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: 2021**

Instructions

1. This paper consists of sections A and B with total of ten questions

2. Each question carries ten marks in section A and fifteen marks in section B.

1. (a) Differentiate the following terms:

(i) Isotopy from isotopes.

Isotopy is the phenomenon where atoms of the same element have the same number of protons but different numbers of neutrons.

Isotopes are the different atomic forms of an element that exhibit isotopy. For example, hydrogen has isotopes such as protium (^1H), deuterium (^2H), and tritium (^3H).

(ii) Atomic spectrum from photon.

An atomic spectrum is the spectrum of frequencies of electromagnetic radiation emitted or absorbed by an atom when its electrons transition between energy levels.

A photon is a quantum of electromagnetic radiation that carries energy corresponding to the frequency of light in an atomic spectrum.

(iii) Continuous spectrum from line spectrum.

A continuous spectrum contains all wavelengths of light within a given range, with no gaps between the colors. It is typically produced by incandescent solids, liquids, or high-pressure gases.

A line spectrum consists of discrete wavelengths emitted or absorbed by atoms, appearing as distinct lines on a dark or bright background. It is characteristic of elements and results from electron transitions in atoms.

(b) Calculate the frequency of a wave in a visible region formed following the emission of energy by an electron falling from energy level n = 4 to the ground level.

Using the Rydberg equation for hydrogen:

$1/\lambda = R (1/n_1^2 - 1/n_2^2)$

where,
$R = 1.097 \times 10^7 \text{ m}^{-1}$ (Rydberg constant),
$n_1 = 1$ (ground state),
$n_2 = 4$ (excited state).

$1/\lambda = 1.097 \times 10^7 (1/1^2 - 1/4^2)$
$= 1.097 \times 10^7 (1 - 1/16)$
$= 1.097 \times 10^7 \times (15/16)$
$= 1.03 \times 10^7 \text{ m}^{-1}$

Using the wave equation:

$c = \nu\lambda$

where,
$c = 3.00 \times 10^8$ m/s (speed of light),
ν = frequency,
$\lambda = 1/(1.03 \times 10^7) = 9.71 \times 10^{-8}$ m.

$\nu = c / \lambda$
$\nu = (3.00 \times 10^8) / (9.71 \times 10^{-8})$
$\nu = 3.09 \times 10^{15}$ Hz

(c) List two uses of mass spectrometer.

- Identification of the molecular structure and isotopic composition of chemical compounds.
- Determination of molecular mass and relative abundance of elements in a sample.

2. (a) Identify a more energetically stable compound among the following pairs:

(i) NaBr and $NaBr_2$

NaBr is more stable because sodium (Na) has a fixed oxidation state of +1 in compounds, and $NaBr_2$ would require an unlikely Na^{2+} ion, which is not energetically favorable.

(ii) ClO_4^- and ClO_3^-

ClO_4^- (perchlorate) is more stable due to greater resonance stabilization and the ability to distribute charge more effectively compared to ClO_3^- (chlorate).

(iii) OF_4 and SeF_4

SeF_4 is more stable because selenium (Se) has available d-orbitals to accommodate bonding electrons, while oxygen (O) does not, making OF_4 highly unstable.

(iv) SO_4^{2-} and XeO_4

SO_4^{2-} (sulfate) is more stable due to resonance stabilization and strong sulfur-oxygen bonds. XeO_4 is unstable because xenon is a noble gas element and does not commonly form stable oxides.

(b) Although the Valency Shell Electron Pair Repulsion theory (VSEPR) predicts correctly the CH_4 and NH_3 molecular geometries (or shapes), it does not account for the differences in the (H-C-H) and (H-N-H) bond angles whose angles are 109.5° and 107.3°, respectively. Give reasons for the deviations.

- CH_4 (methane) has a perfect tetrahedral shape with an ideal bond angle of 109.5° because all four C-H bonds experience equal repulsion.
- NH_3 (ammonia) has a trigonal pyramidal shape, where the lone pair on nitrogen exerts stronger repulsion on the bonding pairs, reducing the bond angle to 107.3°.

(c) Giving a reason, classify the type of bond involved in each of the following chemical equations:

(i) $Ca + 2Cl^- \text{---->} [Ca]^{2+}(Cl^-)_2$

This is an ionic bond because calcium (Ca) donates two electrons to form a Ca^{2+} ion, which is electrostatically attracted to two chloride (Cl^-) ions.

