THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/2 **CHEMISTRY 2**

Time: 3 Hours **ANSWERS** **Mwaka: 2019**

Instructions

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

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1 (a) Define the following terms giving one example in each:

(i) A conjugate base
A conjugate base is the species that remains after an acid donates a proton (H^+).
Example: Cl^- is the conjugate base of HCl.

(ii) A conjugate acid base pair
A conjugate acid-base pair refers to two substances that differ by a proton (H^+). One acts as an acid, the other as its conjugate base.
Example: H_2O and OH^-.

(iii) A conjugate acid
A conjugate acid is the species formed when a base accepts a proton (H^+).
Example: NH_4^+ is the conjugate acid of NH_3.

(iv) Arrhenius acid
An Arrhenius acid is a substance that increases the concentration of hydrogen ions (H^+) in aqueous solution.
Example: HCl.

1 (b) Label the conjugate acids and bases in these reactions:

(i) $S^{2-}(aq) + H_3O^+(aq) \rightleftharpoons HS^-(aq) + H_2O(l)$
S^{2-} is the base, HS^- is its conjugate acid.
H_3O^+ is the acid, H_2O is its conjugate base.

(ii) $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
NH_4^+ is the acid, NH_3 is its conjugate base.
H_2O is the base, H_3O^+ is its conjugate acid.

(iii) $NH_2^-(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + OH^-(aq)$
NH_2^- is the base, NH_3 is its conjugate acid.
H_2O is the acid, OH^- is its conjugate base.

(iv) $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$
CH_3COOH is the acid, CH_3COO^- is its conjugate base.
H_2O is the base, H_3O^+ is its conjugate acid.

1 (c) Calculate the concentration of hydrogen ions and hydroxide ions in 0.01 M solution of:

(i) Hydrochloric acid
HCl is a strong acid and ionizes completely.
$[H^+] = 0.01$ M
$[OH^-] = Kw / [H^+] = 1\times10^{-14} / 0.01 = 1\times10^{-12}$ M

(ii) Acetic acid (α for CH_3COOH is 5%)
$[H^+]$ = 5% of 0.01 M = 0.0005 M
$[OH^-] = Kw / [H^+] = 1\times10^{-14} / 0.0005 = 2\times10^{-11}$ M

1 (d) The Kw of water at 25°C and 65°C are 10^{-14} mol^2dm^{-6} and 2.92×10^{-14} mol^2dm^{-6} respectively.

(i) State the effect of temperature in the dissociation of water.
Increasing temperature increases the dissociation of water. Thus, Kw increases with temperature.

(ii) Calculate the $[H^+]$ at 65°C
$Kw = [H^+]^2$
$[H^+] = \sqrt{2.92\times10^{-14}} = 1.71\times10^{-7}$ M

(iii) Find the pH of water at 65°C
$pH = -\log[H^+] = -\log(1.71\times10^{-7}) = 6.77$

(iv) Calculate the pH of water under neutral condition at 65°C
Under neutrality, $[H^+] = \sqrt{Kw} = 1.71\times10^{-7}$
pH = 6.77

2 (a) Briefly explain the following:

(i) Average rate of reaction
It is the change in concentration of reactants or products divided by the time interval during which the change occurs.

(ii) Rate constant (k)
Rate constant is a proportionality constant in the rate law of a reaction. It indicates how fast a reaction proceeds at a given temperature and is independent of reactant concentrations.

2 (b) (i) If you were in-charge of a chemical company, briefly explain why you would prefer a catalyst that works at room temperature rather than heating the reactants to 200°C.
Using a catalyst at room temperature reduces energy costs, avoids thermal decomposition of reactants, enhances safety, and is more efficient environmentally and economically.

(ii) A student defined a catalyst as "a substance that speeds up a reaction without taking part in the reaction." State what is wrong with the definition.
The error is that a catalyst does take part in the reaction mechanism temporarily but is regenerated at the end. It does not appear in the overall equation but plays a role in reaction steps.

