CHEMISTRY 2 — 2015

(WASSCE JUNE) PAPER 2 — ESSAY

[100 marks]

Answer four questions in all: Question 1 in Section A and three questions from Section B. All questions carry equal marks. No marks will be awarded for answering questions not specified for your own Country. Credit will be given for clarity of expression and orderly presentation of material.

SECTION A

Answer all the questions in this section

1. (a) Define esterification. [2 marks]

(b) State two properties of plastic. [2 marks]

(c) Name the components of duralumin. [2 marks]

(d) What is meant by each of the following terms?

(i) Raw material.

(ii) Primary product. [4 marks]

(e) State *Charles' law*. [2 marks]

(f) List four pieces of protective equipment in the laboratory. [4 marks]

(g) Give two uses of ammonia. [2 marks]

(h) Name the: (i) process by which lighter hydrocarbons are obtained from heavier ones;

(ii) products formed from the reaction between ethanol and sodium metal. [3 marks]

(i) Determine the oxidation number of sulphur in H_2SO_4. [2 marks]

(j) Write the *IUPAC* name for each of the following compounds:

(i) $NaClO_3$.

(ii) $CuSO_4.5H_2O$. [2 marks]

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SECTION B

Answer any three questions in this section.

2. (a) Consider the following table:

Element	Atomic Number	Mass Number
J	9	19
Q	13	27
R	16	32
X	19	39
Y	24	52

(i) Which of the elements:

I. is a halogen?

II. is most likely to be attracted by a magnet?

III. belongs to group 1?

IV. would readily form an ion with a double negative charge?

(ii) What type of bond would exist between J and X when they combine?

(iii) How many neutrons are there in Q?

(iv) Write the formula of the compound formed when R combines with X.

(v) State the element which exists as diatomic molecule.

(vi) Select the element which belongs to the d-block of the periodic table. [9 marks]

(b) (i) Explain briefly the term *atomic orbital*.

(ii) I. State three postulates of Dalton's atomic theory.

II. List two limitations of this theory in the study of the atom.

(iii) Describe briefly the structure of sodium chloride in its solid state. [9 marks]

(c) A sample of carbon is burnt at a rate of 0.50 g per second for 30 minutes to generate heat.

(i) Write a balanced equation for the reaction.

(ii) Determine the:

I. volume of carbon (IV) oxide produced at s.t.p.

II. moles of oxygen used up in the process at s.t.p.

[C = 12.0, O = 16.0, Molar volume Vm = 22.4 dm^3] [7 marks]

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3. (a) (i) Give three characteristics of homologous series. [5 marks]

(ii) Name two groups of compounds which form such a series. [5 marks]

(b) A saturated organic compound A containing two carbon atoms reacted with ethanoic acid in the presence of a mineral acid to form a compound B with a sweet smell.

(i) Name the functional group present in A.

(ii) Draw the structure of A.

(iii) Write a chemical equation to show the formation of B.

(iv) Name the compound B. [5 marks]

(c) (i) Write a balanced equation for the reaction between ethyne and excess bromine.

(ii) Give *IUPAC* name of the product of the reaction in 2(c)(i).

(iii) State two conditions under which cracking takes place. [5 marks]

(d) (i) Outline the preparation of ethanol from starch.

(ii) Give two properties of starch.

(iii) Give a reason why starch does not reduce Fehling's solution.

(iv) Describe briefly a chemical test to confirm the presence of starch. [10 marks]

FOR CANDIDATES IN GHANA ONLY

4. (a) (i) Describe briefly how gold is extracted from its ore.

(ii) List the impurities in the ore.

(iii) Outline how the gold obtained in 4(a)(i) could be purified. [9 marks]

(b) (i) Define *Bronsted-Lowry base*.

(ii) Calculate the pH of 0.01 mol dm^{-3} sodium hydroxide solution. [5 marks]

(c) In the production of tetraoxosulphate (VI) acid, name:

(i) two sources of sulphur;

(ii) the catalyst used;

(iii) the product formed when SO_2 (g) is absorbed in concentrated H_2SO_4. [4 marks]

(d) If 3.08 g of Fe completely reacted with 50.0 cm^3 of 2.20 mol dm^{-3} HCl,

(i) write an equation for the reaction.

(ii) calculate the relative atomic mass of Fe. [7 marks]

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5. (a) (i) Carbon $^{14}_{6}C$ undergoes β-emission to form the nuclide M. Write an equation to illustrate the change.

(ii) $^{226}_{88}Ra$ successively loses three α-particles and further two β-particles.

I. Calculate the mass number and atomic number of the new nuclide N formed.

II. Write out the formula of N. [6 marks]

(b) Consider the following reaction equation:

$CaCO_3$ (s) + 2HCl (aq) → $CaCl_2$ (aq) + H_2O (l) + CO_2 (g)

List three ways by which the rate of reaction can be increased. [3 marks]

(c) (i) Explain briefly an equilibrium reaction.

(ii) Consider the reaction represented by the following equation:

$2NO\ (g) \rightleftharpoons N_2\ (g) + O_2\ (g),\ \Delta H = -90\ kJ\ mol^{-1}$

I. Write an expression for the equilibrium constant Kc.

II. Sketch an energy diagram for the forward reaction.

III. State with reason the effect of decrease in temperature on the equilibrium position of the system. [8 marks]

(d) Consider the following ionic reaction equation:

MnO_4^- (aq) + $C_2O_4^{2-}$ (aq) + H^+ (aq) → Mn^{2+} (aq) + H_2O (l) + CO_2 (g)

(i) Explain briefly why the reaction is described as redox.

(ii) Write the balanced:

I. half-cell equations for the reaction;

II. overall ionic equation. [8 marks]

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FOR CANDIDATES IN NIGERIA, SIERRA LEONE, THE GAMBIA AND LIBERIA

4. (a) Define an *electrochemical cell*. [2 marks]

(b) Aluminium can be prepared commercially by the application of electrolysis.

(i) Name the:

I. electrolyte used in the process;

II. ore from which the electrolyte is obtained;

III. electrodes used in the electrolysis.

(ii) Give two reasons why cryolite, $NaAlF_6$, is added to the electrolyte. [5 marks]

(c) (i) List the two gaseous fuels produced from coke.

(ii) Which of the two gases listed in 4(c)(i) is a better fuel?

(iii) Give a reason for your answer in 4(c)(ii).

(iv) Write a balanced equation for the production of each gaseous fuel. [9 marks]

(d) (i) For each of the following reactions, state what would be observed when:

I. chlorine gas is bubbled through aqueous sodium iodide;

II. chlorine gas is passed over heated iron in a hard glass tube;

III. aqueous silver trioxonitrate (V) is added to aqueous sodium bromide.

(ii) Write a balanced chemical equation for each of the reactions in 4(d)(i). [9 marks]

5. (a) (i) Name two gases that could be used to perform the fountain experiment.

(ii) State the physical property which makes the gases suitable for the experiment in 5(a)(i). [3 marks]

(b) (i) Define each of the following terms:

I. solubility;

II. saturated solution.

(ii) State two factors that affect the solubility of a solid in a liquid.

(iii) A salt Z of mass 10.2 g was dissolved in 15.4 cm^3 of distilled water at 40°C. Calculate the solubility of Z in $moldm^{-3}$ at 40°C. [Mr (Z) = 331] [11 marks]

(c) (i) Town water supplies that have passed through iron pipes contain P and Q ions. In the presence of air, P ions are slowly converted to Q ions.

I. Identify P and Q.

II. Write a balanced equation for the reaction between P ions, hydrogen ions and oxygen to give Q ions and water.

(ii) Explain briefly a test to confirm the purity of water.

(iii) State the effect of:

I. boiling a temporarily hard water;

II. adding sodium trioxocarbonate (IV) crystals to permanent hard water;

(iv) Write a balanced equation for the process in 5(c)(iii)II. [11 marks]

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CHEMISTRY 2 — 2016

WASSCE JUNE 2016 CHEMISTRY 2 THEORY QUESTIONS

SECTION A

1. (a) What are *nucleons*? (b) State *Graham's law of diffusion*. (c) Explain briefly why aluminium does not corrode easily. (d) State three examples of periodic properties. (e) State two reasons why real gases deviate from ideal gas behaviour. (f) List three uses of fractional distillation in industry. (g) What factors determine the selective discharge of ions at the electrodes during electrolysis? (h) State the type of reaction represented by each of the following equations: (i) $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2 + HBr$; (ii) $C_2H_4 + Br_2 \rightarrow CH_2Br_2$. (i) Name the products formed when butane burns in limited supply of air. (j) List three methods of separating a solid from a liquid.

SECTION B

2. (a) Consider the following atoms: $^{R}{}_{(t)}X$; $^{s}{}_{(t)}Y$. (i) State the phenomenon exhibited by the two atoms.
(ii) What is the difference between the atoms? (iii) Give two examples of elements that exhibit the phenomenon stated in 2(a)(i). (iv) If T is 17, write the electron configuration of the element (b)(i) State two differences between metals and non-metals with respect to their: I. physical properties; II. chemical properties.
(ii) Give one example of each of the following compounds: I. an amphoteric oxide; II. a hydride which evolves hydrogen when reacted with water; III. a trioxocarbonate (IV) salt which is readily decomposed on heating; IV. a chloride salt which is readily hydrolyzed in water. (c)(i) State three characteristic properties of transition metals. (ii) Write the electron configuration of $_{30}Zn$. (iii) Explain briefly why zinc is not considered as a typical transition element. (d) Consider the reaction represented by the following equation:
Na_2CO_3 (s) + $MgCl_2$ (aq) → 2NaCl (aq) + $MgCO_3$ (aq). Calculate the mass of sodium trioxocarbonate (IV) needed to produce 3.36 g of

magnesium trioxocarbonate (IV). [C = 12.0, O = 16.0, Na = 23.0, Mg = 24.0]

3. (a)(i) Define *structural isomerism*. (ii) State the class of alkanols to which each of the following compounds belongs: I. $CH_3C(CH_3)_3OH$; II. $CH_3CH(CH_3)CH_2OH$; III. $CH_3CH_2CH(CH_3)OH$.

(b)(i) Write the formulae of the products formed in the following reactions:

I. $CH_3CH_2COOH \xrightarrow{K_2(s)}$

II. $CH_3CH_2COOH \xrightarrow{C_2H_5OH,\ heat\ /\ Conc.\ H_2SO_4}$

III. $CH_3CH_2CH_2OH \xrightarrow{H^+/KMnO_4\ (excess)}$

(ii) Name the major product(s) of each of the reactions in 3(b)(i). (c) A gaseous hydrocarbon R of mass 7.0 g occupies a volume of 2.24 dm^3 at s.t.p. If the percentage composition by mass of hydrogen is 14.3, determine its: (i) empirical formula; (ii) molecular formula. [H = 1.00, C = 12.0, Molar volume of gas at s.t.p. = 22.4 dm^3]

(d) Draw the structures of the isomers of the alkene with molecular formula C_4H_8.

SECTION C

FOR CANDIDATES IN NIGERIA, SIERRA LEONE THE GAMBIA AND LIBERIA

4.(a)(i) Name a suitable drying agent for the preparation of carbon (IV) oxide in the laboratory.

(ii) Using one chemical test, distinguish between carbon (II) oxide and carbon (IV) oxide.

(b)(i) Describe briefly how oxygen and nitrogen could be obtained separately from air on an industrial scale.

(ii) State how a lighted splint can be used to distinguish between samples of oxygen and nitrogen.

(c)(i) Give one reason why bauxite is preferred as the ore for the extraction of aluminium.

(ii) List two main impurities usually present in bauxite.

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(iii) State the function of sodium hydroxide solution in the extraction of aluminium from its ore.

(iv) Explain briefly why it is difficult to extract aluminium by chemical reduction of aluminium oxide.

(v) Write an equation for the reaction of aluminium oxide with aqueous sodium hydroxide.

(d)(i) The melting and boiling points of sodium chloride are 801°C and 1413°C respectively. Explain briefly why sodium chloride does not conduct electricity at 25°C but does so between 801°C and 1413°C.

(ii) State the reason why sodium metal is stored under paraffin oil in the laboratory.

(e)(i) State what would be observed when aqueous sodium trioxocarbonate(IV) is added to a solution containing iron(III) ions.

(ii) Write a balanced equation for the reaction in 4(e)(i).

5.(a)

(i) State the oxidation number of sulphur in $Na_2S_2O_3$.

(ii) Name the allotropes of sulphur.

(iii) State two ways in which the structure of graphite and diamond are similar.

(b)(i) Name two greenhouse gases.

(ii) State one effect of an increased level of greenhouse gases on the environment.

(iii) State one source from which nitrogen(I) oxide is released into the environment.

(iv) Write a chemical equation to show the effect of heat on each of the following compounds:

I. $KNO_3(s)$

II. $AgNO_3(s)$

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(c)(i) Describe briefly how pure dry crystals of calcium chloride could be obtained from a solution of calcium chloride.

(ii) Explain briefly each of the following observations:

I. Ammonia gas is highly soluble in water.

II. The boiling point of chlorine is lower than that of iodine.

(d)Consider the reaction represented by the following equation:

$2NaCl(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2HCl(g)$

Calculate the volume of HCl gas that can be obtained at s.t.p. from 5.85 g of sodium chloride.

[Na = 23.0, Cl = 35.5, Molar volume of gas at s.t.p. = 22.4 dm^3]

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CHEMISTRY 2 — 2017

WASSCE JUNE 2017 CHEMISTRY 2 THEORY QUESTIONS

SECTION A

1. (a)(i) What is an *acid-base indicator?* (ii) Give one example of an acid-base indicator. (b) State the property exhibited by nitrogen(IV) oxide in each of the following equations: (i) $4Cu + 2NO_2 \rightarrow 4CuO + N_2$;

(ii) $H_2O + 2NO_2 \rightarrow HNO_3 + HNO_2$. (c)(i) Define *enthalpy of combustion*. (ii) State why the enthalpy of combustion is always negative. (d)(i) Distinguish between a *primary cell* and a *secondary cell*. (ii) Give an example of each of the cells stated in 1(d)(i). (e) Define the term *mole*. (f) Calculate the amount of hydrochloric acid in 40.0 cm^3 of 0.40 $moldm^{-3}$ dilute HCl. (g) Name two substances which can be used as electrodes during the electroylsis of acidified water. (h) List two forces of attraction that can exist between covalent molecules. (i) Name the products formed when butane undergoes incomplete combustion. (j) Write the electron configuration of $_{26}Fe^{3+}$.

SECTION B

2. (a)(i) I. State the *periodic law*. II. What is meant by the term *periodic property of elements*? (ii) List three properties of an element which show periodicity. (iii) Explain briefly how each of the properties listed in 2(a)(i) varies across the period. (b) Define *relative atomic mass*. (c)(i) What phenomenon is exhibited by an element ^{3z}Z which exist as $^{35}_{17}Z$ and $^{37}_{17}Z$? (ii) What accounts for the difference in the mass numbers of the element Z? (iii) Calculate the relative atomic mass of Z if the percentage abundance of $^{37}_{17}Z$ is 75%

(d)(i) State the method used for collecting each of the following gases:

I. CO_2; II. HCl; III. H_2

(ii) Give a reason for your answer stated in 2(d)(i) 1 and 2(d)(i) II.

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3. (a) Consider the following reaction equation: $C_{12}H_{26}$ —Al_2O_3, 350°C→ X + C_8H_{18}.

(i) What type of reaction is represented by the equation? (ii) Write the molecular formula of X. (iii) Draw the structure of two isomers of X. (iv) Name the isomers drawn in 3(a)(iii). (v) Write a balanced equation for the reaction between X and hydrogen. (b) Describe one test for fats. (c) Sulphur (IV) oxide is converted to tetraoxosulphate (VI) according to the following equation: $2SO_2$ (g) + O_2 (g) + $2H_2O$ (l) → $2H_2SO_4$ (aq). If 1.5 moles of oxygen reacts with sulphur (IV) oxide, calculate the mass of tetraoxosulphate (VI) acid produced. [H = 1.0; O = 16.0; S = 32.0]. (d) Consider the following neutralization reactions:

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$; ΔH_1,

$CH_3COOH + NH_4OH \rightarrow CH_3COONH_4 + H_2O$; ΔH_2,

$NaOH + HCl \rightarrow NaCl + H_2O$; ΔH_3,

(i) Arrange the enthalpy changes for the reactions in order of increasing magnitude.

(ii) Explain briefly your order in 3(d)(i).

(e) Consider the following substances: Cu (s), $BeCl_2$ (s), NaH (s), HF (l) and CCl_4 (l). State the substance(s) which:

(i) can conduct electricity; (ii) is/are soluble in water.

SECTION C

FOR CANDIDATES IN NIGERIA, SIERRA LEONE THE GAMBIA AND LIBERIA

4. (a)(i) Describe briefly the industrial preparation of ammonia. (ii) Write a balanced equation for the reaction in 4(a)(i). (iii) State one way of increasing the yield of ammonia in 4(a)(i). (iv) State two uses of ammonia.

(b) Describe briefly, one chemical test for each of the following gases in the laboratory: (i) hydrogen; (ii) carbon(IV) oxide; (iii) oxygen. (c)(i) State the composition of water gas. (ii) List two uses of water gas.

(d) Describe briefly a simple experiment to determine the type of hardness in a sample of water.

5(a)(i) Describe briefly how trioxonitrate (V) ions could be tested for in the laboratory. (ii) Write balanced equations for the following compounds: I. sodium chloride; II. sodium trioxocarbonate (IV). (b) State *Faraday's first law of electrolysis*.

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(ii) State two applications of electrolysis. (c) Concentrated tetraoxosulphate (VI) acid is added to sugar crystals in a beaker. State what would be observed. Explain briefly your answer. (d) Write an equation for the reaction of zinc powder with: (i) dilute tetraoxosulphate (VI) acid; (ii) concentrated tetraoxosulphate (VI) acid. (e) What property of concentrated tetraoxosulphate (VI) acid is shown in 5 (d)(ii)?

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CHEMISTRY 2 — 2018

WASSCE JUNE 2018 CHEMISTRY 2 THEORY QUESTIONS

SECTION A

1. (a)(i) Define the term *fermentation*. (ii) Name two factors that can be used for this process. (b) Name two factors which determine the choice of an indicator for an acid-base titration. (c) Consider the following reaction equation:

$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$. Calculate the mass of unreacted iron when 5.0 g of iron reacts with 10 cm^3 of 1.0 $moldm^{-3}$ H_2SO_4. [Fe = 56.0] (d) Name one:
(i) heavy chemical used in electrolytic cells; (ii) fine chemical used in textile industries. (e) Explain briefly how a catalyst increases the rate of a chemical reaction. (f)(i) Write the chemical formula for the product formed when ethanoic acid reacts with ammonia. (ii) Give the name of the product formed in 1(f)(i). (g) List three properties of aluminium that makes it suitable for the manufacture of drink cans. (h) State two industrial uses of alkylalkanoates. (i) Name two steps involved in the crystallization of a salt from its solution. (f) List two effects of global warming.

SECTION B

2. (a) State the collision theory of reaction rates. (ii) Using the collision theory, explain briefly how temperature can affect the rate of a chemical reaction. (b)(i) Sketch a graphical representation of Charles' law. (ii) Calculate the volume of oxygen that would be required for the complete combustion of 2.5 moles of ethanol at s.t.p. [molar volume at s.t.p. = 22.4 dm^3] (c)(i) Define esterification. (ii) Give two uses of alkanoates. (iii) Give the products of the alkaline hydrolysis of ethyl ethanoate. (d) A tin coated plate and a galvanized plate were exposed to the same length of time. (i) Which of the two plates corrodes faster? (ii) Explain briefly your answer in 2 (d)(i).

3. (a)(f) Draw the structure of the sixth member of the alkenes. (ii) Calculate the relative molecular mass of the

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sixth member of the alkene. (iii) State one difference between *cracking* and *reforming* in the petroleum industry. [H = 1, C = 12] .

(b)(i) Define the term *enthalpy of neutralization*. (ii) Describe briefly how the enthalpy of neutralization of the reaction of dilute hydrochloric acid and aqueous potassium hydroxide could be determined.

(c) An electrochemical cell is constructed with copper and silver electrodes. (i) State which of the electrodes will be: I. anode; II. cathode. (ii) Give the reason for your answer in 3(c)(i). (iii) State the type of reaction occurring at each electrode.

(iv) Write a balanced equation for the overall cell reaction. (d)(i) Name the compound formed when iron is exposed to moist air for a long time. (ii) Write a balanced chemical equation for the reaction in 3(d)(i). (iii) Name one ore of iron.

SECTION C

FOR CANDIDATES IN NIGERIA AND GAMBIA

4. (a)(i) Draw and label a diagram for the laboratory preparation of a dry sample of sulphur(IV)oxide.

(ii) Write a balanced chemical equation for the reaction in 4(a)(i). (iii) State the precaution that must be taken in the preparation of the gas stated in 4(a)(i). (iv) Give a reason why the precaution stated in 4(a)(ii) must be taken. (b)(i) State *Dalton's law of partial pressures*.

(ii) The volume of a sample of methane collected over water at a temperature of 12°C and a pressure of 700 mmHg was 30 cm^3. Calculate the volume of the dry gas at s.t.p. [Saturated vapour pressure of water at 12°C is 10 mmHg]

(c)(i) Write an equation for the reaction between chlorine and water.

(ii) Why does litmus paper turn red when put in the resulting solution in 4(c)(i)?

(d)(i) State the trend in the boiling points of chlorine, bromine and iodine. (ii) Explain briefly why bromine has a higher boiling point than ammonia.

5. (a)(i) State two industrial uses of hydrogen. (ii) Consider the equation below.

$Mg(HCO_3)_2$ (aq) —heat→ $MgCO_3$ (s) + H_2O (l) + CO_2 (g)

I. State the type of hardness of water being removed as shown by the above equation. II. Give two disadvantages of hardness of water.

(b)(i) In the extraction of aluminium by electrolysis, graphite

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electrodes are used. State the disadvantages of using this type of electrode. (ii) Calcuim oxide reacts with water to form slaked line: I. Write a balanced equation for this reaction; II. State one use of slaked line.

(c)(i) What is meant by *saponification*? (ii) List the raw materials needed for the manufacture of soap. (iii) Name the main by-product obtained from the manufacture of soap. (d) With the aid of chemical equations explain briefly how iron is extracted in the blast furnace using iron ore, coke and limestone as raw materials at the: (i) bottom of the furnace; (ii) middle of the furnace; (iii) top of the furnace.

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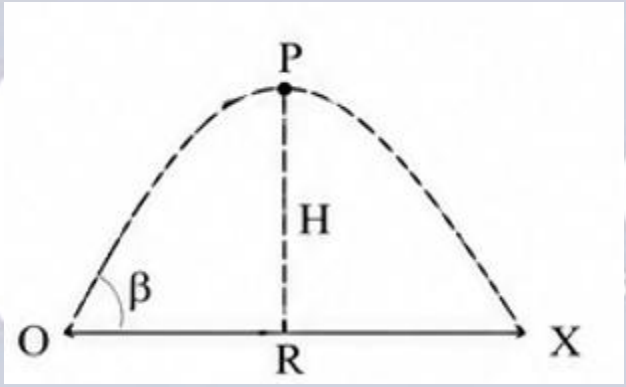
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WASSCE JUNE 2019 PHYSICS 2

THEORY QUESTIONS (PART I)

1. A stone of mass 20 g is released from a catapult whose rubber is stretched through 5 cm. If the force constant of the rubber is 200 N m^{-1}, calculate the speed with which the stone leaves the catapult.



2. (a) The diagram illustrates a projectile motion. Identify each of the physical quantities labelled P, β, H and R.

(b) Write an equation to show the relationship between P, β and R, where g is the acceleration due to gravity and R_max is maximum R.

3. State three observable phenomena in which waves behave like a particle.

4. List three magnetic elements that determine the earth's magnetic field at a point.

5. Explain each of the following terms as used in *Electronics*: (a) *free electrons*; (b) *holes*.

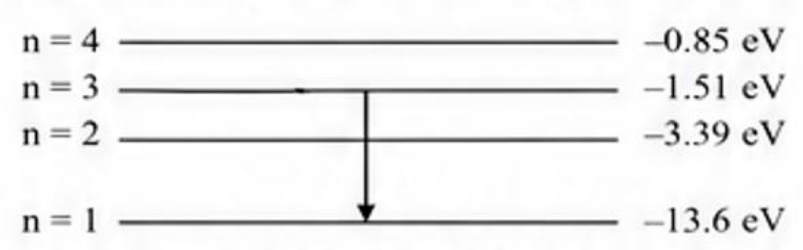
6. (a) State the principle of operation of fibre optics.
(b) State two applications of fibre optics in medicine.
(c) Define *diffusion*. (b) State two factors that affect the rate of diffusion.

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PART II

8. (a)(i) State *Newton's Law of Universal Gravitation*.

(ii) Define *gravitational field*.



(b)(i) Derive the equation relating the universal gravitational constant, G, and the acceleration of free fall, g, at the surface of the earth from Newton's Law of universal gravitation.

(ii) State two assumptions for which the relationship in 8(b)(i) holds.

(c) Calculate the force of attraction between a star of mass 2.00×10^{30} kg and the earth assuming the star is located 1.50×10^{8} au from the earth. [Mass of the earth = 5.98×10^{24} kg; G = 6.67×10^{-11} N m^2 kg^{-2}; au = 10 m^{-1}]

(d)(i) Define *escape velocity*.

(ii) State two differences between the *acceleration of free fall* (g) and the *universal gravitational constant* (G).

(g)(i) Explain *latent heat*.

(ii) State two factors that affect the rate of evaporation of a liquid.

(h) Explain each of the following observations:

(i) On a dry day, water in a clay pot is cooler than water in a closed plastic container.

(ii) Food gets cooked faster in a pressure cooker than in an ordinary cooking pot.

(j) State two effects of heat on a substance.

(d) A 40 V electric heater is used to supply a current of 12 A for 1400 s to a body of mass 1.5 kg at the melting point of the body. The body melts and its temperature rises through 60°C in an extra 72 s. Determine the: (i) latent heat of fusion of the body. (ii) specific heat capacity of the body.

10. (a)(i) Define *atomic spectra*.

(d) Differentiate between *emission spectra* and *absorption spectra*.

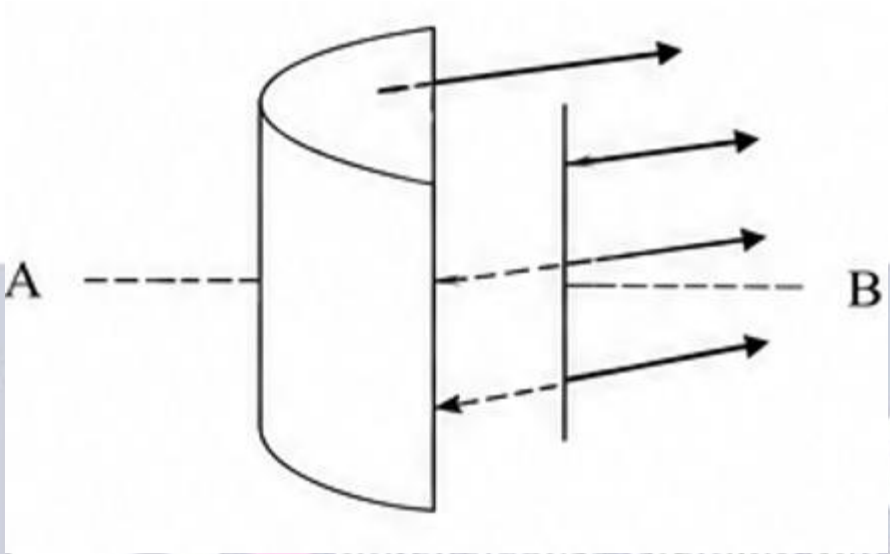
(b) The diagram below illustrates an electron transition from energy level n = 3 to n = 1.

