

***Attention A-Level Students – Uganda Advanced Certificate of Education (New Curriculum)!***

***I, Teacher JoelPCM, the author of Physics, Chemistry, and Mathematics Item Banks, have just released a special compilation of the main questions for A-Level students in Uganda – and this part is absolutely FREE for all students!***

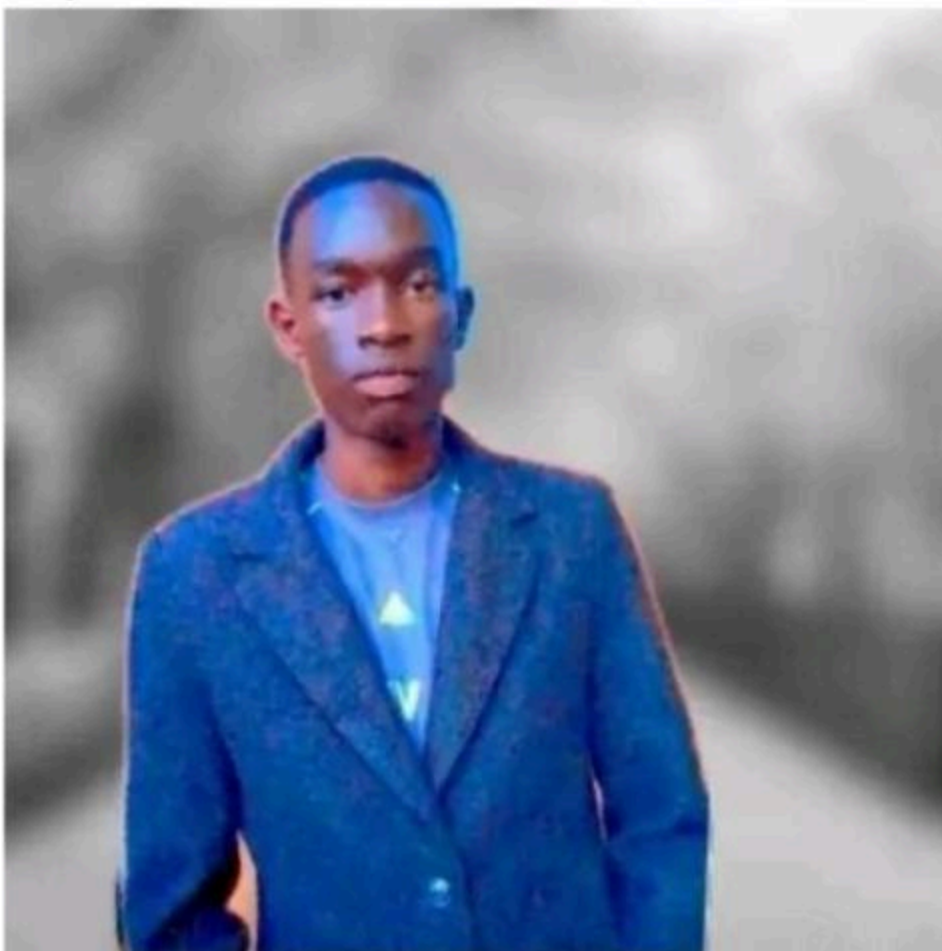
***These questions are carefully compiled to help you revise efficiently, solve problems faster, and succeed in your exams.***

***The full item banks, containing story-based, structured, challenging questions with solutions, are also available for those who want complete practice and mastery.***

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***Take advantage of this opportunity and share with your friends and classmates – let's grow together and achieve success!***

***Teacher Joel PCM***



**Author – Uganda A-Level Item Banks (Physics, Chemistry & Mathematics)**

**ITEM ONE: MOLES AND CHEMICAL EQUATIONS( set by tr joeIPCM)**

*A fertiliser manufacturing company prepared ammonium sulfate by reacting ammonia gas with sulfuric acid according to the equation:*



*In one experiment, 8.50 g of ammonia gas was reacted with 24.5 g of sulfuric acid. After the reaction, 30.0 g of ammonium sulfate was obtained.*

**TASK**

(a)

*Calculate the percentage composition by mass of nitrogen in ammonium sulfate.*

(b)

Calculate the number of moles of ammonia gas and sulfuric acid used in the reaction.

(c)

Determine the limiting reactant, clearly showing all working.

(d)

Calculate the theoretical mass of ammonium sulfate that should be formed.

(e)

Calculate the percentage yield of ammonium sulfate.

DATA

H = 1, N = 14, O = 16, S = 32

## **ORGANIC CHEMISTRY**

### **ITEM ONE**

#### **Organic Synthesis and Reaction Mechanisms**

A petrochemical industry starts with ethene obtained from cracking of petroleum fractions. Ethene is converted stepwise into several organic compounds as shown below:

Ethene → Compound A → Compound B → Compound C

Compound A is formed by reacting ethene with steam in the presence of an acid catalyst.

Compound B is obtained from compound A under controlled oxidation.

Compound C is formed when compound B reacts with aqueous potassium dichromate(VI) in excess.

#### **Tasks**

(a) Identify compounds A, B and C, giving their IUPAC names.

(b) Write balanced chemical equations for each step in the conversion.

