Name: _____ **Date:** _____

Answer Key: Stoichiometry Showdown: Senior Chemists vs. The Law of Mass Action

Challenge students to move beyond basic mole conversions into the realm of non-ideal gas behavior, partial yields, and multi-step industrial synthesis analysis.

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1. In the industrial synthesis of adipic acid ($H_2C_6H_8O_4$), a precursor to Nylon-6,6, a process yields 85.0% of the theoretical mass. If 500.0g of cyclohexane is oxidized, but 25.0g of unreacted starting material is recovered, what is the effective mole-to-mole relationship used to calculate actual yield?

Answer: B) The ratio between the reacted moles of cyclohexane and the product of theoretical yield and 0.85.

Actual yield is the product of theoretical yield (based on reacted starting material) and the fractional percent yield. Stoichiometry must account for the mass actually converted (475g) rather than the initial 500g.

2. In a titration involving a polyprotic acid like H_3PO_4 with NaOH, the stoichiometric point for the second equivalence requires exactly double the moles of base compared to the first, assuming complete dissociation of the second proton.

Answer: A) True

Each neutralization step follows its own stoichiometric ratio. To reach the second equivalence point, two moles of NaOH are required per mole of H_3PO_4 to remove two protons ($H_2PO_4^-$ -> HPO_4^{2-}).

3. A 10.0L vessel contains a mixture of Ne and Ar. If the total pressure is 2.0 atm and the mole fraction of Ne is 0.75, the partial pressure of Ar is _____.

Answer: B) 0.50 atm

Dalton's Law states partial pressure is the product of total pressure and mole fraction. If Ne is 0.75, Ar must be 0.25. (0.25 * 2.0 atm = 0.50 atm).

4. Consider the combustion of a complex hydrocarbon fuel. If the analysis of the exhaust gas shows 12 moles of CO_2 and 14 moles of H_2O, which empirical formula represents the original analyte?

Answer: A) C_3H_7

12 moles of C and 28 moles of H (from 14 H_2O) gives a ratio of 12:28. Dividing by the greatest common divisor (4) yields a 3:7 empirical ratio.

Name: _____ **Date:** _____

5. The limiting reactant in a chemical process is always the substance present in the smallest mass at the start of the reaction.

Answer: B) False

The limiting reactant depends on the molar ratio required by the balanced equation and the molar masses of the substances, not the absolute initial mass.

6. In the decomposition of potassium chlorate (2KClO3 -> 2KCl + 3O2), if 2.0 moles of KClO3 decompose fully, the volume of O2 produced at STP is approximately _____.

Answer: C) 67.2 L

2 moles of KClO3 produce 3 moles of O2 (2:3 ratio). At STP, 1 mole = 22.4L. Therefore, 3 * 22.4 = 67.2L.

7. During the synthesis of aspirin, a student uses a 2:1 molar excess of acetic anhydride relative to salicylic acid. If the reaction has a 70% yield, what factor primarily determines the mass of the final product?

Answer: C) The amount of salicylic acid used.

Since acetic anhydride is in excess, salicylic acid is the limiting reactant. The theoretical yield (and thus the final 70% yield) is strictly dependent on the limiting reagent.

8. An unknown gas has a density of 1.25 g/L at STP. The molar mass of this gas is most likely _____.

Answer: B) 28 g/mol

Molar mass = density * molar volume at STP (1.25 g/L * 22.4 L/mol = 28 g/mol). This likely indicates Nitrogen gas (N2).

9. A solution contains 0.1M Ag+ and 0.1M Pb2+. As Cl- is added, which stoichiometric calculation is required to determine which salt precipitates first?

Answer: A) Comparing the Solubility Product Constants (Ksp) with the ion product (Q).

Precipitation stoichiometry in advanced chemistry requires evaluating the Ksp against the reaction quotient Q; the substance requiring the lowest concentration of the titrant to exceed its Ksp will precipitate first.

10. In a closed system reacting N2 and H2 to form NH3 (Haber process), the total number of moles of gas remains constant throughout the reaction.

Answer: B) False

Name: _____ **Date:** _____

The reaction N2 + 3H2 -> 2NH3 shows 4 moles of gaseous reactants producing 2 moles of gaseous product. The total number of moles changes, affecting pressure in the vessel.