The diagram below illustrates an electron transition from energy level n = 3 to n = 1. Calculate the: (i) energy of the photon; (ii)

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frequency of the photon; (iii) wavelength.

[h = 6.6 × 10^{-34} J s; c = 3.0 × 10^{8} m s^{-1}; 1 eV = 1.6 × 10^{-19} J].



11. (a)(i) Define force and state its S.I. unit.

(ii) List the two types of solid friction.

(b) A car travelling at a constant speed of 30 m s^{-1} for 20 s was suddenly decelerated when the driver sighted a pot-hole. It took the driver 6 s to get to the pot-hole with a reduced speed of 18 m s^{-1}. He maintained the steady speed for another 10 s to cross the pothole. The brakes were then applied and the car came to rest 5 s later.

(i) Draw the velocity time graph for the journey.

(ii) Calculate the deceleration during the last 5 s of the journey.

(iii) Calculate the total distance covered.

12. (a)

The diagram above illustrates the structure of a typical photoelectric cell. (i) Identify each of the parts labelled A and B. (ii) State one function each of A and B. (iii) Einstein's photoelectric equation can be written as E = hν − W_o. State what each of the terms E, hν and W_o represents.

(b) A photon is incident on a metal whose work function is 1.32 eV. An electron is emitted from the surface with maximum kinetic energy of 1.97 eV. Calculate the frequency of the photon.

[1 eV = 1.6 × 10^{-19} J]

(c) Define *half-life* of a radioactive element.

(ii) Sketch a graph of the relation N = N_oe^(−λt) and indicate the half-life.

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WAEC CHEMISTRY PAPER 2 (SC 2020)

ESSAY/THEORY PAST QUESTIONS

[100 marks]

Answer four questions in all: Question 1 in Section A and three questions from Section B. All questions carry equal marks.

No marks will be awarded for answering questions not specified in your own country. Credit will be given for clarity of expression and orderly presentation of material.

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SECTION A

Answer all the questions in this section

Question 1

(a)

(i) State Faraday's first law of electrolysis.

(ii) Distinguish between a *strong electrolyte* and a *weak electrolyte*.

[4 marks]

(b) State one chemical property of *ethyne*.

_____

[1 mark]

(c)

(i) What is meant by the term *unsaturated hydrocarbon*?

_____

_____

(ii) Complete the following reaction equation:

$CH_3COOH + CH_3OH \rightarrow$

_____

(iii) Name the major product formed in the reaction stated in 1(c)(ii).

_____

[4 marks]

_____

(d) State one way by which the rate of esterification could be increased.

_____

[1 mark]

(e) Consider the reaction represented by the following equation:

$Zn(s) + H_2SO_4(aq) \rightarrow ZnOS(aq) + H_2(g)$

If 3.75 g of Zn dust was added to excess H_2SO_4, calculate the number of molecules of hydrogen gas produced.

[Zn = 65.0; $N_a = 6.02 \times 10^{23}$]

_____

_____

_____

[3 marks]

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(f) State one effect of global warming.

_____

[1 mark]

(g) Consider the following reaction equations:

- A. $Pb(NO_3)_2 + H_2S \rightarrow PbS + 2HNO_3$
- B. $H_2 + C_2H_4 \rightarrow C_2H_6$
- C. $Zn(OH)_2 + 2OH^- \rightarrow [Zn(OH)_4]^{2-}$

(i) Which of the equations represent(s) a redox process?

_____

(ii) State the change in oxidation number of species that are oxidized or reduced.

_____

[3 marks]

(h)

(i) State two of the main concepts of Bohr's model of the atom.

_____

_____

(ii) State the limitation of Bohr's model.

_____

_____

[3 marks]

(i)

(i) List three factors that could influence the equilibrium position of a reversible reaction.

_____

_____

_____

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(a) Consider the following compounds:

[3 marks]

(j) Calcium trioxocarbonate(IV) powder is added to separate equimolar solutions of hydrochloric acid and ethanoic acid.

State one:

(i) similarity in the observation in both reactions;

_____

_____

(ii) difference in the observation in both reactions.

_____

[2 marks]

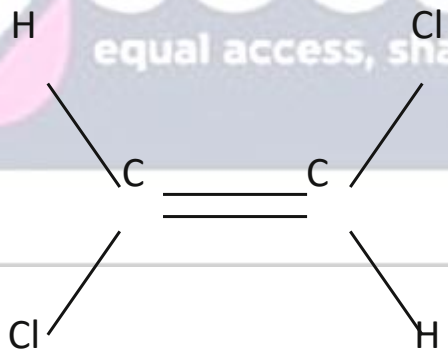
SECTION B

Answer three questions in this section — FOR ALL CANDIDATES

Question 2

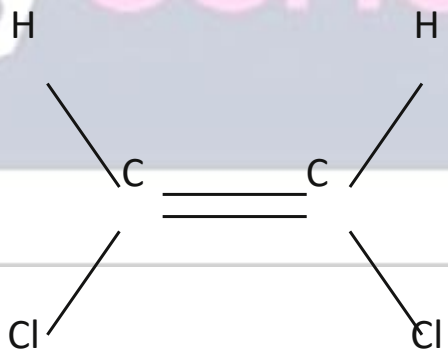
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A



cis-1,2-dichloroethene

B



trans-1,2-dichloroethene

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Compound A and Compound B — Geometric Isomers of 1,2-Dichloroethene

(i) What is the relationship between the compounds labelled A and B?

_____

_____

(ii) Name each of compounds A and B.

A _____

B _____

(iii) Will the chemical properties of compounds A and B be the same?

_____

(iv) Give the reason for the answer stated in 2(a)(iii).

_____

_____

[5 marks]

_____

(b)

(i) Give two characteristic features of boiling.

_____

_____

(ii) What would be the effect of each of the following conditions on the boiling point of water?

I. Addition of crystals of sodium chloride.

_____

_____

II. Reduction of the atmospheric pressure.

_____

_____

(iii) State one way in which *boiling* differs from *evaporation*.

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_____

_____

[5 marks]

(c)

(i) Differentiate between an *unsaturated solution* and a *saturated solution*.

_____

_____

(ii) State two ways by which a saturated solution could be made to dissolve more solute.

_____

_____

(iii) State one factor that could affect the solubility of a solid in a liquid.

_____

(iv) Define the term *mole*.

_____

_____

[5 marks]

(d)

(i) Name two substances responsible for hardness in water.

_____

_____

(ii) State two methods for the removal of hardness in water.

_____

_____

(iii) State two advantages of hard water.

_____

_____

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[6 marks]

Question 3

(a) In an equilibrium reaction between gases Q_2 and R_2 to form QR, the energy content of the reactants is 100 kJ and that of the product is 54 kJ. The energy content of the activated complex is 210 kJ.

(i) Draw an energy profile diagram for the reaction.

(Space for diagram)

(ii) Determine the:

I. activation energy of the reaction;

II. enthalpy change ΔH of the reaction.

(iii) Write a balanced equation for the reaction.

(iv) State whether the reaction is exothermic or endothermic.

(v) Give a reason for the answer given in 3(a)(iv).

[11 marks]

(b) Consider the following table:

Element	**E**	**F**	**G**	**H**
Atomic number	7	9	12	13

(i) Write the electron configuration for each of the elements.

E _____

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F _____

G _____

H _____

(ii) State:

I. two elements that are metals;

_____

_____

II. the element(s) most likely to form an ion with a charge of +3;

_____

III. the element(s) which belong(s) to Group (VII) on the periodic table;

_____

_____

IV. the formula of the compound formed between F and G.

_____

_____

[9 marks]

(c) Define the term *Isotopy*.

_____

_____

[2 marks]

(d) Name the three building blocks of matter.

_____

_____

[3 marks]

Question 4

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(a)

(i) Consider the following reaction equation:

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$

What mass of magnesium oxide is needed to neutralise 25.0 cm^3 of 0.1 mol dm^{-3} hydrochloric acid?

[O = 16.0; Mg = 24.0]

[7 marks]

(b) State three physical properties of metals.

[3 marks]

Question 4 (continued) — Blast Furnace

(b)

(i) Name the main raw materials used for the extraction of iron in the blast furnace.

(ii) Write the equations of the reactions taking place in the blast furnace.

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(iii) What is the name given to the iron obtained directly from the blast furnace?

_____

(iv) State why the iron named in 4(b)(iii) has a relatively low melting point.

_____

_____

_____

(c) The following equation represents one of the reaction steps involved in the contact process:

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $\Delta H = -395.7$ kJ mol^{-1}

(i) Why is the SO_3 produced during the reaction not dissolved directly in water to form H_2SO_4?

_____

_____

(ii) Why is H_2SO_4 regarded as a heavy chemical?

_____

_____

_____

Question 4 (continued) — Tetraoxosulphate(VI) Acid Properties

(iii) State the property exhibited by tetraoxosulphate(VI) acid in each of the following reaction equations.

I. $Pb(NO_3)_2(aq) + H_2SO_4(aq) \rightarrow PbSO_4(s) + 2HNO_3(aq)$

_____

_____

II. $H_2S(g) + H_2SO_4(aq) \rightarrow S(s) + 2H_2O(l) + SO_2(g)$

_____

_____

[5 marks]

_____

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(b) Write a balanced chemical equation for the reaction between *propanol* and *sodium*.

_____

_____

[2 marks]

Question 5

(a)

(i) Name two gases that can be used to perform the fountain experiment.

_____

(ii) What is the aim of the fountain experiment?

_____

_____

(iii) Describe briefly the fountain experiment.

_____

_____

_____

_____

[9 marks]

(b)

(i) Name two chemical industries.

_____

_____

(ii) State three effects of a chemical industry on the community in which it is sited.

_____

_____

_____

[5 marks]

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_____

(c)

(i) Name three products of the destructive distillation of coal.

_____

_____

_____

(ii) Give one use each of any two of the products named in 5(c)(i).

_____

_____

[5 marks]

_____

FOR CANDIDATES IN NIGERIA AND THE GAMBIA ONLY

Question 6 (Nigeria/Gambia)

(a)

(i) In the laboratory preparation of dry chlorine gas, state the:

I. reagents used;

_____

_____

II. drying agent used;

_____

_____

III. the mode of collection.

_____

_____

(ii) Write the equation for the preparation of chlorine gas.

_____

_____

(iii) Write an equation to show how chlorine reacts with hot concentrated NaOH.

[7 marks]

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WAEC CHEMISTRY 2021

PAPER 2 (ESSAY/THEORY)

[100 Marks] | Time Allowed: 2 Hours

INSTRUCTIONS:

*Answer **four questions in all**: Question 1 in Section A **and** three questions from Section B.*

All questions carry equal marks. No marks will be awarded for answering questions not specified for your own country. Credit will be given for clarity of expression and orderly presentation of material. ***(Answer ALL the questions in this section)***

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SECTION A

QUESTION 1

(a) Distinguish between **molecular formula** and **structural formula**.

(b) List **three factors** that determine the ionization energy of an atom.

(c) State the **two conditions** necessary for the establishment of a chemical equilibrium.

(d) Consider the following table:

Element	**A**	**B**	**C**
Ionization energy / kJ mol^{-1}	619	518	594

(i) State which of the elements is the **strongest reducing agent**.

(e) State **Graham's law of diffusion**.

[2 marks]

(f) Consider the following salts: **$Mg(NO_3)_2$, $CaCO_3$, Na_2SO_4.**

State which of the salts is/are:

(i) readily soluble in water;

(ii) insoluble in water.

[3 marks]

(g) Classify each of the following products as **addition polymer** or **condensation polymer**:

(i) Protein

(ii) Perspex

(iii) Nylon

(h) Define **atomic radius**.

(i) Explain briefly why **ethanol** has a higher boiling point than **propane** even though they both have comparable molar masses.

(j) State **three significances** of the **pH value** in everyday life.

[3 marks]

SECTION B

(Answer THREE questions from this section)

QUESTION 2

(a)(i) State **two characteristics** of a homologous series.

(a)(ii) Explain briefly why there are differences in the reaction of **ethane** and **ethene**.

[6 marks]

When crystals of **sodium chloride** were warmed with concentrated **tetraoxosulphate(VI) acid**, a gas evolved.

(i) Name the gas.

(ii) State **two physical properties** of the gas.

(iii) Write a **balanced chemical equation** for the reaction.

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QUESTION 3

(a) In an experiment, **25.0 cm^3 of H_2SO_4** completely neutralized **24.0 cm^3 of a 0.150 mol dm^{-3}** aqueous KOH using a suitable indicator.

(i) Write a **balanced chemical equation** for the reaction.

(b)(i) A burning magnesium ribbon was placed in a gas jar containing **carbon (IV) oxide**.
Write an equation for the reaction.

(b)(II) Explain briefly why the **magnesium ribbon burns** in carbon(IV) oxide although the gas **does not support combustion**.

(c) Define the term **electronegativity**.

[2 marks]

QUESTION 3 (continued)

(c)(i) Consider the organic compound: **$CH_3CH_2CH \equiv CHCOOH$**

State **two chemical reactions** which could be used to identify the compound.

(c)(ii) What would be **observed** in each of the reactions stated in 3(c)(i)?

(d) Describe briefly how **soap is manufactured** using pellets of sodium hydroxide and vegetable oil.

QUESTION 3(b) Mole Calculation (continued)

(b)(ii) Calculate the **percentage by mass of nitrogen** in magnesium trioxonitrate(V).
[N = 14.0, O = 16.0, Mg = 24.0]

QUESTION (c) — Hydrocarbons

(c)(i) What are **hydrocarbons**?

(c)(ii) State **two natural sources** of hydrocarbons.

(c)(iii) A hydrocarbons contain **83% of carbon by mass**. Calculate its **empirical formula**.
[H = 1.0, C = 12.0](d) Draw and label a diagram of a set-up that could be used to **electroplate a copper ornament with silver**. **[5 marks]**

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WAEC CHEMISTRY 2022

PAPER 2 (ESSAY/THEORY)

[100 Marks] | Time Allowed: 2 Hours

INSTRUCTIONS:

Answer four questions in all: Question 1 in Section A and three questions from Section B. All questions carry equal marks. No marks will be awarded for answering questions not specified in your own country. Credit will be given for clarity of expression and orderly presentation of material.

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SECTION A

(Answer ALL the questions in this section)

QUESTION 1

(a)(i) Define an acid according to the Lewis concept.

(a)(ii) Give one example of a Lewis acid.

[3 marks]

(b) Explain salting out in soap preparation.

[2 marks]

(c) State the reagent and condition necessary for the following conversion:

H−C≡C−H → Ag−Ca=C−Ag

[2 marks]

(d) What is the percentage abundance of an isotope?

[2 marks]

(e)(i) Why does the element with atomic number 18 not have an oxide?

(e) ii. Explain why chlorine(I) oxide has a low melting point.

[3 marks]

(f) Describe a test to distinguish between concentrated HNO_3 and concentrated H_2SO_4.

[3 marks]

(g) State two differences between an electrochemical cell and an electrolytic cell.

[2 marks]

(h) How does the trend in ionization energy affect the reactivity of Group 1 elements?

(i) Define the term molecular formula.

(j)(i) State which of the gases H_2 and NH_3 would deviate more from ideal behaviour.

(j)(ii) Give reasons for the answer stated in 1(j)(i).

[3 marks]

SECTION B

(Answer THREE questions from this section)

QUESTION 2

(a)(i) Define the first ionization energy of an element.

(a)(ii) Consider the following table:

Explain briefly why the first ionization energy of B is less than that of Be, despite the fact that the atomic number of B is greater than that of Be.

[8 marks]

(b) When titanium chloride was electrolysed by passing 0.12 A of current through the solution for 500 seconds, 0.015 g of titanium was deposited. What is the charge on the titanium ion?
[IF = 96500 C, Ti = 48.0]

[6 marks]

(c)(i) Aluminium can be obtained by the application of electrolysis. State the electrolyte which yields aluminium on electrolysis.

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(c)(ii) Name two major factors which would favour the siting of an aluminium smelter in a country.

[4 marks]

(d)(i) Define the term paramagnetism.

(d)(ii) Consider the following ions: $_{24}Cr^{2+}$ and $_{24}Cr^{6+}$

(I) Deduce the number of unpaired electrons in each of the ions.

(II) State which of the ions will have a greater power of paramagnetism.

(III) Give a reason for the answer stated in 2(d)(ii)(II).

[7 marks]

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QUESTION 3

(a)(i) Define the term Avogadro's number.

(a)(ii) If 2.30 g of an oxide of nitrogen, x, contains 3.01×10^{22} molecules, calculate the molar mass of x.

(a)(iii) Deduce the formula of x.

[$N_a = 6.02 \times 10^{23}$, N = 14.0, O = 16.0]

[8 marks] (based on visible mark indicator)

(b)(i) Describe briefly what happens when each of the following substances are added to water:

(I) CCl_4 (carbon tetrachloride)

(II) $SiCl_4$ (silicon tetrachloride)

(I) CCl_4 added to water:

Carbon tetrachloride is a non-polar covalent compound. When added to water (a polar solvent), it does not dissolve — it is immiscible with water and forms a separate layer (CCl_4 sinks below water as it is denser). No reaction occurs because the C–Cl bond is not readily hydrolysed under normal conditions; the carbon atom in CCl_4 has no available d-orbitals to accept attack from water molecules, and the molecule is sterically hindered.

(II) $SiCl_4$ added to water:

Silicon tetrachloride undergoes vigorous hydrolysis with water, producing white fumes. It reacts immediately and completely:

$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(g)$

A white solid (silicon dioxide, SiO_2) is formed, and steamy white fumes of hydrogen chloride (HCl) gas are produced. The solution becomes strongly acidic.

(b)(ii) Explain briefly why the reactions in 3(a)(i), (b)(i)(I) and 3(b)(ii)(II) are different.

[6 marks]

(c) Study the diagram below and answer the questions that follow.

(The diagram on page 248 shows an electrolytic cell/set-up with components labelled A, B, and what appears to be a power source/connect terminal.)

(c)(i) What is the set-up used for?

(c)(ii) Mention two compounds that could be used as electrolytes in the cell.

(c)(iii) Write a half-cell equation for the reaction at the anode.

(c)(iv) Calculate the electrochemical equivalent of copper if the cathode gained a mass of 3.2 g when 50 A of current was passed for 3 mins 13 seconds.

[Cu = 64, F = 96500 C]

[10 marks]

QUESTION 4

(a)(i) State two conditions used in the Haber process.

(a)(ii) Explain briefly the effect of increasing the pressure on the rate of reaction in the Haber process.

[5 marks]

(b)(i) A mixture of nitrogen(IV) oxide and oxygen is bubbled into warm water to produce trioxonitrate(V) acid. Write a balanced chemical equation for the reaction.

(b)(ii) Using a balanced chemical equation only, explain what would happen if nitrogen(IV) oxide is bubbled into warm water.

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(b)(iii) Compare the gases evolved when trioxonitrate(V) acid decomposes under each of the following properties:

(i) pH

(ii) Solubility in water

(iii) Reaction with carbon(II) oxide

[10 marks]

(c)(i) Name two oxides of sulphur.

(c)(ii) Write a balanced equation for the reaction between each of the named oxides in 4(c)(i) and water.

[6 marks]

(d) Name one calcium compound:

(i) Used to dry ammonia gas

(ii) Used in the manufacture of cement

(iii) That causes hardness in water

(iv) Name one calcium compound (general)

[4 marks]

QUESTION 5

(a) Describe the observation that would be made when:

(i) Sulphur is heated from room temperature till 119°C

(a)(ii) 50% trioxonitrate(V) acid acts on copper turnings.

[6 marks]

(b)(i) State two gaseous pollutants that can be generated by burning coal.

(b)(ii) What gas is responsible for most of the explosions in coal mines?

(b)(iii) The mining of coal leads to environmental pollution. State two environmental effects of the mining activity.

(b)(iv) Explain briefly why coal burns more easily when it is in pieces than in lump form.

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(b)(v) Name the non-volatile residue after the destructive distillation of coal.

[8 marks]

(c)(i) Describe a chemical test for water.

(c)(ii) State the effect of:

(I) Boiling a temporary hard water

(II) Adding sodium trioxocarbonate(IV) crystals to permanent hard water

(c)(iii) Write an equation for the process in 5(c)(ii)(I).

[6 marks]

(d) With the aid of a labelled diagram, describe briefly the laboratory preparation of oxygen gas.

[5 marks]

Method:

Oxygen is prepared in the laboratory by the catalytic decomposition of hydrogen peroxide (H_2O_2) using manganese(IV) oxide (MnO_2) as a catalyst.

Equation:

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$ (MnO_2 catalyst)

Procedure: Place manganese (IV) oxide powder in a conical flask fitted with a delivery tube. Add hydrogen peroxide solution through a thistle funnel/dropping funnel. Oxygen gas is produced and collected over water by downward displacement (as O_2 is only slightly soluble in water) or by upward displacement of air (as O_2 is denser than air).

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CHEMISTRY PAPER 2

(SC 2023) ESSAY

[100 marks] 2 hours

Answer four questions in all: question 1 in Section A and three questions from Section B. All questions carry equal marks. No marks will be awarded for answering questions not specified in your own country. Credit will be given for clarity of expression and orderly presentation of materials.

SECTION A

Answer all the questions in this section.

1.(a) What is a transition element? [2 marks]

(b) Consider the electron configuration of the following elements:

A = 2:8:6; B = 2:8:2; C = 2:8:1; D = 2:8:8

State the element which forms a:

(i) doubly charged cation;

(ii) soluble trioxocarbonate (IV). [2 marks]

(c) Explain briefly why there is a general increase in the first ionisation energies of the elements across the period in the periodic table. [2 marks]

(d) Give two examples of an aliphatic compound. [2 marks]

(e) Explain briefly why alkanols are stronger bases than water. [3 marks]

(f) State the major raw materials used in the Solvay process. [3 marks]

(g) What is geometric isomerism? [2 marks]

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(h) Give a reason why water gas is a better fuel than producer gas. [2 marks]

(i) Define the term heat of combustion. [2 marks]

(i) State Faraday's second law of electrolysis.

(ii) Calculate the amount of silver deposited when 10,920 coulombs of electricity is passed through a solution of a silver salt.

[1F = 96,500 C mol^{-1}] [5 marks]

SECTION B

Answer three questions only from this section.

2.(a) In an experiment, 20.0 cm^3 of a solution containing 4 g dm^{-3} of sodium hydroxide was neutralized by 8.0 cm^3 of dilute tetraoxosulphate (VI) acid.

(i) write a balanced equation for the reaction;

(ii) calculate the concentration of the acid in mol dm^{-3}. [2 marks]

(b)(i) State two postulates of the Kinetic theory of gases which real gases do not obey.

(ii) Explain briefly why real gases do not obey the postulates stated in 2(b)(i). [6 marks]

(c) Consider the following compound:

H–C(=O)–CH(OH)–CH(OH)–CH(OH)–CH(OH)–CH(OH)–H, with the OH/H groups alternating above and below the chain exactly as drawn in the original script.)

(i) name the compound;

(ii) name the two structural isomers of the compound;

(iii) state the chemical process involved in the preparation of the compound from starch;

(iv) write the chemical equation for the steps involved in the process in 2(c)(iii);

(v) name two enzymes involved in the process in 2(c)(iii). [10 marks]

(d) Explain briefly the term structural isomerism. [3 marks]

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3.(a) A compound contains 52.2% C, 13.1% H and Oxygen only. The vapour density of the compound is 23.

(i) Determine its empirical formula;

(ii) Determine its molecular formula;

(iii) The compound reacts with sodium metal to produce hydrogen gas, and when warmed with acidified $KMnO_4(aq)$, gives a solution which turns from purple to colourless. It also forms a sweet-smelling liquid when heated with ethanoic acid in the presence of concentrated H_2SO_4.

(I) name the functional group present in the compound;

(II) draw the structural formula of the compound.

[H = 1.0, C = 12.0, O = 16.0] [10 marks]

(b) Outline the chemical equations for the production of ethanol from cooked cassava. [6 marks]

(c)(i) Explain briefly why a piece of aluminium does not react with water.

(ii) How can a pure sample of aluminium chloride crystals be prepared from aluminium. [6 marks]

(d) Describe how water can be separated from aqueous $CuSO_4$. [3 marks]

4.(a) Starting with calcium chloride, describe briefly how a solid sample of calcium trioxocarbonate (IV) can be prepared in the laboratory. [5 marks]

(b) With relevant equations, outline the procedure for the purification of impure copper. [7 marks]

(c) Copper reacts with concentrated trioxonitrate (V) acid:

(i) write a balanced chemical equation for the reaction;

(ii) state what would be observed in the reaction;

(iii) state why the copper is oxidized;

(iv) an excess of copper is added to 25.0 cm^3 of 16.0 mol dm^{-3} HNO_3. Calculate the volume of the gas formed at s.t.p.

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[H = 1.0, N = 14.0, O = 16.0, Cu = 63.0; Molar volume of gas at s.t.p. = 22.4 dm^3] [9 marks]

(d)(i) Pure HNO_3 is a colourless liquid, but when exposed to air, it turns yellowish-brown in colour. Explain briefly this observation.

(ii) Write a balanced equation for the laboratory preparation of hydrogen trioxonitrate (V) acid. [4 marks]

5.(a) Describe how iron and aluminium reacts with each of the following substances:

(i) dilute H_2SO_4;

(ii) dilute HNO_3. [8 marks]

(b)(i) Write an equation for the burning of sulphur in air.

(ii) Name the catalyst used in the contact process.

(iii) In the contact process, why is an excess of air used?

(iv) Why is it necessary to cool the catalyst used in 5(b)(ii)?

(v) Give a reason why the air used in the contact process needs to be as clean as possible.

(vi) State two reasons why SO_2 should not be discharged into the atmosphere. [7 marks]

(c)(i) State the reagents and condition used in the laboratory preparation of chlorine.

(ii) State two uses of chlorine. [5 marks]

(d)(i) Name the drying agents for each of the following gases:

(I) hydrogen;

(II) sulphur (IV) oxide;

(III) ammonia.

(ii) State the components of the following alloys:

(I) Bronze;

(II) Brass. [5 marks]

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WAEC 2024

CHEMISTRY 2 (SC) — ESSAY

Answer four questions in all; question 1 in Section A and three questions from Section B. All questions carry equal marks. No marks will be awarded for answering questions not specified in your own country. Credit will be given for clarity of expression and orderly presentation of material.

SECTION A

Answer all the questions in this section.

1.(a) What is an electrochemical cell?
[2 marks]

(b) State three differences between an electrochemical cell and an electrolytic cell.

(c) Explain briefly what would be observed when powdered zinc is added to a solution of copper (II) tetraoxosulphate (VI) in a beaker.

(d) (i) Write an equation for the reaction in 1(c).
[2 marks]

(ii) State the type of reaction which took place in 1(c).
[1 mark]

(e) Name two gases which should be prepared in fume chamber.
[2 marks]

(f) Give the reason why noble gases are chemically inert.
[2 marks]

(h) State four properties of a homologous series.