(c) State the type of reaction and mechanism involved in the conversion of ethene to compound A.

(d) Explain why controlled conditions are necessary in the conversion of compound A to compound B.

(e) State one industrial importance of compound C.

### **ITEM TWO**

### **Synthesis, Isomerism and Functional Groups**

An organic compound D has molecular formula  $C_4H_8O$ . It reacts with Tollens' reagent producing a silver mirror, but does not react with sodium hydrogen carbonate. Compound D can be synthesized from an alkene under acidic conditions.

#### **0Tasks**

- Identify the functional group present in compound D.
- Write the structural formula of compound D.
- Name and draw two structural isomers of compound D.
- Describe how compound D can be synthesized from an alkene, stating the reagents and conditions.
- Write an equation to show the reaction of compound D with Tollens' reagent.

### **SECTION B: PHYSICAL CHEMISTRY**

#### **ITEM THREE:**

##### **Thermochemistry**

A student investigated the enthalpy change for the neutralization reaction between hydrochloric acid and sodium hydroxide.

$50.0\text{ cm}^3$  of  $1.0\text{ mol dm}^{-3}$  HCl at  $25\text{ }^\circ\text{C}$  was mixed with  $50.0\text{ cm}^3$  of  $1.0\text{ mol dm}^{-3}$  NaOH also at  $25\text{ }^\circ\text{C}$ . The maximum temperature recorded after mixing was  $32.5\text{ }^\circ\text{C}$ . The density of the solution is assumed to be  $1.0\text{ g cm}^{-3}$  and the specific heat capacity is  $4.2\text{ J g}^{-1}\text{ K}^{-1}$ .

#### **Tasks**

- Write the balanced chemical equation for the reaction.
- Calculate the temperature change.
- Calculate the heat energy released during the reaction.
- Determine the enthalpy change of neutralization per mole of water formed.
- State two assumptions made in this experiment.

#### **ITEM FOUR**

##### **Chemical Equilibrium and Volumetric Properties**

Nitrogen dioxide and dinitrogen tetroxide exist in equilibrium as shown:



A mixture of the gases is kept in a sealed container at constant pressure.

### Tasks

- Explain the meaning of chemical equilibrium.
- State and explain the effect of increasing temperature on the equilibrium position.
- Describe the effect of increasing pressure on the system.
- Explain how the volume of the system changes when equilibrium shifts to the right.
- State one industrial application where equilibrium principles are important.

## **SECTION C: INORGANIC CHEMISTRY**

### **ITEM FIVE**

#### **Periodicity and Chemical Properties**

Elements E, F and G are in the same period of the periodic table but in different groups.

Element E forms an oxide that dissolves in water to give a strongly alkaline solution.

Element F forms an oxide that reacts with both acids and bases.

Element G forms an oxide that dissolves in water to give an acidic solution.

### Tasks

- Identify the type of oxides formed by E, F and G.
- State the likely groups of E, F and G in the periodic table.
- Explain the trend in acidity and basicity of oxides across the period.
- Write equations to show the reaction of the oxide of F with an acid and with a base.

### **ITEM SIX: Salts and Qualitative Analysis**

A salt H dissolves in water to give a pale green solution. When sodium hydroxide solution is added, a green precipitate is formed which turns

*brown on standing in air. The precipitate is insoluble in excess sodium hydroxide.*

### **Tasks**

- (a) Identify the cation present in salt H.*
- (b) Write an equation for the reaction between salt H and sodium hydroxide.*
- (c) Explain why the precipitate turns brown on standing.*
- (d) State one confirmatory test for the cation in salt H.*
- (e) Suggest one possible anion present in salt H.*

### **ITEM ONE**

#### **SALT HYDROLYSIS**

*A water treatment plant analyzed four salts, A, B, C and D, each dissolved separately to form  $0.10 \text{ mol dm}^{-3}$  aqueous solutions at  $25 \text{ }^\circ\text{C}$ . The pH values obtained were 3.2, 6.0, 7.0 and 9.4 respectively. Salt A was prepared from a weak base and a strong acid, while salt B was prepared from a weak acid and a strong base. Salt C was obtained from a strong acid and a strong base, whereas salt D contained a highly charged metal ion.*

### **Tasks**

- (a) Explain the term salt hydrolysis.*
- (b) For each salt, identify whether hydrolysis occurs and state the ion responsible.*
- (c) Write hydrolysis equations where applicable.*
- (d) Explain why salt D produces an acidic solution despite containing no acidic radical.*
- (e) Account for the observed pH values using equilibrium ideas.*

#### **ITEM TWO: SALT HYDROLYSIS AND CALCULATIONS**

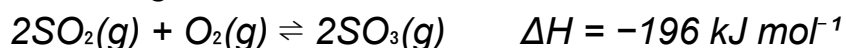
*An aqueous solution of ammonium chloride has a concentration of  $0.20 \text{ mol dm}^{-3}$ . The value of  $K_b$  for ammonia is  $1.8 \times 10^{-5}$ .*

### Tasks

- Write the ionic equation for the hydrolysis occurring in the solution.
- Derive an expression for the hydrogen ion concentration.
- Calculate the pH of the solution.
- Explain how dilution would affect the degree of hydrolysis.
- State one industrial situation where salt hydrolysis is undesirable.