2 (c) Explain the following:

(i) Powdered sugar dissolves faster than crystalline sugar.

Because powdered sugar has a larger surface area, it increases the rate of contact with the solvent, hence dissolves faster.

(ii) It takes more time to cook rice at higher altitudes than low altitudes.
At higher altitudes, atmospheric pressure is lower, hence water boils at a lower temperature which slows cooking.

(iii) We save fuel when we use a pressure cooker.
A pressure cooker increases the boiling point of water, allowing food to cook faster and reducing fuel consumption.

(iv) There is no difference in cooking time between sea level and higher altitude when we use a pressure cooker at both places.
A pressure cooker maintains internal pressure, thus cooking at high temperature regardless of external atmospheric pressure.

2 (d) Consider the reaction with Ea = 75 $kJmol^{-1}$ at 293 K. When a catalyst is used in the same reaction at 20°C, its Ea is lowered to 20 $kJmol^{-1}$. Calculate how fast is the catalyzed reaction with respect to uncatalyzed reaction.

Use Arrhenius equation ratio:
$k_2/k_1 = e^{[(Ea_1 - Ea_2)/RT]}$
$Ea_1 = 75\times10^3\ Jmol^{-1}$, $Ea_2 = 20\times10^3\ Jmol^{-1}$, $R = 8.314\ Jmol^{-1}K^{-1}$, T = 293 K
$k_2/k_1 = e^{[(75000 - 20000)/(8.314\times293)]}$
$= e^{(55000/2437.9)} = e^{22.57} \approx 6.1\times10^9$

The catalyzed reaction is approximately 6.1×10^9 times faster than the uncatalyzed reaction.

3 (a) Describe the following:
(i) The standard electrode potential
The standard electrode potential is the measure of the tendency of an electrode to lose or gain electrons when in contact with its ion solution under standard conditions (1 M concentration, 1 atm pressure, and 25°C). It is measured against the standard hydrogen electrode.
Example: E^0 for Zn^{2+}/Zn = -0.76 V

(ii) Electrochemical series
The electrochemical series is a list of elements arranged in order of their standard electrode potentials. It helps predict the direction of redox reactions and the strength of oxidizing or reducing agents.

3 (b) Write the equation showing how the electromotive force (e.m.f) of the following cell changes with their ion concentration.
Cell: $Ce^{3+}(aq)$ | $Ce^{4+}(aq)$ || $Cr^{3+}(aq)$ | $Cr(s)$
E^0 for Ce^{4+}/Ce^{3+} = 2.33 V and E^0 for Cr^{3+}/Cr = -0.41 V

Cell reaction: $Ce^{4+} + Cr(s) \text{--->} Ce^{3+} + Cr^{3+}$
$E^0cell = E^0(cathode) - E^0(anode) = 2.33 - (-0.41) = 2.74$ V

Using Nernst equation:
$Ecell = E^0cell - (0.059/n) \log ([Ce^{3+}][Cr^{3+}]/[Ce^{4+}])$
Where n = 3 (electrons transferred)

3 (c)(i) Write down the expression for the cell e.m.f for the reaction below:
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \text{---->} Mn^{2+}(aq) + 4H_2O(l)$

$Ecell = E^0 - (0.059/5) \log ([Mn^{2+}]/[MnO_4^-][H^+]^8)$

(ii) State why the oxidizing power of manganate (VII) ions in (i) is quite sensitive to the concentration of hydrogen ions.
Because H^+ appears with a power of 8 in the Nernst equation, even slight changes in $[H^+]$ cause large changes in Ecell, making the reaction highly sensitive to pH variation.

3 (d) Briefly explain any four methods for rusting prevention.
Painting: Coating metal with paint prevents moisture and air contact.
Galvanizing: Coating iron with a layer of zinc protects it from oxidation.
Alloying: Mixing iron with other metals (like chromium or nickel) increases rust resistance.
Oiling and greasing: Used in machinery to form a protective layer against moisture.

4 (a) (i) Define isoelectronic species.
Isoelectronic species are atoms, ions or molecules having the same number of electrons.

