THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/2 **CHEMISTRY 2**

Time: 3 Hours **ANSWERS** **Mwaka: 2014**

Instructions

1. This paper consists of a total of six questions
2. Answer five questions.

1 (a) Give a brief explanation for each of the following terms:

(i) Electrochemical series:
A list of elements arranged in order of their standard electrode potentials.

(ii) Electrochemical equivalent:
The mass of a substance deposited or liberated at an electrode by 1 coulomb of electricity.

(iii) Redox series:
An arrangement of species based on their tendency to lose or gain electrons (oxidation/reduction).

(iv) Redox reaction:
A chemical reaction involving both reduction and oxidation processes simultaneously.

(b) Study the following reactions:
$Zn^{2+} + 2e^- \text{ ---> } Zn(s)$, $E^o = -0.76$ V
$Ni^{2+} + 2e^- \text{ ---> } Ni(s)$, $E^o = -0.25$ V

(i) Which is the feasible reaction:
Reduction of Ni^{2+} by Zn is feasible because Zn has a more negative E^o (stronger reducing agent).

(ii) Balanced redox equation:
$Zn(s) + Ni^{2+}(aq) \text{ ---> } Zn^{2+}(aq) + Ni(s)$

(iii) Cell diagram:
$Zn(s) \mid Zn^{2+} \parallel Ni^{2+} \mid Ni(s)$

(iv) Calculate the e.m.f:
$E_{cell} = E^o(Ni^{2+}/Ni) - E^o(Zn^{2+}/Zn) = (-0.25) - (-0.76) = 0.51$ V

(c) Sodium chlorate (I) is converted to sodium chlorate (V):
$3NaOCl \text{ ---> } NaClO_3 + 2NaCl$

(i) Oxidation: Cl^{+1} in NaOCl ----> Cl^{+5} in $NaClO_3$
(ii) Reduction: Cl^{+1} in NaOCl ---> Cl^{-1} in NaCl

2 (a) (i) Homogeneous catalyst:
A catalyst in the same phase as reactants.
Example: NO in oxidation of SO_2

(ii) Rate expression:
$2N_2O_5 \text{ ---> } 4NO_2 + O_2$
$\text{Rate} = -d[N_2O_5]/dt = \frac{1}{2}\, d[O_2]/dt = \frac{1}{4}\, d[NO_2]/dt$

(iii) Rate law expression:
$-d[CH_4]/dt = ½\ d[O_2]/dt = ½\ d[H_2O]/dt = d[CO_2]/dt$
Balanced equation: $CH_4 + 2O_2 \text{ ---> } CO_2 + 2H_2O$

(b) Rate constant $k = 4.7 \times 10^{-3}\ s^{-1}$ at 25°C, Ea = 33.6 kJ/mol
(i) First-order (unit of rate constant is s^{-1})
(ii) Use Arrhenius equation: $\ln(k_2/k_1) = Ea/R(1/T_1 - 1/T_2)$

(c) Reaction: $4H_2O_2 + 2NO_2 \text{ ---> } 4H_2O + N_2$

(i) Rate expression:
Rate = $k[H_2O_2]^m[NO_2]^n$

(ii) From data:
Compare experiments 1 and 2 (same H_2O_2):
Rate increases by 4 ---> NO_2 order is 2

Compare experiments 2 and 3 (same NO_2):
No rate change ---> Order w.r.t H_2O_2 is 0

3 (a) $Ka = 1.35 \times 10^{-5}\ mol/dm^3$

(i) 0.05 M propanoic acid:
$[H^+] = \sqrt{(Ka \times C)} = \sqrt{(1.35\times10^{-5} \times 0.05)} = 8.2 \times 10^{-4}$
$pH = -\log(8.2\times10^{-4}) \approx 3.09$

(ii) Buffer with CH_3CH_2COOH and CH_3CH_2COONa ---> use Henderson-Hasselbalch equation.

(b) Acid and conjugate base pairs:

(i) $NH_3 + HCl \text{ ---> } NH_4^+ + Cl^-$
Acid: HCl, Base: NH_3
Conjugate acid: NH_4^+, Conjugate base: Cl^-

(ii) $H_2SO_4 + HNO_3 \text{ ----> } HSO_4^- + H_3O^+$
Acid: HNO_3, Base: H_2SO_4
Conjugate acid: H_3O^+, Conjugate base: HSO_4^-

(iii) $NH_4^+ + NH_4Cl \text{ ----> } NH_3 + Cl^-$
Acid: NH_4^+, Base: NH_3

(c) $NH_4HSO_4 + NH_4OH \text{ ----> } pH = 9.35$

Use Henderson-Hasselbalch equation or neutralization to calculate grams of ammonium sulphate.

(d) Predict nature of salt solutions:

(i) NH_4Br --> acidic (NH_4^+ hydrolyzes)
(ii) $CaCl_2$ ---> neutral (strong acid + strong base)
(iii) KCN ----> basic (CN^- hydrolyzes)

4 (a) Briefly explain:

(i) Five factors that affect ionization energy:
- Atomic size
- Nuclear charge
- Shielding effect
- Electron configuration
- Penetration effect

(ii) Four causes of anomalous behaviour:
- Small atomic size
- High ionization energy
- High electronegativity
- Absence of d-orbitals

(iii) Diagonal relationship:
First element of a group has similar properties to second element in next group due to similar size and charge density.