### **ITEM THREE: CHEMICAL EQUILIBRIUM**

In the manufacture of sulfur trioxide, sulfur dioxide reacts with oxygen according to:



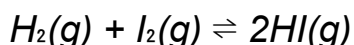
The reaction is carried out in a contact process converter under controlled conditions.

### Tasks

- Define chemical equilibrium.
- Explain the effect of temperature on the yield of sulfur trioxide.
- Discuss the effect of pressure on the equilibrium position.
- Explain why a catalyst does not affect the equilibrium position.
- State why equilibrium is never achieved in practice in an industrial plant.

### **ITEM FOUR: CHEMICAL EQUILIBRIUM WITH $K_c$**

For the equilibrium:



At a certain temperature, the equilibrium concentrations are:

$$[\text{H}_2] = 0.20 \text{ mol dm}^{-3}$$

$$[\text{I}_2] = 0.20 \text{ mol dm}^{-3}$$

$$[\text{HI}] = 0.80 \text{ mol dm}^{-3}$$

### Tasks

- Write the expression for  $K_c$ .
- Calculate the value of  $K_c$ .
- Predict and explain the effect of adding more iodine.
- Explain the effect of decreasing the volume of the system.
- Describe how equilibrium is re-established after disturbance.

### **ITEM FIVE: IONIC EQUILIBRIUM (WEAK ACIDS)**

Ethanoic acid has a dissociation constant  $K_a = 1.8 \times 10^{-5}$ . A student prepared a  $0.10 \text{ mol dm}^{-3}$  solution of ethanoic acid.

#### Tasks

- Write the equilibrium equation for dissociation.
- Define ionic equilibrium.
- Calculate the hydrogen ion concentration.
- Determine the pH of the solution.
- Explain why ethanoic acid is classified as a weak acid.

### **ITEM SIX: BUFFER SOLUTIONS**

A laboratory buffer was prepared by mixing ethanoic acid and sodium ethanoate in equal volumes. The buffer had an initial pH of 4.8.

#### Tasks

- Define a buffer solution.
- Explain how the buffer resists change when a small amount of acid is added.
- Explain how the buffer resists change when a small amount of alkali is added.
- Predict the effect of dilution on the buffer pH.
- State two practical uses of buffer solutions.

### **ITEM SEVEN: BUFFER CALCULATION**

A buffer solution is made by mixing  $0.20 \text{ mol dm}^{-3}$  ethanoic acid and  $0.20 \text{ mol dm}^{-3}$  sodium ethanoate. Given that  $K_a = 1.8 \times 10^{-5}$ .

#### Tasks

- Derive the Henderson equation for the buffer.
- Calculate the pH of the buffer solution.
- Explain why the buffer is most effective at this pH.
- Describe what happens when excess hydrochloric acid is added.
- Suggest one biological system that depends on buffers.

### **ITEM EIGHT: BENZENE – STRUCTURE AND REACTIVITY**

*Benzene reacts differently from alkenes despite having unsaturation. It undergoes substitution rather than addition under normal conditions.*

#### *Tasks*

- (a) Describe the structure of benzene using orbital overlap.*
- (b) Explain why benzene is unusually stable.*
- (c) Write an equation for the nitration of benzene.*
- (d) State the role of the catalyst used.*
- (e) Explain why benzene does not decolourise bromine water.*

### **ITEM NINE: BENZENE DERIVATIVES AND DIRECTING EFFECTS**

*Phenol, an important benzene derivative, reacts readily with bromine water to form a white precipitate.*

#### *Tasks*

- (a) Explain why phenol is more reactive than benzene.*
- (b) Write the equation for the reaction with bromine water.*
- (c) State the type of substitution involved.*
- (d) Explain the directing effect of the –OH group.*
- (e) State one industrial use of phenol.*

### **ITEM TEN: (BENZENE + EQUILIBRIUM)**

*Nitrobenzene is produced from benzene in a reversible reaction. The reaction mixture is kept under controlled temperature conditions.*

#### *Tasks*

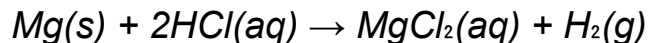
- (a) Write the equation for the nitration of benzene.*
- (b) Explain why temperature control is important.*
- (c) Discuss the reaction using equilibrium principles.*
- (d) Explain how yield can be maximized.*
- (e) State environmental concerns associated with benzene derivatives.*

## **TOPIC: MOLES AND CHEMICAL EQUATIONS**

### **ITEM ONE: MOLE CONCEPT AND STOICHIOMETRY**

A student reacted magnesium ribbon with excess dilute hydrochloric acid in a laboratory experiment.

The reaction produced hydrogen gas according to the equation:



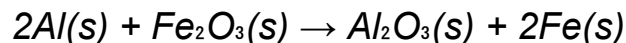
In one experiment, 2.40 g of magnesium was completely reacted and the hydrogen gas produced was collected at room temperature and pressure.

#### **Tasks**

- Calculate the number of moles of magnesium used.
- Determine the number of moles of hydrogen gas produced.
- Calculate the mass of magnesium chloride formed.
- Explain why hydrochloric acid was used in excess.
- State one possible source of error in this experiment.