(j) (i) State graham's law;

(ii) How is the melting point of a sample of a compound related to its purity?

(b) The combination of hydrogen and oxygen to produce water vapour is expressed by the following chemical equation:

$2H_{2(g)} + O2_{(g)} \rightleftharpoons 2H_2O_{(g)} \quad \Delta H = -xkj\ MOL^{-1}$

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Predict the effect of each of the following changes to the system on the direction of equilibrium and give a reason for the answer:

(i) H_2O is removed as it is being generated;

(ii) H_2 is added;

(iii) the system is cooled.

[6 marks]

(c) An aqueous lead (II) chloride solution contains 92.7g of compound.

(i) Calculate the mass of lead present in the solution.

(ii) What current in amperes would be necessary to remove all the lead from the solution in 4.8 hours using an electrolytic cell?

[Pb = 207.0, CL = 35.5, IF = 96500 C]

[8 marks]

(d) (i) Which of the reaction that takes place during the extraction of iron in the blast furnace can be considered as a neutralization reaction?

(ii) Give a reason for the answer given in 2(d)(i).

(iii) Write three other reaction that take place in the blast furnace.

(iv) State the function of $CaCO_3$ in the extraction of iron.

[6 marks]

2.(c) An aqueous lead (II) chloride solution contains 92.7g of compound.

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[6 marks]

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SECTION B

Answer three questions only from this section.

3. (a) If 50.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid reacted with excess zinc:

(i) Write a balanced chemical equation for the reaction;

(ii) Calculate the amount of $H^+_{(aq)}$ ions in the acid solution.

[6 marks]

(b) A solid tetraoxosulphate(VI) salt X when heated with a solution Y, produced a gas Z which turned red litmus paper blue:

(i) name Z;

(ii) suggest what X and Y could be giving one reason for the answer;

(iii) describe a test that could be performed to confirm Z.

[7 marks]

(c) (i) What is an isoelectronic series?

(ii) Consider the organic compound:

CH_3COOH, CH_3CH_2COOH, $CH_3CH_2CH_2COOH$, $CH_3(CH_2)_3COOH$

(i) State two reasons why they form a homologous series.

(ii) State the general name given to these compounds.

(iii) What is the percentage abundance of an isotope?

[7 marks]

(d) (i) Arrange the following compounds in order of increasing boiling point:

$CH_3CH_2CH_3$, CH_3CH_2COOH, $CH_3CH_2CH_2OH$

(ii) Explain briefly the answer given in 3(d)(i).

(iii) State the colour change that would be observed when SO_2 reacts with concentrated trioxonitrate (V) acid.

4. (a) (i) What is air?

(ii) Give the name of a compound found in pure dry air.

(iii) What is a noble gas?

(iv) State three characteristics of a noble gas.

[8 marks]

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(b) (i) Name two compounds that are used as drying agents for gases.

(ii) Write a chemical equation for the laboratory preparation of ammonia.

(iii) State the method of collecting the gas prepared in 4(b)(ii).

(iv) State a reason why there are differences in the method of collecting gases.
[6 marks]

(c) (i) The feedstock of the blast furnace are hematite, coke and limestone. What process does each feedstock undergo in the furnace?

(ii) Differentiate between cast iron and wrought iron;

(iii) Conversion of sulphur (IV) oxide to sulphur (VI) oxide is a reversible exothermic process. State the condition that would favor the reaction.
[6 marks]

(d) (i) Explain briefly why both diamond and graphite have high melting points.

(ii) carbon.

(ii) State two sources of methane in the atmosphere.

(iii) What would be observed when sulphur reacts with iron?

(d) (i) Define the term hardness of water.

(ii) Write balanced chemical equation for the preparation of hydrogen chloride using concentrated H_2SO_4.

(iii) Iron is manufactured in the blast furnace using iron ore, coke and limestone. Write the equations for the reaction at the middle of the furnace.
[8 marks]

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5. (a) Describe briefly how soap is manufactured using pellets of sodium hydroxide and vegetable oil.
[5 marks]

(b) (i) Outline the industrial preparation of oxygen from air.

(iii) State two gases that could be used to rekindle a glowing splint.

(c) State the function of each of the following substances in the treatment of water for town supply:

(i) calcium hydroxide

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MARKING SCHEME

WASSCE CHEMISTRY (THEORY) JUNE 2015

SECTION A (Compulsory)

Question 1

(a) Define esterification.

Esterification is the reaction between an alkanol and an organic (alkanoic) acid to produce an ester (alkanoate) and water in the presence of a mineral acid.

(b) State the properties of plastics.

1. They are good conductors of heat and electricity *(flagged — this is chemically incorrect; plastics are typically poor conductors/insulators — verify against source, may be a transcription error in the original script)*
2. Plastics can be recycled
3. They are durable
4. They can be fashioned to suit a particular purpose
5. Plastics are non-biodegradable
6. They are resistant to chemicals/corrosion
7. They can be remoulded

(c) State the components of Duralumin.

1. Aluminium 2. Manganese 3. Magnesium 4. Copper

(d) (i) What is a raw material?

A raw material refers to the starting material used in producing or manufacturing a product.

(ii) What are primary products?

Primary products are the main products of industries, or intermediate products that can still be converted to other usable products.

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(e) State Charles' Law.

Charles' Law states that the volume of a given mass of gas is directly proportional to its absolute temperature (temperature in Kelvin), provided the pressure is constant.

(f) List protective equipment used in the laboratory.

1. Safety boot 2. Nose mask/shield 3. Laboratory coat/apron 4. Safety goggle 5. Gloves 6. Fume cupboard 7. Gas mask/respirator 8. Fire extinguisher

(g) State the uses of ammonia.

1. Ammonia can be used as a refrigerant
2. It can be used to manufacture fertilizer
3. It is used for electing (extracting) aluminium *(likely OCR/transcription slip — check original; may read "electroplating")*
4. Ammonia acts as a solvent for removing grease and oil stains
5. It is used for softening hard water temporarily
6. It is used for treating insect bites
7. It can act as a precipitating agent for qualitative analysis
8. It is used to manufacture ammonium salts
9. Ammonia is used to manufacture trioxonitrate(V) acid

(h) (i) The process by which lighter hydrocarbons are obtained from heavier ones is **cracking**.

(ii) Products formed from the reaction between ethanol and sodium metal are **sodium ethoxide and hydrogen gas**.

(i) Calculate the oxidation number of sulphur in H_2SO_4.

H_2SO_4: $2(+1) + S + 4(-2) = 0 \rightarrow 2 + S - 8 = 0 \rightarrow S = 6$

Oxidation number of S = +6

(j) (i) IUPAC name for $NaClO_3$ = **Sodium trioxochlorate(V)**

(ii) IUPAC name for $CuSO_4 \cdot 5H_2O$ = **Copper (II) tetraoxosulphate(VI) pentahydrate**

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SECTION B (Answer any four)

Question 2

(a) Reference table:

Element	Atomic Number	Mass Number
J	9	19
Q	13	27
R	16	32
X	19	39
Y	24	52

(i) J is a **halogen**

(ii) Y is most likely to be attracted by a magnet

(iii) X belongs to Group I

(iv) R would readily form an ion with a double negative charge

(v) The type of bond between J and X when combined is **ionic (electrovalent) bond**

(vi) Q has **14 neutrons** (27 − 13)

(vii) Formula of compound formed when R combines with X is **X_2R**

(viii) The element that exists as a diatomic molecule is **J**

(ix) The element belonging to the d-block of the periodic table is **Y**

(b) (i) Define atomic orbital.

An atomic orbital is a region/space within a principal energy level where there is a high probability of finding an electron, or an area where the electron resides.

(ii) I. State the postulates of Dalton's Atomic Theory:

1. Matter is made up of small, indivisible particles called atoms
2. Atoms can neither be created nor destroyed
3. Atoms of a particular element are exactly alike in every way, but different from atoms of other elements
4. Chemical combination takes place between small whole numbers of atoms

II. State the limitations of Dalton's Atomic Theory:

1. Atoms are divisible, hence the presence/occurrence of protons, neutrons and electrons
2. Atoms can be created and destroyed in nuclear reactions

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3. The existence of isotopes

4. The existence of polymers in organic molecules

III. Describe the structure of sodium chloride in its solid state.

Sodium chloride is an ionic solid. The compound exists in a crystal lattice (face-centred cube) which comprises positive and negative ions.

(c) (i) Write the balanced equation for the burning of carbon in air.

$C(s) + O_2(g) \rightarrow CO_2(g)$

(ii) I. Calculate the volume of carbon(IV) oxide produced at s.t.p.

Mass of carbon burnt = 0.5 × 30 × 60 = 900 g

From the equation, 12g of carbon at s.t.p. produces 22.4 dm^3 of CO_2

∴ 900g of carbon will produce (900/12) × 22.4 = **1680 dm^3**

II. Calculate the moles of oxygen used up in the process at s.t.p.

1 mole of O_2 used = 1 mole of CO_2 produced

Recall 22.4 dm^3 of O_2 = 1 mole of O_2

1680 dm^3 of O_2 = (1680/22.4) × 1 = **75.0 mol**

(Alternatively: 900 ÷ 12 = 75 mol)

Question 3

(a) (i) State the characteristics of a homologous series:

1. All members have the same suffixes (e.g. -ane for alkanes, -yl for alkyl, -yne for alkynes)
2. All members can be represented by a simple general formula, e.g. C_nH_{2n+2} for alkanes
3. Each member of the series differs from the next by a constant (fixed number of atoms) — CH_2
4. Members of a homologous series have similar chemical properties
5. All members have the same functional group
6. All members of the group can be prepared using similar methods
7. All members of the series show a gradual change in physical properties like density and solubility

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(ii) State groups of compounds which form such a series:

Alkanes, Alkenes, Alkynes, Alkanols, Alkanoic acids, Alkanoates (esters)

(b) (i) The functional group present in compound A is **hydroxyl**.

(ii) Draw the structure of A.

(Structure: ethanol, CH_3CH_2OH, drawn with full displayed bonds — $H_3C–CH_2–OH$)

(iii) Write the chemical equation to show the formation of B.

$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$

(iv) Compound B is **ethyl ethanoate**.

(c) (i) Write the balanced equation for the reaction between ethyne and excess bromine.

$C_2H_2 + 2Br_2 \rightarrow C_2H_2Br_4$

(ii) IUPAC name of the product in (c)(i): **1,1,2,2-tetrabromoethane**

(iii) State the conditions under which cracking takes place:

1. High temperature 2. High pressure 3. Presence of a suitable catalyst

(d) (i) Outline the preparation of ethanol from starch:

1. Treatment of starch with malt (diastase)
2. Conversion of starch to maltose: $2(C_6H_{10}O_5)n + nH_2O \rightarrow nC_{12}H_{22}O_{11}$
3. Addition of yeast (enzyme)
4. Conversion of maltose to glucose by maltase: $C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$
5. Conversion of glucose to ethanol (and CO_2) by zymase: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

(ii) State the properties of starch:

1. Starch has no smell
2. It is insoluble in water
3. It has no taste
4. Starch can be hydrolysed
5. When a suspension of starch is warmed, it forms a colloidal solution

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(iii) Explain why starch does not reduce Fehling's solution:

It does not contain any free carbonyl group; it has no alkanol group, and no hydrogen is attached to the carbonyl group.

(iv) Describe the chemical test to confirm the presence of starch:

When a few drops of iodine solution are added to a boiled starch sample, a dark-blue (blue-black) colouration appears. This confirms the presence of starch in the food substance.

Question 4

(a) Define electrochemical cell.

An electrochemical cell refers to a device or cell which converts chemical energy to electrical energy. It is electricity generated by a chemical change.

(b) (i) State the electrolyte used [in the extraction of aluminium].

The electrolyte used is aluminium oxide (or molten alumina).

I. Bauxite II. Carbon electrodes/graphite electrodes

(ii) State the reasons for adding cryolite (Na_3AlF_6) to the electrolyte:

1. It acts as a solvent
2. It helps to reduce the melting point of alumina
3. It helps to increase the conductivity of the electrolyte

(c) (i) State the gaseous fuels produced from coke:

Water gas, Producer gas

(ii) Which is a better fuel? **Water gas**

(iii) State reasons supporting water gas as a better fuel:

Producer gas contains about 66.7% more non-combustible nitrogen and 33.3% less combustible carbon(II) oxide, while water gas contains equal amounts of combustible carbon(II) oxide and hydrogen.

(iv) Write balanced equations for the production of each gaseous fuel:

Producer gas: $2C(s) + O_2(g) + 4N_2(g) \rightarrow 2CO_2(g) + 4N_2(g)$

Water gas: $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$

(d) (i) State observations for the following:

I. When chlorine gas is bubbled through aqueous sodium iodide, a colourless solution which turns reddish-brown would be observed.

II. If chlorine gas is passed over heated iron in a hard glass tube, a

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grey/silvery solid which turns brown will be observed.

III. When aqueous silver trioxonitrate(V) is added to aqueous sodium bromide, a pale yellow or cream precipitate will be formed.

(ii) Write balanced chemical equations for the reactions above:

(i) $Cl_2 + 2NaI \rightarrow 2NaCl + I_2$

(ii) $2Fe + 3Cl_2 \rightarrow 2FeCl_3$

(iii) $AgNO_3 + NaBr \rightarrow NaNO_3 + AgBr$

Question 5

(a) (i) State gases that could be used to perform the fountain experiment:

Ammonia gas (NH_3), Hydrogen chloride gas (HCl)

(ii) State the physical property of NH_3 and HCl relevant to the fountain experiment:

The gases are very soluble in water.

(b) (i) I. Define solubility.

Solubility is the maximum amount of solute (in mol or grams) that will dissolve in 1dm³ of the solvent at that temperature. OR:

Solubility is the amount of solute that will saturate 1dm³ of the solvent at that temperature.

II. Define a saturated solution.

A saturated solution is a solution that contains as much solute as can dissolve at a particular temperature, in the presence of undissolved solute particles.

(ii) State factors that affect the solubility of a solid in a liquid:

1. Temperature 2. Nature of solute 3. Nature of the solvent

(c) A salt Z of mass 10.2g dissolved in 15.4cm³ of distilled water at 40°C. Calculate the solubility.

If 15.4cm³ of distilled water dissolves 10.2g of salt Z:

1000cm³ of water = (1000 × 10.2)/15.4 = 10,200/15.4 = 662.3377 g

Molar mass = 331 (implied)

Solubility in mol/dm³ = 662.3377/331 = **2.00 mol/dm³**

(i) I. P ions = Fe^{2+} (iron(II) ions)

Q ions = Fe^{3+} (iron(III) ions)

II. Write the balanced equation for the reaction between P ions, hydrogen and oxygen to give Q ions and water:

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$4Fe^{2+}(aq) + O_2(g) + 4H^+ \rightarrow 4Fe^{3+}(aq) + 2H_2O(l)$

OR: $Fe^{2+} + 4H^+ + O_2 + 3e^- \rightarrow Fe^{3+} + 2H_2O$

(ii) Describe the confirmatory test for the purity of water:

Heat some quantity of water in a beaker or pot until it boils. Measure the temperature of the boiling water with a thermometer. If the boiling point is 100°C and remains constant, then the water is pure.

(iii) I. State the effect of boiling temporarily hard water.

Boiling softens the temporary hard water and removes the hardness of the water.

II. State the effect of adding sodium trioxocarbonate(IV) crystals to permanent hard water.

It removes the hardness of the water.

(iv) Write the balanced equation for removing temporary hardness (as in (c)(iii)I above):

$Ca(HCO_3)_2(aq)$ --heat--> $CaCO_3(s) + CO_2(g) + H_2O(l)$

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WASSCE JUNE 2015 CHEMISTRY 3

PRACTICAL QUESTIONS

ALTERNATIVE A

All your burette readings (initial and final) as well as the size of your pipette must be recorded but no account of experimental procedure is required. All calculations must be done in your answer booklet.

A is 0.100 mol dm^{-3} HNO_3. B is a solution containing 2.50 g of a mixture of Na_2CO_3 and Na_2SO_4 in 250 cm^3 of solution.

(a) Put A into the burette and titrate it against 20.0 cm^3 or 25.0 cm^3 portions of B using methyl orange as indicator. Repeat the exercise to obtain consistent titre values. Tabulate your readings and calculate the average volume of acid A used. The equation of reaction is:

$Na_2CO_3(aq) + 2HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l) + CO_2(g)$

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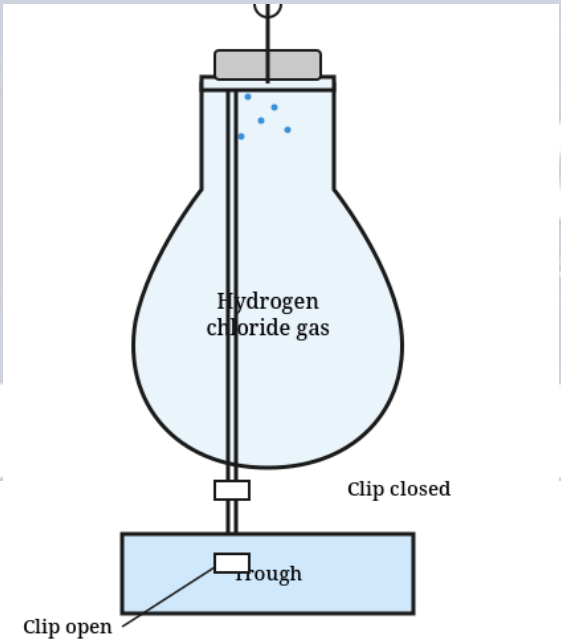
(b) From your results and the information provided, calculate the: (i) concentration of B in $moldm^{-3}$; (ii) concentration of Na_2CO_3 in B in gdm^{-3}; (iii) percentage of Na_2CO_3 in the mixture. [Na_2CO_3 = 106]

Credit will be given for strict adherence to the instructions, for observations precisely recorded and for accurate inferences. All tests, observations and inferences must be clearly entered in your answer book, in ink, at the time they are made. C and D are inorganic salts. E is a

solution of an organic compound. Carry out the following exercises on C, D and E. Record your observations and identify any gas(es) evolved. State the conclusion you draw from the result of each test.

(a) To all of C, add about 2 cm^3 of distilled water in a boiling tube. Shake to dissolve and test the solution with litmus paper.

(b)(i) Test E with litmus paper. (ii) Add all of E to the solution obtained in 2(a). (c)(i) Add about 5 cm^3 of distilled water to D in a test tube and shake. Divide the resulting solution into two portions. (ii) To the first portion, add few drops of $BaCl_2(aq)$ followed by excess dil. HCl. (iii) To the second portion, add $HNO_3(aq)$... then $NH_3(aq)$ in drops and then in excess.



(a) Consider the following diagram

(i) Give the name of the experiment. (ii) What does the experiment demonstrate? (iii) Name one gas that could be used in place of HCl gas. (iv) What colour could be observed in the flask during the spray of water? (v) Could the gases used in the experiment be collected over water? (vi) Explain briefly your answer in 3(a)(v).

(b) A solid substance U when strongly heated decomposes to give a white solid V and carbon (IV) oxide. When water is added to V, W is produced which can be used to test for carbon (IV) oxide. Identify U, V and W.

IMAGE: SOLUTION — Percentage of Na_2CO_3 in the mixture

Recall from given data that:

∴ 1000 cm^3 of B = 1000/250 × 2.50 = 2500/250 = 10.0 g

Now, % of Na_2CO_3 in Mixture = (4.738 × 100) / 10.0

(iii) Percentage of Na_2CO_3 in the mixture

250 cm^3 of B contained 2.50 g of Na_2CO_3

Hence, Mass Concentration of B = 10 g/dm^3

= 473.8 / 10 = 47.38%

Solution to WASSCE JUNE 2015

Chemistry 3 (ALT. A) Practical

(a) Burette Reading

	1st	2nd	3rd
Final Burette Reading (cm^3)	22.30	44.70	32.40
Initial Burette Reading (cm^3)	0.00	22.30	10.00
Volume of Acid Used (cm^3)	22.30	22.40	22.40

Average Titre = (22.30 + 22.40 + 22.40) / 3 = 67.10 / 3 = 22.3667

∴ Average Volume of Acid used = 22.37 cm^3

(b)(i) Concentration of B in mol/dm^3:

Using: $(C_a V_a)/(C_B V_B) = N_A/N_B$

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From the given equation, N_A = 2, N_B = 1

C_a = 0.100, V_a = 22.37, V_B = 25.0; Substituting:

0.100 × 22.37 / (C_B × 25.0) = 2/1

⇒ C_B = (0.100 × 22.37) / (2 × 25.0) = 2.237 / 50.0 = 0.04474

∴ C_B = 0.0447 mol/dm³

(ii) Concentration of Na_2CO_3 in B in g/dm³:

= 0.0447 × Molar Mass of B

= 0.0447 × 106

= 4.7382

∴ Conc. of Na_2CO_3 = 4.738 g/dm³

(vi) The gases (HCl or NH_3) are highly soluble in water.

(b) U = Calcium trioxocarbonate (IV) ($CaCO_3$)

V = Quicklime / Calcium oxide (CaO)

W = Lime water / Calcium hydroxide {$Ca(OH)_2$}

2. QUESTION 2

Test	Observation	Inference
(a) $C_{(s)}$ + H_2O + Litmus paper	Red litmus paper turned blue	Alkaline/Basic solution
(b)(i) $E_{(aq)}$ + litmus paper	Blue litmus paper turned red	Acidic solution
(ii) $E_{(aq)}$ + $C_{(s)}$	Effervescence occurred. Colourless and odourless gas which turned lime water milky evolved	CO_2 gas from HCO_3^- or CO_3^{2-}
(c)(i) $D_{(s)}$ + $H_2O_{(l)}$	D dissolved to give a colourless solution	D is a soluble salt
(ii) $D_{(aq)}$ + $BaCl_{2(aq)}$ + dil. $HCl_{(excess)}$	White precipitate formed. Precipitate insoluble in excess dil. HCl	SO_4^{2-} or CO_3^{2-} or SO_3^{2-} present

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(iii) $D_{(aq)}$ + $NH_{3(aq)}$ in drops; then in excess White gelatinous precipitate formed. Precipitate dissolved in excess NH_3 Zn^{2+} or Al^{3+} present, Zn^{2+} confirmed

(ii) To demonstrate high solubility of hydrogen chloride gas.

(iii) Ammonia can be used in place of HCl.

(iv) It would be colourless.

(v) The gas cannot be collected over water.

QUESTION 3

3(a)(i) The set up is Fountain experiment.

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WAEC/WASSCE JUNE 2016 CHEMISTRY

ESSAY/THEORY ANSWERS

SECTION A

1(a) Nucleons are protons and neutrons that are found in the nucleus of atoms. In other words, nucleons are nuclear particles which are made up of protons and neutrons.

(b) Graham's law of diffusion states that at constant temperature and pressure, the rate of diffusion of a gas is inversely proportional to the square root of its density or molar mass/vapour density.

(c)(i) Aluminium oxide layer forms on the surface of the metal.

(ii) The oxide layer forms a protective coating layer which does not flake off.

(d)

Set 1: (i) Atomic radius (ii) Ionic radius (iii) Ionisation energy

Set 2: (i) Redox potentials (ii) Electronegativity (iii) Electron affinity

Set 3: (i) Melting point (ii) Boiling point (iii) Electrical conductivity

(e) Real gases deviate from ideal gas behaviour because:

(i) Molecules of real gases have significant volume/forces of attraction between them.

(ii) The volume of the molecules of real gases is not negligible.

(iii) Collisions between the molecules are not perfectly elastic.

(f) Uses of fractional distillation in Industry:

(i) To separate crude oil into its components

(ii) To purify ethanol

(iii) To separate liquefied air.

(g) Factors determining selective discharge of ions at the electrodes during electrolysis are:

(i) Position of the ions in the electrochemical series.

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(ii) Concentration of the ions in the electrolyte.

(iii) Nature of the electrodes used.

h. (i) Substitution reaction (ii) Addition reaction

(i) *Carbon or soot *Carbon (II) oxide *Water

J. Methods of separating a solid from a liquid are:

(i) Filtration (ii) Crystallisation (iii) Evaporation (iv) Decantation (v) Centrifugation

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Page 3 — SECTION B

2(a)(i) The phenomenon exhibited is Isotopy.

(ii) They have different mass numbers or number of neutrons.

(iii) Isotopy can be exhibited by: Hydrogen · Chlorine · Carbon · Oxygen

(iv) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

(b)(i)(I) Differences in physical properties of Metals & Non-metals:

Metals	**Non-Metals**
They are good conductors of heat and electricity.	They are poor conductors of heat and electricity.
They are malleable.	They are brittle.
They are ductile.	They are not ductile (brittle).
They possess metallic lustre.	They don't possess metallic lustre.
They are sonorous.	They are not sonorous.
They are solid at room temperature, except mercury.	They can be solids, liquids or gases at room temperature.
They have high melting point.	They have low melting point.

(II) Differences in chemical properties:

Metals	**Non-Metals**

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They are good reducing agents.	They are good oxidizing agents.

Metals	**Non-Metals**
They lose their valence electrons easily.	They gain or share valence electrons easily.
They ionize by losing electrons.	They ionize by gaining electrons.
They form oxides that are basic or amphoteric.	They form oxides that are acidic or neutral.
They have low ionization energy.	They have high ionization energy.
Some react with dilute acids to give off hydrogen.	They do not react with dilute acids to give off hydrogen.
They have lower electronegativities.	They have higher electronegativities.

(ii)

(I) BeO; Al_2O_3; ZnO; SnO_2; PbO; PbO_2

(II) LiH; NaH; KH; CaH_2; MgH_2

(III) LiCl; $BeCl_2$; $MgCl_2$; $CaCl_2$; $ZnCl_2$; $PbCl_2$ *(this row's formulae are hard to fully verify from the photo's cramped handwriting — worth a direct check against the original)*

(IV) $AlCl_3$; $MgCl_2$; PCl_3; $SiCl_4$; NH_4Cl

c(i) Properties of Transition Metals:

- They form coloured compounds or ions.
- They exhibit variable oxidation states.
- They form complex compounds or ions.
- They have magnetic properties (paramagnetism).
- They have catalytic properties.

(ii) $_{30}Zn = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$

implying that the shells are filled.

d. Molar Mass of Na_2CO_3 = (23×2)+(12×1)+(16×3) = 46+12+48 = **106**

Molar Mass of $MgCO_3$ = (24×1)+(12×1)+(16×3) = 24+12+48 = **84**

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Moles of $MgCO_3$ = 3.36/84 = **0.04**

Moles of Na_2CO_3 = Moles of $MgCO_3$ = **0.04**

Hence, Mass of Na_2CO_3 = 0.04 × 106 = **4.24 g**

Alternative Method:

$MgCO_3$ = 84g, Na_2CO_3 = 106g

If 84g of $MgCO_3$ produces 106g of Na_2CO_3

∴ 3.36g of $MgCO_3$ will produce (3.36/84) × 106 = **4.24 g**

3(a)(i) Structural isomerism is the existence of compounds with the same molecular formula but different structural formulae.

