THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/2 **CHEMISTRY 2**

Time: 3 Hours **ANSWERS** **Mwaka: 2016**

Instructions

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

1 (a) Derive an expression relating Kc and Kp for the decomposition of phosphorus pentachloride:

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

We know $Kp = Kc(RT)^n$
Where n = change in moles of gas = (1 + 1) - 1 = 1
So, Kp = Kc × RT

1 (b) Given:
$K_1 = 4.17 \times 10^{-3}$ for $2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$
$K_2 = 2.1 \times 10^5$ for $I_2(g) + Cl_2(g) \rightleftharpoons 2ICl(g)$

To calculate K for:
$2HCl(g) + I_2(g) \rightleftharpoons 2ICl(g) + H_2(g)$

This reaction = $K_1 \times K_2$
$K = 4.17 \times 10^{-3} \times 2.1 \times 10^5 = 876.0$

1 (c) Five factors that affect the rate of chemical reaction:
- Temperature
- Concentration of reactants
- Surface area of solid reactants
- Catalyst presence
- Nature of reactants

2 (a) Define the following terms:

(i) Standard electrode potential:
It is the potential difference developed when a metal is in contact with its ion solution at standard conditions.

(ii) Redox reaction:
A reaction involving oxidation (loss of electrons) and reduction (gain of electrons).

(iii) Corrosion:
It is the gradual degradation of metals by reaction with atmospheric gases, water, or other chemicals.

2 (b) Difference between voltaic and electrolytic cells:
Voltaic cells convert chemical energy into electrical energy spontaneously.
Electrolytic cells use electrical energy to drive non-spontaneous reactions.

2 (c) Balanced ionic equations and identify oxidants and reductants:

(i) $Fe^{2+} + Cr_2O_7^{2-} + 14H^+$ ----> $Fe^{3+} + Cr^{3+} + H_2O$

Oxidant: $Cr_2O_7^{2-}$, Reductant: Fe^{2+}

(ii) $I_2 + 2S_2O_3^{2-} \dashrightarrow 2I^- + S_4O_6^{2-}$
Oxidant: I_2, Reductant: $S_2O_3^{2-}$

(iii) $Cu^{2+} + I^- \dashrightarrow CuI + I_2$
Oxidant: Cu^{2+}, Reductant: I^-

2 (d) Function of moisture in rusting:
Moisture acts as a medium for the electrochemical reactions between iron, oxygen, and water, promoting rust formation.

2 (e) Half cell reactions:
$Au^{3+} + 3e^- \text{---->} Au \quad E^0 = +1.50\ V$
$NO_3^- + 4H^+ + 3e^- \text{---->} NO + 2H_2O \quad E^0 = +0.96\ V$
Since $E^0(Au) > E^0(NO_3^-)$, Au will not dissolve in HNO_3 (Ecell is negative)

3 (a) $[OH^-] = 0.005\ M$
$[H^+] = Kw / [OH^-] = 1.0 \times 10^{-14} / 0.005 = 2 \times 10^{-12}\ M$

3 (b) pH = 10.6, pOH = 14 - 10.6 = 3.4
$[OH^-] = 10^{-3.4} = 3.98 \times 10^{-4}$
$Kb = [OH^-]^2 / [base] = (3.98\times10^{-4})^2 / 0.1 = 1.58\times10^{-6}$

3 (c) pH = 4.60, $Ka = 1.8\times10^{-5}$
Use Henderson-Hasselbalch equation:
4.60 = -log(Ka) + log([salt]/0.12)
4.60 = 4.74 + log([salt]/0.12)
log([salt]/0.12) = -0.14 ---> $[salt]/0.12 = 10^{-0.14} = 0.72$
[salt] = 0.12 × 0.72 = 0.0864 mol
Mass = 0.0864 mol × 82 = 7.09 g CH_3COONa

3 (d) Ksp of $PbCl_2 = 1.6 \times 10^{-5} = [Pb^{2+}][Cl^-]^2$
Let solubility = x ----> $x(2x)^2 = 4x^3$
$4x^3 = 1.6 \times 10^{-5}$ ----> $x^3 = 4 \times 10^{-6}$ ---> $x = 1.6 \times 10^{-2}$ mol/L

3 (e) (i) Solubility = amount that dissolves. Solubility product = equilibrium constant of dissolution.
(ii) Reaction quotient (Q) = current ion concentrations. Equilibrium constant (K) = at equilibrium.

