Cambridge Assessment International Education

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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.

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1 Give the name of the process that is used:

(a) to produce ammonia from nitrogen

View solution

..... [1]

(b) to separate nitrogen from liquid air

View solution

..... [1]

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

View solution

..... [1]

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

View solution

..... [1]

(e) to produce amino acids from proteins

View solution

..... [1]

(f) to separate a mixture of amino acids.

..... [1]

[Total: 6]

View solution

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.

View solution

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

[Total: 5]

3 Potassium reacts with chlorine to form potassium chloride, K*Cl*.

(a) Write a chemical equation for this reaction.

View solution

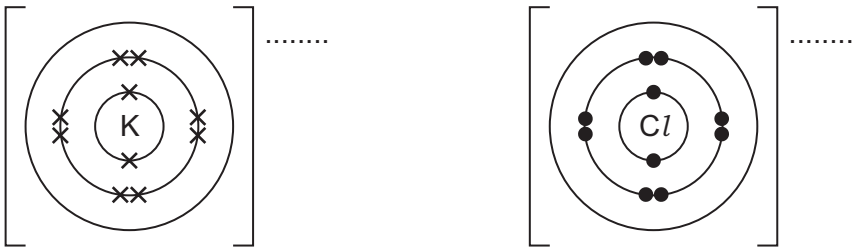
..... [2]

(b) Potassium chloride is an ionic compound.

View solution

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.

View solution

(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.

View solution

(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).

View solution

..... [1]

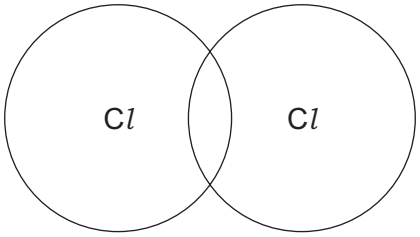
(iii) Name the potassium compound that remains in the solution after electrolysis.

View solution

..... [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.

View solution



[1]

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

View solution

	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.

View solution

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]

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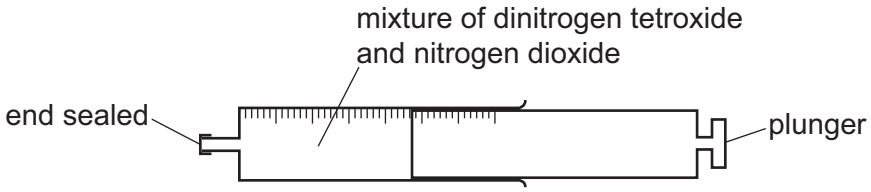
4 Dinitrogen tetroxide, N_2O_4, decomposes into nitrogen dioxide, NO_2. The reaction is reversible.

$$\underset{\text{colourless gas}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown gas}}{2NO_2(g)}$$

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*.

View solution

.....

.....

..... [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.

View solution

$$\underset{\text{colourless gas}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown gas}}{2NO_2(g)}$$

(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.

View solution

(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.

View solution

- 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, $Pb(NO_3)_2$, 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.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

(b) Nitrates decompose when heated.

View solution

(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.

$$2Zn(NO_3)_2 \bullet 6H_2O \rightarrow .....ZnO + ...NO_2 + O_2 + ...H_2O$$ [2]

View solution

(c) Some sulfates are hydrated.

View solution

When hydrated sodium sulfate crystals, $Na_2SO_4 \bullet \boldsymbol{x}H_2O$, are heated, they give off water.

$$Na_2SO_4 \bullet \boldsymbol{x}H_2O(s) \rightarrow Na_2SO_4(s) + \boldsymbol{x}H_2O(g)$$

A student carries out an experiment to determine the value of $\boldsymbol{x}$ in $Na_2SO_4 \bullet \boldsymbol{x}H_2O$.

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 $Na_2SO_4 \cdot \boldsymbol{x}H_2O$ is heated until all the water is given off. The mass of Na_2SO_4 remaining is 0.71 g.

View solution

[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***.

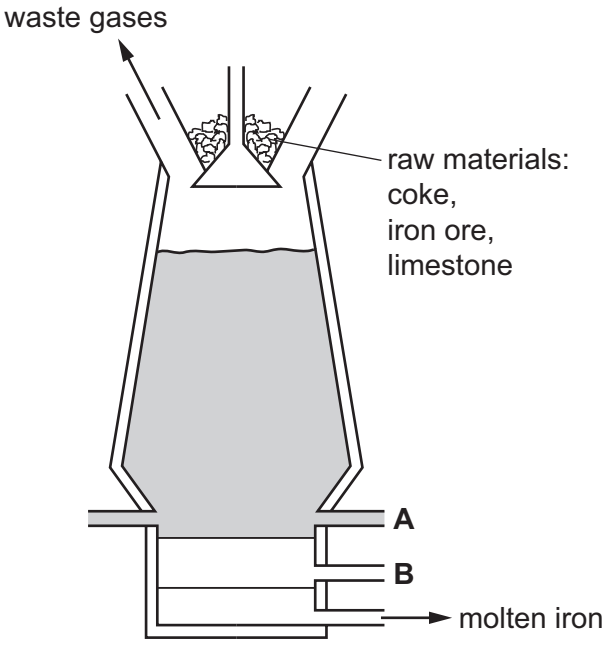
x = ...
[4]

[Total: 15]

6 This question is about iron.

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

View solution



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

..... [1]

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

View solution

..... [1]

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

View solution

..... [1]

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

View solution

1 .....

2 .....

[2]

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

View solution

Deduce the formula of the negative ion in FeS_2.

..... [1]

(c) Iron is a transition element.

View solution

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.

View solution

1 .....

2 .....

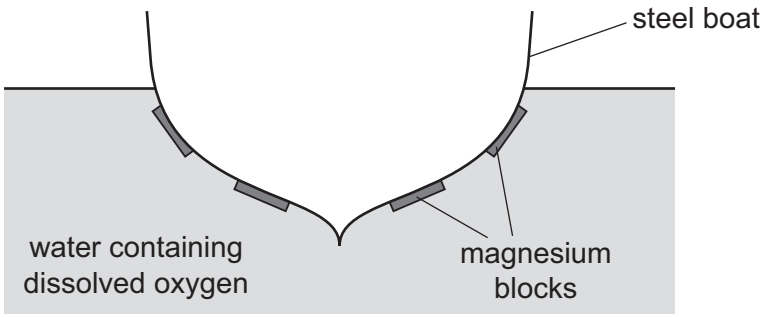
[2]

(d) Steel consists mainly of iron.

View solution

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]

View solution

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

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

View solution

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.

View solution

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

molecular formula = ... [1]

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

View solution

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

Compound **X** has the molecular formula $C_2H_4O_2$.

Compound **Y** has the molecular formula $C_4H_8O_2$.

(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.

View solution

$$CH_3CH=CH_2$$

(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.

View solution

Pentadecane, $C_{15}H_{32}$, is cracked to produce an alkane and propene in a 1 : 2 molar ratio.

Complete the chemical equation for this reaction.

$C_{15}H_{32} \rightarrow$ ..... + ... [2]

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

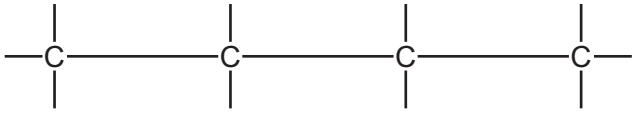
View solution

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).

View solution



[2]

[Total: 15]

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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 –		114 Fl flerovium –		116 Lv livermorium –		

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.).