### **ITEM TWO: LIMITING REACTANT AND MASS CALCULATIONS**

In an industrial process, aluminium reacts with iron(III) oxide in a thermite reaction:



A mixture containing 13.5 g of aluminium and 80.0 g of iron(III) oxide was heated strongly.

#### **Tasks**

- Calculate the number of moles of aluminium and iron(III) oxide present.
- Determine the limiting reactant, showing all working.
- Calculate the mass of iron produced.
- Calculate the mass of excess reactant remaining after the reaction.
- State one industrial application of this reaction.

### **ITEM THREE: PERCENTAGE COMPOSITION AND EMPIRICAL FORMULA**

An oxide of copper was analyzed in the laboratory. The compound was found to contain 79.9% copper and 20.1% oxygen by mass.

#### **Tasks**

- (a) Calculate the empirical formula of the oxide.
- (b) State the molecular formula of the oxide if its relative molecular mass is 159.
- (c) Calculate the percentage composition by mass of copper in the molecular formula.
- (d) Explain the difference between empirical formula and molecular formula.
- (e) State one use of copper oxides.

#### **ITEM FOUR: GAS VOLUMES AND MOLAR RELATIONSHIPS**

Calcium carbonate reacts with dilute nitric acid according to the equation:



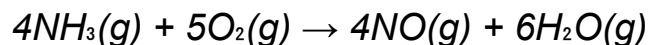
In an experiment, 5.00 g of calcium carbonate was reacted with excess nitric acid. The carbon dioxide gas produced was collected at room temperature and pressure.

##### Tasks

- (a) Calculate the number of moles of calcium carbonate used.
- (b) Determine the number of moles of carbon dioxide produced.
- (c) Calculate the volume of carbon dioxide gas collected at RTP.
- (d) Explain why nitric acid was used in excess.
- (e) State one test to confirm the presence of carbon dioxide.

#### **ITEM FIVE: PERCENTAGE YIELD AND REACTION EFFICIENCY**

Ammonia reacts with oxygen during the Ostwald process as shown:



In an experiment, 17.0 g of ammonia was reacted with excess oxygen. The mass of nitric oxide obtained was 18.0 g, although calculations showed that 24.0 g should have been formed.

##### Tasks

- (a) Calculate the theoretical mass of nitric oxide formed.
- (b) Calculate the percentage yield of the reaction.
- (c) Give two reasons why the percentage yield is less than 100%.
- (d) State the importance of nitric oxide in industry.

(e) Explain the meaning of percentage yield.

## **BACK TITRATION**

### **ITEM ONE BACK TITRATION OF A CARBONATE**

A sample of impure calcium carbonate was analyzed by reacting it with an excess of  $0.50 \text{ mol dm}^{-3}$  hydrochloric acid.

Exactly  $25.0 \text{ cm}^3$  of the acid was added to  $1.25 \text{ g}$  of the sample.

The excess acid was then titrated with  $0.10 \text{ mol dm}^{-3}$  sodium hydroxide, requiring  $12.5 \text{ cm}^3$  to reach the end point.

#### Tasks

(a) Write the equation for the reaction between calcium carbonate and hydrochloric acid.

(b) Calculate the number of moles of hydrochloric acid initially added.

(c) Calculate the number of moles of hydrochloric acid remaining after reaction.

(d) Determine the number of moles of hydrochloric acid that reacted with the carbonate.

(e) Calculate the percentage purity of the calcium carbonate sample.

### **ITEM TWO: BACK TITRATION OF AN ALKALI**

A student analyzed a solution of sodium hydroxide by adding an excess of  $0.25 \text{ mol dm}^{-3}$  sulfuric acid.

A volume of  $30.0 \text{ cm}^3$  of the acid was added to  $25.0 \text{ cm}^3$  of the alkali.

The excess acid required  $10.0 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3}$  sodium hydroxide for neutralization.

#### Tasks

(a) Write balanced equations for all reactions involved.

(b) Calculate the initial moles of sulfuric acid added.

(c) Calculate the moles of sulfuric acid remaining after reaction.

(d) Determine the moles of sulfuric acid that reacted with the alkali.

(e) Calculate the concentration of the original sodium hydroxide solution.

### **ITEM THREE: BACK TITRATION OF A METAL OXIDE**

A laboratory technician determined the purity of magnesium oxide by reacting 2.00 g of the solid with 50.0 cm<sup>3</sup> of 1.00 mol dm<sup>-3</sup> hydrochloric acid.

The excess acid required 20.0 cm<sup>3</sup> of 0.50 mol dm<sup>-3</sup> sodium hydroxide for complete neutralization.

#### Tasks

- Write the equation for the reaction between magnesium oxide and hydrochloric acid.
- Calculate the initial moles of hydrochloric acid added.
- Calculate the moles of hydrochloric acid remaining.
- Determine the moles of magnesium oxide present in the sample.
- Calculate the percentage purity of the magnesium oxide.

#### **ITEM FOUR: BACK TITRATION OF AMMONIA SOLUTION**

A volume of 25.0 cm<sup>3</sup> of aqueous ammonia was treated with 40.0 cm<sup>3</sup> of 0.20 mol dm<sup>-3</sup> hydrochloric acid.