(ii)

I — Tertiary alcohol/alkanol

II — Primary alcohol/alkanol

III — Secondary alcohol/alkanol

(ii) Major products formed:

I — Potassium propanoate

II — Butyl propanoate

III — Butanoic acid

C(i) % Carbon by mass = 100 − 14.3 = **85.7%**

Ratio of atoms:

C: 85.7/12.0 = 7.1425

H: 14.3/1.0 = 14.3

7.1425/7.1425 : 14.3/7.1425 = **1 : 2**

Empirical formula = CH_2

(ii) 2.24 dm^3 = 7.0 g of R

⟹ 22.4/2.24 = X/7.0

X = (22.4/2.24) × 7.0 = **70 g mol^{-1}**

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(b)(i)

I — CH_3CH_2COOK, H_2

II — $CH_3CH_2COOC_4H_9$, H_2O

III — $CH_3CH_2CH_2COOH$

ALTERNATIVE METHOD

Recall: Molar volume of a gas = 22.4 dm^3 @ STP

⟹ 22.4 dm^3 = 1 mole

Alternatively, we use:

2.24 dm^3 = (2.24/22.4) × 1 = **0.1 mole**

But No. of Moles = 7.00/0.1 = **70 g/mol**

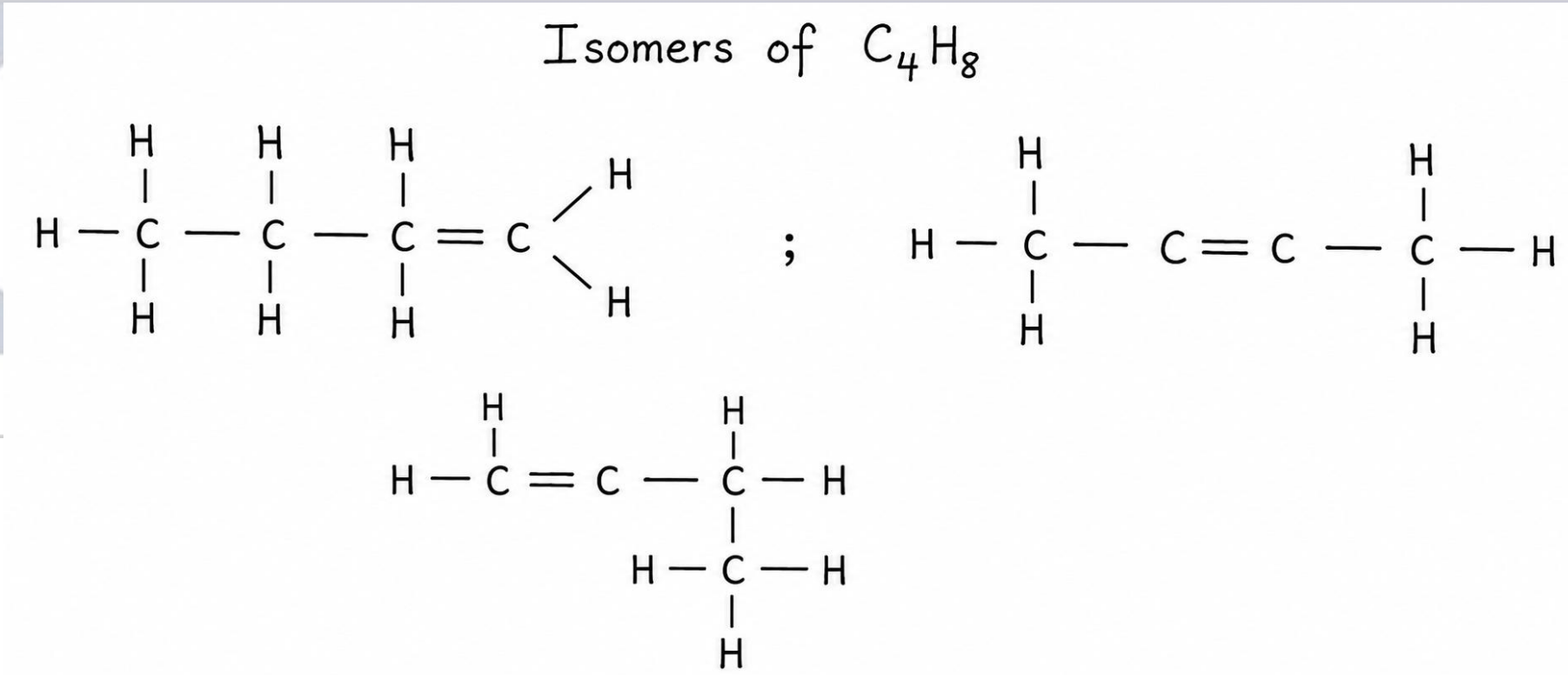
Hence, Molar formula of C_5H_{10}:

$\Longrightarrow (CH_2)n = 70$

$\Longrightarrow 14n = 70$

$\therefore$ **n = 70/14 = 5**

d. Isomers of C_4H_8:



d(i) The ions are not free at 25°C because Sodium Chloride is in the solid state, but between 801°C and 1413°C, the ions are mobile since they are now in the molten/liquid state.

C(i) Brown precipitate/reddish brown/orange solid formed.

(ii) $3Na_2CO_3 + 2Fe^{3+} \rightarrow Fe_2(CO_3)_3 + 6Na^+$

5(a)(i) Let the oxidation number of sulphur be x

$\Longrightarrow Na_2S_2O_3$

$2(1) + 2x + 3(-2) = 0$

$2 + 2x - 6 = 0$

$2x = 6 - 2$

$2x = 4$

$\therefore$ **x = +2**

(ii) Allotropes of sulphur are thus:

- Rhombic (alpha sulphur)
- Monoclinic (Beta sulphur)/Prismatic sulphur
- Amorphous (Delta sulphur)
- Plastic (Gamma sulphur)

(ii) Sodium metal is very reactive with air and so tarnishes easily.

(iii) Macromolecule/Giant molecule

- Carbon atoms are covalently bonded.
- They are crystalline in nature.

(i) Greenhouse gases:

- Carbon (IV) oxide
- Methane
- Nitrogen (I) oxide
- Water vapour
- Ozone
- Chlorofluorocarbons (CFCs)

(ii) Global Warming/climate change.

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(iii) Ammonium trioxonitrate(V)/aerosol; Combustion of fuel at high temperature.

(iv)

$2KNO_3 \rightarrow 2KNO_2 + O_2$

$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$

C(i)

- Heat the solution to concentrate it or leave in a warm place.
- Partially evaporate solution and allow to cool.
- Filter off crystals.
- Pick out crystals.
- Dry crystals with filter paper.

C(ii)

I. Ammonia is readily associated with water molecules through hydrogen bonding.

II. Chlorine molecules are smaller or have fewer number of electrons compared to iodine, **OR:** Iodine molecules are heavier and the van der Waal forces between molecules are stronger than that of chlorine.

(d) Molecular Mass of NaCl = 23.0 + 35.5 = **58.5 g/mol**

Amount of NaCl in 5.85g = 5.85/58.5 = **0.1**

Now if 1 mol of NaCl = 22.4 dm^3 of HCl

$\Longrightarrow$ 0.1 mol = 0.1 × 22.4 = **2.24 dm^3**

Alternative Method:

Molar Mass of NaCl = 23.0 + 35.5 = 58.5 g/mol

Now if 58.5g of NaCl = 22.4 dm^3 HCl

$\therefore$ 5.85g = (5.85/58.5) × 22.4 = **2.24 dm^3**

SECTION C

4(a)(i)

- Concentrated tetraoxosulphate(VI) acid

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- Fused Calcium Chloride

(ii) Pass each gas into lime water:

- If lime water turns milky, then CO_2 is present.
- If no reaction occurs, then CO is present.

(b)(i) Atmospheric air is compressed and cooled to liquefy it. The liquefied air undergoes fractional distillation — nitrogen boils out first at −196°C, followed by oxygen at −183°C.

(ii)

- Splint burns brighter in oxygen.
- Splint is extinguished in nitrogen.

C(i) Bauxite is more abundant than any other ore. Bauxite has less percentage of silicates as impurity.

(ii) Iron(III) oxide; Trioxosilicate(IV)/Silica/Sand

(iii) To dissolve the aluminium oxide, so that the impurities can be filtered off.

(iv) Aluminium is too reactive to be reduced by the common reducing agent(s) used in extraction.

(v)

$Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$

OR

$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$

(i) The ions are not free at 25°C because Sodium Chloride is in the solid state, but between 801°C and 1413°C, the ions are mobile since they are now in the molten (liquid) state.

(ii) Sodium metal is very reactive with air and so tarnishes easily.

(i) Brown precipitate / reddish-brown/orange solid formed.

(ii) $3Na_2CO_3 + 2Fe^{3+} \rightarrow Fe_2(CO_3)_3 + 6Na^+$

(a)(i) Let the oxidation number of sulphur be *x*

$\rightarrow Na_2S_2O_3$

$= 2(+1) + 2x + 3(-2) = 0$

$2 + 2x - 6 = 0$

$2x = 6 - 2$

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2x = 4

∴ x = +2

(ii) Allotropes of sulphur are thus:

- Rhombic (alpha sulphur)
- Monoclinic (Beta sulphur) / Prismatic sulphur
- Amorphous (Delta sulphur)
- Plastic (Gamma sulphur)

(iii) Macromolecule / Giant molecule

- Carbon atoms are covalently bonded
- They are crystalline in nature

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(i) Greenhouse gases:

- Carbon (IV) oxide
- Methane
- Nitrogen (I) oxide
- Water vapour
- Ozone
- Chlorofluorocarbons (CFCs)

(ii) Global Warming / climate change.

(iii) Ammonium trioxonitrate(V) / aerosol

- Combustion of fuel at high temperature.

(iv)

$2KNO_3 \rightarrow 2KNO_2 + O_2$

$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$

C(i) How to obtain crystals from a solution:

- Heat the solution to concentrate it, or leave in a warm place.
- Partially evaporate the solution and allow it to cool.
- Filter off the crystals.
- Pick out the crystals.
- Dry the crystals with filter paper.

C(ii)

I. Ammonia readily associates with water molecules through hydrogen bonding.

II. Chlorine molecules are smaller, or have a fewer number of electrons, compared to iodine.

OR: Iodine molecules are bigger, and the Van der Waal forces between molecules are stronger than that of chlorine.

Molecular Mass of NaCl = 23.0 + 35.5 = 58.5 g/mol

∴ Mass of NaCl = 58.5 g/mol

Amount of NaCl in 5.85 g = 5.85 / 58.5 = 0.1 mol

Now, if 1 mol of NaCl → 22.4 dm^3 of HCl

→ 0.1 mol = 0.1 × 22.4 = **2.24 dm^3**

Alternative Method:

Molar Mass of NaCl = 23.0 + 35.5 = 58.5 g/mol

Now, if 58.5 g of NaCl → 22.4 dm^3 HCl

∴ 5.85 g = (5.85 × 22.4) / 58.5 = **2.24 dm^3**

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2016 PRACTICAL CHEMISTRY

WASSCE JUNE 2016 – CHEMISTRY 3 PRACTICAL (ALTERNATIVE A)

All burette readings (initial and final) and the pipette size must be recorded. All calculations must be done in your answer booklet.

1A is 0.050 mol/dm³ $H_2C_2O_4$ (ethanedioic acid).

B is **$KMnO_4$ (potassium tetraoxomanganate(VII))** of unknown concentration.

(a) Put B into the burette. Pipette **20.0 cm³ or 25.0 cm³** of A into a conical flask and add about **10.0 cm³** of dilute H_2SO_4.

Heat the mixture to about **40°C – 50°C** and titrate while still hot with B. Repeat to obtain consistent titre values.

Tabulate your results and calculate the average volume of B used.

The equation of reaction is:

$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$

(b) From your results and the information provided, calculate the:

(i) Concentration of MnO_4^- in B in **mol/dm³**

(ii) Concentration of $KMnO_4$ in B in **g/dm³**

(iii) Volume of CO_2 evolved at **s.t.p.** when **25.0 cm³** of $H_2C_2O_4$ reacted completely.

[O = 16.0, K = 39.0, Mn = 55.0; Molar volume of gas at s.t.p. = 22.4 dm³ mol⁻¹]

2

C is a mixture of two salts, containing **one cation and two anions**.

Carry out the following exercises on C.

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Record your observations and identify any gas(es) evolved. State the conclusion you draw from the result of each test.

Credit will be given for strict adherence to instructions. All tests, observations and inferences must be clearly entered.

(a) Put all of C in a beaker and add about **10 cm^3** of distilled water. Stir well and filter. Keep the filtrate and the residue.

(b) To about **2 cm^3** of the filtrate, add a few drops of **$AgNO_3$** followed by **HNO_3**. Add excess **NH_3** to the resulting mixture.

(c)

(i) Put all of the residue into a clean test tube and add about **5 cm^3** of **HNO_3**.

(ii) To about **2 cm^3** of the solution from **2(c)(i)**, add **NaOH** in drops and then in excess.

(iii) To another **2 cm^3** of the solution from **2(c)(i)**, add **NH_3** in drops and then in excess.

3

(a) What differences in physical properties enable the separation of mixtures by:

(i) Simple distillation

(ii) Paper chromatography

(iii) Fractional distillation

(b) Give a reason for each of the following practices during titration in the laboratory:

(i) White tile is placed under the conical flask.

(ii) Burette readings are always recorded to two decimal places.

(c) Calculate the volume of **2.5 mol/dm^3** stock HCl required to prepare **500 cm^3** of **0.20 mol/dm^3** HCl.

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ANSWER SHEET

QUESTION 1 (Alternative A)

(a) Titration Table

Volume of pipette (base) used = 25.0 cm^3

Burette Reading	**1st Titration**	**2nd Titration**	**3rd Titration**
Final burette reading (cm^3)	26.80	41.70	30.40
Initial burette reading (cm^3)	1.90	17.10	5.90
Volume of acid used (cm^3)	24.90	24.60	24.50

Consistent values: ✓

Titre Value

= (24.60 + 24.50) ÷ 2

= 49.10 ÷ 2

= 24.55 cm^3

Titre = 24.55 cm^3

(b) Molar Concentration of $KMnO_4$

Using the formula:

(Concentration of MnO_4^- × Volume of MnO_4^-) ÷ (Concentration of $C_2O_4^{2-}$ × Volume of $C_2O_4^{2-}$) = (Number of moles of MnO_4^-) ÷ (Number of moles of $C_2O_4^{2-}$)

From the equation:

$n(MnO_4) = 2$

$n(C_2O_4) = 5$

Therefore,

$C(MnO_4) \times 24.55 / 0.05 \times 25.00 = 2/5$

$C(MnO_4) = (0.05 \times 25.00 \times 2) / (24.55 \times 5)$

$C(MnO_4) = 2.50 / 122.75$

$\therefore C(KMnO_4) = 0.0204$ mol/dm^3

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(b)(i) Mass Concentration of $KMnO_4$

Molar mass of $KMnO_4$

= 39 + 55 + (16 × 4)

= 39 + 55 + 64

= 158 g/mol

Mass concentration

= C × Molar mass

= 0.0204 × 158

∴ Mass concentration = 3.22 g/dm³

CO_2 Volume & Question 2 Analysis

(b)(ii) Volume of CO_2 at S.T.P.

From the equation:

5 mol $C_2O_4^{2-}$ → 10 mol CO_2

Amount of $H_2C_2O_4$ used

= 0.050 × (25/1000)

= 0.00125 mol

Therefore,

0.00125 mol $C_2O_4^{2-}$

= 0.00125 × (10/5)

= 0.0025 mol CO_2

At S.T.P.,

1 mol CO_2 = 22.4 dm³

Volume of CO_2

= 0.0025 × 22.4

= 0.056 dm³

= 56.0 cm³

∴ Volume of CO_2 = 56.0 cm³

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QUESTION 2 — Salt C Analysis

Test	Observation	Inference
a. C + distilled water + filter	Partly dissolved. Colourless filtrate and white residue obtained.	C contains soluble and insoluble ions.
b. Filtrate C + $AgNO_3$ + HNO_3 + NH_3	White precipitate formed. Precipitate insoluble in HNO_3. Precipitate dissolved in NH_3.	Cl^- or CO_3^{2-} or SO_4^{2-} present. Cl^- likely. Cl^- present ✓
c(i). Residue + HNO_3	Effervescence. Colourless, odourless gas evolved. Gas turned lime water milky.	CO_2 gas evolved from CO_3^{2-}.
c(ii). Solution from c(i) + NaOH (drops then excess)	White gelatinous precipitate formed. Precipitate dissolved in excess.	Zn^{2+} or Al^{3+} present.
c(iii). Solution from c(i) + NH_3 (drops then excess)	White gelatinous precipitate formed. Precipitate dissolved in excess.	Zn^{2+} or Al^{3+} present. Since the precipitate dissolved in excess NH_3, Zn^{2+} present ✓

Conclusion

Salt C contains Zn^{2+}, Cl^- and CO_3^{2-}.

QUESTION 3

(a) Physical properties enabling separation of mixtures

(i) Simple distillation

Wide difference in boiling points of components / difference in physical state

(ii) Paper chromatography

Difference in absorption rate / solubility of components in the solvent

(iii) Fractional distillation

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Close difference in boiling points of the components

(b) Reasons for titration laboratory practices

(i) White tile placed under the conical flask

To make the end-point colour change easily visible against a white background

(ii) Burette readings recorded to two decimal places

To ensure accuracy and precision of the titre value

(c) Volume of stock HCl required

Prepare 500 cm^3 of 2.5 mol/dm^3 HCl from 2.5 mol/dm^3 stock HCl.

Using:

$C_1V_1 = C_2V_2$

$2.5 \times V1 = 0.20 \times 5002.5 \times V_1 = 0.20 \times 5002.5 \times V1 = 0.20 \times 500$

$V1 = 0.20 \times 5002.5 = 40.0 \text{ cm}3V_1 = \frac{0.20 \times 500}{2.5} = 40.0 \text{ cm}^3V1 = 2.50.20 \times 500 = 40.0 \text{ cm}3$

$V_1 = 40.0 \text{ cm}^3$

Measure 40.0 cm^3 of the 2.5 mol/dm^3 stock HCl and make up to 500 cm^3 with distilled water.

Summary — Question 3

(a)(i) Wide difference in boiling points of components

(a)(ii) Difference in absorption/solubility rate of components

(a)(iii) Close difference in boiling points of components

(b)(i) To see colour change at end point clearly

(b)(ii) To ensure accuracy of titre value

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WASSCE JUNE 2017

CHEMISTRY 2 ESSAY

SECTION A

1(a)(i) An acid-base indicator could be either a weak organic acid or base which gives different colours in an acidic or basic medium.

(ii) Examples of acid-base indicators are:

- Phenolphthalein
- Methyl orange
- Methyl red
- Methyl yellow
- Methyl violet
- Litmus paper solution
- Bromothymol blue
- Bromocresol green, etc.

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(b) Property of Nitrogen (IV) oxide in the equations below:

(i) In $4Cu + 2NO_2 \rightarrow 4CuO + N_2$; it acts as an oxidizing agent.

(ii) In $H_2O + 2NO_2 \rightarrow HNO_3 + HNO_2$; it acts as an oxidizing agent. Hence, it behaves as an acid anhydride.

(c)(i) Enthalpy of combustion refers to the amount of heat evolved when one mole of a substance is burnt completely in excess oxygen.

(ii) Enthalpy of combustion is always negative because heat is usually given out, which is an exothermic reaction.

(d)(i) Differences between a primary cell and a secondary cell:

Primary Cell	**Secondary Cell**
It cannot be recharged when it runs down	It can be recharged when it runs down

Primary cells do not last long	Secondary cells last long
Reactions in primary cells are not reversible	Reactions here are reversible

(ii) Examples of primary cells are: radio battery, dry cell, Leclanché cell, Daniel cell, torch battery, alkaline battery.

Examples of secondary cells are: lead-acid accumulator, car battery, nickel-metal hydride cell, phone battery, lithium-ion battery, nickel-cadmium cell, etc.

(e) Mole refers to the amount of substance containing 6.02×10^{23} particles of that substance as present in 12 g of Carbon-12. It can also be defined as the amount of substance that contains as many elementary entities as there are atoms in 12 g of Carbon-12.

(f) Amount of HCl in 40.0 cm^3 of 0.40 mol/dm^3 dilute HCl can be calculated using:

n = CV

$= 0.40 \times 40/1000 = 16/1000 = 0.016$

Hence, n(mol) = 0.016 mol

(g) Substances that can be used as electrodes during electrolysis of acidified water are:

- Graphite (carbon)
- Platinum

(h) Forces of attraction that can exist between covalent molecules are:

- Van der Waals' forces
- Hydrogen bonds
- Permanent dipole–dipole interactions

(i) When butane undergoes incomplete combustion, the products formed are Carbon(II) oxide and water.

(j) The electron configuration of $_{26}Fe^{3+}$:

$_{26}Fe \Rightarrow Fe - 3e^- \rightarrow Fe^{3+}$ (lost 3 electrons)

$_{26}Fe$: 26 protons + 26 electrons

$\Rightarrow {}_{26}Fe^{3+}$: 26 protons + 23 electrons

Hence, $_{26}Fe^{3+} \rightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5$

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SECTION B

2(a)(i) The periodic law states that the properties of the elements are a periodic function of their atomic numbers.

(ii) Properties of an element which show periodicity are:

- Ionization energy
- Electron affinity
- Electronegativity/electropositivity
- Melting point
- Boiling point
- Ionic radius/atomic radius
- Thermal conductivity

(iii) Brief explanation of the properties of elements which exhibit periodicity:

- Ionization energy increases due to increase in proton number and decrease in atomic radius.
- Electron affinity increases due to decrease of atomic radius.
- Electronegativity of an element increases due to decrease in atomic radius.
- Melting/boiling points of metallic elements increase due to increase in strength of the metallic bond, but decrease due to decrease in Van der Waals forces of attraction.
- Atomic/ionic radius decreases due to increased nuclear charge or increase in proton number.
- Thermal conductivity decreases due to increase in covalent compounds.

(b) Relative atomic mass is the ratio of the average mass per atom of an element to one-twelfth (1/12) of the mass of a Carbon-12 atom.

(c)(i) The phenomenon exhibited by element Z is isotopy.

(ii) Difference in the number of neutrons in the nucleus of the element accounts for the difference in mass number.

(iii) 75% ($^{35}_{17}Z$) + 37 $^{37}_{17}Z$; Recall 100 − 75 = 25%

⇒ 75% $^{35}_{17}Z$ + 25% $^{37}_{17}Z$

= (75/100 × 35) + (25/100 × 37)

= (3/4 × 35) + (1/4 × 37)

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= 105/4 + 37/4

= (105 + 37)/4 = 142/4

= 35½ = 35.5

∴ Relative atomic mass of Z = 35.5

(d)(i)

(I) Method of collecting CO_2 is by upward displacement of air or by downward delivery.

(II) HCl is collected by downward delivery or upward displacement of air.

(III) H_2 is collected by downward displacement of air or upward delivery.

(ii) Reasons for using the above methods in 2d(i) I & II are thus:

(I) $CO_2(g)$ is heavier or denser than air.

(II) HCl is also denser or heavier than air.

3(a) In the reaction equation $C_{12}H_{26}$ —$(Al_2O_3, 350°C)$→ X + C_8H_{18}

(i) The reaction is catalytic cracking.

(ii) Molecular formula of X = C_4H_8 because 12 − 8 = 4 for Carbon, and 26 − 18 = 8 for Hydrogen.

(iii) The isomers of X:

I: H–C(H)(H)–C(H)(H)–CH=CH–H *(But-1-ene structure)*

II: H–C(H)(H)–C(H)=CH–H with a CH_3 branch *(But-2-ene structure)*

III: H–C(H)(H)–C(H)=C(H)–C(H)(H)–H with branch *(2-methylpropene structure)*

(Note: these are hand-drawn structural formulas — see image 9 for the exact bond diagrams; I've kept the line notation approximate.)

(iv)

I: But-1-ene

II: But-2-ene

III: 2-methylpropene

(v) Balanced equation for reaction of X and hydrogen:

$C_4H_8 + H_2 \rightarrow C_4H_{10}$

(b) Test for fats:

- If a small quantity of the substance is placed on a filter paper and warmed for a while, there would be formation of a translucent spot on the filter paper. This indicates the presence of fats.

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- If a small quantity of the substance is treated with Sudan III reagent, a red colouration would be observed. This indicates the presence of fats.

(c) Recall that the molar mass of H_2SO_4 = (2×1) + 32 + (4×16) = 2 + 32 + 64 = 98 g/mol

If 1 mole of $O_2(g)$ = 2 moles of H_2SO_4

∴ 1.5 mole of $O_2(g)$ = (2 × 1.5) moles of H_2SO_4 = 3 moles of H_2SO_4

Hence, mass of 3 moles of H_2SO_4 = 3 × 98 = 294 g

(d)(i) Enthalpy changes for reactions in increasing magnitude (order):

$\Delta H_2 < \Delta H_1 < \Delta H_3$, or

$\Delta H_2 : \Delta H_1 : \Delta H_3$, or

$\Delta H_3 > \Delta H_1 > \Delta H_2$

(ii) Explanation of the order in 3(d)(i):

Neutralisation involves the combination of H^+ and OH^- ions to produce specific amounts of energy. The greater the ionisation, the greater the energy given off. Hence:

- ΔH_2 involves a weak acid and a weak base/weak electrolyte.
- ΔH_1 involves a stronger base and a weak acid.
- ΔH_3 involves a strong acid and a strong base (alkali).

(e)(i) From the given substances: Cu(s) can conduct electricity.

(ii) NaH(g), $BeCl_2$(s), and HF(l) are soluble in water.

SECTION C

4(a)(i) Industrial preparation of ammonia: Dry nitrogen gas mixed with dry hydrogen gas in the ratio of 1:3 and passed over a pressure of between 200 and 500 atmospheres at a temperature of between 450°C and 500°C. Finely divided iron is used as a catalyst.

(ii) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is the balanced equation for the reaction above.

(iii) Ways of increasing the yield of ammonia is the continuous removal of ammonia as it is formed, or liquefying the ammonia gas formed at a low temperature or high pressure.

(iv) Uses of ammonia:

- Ammonia can be used as a precipitating agent.
- It can be used to manufacture fertilizers.

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- It can be used to manufacture trioxonitrate(V) acid.
- It can be used to manufacture sodium trioxocarbonate(IV).
- It can be used to manufacture pesticides, detergents/laundry materials.
- It can be used in the manufacture of plastics.
- It is used extensively in pharmaceuticals as a refrigerant, softening temporary hard water, and removing insect stings.

(b)(i) Chemical test for hydrogen ($H_2(g)$): A lighted wooden splint is brought to the tip of a test tube containing the gas. The gas will give a "pop" sound, indicating the presence of hydrogen gas.

(ii) Test for $CO_2(g)$: If the gas is bubbled through lime water, the lime water solution will turn milky, showing the presence of $CO_2(g)$.

(iii) Test for $O_2(g)$: If a glowing splint is dipped into a test tube of the gas, the splint will be rekindled, indicating that oxygen gas is present.

(c)(i) Composition of water gas: Carbon(II) oxide and hydrogen gas ($CO(g)$ and $H_2(g)$).

(ii) Uses of water gas:

- It is used as fuel.
- It can be used in the industrial manufacture of hydrogen.
- It can be used in industries for the manufacture of methanol/butanol.

(d) A simple experiment to determine the type of hardness in a sample of water: If the sample of water is boiled and soap is added and shaken, if it forms lather easily, it is temporary hardness, but if it takes a long time to form lather, it is permanent hardness.