(b) Four reactions showing beryllium
- $Be + O_2$ ---> BeO
- $Be + HCl$ ---> $BeCl_2 + H_2$
- $Be + H_2O$ ---> No reaction
- $Be + NaOH$ ---> $Be(OH)_2$

(c) Oxides of period 3 elements:
Trend: from basic to acidic across the period
Na_2O, MgO – basic
Al_2O_3 – amphoteric
SiO_2, P_4O_{10}, SO_3 – acidic

5 (a) Differentiate the following terms:

(i) Electrolytic cell and electrochemical cell:

Electrolytic cell uses electrical energy to drive a non-spontaneous reaction.
Electrochemical cell converts chemical energy into electrical energy in a spontaneous reaction.

(ii) Molarity and molality:
Molarity (M) is moles of solute per liter of solution (mol/dm^3).
Molality (m) is moles of solute per kg of solvent (mol/kg).

(iii) Anode and cathode:
Anode is the electrode where oxidation occurs.
Cathode is the electrode where reduction occurs.

(iv) Positive pole and negative pole:
Positive pole is the electrode with a higher potential in an electrochemical cell (cathode).
Negative pole is the electrode with a lower potential in an electrochemical cell (anode).

(b) Find out whether there will be formation of a precipitate when 200 cm^3 of 0.0040 M $BaCl_2$ is added to 600 cm^3 of 0.0080 M K_2SO_4 given that $Ksp(BaSO_4) = 1.1 \times 10^{-10}$.

$[Ba^{2+}] = (0.0040 \times 200) / (200 + 600) = 0.001$ M
$[SO_4^{2-}] = (0.0080 \times 600) / (200 + 600) = 0.006$ M
Ion product $Q = [Ba^{2+}][SO_4^{2-}] = (0.001)(0.006) = 6 \times 10^{-6}$
Since $Q > Ksp$ ($6 \times 10^{-6} > 1.1 \times 10^{-10}$), precipitation occurs.

(c) Calculate the number of moles of silver chloride (AgCl) which will saturate 250 cm^3 of 0.0001 M sodium chloride solution, given that $Ksp(AgCl) = 1.6 \times 10^{-10}$ mol^2/dm^6.

$Ksp = [Ag^+][Cl^-]$
$[Ag^+] = Ksp / [Cl^-] = (1.6 \times 10^{-10}) / (0.0001) = 1.6 \times 10^{-6}$ M
Moles of AgCl = $(1.6 \times 10^{-6}) \times (250/1000) = 4.0 \times 10^{-7}$ moles

6 (a) Explain briefly why transition elements:

(i) Have variable oxidation states
They involve both (n-1)d and ns electrons in bonding.

(ii) Form coloured compounds
Due to d-electron transitions that absorb visible light.

(iii) Exhibit magnetic properties
Due to the presence of unpaired electrons in d-orbitals.

(b) Give IUPAC names and oxidation states for:

(i) $K_3[Co(NO_2)_6]Cl_3Br_2$ – Potassium hexanitrocobalt(III) chloride bromide; oxidation state: +3
(ii) $[Ag(NH_3)_2]^+$ – Diamminesilver(I) ion; oxidation state: +1
(iii) $[AuCl_4]^-$ – Tetrachloroaurate(III) ion; oxidation state: +3
(iv) $[Pd(CN)_6]^{2-}$ – Hexacyanopalladate(IV) ion; oxidation state: +4
(c) Reaction of Fe complex to form acidic solution:
$[Fe(H_2O)_6]^{3+} + 3Cl^- + H_2O \rightleftharpoons [Fe(H_2O)_5OH]^{2+} + H^+ + 3Cl^-$

(i) Name the ligands and their role:
Ligands: H_2O and OH^- – donate electron pairs to Fe^{3+}

(ii) Shape of $[Fe(H_2O)_5OH]^{2+}$:
Octahedral

(iii) Why $Fe(H_2O)_5OH^{2+}$ loses H^+ less easily than $Fe(H_2O)_6^{3+}$:
OH^- increases electron density, making proton loss more difficult.

7 (a) (i) Froth flotation means separation of mineral particles by attaching to air bubbles and floating, leaving gangue behind.