The excess acid was titrated against 0.10 mol dm<sup>-3</sup> sodium hydroxide, requiring 15.0 cm<sup>3</sup>.

#### Tasks

- Write equations for all reactions involved.
- Calculate the initial moles of hydrochloric acid added.
- Determine the moles of hydrochloric acid remaining.
- Calculate the moles of ammonia in 25.0 cm<sup>3</sup> of solution.
- Determine the concentration of the ammonia solution.

#### **ITEM FIVE: BACK TITRATION OF AN ACIDIC SALT**

A sample of impure ammonium hydrogen carbonate weighing 1.50 g was reacted with 30.0 cm<sup>3</sup> of 0.40 mol dm<sup>-3</sup> hydrochloric acid.

The excess acid was titrated with 0.20 mol dm<sup>-3</sup> sodium hydroxide, requiring 10.0 cm<sup>3</sup>.

#### Tasks

- (a) Write the equation for the reaction between ammonium hydrogen carbonate and hydrochloric acid.
- (b) Calculate the initial moles of hydrochloric acid added.
- (c) Calculate the moles of hydrochloric acid remaining.
- (d) Determine the moles of ammonium hydrogen carbonate in the sample.
- (e) Calculate the percentage purity of the sample.

## **TOPIC: ELECTROCHEMISTRY**

### **ITEM ONE: ELECTROCHEMICAL CELLS AND EMF**

A student constructed an electrochemical cell using a zinc electrode dipped in  $1.0 \text{ mol dm}^{-3} \text{ ZnSO}_4(\text{aq})$  and a copper electrode dipped in  $1.0 \text{ mol dm}^{-3} \text{ CuSO}_4(\text{aq})$ . The two half-cells were connected by a salt bridge containing potassium nitrate solution. When the circuit was completed, the voltmeter showed a steady reading, and a reddish-brown deposit formed on one electrode while the other electrode gradually lost mass.

#### Tasks

- (a) Identify the anode and cathode, giving reasons.
- (b) Write the half-equations occurring at each electrode.
- (c) Write the overall cell reaction.
- (d) State the direction of electron flow in the external circuit.
- (e) Explain the function of the salt bridge.

### **ITEM TWO: STANDARD ELECTRODE POTENTIALS**

In an electrochemical experiment, a student measured the standard electrode potentials of three metals X, Y and Z. When X was connected to the standard hydrogen electrode, the cell emf was  $+0.34 \text{ V}$ . When Y was connected to the hydrogen electrode, the emf was  $-0.76 \text{ V}$ . Metal Z displaced copper from copper(II) sulfate solution but did not displace hydrogen from dilute acids.

#### Tasks

- (a) Arrange the metals X, Y and Z in order of increasing reducing power.
- (b) Identify which metal is most likely to be zinc, giving a reason.

- (c) Predict which metal would corrode fastest in moist air.*
- (d) Explain the meaning of standard electrode potential.*
- (e) State two conditions required for standard electrode potential measurements.*

### **ITEM THREE: ELECTROLYSIS OF AQUEOUS SOLUTIONS**

*A concentrated aqueous solution of sodium chloride was electrolysed using inert graphite electrodes. During electrolysis, a gas with a choking smell was observed at one electrode, while another gas that rekindled a glowing splint was observed at the other electrode. After some time, the solution became alkaline.*

#### **Tasks**

- (a) Identify the products formed at each electrode.*
- (b) Write the half-equations for the reactions at the anode and cathode.*
- (c) Explain why the solution becomes alkaline during electrolysis.*
- (d) State one industrial use of each product formed.*
- (e) Explain why graphite electrodes are preferred in this process.*

### **ITEM FOUR: ELECTROLYSIS AND SELECTIVE DISCHARGE**

*A student electrolysed dilute sulfuric acid using platinum electrodes. Hydrogen gas was collected at one electrode, while oxygen gas was collected at the other. The volumes of gases collected were in the ratio 2 : 1.*

#### **Tasks**

- (a) Identify the gas produced at each electrode.*
- (b) Write the half-equations for the electrode reactions.*
- (c) Explain why the volumes of gases are in the ratio 2 : 1.*
- (d) State the role of sulfuric acid in the electrolysis.*
- (e) Explain the term selective discharge of ions.*

### **ITEM FIVE: CORROSION AND ELECTROCHEMISTRY**

*A transport company noticed that steel fuel tanks on their vehicles corroded faster near coastal areas than inland. Engineers observed that rusting occurred more rapidly when the metal was in contact with salty water and*

when two different metals were joined together. As a result, the company introduced protective measures to extend the lifespan of their equipment and reduce maintenance costs.

### Tasks

- (a) Explain corrosion in terms of electrochemical reactions.
- (b) Write the half-equations involved in the rusting of iron.
- (c) Explain why corrosion is faster in coastal areas.
- (d) Describe how sacrificial protection prevents corrosion.
- (e) State two economic advantages of corrosion prevention.

## **TOPIC: GROUP II (ALKALINE EARTH METALS)**

### **ITEM 1: ATOMIC AND IONIC RADII**

The following data show the atomic radii and ionic radii of some Group II elements.