(ii) $H^+ + :F^- \text{---->} H:F^-$

This is a dative covalent bond (coordinate bond) because the fluoride ion (F^-) donates a lone pair of electrons to bond with the hydrogen ion (H^+).

3. (a) Calculate the partial vapour pressure of water in a mixture of 36 g of water and 32 g of methanol at 298 K, if the vapour pressure of pure water at 298 K is 3.2 kPa.

Step 1: Calculate the mole fraction of water.

Moles of water = 36 g / 18 g/mol = 2 mol
Moles of methanol = 32 g / 32 g/mol = 1 mol

Total moles = 2 + 1 = 3

Mole fraction of water = 2/3 = 0.667

Step 2: Calculate the partial vapour pressure of water.

$P_{water} = X_{water} \times P°_{water}$
$P_{water} = 0.667 \times 3.2$ kPa
$P_{water} = 2.13$ kPa

(b) A candle wax is approximately a non-volatile organic compound with molecular formula $C_{22}H_{46}$ and soluble in carbon tetrachloride. Calculate the vapour pressure of a solution made by dissolving 10 g of the wax in 40 g of carbon tetrachloride at 23°C, if the carbon tetrachloride has a vapour pressure of 100 mmHg at 23°C.

Step 1: Calculate the mole fraction of carbon tetrachloride.

Moles of wax = 10 g / 310 g/mol = 0.032 mol
Moles of CCl_4 = 40 g / 154 g/mol = 0.26 mol

Total moles = 0.032 + 0.26 = 0.292

Mole fraction of CCl_4 = 0.26 / 0.292 = 0.89

Step 2: Calculate the vapour pressure of the solution.

$P_{solution} = X_{CCl_4} \times P°_{CCl_4}$
$P_{solution} = 0.89 \times 100$ mmHg
$P_{solution} = 89$ mmHg

(c) Comment on the observation that, further dilution of 0.1 M KCl solution causes the observed relative molecular mass to approach the theoretical value 37.3.

Dilution reduces ion-ion interactions in the solution, minimizing ion-pairing effects. As dilution increases, more potassium and chloride ions behave as independent particles, leading to the observed molar mass approaching the theoretical value.

4. (a) Using the following chemical equations and values provided for each, calculate the enthalpy of formation of $Ca(OH)_2$.

$H_2(g) + 1/2O_2(g) \text{---->} H_2O(l) \quad \Delta H = -68.3$ kcal

$Ca(s) + H_2O(l) \text{---->} Ca(OH)_2(s) \quad \Delta H = -15.3$ kcal

$Ca(s) + O_2(g) \text{---->} CaO(s) \quad \Delta H = -151.8$ kcal

Step 1: Write the formation reaction of $Ca(OH)_2$.

$Ca(s) + H_2(g) + 1/2O_2(g) \text{---->} Ca(OH)_2(s)$

Step 2: Add the given reactions accordingly.

- 1. $H_2(g) + 1/2O_2(g) \text{---->} H_2O(l) \quad \Delta H = -68.3$ kcal
- 2. $Ca(s) + H_2O(l) \text{---->} Ca(OH)_2(s) \quad \Delta H = -15.3$ kcal

Step 3: Add the enthalpy changes.

$\Delta H = (-68.3) + (-15.3)$
$\Delta H = -83.6$ kcal

(b) Diborane (B_2H_6) is synthesized in the laboratory according to the equation:

$2B(s) + 3H_2(g) \longrightarrow B_2H_6(g)$

Calculate the heat change for the synthesis of diborane from its elements, using enthalpies provided in the following table:

S/N	Reaction	ΔH (kJ)
1	$2B(s) + O_2(g) \longrightarrow B_2O_3(s)$	-1273
2	$B_2H_6(g) + 3O_2(g) \longrightarrow B_2O_3(s) + 3H_2O(g)$	-2035
3	$H_2(g) + 1/2O_2(g) \longrightarrow H_2O(g)$	-286
4	$H_2O(g) \longrightarrow H_2O(l)$	-44

Step 1: Write the required reaction.

$2B(s) + 3H_2(g) \longrightarrow B_2H_6(g)$

Step 2: Apply Hess's Law.

