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Answer Key: Your Mission to Mars: A Junior Chemist's Mastery of Molar Ratios

Students synthesize complex stoichiometric data and analyze limiting reactants to fuel a simulated deep-space expedition using gravimetric and volumetric analysis.

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1. An aerospace engineer uses the combustion of hydrazine ($N_2H_4 + O_2 \rightarrow N_2 + 2H_2O$) to power a thruster. If 80.0 grams of hydrazine reacts with 128.0 grams of oxygen gas, which reagent is strictly responsible for halting the reaction?

Answer: B) Hydrazine (N_2H_4)

Molar mass of N_2H_4 is ~32g/mol, so 80g is 2.5 moles. Molar mass of O_2 is 32g/mol, so 128g is 4.0 moles. The stoichiometric ratio is 1:1; since there are fewer moles of hydrazine, it is the limiting reactant.

2. To synthesize aspirin ($C_9H_8O_4$), a chemist reacts 2.00 moles of salicylic acid with excess acetic anhydride. If the actual yield collected is 324.0 grams, the percentage yield of the reaction is _____ %.

Answer: C) 90%

Theoretical yield = 2.00 moles * 180.16 g/mol (molar mass of aspirin) = 360.32g. Percent yield = (324.0 / 360.32) * 100 = 90%.

3. In a closed system, the total mass of the reactants must always equal the total mass of the products, regardless of whether the reaction goes to 100% completion or which reactant is limiting.

Answer: A) True

According to the Law of Conservation of Mass, matter is neither created nor destroyed; therefore, the mass of all starting materials (including unreacted excess) equals the mass of all substances present after the reaction.

4. When analyzing a hydrate of copper(II) sulfate ($CuSO_4 \cdot xH_2O$), a student heats 5.00g of the sample until only 3.20g of anhydrous salt remains. What is the value of 'x' in the chemical formula?

Answer: C) 5

Mass of water lost = 1.80g (0.10 moles). Mass of $CuSO_4$ = 3.20g (0.02 moles). The ratio of moles of water to moles of salt is 0.10 / 0.02 = 5.

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5. A balloon contains 48.0 grams of Ozone (O3) gas. The total number of oxygen ATOMS present in this balloon is _____ times Avogadro's number.

Answer: C) 3.0

Molar mass of O3 is 48g/mol. 48g is 1 mole of O3 molecules. Since each molecule contains 3 atoms, there are 3 moles of oxygen atoms (3 * 6.022 x 10^23 atoms).

6. Consider the Ostwald process: 4NH3 + 5O2 '4NO + 6H2O. If you aim to produce 120 grams of NO, how many moles of NH3 must be consumed, assuming 100% efficiency?

Answer: B) 4.0 moles

The molar mass of NO (14+16) is 30g/mol. 120g / 30g/mol = 4.0 moles of NO. The stoichiometric ratio between NH3 and NO is 4:4 (or 1:1), so 4.0 moles of NH3 are required.

7. The empirical formula of a compound represents the actual number of atoms of each element in a molecule, while the molecular formula refers to the simplest whole-number ratio.

Answer: B) False

The definitions are swapped; the empirical formula is the simplest ratio, while the molecular formula shows the actual counts of atoms.

8. A sample of a hydrocarbon is 80% Carbon and 20% Hydrogen by mass. If its molar mass is 30.07 g/mol, which of the following is its molecular formula?

Answer: B) C2H6

Carbon: 80g/12 = 6.67 mol. Hydrogen: 20g/1 = 20 mol. Ratio is 1:3 (Empirical formula CH3, mass 15). Since molar mass is 30, the molecular formula is (CH3)2 = C2H6.

9. In the precipitation reaction AgNO3 + NaCl 'AgCl + NaNO3, if 0.50 moles of AgNO3 react with 0.50 moles of NaCl, the mass of AgCl (molar mass ~143.3 g/mol) produced is _____ grams.

Answer: B) 71.65

The ratio is 1:1. 0.50 moles of AgNO3 produces 0.50 moles of AgCl. 0.50 * 143.3 g/mol = 71.65 grams.

10. The molar volume of any ideal gas at Standard Temperature and Pressure (STP) is 22.4 Liters per mole, which allows for direct stoichiometric conversions between gas volume and moles.

Answer: A) True

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Avogadro's Law states that equal volumes of gases at the same temperature and pressure contain equal numbers of particles. At STP, one mole of ideal gas occupies 22.4L.