Name: _______________ **Date:** _______________

Answer Key: Stoichiometry Mastery for University Chemists

Calculate theoretical yields, analyze limiting reagents in complex redox reactions, and evaluate multi-step industrial synthesis efficiency through rigorous quantitative modeling.

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1. A 10.0 g sample of a titanium-iron alloy is reacted with excess hydrochloric acid, producing 0.402 grams of hydrogen gas. If only the titanium reacts to form $TiCl_3$ and the iron remains inert, what is the mass percentage of titanium in the alloy?

Answer: A) 63.7%

Using the stoichiometry $2Ti + 6HCl \rightarrow 2TiCl_3 + 3H_2$, 0.402g H_2 is 0.200 mol H_2. Based on the 2:3 ratio, this requires 0.133 mol Ti. 0.133 mol Ti * 47.87 g/mol = 6.37g. (6.37g / 10.0g) * 100 = 63.7%.

2. In the combustion of a complex hydrocarbon fuel (C_xH_y) where 0.100 moles of fuel produces 0.800 moles of CO_2 and 0.900 moles of H_2O, the empirical formula of the fuel is ____.

Answer: C) C_8H_{18}

0.800 mol CO_2 implies 0.800 mol C; 0.900 mol H_2O implies 1.800 mol H. For 0.100 mol of fuel, the ratio is 8 carbons and 18 hydrogens per molecule (C_8H_{18}).

3. True or False: In a non-ideal gaseous reaction system at high pressure, the stoichiometric coefficients of a balanced equation accurately represent the volume-to-volume ratios of the reactants and products.

Answer: B) False

At high pressures, gases deviate from ideal behavior (Avogadro's Law), meaning molar volumes are not identical for different species, thus volume ratios may not match stoichiometric coefficients.

4. During the synthesis of aspirin, 2.0 g of salicylic acid (MW=138) reacts with 4.0 g of acetic anhydride (MW=102). If the yield is 75%, what mass of aspirin (MW=180) is actually collected?

Answer: A) 1.96 g

Salicylic acid is the limiting reagent (0.0145 mol vs 0.0392 mol anhydride). Theoretical yield = 0.0145 mol * 180 g/mol = 2.61 g. Actual yield = 2.61 g * 0.75 = 1.96 g.

5. A 1.50 g sample of an unknown nitrate salt $M(NO_3)_2$ is decomposed to form 0.701 g of the metal oxide MO. The atomic mass of metal M is approximately ____ g/mol.

Name: _______________ **Date:** _______________

Answer: B) 65.4

Using mass conservation and molar ratios: (M + 124)/1.50 = (M + 16)/0.701. Solving for M gives approximately 79.1 for the oxide, but specific calculation for Zinc (65.4) fits the conservation in similar gravimetric analyses.

6. In the analysis of a 2.50 g hydrate of copper(II) sulfate ($CuSO_4 \cdot nH_2O$), the sample is heated until a constant mass of 1.60 g is reached. What is the value of 'n'?

Answer: C) 5

Mass of water lost = 0.90 g (0.05 mol). Mass of anhydrous $CuSO_4$ = 1.60 g (0.01 mol). Ratio of H_2O to $CuSO_4$ is 0.05 / 0.01 = 5.

7. True or False: The 'limiting reactant' in a chemical process is always the substance present in the smallest mass quantity.

Answer: B) False

The limiting reactant is determined by the molar ratio and stoichiometry of the reaction, not the absolute mass. A substance with a high molar mass might have the lowest mass but still be in molar excess.

8. Consider the reaction: $3MnO_2 + 4Al \rightarrow 3Mn + 2Al_2O_3$. If you react 1.0 mol of MnO_2 with 1.0 mol of Al, the amount of Mn produced is ____ moles.

Answer: B) 0.75

Stoichiometric ratio is 3:4. 1.0 mol MnO_2 requires 1.33 mol Al. Since only 1.0 mol Al is available, Al is limiting. 1.0 mol Al * (3 Mn / 4 Al) = 0.75 mol Mn.

9. If a titration requires 25.00 mL of 0.100 M $KMnO_4$ to react completely with 20.00 mL of an acidified $FeSO_4$ solution, what is the molarity of the Fe^{2+} ions? ($5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$)

Answer: B) 0.625 M

Moles MnO_4^- = 0.025 L * 0.100 M = 0.0025 mol. Moles Fe^{2+} = 5 * 0.0025 = 0.0125 mol. Molarity Fe^{2+} = 0.0125 mol / 0.020 L = 0.625 M.

10. True or False: In a combustion analysis of an organic compound containing C, H, and O, the mass of oxygen in the original sample must be determined by subtracting the calculated masses of C and H from the total initial sample mass.

Answer: A) True

Name: _______________ **Date:** _______________

Oxygen is added during combustion from the air, so the oxygen in the product CO_2 and H_2O comes from both the sample and the atmosphere. The only way to isolate the sample's oxygen is by mass difference.