(ii) Write down processes after froth flotation of $CuFeS_2$ ore:
Roasting: $2CuFeS_2 + 4O_2 \rightarrow Cu_2S + 2FeO + 2SO_2$
Matte smelting: $Cu_2S + FeS + SiO_2 \rightarrow Cu_2S + FeSiO_3$ (slag)
Conversion: $Cu_2S + O_2 \rightarrow 2Cu + SO_2$

(b) Stages in bauxite purification before electrolysis:
Crushing and grinding
Digestion with NaOH (Bayer process)
Filtration of undissolved impurities
Precipitation of $Al(OH)_3$
Calcination to Al_2O_3

8 (a) Six advantages and four disadvantages of using manures

Advantages:
Improves soil fertility
Environmentally friendly
Increases water retention
Reduces soil erosion
Cost-effective
Contains organic matter

Disadvantages:
Slow nutrient release

Bulky and difficult to transport
May contain pathogens
Requires large quantities

(b) (i) Immobilization vs ammonification
Immobilization is when nutrients are incorporated into microbial cells
Ammonification is the conversion of organic nitrogen to ammonia

(ii) How farm manure should be handled and stored
Stored in covered pits
Avoid exposure to rain
Proper mixing to allow decomposition
Use within a short time to prevent nutrient loss

(c) A soil requires 80 kg N per hectare. Calculate required ammonium sulphate

Molar mass of $(NH_4)_2SO_4$ = 132 g/mol
Nitrogen content = 2×14 = 28 g
28/132 = 21.2%
Required amount = (80×100)/21.2 = 377.36 kg ammonium sulphate per hectare
9 (a) Give the structural formulae of the following compounds:

(i) Methylphenyl ether: $C_6H_5–O–CH_3$
(ii) Methanol: CH_3OH
(iii) Propanone: $CH_3–CO–CH_3$
(iv) Methyl ethanoate: CH_3COOCH_3
(v) 3-phenyl-1-pentene: $CH_2=CH–CH_2–CH(C_6H_5)–CH_3$

(b) Give the structure and the name of the product(s) formed in the following reactions:

(i) Benzaldehyde + HNO_3/H_2SO_4 ----> 3-nitrobenzaldehyde (electrophilic substitution at meta position)

(ii) Nitrobenzene + HNO_3/H_2SO_4 ----> 1,3-dinitrobenzene (substitution at meta position)

(c) Identify stronger acid among the following pairs and give reason(s) for your choice:

(i) $CH_3CHClCH_2OH$ and $CH_3CH_2CH_2OH$ ----> $CH_3CHClCH_2OH$ is stronger due to inductive effect of chlorine increasing acidity.

(ii) Benzoic acid and p-bromobenzoic acid ----> p-bromobenzoic acid is stronger due to electron withdrawing effect of bromine.

(iii) CHF_2COOH and $CH_3ClCOOH$ ----> CHF_2COOH is stronger because fluorine has greater electronegativity and stronger inductive effect.

(d) Write balanced chemical equations for the reaction of $HO–C_6H_4–CH=CH–OH$ with:

(i) Sodium metal:
$HO–C_6H_4–CH=CH–OH + 2Na$ ----> $NaO–C_6H_4–CH=CH–ONa + H_2$

(ii) Dilute $KMnO_4$:
$HO–C_6H_4–CH=CH–OH + [O]$ ----> $HO–C_6H_4–COOH–COOH$

(iii) Acetic acid:
$HO–C_6H_4–CH=CH–OH + CH_3COOH$ ----> $HO–C_6H_4–CH=CH–OCOCH_3 + H_2O$

(iv) Hydrogen/Ni:
$HO–C_6H_4–CH=CH–OH + H_2/Ni$ ----> $HO–C_6H_4–CH_2–CH_2–OH$

10 (a) (i) Aldol condensation is a reaction where two molecules of aldehyde or ketone having alpha hydrogen react to form a β-hydroxy aldehyde or ketone followed by dehydration to form α,β-unsaturated carbonyl compounds.

(ii) $(CH_3)_2CO$ and CH_3CHO undergo aldol condensation because they have alpha hydrogen.
$(CH_3)_3CCHO$ and $(CH_3)_3COH$ do not have alpha hydrogen and cannot undergo aldol condensation.

(b) Distinguish the following molecules:

(i) CH_3COCl and $HCOCH_2Cl$
CH_3COCl reacts with water releasing white fumes of HCl
$HCOCH_2Cl$ does not produce such effect

(ii) Phenol and Benzyl alcohol
Phenol gives violet color with $FeCl_3$
Benzyl alcohol does not

(iii) HCOOH and CH_3COOH
HCOOH reduces Tollens' reagent
CH_3COOH does not

(c) Show how the following conversions can be achieved in not more than three steps:

(i) $CH_3CH_2CH_2CONH_2$ ----> $CH_3CH_2CH_2C\equiv N$
Use P_2O_5 or $SOCl_2$ to convert amide to nitrile

(ii) Benzene ----> isopropylbenzene
Benzene + $CH_3CHClCH_3/AlCl_3$ ----> $C_6H_5CH(CH_3)_2$

(iii) Benzene ----> acetophenone
Benzene + $CH_3COCl/AlCl_3$ ----> $C_6H_5COCH_3$

(iv) $NH_2CH_2COONH_4^+$ ----> NH_2CH_2COOH
Heat to decompose salt to amino acid (glycine)

(v) Aniline ----> m-dinitrobenzene
Step 1: Aniline ----> Acetanilide
Step 2: Acetanilide + HNO_3/H_2SO_4 ----> m-nitroacetanilide
Step 3: Hydrolysis ----> m-dinitroaniline