THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/2 **CHEMISTRY 2**

Time: 3 Hours **ANSWERS** **Mwaka: 2018**

Instructions

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

1 (a) Define the following:

(i) Rate of reaction
The rate of reaction is the change in concentration of a reactant or product per unit time.

(ii) Rate constant
Rate constant (k) is a proportionality constant in the rate equation which is specific for a particular reaction at a given temperature.

(iii) Reaction mechanism
Reaction mechanism is the step-by-step sequence of elementary reactions by which an overall chemical change occurs.

(iv) Molecularity of reaction
Molecularity is the number of reacting species (atoms, ions, molecules) involved in an elementary reaction step.

(v) Zero order reaction
A reaction in which the rate is independent of the concentration of the reactant.

(vi) Half-life
Half-life is the time required for the concentration of a reactant to reduce to half its initial value.

1 (b)
$2NO(g) + 2H_2(g) \text{ ----> } N_2(g) + 2H_2O(g)$

Experiment	[NO]	$[H_2]$	Initial rate
1	5×10^{-3}	2×10^{-3}	1.3×10^{-5}
2	10×10^{-3}	2×10^{-3}	5×10^{-5}
3	10×10^{-3}	4×10^{-3}	1×10^{-4}

(i) Determine the order with respect to each reactant and the overall order.
Comparing experiment 1 and 2: [NO] doubles, rate increases 4 times. So order with respect to NO is 2.
Comparing experiment 2 and 3: $[H_2]$ doubles, rate doubles. So order with respect to H_2 is 1.
Overall order = 2 + 1 = 3

(ii) Establish the rate law for the reaction.
$\text{Rate} = k[NO]^2[H_2]$

(iii) Calculate the rate constant.
Using experiment 1:
$1.3\times10^{-5} = k \times (5\times10^{-3})^2 \times (2\times10^{-3})$
$1.3\times10^{-5} = k \times 5\times10^{-8}$

$k = 1.3\times10^{-5} / 5\times10^{-8} = 260\ s^{-1}\cdot M^{-2}$

1 (c) Conversion of cyclopropane to propene is first order, rate constant $k = 6.7\times10^{-4}\ s^{-1}$

(i) $[A]_0 = 0.25$ M, t = 8.8 min = 528 sec
$[A] = [A]_0e^{(-kt)} = 0.25e^{(-6.7\times10^{-4} \times 528)} = 0.25e^{(-0.354)} \approx 0.25 \times 0.702 \approx 0.176$ M

(ii) Time for [A] to decrease from 0.25 M to 0.15 M:
$\ln([A]_0/[A]) = kt \rightarrow \ln(0.25/0.15) = 6.7\times10^{-4} \times t$
$t = \ln(1.667)/6.7\times10^{-4} = 0.511/6.7\times10^{-4} \approx 763$ sec ≈ 12.7 min

(iii) Time for 74% conversion → 26% remaining = 0.25×0.26 = 0.065 M
$\ln(0.25/0.065) = 6.7\times10^{-4} \times t$
$t = \ln(3.846)/6.7\times10^{-4} = 1.35/6.7\times10^{-4} \approx 2015$ sec ≈ 33.6 min

2 (a)
(i) Briefly explain the term oxidation–reduction reaction.
It is a chemical reaction in which electrons are transferred between species, involving oxidation (loss of electrons) and reduction (gain of electrons).

(ii) Reaction: $Cr_2O_7^{2-} + Cl^- \text{---->} Cr^{3+} + Cl_2$
Half equations:
Oxidation: $2Cl^- \text{---->} Cl_2 + 2e^-$
Reduction: $Cr_2O_7^{2-} + 14H^+ + 6e^- \text{---->} 2Cr^{3+} + 7H_2O$
Balanced redox equation:
$Cr_2O_7^{2-} + 14H^+ + 6Cl^- \text{---->} 2Cr^{3+} + 7H_2O + 3Cl_2$

2 (b) State which of the following are oxidation-reduction reactions:

(i) $CH_4(g) + 2O_2(g) \text{---->} CO_2(g) + 2H_2O(g)$
This is an oxidation-reduction (redox) reaction. Carbon in CH_4 is oxidized (from -4 to +4 in CO_2), and oxygen is reduced (from 0 to -2 in H_2O).

(ii) $Zn(s) + 2HCl(aq) \text{---->} ZnCl_2(aq) + H_2(g)$
This is a redox reaction. Zinc is oxidized from 0 to +2 and hydrogen ions in HCl are reduced from +1 to 0 in H_2.