(ii) Name a species that will be isoelectronic with each of the following:
$F^- \rightarrow$ Neon (Ne), both have 10 electrons
$O^{2-} \rightarrow Na^+$, both have 10 electrons
$Mg^{2+} \rightarrow$ Neon (Ne), both have 10 electrons

4 (b) Among the elements of the second period, Li to Ne, identify the one(s):

(i) With the highest first ionization energy
Neon (Ne) – it has full outer shell and strong nuclear attraction.

(ii) With the highest electronegativity
Fluorine (F) – highest ability to attract electrons in a bond.

(iii) With the largest atomic radius
Lithium (Li) – smallest nuclear charge among the period elements.

(iv) That is most reactive non-metal
Fluorine (F) – high reactivity due to high electronegativity and low bond dissociation energy.
(v) That is the most reactive metal
Lithium (Li) – only metal in the group, loses electron easily.

4 (c) Write a chemical equation representing the following:

(i) In moist air copper corrodes to produce a greenish layer on the surface.
$2Cu + H_2O + CO_2 + O_2$ ----> $Cu(OH)_2 \cdot CuCO_3$ (Basic copper carbonate – green layer)

(ii) Chlorination of calcium hydroxide produces a bleaching powder.
$Ca(OH)_2 + Cl_2$ ---> $CaOCl_2 + H_2O$

(iii) Adding concentrated H_2SO_4 in sugar produces a dense brownish black mass.
$C_{12}H_{22}O_{11} + H_2SO_4$ ----> $12C + 11H_2O$ + heat

(iv) Action of phosphorus on concentrated HNO_3
$P + 5HNO_3$ -----> $H_3PO_4 + 5NO_2 + H_2O$

(v) Oxidation of hydrogen peroxide with potassium permanganate in acidic medium.
$2MnO_4^- + 5H_2O_2 + 6H^+$ ----> $2Mn^{2+} + 5O_2 + 8H_2O$

(vi) Action of zinc on dilute nitric acid.
$Zn + 2HNO_3$ ----> $Zn(NO_3)_2 + H_2$

4 (d) Element A burns in nitrogen to give an ionic compound B. B reacts with water to give C. C reacts with CO_2 to give D. Also C gives a milky colouration on bubbling with CO_2. Excess bubbling of C gives a clear solution E. Use chemical equations to identify A, B, C, D and E.

A = Calcium
$A + N_2$ ---> Ca_3N_2 (B)
$Ca_3N_2 + H_2O$ ----> $Ca(OH)_2$ (C) + NH_3
$C + CO_2$ ----> $CaCO_3$ (D) (milky precipitate)
Excess CO_2 ----> $Ca(HCO_3)_2$ (E) – clear solution
5 (a) With the aid of chemical equation, show how the following oxides can be prepared:

(i) Calcium oxide (Direct method)
$CaCO_3$ ---> $CaO + CO_2$ (Thermal decomposition of limestone)

(ii) Magnesium oxide (Direct method)
$MgCO_3$ ----> $MgO + CO_2$ (Thermal decomposition of magnesite)

(iii) Copper oxide (Indirect method)

$2Cu + O_2 \text{ ----> } 2CuO$ (Heating copper metal in air)

(iv) Zinc oxide (Indirect method)
$2ZnS + 3O_2 \text{ ----> } 2ZnO + 2SO_2$ (Roasting of zinc sulphide ore)

5 (b) With the aid of chemical equation, show how the following carbonates can be prepared:

(i) Sodium carbonate
$NaOH + CO_2 \text{ ----> } Na_2CO_3 + H_2O$ (Solvay process)

(ii) Magnesium carbonate
$Mg(OH)_2 + CO_2 \text{ ----> } MgCO_3 + H_2O$

(iii) Zinc carbonate
$ZnSO_4 + Na_2CO_3 \text{ ----> } ZnCO_3 + Na_2SO_4$

5 (c) State three uses of metal oxides.
Used in ceramics and glass production
Act as catalysts in chemical reactions (e.g., MnO_2 in decomposition of H_2O_2)
Used in coloring pigments for paints and plastics

6 (a) (i) Explain how do $[PtCl_2(NH_3)_2]$ and $[Pt(NH_3)_6]Cl_4$ differ in electrolytic conductance.
$[PtCl_2(NH_3)_2]$ is a neutral complex and does not ionize in solution, so it has low conductance.
$[Pt(NH_3)_6]Cl_4$ dissociates into 4 ions (1 cation and 3 Cl^-), resulting in higher conductance.