Element: Be

Atomic radius / nm: 0.112

Ionic radius / nm: 0.030

Element: Mg

Atomic radius / nm: 0.160

Ionic radius / nm: 0.065

Element: Ca

Atomic radius / nm: 0.197

Ionic radius / nm: 0.094

Element: Sr

Atomic radius / nm: 0.215

Ionic radius / nm: 0.110

Element: Ba

Atomic radius / nm: 0.221

Ionic radius / nm: 0.134

### Tasks

- (a) Explain what is meant by the term atomic radius.
- (b) Explain why the ionic radius of each element is smaller than its atomic radius.
- (c) Explain why atomic radius increases from beryllium to barium.
- (d) The potassium ion,  $K^+$ , and the calcium ion,  $Ca^{2+}$ , have the same electronic configuration. Explain why the potassium ion is larger than the calcium ion.

## **ITEM 2: STANDARD ELECTRODE POTENTIALS**

The standard electrode potentials of some Group II metals are given below.

Element: Mg

Standard electrode potential,  $E^\circ / V$ :  $-2.34$

Element: Ca

Standard electrode potential,  $E^\circ / V$ :  $-2.87$

Element: Sr

Standard electrode potential,  $E^\circ / V$ :  $-2.89$

Element: Ba

Standard electrode potential,  $E^\circ / V$ :  $-2.91$

Tasks

(a)

(i) Identify the element which is the most powerful reducing agent.

(ii) Give a reason for your answer.

(b)

(i) State the trend in standard electrode potentials of the elements down the group.

(ii) Explain this trend.

## **ITEM 3: REACTIONS OF GROUP II ELEMENTS**

Beryllium, magnesium, calcium and barium are elements of Group II of the Periodic Table.

Tasks

(a) State how these elements react with dilute sulphuric acid and give any conditions required.

(b)

*(i) State how the solubility of sulphates of Group II elements varies down the group.*

*(ii) Explain the trend stated in (b)(i).*

*(c) Write balanced chemical equations for the reactions of:*

*(i) Beryllium with aqueous sodium hydroxide.*

*(ii) Calcium carbide with water.*

#### **ITEM 4: AMPHOTERIC BEHAVIOUR**

*Some metals and their oxides react with both acids and alkalis.*

*Tasks*

*Write balanced chemical equations for the reactions between sodium hydroxide solution and each of the following:*

*(a) Beryllium*

*(b) Aluminium*

*(c) Beryllium oxide*

*(d) Aluminium oxide*

*State the name given to substances that show this behaviour.*

#### **ITEM 5: ELECTRONIC CONFIGURATION AND PERIODIC TRENDS**

*The elements beryllium, magnesium, calcium, strontium and barium belong to Group II of the Periodic Table.*

*Tasks*

*(a) Write the general outer electronic configuration of Group II elements.*

*(b) Explain why:*

*(i) The second and third ionisation energies of magnesium differ greatly.*

*(ii) The melting points of chlorides of Group II elements generally increase from beryllium chloride to barium chloride.*

#### **ITEM 1: INORGANIC CHEMISTRY**

##### **Topic: Group II Elements & Periodic Trends**

*A student research team at a senior six science camp investigated the properties of some Group II metals obtained from a local laboratory. They labeled the metals A, B, C and D, which were later identified as magnesium, calcium, strontium and barium, though not in that order. The students observed that when the metals were reacted separately with cold*

water, metal D reacted violently producing a lot of heat and hydrogen gas, while metal A reacted very slowly. They also measured the atomic and ionic radii of the metals and noticed a steady increase in atomic radius from metal A to metal D. Further experiments showed that the sulphate of metal D was almost insoluble in water, while that of metal A was fairly soluble. During electrochemical studies, metal D was found to have the most negative standard electrode potential.

### Tasks

- Identify metal A and metal D. Give reasons for your answers.
- Explain why the atomic radius of Group II elements increases down the group.
- Explain why the sulphates of Group II elements become less soluble down the group.
- Using electronic configuration, explain why Group II elements form +2 ions.

## **ITEM 2: PHYSICAL CHEMISTRY**

### **Topic: Ionic Equilibrium, Salt Hydrolysis & pH Calculations**

During a chemistry practical lesson, students prepared three aqueous salt solutions labelled X, Y and Z. Salt X was ammonium chloride, salt Y was sodium ethanoate, and salt Z was sodium chloride. Each solution had the same concentration of  $0.10 \text{ mol dm}^{-3}$ . The students tested the pH of each solution using a pH meter. Solution X had a pH of 5.1, solution Y had a pH of 8.9, while solution Z had a pH close to 7.0. The teacher explained that the differences in pH were due to hydrolysis of the ions present in solution. The students were reminded that the acid dissociation constant,  $K_a$ , of ethanoic acid is  $1.8 \times 10^{-5}$  and the ionic product of water,  $K_w$ , is  $1.0 \times 10^{-14}$  at room temperature.

### Tasks

- Explain why solution X is acidic while solution Y is alkaline.
- Write the ionic equation for the hydrolysis occurring in solution X.
- Calculate the pH of solution Y.
- Explain why solution Z does not undergo hydrolysis.