(iii) $Cr_2O_7^{2-}(aq) + 2OH^-(aq) \text{---->} 2CrO_4^{2-}(aq) + H_2O(l)$
This is a redox reaction. Chromium changes oxidation state from +6 in $Cr_2O_7^{2-}$ to +6 in CrO_4^{2-}, but this change is not redox in terms of electron transfer — it is a rearrangement in oxidation states within the same element and usually referred to as an acid-base reaction in alkaline medium.

(iv) $O_3(g) + NO(g) \text{---->} O_2(g) + NO_2(g)$

This is a redox reaction. NO is oxidized (N from +2 to +4), and O_3 is reduced (O from 0 to -2 in O_2).

Therefore:
(i) ✓ Redox reaction
(ii) ✓ Redox reaction
(iii) ✗ Not a redox reaction in conventional electron-transfer terms
(iv) ✓ Redox reaction

2 (c) Identify oxidizing and reducing agents, oxidized and reduced species in 2(b):

(i) Oxidizing agent: O_2, Reducing agent: CH_4
CH_4 oxidized to CO_2, O_2 reduced to H_2O

(ii) Oxidizing agent: HCl, Reducing agent: Zn
Zn oxidized to Zn^{2+}, H^+ reduced to H_2

(iii) Oxidizing agent: $Cr_2O_7^{2-}$, Reducing agent: OH^-
OH^- oxidized to H_2O, Cr reduced to CrO_4^{2-}

(iv) Oxidizing agent: O_3, Reducing agent: NO
NO oxidized to NO_2, O_3 reduced to O_2

2 (d) Calculate e.m.f of cell:
$Pb(s)/Pb^{2+}(1\times10^{-3}\ M)//Cu^{2+}(1\times10^{-2}\ M)/Cu(s)$

$E^0cell = E^0(Cu) - E^0(Pb) = 0.34 - (-0.126) = 0.466\ V$
$Ecell = E^0cell - (0.059/n) \log([Pb^{2+}]/[Cu^{2+}])$
$Ecell = 0.466 - (0.059/2) \log(10^{-3}/10^{-2})$
$Ecell = 0.466 - 0.0295 \times \log(0.1) = 0.466 - 0.0295\times(-1) = 0.4955\ V$

3 (a) Define the following:

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

(ii) 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.

(iii) Conjugate acid-base pair

These are two species that differ by one proton (H^+), where one is the acid and the other is its conjugate base or vice versa.
Example: H_2O and OH^-

3 (b) Identify the acid, base and acid-base conjugates for each of the following equations:
(i) $H_2O + HCl$ ----> $H_3O^+ + Cl^-$
Acid: HCl
Base: H_2O
Conjugate acid: H_3O^+
Conjugate base: Cl^-

(ii) $CH_3COOH + H_2O$ ----> $H_3O^+ + CH_3COO^-$
Acid: CH_3COOH
Base: H_2O
Conjugate acid: H_3O^+
Conjugate base: CH_3COO^-

(iii) $CH_3COOH + H_2SO_4$ ----> $CH_3COOH_2^+ + HSO_4^-$
Acid: H_2SO_4
Base: CH_3COOH
Conjugate acid: $CH_3COOH_2^+$
Conjugate base: HSO_4^-

(iv) $C_6H_5NH_2 + NH_3$ ----> $C_6H_5NH^- + NH_3^+$
Acid: $C_6H_5NH_2$
Base: NH_3
Conjugate acid: NH_4^+
Conjugate base: $C_6H_5NH^-$

3 (c) Calculate the concentration of sodium propanoate (CH_3CH_2COONa) that must be present in a 0.01 M solution of propanoic acid (CH_3CH_2COOH) to produce a pH of 4.30 if Ka for propanoic acid is 1.3×10^{-5}.

Using Henderson-Hasselbalch equation:
$pH = pKa + \log([salt]/[acid])$
$4.30 = -\log(1.3\times10^{-5}) + \log([salt]/0.01)$
$4.30 = 4.89 + \log([salt]/0.01)$
$\log([salt]/0.01) = 4.30 - 4.89 = -0.59$
$[salt]/0.01 = 10^{-0.59} \approx 0.257$
$[salt] = 0.00257$ M

3 (d) Calculate the pH of 0.02 M acetic acid (CH_3COOH). The dissociation constant (Ka) of acetic acid is 1.8×10^{-5}.