4 (a) Chemical formulae:
Potassium hexacyanocobaltate(III): $K_3[Co(CN)_6]$
Potassium hexacyanoferrate(II): $K_4[Fe(CN)_6]$

4 (b) Complex ion: $[Co(NH_3)_3(H_2O)_2Cl]^{2+}$
Ligands: NH_3, H_2O, Cl^-
Charge: +2
Geometry: Octahedral

4 (c) Titanium(II) has two unpaired d-electrons ---> paramagnetic due to presence of unpaired electrons.

4 (d) IUPAC names:
(i) Dicopper(I) hexacyanoferrate(II)
(ii) Tetraamminecopper(II) sulfate
(iii) Silver(I) chloride
(iv) Dichlorobis(ethane-1,2-diamine)nickel(II)
(v) Tris(ethylenediamine)chromium(III) nitrate

4 (e) Find oxidation state of the central metal ion or atom in the following compounds:

(i) $KMnO_4$
Let oxidation state of Mn be x:
$+1 (K) + x + (-2 \times 4) = 0$
$+1 + x - 8 = 0$
$x = +7$
Mn ---> +7

(ii) $[Pt(NH_3)_4]PtCl_4$
For $[Pt(NH_3)_4]^{2+}$:
NH_3 is neutral
$x + 0 = +2$
Pt ---> +2

For $PtCl_4^{2-}$:
Cl = -1 each
$x - 4 = -2$
$x = +2$
Pt ---> +2

(iii) $Ag(CH_3CH_2CH_2CH_2NH_2)_2(SO_4)$
Each ligand is neutral, $SO_4 = -2$
$x + 0 - 2 = 0$ --> $x = +2$
Ag ---> +2

(iv) $[Co(NH_3)_4Br_2]SO_4$
NH_3 is neutral, Br = -1 each, $SO_4 = -2$

$x + 0 - 2 = +2 \longrightarrow x = +4$
Co ---> +4
5 (a) (i) Identify with reason the block in which elements A, C, D and E are to be found if their electronic configurations are as follows:

A: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$
Last electron in s-orbital
A is in s-block
C: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^4$
Last electron in p-orbital
C is in p-block
D: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$
Last electron in p-orbital
D is in p-block
E: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$
Last electron in s-orbital
E is in s-block

(ii) Write the molecular formula of a compound formed when D combines with E.
D is a halogen (p^5 configuration) --> forms D^-
E is a group II element (s^2 configuration) ---> forms E^{2+}
Formula: ED_2

(b) (i) Justify that the first ionization energy of J is larger than that of G although both are found in the same period.
J is in group VIII (noble gas), has a stable electronic configuration with a fully filled shell, requiring more energy to remove an electron than G which is a halogen.

(ii) Account for the increase of metallic nature from M to H.
As we go down a group from M to H, atomic size increases and ionization energy decreases, hence metallic character increases.

(c) Briefly explain each of the following trends:

(i) Some members in the periodic table are said to be related diagonally.
Diagonal relationships arise between the first element of a group and the second element of the next group due to similar electronegativity and charge/size ratio. e.g., Li and Mg, Be and Al.

(ii) Fluorine is more reactive than other members of the halogen group.
Fluorine is the smallest and most electronegative element with the highest oxidizing power. It forms bonds readily due to its strong attraction for electrons.

(d) Describe how hydrides of the elements in period 3 react with water.