$\Delta H = \Delta H_2 - (\Delta H_1 + 3\Delta H_3)$

$\Delta H = (-2035) - [(-1273) + 3(-286)]$

$\Delta H = -2035 + 1273 + 858$

$\Delta H = 96$ kJ

5. (a) Justify on the following facts:

(i) Ion exchange in the soil system is a reversible process.

Ion exchange occurs when soil particles adsorb or release cations and anions based on their concentrations in the soil solution. Since these ions can be displaced by other competing ions, the process is reversible, allowing nutrient availability to change dynamically.

(ii) All calcium or magnesium compounds can be used as liming materials.

Calcium and magnesium compounds, such as CaO, $Ca(OH)_2$, $CaCO_3$, MgO, and $MgCO_3$, neutralize soil acidity by reacting with hydrogen ions, increasing soil pH. Their ability to dissociate and release hydroxide (OH^-) or carbonate (CO_3^{2-}) ions makes them effective liming materials.

(iii) Aluminium contributes to soil acidity.

Aluminium ions (Al^{3+}) hydrolyze in soil water to produce hydrogen ions (H^+), increasing soil acidity.

$Al^{3+} + 3H_2O \text{ ----> } Al(OH)_3 + 3H^+$

(b) Rungewe high school farm soil requires 100 kg of nitrogen to fulfill the plant requirement of nitrogen per hectare. If the farm has 60 hectares, calculate the number of bags of ammonium sulfate, $(NH_4)_2SO_4$ fertilizer required to meet this demand. One bag of fertilizer weighs 25 kg.

Step 1: Calculate the total nitrogen needed.

Total nitrogen = 100 kg/ha × 60 ha
= 6000 kg

Step 2: Determine the nitrogen percentage in $(NH_4)_2SO_4$.

Molar mass of $(NH_4)_2SO_4$ = 132 g/mol
Mass of nitrogen in $(NH_4)_2SO_4$ = 2 × 14 = 28 g/mol

Nitrogen percentage = (28/132) × 100
= 21.2%

Step 3: Calculate the total fertilizer required.

Mass of fertilizer = 6000 kg / 0.212
= 28302 kg

Step 4: Determine the number of bags.

Number of bags = 28302 kg / 25 kg
= 1132 bags

6. (a) When dilute hydrochloric acid is added to a yellow solution of potassium chromate, an orange solution of dichromate is produced. Briefly, explain what would be observed as a result of:

(i) Adding more hydrochloric acid.

Adding more HCl shifts the equilibrium further towards the dichromate ($Cr_2O_7^{2-}$), deepening the orange color.

$2CrO_4^{2-} + 2H^+ \text{ ----> } Cr_2O_7^{2-} + H_2O$

(ii) Adding dilute sodium hydroxide solution.

Adding NaOH increases the OH^- concentration, shifting equilibrium back to chromate (CrO_4^{2-}), turning the solution yellow.

$Cr_2O_7^{2-} + 2OH^-$ ----> $2CrO_4^{2-} + H_2O$

(iii) Adding anhydrous calcium chloride.

Ca^{2+} ions precipitate chromate as calcium chromate ($CaCrO_4$), removing CrO_4^{2-} from solution and shifting the equilibrium towards $Cr_2O_7^{2-}$, deepening the orange color.

(b) Briefly explain the following:

(i) Hydrogen gas is evolved when magnesium is introduced into a beaker containing aqueous solution of ammonium chloride.

Mg reacts with NH_4^+ ions, reducing them to NH_3 gas while releasing H_2 gas.
$Mg + 2NH_4^+$ ----> $Mg^{2+} + 2NH_3 + H_2$

(ii) $AlCl_3$ reacts chemically with water while NaCl does not.
$AlCl_3$ is covalent and hydrolyzes in water, forming $Al(OH)_3$ and HCl, while NaCl is ionic and dissolves without reaction.

$AlCl_3 + 3H_2O$ ----> $Al(OH)_3 + 3HCl$

7. (a) (i) What are the two properties that make organic compounds suitable sources of fuel?

- High energy content: Organic compounds, particularly hydrocarbons, have high calorific values, making them efficient energy sources when burned.
- Combustibility: Organic compounds easily react with oxygen in combustion reactions, releasing heat energy required for various applications.

