate of the backward reaction when the temperature of the mixture is increased.

rate of the forward reaction

rate of the backward reaction

[2]

[Total: 7]

5 This question is about salts.

(a) Salts that are insoluble in water are made by precipitation.

- Lead(II) iodide, PbI_2 , is insoluble in water.
- All nitrates are soluble in water.
- All sodium salts are soluble in water.

You are provided with solid lead(II) nitrate, $\text{Pb}(\text{NO}_3)_2$, and solid sodium iodide, NaI .

Describe how you would make a pure sample of lead(II) iodide by precipitation.

Your answer should include:

- practical details
- a chemical equation for the precipitation reaction.

.....

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..... [5]

(b) Nitrates decompose when heated.

(i) When hydrated zinc nitrate is heated, oxygen gas is given off.

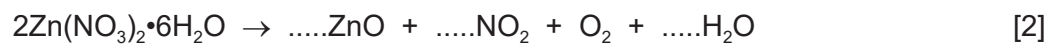
Describe a test for oxygen.

test

observations

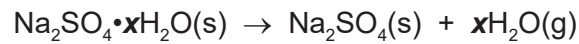
[2]

(ii) Complete the equation for the decomposition of hydrated zinc nitrate.



(c) Some sulfates are hydrated.

When hydrated sodium sulfate crystals, $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$, are heated, they give off water.



A student carries out an experiment to determine the value of x in $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$.

step 1 Hydrated sodium sulfate crystals are weighed.

step 2 The hydrated sodium sulfate crystals are then heated.

step 3 The remaining solid is weighed.

(i) Describe how the student can check that all the water has been given off.

.....

.....

..... [2]

- (ii) In an experiment, 1.61 g of $\text{Na}_2\text{SO}_4 \cdot x\text{H}_2\text{O}$ is heated until all the water is given off. The mass of Na_2SO_4 remaining is 0.71 g.

[M_r : Na_2SO_4 , 142; H_2O , 18]

Determine the value of x using the following steps.

- Calculate the number of moles of Na_2SO_4 remaining.

..... mol

- Calculate the mass of H_2O given off.

..... g

- Calculate the number of moles of H_2O given off.

..... mol

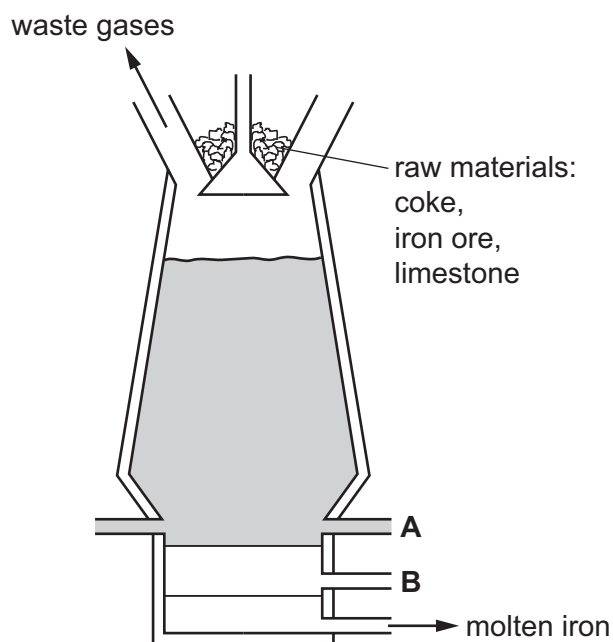
- Determine the value of x .

$x =$
[4]

[Total: 15]

6 This question is about iron.

(a) Iron is extracted from its main ore in a blast furnace.



(i) Name the main ore of iron used in the blast furnace.

..... [1]

(ii) Name the substance that enters the blast furnace at **A**.

..... [1]

(iii) Name the substance that leaves the blast furnace at **B**.

..... [1]

(iv) Give **two** reasons for using coke in the blast furnace.

1

2 [2]

(b) Another ore of iron is iron pyrites, FeS_2 . Iron pyrites contains the positive ion, Fe^{2+} .

Deduce the formula of the negative ion in FeS_2 .

..... [1]

(c) Iron is a transition element.

A list of properties of iron is shown.

- Iron is a good conductor of electricity.
- Iron forms soluble salts.
- Iron forms coloured compounds.
- Iron has variable oxidation states.
- Iron acts as a catalyst.
- Iron forms a basic oxide.

(i) Give **two** properties from the list in which iron differs from Group I elements.

1

2 [2]

(ii) Give **two** properties from the list in which iron is similar to Group I elements.