(ii) Write the hybridization states of Pt in compounds at 6 (a)(i).
In $[PtCl_2(NH_3)_2]$: Pt is dsp^2 hybridized (square planar geometry)
In $[Pt(NH_3)_6]Cl_4$: Pt is d^2sp^3 hybridized (octahedral geometry)

6 (b) Identify the coloured complexes from the following and give one reason for each compound of your selection.

(i) $[Ti(NO_3)_4]$ – Coloured (Ti^{4+} has d^0 but nitrate ligand can allow charge transfer giving colour)
(ii) $[Cu(NH_3)_4]BF_4$ – Coloured (Cu^{2+} has d^9 configuration, d-d transitions possible)
(iii) $[Cr(NH_3)_6]Cl_3$ – Coloured (Cr^{3+} has d^3 configuration, d-d transitions possible)
(iv) $K_3[VF_6]$ – Coloured (V^{3+} has d^2 configuration, d-d transitions possible)

6 (c) (i) Distinguish paramagnetism from diamagnetism.
Paramagnetism is due to presence of unpaired electrons, substances are attracted by magnetic field.
Diamagnetism is due to paired electrons, substances are slightly repelled by magnetic field.

(ii) With reasons, identify the paramagnetic and diamagnetic compound in $[Fe(CN)_6]^{3-}$ and $[Fe(CN)_6]^{4-}$
$[Fe(CN)_6]^{3-}$ is paramagnetic (Fe^{3+} has 5 unpaired electrons)

$[Fe(CN)_6]^{4-}$ is diamagnetic (Fe^{2+} forms low-spin complex with all electrons paired)

6 (d) An element X with common oxidation state of +2 is obtained as a white gelatinous precipitate when sodium hydroxide is added to its ionic solution. When excess amount of alkali is used, the precipitate dissolves. The precipitate also dissolves when an aqueous solution of ammonia is added in excess amount. Deduce element X using proper chemical equations from the given information.

X is Zn (Zinc).
$Zn^{2+} + 2NaOH$ ---> $Zn(OH)_2$ (white precipitate)
$Zn(OH)_2$ + excess NaOH ----> $[Zn(OH)_4]^{2-}$ (soluble complex)
$Zn(OH)_2 + 4NH_3$ ---> $[Zn(NH_3)_4]^{2+} + 2OH^-$ (soluble complex)

7 (a) (i) State four significance of soil colloids.
Hold water and nutrients
Exchange cations with plant roots
Improve soil structure
Influence soil pH buffering

(ii) Briefly explain two effects of soil pH on plant growth.
Affects nutrient availability (some nutrients become insoluble at extreme pH)
Influences microbial activity and root development

7 (b) Why is it important to manage the soil pH?
Proper pH optimizes nutrient uptake, prevents toxicity, enhances microbial activity and ensures better crop yield.

7 (c) A certain soil sample was analyzed in the laboratory and found to contain the following ions in meq/100 g of oven dry soil: $K^+ = 0.28$, $Mg^{2+} = 0.12$, $Ca^{2+} = 1.00$, $Na^+ = 0.03$ and $H^+ = 10.00$. If the cation exchange capacity (C.E.C) of the soil is 3.83 meq/100 g of oven dry soil, calculate the percentage base saturation (PBS).