(ii) Compressed natural gas methane, (CH_4) is a fossil fuel found in large quantities in our country, Tanzania. Due to its several advantages, compressed natural gas is considered the most promising vehicle fuel, and thus it should be promoted as the main fuel in our country. State four benefits offered by the compressed natural gas over conventional fuel like gasoline and diesel.

- Environmentally friendly: Methane combustion produces fewer pollutants such as sulfur oxides (SO_x) and nitrogen oxides (NO_x) compared to gasoline and diesel.
- Higher efficiency: Compressed natural gas has a higher octane rating, allowing for better engine performance and fuel efficiency.
- Reduced greenhouse gas emissions: It emits less carbon dioxide (CO_2) per unit of energy compared to conventional fuels, helping to mitigate climate change.

4. Abundant and cost-effective: Tanzania has vast reserves of natural gas, making it a cheaper and more sustainable fuel option.

(b) Suggest suitable chemical tests to distinguish between the following compounds:

(i) Butane and 1-butene

Bromine water test: 1-butene decolorizes bromine water due to the presence of a double bond, while butane does not react.

$CH_2=CH-CH_2-CH_3 + Br_2 \text{ ----> } CH_2Br-CHBr-CH_2-CH_3$

(ii) Propyne and propene

Ammoniacal silver nitrate test: Propyne reacts with ammoniacal silver nitrate to form a white precipitate of silver acetylide, while propene does not react.

$HC\equiv CCH_3 + AgNO_3 \text{ ----> } AgC\equiv CCH_3 + HNO_3$

(iii) Pent-1-yne and pent-2-yne

Ammoniacal silver nitrate test: Pent-1-yne gives a white precipitate with ammoniacal silver nitrate, while pent-2-yne does not, since the terminal hydrogen is absent in pent-2-yne.

$HC\equiv C-C_3H_7 + AgNO_3 \text{ ----> } AgC\equiv C-C_3H_7 + HNO_3$

(iv) Propane and 1-bromo propane

Silver nitrate test: 1-bromo propane reacts with alcoholic silver nitrate to form a white precipitate of silver bromide (AgBr), whereas propane does not react.

$C_3H_7Br + AgNO_3 \text{ ----> } AgBr + C_3H_7NO_3$

8. (a) (i) State Le Chatelier's principle.

Le Chatelier's principle states that if an external stress (such as a change in concentration, temperature, or pressure) is applied to a system in equilibrium, the system will adjust itself to counteract the imposed change and restore a new equilibrium state.

(ii) How does homogeneous equilibrium differ from heterogeneous equilibrium as applied in chemistry?
Homogeneous equilibrium involves reactants and products in the same phase, such as all gases or all liquids.

Heterogeneous equilibrium involves reactants and products in different phases, such as a reaction involving solids and gases.

(b) Predict the direction of the net reaction for each of the following equilibrium reactions when the pressure of the system is doubled at constant temperature. Give one reason for each case.

(i) $2Pb(s) + 3O_2(g) \rightleftharpoons 2PbO(s) + 2O_2(g)$
No change. The number of gas molecules is the same on both sides, so increasing pressure has no effect on the equilibrium position.
(ii) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

Shifts left. The reactant side has fewer gas molecules (1 mole) than the product side (2 moles), so increasing pressure favors the side with fewer moles, shifting equilibrium towards PCl_5.

(iii) $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$

No change. The number of gas molecules is the same on both sides, so changing pressure does not affect the equilibrium position.

(c) Hydrogen iodide gas was synthesized from hydrogen gas and iodine vapor at 450°C in a 2.0-liter vessel. The value of the equilibrium constant, Kc for the reaction was found to be 50.5. If 1.0×10^{-2} moles of hydrogen gas, 3.0×10^{-2} moles of iodine vapor, and 2.0×10^{-2} moles of hydrogen iodide were placed in a vessel at the stated temperature:

(i) Write a balanced equilibrium reaction equation for the synthesis of hydrogen iodide gas.
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(ii) Calculate the reaction quotient (Q) for the reaction.

