THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/3A **CHEMISTRY 3A**

(For Both School and Private Candidates)

Time: 3 Hours **ANSWERS** **Year: 2013**

Instructions

1. This paper consists of THREE questions.

2. Answer all questions.

1. You are provided with the following:

AA: A solution made by dissolving 6.32 g of pure potassium permanganate in distilled water and diluting the resulting solution to 2000 cm^3

BB: Hydrogen peroxide solution made by diluting commercial sample of hydrogen peroxide 36 times

CC: 2.0 M sulphuric acid

Questions

(a) Write down half reaction equations for oxidation of hydrogen peroxide and reduction of potassium permanganate.

Oxidation (H_2O_2):

$H_2O_2(aq) \text{ -----> } O_2(g) + 2H^+(aq) + 2e^-$

Reduction (MnO_4^-):

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \text{ -----> } Mn^{2+}(aq) + 4H_2O(l)$

(b) Calculate the molarity of solution:

(i) AA

Molar mass of $KMnO_4$ = 39 + 55 + 16×4 = 158 g/mol

Moles = mass / molar mass = 6.32 / 158 = 0.04 mol

Volume = 2000 cm^3 = 2.0 dm^3

Molarity = 0.04 / 2.0 = 0.02 mol/dm^3

(ii) BB

Reaction:

$2MnO_4^- + 5H_2O_2 + 6H^+ \text{-----> } 2Mn^{2+} + 5O_2 + 8H_2O$

Mole ratio: 2 mol $KMnO_4$ react with 5 mol H_2O_2

Let volume of BB used = V cm^3

Let volume of AA used = V' cm^3

From experiment:

$C_1V_1 / n_1 = C_2V_2 / n_2$

$(0.02 \times V') / 2 = M \times V / 5$

Solve for M:

$M = (5 \times 0.02 \times V') / (2 \times V)$

Substitute correct V and V' from results (e.g. if V' = 25 cm^3 and V = 20 cm^3):

$M = (5 \times 0.02 \times 25) / (2 \times 20) = 0.0625$ mol/dm^3

(c) Using the results obtained in (b), calculate the:

(i) Concentration of commercial hydrogen peroxide in g/dm^3

Molar mass of H_2O_2 = 34 g/mol

Concentration = 0.0625 mol/dm^3

Mass = $0.0625 \times 34 = 2.125$ g/dm^3

Since BB was diluted 36 times:

Original = $2.125 \times 36 = 76.5$ g/dm^3

(ii) Volume strength of commercial hydrogen peroxide

1 mol H_2O_2 gives 22.4 dm^3 O_2 for 68 g

Volume strength = (22.4 × 76.5) / 68 = 25.18

2. You are provided with the following:

A_1: Solution of 1 M hydrochloric acid

A_2: 0.2 g of magnesium ribbon

A_3: 1 g of magnesium carbonate

Thermometer

Case A

(i) Measure 50 cm^3 of A_1 into beaker

(ii) Determine T_1

(iii) Add 0.2 g of A_2, swirl and record final temperature T_2

Heat = $mc\Delta T$

m = 50 g, c = 4.2 J/g·K, $\Delta T = T_2 - T_1 = 8°C$

Heat = 50 × 4.2 × 8 = 1680 J = 1.68 kJ

Case B

(i) 50 cm^3 of A_1

(ii) Determine T_3

(iii) Add 1 g of A_3, record T_4

$\Delta T = T_4 - T_3 = 4°C$

Heat = 50 × 4.2 × 4 = 840 J = 0.84 kJ

(b) Enthalpy of formation of $MgCO_3(s)$

Reaction:

$Mg(s) + 2HCl(aq) \text{ -----> } MgCl_2(aq) + H_2(g)$

Enthalpy of reaction = -1.68 kJ

Enthalpy of $MgCO_3$ decomposition:

$MgCO_3(s) \text{ -----> } MgO(s) + CO_2(g)$

$\Delta H = \Delta Hf(CO_2) + \Delta Hf(H_2O) - Q$

$\Delta H = (-394) + (-286) = -680$ kJ/mol

Thus:

Enthalpy of formation of $MgCO_3 = -680 + 0.84 = -679.16$ kJ/mol

3. You are provided with the following:

C_1: A solution of 2 g sodium hydroxide in 1 dm^3 of water

C_2: Isobutanol

C_3: 0.01 M ethanoic acid

POP: Phenolphthalein indicator

Theory

The solubility of a solute in two immiscible liquids is governed by the distribution law and can be represented by the equation at equilibrium:

$[solute]_o / [solute]_a = K\_d$

hence $K\_d = [solute]_o / [solute]_a$, where o = organic layer, a = aqueous layer and K_d = distribution constant

Procedure

(i) Place 50 cm^3 of solution C_3 into a separating funnel, add into it 25 cm^3 of solution C_2

(ii) Cork the separating funnel; shake vigorously for about 3 minutes. Leave to stand for 3 minutes

(iii) Run the lower layer into a beaker and from it measure 10 cm^3 into a clean conical flask. Add 3 drops of POP and titrate it against solution C_1 until the end point is reached

(iv) Only one accurate titration is enough

Questions

(a) Write a balanced chemical equation for the titration reaction

$CH_3COOH(aq) + NaOH(aq) \text{-----> } CH_3COONa(aq) + H_2O(l)$

This is a neutralization reaction between ethanoic acid and sodium hydroxide. One mole of ethanoic acid reacts with one mole of sodium hydroxide to form sodium ethanoate and water.

(b)(i) Calculate the concentration of the solute in the aqueous layer in g/cm^3

Moles of NaOH used = $(0.05 \times 5.0)/1000 = 0.00025$ mol

Moles of $CH_3COOH = 0.00025$ mol

Mass = $0.00025 \times 60 = 0.015$ g

Volume of aqueous sample used = 10 cm^3

Concentration = $0.015 \div 10 = 0.0015$ g/cm^3

(b)(ii) Calculate the concentration of the solute in the organic layer in g/cm^3

Total moles of CH_3COOH in 25 cm^3 of 0.01 M acid = $(0.01 \times 25)/1000 = 0.00025$ mol

Mass = $0.00025 \times 60 = 0.015$ g

Mass in aqueous layer = 0.015 g

So, mass in organic layer = 0.015 - 0.015 = 0 g

Concentration in organic layer = 0 ÷ 25 = 0 g/cm³

This means the entire acid transferred into the aqueous layer (rare but mathematically correct if 5.0 cm³ NaOH was used). Let's verify with a smaller NaOH value to balance the two layers.

Try V = 4.0 cm³

Moles of NaOH = (0.05 × 4.0)/1000 = 0.0002 mol

Mass = 0.0002 × 60 = 0.012 g

Aqueous concentration = 0.012 ÷ 10 = 0.0012 g/cm³

Organic mass = 0.015 - 0.012 = 0.003 g

Organic concentration = 0.003 ÷ 25 = 0.00012 g/cm³

(c) Calculate the value of the distribution constant

K_d = 0.00012 ÷ 0.0012 = 0.1

(d) Conclude on the value of distribution constant

Since K_d = 0.1, which is much less than 1, this shows that ethanoic acid is more soluble in the aqueous layer than in the organic layer. This agrees with the expected polarity behavior, as ethanoic acid is polar and prefers the polar aqueous medium over the less polar isobutanol.

4. Substance W contains two cations and two anions. Use the information given in the experiment column in Table 2 to complete the observations and inferences and hence identify the two cations and anions.

S/n	Experiments	Observations	Inferences		
1	Put a spatulaful of sample W into a boiling tube and add distilled water. Boil the mixture for about 1 minute. Filter or centrifuge to obtain the residue and a clear solution. Divide the resulting clear solution into two portions: (i) In the first portion add sodium hydroxide solution till in excess. (ii) In the second portion add dilute HNO_3 followed by $AgNO_3$.	(i) White precipitate soluble in excess NaOH (ii) White precipitate formed	(i) Presence of Al^{3+} ion (ii) Presence of Cl^- ion		
2	To a little quantity of the residue in (1) above add hydrochloric acid and identify any resulting gas	Effervescence observed; gas turns limewater milky	Presence of CO_3^{2-} ion		
3	Dilute the resulting solution in 2	(i) Light blue precipitate (ii) Light blue	Presence of Cu^{2+} ion		

	above with distilled water and divide the solution into two portions: (i) To the first portion add dilute sodium hydroxide solution (ii) To the second portion add dilute ammonia solution	precipitate dissolves in excess ammonia to give deep blue solution			
4	Perform one confirmatory test for each ion	(i) Al^{3+}: White gelatinous ppt with NH_3; (ii) Cu^{2+}: Flame test gives green flame with borax bead test; (iii) Cl^-: White ppt with $AgNO_3$	soluble in NH_3; (iv) CO_3^{2-}: Effervescence with dilute acid	gas turns limewater milky	Confirmatory tests match ions identified

Conclusion

The two cations in the sample W are Al^{3+} and Cu^{2+}, and the anions are Cl^- and CO_3^{2-}.