$K_a = [H^+]^2 / [acid]$
$[H^+]^2 = K_a \times [acid] = 1.8\times10^{-5} \times 0.02 = 3.6\times10^{-7}$
$[H^+] = \sqrt{3.6\times10^{-7}} = 6\times10^{-4}$ M
pH = $-\log(6\times10^{-4}) = 3.22$

4 (a) Write the solubility product constant (Ksp) expressions for the solubility equilibria of each of the following compounds:

(i) Copper(I) bromide: $CuBr \rightleftharpoons Cu^+ + Br^-$
$K_{sp} = [Cu^+][Br^-]$

(ii) Bismuth sulphide: $Bi_2S_3 \rightleftharpoons 2Bi^{3+} + 3S^{2-}$
$K_{sp} = [Bi^{3+}]^2[S^{2-}]^3$

(iii) Copper(I) iodate: $Cu(IO_3) \rightleftharpoons Cu^+ + IO_3^-$
$K_{sp} = [Cu^+][IO_3^-]$

(iv) Silver chromate: $Ag_2CrO_4 \rightleftharpoons 2Ag^+ + CrO_4^{2-}$
$K_{sp} = [Ag^+]^2[CrO_4^{2-}]$

4 (b) The $[Ag^+]$ of a solution is 4×10^{-3}. Calculate the $[Cl^-]$ that must be exceeded before AgCl can precipitate. The Ksp of AgCl is 1.0×10^{-10}.

$K_{sp} = [Ag^+][Cl^-]$
$1.0\times10^{-10} = 4\times10^{-3} \times [Cl^-]$
$[Cl^-] = 1.0\times10^{-10} / 4\times10^{-3} = 2.5\times10^{-8}$ M

4 (c) 25 cm³ of 0.001 M $BaCl_2$ solution were mixed with 40 cm³ of 0.002 M Na_2SO_4 solution. Will $BaSO_4$ precipitate from this solution?

Moles of $Ba^{2+} = 0.001 \times 25/1000 = 2.5\times10^{-5}$
New concentration after mixing = $2.5\times10^{-5} / (25+40)$mL = $2.5\times10^{-5} / 65\times10^{-3} = 3.85\times10^{-4}$ M

Moles of $SO_4^{2-} = 0.002 \times 40/1000 = 8\times10^{-5}$
New $[SO_4^{2-}] = 8\times10^{-5} / 65\times10^{-3} = 1.23\times10^{-3}$ M

$Q = [Ba^{2+}][SO_4^{2-}] = 3.85\times10^{-4} \times 1.23\times10^{-3} = 4.74\times10^{-7}$
Since Q > Ksp (1.12×10^{-10}), $BaSO_4$ will precipitate.

4 (d) (i) Outline four factors which affect the solubility of sparingly soluble salts:
Common ion effect
Temperature
pH of the solution

Presence of complexing agents

(ii) Calculate the solubility of AgCl in 0.20 M $AgNO_3$.
Ksp = $[Ag^+][Cl^-]$
$[Ag^+] = 0.20$ M
$1\times10^{-10} = 0.20 \times [Cl^-]$ ---> $[Cl^-] = 5\times10^{-10}$ M
5. (a) Why hydrogen element was placed in group I in the modern periodic table?

Hydrogen has one electron in its outermost shell-like alkali metals in group I and forms H^+ ion by losing that electron, similar to alkali metals.

5 (b) Account for the following:

(i) The cationic size of an element is smaller than its atomic size.
When an atom loses electrons to form a cation, the remaining electrons experience a stronger electrostatic pull from the nucleus, hence the cation becomes smaller.

(ii) Group I elements are called alkaline metals.
Group I elements form alkaline solutions (hydroxides) when they react with water, hence they are known as alkali metals.

(iii) Group II elements melt at higher temperatures than group I elements.
Group II elements have stronger metallic bonds due to smaller atomic radii and more delocalized electrons per atom, leading to higher melting points.

(iv) Some compounds are said to be polarized.
A compound is said to be polarized if there is an uneven distribution of electron density between bonded atoms, resulting in partial charges due to differences in electronegativity.

5 (c) Briefly explain the following facts:

(i) Every first member of the group in the periodic table behaves anomalously from other members.
First members like Li, Be, B, C etc. have small size, high ionization energy, and high electronegativity, leading to differences in behavior compared to others in the group.

(ii) Some elements in the periodic table show diagonal relationships.
Certain elements (e.g., Li with Mg, Be with Al) show similarities in properties due to similar size and charge density, known as diagonal relationships.

