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CHEMISTRY **0620/41**

Paper 4 Theory (Extended) **May/June 2022**

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 A list of substances is shown.

aluminium oxide	**carbon dioxide**	**chlorine**	**diamond**	**ethanol**
glucose	**iron(III) oxide**	**limestone**	**nitrogen**	**oxygen**

Answer the questions using the list of substances.

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

State which of the substances:

(a) is a reactant in photosynthesis

View solution

..... [1]

(b) is the main constituent of bauxite

View solution

..... [1]

(c) are **two** products of fermentation

View solution

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

(d) is used as a fuel

View solution

..... [1]

(e) is a gas used to convert iron into steel

View solution

..... [1]

(f) is a greenhouse gas

View solution

..... [1]

(g) is a gas that is approximately 78% of clean, dry air

View solution

..... [1]

(h) is a form of carbon.

View solution

..... [1]

[Total: 9]

2 **(a)** Atoms are made of protons, neutrons and electrons. Atoms of the same element are known as isotopes.

View solution

(i) Complete the table.

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

[2]

(ii) $^{24}_{12}Mg$ and $^{25}_{12}Mg$ are isotopes of magnesium.

Complete the table to show the numbers of electrons, neutrons and protons in these isotopes of magnesium.

View solution

isotope	number of electrons	number of neutrons	number of protons
$^{24}_{12}Mg$			
$^{25}_{12}Mg$			

[2]

(iii) Explain why magnesium ions have a charge of 2+.

View solution

.....

..... [1]

(b) Mg^{2+} ions have the electronic structure 2,8.

Give the formula of the following particles which have the same electronic structure as Mg^{2+} ions.

View solution

- a cation (positive ion)

.....

- an anion (negative ion)

.....

- an atom

.....

[3]

[Total: 8]

3 This question is about sodium and compounds of sodium.

(a) (i) Describe the bonding in a metallic element such as sodium.

View solution

You may include a diagram as part of your answer.

.....

.....

..... [3]

(ii) Describe how solid sodium conducts electricity.

View solution

..... [1]

(b) Some properties of sodium chloride are shown:

View solution

- melting point of 801 °C
- non-conductor of electricity when solid
- conductor of electricity when molten
- soluble in water.

(i) Name the type of bonding in sodium chloride.

..... [1]

(ii) Explain why sodium chloride conducts electricity when molten.

View solution

.....

..... [1]

(c) A student determines the concentration of a solution of dilute sulfuric acid, H_2SO_4, by titration with aqueous sodium hydroxide, NaOH.

View solution

step 1 25.0 cm^3 of 0.200 mol/dm^3 NaOH is transferred into a conical flask.

step 2 Three drops of methyl orange indicator are added to the conical flask.

step 3 A burette is filled with H_2SO_4.

step 4 The acid in the burette is added to the conical flask until the indicator changes colour. The volume of acid is recorded. This process is known as titration.

step 5 The titration is repeated several times until a suitable number of results is obtained.

(i) Name the piece of apparatus used to measure exactly 25.0 cm^3 of 0.200 mol/dm^3 NaOH in **step 1**.

..... [1]

(ii) State the colour change of the methyl orange indicator in **step 4**.

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

(iii) State how the student decides that a suitable number of results have been obtained.

.....

..... [1]

(iv) 20.0 cm^3 of H_2SO_4 reacts with 25.0 cm^3 of 0.200 mol/dm^3 NaOH.

The equation for the reaction is shown.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

Calculate the concentration of H_2SO_4 using the following steps.

- Calculate the number of moles in 25.0 cm^3 of 0.200 mol/dm^3 NaOH.

..... mol

- Determine the number of moles of H_2SO_4 that react with the NaOH.

..... mol

- Calculate the concentration of H_2SO_4.

..... mol/dm^3
[3]

[Total: 12]

4 This question is about compounds of sulfur.

(a) Sulfuric acid, H_2SO_4, is manufactured using the Contact process. This manufacture involves four stages.