$Q = [HI]^2 / ([H_2] [I_2])$

Given:
$[HI] = (2.0 \times 10^{-2}) / 2.0 = 0.01$ M
$[H_2] = (1.0 \times 10^{-2}) / 2.0 = 0.005$ M
$[I_2] = (3.0 \times 10^{-2}) / 2.0 = 0.015$ M

$Q = (0.01)^2 / (0.005 \times 0.015)$
$Q = 0.0001 / 0.000075$
$Q = 1.33$

(iii) State whether the reaction will proceed to the right or left of the equilibrium. Give a reason.

Since Q (1.33) is less than Kc (50.5), the reaction will shift to the right to increase the concentration of products (HI) until equilibrium is established.

(iv) With a reason, comment on a possible effect regarding the equilibrium position if the pressure of the reaction system is increased.

Increasing pressure has no effect on equilibrium because the number of gas molecules is the same on both sides of the reaction.

(d) Consider the reaction:

$K_2 + N_2 \rightleftharpoons 2KN \quad \Delta H = -20J\ mol^{-1}$
which has an equilibrium constant, Kc = 10 at 25°C. Calculate the equilibrium constant in terms of partial pressure (Kp) at the same temperature.

Using the relationship between Kc and Kp:
$Kp = Kc(RT)^{\wedge}(\Delta n)$

where,
Δn = moles of gaseous products - moles of gaseous reactants = 2 - (1) = 1
$R = 0.0821\ L\cdot atm\cdot mol^{-1}\cdot K^{-1}$
T = 298 K
$Kp = 10 \times (0.0821 \times 298)^1$
$Kp = 10 \times (24.5058)^1$
Kp = 245.06

9. (a) Write the IUPAC name of the following organic compounds:

(i) CCl_3CH_3
1,1,1-Trichloroethane

(ii) $CHCl_2CCl_2CHCl_2$
1,1,2,2,3,3-Hexachloropropane

(iii)

Br
|
|
Cl— □
1-Bromo-2-chlorobenzene

(iv) $CCl_3CH_2CCl_3$
1,1,2,2-Tetrachloroethane

(b) With the aid of a chemical equation (no reaction mechanisms is needed), give a reason for the position occupied by bromide atom when bromine reacts with:

(i) Phenol
Bromine reacts with phenol in an electrophilic substitution reaction at the ortho and para positions due to the activating effect of the hydroxyl (-OH) group.

$C_6H_5OH + Br_2$ ----> 2,4,6-Tribromophenol + HBr

(ii) Benzene carbaldehyde
Bromine reacts with benzene carbaldehyde at the meta position because the -CHO group is an electron-withdrawing group, which deactivates the ortho and para positions.

$C_6H_5CHO + Br_2$ ----> 3-Bromobenzaldehyde + HBr

(c) Write the structures and the names of five products in the following reaction:

CH_3
|
|

□ + Cl_2 ----> (UV light, no Fe) Three (3) products
|

(Dark, Fe) Two (2) products

- In UV light, free radical substitution occurs, forming:
  1. Benzyl chloride ($C_6H_5CH_2Cl$)
  2. Benzyldichloride ($C_6H_5CHCl_2$)
  3. Benzyltrichloride ($C_6H_5CCl_3$)

- In the presence of Fe in dark conditions, electrophilic substitution occurs, forming:
  4. o-Chlorotoluene
  5. p-Chlorotoluene

(d) Write the product of each of the following nucleophilic substitution reactions:
(i) CH_2Cl + NaCN ---->

CH_2CN + NaCl (Formation of ethyl cyanide)

(ii) $CH_3I + NaOH$ ---->
$CH_3OH + NaI$ (Formation of methanol)

(e) Write a chemical test to distinguish the following chemical compounds:

(i) Bromobenzene from chlorobenzene

Silver nitrate test: Bromobenzene reacts with alcoholic silver nitrate, forming a pale yellow precipitate of AgBr, whereas chlorobenzene forms a white precipitate of AgCl.

$C_6H_5Br + AgNO_3$ ----> $AgBr + C_6H_5NO_3$
$C_6H_5Cl + AgNO_3$ ----> $AgCl + C_6H_5NO_3$

(ii) Vinyl bromide from p-chlorobenzene

Bromine water test: Vinyl bromide decolorizes bromine water due to the presence of a double bond, whereas p-chlorobenzene does not react.