PBS = $(K^+ + Mg^{2+} + Ca^{2+} + Na^+)$ / CEC × 100
PBS = (0.28 + 0.12 + 1.00 + 0.03) / 3.83 × 100 = 1.43 / 3.83 × 100 ≈ 37.34%

7 (d) A 21 g of soil sample was dried in oven and lost its weight by 1 g. The soil was analyzed and found to contain 0.0015 g of Ca^{2+}. Calculate the concentration (in meq/100 g oven dry soil) of calcium in the soil sample (Ca = 40 $gmol^{-1}$).

Mass of dry soil = 21 - 1 = 20 g
Converting to 100 g basis = (0.0015 g / 20 g) × 100 = 0.0075 g/100 g
Moles of Ca^{2+} = 0.0075 / 40 = 0.0001875 mol
meq = 0.0001875 mol × 1000 × 2 = 0.375 meq/100 g oven dry soil

8 (a) An alcohol with a formula $C_6H_{11}OH$ does not react with bromine or bromine water.

(i) What does the information about bromine tell you?
It shows that the alcohol does not contain a carbon-carbon double bond (C=C), meaning it is a saturated compound and not an alkene.

(ii) Identify the number of rings the compound possesses.
C_6H_{12} is the general formula of a saturated cyclic compound. Since this compound has C_6H_{12} minus one hydrogen ($C_6H_{11}OH$), it suggests the presence of a single ring – a cyclohexane ring.

(iii) Draw the structure of the alcohol.
Structure: A cyclohexane ring with an -OH group attached.
OH
|
Cyclohexane ring (six-membered)

(iv) Suggest the name for alcohol in (a)(ii).
Cyclohexanol

8 (b)
(i) Show the structure and IUPAC name of the resulting organic compound when propan-1-ol reacts with ethanoic acid in mineral acid.
$CH_3CH_2CH_2OH + CH_3COOH$ ----> $CH_3COOCH_2CH_2CH_3 + H_2O$
IUPAC name: Propyl ethanoate

(ii) Phenol has a structure very much like ethanol. Draw the structure of the molecules and predict whether anything would happen if the two liquids are mixed with hot benzoyl chloride in acidic medium.

Structure of ethanol: CH_3CH_2OH
Structure of phenol: C_6H_5OH

Reaction with benzoyl chloride:
$C_6H_5OH + C_6H_5COCl$ ----> $C_6H_5OCOC_6H_5 + HCl$
Phenol reacts with benzoyl chloride to give phenyl benzoate.
Ethanol will also react but less efficiently. Phenol reacts faster due to resonance stabilization of the phenoxide ion.

8 (c)
(i) Can alcohols act as nucleophiles? Give reason for your answer.
Yes. Alcohols contain lone pairs of electrons on oxygen which can attack electron-deficient centers (like carbocations or carbon in acyl halides), acting as nucleophiles.

(ii) If you were using PCl_5 or $SOCl_2$ to test for the presence of OH^- groups, explain why the chemicals and apparatus must be dry.
OH^- groups in alcohols or phenols react with PCl_5 or $SOCl_2$ forming alkyl halides and releasing HCl or SO_2. If moisture is present, it reacts with the reagents giving false results or side reactions.

9 (a) An unknown compound with a molecular mass of 86 amu contains 69.8% carbon, 11.6% hydrogen and the rest is oxygen. The compound does not reduce Fehling's solution but gives a positive Iodoform test. Describe the possible structure of the compound.

Empirical formula calculation:
C = 69.8/12 = 5.82
H = 11.6/1 = 11.6
O = 100 - (69.8 + 11.6) = 18.6
O = 18.6/16 = 1.16
Mole ratio ≈ C: 5, H: 10, O: 1 → Empirical formula = $C_5H_{10}O$

Molecular mass = 86
Empirical formula mass = 86 → Molecular formula = $C_5H_{10}O$

Positive iodoform test indicates a methyl ketone group (CH_3CO–). So structure is likely to be 2-pentanone:
$CH_3CH_2COCH_2CH_3$

9 (b) By using chemical reactions, show how propanoic acid reacts with the following compounds:

(i) Hydroxylamine
$CH_3CH_2COOH + NH_2OH$ ----> $CH_3CH_2C{=}NOH + H_2O$ (Oxime)

(ii) Hydrazine
$CH_3CH_2COOH + NH_2NH_2$ ----> $CH_3CH_2C{=}NNH_2 + H_2O$ (Hydrazone)

(iii) Phenyl hydrazine
$CH_3CH_2COOH + C_6H_5NHNH_2$ ----> $CH_3CH_2C{=}NNHC_6H_5 + H_2O$ (Phenylhydrazone)

(iv) Phosphorus pentachloride
$CH_3CH_2COOH + PCl_5$ ----> $CH_3CH_2COCl + POCl_3 + HCl$

9 (c) Explain the following statements:

(i) o-hydroxybenzaldehyde is a liquid at room temperature while p-hydroxybenzaldehyde is a high melting solid.
o-Hydroxybenzaldehyde forms intramolecular hydrogen bonds preventing strong intermolecular bonding, hence it remains liquid.

p-Hydroxybenzaldehyde forms strong intermolecular hydrogen bonds, leading to high melting point due to crystal lattice formation.

(ii) It is incorrect to name butanone as butan-2-one.
This statement is false. Actually, it is correct to name butanone as butan-2-one according to IUPAC naming because the carbonyl group is on carbon 2, making it a ketone.

10 (a) Show the initiation step and propagation step for the following polymerization types for Polytetrafluoroethene (PTFE) polymer:

(i) Free radical polymerization
Initiation:
$R\bullet + CF_2{=}CF_2$ ----> $R{-}CF_2{-}CF_2\bullet$

Propagation:
$R{-}CF_2{-}CF_2\bullet + CF_2{=}CF_2$ ----> $R{-}CF_2{-}CF_2{-}CF_2{-}CF_2\bullet$
Repeat propagation until desired chain length is reached.

(ii) Cationic polymerization
Initiation:
$H^+ + CF_2{=}CF_2$ ----> $CF_2^+{-}CF_2H$ (formation of carbocation)

Propagation:
$CF_2^+{-}CF_2H + CF_2{=}CF_2$ ----> $CF_2{-}CF_2{-}CF_2^+{-}CF_2H$
Further propagation continues via carbocation transfer.

(iii) Anionic polymerization
Initiation:
$R^- + CF_2{=}CF_2$ ----> $R{-}CF_2{-}CF_2^-$

Propagation:
$R{-}CF_2{-}CF_2^- + CF_2{=}CF_2$ ----> $R{-}CF_2{-}CF_2{-}CF_2{-}CF_2^-$
Propagation continues with the nucleophilic chain end.

10 (b) Give the IUPAC names of monomers in the following polymers:

(i) Semi aromatic polyamide
Monomers: 1,4-Benzenedicarboxylic acid (terephthalic acid) and 1,3-diaminopropane

(ii) Neoprene (oil resistant elastomer)
Monomer: 2-chlorobuta-1,3-diene

(iii) Saran (packaging film)

Monomers: Vinylidene chloride (1,1-dichloroethene) and vinyl chloride

(iv) Oil soluble polymer
Monomer: Propene ($CH_2=CH-CH_3$)

10 (c) Alanine (A), Glycine (G), and Valine (V) with the following structures are among the natural amino acids for protein synthesis:

(i) Identify the functional groups in those amino acids.
Each amino acid contains two main functional groups:
$-NH_2$ (amino group) and –COOH (carboxylic acid group)

(ii) Show how polymerization of those monomers can be done.
Polymerization occurs via condensation between $-NH_2$ of one amino acid and –COOH of another forming a peptide bond with loss of H_2O:
$-COOH + -NH_2 \text{ ----> } -CO-NH- + H_2O$

(iii) Provide the common name of the resulting polymer in (ii).
Polypeptide or protein

(iv) Write the minor product common to all in (ii).
Water (H_2O)

(v) What name is given to the bond combining the three amino acids?
Peptide bond or amide bond