View solution

stage 1 Molten sulfur burns in air to produce sulfur dioxide.

stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide.

stage 3 Sulfur trioxide combines with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

stage 4 Oleum reacts to form concentrated sulfuric acid.

(i) Write a chemical equation for the reaction occurring in **stage 1**.

..... [1]

(ii) State the essential conditions that are necessary for **stage 2**. Write an equation for the chemical reaction that occurs.

.....

.....

.....

..... [4]

(iii) Write a chemical equation for the reaction occurring in **stage 3**.

..... [1]

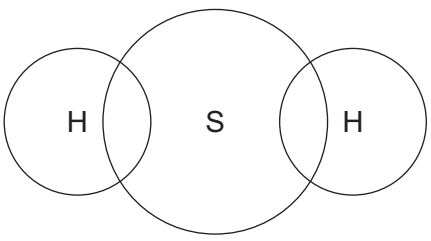
(iv) Name the substance that reacts with oleum in **stage 4**.

..... [1]

(b) Hydrogen sulfide has the formula H_2S.

(i) Complete the dot-and-cross diagram to show the electron arrangement in a molecule of hydrogen sulfide. Show outer shell electrons only.

View solution



[2]

(ii) Balance the chemical equation for the reaction of hydrogen sulfide with sulfur dioxide shown.

View solution

$$.....H_2S + SO_2 \rightarrow .....S + ...H_2O$$ [1]

[Total: 10]

5 Ethanoic acid is manufactured by the reaction of methanol with carbon monoxide.

An equilibrium mixture is produced.

$$CH_3OH(g) + CO(g) \rightleftharpoons CH_3COOH(g)$$

View solution

(a) State **two** characteristics of an equilibrium.

1 .....

2 .....

[2]

(b) The purpose of the industrial process is to produce a high yield of ethanoic acid at a high rate of reaction.

View solution

The manufacture is carried out at a temperature of 300 °C.

The forward reaction is exothermic.

Use this information to state why the manufacture is **not** carried out at temperatures:

- **below** 300 °C

.....

- **above** 300 °C.

.....

[2]

(c) Complete the table using only the words *increases*, *decreases* or *no change*.

View solution

	effect on the rate of the forward reaction	effect on the equilibrium yield of $CH_3COOH(g)$
adding a catalyst		no change
decreasing the pressure		

[3]

(d) Suggest which of the following metals is a suitable catalyst for the reaction. Give a reason for your answer.

View solution

aluminium **calcium** **cobalt** **magnesium** **potassium**

suitable catalyst .....

reason .....

[2]

(e) Ethanoic acid is a member of the homologous series of carboxylic acids.

State the general formula of this homologous series.

View solution

..... [1]

(f) Draw the structure of the carboxylic acid containing three carbon atoms. Show all of the atoms and all of the bonds.

View solution

[2]

(g) When carboxylic acids react with alcohols, esters are produced.

View solution

The formula of ester **X** is $CH_3CH_2CH_2COOCH_3$.

(i) Name ester **X**.

..... [1]

(ii) Give the name of the carboxylic acid and the alcohol that react together to produce ester **X**.

carboxylic acid .....

alcohol .....

[2]

(h) Ester **Y** has the following composition by mass:

View solution

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

Calculate the empirical formula of ester **Y**.

empirical formula = ... [3]

(i) Ester **Z** has the empirical formula C_2H_4O and a relative molecular mass of 88.

Determine the molecular formula of ester **Z**.

View solution

molecular formula = ... [1]

[Total: 19]

6 This question is about zinc and its compounds.

View solution

(a) Zinc is extracted from its ore which is mainly zinc sulfide, ZnS.

The steps for this extraction are shown.

step 1 Zinc sulfide is converted into zinc oxide.

step 2 The zinc oxide is then reduced to zinc in a furnace. The zinc formed becomes a gas.

step 3 The zinc gas is cooled to form molten zinc.

(i) Name the ore of zinc, which is mainly zinc sulfide.

..... [1]

(ii) Describe how zinc sulfide is converted into zinc oxide in **step 1**.

.....