- NaH reacts violently with water: $NaH + H_2O \text{--->} NaOH + H_2$
- MgH_2 reacts slowly with water: $MgH_2 + 2H_2O \text{--->} Mg(OH)_2 + 2H_2$
- AlH_3 is unstable and reacts easily: $2AlH_3 + 6H_2O \text{--->} 2Al(OH)_3 + 3H_2$
- SiH_4 hydrolyzes slowly: $SiH_4 + 2H_2O \text{--->} SiO_2 + 4H_2$
- PH_3 is slightly soluble, produces weakly acidic solution: $PH_3 + H_2O$ ---> no vigorous reaction
- H_2S and HCl dissolve in water forming acids: $H_2S + H_2O \text{--->} H_3O^+ + HS^-$, $HCl + H_2O \text{--->} H_3O^+ + Cl^-$

6 (a) (i) Anhydrous magnesium chloride cannot be prepared by heating hydrated crystals of $MgCl_2{\cdot}6H_2O$.
Because $MgCl_2$ hydrolyzes on heating and forms basic chlorides and HCl gas instead of anhydrous salt.

(ii) Most metal carbonates are prepared by precipitation method but aluminium carbonate has never been prepared by this method.
Because Al^{3+} hydrolyzes water to form $Al(OH)_3$ instead of forming $Al_2(CO_3)_3$.

(iii) Aqueous aluminium nitrate turns blue litmus red.
Because $Al(NO_3)_3$ hydrolyzes in water to release H_3O^+ ions, making the solution acidic.

(iv) Zinc oxide is amphoteric.
ZnO reacts with acids and bases:
$ZnO + 2HCl \text{--->} ZnCl_2 + H_2O$
$ZnO + 2NaOH + H_2O \text{--->} Na_2[Zn(OH)_4]$

(v) Lead (II) chloride is soluble in concentrated hydrochloric acid.
Forms complex ion: $PbCl_2 + 2Cl^- \text{--->} PbCl_4^{2-}$

(vi) Addition of ammonia solution to aqueous copper (II) sulphate gives a pale blue precipitate initially and deep blue solution when more ammonia is used.
$Cu^{2+} + 2OH^- \text{--->} Cu(OH)_2$ (pale blue ppt)
Excess NH_3: $Cu^{2+} + 4NH_3 \text{--->} [Cu(NH_3)_4]^{2+}$ (deep blue solution)

(b) Write the chemical formulae of three oxides of lead and give their uses.
PbO – used in storage batteries
PbO_2 – used in lead-acid battery cathodes
Pb_3O_4 – used in red paints and anti-rust primers

(c) Two uses of lead:
- In storage batteries
- As shielding from radiation

Two hazards of lead:
- Toxic to nervous system
- Causes kidney and developmental problems

7 (a) (i) Metals do not occur as nitrates in nature.
Because nitrates are highly soluble and reactive, they get washed away by water.

(ii) Activity series of metals:
A list of metals arranged in decreasing order of reactivity with water and acids.

(iii) Metal A is in free state and B in combined state.
Metal A is more reactive, so closer to the top of activity series.

(iv) Aluminium cannot be extracted by reducing alumina with carbon.
Because Al has high affinity for oxygen, stronger than C ---> electrolysis used instead.

(v) Limestone is added to the blast furnace in the extraction of iron from haematite.
$CaCO_3$ ---> $CaO + CO_2$
$CaO + SiO_2$ ---> $CaSiO_3$ (slag formation)

(b) Methods of extraction:

(i) Very reactive metals – Electrolysis (e.g., Na, Al)
(ii) Less reactive metals – Reduction with carbon or hydrogen (e.g., Fe, Pb)

8 (a) (i) Three human activities that increase CO_2:
- Burning fossil fuels
- Deforestation
- Industrial emissions

(ii) Greenhouse effect:
CO_2 and other gases trap heat in the atmosphere, leading to warming.

(iii) Climatic effects of greenhouse:
- Global warming
- Melting glaciers and rising sea level
- Changes in rainfall patterns

(b) (i) Cation exchange capacity (CEC) is the soil's ability to hold and exchange cations.
(ii) CEC is measured by replacing cations with ammonium or sodium ions and measuring them by titration or spectroscopy.