$CH_2=CHBr + Br_2$ ----> $CH_2Br\text{-}CHBr$

(f) Using chemical equations, show step-wise conversion of 2-phenol into each of the following organic compounds:

(i) CH_2CH_2Br

Step 1: Bromination of 2-phenol with PBr_3

$C_6H_4OH + PBr_3$ ----> $C_6H_4Br + HBr$

Step 2: Alkylation using ethylene dibromide

$C_6H_4Br + CH_2CH_2Br$ ----> $C_6H_4CH_2CH_2Br$

(ii) $CHClCH_3$

Step 1: Chlorination of 2-phenol

$C_6H_4OH + Cl_2$ ----> C_6H_4ClOH

Step 2: Friedel-Crafts alkylation with ethyl chloride

$C_6H_4ClOH + CH_3CH_2Cl \text{ ----> } C_6H_4CHClCH_3$

10. (a) Show how Boyle's law and Charles's law are special cases of the ideal gas law.

Boyle's Law:

$PV = nRT$
At constant temperature (T) and number of moles (n), PV = constant, leading to Boyle's Law:

$P_1V_1 = P_2V_2$

Charles's Law:

$PV = nRT$
At constant pressure (P) and number of moles (n), V/T = constant, leading to Charles's Law:

$V_1/T_1 = V_2/T_2$

(b) (i) Theoretically, ideal gases cooled to a temperature of -273.15 °C will occupy zero (0) volume. With reason(s) comment on whether gases practically occupy zero volume at such temperature.

Practically, gases do not occupy zero volume at absolute zero because real gases deviate from ideal behavior due to intermolecular forces and finite molecular volume. Instead, they condense into liquids or solids before reaching absolute zero.

(ii) Molecule A is twice as heavy as molecule B. Which of these has higher kinetic energy at any temperature? Give a reason.

Both molecules have the same kinetic energy at a given temperature because kinetic energy is determined by temperature, not molecular mass.

$KE = (3/2)\ kT$

(c) Briefly explain the following:

(i) Liquid ammonia bottle is cooled before opening the seal.

Cooling reduces the vapor pressure of ammonia, minimizing the risk of rapid expansion and evaporation when the bottle is opened.

(ii) The tire of an automobile is inflated to a slightly lower pressure in summer than in winter.

In summer, higher temperatures cause air expansion, increasing pressure inside the tire. Inflating to a lower pressure prevents excessive pressure buildup, reducing the risk of tire bursts.

(d) A 1.0 liter sample of dry air at 25 °C and 786 mmHg contains 0.925 g of nitrogen gas (N_2) and other gases. Considering dry air to behave ideally, calculate the:

(i) Mole fraction of N_2 in the gas sample.

Step 1: Calculate moles of N_2.

Moles of N_2 = 0.925 g / 28 g/mol
= 0.033 mol

Step 2: Calculate total moles using PV = nRT.

P = 786 mmHg = 1.034 atm
V = 1.0 L
R = 0.0821 $L \cdot atm \cdot mol^{-1} \cdot K^{-1}$
T = 25 + 273 = 298 K

n = PV / RT
= (1.034 × 1.0) / (0.0821 × 298)
= 0.042 mol

Step 3: Calculate mole fraction of N_2.

X_N_2 = 0.033 / 0.042
= 0.785

(ii) Partial pressure of N_2 in the gas sample (in mmHg).

$P\_N_2 = X\_N_2 \times P\_total$
= 0.785 × 786 mmHg
= 617 mmHg

(e) The volume of 200 cm^3 of oxygen gas required 250 seconds to diffuse through a porous membrane. Under the identical conditions, 200 cm^3 of gas 'Z' diffused in 177 seconds. Calculate the relative molecular mass of gas 'Z'.

Using Graham's law:

Rate of diffusion of gas Z / Rate of diffusion of O_2 = $\sqrt{(M\_O_2 / M\_Z)}$

$(200/177) / (200/250) = \sqrt{(32 / M_Z)}$

$(250 \times 200) / (177 \times 200) = \sqrt{(32 / M_Z)}$

$250 / 177 = \sqrt{(32 / M_Z)}$

$(250/177)^2 = 32 / M_Z$

$M_Z = 32 \times (177^2 / 250^2)$

$M_Z = 32 \times (31329 / 62500)$

$M_Z = 16.05$ g/mol