..... [1]

(iii) Name the reducing agent used in **step 2**.

..... [1]

(iv) Explain why the zinc forms a gas in **step 2** inside the furnace.

..... [1]

(v) State the name of the physical change occurring when zinc gas is converted into molten zinc.

..... [1]

(b) Zinc sulfate crystals, $ZnSO_4 \cdot 7H_2O$, are hydrated.

Zinc sulfate crystals are made by reacting zinc carbonate with dilute sulfuric acid.

The equation for the overall process is shown.

$$ZnCO_3 + H_2SO_4 + 6H_2O \rightarrow ZnSO_4 \cdot 7H_2O + CO_2$$

step 1 Large pieces of solid zinc carbonate are added to dilute sulfuric acid until the zinc carbonate is in excess. This forms aqueous zinc sulfate.

step 2 The excess zinc carbonate is separated from the aqueous zinc sulfate.

step 3 The aqueous zinc sulfate is heated until a saturated solution is formed.

step 4 The saturated solution is allowed to cool and crystallise.

step 5 The crystals are removed and dried.

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(i) In **step 1**, zinc carbonate is in excess when no more zinc carbonate dissolves.

State one **other** observation that indicates the zinc carbonate is in excess in **step 1**.

View solution

..... [1]

(ii) Name a different substance, other than zinc carbonate, that can be added to dilute sulfuric acid to produce aqueous zinc sulfate in **step 1**.

..... [1]

(iii) **Step 1** is repeated using powdered zinc carbonate instead of large pieces.

All other conditions are kept the same.

The rate of reaction increases.

Give a reason why the rate of reaction increases. Explain your answer in terms of particles.

.....

.....

..... [2]

(iv) Suggest what is observed when the solution is saturated in **step 3**.

.....

.....

..... [1]

(v) The formula of zinc sulfate crystals is $ZnSO_4 \cdot 7H_2O$.

Give the formula of the solid formed if the crystals are heated to dryness in **step 3**.

..... [1]

[Total: 11]

7 The Periodic Table can be used to classify elements.

(a) Group I elements react with cold water to form alkaline solutions.

(i) Place the Group I elements caesium, lithium, potassium, rubidium and sodium in their order of reactivity with water.

View solution

Put the most reactive element first.

most reactive ⟶ least reactive

[1]

(ii) Name the alkaline solution formed when caesium reacts with cold water. View solution

..... [1]

(b) Group I elements have lower melting points than transition elements. View solution

Describe one **other** difference in the **physical** properties of Group I elements and transition elements.

..... [1]

(c) Group VII elements are known as the halogens. View solution

Astatine is below iodine in Group VII.

Predict the physical state of astatine at room temperature and pressure.

..... [1]

(d) Some Group VII elements react with aqueous solutions containing halide ions. View solution

When aqueous chlorine is added to aqueous potassium bromide a reaction occurs.

The ionic half-equations for the reaction are shown.

$$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$$

$$2Br^-(aq) \rightarrow Br_2(aq) + 2e^-$$

(i) Describe the colour change of the solution.

original colour of potassium bromide solution .....

final colour of reaction mixture .....

[2]

(ii) Identify the species that is oxidised.

View solution

Explain your decision.

species oxidised .....

explanation .....

[2]

(e) Bromine monochloride, BrC*l*, is made by the reaction between bromine and chlorine. The chemical equation is shown.

View solution

$$Br_2(g) + Cl_2(g) \rightarrow 2BrCl(g)$$

bond	bond energy in kJ / mol
Br–Br	190
C*l*–C*l*	242
Br–C*l*	218

Calculate the overall energy change for the reaction using bond energies.

Use the following steps.

- Calculate the total amount of energy required to break the bonds in 1 mole of $Br_2(g)$ and 1 mole of $Cl_2(g)$.

..... kJ

- Calculate the total amount of energy released when the bonds in 2 moles of BrC*l*(g) are formed.

..... kJ

- Calculate the overall energy change for the reaction.

..... kJ / mol

[3]

[Total: 11]

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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.).