### **ITEM 3: ORGANIC CHEMISTRY**

#### **Topic: Alkanes, Alkenes, Isomerism & Reaction Mechanisms**

*A petroleum processing company supplied a chemistry class with a hydrocarbon mixture obtained from fractional distillation of crude oil. One of the hydrocarbons, compound P, was found to be saturated and reacted with chlorine in the presence of ultraviolet light to form a mixture of substituted products. Another compound, Q, decolourised acidified potassium manganate(VII) solution at room temperature to form a colourless solution and a diol. Compound Q was also observed to exist in two geometric forms. When compound Q reacted with hydrogen bromide, two different products were obtained depending on the reaction conditions. Under normal conditions, one major product was formed, but in the presence of peroxides, a different product was obtained.*

#### **Tasks**

- Identify the homologous series to which compounds P and Q belong.*
- Write the mechanism for the reaction between compound P and chlorine.*
- Explain the existence of geometric isomerism in compound Q.*
- Using reaction equations, explain the difference between the two products formed when Q reacts with hydrogen bromide under different conditions.*

### **ITEM 1: ATOMIC STRUCTURE & PERIODICITY**

*A research team in a school laboratory studied elements X, Y and Z which lie in the same period of the periodic table. Element X readily lost two electrons to form a stable ion, while element Y gained one electron to form a negative ion. Element Z did not easily react with other substances. The students observed that the first ionisation energy increased from X to Z across the period. They also noted that the oxides of X were basic, those of Y were acidic, while those of Z were largely unreactive. These observations were linked to changes in atomic size and nuclear charge across the period.*

### Tasks

- (a) Explain why the first ionisation energy increases across a period.
- (b) Explain why element X readily forms a cation.
- (c) Explain why the oxides change from basic to acidic across the period.
- (d) Explain why element Z is chemically unreactive.

### **ITEM 2: MOLE CONCEPT & STOICHIOMETRY**

A student reacted excess zinc granules with  $50.0 \text{ cm}^3$  of  $1.0 \text{ mol dm}^{-3}$  hydrochloric acid to prepare hydrogen gas. The gas produced was collected and its volume measured. After the reaction, some zinc remained unreacted at the bottom of the flask. The student was interested in determining the limiting reagent and the efficiency of the reaction. The molar volume of a gas at room temperature was taken as  $24 \text{ dm}^3 \text{ mol}^{-1}$ .

### Tasks

- (a) Write a balanced equation for the reaction.
- (b) Calculate the number of moles of hydrochloric acid used.
- (c) Identify the limiting reagent, giving a reason.
- (d) Calculate the maximum volume of hydrogen gas produced.

### **ITEM 3: THERMOCHEMISTRY**

In a calorimetry experiment, students reacted magnesium powder with dilute hydrochloric acid in a polystyrene cup. The temperature of the solution rose from  $25^\circ\text{C}$  to  $39^\circ\text{C}$ . The mass of the solution was  $100 \text{ g}$  and its specific heat capacity was  $4.2 \text{ J g}^{-1} \text{ K}^{-1}$ . The teacher explained that the reaction was exothermic and involved the transfer of energy to the surroundings.

### Tasks

- (a) Explain what is meant by an exothermic reaction.
- (b) Calculate the heat energy released in the reaction.
- (c) Write a thermochemical equation for the reaction.
- (d) State one source of error in this experiment.

### **ITEM 4: GROUP II CHEMISTRY**

*Samples of magnesium, calcium, strontium and barium were supplied to a chemistry class. The students observed that reactivity with water increased from magnesium to barium. They also noted that the solubility of the sulphates decreased down the group. During electrochemical studies, barium had the most negative standard electrode potential.*

#### **Tasks**

- (a) Explain why reactivity increases down Group II.*
- (b) Explain the trend in solubility of Group II sulphates.*
- (c) Identify the strongest reducing agent in the group.*
- (d) Explain why Group II elements form +2 ions.*

#### **ITEM 5: HYDROLYSIS OF SALTS**

*Three salt solutions A, B and C were prepared. Solution A was ammonium chloride, B was sodium carbonate and C was potassium nitrate. The pH values measured were 5.2, 10.1 and 7.0 respectively. The teacher explained that the behaviour of the solutions depended on the nature of the ions present.*

#### **Tasks**

- (a) Explain why solution A is acidic.*
- (b) Write the ionic equation for the hydrolysis in solution B.*
- (c) Explain why solution C is neutral.*
- (d) State one use of a basic salt in everyday life.*

#### **ITEM 6: CHEMICAL EQUILIBRIUM**

*Nitrogen and hydrogen gases were mixed in a sealed container to produce ammonia using an iron catalyst. The system reached equilibrium at a certain temperature and pressure. When more hydrogen was added, the yield of ammonia increased. Increasing the temperature, however, reduced the yield.*

#### **Tasks**

- (a) Write the equilibrium equation for the reaction.*
- (b) Explain the effect of adding hydrogen on the equilibrium position.*

- (c) Explain the effect of increasing temperature.
- (d) State the role of the catalyst.