5(a)(i) Test of trioxonitrate(V) ions in the lab:

Test	**Observation**
I. Apply heat to a sample of conc. H_2SO_4	Brown fumes of NO_2 evolved
II. Sample + copper + conc. H_2SO_4 + heat	Reddish brown fumes of NO_2 formed
III. Cold sample solution + freshly prepared $FeSO_4$ solution, accompanied by conc. H_2SO_4 (in drops) to the sample	A brown ring observed between the junction

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solution + freshly prepared $FeSO_4$, keeping in slant position	of the acid and the sample solution

(ii) Uses of the following compounds:

(I) Sodium Chloride (NaCl):

- It is used in food preservation.
- It is used in food seasoning.
- It is used in soap manufacturing.
- It is used in crude oil refining.
- It is used in water softening.
- It is used in production of chlorine, hydrogen, and sodium metal.
- It is also used in glazing pottery and in tannery industry.

(II) Sodium trioxocarbonate(IV) (Na_2CO_3):

- It is used in the manufacture of glass.
- It is used in the production of detergents, soaps.
- It is used to soften water.
- It is used to manufacture paper.
- It is used in the manufacture of NaOH.

(b)(i) Balanced equations for the reactions involved in the extraction of iron in the blast furnace:

$C(s) + O_2(g) \rightarrow CO_2(g)$

$CO_2(g) + C(s) \rightarrow 2CO(g)$

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(s)$

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

(ii) Faraday's first law of electrolysis states that the mass of an element discharged at the electrode is directly proportional to the quantity of electricity passed through the electrolyte.

(iii) Applications of electrolysis:

- In electroplating
- In extraction of metals
- In purification of metals

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- In preparation of compounds and elements
- In preparation of some gases

(c) Observations when conc. H_2SO_4 is added to sugar crystals in a beaker:

(I) Conc. H_2SO_4 will dehydrate the sugar.

(II) A mass of sugar charcoal will be formed, or a mass of black soot (carbon) will be formed.

(d) Equation for the reaction of zinc powder with:

(I) Dilute H_2SO_4: $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

(II) Conc. H_2SO_4: $Zn(s) + 2H_2SO_4(aq) \rightarrow ZnSO_4(aq) + SO_2(g) + 2H_2O(l)$

(e) Property of conc. H_2SO_4 shown above is that it acts as an oxidizing agent.

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WASSCE JUNE 2017 CHEMISTRY 3

PRACTICAL QUESTIONS — ALTERNATIVE A

All your burette readings (initials and final) as well as the size of your pipette must be recorded but no account of experimental procedure is required. All calculations must be done in your answer booklet.

1. A is 0.200 $moldm^{-3}$ of HCl. C is a solution containing 14.3g of $Na_2CO_3 . xH_2O$ in 500 cm^3 of solution.

(a) Put A into the burette and titrate it against 20.0 cm^3 or 25.0cm^3 portions of C using methyl orange as indicator. Repeat the titration to obtain Consistent titre values. Tabulate your results and calculate the average volume of A used. The equation for the reaction is:

$Na_2CO_3 . xH_2O + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + (x+1) H_2O_{(l)}$

(b) From your results and the information provided, calculate the:

(i) concentration of C in $moldm^{-3}$;

(ii) concentration of C in gdm^{-3};

(iii) molar mass of $Na_2CO_3 . xH_2O$;

(iv) the value of x in $Na_2CO_3 . xH_2O$.

[H = 1.0; C = 12.0; O =16.0; Na=23.0]

2. F is a mixture of two inorganic salts. Carry out the following exercises on F. Record your observations and identify any gas(es) evolved. State the conclusions you draw from the result of each test.

(a) Put all of F in a beaker and add about 10 cm^3 of distilled water. Stir well and filter. Keep the filtrate and the residue.

(b)(i) To about 2cm^3 of the filtrate, add $NaOH_{(aq)}$ in drops and then in excess.

(ii) To another 2cm^3 portion of the solution, add $NH_{3(aq)}$ in drops and then in excess.

(c) To another 2cm^3 portion of the solution, add a few drops of $HNO_{3(aq)}$ followed by few drops of $AgNO_{3(aq)}$.

(d)(i) Put all the residue into a clean test-tube and add $HNO_{3(aq)}$.

(ii) To a portion of the solution from 2(d)(i) add $NaOH_{(aq)}$ in drops and then in excess.

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3. State what would be observed if the following reactions are carried out in the laboratory:

(i) methyl orange is dropped into a solution of lime juice;

(ii) hydrogen sulphide gas is bubbled through Iron (III) chloride solution;

(iii) sulphur (IV) oxide gas is bubbled into acidified solution of $KMnO_4$;

(iv) ethanoic acid is added to a solution of K_2CO_3.

ANSWERS TO WASSCE JUNE 2017 CHEMISTRY 3 PRACTICAL (ALTERNATIVE A)

Question 1

The volume of the base used = 25.00 cm^3

The Indicator used = methyl orange

RESULT

Titration	1st Titre	2nd Titre	3rd Titre
Final burette readings (cm^3)	24.90	24.80	34.70
Initial burette readings (cm^3)	0.00	0.00	10.00
Volume of acid used (cm^3)	24.90	24.80	24.70

Average Titre = (24.90 + 24.80 + 24.70) / 3 = 74.4 / 3 = **24.80**

∴ Average Volume of A used = **24.80 cm^3**

(i) From the given equation of the reaction; nA = 2 and nB = 1

Using: $C_aV_a/nA = C_BV_B/nB$

Where: $V_B = 25.00\ cm^3$, $V_a = 24.80\ cm^3$, $C_a = 0.200\ mol/dm^3$, C_B = ?

⇒ $C_B = (C_a \cdot V_a \cdot nB) / (nA \cdot V_B) = (0.200 \times 24.80 \times 1) / (2 \times 25.00)$

⇒ C_B = 4.96 / 50.00 = **0.0992**

∴ Conc. of C in mol/dm^3 = **0.0992 mol/dm^3**

(ii) Concentration of C in g/dm^3:

If 500 cm^3 — 14.3g

⇒ 1000 cm^3 — (1000 × 14.3)/500 = 2 × 14.3

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= **28.6 g/dm³**

(iii) Molar Mass of $Na_2CO_3 . xH_2O$

Recall: Molar Conc. in mol/dm³ = Conc. in g/dm³ / Molar Mass

⇒ Molar Mass in g/mol = Conc. in g/dm³ / Molar Conc. in mol/dm³

= 28.6 g/dm³ / 0.0992 mol/dm³

= 288.30645

Hence, Molar Mass ≈ **288 g/mol**

(iv) Value of x in $Na_2CO_3 . xH_2O$

= 2(23) + 12 + 3(16) + x(2×1) + 1(16) = 288

= 46 + 12 + 48 + x(2+16) = 288

= 46 + 60 + 18x = 288

= 106 + 18x = 288

⇒ 18x = 288 − 106

18x = 182

∴ x = 182/18 = 10.11

Hence, **x ≈ 10**

Question 2 — Qualitative Analysis of F (mixture of two inorganic salts)

Test	Observation	Inference
(a) **F + dist. water + stir + filter**	Effervescence occurs. Colourless and odourless gas evolved. After filtration, pale blue/colourless filtrate and green residue formed.	—
(b)(i) **Filtrate + NaOH in drops & in excess**	White precipitate formed; precipitate insoluble in excess NaOH	Ca^{2+}/Pb^{2+} suspected. Ca^{2+} present
(b)(ii) **Filtrate + NH_3 in drops & in excess**	No visible reaction; No visible reaction	Ca^{2+} present; Ca^{2+} confirmed
OR (b)(i) **Filtrate + NaOH in drops & in excess**	Blue gelatinous precipitate formed. Precipitate insoluble	Cu^{2+} present; Cu^{2+} present

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(b)(ii) **Filtrate + NH_3 in drops & in excess**	Pale/light blue gelatinous precipitate formed. Precipitate dissolves in excess NH_3 to form deep blue solution	Cu^{2+} present; **Cu^{2+} confirmed**
(c) **Filtrate + HNO_3 + $AgNO_3$**	No visible reaction; No gas evolved; White precipitate formed	Cl^- present
(d)(i) **Residue + HNO_3**	Effervescence occurs. Colourless & odourless gas evolved which turns blue litmus paper red and turns lime water milky	CO_2; CO_3^{2-} present
(d)(ii) **Solution from 2(d)(i) + NaOH in drops & in excess**	Blue precipitate formed; Precipitate insoluble in excess NaOH	Cu^{2+} present; **Cu^{2+} confirmed**

(Overall inference: F is a mixture of copper(II) trioxocarbonate(IV) [$CuCO_3$] and a chloride salt — consistent with the confirmed presence of Cu^{2+}, CO_3^{2-}, and Cl^-.)

Question 3 — Observations

(i) Methyl orange is dropped into a solution of lime juice: the lime juice solution would turn **pink or red** in colour.

(ii) Hydrogen sulphide gas is bubbled through iron (III) chloride solution: the $FeCl_3$ solution will change colour **from brown to green**, and a **yellow deposit** (precipitate of sulphur) is produced.

(iii) Sulphur (IV) oxide gas is bubbled into acidified solution of $KMnO_4$: the purple colour of the $KMnO_4$ solution will turn **colourless**.

(iv) Ethanoic acid added to a solution of K_2CO_3: the solution of K_2CO_3 will react with the ethanoic acid to liberate a **colourless and odourless gas**, and **effervescence will occur**.

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CHEMISTRY 2 ESSAY

SECTION A

1(a)(i) Fermentation refers to the conversion of aqueous glucose or sugar to ethanol/alcohol and release of carbon (IV) oxide as a by-product.

(ii) The catalyst used for fermentation is Yeast or Zymase.

(b) Factors which determine the choice of an indicator for an acid-base titration are:

- The colour change of the indicator, which must be sharp or distinct.
- The strength of the acid and the base involved in the titration, whether strong or weak.

(c) Considering the equation: $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

Number of moles of H_2SO_4 = (10/1000) × 1.0 = 0.01 mol

→ 1 mole of H_2SO_4 reacted with 1 mole of Fe.

→ Mass of Fe that reacted = 56 × 0.01g = 0.56g

∴ Mass of unreacted Fe = (5.0 − 0.56)g = **4.44g**

OR

Number of moles of Fe = 5/56 = 0.0892857 ≈ 0.0893

→ Mole of unreacted = 0.0893 − (no. of moles of H_2SO_4)

= 0.0893 − 0.01 = 0.0793 mol

⇒ Mass of Unreacted Fe = 0.0793 × 56 = **4.44g**

d(i) Heavy chemical used in electrolytic cells is tetraoxosulphate(VI) acid.

(ii) Fine chemical used in textiles industries is dyes.

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(e) Catalyst increases the rate of a chemical reaction because it provides an alternative pathway for the reaction to occur by lowering the activation energy.

f(i) Chemical formula for the product formed when ethanoic acid reacts with ammonia:

$CH_3COOH(g) + NH_3(g) \rightarrow CH_3COONH_4(s)$

(ii) The product is ammonium ethanoate.

(g) Properties of aluminium that make it suitable for the manufacture of drink cans:

- It is malleable
- It does not corrode
- It has low density (it is light)
- It does not react with the acid in drinks

(h) Industrial uses of alkanoates:

- Used to produce soap.
- Used as flavouring agents.
- Used as solvents for paints, nail varnishes, adhesives etc.
- Used to produce perfumes and cosmetics.

(i) Steps involved in the crystallisation of a salt from its solution:

- Concentration by heating of the solution.
- Cooling of the solution.
- By filtration.

(j) Effects of global warming:

- Rising sea level.
- Flooding of seas/rivers
- Severe climatic changes
- Severe droughts
- Glaciers melting.
- Polar ice-melting

SECTION B

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2(a)(i) Collision theory of reaction rates states that atoms/molecules/ions/particles involved in a chemical reaction must collide with effective collision before reaction can take place.

(ii) Using collision theory to explain the effect of temperature on rate of reaction:

- Increase in temperature makes reacting molecules gain kinetic energy and move faster.
- If temperature decreases, reacting molecules lose kinetic energy and move slower.
- Frequency of collision and effective collision increase or decrease, hence the rate of reaction either increases or decreases.

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b(i) Graphical representation of Charles' Law

[Graph 1: Volume (cm^3) vs Temp (°C) — line extrapolating from −273 through 0]

OR

[Graph 2: V (cm^3) vs T (K) — straight line through the origin]

(ii) Volume of oxygen gas required for complete combustion of 2.5 moles of ethanol at s.t.p.:

$C_2H_5OH(aq) + 3O_2 \rightarrow 3H_2O(l) + 2CO_2(g)$

→ 1 mole of ethanol = $3 \times 22.4\ dm^3$ of $O_2(g)$

∴ 2.5 moles of ethanol = $3 \times 22.4 \times 2.5 =$ **$168.0\ dm^3$**

(i) Esterification is the reaction between an alkanol and an alkanoic acid to produce an alkanoate (ester) and water in the presence of a mineral acid.

(ii) Uses of Alkanoates:

- Alkanoates are used to produce soaps
- They are used as plasticizers.
- They are used in artificial flavouring for foods.
- They are used in production of perfumes and cosmetics.

(iii) Products of the alkaline hydrolysis of ethyl ethanoate are:

- Ethanol and sodium ethanoate OR
- Ethanol and potassium ethanoate

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d(i) Tin-coated plate corrodes faster.

(ii) Zinc is more reactive than tin, higher in the electrochemical series than tin. When the tin-coated plate is exposed, the plate goes into solution and corrodes. In a zinc-coated (galvanized) plate, it is zinc that dissolves and corrodes, thereby protecting the plate better. Moreover, the zinc-coated plate does not corrode.

3(a)(i) Structure of the sixth member of the alkenes: C_7H_{14}, from C_nH_{2n} where n = 7.

[Structural diagram: a 7-carbon chain, H–C–C–C–C–C–C=C–H, single bonds with H atoms attached along the chain, ending in a C=C double bond]

(ii) Relative molecular mass of the 6th member of alkene (C_7H_{14}):

= 7×12 + 14×1 = 84 + 14 = **98**

(iii) Differences between cracking and reforming in the petroleum industry:

Cracking	Reforming
Used to increase the quantity of petrol.	Used to improve the quality of petrol.
Can be achieved catalytically or thermally.	Occurs in the presence of a catalyst.
Involves breaking large molecules of petroleum fractions into smaller molecules.	Involves re-arrangement of atoms in molecules of petroleum fractions to obtain branched and cyclic hydrocarbons.

b(i) Enthalpy of neutralization is the heat evolved when an acid reacts with a base to produce one mole of water. Or: when one mole of H^+ from an acid reacts with one mole of OH^- from a base to produce one mole of water.

(ii) Determination of enthalpy of neutralization of the reaction of dilute hydrochloric acid and aqueous potassium hydroxide:

$HCl(aq) + KOH(aq) \rightarrow KCl(s) + H_2O(l)$

Equimolar solutions of hydrochloric acid and potassium hydroxide are prepared separately. A known volume of the acid is placed in a

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calorimeter and the temperature noted (recorded). The same volume of the potassium hydroxide solution at the same temperature is poured

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into the calorimeter and the mixture stirred gently. The maximum temperature of the mixture is also recorded.

Heat lost in the reaction = Heat gained by the solution formed.
⇒ ΔH neutralization = Mass of solution × specific heat capacity of water × temperature change

(c) An electrochemical cell connected with copper and silver electrodes:
(i) Anode: Copper electrode
(ii) Cathode: Silver electrode

(iii) Silver electrode has a more positive standard electrode potential than copper.

- Copper is more electropositive than silver.
  OR: Copper is higher in the electrochemical series.

(iv) Type of reaction occurring at each electrode:

- Anode: Oxidation occurs at the Cu electrode
- Cathode: Reduction occurs at the silver electrode

(v) Balanced chemical equation for the cell reaction:
$Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

(d) Compound formed when iron is exposed to moist air for a long time:
(i) Hydrated iron(III) oxide
(ii) Balanced chemical equation for the above reaction:
$4Fe(s) + 3O_2(g) + 2xH_2O(l) \rightarrow 2Fe_2O_3 \cdot xH_2O$, where x = 1
$4Fe(s) + 3O_2(g) + 2H_2O(l) \rightarrow 2Fe_2O_3 \cdot H_2O$

(iii) One ore of iron: Haematite

- Magnetite
- Siderite
- Iron pyrites
- Limonite

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SECTION C

4(a)(i) Labelled diagram for the laboratory preparation of a dry sample of Sulphur(IV) oxide.

[Diagram: Retort stand with clamp holding a round-bottomed flask containing sodium trioxosulphate(IV) with concentrated hydrochloric acid added via a thistle/tap funnel, heated gently; delivery tube leads to a conical flask (as a wash bottle stage) containing concentrated tetraoxosulphate(VI) acid, then on to a gas jar collecting sulphur(IV) oxide by downward delivery.]

Note that in the absence of MnO_2, $KMnO_4$...

(ii) Balanced chemical equation for the reaction in 4(a)(i) above:

$NaSO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + SO_2(g)$

OR

$K_2SO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(l) + SO_2(g)$

$NaSO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4 + H_2O(l) + SO_2(g)$

$Cu(s) + 2H_2SO_4(aq) \rightarrow CuSO_4 + 2H_2O(l) + SO_2(g)$

$MgSO_3(aq) + H_2SO_4(aq) \rightarrow MgSO_4 + H_2O(l) + SO_2(g)$

(iii) Precaution in the preparation of Sulphur(IV) oxide:

- The gas should be prepared in a fume cupboard (chamber)

(iv) Reason for the above precaution: the gas is poisonous.

4(i) Dalton's Law of Partial Pressure states that for a mixture of gases which do not react, the total pressure is equal to the sum of the partial pressures of the individual gases.

(ii) Volume of methane (CH_4) collected over water at a temperature of 12°C and a pressure of 700 mmHg was 30 cm^3. Volume of the dry gas at s.t.p. can be calculated using:

$P_1V_1/T_1 = P_2V_2/T_2$

$P_1 = (700-10) = 690$ mmHg (dry gas)

$T_1 = 12+273 = 285K$

$P_2 = 760$ mmHg

$T_2 = 273K$

$V_1 = 30cm^3$

$V_2 = ?$

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$\Rightarrow V_2 = P_1V_1T_2 / P_2T_1 = (690\times30\times273) / (760\times285) = 26.09\ cm^3$

$\therefore V_2 \approx$ **26.10 cm³**

c(i) Equation for the reaction between chlorine and water:

$Cl_2 + H_2O \rightarrow HCl + HClO$

(ii) Litmus paper turned red from blue because H^+ ions are released. Hence, the HCl produced is acidic as well as HClO. Therefore, the solution is acidic too.

d(i) Trend in the boiling points of chlorine, bromine and iodine:

Boiling point of iodine is greater than that of bromine, which is greater than that of chlorine.

Boiling point increases from chlorine to iodine.

(ii) Water has a higher boiling point than ammonia because water has stronger hydrogen

bonds than ammonia. Again, because the oxygen atom has two lone pairs of electrons and the nitrogen atom has one lone pair of electrons. Still, oxygen is more electronegative than nitrogen.

5(a)(i) Industrial uses of hydrogen:

1. In filling weather balloons.
2. In manufacturing plastics.
3. In manufacturing ammonia via Haber process.
4. In manufacturing methanol.
5. In hydrocracking in oil refinery.
6. In fuelling cells
7. In manufacturing margarine
8. In producing oxy-hydrogen flame for welding and cutting metals.
9. In space travel as rocket fuel.

(ii) $Mg(HCO_3)_2(aq) \xrightarrow{\Delta} MgCO_3(s) + H_2O(l) + CO_2(g)$

In the above equation:

(i) The type of hardness of water being removed is temporary hardness of water.

(ii) Disadvantages of hardness of water:

1. It leads to wastage of soap

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2. It brings about scales or furring of kettles and pipes, thereby causing blockage
3. It is not suitable for use in tanning, textiles, and paper production.

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b(i) Disadvantages of using graphite electrodes in the extraction of aluminium by electrolysis:

- At high temperature, oxygen gas produced at the anode reacts with the graphite electrodes to form carbon(IV) oxide.

(ii) Balanced equation of reaction between calcium oxide and water to form slaked lime:

$CaO + H_2O \rightarrow Ca(OH)_2$

(iii) Uses of slaked lime:

- For treating acidic soil
- For making mortar/plasters/cement used in holding bricks/blocks
- For manufacturing glass
- For purification of water
- For removal of hardness in water
- For producing white ash
- To test for carbon(IV) oxide
- To produce bleaching powder
- To produce ammonia from ammonium chloride, used in the Solvay process.

c(i) Saponification is the alkaline hydrolysis of fats/oils to produce soap and propane-1,2,3-triol.

(ii) Raw materials needed for the manufacture of soap:

- Oil/fat
- Alkali (sodium hydroxide or potassium hydroxide)

(iii) Main by-product obtained from the manufacture of soap is propane-1,2,3-triol.

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(d) Extraction of iron in the blast furnace using iron ore, coke, and limestone as raw materials, with the aid of chemical equations:

I. Bottom of furnace: The O_2 in the hot air combines with carbon (coke) to produce carbon(IV) oxide, which is reduced to carbon(II) oxide.

$C + O_2 \rightarrow CO_2$

$CO_2 + C \rightarrow 2CO$

II. Middle of the furnace: The calcium trioxocarbonate(IV) ($CaCO_3$) decomposes under great heat to produce CaO and CO_2. Again, $CaCO_3$ decomposes to remove the impurity SiO_2.

$CaCO_3 \rightarrow CaO + CO_2$

$CaO + SiO_2 \rightarrow CaSiO_3$

(iii) Top of furnace: Iron(III) oxide is reduced to metallic iron thus:

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ OR:

$Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$

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CHEMISTRY 3 PRACTICAL — ALTERNATIVE A

QUESTION PAPER

All your burette readings (initial and final) as well as the size of your pipette must be recorded, but no account of the experimental procedure is required. All calculations must be done in your answer booklet.

A is a solution of potassium tetraoxomanganate(VII).

B is a solution of iron(II) chloride containing 4.80 g of the salt in 250 cm^3 of solution.

Question 1

(a)

Put A into the burette. Pipette 20.0 cm^3 or 25.0 cm^3 of B into a conical flask, add 20.0 cm^3 of $H_2SO_4(aq)$ and titrate with A. Repeat the titration to obtain concordant titre values.

Tabulate your results and calculate the average volume of A used.

The equation of the reaction is:

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

From your results and the information provided, calculate:

The concentration of B in mol dm^{-3}.

The concentration of A in mol dm^{-3}.

The number of moles of Fe^{2+} in the volume of B pipetted.

($FeCl_2$ = 127 g mol^{-1})

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Question 2

C and D are inorganic salts.

Carry out the following experiments and record your observations, identify any gas evolved, and state your conclusions.

(a)

Put all of C into a test tube and add about 5 cm^3 of distilled water. Shake thoroughly and test the solution with litmus paper.

Divide the solution into three portions.

(i) Add NaOH(aq) in drops, then in excess.

(ii) Add NH_3(aq) in drops, then in excess.

(iii) Add $AgNO_3$(aq), followed by HCl(aq).

(b)

(i) Put all of D into a test tube and add about 2 cm^3 of distilled water. Shake thoroughly and feel the test tube.

(ii) To about 2 cm^3 of the solution, add HCl(aq).

Question 3

State the observation made when each of the following reactions is carried out.

(a) Add 2 cm^3 bench H_2SO_4(aq) to 2 cm^3 barium chloride solution.

(b) Add 2 cm^3 dilute HCl to 1 g powdered iron(II) sulphide (FeS).

(c) Add 2 cm^3 dilute HCl to 1 g iron filings and allow to stand for some time.

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ANSWERS

Question 1

(a) Titration Results

Volume of base used = 25.00 cm^3

Titration	Final Reading (cm^3)	Initial Reading (cm^3)	Titre (cm^3)
1st	15.60	0.00	15.60
2nd	31.10	15.60	15.50
3rd	46.50	31.10	15.40

Average titre:

15.60+15.50+15.403=15.50 cm3\frac{15.60+15.50+15.40}{3}=15.50\ \text{cm}^3315.60+15.50+15.40=15.50 cm3

Average volume of A used = 15.50 cm^3

(b)(i) Concentration of B

250 cm^3 contains 4.80 g $FeCl_2$

1000 cm^3 contains:

1000250×4.80=19.20 g dm−3\frac{1000}{250}\times4.80=19.20\text{ g dm}^{-3}2501000×4.80=19.20 g dm−3

Concentration:

19.20127=0.151 mol dm−3\frac{19.20}{127}=0.151\text{ mol dm}^{-3}12719.20=0.151 mol dm−3

Concentration of B = 0.151 mol dm^{-3}

(b)(ii) Concentration of A

Using:

CAVAnA=CBVBnB\frac{C_AV_A}{n_A}=\frac{C_BV_B}{n_B}nACAVA=nBCBVB

CA×15.500.151×25.00=15\frac{C_A\times15.50}{0.151\times25.00}=\frac{1}{5}0.151×25.00CA×15.50=51

CA=0.151×25.005×15.50C_A=\frac{0.151\times25.00}{5\times15.50}CA=5×15.500.151×25.00 CA=0.0487 mol dm−3C_A=0.0487\text{ mol dm}^{-3}CA=0.0487 mol dm−3

Concentration of A = 0.0487 mol dm^{-3}

(b)(iii) Number of moles of Fe^{2+}

251000×0.151=0.003775\frac{25}{1000}\times0.151=0.0037751000 25×0.151=0.003775

≈ 0.00378 mol

Question 2

(a)

Test	Observation	Inference

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C + distilled water	Blue/green solution formed	—
Litmus paper	Blue litmus turns red	Solution is acidic
+ NaOH	Blue precipitate; insoluble in excess	Cu^{2+} present
+ NH_3	Light blue precipitate; dissolves in excess to form deep blue solution	Cu^{2+} confirmed
+ $AgNO_3$ then HCl	White precipitate; insoluble in HCl	Chloride ion (Cl^-) present

(b)

Test	Observation	Inference
D + water	Colourless solution formed; test tube became cold	Endothermic process
+ HCl	Effervescence; colourless gas evolved; limewater turned milky	CO_2 evolved; carbonate or hydrogencarbonate present

Question 3

(a)

Reaction

H2SO4+BaCl2→BaSO4+2HCl\mathrm{H_2SO_4 + BaCl_2 \rightarrow BaSO_4 + 2HCl}H2SO4+BaCl2→BaSO4+2HCl

Observation

A white precipitate of barium sulphate ($BaSO_4$) is formed.

(b)

Reaction

FeS+2HCl→FeCl2+H2S\mathrm{FeS + 2HCl \rightarrow FeCl_2 + H_2S}FeS+2HCl→FeCl2+H2S

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Observation

Effervescence occurs.

A gas with a rotten egg smell is evolved (H_2S).

A green solution is formed.

(c)

Reaction

Fe+2HCl→FeCl2+H2\mathrm{Fe + 2HCl \rightarrow FeCl_2 + H_2}Fe+2HCl→FeCl2+H2

Observation

Effervescence occurs.

A colourless, odourless gas (hydrogen) is evolved.

A light green solution of $FeCl_2$ is formed.

On standing, the solution gradually turns brown due to oxidation of Fe^{2+} to Fe^{3+}.

Inference: Oxidation occurs.

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CHEMISTRY 2 ESSAY

SECTION A

1(a) Conditions necessary for cracking long-chain hydrocarbons to produce more gasoline:

1. High temperature of about 500°C
2. Presence of a catalyst

(b) Reasons for electroplating metallic objects:

1. To prevent corrosion or rusting
2. To make the objects shine/look beautiful
3. To make their surfaces harder and thicker
4. To make them more resistant to chemicals
5. To make them durable
6. To reduce friction on their surfaces

(c)(i) Calcium oxide cannot be used to dry hydrogen chloride gas because hydrogen chloride is acidic and it will react with it to form salt and water.

