THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

132/1 **CHEMISTRY 1**

(For Both School and Private Candidates)

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

Instructions

1. This paper consists of sections A, B and C with total of fourteen questions

2. Each question carries ten marks.

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1. (a) Differentiate nuclear reaction from chemical reaction.

- A nuclear reaction involves changes in the nucleus of an atom, leading to the transformation of elements and emission of radiation.
- A chemical reaction involves the rearrangement of electrons in atoms, without changing the atomic nuclei.

(b) Complete the following nuclear equations:

(i) $^{37}_{19}K$ ------> $^{37}_{37}Rb + \beta^-$

(ii) $^{53}_{24}Cr + ^{3}_{2}He$ ------> $^{56}_{26}Fe + n$

(iii) $^{235}_{92}U + ^{1}_{0}n$ ------> $^{140}_{56}Ba + ^{93}_{36}Kr + 3^{1}_{0}n$

(iv) $^{14}_{7}N + ^{1}_{0}n$ ------> $^{15}_{8}O + ^{1}_{1}H$

(c) The following figure shows the mass spectrum of lead. The highest peaks and the mass numbers of the isotopes are shown. Calculate the average atomic mass of lead.

Average atomic mass = (204 × 1.5 + 206 × 22.6 + 207 × 23.6 + 208 × 52.3) / (1.5 + 22.6 + 23.6 + 52.3)

= (306 + 4655.6 + 4895.2 + 10878.4) / 100

= 207.2 g/mol

2. (a) Lyman discovered a series of spectral lines for hydrogen in the ultraviolet region of the electromagnetic spectrum. What value must n_x have for this series? Give a reason for your answer.

$n_x = 1$, because the Lyman series corresponds to electronic transitions where electrons fall to the first energy level (n = 1).

(b) Calculate the energy of a line in the Lyman series with $n_1 = 1$ and $n_2 = \infty$.

Using $\Delta E = 2.18 \times 10^{-18}$ J $(1/n_1^2 - 1/n_2^2)$

$= 2.18 \times 10^{-18}$ J $(1/1^2 - 1/\infty^2)$

$= 2.18 \times 10^{-18}$ J

(c) An experimental iodine laser emits light of wavelength 1.315 μm. Calculate the frequency of this light and the energy per photon.

$\nu = c/\lambda$

$= (3.0 \times 10^8 \text{ m/s}) / (1.315 \times 10^{-6} \text{ m})$

$= 2.28 \times 10^{14}$ Hz

Energy per photon, $E = h\nu$

$= (6.626 \times 10^{-34} \text{ J·s}) \times (2.28 \times 10^{14} \text{ Hz})$

$= 1.51 \times 10^{-19}$ J

3. (a) Predict the hybridization of the following:

(i) $PCl_5 \rightarrow sp^3d$
(ii) $SF_6 \rightarrow sp^3d^2$
(iii) $CO_2 \rightarrow sp$
(iv) $BCl_3 \rightarrow sp^2$

4. (a) Arrange the following substances in order of increasing melting points: CO_2, H_2O, CO, H_2, and Ar.

$H_2 < Ar < CO_2 < CO < H_2O$

(b) Use VSEPR theory to predict the molecular geometry of the species:

PCl_3 → Trigonal pyramidal
NH_3 → Trigonal pyramidal
PCl_5 → Trigonal bipyramidal

(c) State two characteristics of compounds which are suitable for steam distillation.

- Must have appreciable volatility with steam.
- Should not decompose at boiling temperature.

5. (a) An aromatic compound Z was steam distilled at 98.6°C and 1 atm pressure. The distillate contained 25.5 g of water and 7.4 g of aromatic compound Z.

Given that the saturated vapour pressure of water at 98.6°C is 720 mmHg, calculate the relative molecular mass of the aromatic compound.

Moles of water = 25.5 / 18 = 1.417 mol

Since pressure is proportional to moles,

Moles of Z = (7.4 / M_Z)

Ratio of moles = 720 mmHg / 1 atm

Solving for M_Z, we get:

M_Z = 132 g/mol

(b) Benzene (C_6H_6) and toluene ($C_6H_5CH_3$) form a nearly ideal solution. At 313 K, the vapour pressure of pure benzene is 150 mmHg and that of pure toluene is 50 mmHg. Calculate the vapour pressure of a mixture of these two liquids containing equal masses at the given temperature.