### **ITEM 7: BUFFER SOLUTIONS**

A buffer solution was prepared by mixing ethanoic acid and sodium ethanoate. When small amounts of hydrochloric acid were added, the pH changed only slightly. The teacher explained that buffers resist changes in pH.

#### **Tasks**

- (a) Define a buffer solution.
- (b) Explain how the buffer resists added acid.
- (c) Write an ionic equation illustrating buffer action.
- (d) State one use of buffer solutions in biology.

### **ITEM 8: ALKANES – PREPARATION & PROPERTIES**

A saturated hydrocarbon P was prepared in the laboratory by heating sodium ethanoate with soda lime. Compound P reacted with chlorine in sunlight to form a mixture of substituted products. It did not decolourise bromine water.

#### **Tasks**

- (a) Identify the homologous series of compound P.
- (b) Write an equation for the preparation of P.
- (c) Describe the reaction between P and chlorine.
- (d) State one use of alkanes.

### **ITEM 9: ALKENES & ISOMERISM**

Compound Q was found to decolourise bromine water and existed in two geometric forms. When reacted with acidified potassium manganate(VII), a colourless diol was formed.

#### **Tasks**

- (a) Identify the homologous series of Q.
- (b) Explain the cause of geometric isomerism in Q.

- (c) Write the equation for oxidation of Q with  $\text{KMnO}_4$ .  
(d) State one industrial use of alkenes.

### **ITEM 10: ELECTROCHEMISTRY**

A Daniell cell was set up using zinc and copper electrodes. The voltage produced was measured. Zinc gradually dissolved while copper increased in mass.

#### Tasks

- (a) Identify the anode and cathode.  
(b) Write half-equations for the reactions.  
(c) Explain why zinc loses mass.  
(d) Calculate the cell potential given standard values.

### **ITEM 11: REDOX REACTIONS**

Iron(II) ions were oxidised to iron(III) ions using acidified potassium dichromate(VI). The colour changed from green to orange.

#### Tasks

- (a) Define oxidation in terms of electrons.  
(b) Identify the oxidising agent.  
(c) Write the ionic equation for the reaction.  
(d) State one use of potassium dichromate(VI).

### **ITEM 12: VOLUMETRIC ANALYSIS**

A student titrated sodium hydroxide with hydrochloric acid using phenolphthalein as an indicator. The average titre was recorded.

#### Tasks

- (a) Define a standard solution.  
(b) Write a balanced equation for the reaction.  
(c) Calculate the concentration of sodium hydroxide.  
(d) Explain the choice of indicator.

### **ITEM 13: BACK TITRATION**

*An impure sample of calcium carbonate was reacted with excess hydrochloric acid. The remaining acid was titrated with sodium hydroxide.*

**Tasks**

- (a) Explain why back titration was used.*
- (b) Write equations involved.*
- (c) Calculate the purity of calcium carbonate.*
- (d) State one source of error.*

**ITEM 14: ORGANIC ISOMERISM**

*Two compounds A and B had the same molecular formula but different boiling points. A was an alcohol while B was an ether.*

**Tasks**

- (a) Name the type of isomerism shown.*
- (b) Explain the boiling point difference.*
- (c) Write structures for A and B.*
- (d) State one test to distinguish them.*

**ITEM 15: CARBONYL COMPOUNDS**

*Compound R reacted with Tollens' reagent to give a silver mirror but did not react with Fehling's solution.*

**Tasks**

- (a) Identify the functional group in R.*
- (b) Explain the observation.*
- (c) Write the reaction equation.*
- (d) State one use of aldehydes.*

**ITEM 16: BENZENE & DERIVATIVES**

*Benzene was reacted with concentrated nitric acid in the presence of sulphuric acid to form nitrobenzene.*

**Tasks**

- (a) Name the type of reaction.*

- (b) State the role of sulphuric acid.*
- (c) Write the reaction equation.*
- (d) Explain why benzene undergoes substitution not addition.*

### **ITEM 17: HALOGENATION OF ALKANES**

*Methane was exposed to chlorine gas in sunlight producing chloromethane and other products.*

#### **Tasks**

- (a) Name the reaction mechanism.*
- (b) Write initiation, propagation and termination steps.*
- (c) Explain why multiple products form.*
- (d) State one industrial importance.*

### **ITEM 18: MARKOVNIKOV'S RULE**

*Propene reacted with hydrogen bromide under different conditions, producing different major products.*

#### **Tasks**

- (a) State Markovnikov's rule.*
- (b) Explain product formation under normal conditions.*
- (c) Explain the peroxide effect.*
- (d) Write equations for both reactions.*

### **ITEM 19: COLLIGATIVE PROPERTIES**

*Adding salt to water increased its boiling point. The teacher explained this using intermolecular forces.*

#### **Tasks**

- (a) Define boiling point elevation.*
- (b) Explain why boiling point increases.*
- (c) State one other colligative property.*
- (d) Give one application.*

### **ITEM 20: ENVIRONMENTAL CHEMISTRY**

*Sulphur dioxide from industries was linked to acid rain affecting crops and buildings.*

**Tasks**

- (a) Explain how sulphur dioxide forms acid rain.*
- (b) Write relevant chemical equations.*
- (c) State two effects of acid rain.*
- (d) Suggest one method of control.*

**End Note:**

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