**Name:** _______________ **Date:** _______________

# Answer Key: Shatter the Limits of Stoichiometric Synthesis for Collegiate Chemists

Limiting reagents, theoretical yield, and percent atom economy — simulate high-stakes industrial chemical manufacturing across 10 rigorous scenario-based problems.

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**1. A research team is synthesizing cisplatin [Pt(NH3)2Cl2] from K2PtCl4 and NH3. If the starting material contains 15.0 g of K2PtCl4 (MW: 415.1 g/mol) and an excess of ammonia, but the process yields only 9.20 g of cisplatin (MW: 300.0 g/mol), what is the percent yield and the primary stoichiometric bottleneck?**

**Answer:** A) 84.9% yield; Theoretical yield is 10.84 g

Calculated as: (15.0 g / 415.1 g/mol) = 0.03613 mol of K2PtCl4. In a 1:1 ratio, theoretical mass = 0.03613 * 300.0 = 10.84 g. Percent yield = (9.20 / 10.84) * 100 = 84.9%.

**2. In the combustion of a 1.500 g sample of an unknown hydrocarbon (CxHy), 4.714 g of CO2 and 1.285 g of H2O are produced. Determine the whole-number coefficient of 'x' in the empirical formula.**

**Answer:** A) 3

Convert masses to moles: 4.714g CO2 = 0.1071 mol C; 1.285g H2O = 0.1426 mol H. The ratio 0.1071 : 0.1426 is approx 3:4. The empirical formula is C3H4, so x = 3.

**3. True or False: In a system where the reaction 3A + 2B ’C occurs, if you start with equal masses of A and B, and the molar mass of A is exactly 1.5 times the molar mass of B, then B must be the limiting reactant.**

**Answer:** A) True

Let mass = m. Moles A = m/1.5M; Moles B = m/M. Comparison of stoichiometric availability: (m/1.5M)/3 vs (m/M)/2 results in m/4.5M for A vs m/2M for B. Since m/4.5M is less than m/2M, A is actually the limiting reactant, making the statement false. Wait, calculating again: A is m/4.5M, B is m/2M. A is the smaller quantity per mole required. Therefore, B is in excess and the statement is False.

**4. A 2.50 g sample of a mixture containing NaHCO3 and Na2CO3 was heated, yielding 0.310 g of CO2 according to the decomposition of NaHCO3 (2 NaHCO3 ’Na2CO3 + H2O + CO2). What is the mass percentage of NaHCO3 in the original mixture?**

**Answer:** B) 47.3%

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0.310 g $CO_2$ / 44.01 g/mol = 0.00704 mol $CO_2$. From stoichiometry, 0.01408 mol $NaHCO_3$ was present. 0.01408 * 84.01 g/mol = 1.183 g $NaHCO_3$. (1.183 / 2.50) * 100 = 47.3%.

**5. Consider the reaction: $P_4$ + 6 $Cl_2$ ’4 $PCl_3$. If 2.0 mol of Phosphorus reacts with 9.0 mol of Chlorine, how many moles of the excess reactant remain after the reaction reaches completion?**

**Answer:** A) 0.50 mol

$Cl_2$ is limiting: 9.0 mol $Cl_2$ requires 9/6 = 1.5 mol $P_4$. Excess $P_4$ = 2.0 - 1.5 = 0.5 mol.

**6. True or False: The concept of 'Atom Economy' in green chemistry is equivalent to 'Percent Yield' because both measure the efficiency of a chemical processes converting reactants to products.**

**Answer:** B) False

Percent yield measures efficiency based on actual vs theoretical output; Atom Economy measures how much of the reactant mass ends up in the desired product versus waste.

**7. A sample of an unknown metal oxide ($M_2O_3$) with a mass of 1.52 g is reduced to 1.04 g of pure metal. Identify the metal M.**

**Answer:** C) Chromium (Cr)

Mass of Oxygen = 1.52 - 1.04 = 0.48 g. Moles O = 0.48 / 16 = 0.03 mol. Since formula is $M_2O_3$, moles M = (2/3) * 0.03 = 0.02 mol. Molar mass of M = 1.04 g / 0.02 mol = 52 g/mol. This is Chromium.

**8. Determine the molarity of a solution prepared by dissolving 25.0 g of $BaCl_2$ (MW: 208.2 g/mol) into enough water to make 450 mL of solution. The value is ______ M.**

**Answer:** B) 0.267

Moles = 25.0 / 208.2 = 0.120 mol. Molarity = 0.120 mol / 0.450 L = 0.2666... M.

**9. True or False: In the combustion of any pure liquid alcohol ($C_nH_{2n+1}OH$), the number of moles of water produced will always be greater than the number of moles of carbon dioxide produced.**

**Answer:** A) True

Balanced general equation: $C_nH_{(2n+2)}O + O_2 \rightarrow nCO_2 + (n+1)H_2O$. Since n+1 is always > n, moles of $H_2O$ always exceed $CO_2$.

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**10. What is the total number of ions present in 50.0 mL of a 0.150 M solution of Aluminum Sulfate [Al2(SO4)3]?**

**Answer:** A) 2.26 x 10^22

Moles = 0.050 L * 0.150 M = 0.0075 mol. Aluminum sulfate dissociates into 5 ions (2 Al, 3 SO4). Total moles of ions = 0.0075 * 5 = 0.0375 mol. 0.0375 * (6.022 x 10^23) = 2.26 x 10^22.