$CaO(s) + 2HCl(g) \rightarrow CaCl_2(s) + H_2O(l)$

(ii) Drying agent for hydrogen chloride gas could be any of the following:

1. Fused $CaCl_2$
2. Conc. H_2SO_4
3. Silica gel
4. Phosphorus(V) oxide

(d) Heating a mixture of conc. HNO_3 and $FeSO_4$: The mixture turned from pale green to yellow with the evolution of a brown gas. Since

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HNO_3 is a strong oxidizing agent, it oxidizes pale green Fe^{2+} ions to yellow Fe^{3+} ions and itself reduced to nitrogen(IV) oxide.

(e)(i) Equation for the reaction between zinc oxide and:

1. Dilute H_2SO_4: $ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l)$
2. NaOH solution: $ZnO(s) + 2NaOH(aq) \rightarrow Na_2Zn(OH)_4$
   OR: $ZnO(s) + 2NaOH(aq) \rightarrow Na_2ZnO_2 + H_2O$

(ii) Property of ZnO shown in e(i) above is Amphoterism (amphoteric properties).

(f) $^{35}_{17}Cl$ and $^{37}_{17}Cl$

- Similarity: They have the same number of protons (17); same number of electrons (17) and same atomic number 17.
- Difference: They have different mass numbers of 35 and 37. They have different number of neutrons in their nuclei of 18 and 20 respectively.

(g) Products formed when chlorine is exposed to sunlight are:

1. Hydrochloric acid (HCl)
2. Oxygen gas (O_2)

(c)(ii) Redox reaction occurs when NaH is added to water. NaH dissolves and $H_2(g)$ is evolved while an alkaline solution is formed.
Addition of H_2 to water: no reaction occurs and H_2 is slightly soluble.
Addition of H_2S to water: H_3O^+ and S^{2-} will be formed. H_2S dissolves and a slightly acidic solution is formed.
Addition of NH_4Cl to water: NH_4Cl dissolves in water to produce ammonia, hydroxonium ion and chloride ion.

Chemical equations of the reactions occurring from the above processes:

- $NaH + H_2O \rightarrow NaOH + H_2$
- $H_2S + 2H_2O \rightarrow 2H_3O^+ + S^{2-}$
- $NH_4Cl + H_2O \rightleftharpoons NH_3 + H_3O^+$
  OR: $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

(d) Element J electron configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2$

(i) There are no unpaired electrons in J.
(ii) J will be a good reducing agent.
(iii) The reason for the answer above is because it loses the two electrons in its outermost shell.

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SECTION B

2(a) $H_2S + SO_2 \xrightarrow{(H^+)} S + H_2O$

1. Species that undergo oxidation in H_2S.
2. Oxidizing agent is SO_2.

(b) Carbon-12 scale is the mass reference scale in which the atom of the ^{12}C isotope is taken to have twelve units of atomic mass. It is a scale that uses the ^{12}C isotope as the standard for comparing the atomic masses of other elements.

(c) Properties of a chemical system in equilibrium:

1. Gibb's free energy/ΔG is zero.
2. There is no net change in the concentration of each substance.
3. The rate of forward reaction equals the rate of backward reaction because the system is dynamic.
4. The equilibrium composition of the substances can be approached from either reactants or products.

SECTION B (cont'd)

(i) $C_{10}H_{22} \xrightarrow{(cracked)} C_6H_{14} + P\ (C_4H_8)$

(ii) Structures of two isomers of P:

Isomer 1: H–C(H)(H)–C(H)=C(H)–C(H)(H)–H *(But-2-ene)*
Isomer 2 (OR): H–C(H)(H)–C(H)=CH_2 with a CH_3 branch *(2-methylpropene/isobutylene structure)*

(iii) "P" could be polymerised because it is an alkene and so has a double bond.

(b) Guiding principles for explaining the way electrons of the atoms of elements are arranged in atomic orbitals are thus:

1. Electrons enter orbitals of lowest energy (Aufbau Principle).
2. Pauli Exclusion Principle: two electrons in the same orbital will have different spins, implying that no two electrons can have all four quantum numbers the same.
3. Hund's Rule of Maximum Multiplicity, where electrons filling into degenerate orbitals of same energy fill in singly before pairing up.

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(c)(i) The nature of the intermolecular forces holding the units or molecules together in the condensed state:

- NaH: Ionic/electrostatic forces (charges) holding Na^+ and H^-.
- H_2: Van der Waals' forces — weak instantaneous dipole–dipole interactions holding molecules together.
- H_2S: Dipole–dipole interactions/H-bonding resulting from charge separation along S–H bond because of higher electronegativity of sulphur.
- NH_4Cl: Ionic/electrostatic forces between NH_4 and Cl, holding the NH_4^+ and Cl^- units.

3(a) Functions of the following substances in Solvay process, with equations:

(i) Limestone:

- Source of CO_2 for the carbonating towers.
- Source of CaO for the recovery of ammonia.
  $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

(ii) Ammonia: Ammoniation of brine to make brine alkaline:

$NaCl(aq) + NH_3(g) + H_2O(l) + CO_2(g) \rightarrow NaHCO_3(aq) + NH_4Cl(aq)$

OR: $NH_4HCO_3 + NaCl \rightarrow NH_4Cl + NaHCO_3$

(b)(i) Chemical equation for the fermentation of glucose:

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$

(ii) On standing for some time, a tightly corked bottle filled to the brim with fresh palm wine shatters because there is a build-up of CO_2 released by the fermentation process, causing the pressure in the glass bottle to build up, and that eventually shatters the bottle.

(c) Na, Fe, K and Cu

(i) Order of increasing reactivity: Cu, Fe, Na, K

(ii) K and Na will react with cold water.

(iii) Fe and Cu can form coloured salts.

(iv) Balanced equations of the half reactions for any two of the redox reactions in 3(a)(i):

I. $Na \rightarrow Na^+ + e^-$; $Cl_2 + 2e^- \rightarrow 2Cl^-$

III. $Fe^{3+} + e^- \rightarrow Fe^{2+}$

$I^- \rightarrow \frac{1}{2}I_2 + e^-$

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SECTION C

4(a) Reaction scheme is an illustration of the Contact process:

X(gas) —I→ Sulphur(IV) oxide —II(catalyst)→ Sulphur(IV) oxide →

Oleum —III→ ... —IV→ Conc. H_2SO_4

Y(solid) also feeds into step I

(i) X = Oxygen; Y = Sulphur

(ii)

I. $S(s) + O_2(g) \rightarrow SO_2(g)$

II. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

III. $SO_3(g) + H_2SO_4(aq) \rightarrow H_2S_2O_7(l)$ (oleum)

IV. $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(aq)$

(iii) Vanadium(V) oxide

(iv) From Le Chatelier's principle, increasing the temperature would not favour the reaction because the reaction is exothermic.

(v) Uses of SO_2 are thus:

1. It can be used as preservative for grains and fruits.
2. It can be used in the manufacture of H_2SO_4.
3. It acts as a reducing agent in metallurgy.
4. It is used for dechlorination.
5. It can be used as germicide and fumigant.
6. It is used extensively in bleaching wood pulp, wood silk, etc.

(b) From the equation:

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

2 moles : 1 mole : 2 moles

= 2 volumes : 1 volume : 2 volumes

i.e.: 40 cm^3 H_2 : 20 cm^3 O_2 = 40 cm^3 H_2O

Hence, volume of unused gas (O_2) = (30 − 20) cm^3 = 10 cm^3

(c)(i) Equation for the reaction:

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

CO_2 is evolved and CaO is the residue.

(ii) $CaCO_3$ = 40 + 12 + 3(16) = 100 g

CaO = 40 + 16 = 56 g

If 100 g of $CaCO_3$ yielded 56 g of CaO

⇒ 1.0 g of $CaCO_3$ will yield (1/100 × 56) g of CaO

∴ Mass of residue (CaO) = 0.56 g

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(iii) 1 mole of a gas at STP = 22.4 dm^3

⇒ 1 mole of $CaCO_3$ produces 1 mole of CO_2

∴ 100 g of $CaCO_3$ produces 22.4 dm^3 of CO_2

⇒ 1 g of $CaCO_3$ will produce = 1/100 × 22.4 of CaO

= 0.224 dm^3 of CO_2

(iv) Volume at 15°C and 760 mmHg:

Temperature = 273 + 15 = 288 K

Using $V_1/T_1 = V_2/T_2$

V_1 = 0.224 dm^3, T_1 = 273 K, T_2 = 288 K

$V_2 = V_1T_2/T_1 = 0.224 \times 288/273 = 64.512/273 = 0.236307$

∴ $V_2 \approx 0.236$ dm^3

QUESTION 5

5(a)(i) Preparation and collection of dry chlorine gas in the laboratory *(diagram: conc. HCl dripped onto MnO_2 with heat → water wash bottle → conc. H_2SO_4 drying agent → dry Cl_2 collected)*

Note that in the above set-up, MnO_2 can be replaced by $KMnO_4$(s), but there would be no application of heat.

Cl_2(g) is collected by downward delivery or upward displacement of air.

The water in the wash bottle will remove the HCl impurity.

(ii) Uses of chlorine are thus:

1. For bleaching materials in textiles and wood pulp.
2. For production of HCl in large quantity.
3. For production of polymers/plastics, etc.
4. For production of chlorinated chemicals.
5. In medicine to produce chloroform (trichloromethane).
6. In production of dyes.
7. For water treatment.
8. For production of insecticides, germicides, etc.

(b) Preparation of hydrogen from water gas (CO(g) + H_2(g)): Steam is mixed with water gas and passed over heated catalyst of iron(III) oxide or chromium(III) oxide at 450°C. CO in water gas is converted to CO_2, with further yield of hydrogen. The CO_2 is removed by dissolving the mixture in water/NaOH/KOH or $Ca(OH)_2$ solutions.

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(d)(i) The chief ore of aluminium is Bauxite.

(ii) The ore is purified to:

- Produce aluminium oxide/alumina
- Prevent poisoning of the electrode

(iii) Electrode used in the electrolysis is carbon/graphite.

(iv) Cryolite (Na_3AlF_6) is added to the electrolyte in order to:

- Reduce some of the energy involved in extracting aluminium.
- Increase the electrical conductivity of alumina.
- Lower the melting points of the alumina.

(d) Products obtained directly from the destructive distillation of coal are:

- Coke
- Coal tar
- Coal gas
- Ammoniacal liquor

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WASSCE JUNE 2019 CHEMISTRY 3

PRACTICAL QUESTIONS (ALTERNATIVE A)

All your burette readings (initials and final) as well as the size of your pipette must be recorded, but no account of experimental procedure is required. All calculations must be done in your answer booklet.

1. A is a solution containing 15.8 g dm^{-3} of $Na_2S_2O_3$. B was obtained by dissolving 9.0 g of an impure sample of I_2 in aqueous KI and the solution made up to 1 dm^3.

(a) Put A into the burette and titrate it against 20.0 cm^3 or 25.0 cm^3 portions of B. Use starch solution as indicator. Repeat the titration to obtain concordant titre values. Tabulate your results and calculate the average volume of A used.

The equation for the reaction involved in the titration is:

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

(b) From your results and the information provided, calculate:

(i) the concentration of A in mol dm^{-3};

(ii) the concentration of I_2 in B in mol dm^{-3};

(iii) the percentage by mass of I_2 in the sample.

(c) Give reasons why the starch indicator was not added to the titration mixture at the beginning of the titration.

[O = 16.0, Na = 23.0, S = 32.0, I = 127.0]

Credit will be given for strict adherence to the instructions for titration. All tests, observations and inferences must be clearly and accurately recorded in the booklet in ink at the time they are made.

2. C is a mixture of two inorganic compounds. Carry out the following exercises on C. Record your observations and identify any gas(es) evolved. State the conclusions you draw from the result of each test.

(a) Put all of C in a boiling tube and add about 10 cm^3 of distilled water. Shake thoroughly and filter. Keep both the residue and the filtrate.

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(b)(i) To about 2 cm^3 of the filtrate, add a few drops of silver trioxonitrate(V), followed by dilute HNO_3.

(ii) Add excess NH_3 solution to the resulting mixture in 2(b)(i).

(c)(i) Put the residue in a test tube, add about 2 cm^3 of dilute HCl, and shake.

(ii) Add NH_3 solution in drops to the mixture from 2(c)(i), then in excess.

3. (a)(i) State what would be observed when $BaCl_2$ solution is added to a portion of a saturated Na_2CO_3 solution, followed by dilute HCl in excess.

(ii) A gas Q decolourized acidified $KMnO_4$ solution. Suggest what Q could be.

(b) Name one substance used in the laboratory for drying each of the following:

(i) ammonia gas;

(ii) carbon(IV) oxide.

(c) Give a reason why a given mass of sodium hydroxide pellets cannot be used to prepare a standard solution.

ANSWERS TO WASSCE JUNE 2019

CHEMISTRY 3 PRACTICAL (ALTERNATIVE A)

Question 1

(a) Volume of pipette used = 25.00 cm^3

Titration	1st Titre	2nd Titr
Final reading (cm^3)	12.40	25.00
Initial reading (cm^3)	0.00	12.40
Volume of Acid (cm^3)	12.40	12.60

Average titre = (12.40 + 12.60 + 12.50) / 3 = 37.50 / 3 = 12.50

∴ Average volume of acid used = 12.50 cm^3

Equation of the reaction:

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$ (mole ratio 1 : 2)

(b)(i) Concentration of A in mol/dm^3 = (Conc. of A in g/dm^3) ÷ (Molar mass of A in g/mol)

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Molar mass of $Na_2S_2O_3$ = 2(23) + 2(32) + 3(16) = 46 + 64 + 48 = 158 g/mol

⇒ Conc. of A = 15.8 g/dm³ ÷ 158 g/mol = 0.100 mol/dm³

(ii) Concentration of I_2 in B, in mol/dm³:

Using: $C_a V_a / C_B V_B = n_a / n_B$

⇒ $C_B = (n_B \times C_a \times V_a) / (n_a \times V_B)$

= (2 × 0.100 × 12.50 × 1) / (1 × 25.00)

Wait — following the working exactly as shown:

C_B = (0.100 × 12.50 × 1) / (2 × 25.00) = 1.25 / 50.00 = 0.025

∴ C_B = 0.025 mol/dm³

(iii) Percentage by mass of I_2 in the sample:

= (Concentration of pure I_2 in g/dm³ ÷ 9.0 g/dm³ of impure sample) × 100%

Conc. of pure I_2 in g/dm³ = C_B × Molar mass of I_2 = 0.025 × (127 × 2)

= 0.025 × 254 = 6.35 g/dm³

Hence, percentage by mass of I_2 in the sample = (6.35 / 9.0) × 100 = 70.55556 ≈ 70.56%

(c) Starch indicator was not added to the titration mixture at the beginning of the titration in order to obtain an accurate end point / to prevent the formation of a complex (starch–iodine) solution, which would have reduced the accuracy of the titre value.

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Question 2

"C" is a mixture of two inorganic compounds.

	Test	Observation	Inference
(a)	C + distilled water, filter	C partially dissolved to form a green residue with colourless filtrate	Fe^{2+} or Cu^{2+} salt present
(b)(i)	2 cm^3 of filtrate + $AgNO_3$ + HNO_3	White precipitate formed; precipitate insoluble when HNO_3 was added	Cl^-, ClO_3^-, S^{2-} or SO_3^{2-} present → Cl^- present
(b)(ii)	Resulting mixture in b(i) + excess NH_3	Precipitate dissolves	Cl^- present
(c)(i)	Residue + dilute HCl	Residue dissolved forming a blue solution. Effervescence occurred with evolution of a colourless, odourless gas that turned blue litmus paper red and turned lime water milky	Cu^{2+} present; CO_2 from CO_3^{2-} is present
(c)(ii)	Portion of mixture from c(i) + NH_3 in drops, then in excess	Light (pale) blue precipitate formed with drops of NH_3; precipitate dissolved in excess NH_3 to form a deep blue solution	Cu^{2+} confirmed

Question 3

(a)(i) When $BaCl_2$ solution is added to saturated Na_2CO_3 solution, followed by dilute HCl in excess: a white precipitate will be formed; effervescence will occur and the white precipitate will dissolve in excess dilute HCl.

(ii) Gas Q that decolourized acidified $KMnO_4$ solution could be either SO_2, H_2S, or an unsaturated hydrocarbon like C_2H_2, C_2H_4, etc.

(b) The drying agents for:

(i) ammonia gas = Calcium oxide

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(ii) carbon(IV) oxide = Calcium chloride or concentrated tetraoxosulphate(VI) acid

(c) Sodium hydroxide pellets cannot be used to prepare a standard solution because it is deliquescent and so absorbs water vapour (moisture) and carbon(IV) oxide from the air, which would increase its mass.

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WAEC, 2020 FINAL MARKING SCHEME — CHEMISTRY 2 (ESSAY)

NIGERIA & THE GAMBIA

SECTION A — ***Answer all the questions in this section. Maximum Obtainable Mark [100 Marks]***

Question 1

(a)(i) Faraday's first law of electrolysis states that the amount of a substance discharged at/dissolved from an electrode is directly proportional to the quantity of electricity that passes through the electrolyte. (2 marks)

OR

– the mass of an element deposited at the electrode is directly proportional to the quantity of electricity passed. (2 or 1) [4 marks]

(ii) Strong electrolytes: dissociate/ionize completely in aqueous solutions, while weak electrolytes dissociate/ionize partially in aqueous solution. (2 marks)

(b) – it burns in air/oxygen – it undergoes addition reaction – it undergoes polymerization – it undergoes substitution/precipitation reaction Any 1 x 1 = [1 mark]

(c)(i) hydrocarbon with double/triple bond / multiple bonds (1) between at least a pair of carbon atoms (1) (2 marks)

(ii) $CH_3COOH + CH_3OH \rightleftharpoons CH_3COOCH_3 + H_2O$ (1) (2 marks) (candidate can score without sign of reversibility)

(iii) Methylethanoate (1)

(d) – addition of concentrated H_2SO_4 – removal of the ester as soon as it forms – increase the concentration of one of the reactants [4 marks] Any 1 x 1 = [1 mark]

(e) – sea level rising – severe climate changes / depletion of coral reefs – alters ecosystem balance / setting animals on the move – severe drought – flooding of low-lying areas – polar ice melting Any 1 x 1 = (1 mark) [3 marks]

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65.0 g of Zn will produce 6.02 x 10^{23} molecules of H_2

OR

65.0 g of Zn ÷ 65 = 3.75 g of Zn = 3.75 x 6.02 x 10^{23} (1)

= 3.47 x 10^{22} molecules (1) [3 marks]

(f) equation B / $H_2 + C_2H_4 \rightarrow C_2H_6$(l) Any 1 x 1 = (1 mark)

(g)(i) In equation B: H changes from zero to –1 (1); C changes from +2 to +3 (1) [3 marks]

(ii) – an electron in an atom exists/revolves in a circular orbit – energy of an electron is quantized/has a fixed value – an electron emits energy in the form of radiation when it moves from a higher energy state to a lower energy state Any 2 x 1 = 2 marks [3 marks]

Bohr's model cannot explain the more complicated spectra observed in spectra other than that of hydrogen (1) [3 marks]

(h)(i) – Temperature (1) – Pressure/Volume (1) – Concentration (1) [3 marks]

(ii) Produces a gas/effervescence/bubbles/gas given off (1)

HCl will produce a more vigorous reaction (1)

CH_3COOH will produce a less vigorous reaction (1)

TOTAL QUESTION 1 = (25 marks)

Section B — Answer any three questions in this section

Question 2

(a)(i) They are geometric cis-trans isomers (1)

(ii) Compound A: Trans-1,2-dichloroethene (1)

Compound B: Cis-1,2-dichloroethene (1)

(iii) The chemical properties will be the same (1), Yes

(iv) – because they both contain the same functional group – They have the same type of atoms connected in the same way Any 1 x 1 = [1 mark]

(b)(i) – boiling takes place at a specific temperature – boiling takes place throughout the liquid – bubbles are formed – vapour pressure is equal to atmospheric pressure Any 2 x 1 = [2 marks]

(ii)

Boiling	**Evaporation**

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occurs throughout the liquid	occurs only at the surface of the liquid
occurs at a particular constant temperature	takes place at all temperatures
Exothermic	Endothermic
has no cooling effect	has a cooling effect
occurs using external source of heat, not spontaneous	occurs using internal energy, spontaneous
bubbles are observed	bubbles are not observed
not affected by humidity	affected by humidity
fast process	slow process

Any 1 x 1 (1 mark) [2 marks] (different rows must correspond to score)

Unsaturated solution	**Saturated solution**
Can dissolve more solute at that temperature	Cannot dissolve any more solute at that temperature
Does not contain undissolved solute at that temperature	Contains undissolved solute at that temperature

(c)(difference must be correct to score) (2 marks)

(ii) – increasing the temperature (1) – increasing the volume of solvent (1) (2 marks)

(iii) – temperature – nature of solvent – volume of solvent – nature of solute Any 1 x 1 = 1 mark

(d)(i) The amount of substance containing 6.02 x 10^{23} particles of that substance / amount of substance containing as many particles as there are atoms in 12 g of carbon-12. (2 or 0)

(ii) n(HCl) = 25.0 x 10^{-3} dm^3 x 0.1 mol dm^{-3}

n(HCl) = 2.5 x 10^{-3} mol

From the equation of the reaction:

n(MgO)/n(HCl) = 1/2

molar mass of MgO = 24 + 16 = 40 g mol^{-1} (1)

mass of MgO = (1 x 2.5 x 10^{-3} x 40) / 2 (1)

= 0.050 g (1)

Any 1 x 1 = 1 mark [5 marks]

ALTERNATIVE METHODS

No. of moles of HCl:

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$C_1V_1 = C_2V_2$

$0.1 \times 25 = C_2 \times 25 / 1000$

$C_2 = (0.1 \times 25) / 1000$ (1) = 0.0025 mol

2 mol HCl gave 1 mole MgO

:. mol of MgO = 0.0025 ÷ 2 (1) = 0.00125 mol

Molar mass of MgO = 24 + 16 (1) = 40

:. mass of MgO = 40 x 0.0125 (1) = 0.05 g (1)

OR

mol of HCl = 0.025 x 0.1 (1) = 0.0025

mol of MgO = 0.0025 ÷ 2 (1) = 0.00125 mol

Molar mass (RAM) of MgO = 24 + 16 (1) = 40

mass of MgO = 40 x 0.0125 (1) = 0.05 g (1)

0.0025 mol HCl gave ½ x 0.0025 (1) of MgO

25 cm^3 → 25 x 0.1 ÷ 1000 (1) = 0.1/40 – 0.0025 mol (1)

1000 cm^3 → ?

[5 marks] [7 marks]

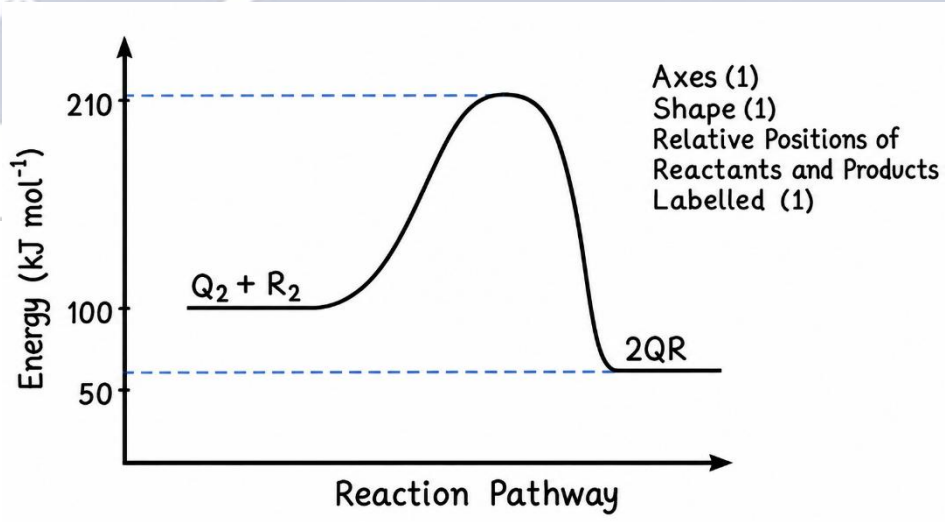
(e) – are malleable – are ductile – are lustrous – have high melting point / boiling point – have high tensile strength / hard / strong – solids at room temperature except mercury – good conductors of heat – good conductors of electricity – sonorous

Any 3 x 1 = [3 marks]

TOTAL QUESTION 2 = (25 marks)

Question 3

(a)(i) Energy profile diagram. (Candidates must indicate energy content of products and reactants on the energy profile to score for axes.) Marking points: Axes (1), Shape (1), Relative positions of Reactants and Products (1), Labelled (1)



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(ii) Activation energy = 210 – 100 (1) = 110 kJ (1)

(iii) $\Delta H = Hp - Hr = 54 - 100 = -46$ kJ mol^{-1} (no units, no mark)

(iv) $Q_2 + R_2 \rightarrow 2QR$ (1)

(v) The reaction is exothermic (1) (2 marks)
because energy is given out / ΔH is negative / energy of product is lower than energy of reactant (1) [11 marks]

$CaO + SiO_2 \rightarrow CaSiO_3(l)$
Pig iron (1)
because it contains impurities / not pure (1) (6 marks)

(a)(i) The dissolution of SO_2 in water is highly exothermic (1); mist of acid droplets would be formed (1) [11 marks]

(ii) – It is produced on a large scale – It is required by many industries as a raw material – It is in high demand by other industries (1)

(iii) Pig iron (1)
(iv) because it contains impurities / not pure (1) (6 marks)

(d) $2CH_3CH_2OH + 2Na \rightarrow 2CH_3CH_2ONa - H_2$
OR
$2C_3H_5OH + 2Na \rightarrow 2C_3H_5ONa + H_2$
(5 marks) (2 marks)
TOTAL QUESTION 4 = (25 marks)

Question 5

(a)(i) – ammonia – hydrogen chloride – sulphur(IV) oxide

(ii) To demonstrate high/extreme solubility of gases / HCl / SO_2 / NH_3 in water. Any 2 x 1 = 2 marks

(iii) A flask, fitted with a glass jet (1), is filled with dry ammonia or any soluble gas (1). Inject water through the inlet into the flask (1); this dissolves the ammonia/soluble gas (1) and causes a fountain through the jet (1). [9 marks]

(iv) – Invert the flask into a beaker of water (1) – Open a clip A to allow a small volume of water to enter the flask, then close it (1) – The gas dissolves in water (1), causing sudden reduction of pressure in the flask – Open clip B (1); reduced gas pressure causes water

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from the beaker to be drawn through the delivery tube into the flask, forming a fountain [9 marks]

OR

– Around-bottomed flask is filled with gas and fitted with two delivery tubes(1) and closed by use of clips A and B

(d)(i) – calcium hydrogen trioxocarbonate (IV) – calcium tetraoxosulphate (VI) – magnesium tetraoxosulphate (VI) – magnesium hydrogen trioxocarbonate (IV) – iron(III) chloride

Any 2 x 1 = 2 marks

(ii) – heating the water to boiling/distillation – addition of calculated amount of calcium hydroxide – addition of washing soda crystals – ion exchange resin/permutit method

Any 2 x 1 = 2 marks

(iii) Calcium ions in the water are good for children's teeth and bones:

– It helps to reduce heart diseases

– Does not dissolve lead pipes

– Tastes better than soft water

– Provides calcium salts used in manufacturing of food in plants

– Production of exoskeleton of animals/shells

Any 2 x 1 = [2 marks]

TOTAL QUESTION 5 = (25 marks)

Question 4

(a)(i)

I. (Conc.) HCl and MnO_2 / $KMnO_4$ (1)

II. (Conc.) H_2SO_4 (1)

III. Downward delivery/upward displacement of air (1) (3 marks)

(ii) $16HCl_{(aq)} + 2KMnO_{4(aq)} \rightarrow 2MnCl_{2(aq)} + 2KCl_{(aq)} + 8H_2O_{(l)} + 5Cl_{2(g)}$ (1)

(iii) $3Cl_{2(g)} + 6NaOH_{(aq)} \rightarrow 5NaCl_{(aq)} + NaClO_{3(aq)} + 3H_2O$ (1) (2 marks)

OR

$MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$ (2 marks)

(b)(i) I. Atoms (1) — II. Ions (1) — III. Molecules (1)

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(c) Isotopes: The existence of atoms of the same element with the same atomic number but different mass numbers/numbers of neutrons [2 or 0]

(Do not accept F,G or name of element)

(d)(i) E — $1s^2\ 2s^2\ 2p^5$ (1)

F — $1s^2\ 2s^2\ 2p^6$ (1)

G — $1s^2\ 2s^2 2p^6\ 3s^2$ (1)

H — $1s^2\ 2s^2\ 2p^6\ 3s^2 3p^1$ (1)

(ii) I. Elements H(1) and G(1)

II. Element H (1)

III. Element F (1)

IV. GF_2 (1)

[9 marks]

(b)(i) I. Haematite (1) — Coke (1) — Limestone (1)

(ii) $C + O_2 \rightarrow CO_2$ (1)

$C + CO_2 \rightarrow 2CO$ (1)

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (1)

$CaCO_3 \rightarrow CaO + CO_2$ (1)

(reactants and products (1) balancing (1)) (2)(3 marks) [7 marks]

TOTAL QUESTION 3 = (25 marks)

(Do not accept named industry)

(b)(i) – Textiles – Tannery – Brewery – Bottling company – Soaps and detergents – Food industry – Pharmaceuticals – Cosmetics – Petrochemical industry – Petroleum industry – Dyes – Paints – Agrochemicals – Fertilizers – Pesticides – Plastic

Any 2 x 1 = 2 marks

(ii) – improvement in the standard of living of people – employment opportunities – development in the economy – pollution (air, land, water, etc.)

