

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Answer Key: A Mole of Two Cities: Advanced 12th Grade Reaction Stoichiometry

Students synthesize complex limiting reactant data and gas laws to predict yields in multicomponent industrial and environmental chemical systems.

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**1. A 10.0 g sample of impure magnesium carbonate ( $\text{MgCO}_3$ ) is decomposed to form  $\text{MgO}$  and  $\text{CO}_2$ . If 3.82 g of  $\text{MgO}$  is actually recovered, and the reaction has a 92% yield, what was the approximate mass percent of  $\text{MgCO}_3$  in the original sample? (Molar masses:  $\text{MgCO}_3 = 84.3 \text{ g/mol}$ ,  $\text{MgO} = 40.3 \text{ g/mol}$ )**

**Answer:** C) 91.3%

First, calculate the theoretical yield needed for a 92% recovery:  $3.82 \text{ g} / 0.92 = 4.152 \text{ g MgO}$ . Convert this to moles:  $4.152 \text{ g} / 40.3 \text{ g/mol} = 0.103 \text{ mol}$ . Since the ratio is 1:1, there were 0.103 mol of  $\text{MgCO}_3$ , which equals 8.68 g.  $(8.68 \text{ g} / 10.0 \text{ g}) * 100 = \sim 91.3\%$ .

**2. In the combustion of a complex hydrocarbon, if the calculated mass of water produced exceeds the initial mass of the fuel, the Law of Conservation of Mass has been violated.**

**Answer:** B) False

False. In combustion, oxygen from the atmosphere is a reactant. The total mass of products ( $\text{CO}_2$  and  $\text{H}_2\text{O}$ ) must equal the mass of the fuel plus the mass of the consumed oxygen, often resulting in product masses higher than the initial fuel mass.

**3. An unknown gas with a mass of 1.43 g occupies 0.500 L at 298 K and 1.00 atm. Using the ideal gas law ( $R=0.0821$ ) and the mole concept, identify the likely identity of this diatomic gas: \_\_\_\_\_.**

**Answer:** C) Chlorine ( $\text{Cl}_2$ )

Solve for moles using  $n = PV/RT$ :  $(1.00 * 0.500) / (0.0821 * 298) = 0.0204 \text{ moles}$ . Molar mass = mass / moles =  $1.43 / 0.0204 = 70.1 \text{ g/mol}$ . Chlorine gas ( $\text{Cl}_2$ ) has a molar mass of approximately 70.9 g/mol, making it the closest match.

**4. Consider the titration of 25.0 mL of 0.150 M  $\text{H}_2\text{SO}_4$  with 0.200 M  $\text{KOH}$ . What volume of  $\text{KOH}$  is required to reach the second equivalence point?**

**Answer:** B) 37.50 mL

$\text{H}_2\text{SO}_4$  is diprotic, reacting with 2 moles of  $\text{KOH}$  per 1 mole of acid. Moles of acid =  $0.025 \text{ L} * 0.150 \text{ M} = 0.00375 \text{ mol}$ . Moles of  $\text{KOH}$  needed = 0.00750 mol. Volume  $\text{KOH} = 0.00750 \text{ mol} / 0.200 \text{ M} = 0.0375 \text{ L}$  or 37.50 mL.

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**5. In the synthesis of adipic acid for nylon production, a chemist uses 120 g of cyclohexane (C<sub>6</sub>H<sub>12</sub>) as the starting material. If the theoretical mole ratio of cyclohexane to adipic acid (C<sub>6</sub>H<sub>10</sub>O<sub>4</sub>) is 1:1, the theoretical yield of adipic acid is \_\_\_\_\_ grams.**

**Answer:** C) 208.4 g

Moles of cyclohexane = 120 g / 84.16 g/mol = 1.426 mol. Applying the 1:1 ratio, theoretical moles of adipic acid = 1.426 mol. Theoretical mass = 1.426 mol \* 146.14 g/mol = 208.4 g.

**6. At constant temperature and pressure, the volume ratios of gaseous reactants and products are equivalent to their stoichiometric mole ratios.**

**Answer:** A) True

True. This is Avogadro's Law of Combining Volumes, which states that under the same conditions of T and P, equal volumes of gases contain equal numbers of moles.

**7. Determine the limiting reactant when 5.0 moles of Silver Nitrate (AgNO<sub>3</sub>) reacts with 2.0 moles of Aluminum Chloride (AlCl<sub>3</sub>) to form Silver Chloride and Aluminum Nitrate.**

**Answer:** A) Silver Nitrate

The balanced equation is  $3\text{AgNO}_3 + \text{AlCl}_3 \rightarrow 3\text{AgCl} + \text{Al}(\text{NO}_3)_3$ . 5 moles of AgNO<sub>3</sub> requires (5/3) = 1.67 moles of AlCl<sub>3</sub>. Since we have 2.0 moles of AlCl<sub>3</sub>, AgNO<sub>3</sub> will be exhausted first, making it the limiting reactant.

**8. A hydrate of Cobalt(II) chloride, CoCl<sub>2</sub>·xH<sub>2</sub>O, is heated. The mass of the sample drops from 2.38 g to 1.30 g. The integer value of 'x' in the formula is \_\_\_\_\_.**

**Answer:** C) 6

Mass of water lost = 2.38 - 1.30 = 1.08 g. Moles of H<sub>2</sub>O = 1.08 / 18.02 = 0.0599 mol. Moles of anhydrous CoCl<sub>2</sub> (129.8 g/mol) = 1.30 / 129.8 = 0.0100 mol. Ratio x = 0.0599 / 0.0100 = ~6.

**9. The empirical formula of a compound can be determined using only the percent composition by mass, without knowing the total molar mass of the compound.**

**Answer:** A) True

True. The empirical formula represents the simplest whole-number ratio of atoms. This ratio is derived from the relative moles of each element calculated from mass percentages. The molecular mass is only needed to find the molecular formula.

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**10. In a redox titration, 32.0 mL of 0.100 M  $\text{KMnO}_4$  is needed to oxidize 25.0 mL of an acidic  $\text{Fe}^{2+}$  solution to  $\text{Fe}^{3+}$ . What is the molarity of the  $\text{Fe}^{2+}$  solution? (Mn is reduced from +7 to +2)**

**Answer:** C) 0.640 M

The balanced redox equation shows 1 mole of  $\text{MnO}_4^-$  reacts with 5 moles of  $\text{Fe}^{2+}$ . Moles of  $\text{MnO}_4^- = 0.032 \text{ L} * 0.100 \text{ M} = 0.0032 \text{ mol}$ . Moles of  $\text{Fe}^{2+}$  required =  $0.0032 * 5 = 0.016 \text{ mol}$ . Molarity of  $\text{Fe}^{2+} = 0.016 \text{ mol} / 0.025 \text{ L} = 0.640 \text{ M}$ .