(iii) Some elements are called d-block elements.
d-block elements are those whose last electron enters the d-orbital. They are transition metals in groups 3–12.

(iv) The compounds of Sc^{3+} are colourless.
Sc^{3+} has no electrons in its d-orbital (d^0 configuration), so no d–d transitions occur, hence its compounds are colourless.

5 (d) The valency shell electronic configuration of element X is represented as $6s^26p^1$.

(i) Give the block, group and period of element X in the periodic table.
Block: p-block
Group: Group 13
Period: Period 6

(ii) Give the possible oxidation state of element X.
+3 and +1 (common for group 13 elements)

(iii) Give the formula of the oxide of X.
X_2O_3 (if oxidation state is +3)

6 (a) Briefly describe the extraction process of tin from its chief ore.

Tin is extracted from its ore cassiterite (SnO_2) using the following steps:
1. Crushing and concentration by gravity separation.
2. Roasting to remove impurities like sulphur and arsenic.
3. Reduction using carbon: $SnO_2 + C \text{ ----> } Sn + CO_2$
4. Purification by liquation or electrolytic refining.

6 (b) Briefly describe the chemical extraction of aluminum from its chief ore.

1. Ore: Bauxite ($Al_2O_3 \cdot 2H_2O$)
2. Purification: Bayer's process – dissolving bauxite in NaOH, filtering out impurities, and precipitating pure $Al(OH)_3$
3. Electrolysis: Hall-Heroult process – Electrolysis of Al_2O_3 dissolved in molten cryolite.
Cathode: $Al^{3+} + 3e^- \text{ ----> } Al$
Anode: $C + O^{2-} \text{ ----> } CO_2$

7 (a) (i) Classify the following oxides:
Al_2O_3 – Amphoteric
Na_2O – Basic
ZnO – Amphoteric
CaO – Basic

(ii) Uses of sulphates of selected metals in different fields:
$MgSO_4$ – used in medicine (Epsom salt)
$FeSO_4$ – used in fertilizers

$CuSO_4$ – used as fungicide
$Al_2(SO_4)_3$ – used in water purification
$BaSO_4$ – used in radiology as contrast medium

7 (b) Explain these facts with suitable equations:

(i) The aqueous solution of iron (III) chloride is acidic.
$FeCl_3 + 3H_2O$ ----> $Fe(OH)_3 + 3HCl$
(ii) Gaseous iron (III) chloride at low temperature exists as a dimer and is a covalent compound.
$2FeCl_3$ ----> Fe_2Cl_6 (dimer)

(iii) Red hot iron decomposes steam reversibly.
$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$

(iv) The aqueous solution of sodium hydrogen carbonate is alkaline.
$NaHCO_3 + H_2O \rightleftharpoons Na^+ + OH^- + H_2CO_3$

7 (c) Why iron (III) carbonate does not exist?
Fe^{3+} ion is small and highly charged, polarizing the large CO_3^{2-} ion, leading to decomposition into $Fe(OH)_3$ and CO_2 in water.

7 (d) With suitable examples, describe the chemistry of zinc oxide (ZnO).

ZnO is amphoteric.
With acids: $ZnO + 2HCl$ ----> $ZnCl_2 + H_2O$
With bases: $ZnO + 2NaOH + H_2O$ ----> $Na_2[Zn(OH)_4]$

8 (a) Outline any six control measures which are useful in minimizing the chemical pollution of water bodies.
Proper waste treatment
Use of biodegradable substances
Reducing use of chemical fertilizers
Proper disposal of industrial effluents
Legislation and regulation enforcement
Public awareness campaigns

8 (b) Outline any four possible causes of environmental degradation.
Deforestation
Industrial pollution
Overgrazing
Urbanization and poor waste disposal

8 (c) Briefly explain eight effects of air pollution to living organisms.

Respiratory diseases
Irritation of eyes and skin
Reduction in crop yield
Acid rain effect
Damage to wildlife
Ozone layer depletion
Neurological disorders
Premature death in sensitive individuals

9 (a) Arrange the following amines in order of increasing basic strength:
Aniline < N-methylaniline < Benzylamine < Ethylamine

Reason: Aniline's lone pair delocalizes into benzene ring reducing availability for protonation. Alkyl groups increase electron density on nitrogen enhancing basicity.