Any 3 x 1 = 3 marks (5 marks)

(c)(i) – coke – coal tar – coal gas – ammoniacal liquor

Any 3 x 1 = 3 marks (5 marks)

(ii) Coke — (solid) fuel / production of water gas / extraction of metals Any 1 x 1 = 1 mark

Coal tar — synthesis of chemicals/perfumes/dyes/paints/drugs/plastics/explosives/tarring

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of roads Any 1 x 1 = 1 mark

Coal gas — as fuel (in homes and industries) (1)

Ammoniacal liquor — production of fertilizer (1)

of roads Any 1 x 1 = 1 mark

Coal gas — as fuel (in homes and industries) (1)

Ammoniacal liquor — production of fertilizer (1)

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WAEC/WASSCE JUNE 2021 CHEMISTRY

ESSAY/THEORY ANSWERS

SECTION A

Answer all the questions in this section

Question 1

(a) Molecular formula gives the actual number of each kind of atom in one molecule while structural formula is a graphic representation of a molecule of a compound which shows how the atoms are linked/bonded together

OR

molecular formula gives the total number of atoms of each element in one molecule of a compound while structural formula shows the arrangements/relative position of atoms/atoms and bonds in one molecule of the compound

(b) Atomic radius/size of atom

Nuclear charge

Shielding effect/screening effect

Electron configuration

Penetration effect

(Any 3 × 1 = 3 marks)

(c) The rates of the forward and backward reactions must be equal

ΔG must be zero

The temperature must be constant

System must be dynamic/all reactant and product must be present

System must be closed

(2 × 1 = 2 marks)

(d)(i) Element B

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(ii) Because it has the lowest ionization energy/ it loses electrons most easily.

(e) The rate of diffusion of a gas at the same temperature and pressure is inversely proportional to the square root of its vapour density/molar mass.

(f)(i)

$Mg(NO_3)_2$

Na_2SO_4

(ii) $CaCO_3$

(g)(i) protein — Condensation
(ii) Perspex — Addition
(iii) Nylon — Condensation

(h) It is defined as half the distance between the nuclei of any two close atoms in a molecule / Is a measure of the size of its atoms, the mean distance from the centre of the nucleus to the boundary of the surrounding shells of electrons.

(i) The intermolecular forces in ethanol are hydrogen bonds (1) which are stronger (1) than the van der Waal's forces (1) in propane.

(j)

digestion of food

determination of pH of soil/used in agriculture

important role in the survival of animals (self-defence)/existence of living being

pH change as the cause of tooth decay

treatment of water for public supply

treatment of industrial effluent/liquid waste

in pharmaceuticals

in medicine (to determine pH of body fluid/urine/blood)
(Any 3 × 1 = 3 marks)

[TOTAL QUESTION 1 = 25 MARKS]

SECTION B

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Answer three questions

Question 2

(a)(i)

All members can be represented by a general formula

Each member of the series differs from the next by a constant/fixed number of atoms — CH_2/14 amu.

All members of the series show a gradual change in physical properties such as density

All members have similar chemical properties/same functional group

All members of the group are prepared using similar chemical methods

(Any 2 × 1 = 2 marks)

(ii) Ethane is a saturated (1) hydrocarbon containing single bond and therefore undergoes mainly substitution reaction (1) while ethene is an unsaturated (1) hydrocarbon containing a double bond and hence undergoes addition reaction (1)

(b)(i) hydrogen chloride (gas)

(do not accept hydrochloric acid gas)

(ii)

Colourless

Has choking smell/irritating smell

Denser than air

Soluble in water

Fumes in moist air

(iii) $2NaCl(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2HCl(g)$

OR

$NaCl(s) + H_2SO_4(aq) \rightarrow NaHSO_4(aq) + HCl(g)$

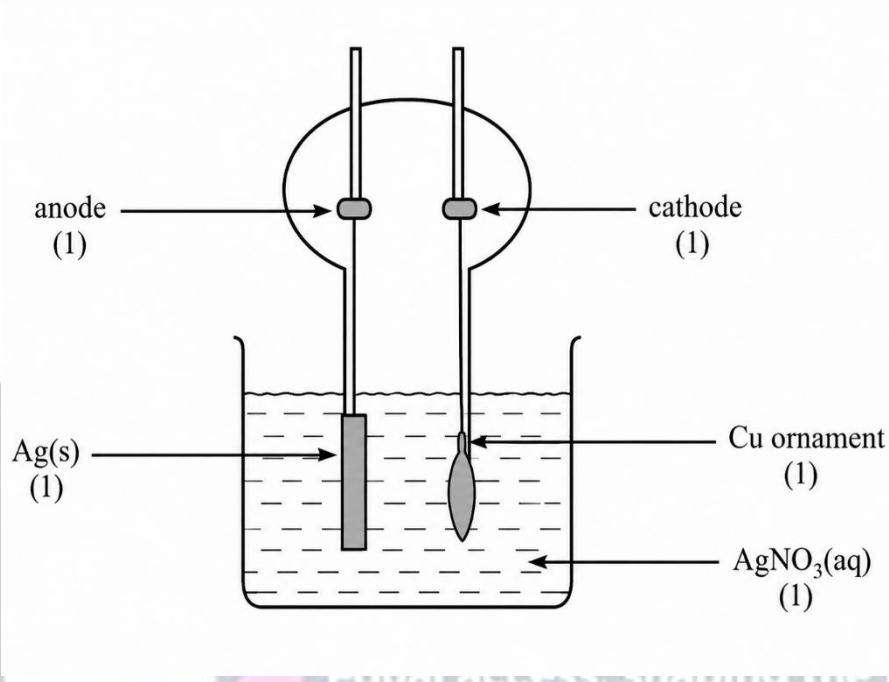
(Any 2 × 1 = 2 marks)

(c)(i) Hydrocarbons are compounds containing only hydrogen and carbon

(ii)

Coal

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Petroleum/crude oil

Natural gas

(Any 2 × 1 = 2 marks; [NB: Fossil fuel scores only 1 mark])

(d) SEE DIAGRAM

(Anode, Cathode, Cu ornament, $AgNO_3(aq)$ labels — 5 marks)

[TOTAL QUESTION 2 = 25 MARKS]

Question 3

(a)(i) $2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

(ii) Amount of KOH used = 24/1000 × 0.150 = 0.0036 mol

Mole ratio of acid to base = 1 : 2

Amount of H_2SO_4 used = 0.0036/2 = 0.0018 mol

∴ Concentration of H_2SO_4 = 0.0018/0.025 = 0.072 mol dm^{-3}

Alternative method:

$C_aV_a/C_bV_b = 1/2$

$C_a \times 25 / (0.150 \times 24) = 1/2$

$C_a = (0.150 \times 24)/(2 \times 25)$

∴ C_a = 0.072 mol dm^{-3}

(b)(i)

I. $2Mg(s) + CO_2(g) \rightarrow 2MgO(s) + C(s)$

II. The heat of the reaction is high enough to decompose CO_2 (1) to produce oxygen which then reacts with magnesium to form magnesium oxide (1)

(ii) Molar mass of $Mg(NO_3)_2$ = 24 + 2×[14+(3×16)] = 148 g mol^{-1}

Mass of N_2 = 2 × 14 = 28

% Nitrogen = 28/148 × 100 = 18.9%

(iii) C = 83.0%

%H_2 = 100 − 83 = 17%

	Carbon	**Hydrogen**
	83.0/12	17.0/1
	6.92	17.0
	6.92/6.92	17.0/6.92
	1	2.46 ≅ 2.5

(Multiply through by 2)

Empirical formula = C_2H_5

(d) SEE DIAGRAM

[TOTAL QUESTION 2 = 25 MARKS] (as printed — likely a typo for Question 3)

Question 4

(a)(i)

I. graphite — hexagonal

II. diamond — tetrahedral/octahedral

(b) (continues into the next question's page — see below, appears out of sequence in the marking scheme's own layout)

(c)(i)

reaction with bromine in CCl_4/bromine water/$H^+/KMnO_4$/$H^+/K_2Cr_2O_7$

reaction with aqueous $NaHCO_3$/Na_2CO_3 (1) OR reaction with alkanol + Conc. H_2SO_4

(ii)

compound will decolourise bromine in CCl_4/bromine water

change $H^+/K_2Cr_2O_7$ from orange to green

change $H^+/KMnO_4$ from purple to colourless

(Any 1 × 1 = 1 mark)

there will be effervescence/evolution of gas in reaction with $NaHCO_3$(aq)

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production of sweet-smelling/fruity odour

(reaction and observation must correspond to score)

[4 marks]

(d) add sufficient water to dissolve the pellets of NaOH (1); the solution is then added to the vegetable oil (1), stirred and boiled (1). It is cooled to precipitate the soap/salt-out the salt (1). Filter off the soap/take off the soap crust (1)

[5 marks]

(e) The tendency of an atom to pull to itself the shared pair of electrons in a covalent bond / The ability of an atom to attract shared electrons between it and another atom in a chemical bond.

(2 or 0)

[2 marks]

(ii) In diamond, each carbon atom is covalently bonded to four other carbon atoms forming an interlocking three-dimensional network hence the hardness. (1) Each of the four valence electrons is localized in a covalent bond hence there are no free/mobile electrons (1) while in graphite each carbon atom is bonded to three other carbon atoms forming large sheets (1) with van der Waal's force between the sheets (1) which can easily slide over one another. One of the valence electrons of each atom is delocalized in a covalent bond and can act as a conduction electron (1)

[7 marks]

OR

Diamond is hard because it has a rigid/three dimensional structure (1). It has no free/mobile electrons (1) hence it does not conduct electricity. Graphite has layered structure (1) held together by weak van der Waal's forces (1) hence it is soft. It conducts electricity because it has free/mobile electron (1)

(b)(i)

I. aeration — removes odour/kill bacteria (1)

II. screening — removal of large debris (1)

III. sedimentation — removal of suspended dirt particles after coagulation (1)

[3 marks]

(ii)

Calcium hydrogen trioxocarbonate(IV)

Magnesium hydrogen trioxocarbonate(IV)

Magnesium chloride

Magnesium tetraoxosulphate(VI)

Calcium tetraoxosulphate(VI)

Iron(II) hydrogen trioxocarbonate(IV)

Calcium Chloride

Iron(II) chloride

Iron(II) tetraoxosulphate(VI)

[2 marks]

(iii)

by adding washing soda (Na_2CO_3)

adding $Ca(OH)_2$/Slaked lime

using ion-exchange resin/permutit/Zeolite

boiling/Distillation

(Accept formula; Any 2 × 1 = 2 marks)

(iv)

furring of kettle/pipes causes blockage leading to power wastage/scales in boilers

soap is wasted/forms scums

cannot be used in dyeing/tanning

cannot be used in paper manufacturing

not suitable for laundry

not suitable for textile industry

(Any 1 × 1 = 1 mark)

[8 marks]

(c)(i) the ore is concentrated/crushed and washed with water (1), it is then roasted in air (1) to remove impurities. The product is mixed with charcoal/carbon/coke (1) and heated (1) to reduce the oxide. It is then refined to obtain pure tin.

[4 marks]

(ii) $SnO_2(s) + 2C(s) \rightarrow Sn(l) + 2CO(g)$

(2/0)

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(iii)

I. $Sn(s) + O_2(g) \rightarrow SnO_2(s)$

(reactant and product (1), balancing (1))

II. $Sn(s) + 2Cl_2(g) \rightarrow SnCl_4(s)$

(reactant and product (1), balancing (1))

[10 marks]

[TOTAL QUESTION 4 = 25 MARKS]

Question 5

(a)(i) Aluminium first reacts with oxygen in the air (1) to form a film of oxide/oxide layer is formed on the surface

$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

(reactant and product (1), balancing (1))

The film of oxide formed is not porous and insoluble in water (in the air) (1) and hence protects the metal underneath from further attack / The film of oxide coats the metal (1) and prevents it from further attack (1)

[5 marks]

(ii)

I. — aqueous sodium hydroxide/caustic soda solution/$NaOH(aq)$ (1)

II. — cryolite/Na_3AlF_6 (1)

— Alumina/Al_2O_3 (1)

[3 marks]

[TOTAL: 8 marks]

(b) $ZnO(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2O(l)$ (2)

$ZnO(s) + 2NaOH(aq) \rightarrow Na_2ZnO_2(aq) + H_2O(l)$ (2)

(accept any correct acid or alkaline)

[4 marks]

(c)(i)

glass production

water treatment/softening hard water

production of soaps and detergents

paper production

production/preparation of $NaHCO_3$

preparation of baking powder

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removal of sulphur(IV) oxide in power stations

as a standard alkali in acid-base titration

as an analytical reagent

production of rayon polymer

as a household cleaning agent/in laundry

as food additive

use in textile industry

in petroleum refining

manufacture of other sodium compounds

(Any 3 × 1 = 3 marks)

(ii) The yellowish colour is caused by dissolved nitrogen(IV) oxide (1)

which results from the slow decomposition of the acid (1)

[2 marks]

(iii) To the solution, add freshly prepared Iron(II)

tetraoxosulphate(VI) solution (1) and follow by Conc. H_2SO_4 (1) /

warm the solid (1) with (copper turnings and Conc. H_2SO_4 (1) in a

test tube. Brown fumes are observed.

[3 marks]

[8 marks]

(d)(i)

I. $H_2SO_4(aq) + 2NaCl(s) \rightarrow 2HCl(g) + Na_2SO_4(aq)$ / $H_2SO_4 + 2KCl \rightarrow 2HCl(g) + K_2SO_4(aq)$

(2/0)

II. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

(2/0)

(ii)

manufacturing of drug

cleaning

pickling

electroplating metals

tanning leather

refining

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production of CH_3Cl/PVC/plastics

(Any 1 × 1 = 1 mark)

[5 marks]

[TOTAL QUESTION 5 = 25 MARKS]

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WAEC/WASSCE JUNE 2022 CHEMISTRY

ESSAY/THEORY ANSWERS

SECTION A

Answer all the questions in this section

Question 1

(b) Is the addition of NaCl (1) to the reaction mixture (1) in soap production to facilitate the precipitation of soap (1) from the mixture

[3 marks]

(c) Reagent — $AgNO_3$ in $NH_3(aq)$ / Ammoniacal silver trioxonitrate (V) (1)

Condition — heat (1)

[2 marks]

(d) Is the fraction of a given isotope (1) in a mixture of isotopes of the same element (1)

OR

The % of an isotope with a specific atomic mass (1) found in a naturally occurring sample of an element (1)

[2 marks]

(e)(i) Because the element is/has:

unreactive

stable

inert

a noble gas

completely filled outermost shell

[Any 2 × 1 = 2 marks]

(ii) Because of weak forces between the molecules (1) hence not much heat (1) is needed to break the forces (1)

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(3 marks)

[5 marks]

(f) - (Conc) HNO_3 produces brown fumes (1) (of NO_2) when copper turnings are added (1) to it / copper (II) salt is added but H_2SO_4 will not react with the copper turning / copper (II) salt (1).

When Conc. H_2SO_4 is added to sugar (1) it chars (1) the sugar but Conc. HNO_3 will not (1)

Add $BaCl_2$ solution to each acid (1); white precipitate indicates H_2SO_4 (1); no precipitate indicates HNO_3 (1)

[Any 1 × 3 = 3 marks]

(g) Differences between Electrochemical cell and Electrolytic cell:

Electrochemical cell:

The anode is negative / cathode is positive

Chemical energy is converted to electrical energy

The two half cells are in separate containers and connected by a salt bridge

Reaction is spontaneous

Current is generated from within the cell

Electrolytic cell:

Anode is positive / cathode is negative

Electrical energy is converted to chemical energy

The two half cells are in the same container

Non-spontaneous

Current is generated from external source / battery

[Any 2 × 1 = 2 marks] (differences must correspond to score)

(h) Group 1 elements react by forming positive ions (1); the higher the ionization energy, the more difficult it is to lose the electron (1) hence the lower the reactivity of the elements (1)

OR

Ionization energy decreases down group 1 elements (1); the lower the ionization energy, the easier to lose an electron (1) hence the higher the reactivity (1) of the elements

[3 marks]

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(i) Molecular formula shows the actual number of atoms of each element in a molecule

(2 or 0)

(j)(i) NH_3 will deviate more (1)

(ii) Because it has a larger volume (1) and also it has a stronger intermolecular forces (1)

[3 marks]

[Total Question 1 = 25 marks]

SECTION B

Answer three questions only from this section

Question 2

(a)(i) Is the energy required to remove one electron from a mole of a gaseous atom

OR

Is the minimum energy required to convert one mole of a gas of atom into one mole of a gaseous plus 1 ions

(2 or 0)

(ii) $_4Be : 1s^2\ 2s^2$ (1)

$_5B : 1s^2\ 2s^2\ 2p^1$ (1)

The electron to be removed from Be is in the 2s orbital which is closer to the nucleus (1); nuclear attraction is greater (1) hence first ionization energy is greater. But the electron to be removed from B is in the 2p orbital which is farther away from the nucleus (1), hence nuclear attraction is weaker (1) hence first ionization energy is smaller.

OR

2p has less energy than 2s (1)

So it is easier to remove an electron from 2p (1) as the nuclear charge is weaker in 2p (1) because 2p is further away from the nucleus (1). Hence, first ionization energy is small.

(4 marks)

[8 marks]

(b) Q = It (1)

Q = 0.12 × 500 (1)

= 60 C

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96500 C ≡ 1 F

60 C liberates 0.015 g

∴ 96500 will liberate (96500 × 0.015) / 60 (1)

= 24 g (1)

n(Ti) = m/M

= 24/48

= 0.5 mol (1)

1 F ≡ 0.5 mol

∴ 2F ≡ 1 mol

hence charge = +2 (1)

[6 marks]

Alternative A

Q = It (1)

= 0.12 × 500 (1)

= 60 C

0.015 g of Ti is deposited by 60 C

∴ 48 g will be deposited by (60/0.015) × 48 (1)

= 192000 C

96500 C ≡ 1 mole of electron (1)

∴ 192000 C = (1/96500) × 192 (1)

= 1.989

≅ 2.0 moles of electron

∴ charge on Ti ion is +2 (1)

Alternative B

m = It

M nF

n = MIt (1)

mF

= (48 × 0.12 × 500) (2)

(0.015 × 96500)

≅ 1.989 ≅ 2 (1)

∴ Charge on Ti ion is +2 (1)

(c)(i) Alumina (Al_2O_3) mixed with molten cryolite (Na_3AlF_6)

(Accept name or formula)

(2 / 0)

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(ii) - Abundant deposits of bauxite (1)

Cheap source of electricity (1)

(2 marks)

[4 marks]

(d)(i) Is the ability of a substance to be attracted strongly into a magnetic field

(2 or 0)

(ii) I. $_{24}Cr^{2+}$ — $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 3d^4$

unpaired electrons = 4 (1)

$_{24}Cr^{6+}$ — $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

unpaired electrons = 0 (1)

II. $_{24}Cr^{2+}$ (1)

III. The greater the number of unpaired electrons in the 3d-orbital (1), the greater the paramagnetism (1)

[7 marks]

[Total Question 2 = 25 marks]

Question 3

(a)(i) Number of particles (atoms, molecules, ions etc) present in one mole of a substance

OR

Number of particles present in 12.0 g of carbon – 12

(2 or 0)

(ii) n = N/L (1)

moles of X = $(3.01 \times 10^{22}) / (6.02 \times 10^{23})$ (1)

= 0.05

but no. of moles = 2.30 g / Molar mass (1)

or Molar mass = 2.30 g / No. of moles (1)

= 2.30 / 0.05 (1)

= 46 g (1)

Alternative

3.0×10^{22} molecules has a mass of 2.30 g (1)

1 mole of a substance contains = 6.02×10^{23} molecules (1)

∴ 6.02×10^{23} has a mass of $(2.30 \times 6.02 \times 10^{23}) / (3.0 \times 10^{22})$ (2)

= 46 g mol^{-1} (1)

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(iii) Let N_xO_y be the formula of the oxide

or $14x + 16y = 46$

$\therefore x = 1, y = 2$

i.e. $14(1) + 16(2) = 46$ (1)

$\therefore$ formula of x = NO_2 (1)

[9 marks]

(b)(i) I. Two layers are formed / no reaction / immiscible (1)

II. There is a reaction / hydrolysis (1) with steamy fumes / white fumes (1)

(3 marks)

(ii) The reaction occurs by interaction of the lone pair of electrons of water binding to the central atom (1) (silicon or carbon) / attaching to the central atom

In silicon, the 3d-orbital is available to accept the pairs of electrons (1) but in carbon there is no vacant orbitals for bonding (1)

OR

Water is polar (1) hence the reaction with $SiCl_4$ (1). But CCl_4 is non-polar (1) hence there is no reaction

(3 marks)

[6 marks]

(c)(i) - Purification of metals / copper

Electroplating

Extraction of copper

[Any 1 × 1 = 1 mark]

(ii) - $CuSO_4$

$Cu(NO_3)_2$

$CuCl_2(aq)$

[Any 2 × 1 = 2 marks] (Accept the IUPAC names)

(iii) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-(aq)$

(2 or 0)

(iv) m = ZIt (1)

t = 3 mins 13 sec = 193 sec (1)

Z = m/(It)

= 3.2 / (50 × 193) (1)

= 3.32×10^{-4} (1) g/C (1)

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(5 marks)

[10 marks]

[Total Question 3 = 25 marks]

Question 4

(a)(i) Temperature: 350 – 500°C / high temperature

Pressure: 150 – 1000 atm / high pressure

Catalyst: (Finely divided) Iron

[Any 2 × 1 = 2 marks]

(ii) Rate of the reaction increases (1) as particles are closer together / more particles per unit volume (1). There are more collisions per second / collisions are more often (1)

(3 marks)

[5 marks]

(b)(i) $4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$

(2 or 0)

(ii) $2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$

A mixture of two acids will be produced (1)

(2 or 0)

(iii) $4HNO_3(aq) \rightarrow 4NO_2(g) + O_2(g) + 2H_2O(l)$ (2)

I. Oxygen is neutral while NO_2 is acidic (1) / The pH of O_2 is 7 while the pH of NO_2 is less than 7.

II. NO_2 is soluble while O_2 is sparingly soluble in water (1)

III. O_2 reacts with CO to form CO_2 while NO_2 reacts with CO to form a mixture of N_2 and CO_2 (1)

[10 marks]

[Comparison of the two gases must be correct to score the mark]

(c)(i) - Sulphur (IV) oxide (1)

Sulphur (VI) oxide (1)

(ii) $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ (2)

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$ (2)

[6 marks]

(d)(i) - Calcium oxide

Quick lime

[Any 1 × 1 = 1 mark]

(ii) - Calcium trioxocarbonate (IV)

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Limestone

Calcium oxide

Quick lime

[Any 1 × 1 = 1 mark]

(iii) - Calcium tetraoxosulphate (VI)

Calcium hydrogen trioxocarbonate (IV)

Calcium chloride

[Any 1 × 1 = 1 mark]

(iv) Calcium tetraoxosulphate (VI) (dihydrate) (1)

[4 marks]

[Total Question 4 = 25 marks]

Question 5

(a)(i) Its colour darkens from pale yellow to amber (1) colour while its crystals become needle-like (1) and at 119°C it begins to melt (1)

[3 marks]

(ii) The solution turns green (1), bubbles of colourless gas rise from the bottom of the mixture, but brown fumes of NO_2 (1) are produced and the solution later turns blue (1)

(3 marks)

[6 marks]

(b)(i) - SO_2

NO_2

CO

CO_2

H_2S

(Accept IUPAC name)

[Any 2 × 1 = 2 marks]

(ii) Methane (CH_4)

(1 mark)

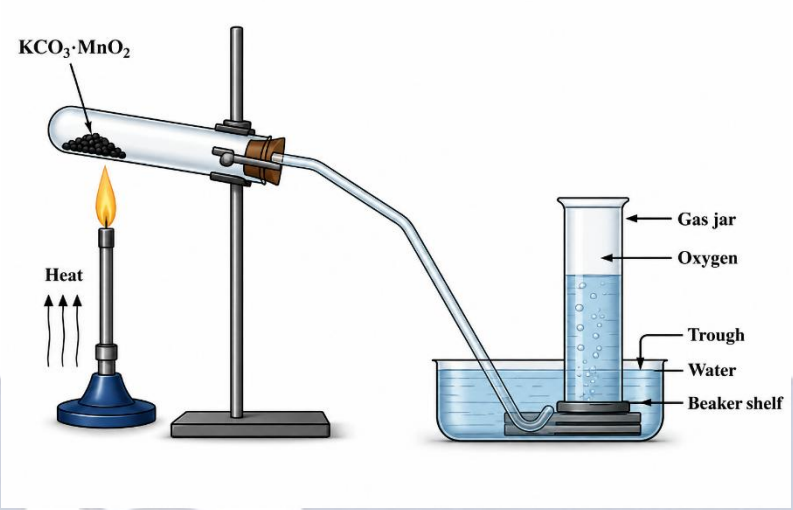
(iii) - Contamination of soil

Contamination of ground water

Soil erosion

Loss of biodiversity

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Formation of sink holes

[Any 2 × 1 = 2 marks]

(iv) Because of the large surface area (1) and the higher the area the faster the rate of reaction (1)

(v) Coke (1)

[8 marks]

(c)(i) The sample is added to anhydrous copper (II) tetraoxosulphate (VI) (1) when it turns from white to blue (1) confirms the presence of water / sample is added to anhydrous cobalt chloride / cobalt chloride paper when it turns from blue to pink indicates the presence of water.