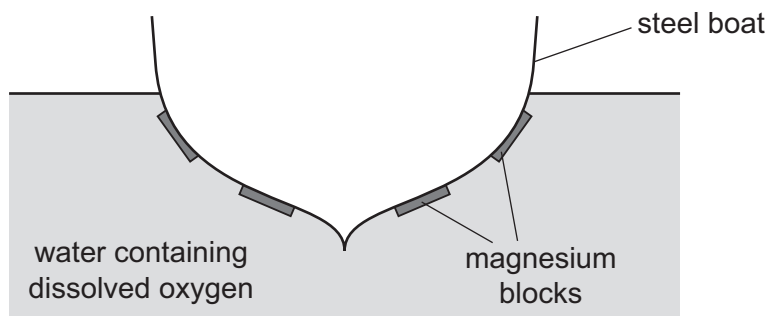
1

2 [2]

(d) Steel consists mainly of iron.

Iron forms rust when it reacts with water and oxygen.

Magnesium blocks can be attached to the bottom of steel boats. The magnesium does not completely cover the steel.



(i) Explain how the magnesium blocks prevent iron from rusting.

.....

.....

.....

..... [2]

- (ii) Explain why replacing the magnesium blocks with copper blocks will **not** prevent the bottom of the boat from rusting.

.....

..... [1]

[Total: 13]

7 Many organic compounds contain carbon, hydrogen and oxygen only.

(a) An organic compound **V** has the following composition by mass.

C, 48.65%; H, 8.11%; O, 43.24%

Calculate the empirical formula of compound **V**.

empirical formula = [3]

(b) Compound **W** has the empirical formula CH_4O and a relative molecular mass of 32.

Calculate the molecular formula of compound **W**.

molecular formula = [1]

(c) Compounds **X** and **Y** have the same general formula.

X and **Y** are both carboxylic acids.

Compound **X** has the molecular formula $\text{C}_2\text{H}_4\text{O}_2$.

Compound **Y** has the molecular formula $\text{C}_4\text{H}_8\text{O}_2$.

(i) Deduce the general formula of compounds **X** and **Y**.

..... [1]

- (ii) Draw the structure of compound Y. Show all of the atoms and all of the bonds.

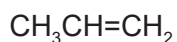
Name compound Y.

name [3]

- (iii) Give the name used to describe a 'family' of similar compounds with the same general formula, similar chemical properties and the same functional group.

..... [1]

- (d) Propene is an unsaturated hydrocarbon. The formula of propene is shown.



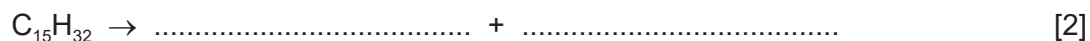
- (i) State the colour change observed when propene is added to aqueous bromine.

from to [1]

- (ii) Propene can be produced by cracking long chain alkanes.

Pentadecane, $\text{C}_{15}\text{H}_{32}$, is cracked to produce an alkane and propene in a 1 : 2 molar ratio.

Complete the chemical equation for this reaction.

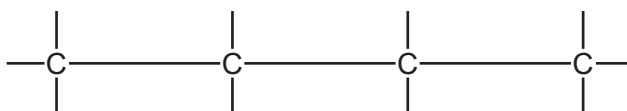


- (iii) Propene can be converted into poly(propene).

Name the type of polymerisation that occurs when propene is converted into poly(propene).

..... [1]

- (iv) Complete the diagram to show a section of poly(propene).



[2]

[Total: 15]

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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	Al aluminium 13	Si silicon 14	P phosphorus 15	S sulfur 16	Cl chlorine 17	Ar argon 18	K potassium 19	Ca calcium 20	Sc scandium 21	Ti titanium 22	V vanadium 23	Cr chromium 24	Mn manganese 25	Fe iron 26	Co cobalt 27	Ni nickel 28	Cu copper 29	Zn zinc 30	Ga gallium 31	Ge germanium 32	As arsenic 33	Se selenium 34	Br bromine 35	Kr krypton 36								
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57–71 lanthanoids	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Rb rubidium 85	Sr strontium 88	Y yttrium 89	Zr zirconium 90	Nb niobium 91	Mo molybdenum 92	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	Cs caesium 133	Ba barium 137	La lanthanum 139	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 actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Fl flerovium —	Lv livermorium —	Uu ununoctium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uup ununpentium —	Uuq ununhexium —	Uuh ununheptium —	Uuo ununoctium —	Uuq ununnonium —	Uuq unundecium —	Uuq ununtridecium —	Uuq ununpentadecium —	Uuq ununheptadecium —	Uuq ununnonadecium —	Uuq ununvigintiium —	Uuq ununtriacontium —	Uuq ununquadragintaium —	Uuq ununquinquagintaium —	Uuq ununsexagintaium —	Uuq ununseptuagintaium —	Uuq ununoctogintaium —	Uuq ununnonagintaium —

Group

1
H
hydrogen
1

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