9 (b) How n-propylamine could be prepared from each compound:

(i) n-Propylbromide: $CH_3CH_2CH_2Br + NH_3 \longrightarrow CH_3CH_2CH_2NH_2 + HBr$
(ii) n-Propylalcohol: Convert to propyl bromide first, then react as above.
(iii) n-Butylalcohol: Shorten chain by oxidation to butanal, convert to propanal and then to n-propylamine.
(iv) Propanenitrile: $CH_3CH_2CN + 2H_2 \longrightarrow CH_3CH_2CH_2NH_2$ (hydrogenation)

9 (c) In two steps, describe how to convert benzene into aniline (phenylamine):
1. Nitration: $C_6H_6 + HNO_3 \longrightarrow C_6H_5NO_2 + H_2O$
2. Reduction: $C_6H_5NO_2 + 6[H] \longrightarrow C_6H_5NH_2 + 2H_2O$

9 (d) Reactions of phenylamine:

(i) With ethanoic anhydride:
$C_6H_5NH_2 + (CH_3CO)_2O \longrightarrow C_6H_5NHCOCH_3 + CH_3COOH$
Product: Acetanilide

(ii) With aqueous bromine:
$C_6H_5NH_2 + 3Br_2 \longrightarrow$ 2,4,6-tribromoaniline + 3HBr

(iii) Ethanoic anhydride followed by bromine water:
Acetanilide formation first, then bromination at para position.

(iv) With sodium nitrite and hydrochloric acid below 10°C:
$C_6H_5NH_2 + HNO_2 + HCl \longrightarrow C_6H_5N_2^+Cl^- + 2H_2O$
Product: Benzenediazonium chloride

10 (a) Arrange the following compounds in the order of increasing acidic strength:

(i) Phenol, Benzyl alcohol, Benzoic acid, Nitrobenzoic acid
Increasing acidity:
Benzyl alcohol < Phenol < Benzoic acid < Nitrobenzoic acid
Reason: Electron-withdrawing NO_2 group increases acidity of benzoic acid, while benzyl alcohol is the least acidic due to lack of resonance stabilization of its conjugate base.

(ii) Ethanoic acid, Propanoic acid, Methanoic acid, 2-chloroethanoic acid, 2-methylpropanoic acid
Increasing acidity:
2-methylpropanoic acid < Propanoic acid < Ethanoic acid < Methanoic acid < 2-chloroethanoic acid
Reason: Electron withdrawing groups (like Cl) increase acidity, while electron donating groups (like CH_3) decrease it.

10 (b) Provide the major products of the following reactions:

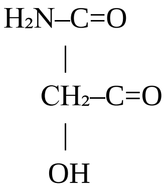
(i) $CH_3CH_2OH + KMnO_4, H_2O, H^+$
CH_3CH_2OH ----> CH_3COOH (ethanoic acid)

(ii) Benzoic acid + PCl_5
$C_6H_5COOH + PCl_5$ ----> $C_6H_5COCl + POCl_3 + HCl$
(Product: Benzoyl chloride)

(iii) $CH_3COOH + C_2H_5OH$ (acid catalyst)
$CH_3COOH + C_2H_5OH$ ----> $CH_3COOC_2H_5 + H_2O$
(Product: Ethyl ethanoate - esterification)

(iv) $CH_3CO–O–COCH_3 + H_2O$ ----> $2CH_3COOH$
(Acid hydrolysis of acetic anhydride yields two molecules of acetic acid)

10 (c) A compound with the following structural formula:



$H_2N–C=O$
|
$CH_2–C=O$
|
OH

(i) With nitrous acid (HNO_2):
Reaction with primary amine produces nitrogen gas, alcohol, water, and carboxylic acid derivative:
$H_2N–CHR–COOH + HNO_2$ ----> $HO–CHR–COOH + N_2 + H_2O$

(ii) With ethanol:
Forms ester via esterification: –COOH group reacts with ethanol:
$R–COOH + C_2H_5OH$ ----> $R–COOC_2H_5 + H_2O$

(iii) With $LiAlH_4$:
Reduces both –COOH and –C=O groups to alcohols:
Product will be: $CH_2OH–CHR–CH_2OH$

(iv) With potassium dichromate:
Oxidizes –OH groups or α-keto acid group (if present) to dicarboxylic acid.

(v) With PCl_5:
Carboxylic group is converted to acid chloride: R–COCl, ketone remains unchanged.

10 (d) Briefly explain the uses and hazards of carboxylic acids.

Uses:
Used in food preservatives (e.g., benzoic acid), production of polymers, esters, solvents, and in pharmaceuticals.

Hazards:
Carboxylic acids are corrosive, can irritate skin and mucous membranes, and some volatile acids (e.g., formic acid) can affect respiratory system.