(2 marks)

(ii) I. It softens temporary hard water (1)

II. To remove permanent hardness / soften hard water (1)

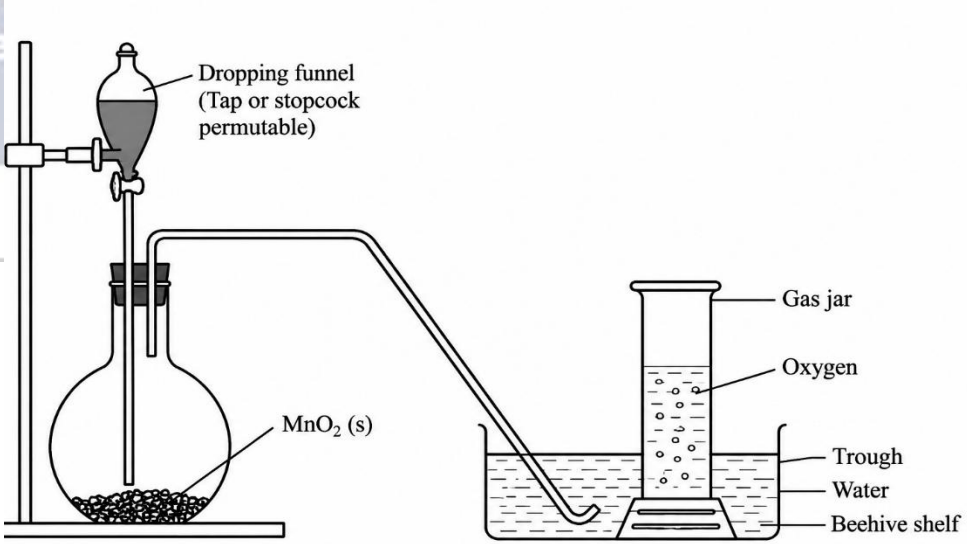
(iii) - $Ca(HCO_3)_2$ —heat→ $CaCO_3 + CO_2 + H_2O$

$Mg(HCO_3)_2$ —heat→ $MgCO_3 + CO_2 + H_2O$

[Any 1 × 2 = 2 marks]

[6 marks]

(d) SEE DIAGRAM



Pour hydrogen peroxide into a conical flask (1) containing some manganese (IV) oxide (1); the gas produced is collected in an upside-down gas jar filled with water (1)

OR

SEE DIAGRAM

Powdered $KClO_3$ and MnO_2 are placed in a conical flask (1). Mixture is heated (1) gently. Collect gas produced over water (1) in a gas jar

[1 mark for workability, 1 mark for two labelling]

[5 marks]

[Total Question 5 = 25 marks]

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ESSAY/THEORY ANSWERS

QUESTION 1

(a) A transition element has incompletely filled d-orbitals. [2 marks]

(b) (i) B (1)

(ii) C (1)

(Do not accept name or symbol of the element) [2 marks]

(c) Across a period (from left to right) there is a gradual increase in the number of protons in the nucleus/effective nuclear charge (1). This increases the force of attraction between the nucleus and the electrons (1), hence more energy is needed to remove the outermost electron. [2 marks]

(d) methane, ethene, ethyne, ethanol, ethanoic acid (accept any two correct aliphatic compounds) — Any 2×1 = 2 marks

(e) Alkanols are formed by replacing one hydrogen of water by an alkyl group (1); Alkyl groups have a positive inductive effect/are electron releasing/electron donating (1); This increases the electron density of the oxygen (1). — 3×1 = 3 marks

(f) NaCl, $CaCO_3$, NH_3, C (accept names) — Any 3×1 = 3 marks

(g) Geometric isomerism is the existence of two compounds with the same molecular formula (1) but differ in the arrangement of groups attached to the carbon containing the double bond (1). [2 marks]

(h) This is because constituents of water gas (CO and H_2) are both combustible (1) and give a higher calorific/heat value (1) than producer gas. [2 marks]

(i) It is defined as the heat change/released when 1 mole of a substance is burnt in excess oxygen. OR: It is defined as the heat change/released when 1 mole of a substance is completely burnt in air. (2 or 0)

(j) (i) When the same quantity of electricity is passed through different electrolytes, the relative number of moles of the elements

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discharged are inversely proportional to the charges on the ions of the element. (2 or 0)

(ii) 96,500 C liberates 1.0 mol of Ag(s) (1)

∴ 10,920 C will liberate = 10,920/96,500 = 0.113 mole (1) [5 marks]

[Total Question 1 = 25 marks]

Question 2

(a) (i) $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ (2)

(ii) Concentration of NaOH (C_β):

$C_\beta = 4/40 = 0.1$ mol dm^{-3} (1)

$C_aV_a/C_\beta V_\beta = 1/2$

$C_a \times 8/(0.1 \times 20) = 1/2$ (1)

$C_a = (0.1 \times 20 \times 1)/(2 \times 8)$ (1)

$= 0.125$ mol dm^{-3} (1) [6 marks]

Alternative method:

$C_\beta = 4/40 = 0.1$ mol dm^{-3} (1)

$V_\beta = 20/1000 = 0.02$ dm^3

$n_\beta = 0.1 \times 0.02 = 0.002$ mol (1)

$\therefore n_a = 0.002/2 = 0.001$ mol

8 cm^3 of acid ≡ 0.001 mol

∴ 1000 cm^3 = (0.001/8)×1000 (1)

$= 0.125$ mol dm^{-3} (1)

(b) (i) The volume of a gas is negligible compared to the total volume of the container (1). There are no forces of attraction or repulsion between molecules of the gas / collision between molecules are elastic (1). [2 marks]

(ii) The volume of a gas is not negligible (1) because at high pressure the molecules occupy volume (1) which is appreciable, and at low temperature the intermolecular forces of attraction and repulsion become significant (1). [4 marks] [6 marks]

(c) (i) Glucose (1)

(ii) Fructose (1); Galactose (1)

(iii) hydrolysis (1)

(iv) $2(C_6H_{10}O_5)n + nH_2O \rightarrow nC_{12}H_{22}O_{11}$ (2)

$C_{12}H_{22}O_{11} + H_2O \rightarrow 2C_6H_{12}O_6$ (2)

(v) maltase (1); diastase (1) [10 marks]

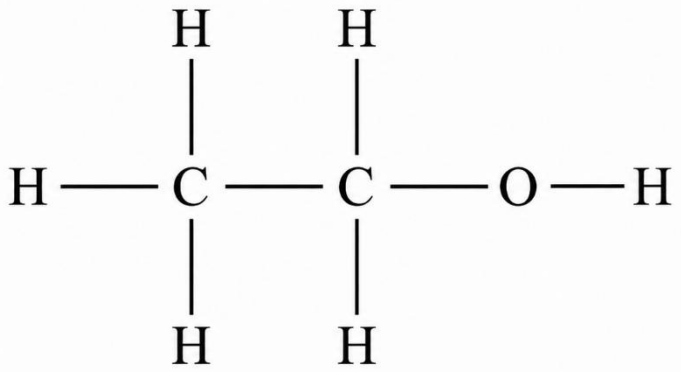
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(d) Is the existence of compounds (1) with the same molecular formula (1) but different structural formulae/arrangement of the atoms/linkage of the atoms (1). [3 marks]

[Total Question 2 = 25 marks]

(iii) I. Hydroxyl (1)

II.



Question 3

(a) (i) %O = 100 − (52.2 + 13.1) = 34.7 (1)

(b)

	C	H	O
%	52.2	13.1	34.7
÷ atomic mass	12	1	16
=	4.35	13.1	2.168
÷ smallest (2.168)	2.00	6.04	1

(1 mark each step)

Empirical formula = C_2H_6O (1)

(ii) 2 × vapour density = molecular mass

2 × 23 = 46 (1)

$(C_2H_6O)n = 46$ (1)

$[(12\times2)+(1\times6)+16]n = 46$

46n = 46

n = 1 (1)

∴ Molecular formula = C_2H_6O (1)

(iii) I. Hydroxyl (1)

II. SEE DIAGRAM (structural formula of ethanol: H–C–C–O–H with hydrogens attached to both carbons) (1)

(Accept -OH) [10 marks]

(b) $2(C_6H_{10}O_5)n + nH_2O$ —diastase→ $nC_{12}H_{22}O_{11}$ (2)

$C_{12}H_{22}O_{11} + H_2O$ —maltase→ $C_6H_{12}O_6 + C_6H_{12}O_6$ (2)

$C_6H_{12}O_6$ —zymase→ $2C_2H_5OH + 2CO_2$ (2) [6 marks]

(c) (i) The reaction starts but the metal produces a layer of an oxide/aluminium oxide layer (1) on its surface which is impermeable (to water) and stops the reaction (1). [2 marks]

(ii) Add dilute hydrochloric acid (1) to excess aluminium (1); filter off the excess metal (1); leave filtrate in a warm place/evaporate filtrate to point of crystallization/leave in the sun (1). [4 marks] [6 marks]

(d) The flask is connected to condenser and the solution is heated (1). The water vaporizes (1) and is converted to (liquid) water (1) in the condenser. [3 marks]

[Total Question 3 = 25 marks]

Question 4

(a) Water is added to $CaCl_2$ (1) to form a solution (1). Na_2CO_3 is then added to the solution (1) to precipitate $CaCO_3$ (1) which is filtered, washed and dried (1). [5 marks]

(b) Electricity is passed through a solution of $CuSO_4$ (1) using an impure copper as the anode (1) and pure copper as the cathode (1). During electrolysis, the anode loses mass as copper dissolves (1) and the cathode gains mass as copper is deposited (1).

Anode: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ (1)

Cathode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ (1) [7 marks]

(c) (i) $Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$ (2)

(ii) — blue solution

— (reddish) brown gas

— gas bubbles/effervescence

— metal dissolves/metal disappears

Any 2×1 = 2 marks

(iii) Because copper loses electrons/oxidation number increases (1)

(iv) Moles of acid = 0.025 × 16 = 0.4 mole (1)

Moles of NO_2 = moles of acid/2 = 0.2 mole (1)

Volume of gas (NO_2) at s.t.p. = 0.2 × 22.4 dm^3 = 4.48 dm^3 (1)

Alternative:

$C_1V_1 = C_2V_2$

$16.0 \times 25 = C_2 \times 1000$

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C_2 = (16.0×25)/1000 = 0.40 mol (1)

4 mol HNO_3 = 63g Cu

0.4 mol = 6.3g Cu

63g Cu = 2×22.4 dm^3 NO_2 (1)

6.3g Cu = (44.8/63)×6.3 (1) = 4.48 dm^3 (1) [9 marks]

(d) (i) Pure HNO_3 undergoes decomposition to NO_2 (brown gas) (1). This gas dissolves (1) in the rest of the acid, leaving it with that colour. [2 marks]

(ii) — $2KNO_3 + H_2SO_4 \rightarrow K_2SO_4 + 2HNO_3$

— $NaNO_3 + H_2SO_4 \rightarrow NaHSO_4 + HNO_3$

— $2NaNO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2HNO_3$

— $KNO_3 + H_2SO_4 \rightarrow KHSO_4 + HNO_3$

Any 1×2 [4 marks]

[Total Question 4 = 25 marks]

Question 5

(a) (i) Iron dissolves (1) readily in dilute H_2SO_4 liberating hydrogen (1) and forming $FeSO_4$ (1), while with Aluminium there is no reaction (1). [4 marks]

(ii) With aluminium there is no reaction (1), while iron dissolves (1) in dilute HNO_3 liberating hydrogen (1) and forming $Fe(NO_3)_2$ (1). [4 marks] [8 marks]

(b) (i) $S + O_2 \rightarrow SO_2$ (1)

(ii) Vanadium (V) oxide/platinized asbestos (1)

(iii) To favour the formation of more product/SO_3 (1)

(iv) The reaction is exothermic/high temperature favours the formation of more reactants/backward reaction (1)

(v) Catalysts are easily poisoned/easily damaged by dirt (1)

(vi) — SO_2 damages buildings

— damages living things

— causes acid rain

— causes irritation to eyes, nose and throat

— causes lungs and respiratory diseases e.g. coughing, bronchitis etc.

Any 2×1 = 2 marks [7 marks]

(c) (i) reagents — manganese (IV) oxide/MnO_2 (1); concentrated HCl (1)

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condition — heating (1)

OR

Concentrated HCl (1)

Bleaching powder/$CaOCl_2$/$KMnO_4$ crystals (1)

Room temperature (1)/heat is not required [3 marks]

(ii) — for bleaching wood pulp and textiles

— for production of plastics

— for recovering of tin from its ore/extraction of tin

— as a germicide and disinfectant/insecticide/in swimming pools

— to sterilize/purification of water supply

— for commercial manufacture of HCl

— production of dyes and drugs

— manufacture of solvents e.g. CCl_4, $CHCl_3$

Any 2×1 = 2 marks

(d) (i) I. Hydrogen — fused calcium chloride/conc. tetraoxosulphate (VI) acid (1)

II. Sulphur (IV) oxide — concentrated tetraoxosulphate (VI) acid/anhydrous Calcium chloride (1)

III. Ammonia — calcium oxide/quick lime/silica gel (1)

(Do not accept chemical formula) [3 marks]

(ii) I. Bronze — copper + tin (1)

II. Brass — copper + zinc (1)

(both components must be correct to score) [2 marks] [5 marks]

[Total Question 5 = 25 marks]

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ESSAY/THEORY ANSWERS

SECTION A — Answer all the questions in this section

Question 1

(a) A device for converting chemical energy to electrical energy / A device that uses a chemical/redox reaction to generate electrical current. [2 marks]

(b) comparison table, reproduced below:

Electrochemical cell	**Electrolytic cell**
Chemical reaction produces electricity	Electric current/electricity is used to produce chemical reaction
Electrons are produced as a result of oxidation at anode	Electrons are consumed as a result of reduction at the cathode
Cathode is the positive electrode	Cathode is the negative electrode
Anode is the negative electrode	Anode is the positive electrode
Electrodes are in separate compartments/contain two half cells/contain a salt bridge	Electrodes are in the same compartment/only one compartment/No salt bridge
Does not require an external source of energy/spontaneous	Requires external source of energy/non-spontaneous

(Differences must correspond to score) [Any 3 points]

(c) Colour changes from blue to colourless, a brown deposit is observed. [3 marks]

(d)(i) $Zn(s) + CuSO_4(aq) \rightarrow Cu(s) + ZnSO_4(aq)$ [2 marks]

(d)(ii) Displacement/Redox reaction [1 mark]

(e) [Any 2 points]

Chlorine

Sulphur (IV) oxide

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Hydrogen sulphide

Ammonia

Question 1 (continued)

(f) [3×1=3 marks]

high temperature

high pressure

catalyst

(g) The noble gases are chemically inert because their outermost shells/valency shells are completely filled. [2 marks]

(h) [Any 4×1=4 marks]

A member differs from the preceding/successive member by $-CH_2$/14amu

Members conform to a general formula

Members have similar chemical properties

Members have similar methods of preparation

There is a gradual change in physical properties as the molar mass increases

Members have same functional group

(i) Global warming is an increase in the earth's surface temperature / Increase in the temperature of the atmosphere due to trapping of heat by greenhouse gases. [2 marks]

(j) [Any 1×1=1 mark]

burning of fossil fuels

cutting down forest / deforestation

excess CO_2

using transportation

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SECTION B — Answer three questions from this section

Question 2

(a)(i)(I) Deliquescence — This is the phenomenon of a substance absorbing water vapour from the atmosphere resulting in the formation of a solution. [2 or 0 marks]

(I) Efflorescence — This refers to the phenomenon of a substance to give off its water of crystallization when exposed to the atmosphere. [2 or 0 marks]

(ii) Example of deliquescence: $MgCl_2$, NaOH, $FeCl_3$, KOH, P_2O_5, $Ca(NO_3)_2$ [Any 1]

Example of efflorescence: $Na_2CO_3.10H_2O$, $CuSO_4.5H_2O$, $FeSO_4.7H_2O$, $ZnSO_4.7H_2O$, $Cu(NO_3)_2.3H_2O$, $MgSO_4.7H_2O$, $Zn(NO_3)_2.6H_2O$ [Any 1]

(b)(i) This is the energy required to remove one mole of electrons from the valence shell of an isolated/gaseous atom to form one mole of an isolated gaseous cation.

OR: The energy required to remove an electron from an isolated gaseous atom. [2 or 0 marks]

(b)(ii) The first ionization energy removes the valence electron from an isolated/gaseous sodium atom (1), the remaining electrons are more strongly attracted to same number of protons in the nucleus (1) and therefore more energy is required to remove the second electron (1). [3 marks]

(c)(i) Charle's law states that the volume of a fixed mass of a gas at constant pressure is directly proportional to its absolute temperature. [2 or 0 marks]

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(c)(ii) Two graphs: Volume (cm^3) vs Temperature (°C), showing a line extrapolated back to −273°C on the x-axis (labelled "Shape = 1, Axes = 1, Abs. Zero = 1" for marking); and Volume vs Temperature (K), a line through the origin. [3 marks]

(c)(iii) Given: V1 = 150cm^3, T1 = 21°C = (21+273) = 294K, T2 = 45°C = (45+273) = 318K, V2 = ?

At constant pressure, V1/T1 = V2/T2

V2 = (V1 × T2)/T1

V2 = (150 × 318)/294

V2 = 162.24 cm^3 (1 mark)

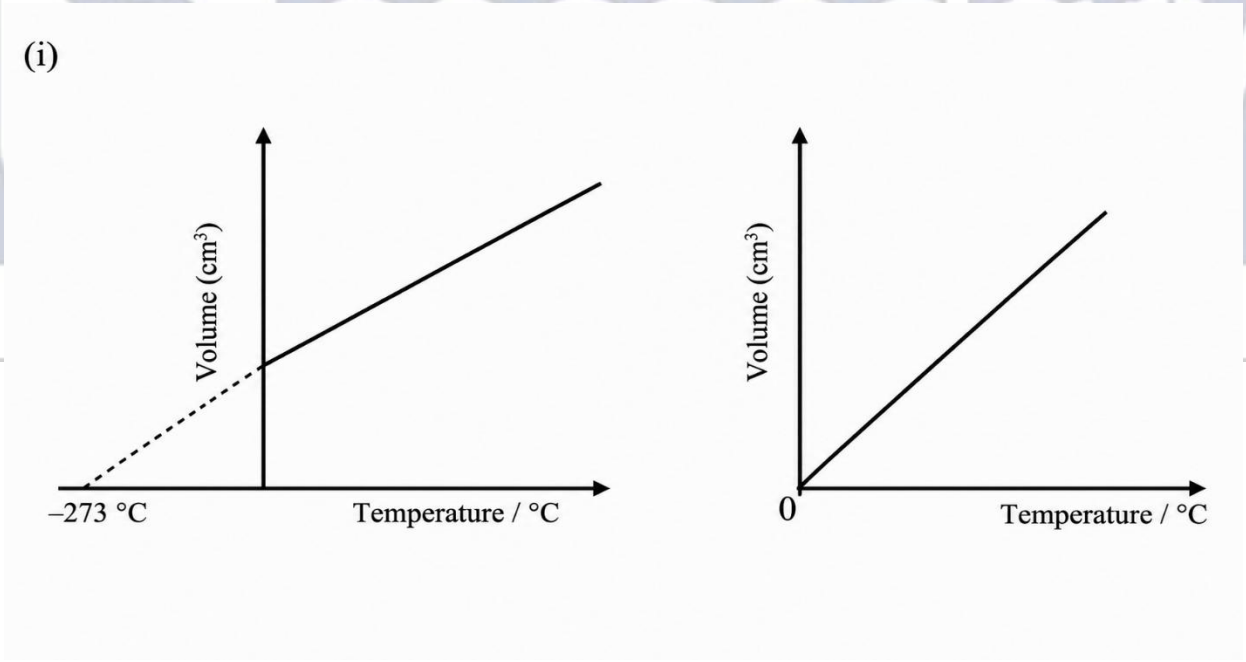
(d)(i)

(I) $Na_2O + H_2O \rightarrow 2NaOH$ (1)

(II) $P_2O_3 + 3H_2O \rightarrow 2H_3PO_3$ / $P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$ (1)

(III) $Cl_2O_7 + H_2O \rightarrow 2HClO_4$ (1)

(IV) $MgO + H_2O \rightarrow Mg(OH)_2$ (1)



(Continues onto the next question's page — properties list appears there, part of a later sub-question, likely (b)(iii) of a gas properties question)

(iii) Properties listed:

colourless

odourless

less dense than air

gas at room temperature

insoluble in water

(c)(i) basic

(c)(ii) Amphoteric

(c)(iii) acidic

(c)(iv) acidic

(c)(v) neutral

[Any 2 points = 2 marks]

(5 marks)

[Total Question 4 = 25 marks]

(Note: the acidity/basicity list above and the $NaOH \rightarrow Mg(OH)_2 \rightarrow H_3PO_3 \rightarrow HClO_4$ acidity ordering appear to belong to Question 4, not Question 2 — the scanned pages show this content is out of sequence relative to the page numbering. I've kept it grouped as it physically appeared in the images.)

(a) (continuing sequence) $NaOH \rightarrow Mg(OH)_2 \rightarrow H_3PO_3 \rightarrow HClO_4$, increasing acidity [1 mark]

[Total Question 2 = 25 marks]

Question 3

(a)(i)

(I) $Pb + Cl_2 \rightarrow PbCl_2$ (2 marks)

(II) $Pb(NO_3)_2 + 2NaCl \rightarrow PbCl_2 + 2NaNO_3$ (Do not accept AgCl and $HgCl_2$, reaction should be between $Pb(NO_3)_2$ and a soluble chloride) (2 marks)

(III) $Pb + 2HCl \rightarrow PbCl_2 + H_2$ (2 marks)

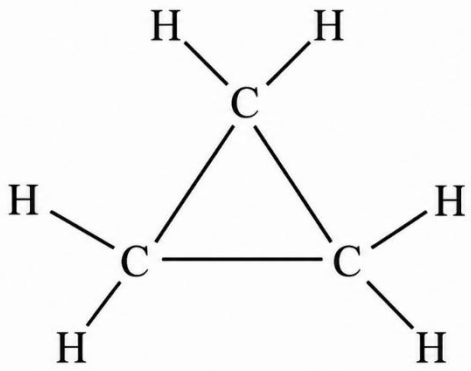
(a)(ii)

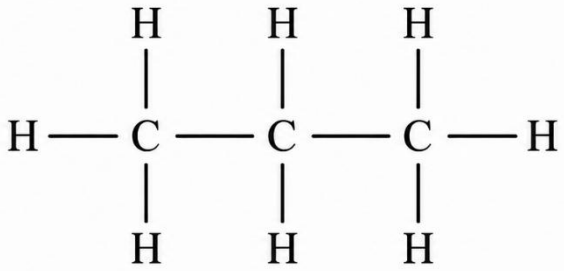
(I) increasing the surface area of lead / using powdered lead (1 mark)

(II) increasing temperature / increasing concentration of reactant (1 mark)

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(c)





[1 mark]

(III) increasing the concentration of HCl / increasing surface area of lead / increasing the temperature (1 mark)

(b)(i) [Any 2 points = 2 marks]

Removing the products/SO_3 formed

addition of any of the reactants (O_2, SO_2)

increasing pressure

increasing temperature

(b)(ii)

$2SO_2 : O_2 : 2SO_3$ (1)

60 : 30 : 60 (1)

Excess volume of O_2 = 40−30 = 10cm^3 (1)

Residual gas = product + unused reactant = 60 + 10 = 70cm^3 (1)

(b)(iii) from +4 to +6 (1)

Two structural diagrams: cyclopropane (three carbons in a triangular ring, each with two hydrogens, labelled H's around the ring) and propane (H−C−C−C−H straight chain with all hydrogens shown). [1 mark each]

They are two different compounds and do not belong to the same homologous series / Molecular formula of propane is C_3H_8, and that of cyclopropane is C_3H_6 (1 mark)

(d)(i) X is propanol (1)

Y is propyl butanoate (1)

(d)(ii) The functional group of X is −OH/hydroxyl (1)

(d)(iii) $C_3H_7OH + C_3H_7COOH \rightarrow C_3H_7COOC_3H_7 + H_2O$ (2)

[Total Question 3 = 25 marks]

Question 4

(a)(i) $2NH_3(g) + 3CuO(s) \rightarrow 3Cu(s) + 3H_2O(g) + N_2(g)$ (2)

(a)(ii) $4NH_3(g) + 3O_2(g) \rightarrow 6H_2O(g) + 2N_2(g)$ (2)

(a)(iii) $2KI(aq) + Cl_2(g) \rightarrow 2KCl(aq) + I_2(s)$ (2)

(a)(iv) $Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$ (2)

(a)(v) $Pb(NO_3)_2 + 2HCl \rightarrow PbCl_2(s) + 2HNO_3(aq)$ (2)

(b)(i) [tin extraction process]

tin ore is crushed and washed with water (1)

then filtered (1)

roasted in air to remove impurities (1)

the product is then mixed with powdered charcoal/coke and heated (1)

the molten tin is then tapped off (1)

(b)(ii) Uses of ammonia [Any 3 points = 3 marks]

in the production of margarine

in rocket fuel

as a reducing agent

in filling balloons

production of ammonia (by Haber's process)

oxy-hydrogen flame for cutting metals

converting coal to crude oil

manufacture of methanol

Production of industrial fuel/water/gas/coal gas

synthesis of HCl

Question 5

(a)(i) Al_2O_3 (1)

(a)(ii)

(I) NaOH/Caustic soda (1)

(II) Na_3AlF_6/cryolite (1)

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(a)(iii) anode: graphite (1); Cathode: graphite (1)

(a)(iv) the anode is constantly/consistently replaced/much electricity is consumed (2 marks)

(a)(v)

(I) oxygen (1)

(II) $C(s) + O_2(g) \rightarrow CO_2(g)$ (2 marks)

(b)(i) Ca^{2+}, Mg^{2+}, Fe^{2+} [Any 2 points = 2 marks]

(b)(ii) Advantages:

Provides calcium for the development of bones and teeth of animals / shell of aquatic animals

Can improve the taste of the water / taste better than soft water

reduce heart diseases

can be supplied in lead pipes / less likely to cause corrosion in lead pipes

[Any 2 points = 2 marks]

Disadvantages:

wastes a lot of soap

formation of fur in kettles and boilers

not good in dyeing and tanning industries

causes dry itchy skin

[Any 2 points = 2 marks]

(c)(i) This is the heating of coal in the absence of air (2)

(c)(ii) [Any 4 points = 4 marks]

coke

coal gas

ammoniacal liquor

coal tar

(c)(iii) (implied sub-part)

Hydrogen chloride gas (1)

Ammonia gas (1)

(iv) They are very/highly soluble in water (1)

[Total Question 5 = 25 marks

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