Moles of benzene = (1 / 78)
Moles of toluene = (1 / 92)

Mole fraction of benzene, X_B = (1/78) / [(1/78) + (1/92)]

Mole fraction of toluene, X_T = 1 - X_B

Total vapour pressure = X_B × P_B + X_T × P_T

= 0.541 × 150 + 0.459 × 50

= 81.15 + 22.95

= 104.1 mmHg

6. (a) Define the following:

(i) Molar volume of a gas at STP: The volume occupied by one mole of an ideal gas at standard temperature and pressure (22.4 L).

(ii) Dalton's law of partial pressures: The total pressure of a gas mixture is equal to the sum of the partial pressures of each gas.

(b) Two gas burettes, one containing 10 cm^3 of SO_2 and the other containing 30 cm^3 of H_2S, are separated by a stopcock. When the stopcock is opened, the gases react according to:

$SO_2(g) + 2H_2S(g)$ ------> $3S(s) + 2H_2O(g)$

(i) Limiting reagent: H_2S (completely consumed).

(ii) Final pressure = (20 cm^3 of excess SO_2) × (1 atm / 40 cm^3)

= 0.5 atm

7. (a) Three elements F, G, and H have atomic numbers 17, 18, and 19 respectively.

(i) Electronic configurations:

F = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

G = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

H = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

(ii) Type of ions:

F = Anion (Cl^-)

G = No ion (Noble gas)

H = Cation (K^+)

(iii) Periodic table placement:

F = Period 3, Group 17

G = Period 3, Group 18

H = Period 4, Group 1

(b) Study the hypothetical periodic table and answer the following:

(i) Most electronegative element: D

(ii) Pair of elements likely to form the strongest electrovalent bond: A and D

(iii) Two elements likely to have strongest reducing properties: A and F

(iv) Two elements which form neither negative nor positive ions: E and G

7. (a)

(i) Electronic configurations:

F (17) → $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

G (18) → $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

H (19) → $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

(ii) Type of ions formed:

F → Anion (Cl^-)

G → No ion (Noble gas)

H → Cation (K^+)

(iii) Group and period placement:

F → Group 17, Period 3

G → Group 18, Period 3

H → Group 1, Period 4

(b) (i) Most electronegative element → D
(ii) Strongest electrovalent bond → A and D
(iii) Strongest reducing properties → A and F
(iv) Elements forming neither negative nor positive ions → E and G

8. (a) (i) Diagonal relationship → Similarity in properties of elements placed diagonally in the periodic table due to comparable charge-to-radius ratio. Example: Li and Mg.
(ii) Anomalous behaviour → Deviations from expected periodic trends due to small size, high ionization energy, or strong hydrogen bonding. Example: Fluorine in Group 17.

(b) Hydrides of Period 3 elements react with water differently:
- NaH reacts violently forming $NaOH$ and H_2.
- MgH_2 reacts slowly forming $Mg(OH)_2$.
- AlH_3 decomposes in water releasing H_2.

(c) Arrange the oxides in order:

(i) Increasing basic character: $SiO_2 < P_2O_5 < Al_2O_3 < MgO < Na_2O$
(ii) Decreasing ionic character: $Na_2O > MgO > Al_2O_3 > P_2O_5 > SiO_2$

9. (a)

(i) First ionization energy removes the outermost electron; second ionization removes an electron from an already positively charged ion.
(ii) The second ionization energy of sodium is much higher than the first because removing an electron from a stable noble gas configuration (Na^+) requires significantly more energy.

(b) Sodium reactions:

(i) $2Na + C_2H_5OH$ ------> $2C_2H_5ONa + H_2$
(ii) $2Na + 2NH_3$ ------> $2NaNH_2 + H_2$
(iii) $2Na + O_2$ ------> Na_2O_2
(iv) $2Na + 2H_2O$ ------> $2NaOH + H_2$

10. (a) Law of mass action: The rate of a reaction is proportional to the product of the concentrations of the reactants raised to their stoichiometric coefficients.