(c) Given:
$Na^+ = 2.00$, $K^+ = 3.00$, $Mg^{2+} = 10.00$, $Ca^{2+} = 15.00$
CEC = 30.00
PBS = $(Ca^{2+} / CEC) \times 100 = (15 / 30) \times 100 = 50\%$

(ii) Sodium equivalent weight = 23
Amount in meq = 2.00
2.00 meq = 2.00 × 23 / 1000 = 0.046 g sodium

(d) pH < 5: prevalent ions = H^+ and Al^{3+}
To raise pH: Add $CaCO_3$ or $Ca(OH)_2$

9 (a) Arrange the following compounds in the order of decreasing basic strength:

NH_3, $C_6H_5NH_2$, $CH_3CH_2NH_2$, CH_3NH_2, CH_3-NH-CH_3

Order of decreasing basic strength:
CH_3-NH-CH_3 > CH_3NH_2 > $CH_3CH_2NH_2$ > NH_3 > $C_6H_5NH_2$
Reason: Electron-donating alkyl groups increase basic strength; lone pair in aniline is delocalized into benzene ring reducing basicity.

(b) (i) Structural formulae:

Hexane-1,6-dioic acid: $HOOC\text{-}(CH_2)_4\text{-}COOH$
Hexane-1,6-diamine: $H_2N\text{-}(CH_2)_6\text{-}NH_2$

(ii) This pair is suitable for polymerization due to presence of two functional groups (diacid and diamine) which undergo condensation to form amide bonds.

(iii) Structure of polymer formed:
$\text{-[-OC-}(CH_2)_4\text{-CO-NH-}(CH_2)_6\text{-NH-]-n}$ → Nylon 6,6

(iv) Repeating unit:
$\text{-CO-}(CH_2)_4\text{-CO-NH-}(CH_2)_6\text{-NH-}$

(c) Indicate monomer and polymerization method used in:

(i) $CF_2{=}CF_2$ → addition polymerization → polytetrafluoroethylene (Teflon)

(ii) $CH_2{=}CH\text{-}CH{=}CH_2$ → addition polymerization → polybutadiene

(iii) $NH\text{-}(CH_2)_5\text{-}CO\text{-}NH\text{-}(CH_2)_5\text{-}CO\text{-}NH\text{-}(CH_2)_5\text{-}CO_2$ → condensation polymerization (polyamide or Nylon 6)

(d) Statement:
O=C-Cl and $HOCH_2CH_2OH$ cannot form a polymer because acid chloride and mono alcohol cannot provide enough functional groups for chain propagation.

10 (a) Acetic acid, ethyl alcohol and acetaldehyde can be identified:

- Acetic acid: add sodium bicarbonate → effervescence (CO_2 gas)
- Acetaldehyde: positive Tollen's test and iodoform test
- Ethanol: positive iodoform test, negative Tollen's test

(b) Arrange in decreasing acidic strength:
$Cl_2CHCOOH > ClCH_2COOH > CH_3COOH > CH_3CH_2COOH > HCOOH$
Electron withdrawing groups increase acidity

(c) Identify structures in reaction sequences:

(i) CH_3COCH_3 --$LiAlH_4$--> $CH_3CH(OH)CH_3$ (A)
$CH_3CH(OH)CH_3$ + HBr ---> $CH_3CH(Br)CH_3$ (B)
$CH_3CH(Br)CH_3$ + alc.KOH ---> $CH_2{=}CHCH_3$ (C)

(ii) $CH{\equiv}CH + H_2/Hg^{2+}$ ---> CH_3CHO (D)
$CH_3CHO + CH_3MgBr$ ---> $CH_3CH(OH)CH_3$ (E)
$CH_3CH(OH)CH_3 + K_2Cr_2O_7/H_2SO_4$ ---> CH_3COCH_3 (F)

(d) Ozonolysis of alkene (C_6H_{12}) gives P and Q
Q gives positive iodoform test → CH_3CO-R (methyl ketone)
P gives negative Tollen's test → alcohol
C_6H_{12} must be 2-methylpent-2-ene
P = $CH_3CH_2CH_2OH$
Q = CH_3COCH_3
Alkene = 2-methylpent-2-ene