(b)
$PCl_5 \rightleftharpoons PCl_3 + Cl_2$
10% dissociation means 0.1 mole PCl_5 decomposes from 1 mole.
Total moles at equilibrium = 1 - 0.1 + 0.1 + 0.1 = 1.1
Total pressure = 4 atm

(i) $K_p = (P\_PCl_3 \times P\_Cl_2) / P\_PCl_5$
$= [(0.1/1.1) \times 4]^2 / [(0.9/1.1) \times 4]$
$= (0.36/3.6)$
$= 0.1$ atm

(ii) At 20% dissociation:

Total moles = 1 - 0.2 + 0.2 + 0.2 = 1.2
Using P_total / n_total = constant,
New total pressure = 4 × (1.2 / 1.1) = 4.36 atm

11. (a) Complete the following equations:

(i) $(CH_3)_3CCH(CH_3)_2 + O_2$ ------> $CO_2 + H_2O$
(ii) $CH_3CH_2CH_2CH_3 + Cl_2$/light ------> $CH_3CH_2CHClCH_3 + HCl$
(iii) $(CH_3)_2CHCH_3 + Br_2$/light ------> $(CH_3)_2CBrCH_3 + HBr$

(b) Structural isomers of alkylcyclohexane (C_8H_{12}):
1. Methylcyclohexane
2. Ethylcyclopentane
3. Dimethylcyclopentane

(c) Alkenes preparation:

(i) $CH_3CH_2CH_2CH_2Br$ + alc.KOH ------> $CH_3CH_2CH{=}CH_2 + HBr$
(ii) $(CH_3)_2CHC(OH)(CH_3)_2 + H_2SO_4$ ------> $(CH_3)_2C{=}CH_2 + H_2O$
(iii) $(CH_3)_2CBrCH_3$ + alc.KOH ------> $(CH_3)_2C{=}CH_2 + HBr$
(iv) $CH(OH)CH_3 + H_2SO_4$ ------> $CH_2{=}CHCH_3 + H_2O$

12. (a) Write the structure of the functional groups of the following sets of compounds:

(i) Alkanes: $-CH_3$ (single-bonded hydrocarbons)
(ii) Alkenes: $-CH{=}CH_2$ (double-bonded hydrocarbons)
(iii) Alkynes: $-C{\equiv}C-$ (triple-bonded hydrocarbons)
(iv) Alcohols: -OH (hydroxyl functional group)
(v) Ketones: -C=O- (carbonyl functional group within the chain)
(vi) Aldehydes: -CHO (carbonyl functional group at the end of the chain)
(vii) Carboxylic acid: -COOH (carboxyl functional group)
(viii) Tertiary amines: $-N(CH_3)_2$ (a nitrogen atom bonded to three carbon atoms)

(b) Give the IUPAC names of the following compounds:

(i) 2-Methylhexane
(ii) 3,3-Dimethylheptane
(iii) 3-Methyl-1-butyne
(iv) 2,4-Hexyne
(v) 2-Methyl-1-butene
(vi) 3-Methyl-1-butyne

13. With support of chemical reactions, show how the following compounds can be prepared from ethanol as a source of carbon atoms:

(a) Benzene
C_2H_5OH ------> $C_2H_4 + H_2O$
C_2H_4 ------> $C_6H_6 + H_2$

(b) Ethyl benzene
$C_6H_6 + C_2H_5Cl + AlCl_3$ ------> $C_6H_5C_2H_5 + HCl$

14. (a) Write the structure of the major products for the reaction of gaseous hydrogen bromide with the following:

(i) $CH_2{=}CH{-}CH_2{-}CH_2{-}CH_3 + HBr$ ------> $CH_3{-}CHBr{-}CH_2{-}CH_2{-}CH_3$
(ii) $CH_3{-}CH{=}CH{-}CH_2{-}CH_3 + HBr$ ------> $CH_3{-}CHBr{-}CH_2{-}CH_2{-}CH_3$
(iii) $CH_3{-}CH{=}CH{-}CH_2{-}CH_3 + HBr$ ------> $CH_3{-}CHBr{-}CH_2{-}CH_2{-}CH_3$
(iv) Cyclohexene + HBr ------> Bromocyclohexane
(v) Methylcyclohexene + HBr ------> 1-Bromo-1-methylcyclohexane

(b) Explain how you can distinguish the following compounds:

(i) $CH_3CH_2CH_2CH_3$ and $CH_2{=}CHCH_2CH_3$: Bromine water test (alkene decolorizes bromine water).
(ii) $CH_3CHCHCH_3$ and $CH_3C{\equiv}CH$: Baeyer's test (alkyne reacts with ammoniacal silver nitrate).
(iii) $CHCCH_2CH_3$ and $CH_3C{\equiv}CCH_3$: Tollen's test (terminal alkynes form precipitate).
(iv) Phenol (OH attached to benzene) and Cyclohexanol (OH attached to a saturated ring): Ferric chloride test (phenol gives a violet color).
(v) Benzaldehyde and Benzyl alcohol: Tollen's test (benzaldehyde gives silver mirror).