Answers to Knowledge/Understanding Questions

1. The coefficients in a balanced chemical equation provide information on the amount of atoms and molecules that participate in a reaction. The coefficients can also represent the number of moles of a specific atom or molecule participating in a reaction.

2. A balanced chemical equation is necessary for stoichiometric calculations in order to accurately determine the relationship between reactants and products in a reaction. A balanced chemical equation allows one to predict the amount of products expected from a known amount of reactants, to calculate the necessary amounts of reactants required to yield a specific amount of product, and to calculate any other quantitative relationships between reactants and products. Without a balanced chemical equation, these calculations will be incorrect.

3. It is not necessary to determine the limiting reactant before beginning any stoichiometric calculations when the reactants are present in stoichiometric amounts. In this case, the reactants are present in a mole ratio that corresponds exactly to the mole ratio predicted by the balanced chemical equation. That is, when the reaction is complete, there are no reactants left. Also, when the amount of limiting reactant is given, and the other reactants are stated to be in excess, there is no need to do any calculations to determine the limiting reactant. In decomposition reactions, there is only one reactant present. Therefore, there is no need to determine the limiting reactant.

4. The concept of percentage yield was introduced because the theoretical yield predicted from the balanced chemical equation is not always the same as the actual yield obtained in an experiment.

5. The student's reasoning is incorrect. The coefficients of a chemical equation do not represent the mass ratio of the molecules or atoms. The coefficients give information on the relative amounts of the atoms/molecules taking part in the reaction. The correct way for the student to determine the mass of aluminum oxide produced would be to state that 4 mol of aluminum reacts with 3 mol of oxygen to produce 2 mol of aluminum oxide. The mass of the product can then be calculated using this information.

Answers to Inquiry Questions

6.

	$4Al_{(s)}$	$+3O_{2(g)}$	→	$2Al_2O_{3(s)}$
mole ratio	4	3		2
molar mass	26.98 g/mol	32.00 g/mol		
given/required	0.400 mol	*m*		

$\frac{4 \text{ mol Al}}{3 \text{ mol } O_2} = \frac{0.400 \text{ mol Al}}{n \text{ mol } O_2}$

$n \text{ mol } O_2 = 0.400 \text{ mol Al} \times \frac{3 \text{ mol } O_2}{4 \text{ mol Al}} = 0.300 \text{ mol } O_2$

$m = 0.300 \text{ mol } O_2 \times 32.00 \text{ g/mol} = 9.60 \text{ g } O_2$

7.

	$Ca_{(s)}$	$+Cl_{2(g)}$	→	$CaCl_{2(s)}$
mole ratio	1	1		1
molar mass	40.08 g/mol			110.98 g/mol
given/required	5.3 g			*N*

$\text{Amount of Ca} = \frac{5.3 \text{ g Ca}}{40.08 \text{ g/mol}} = 0.13 \text{ mol Ca}$

$\frac{1 \text{ mol Ca}}{1 \text{ mol } CaCl_2} = \frac{0.13 \text{ mol Ca}}{n \text{ mol } CaCl_2}$

$n \text{ mol Ca} = 0.13 \text{ mol Ca} \times \frac{1 \text{ mol } CaCl_2}{1 \text{ mol Ca}} = 0.13 \text{ mol } CaCl_2$

$N = 0.13 \text{ mol } CaCl_2 \times 6.02 \times 10^{23} \text{ formula units/mol}$

$= 8.0 \times 10^{22} \text{ formula units of } CaCl_2$

8.

	C_3H_8	$+5O_{2(g)}$	→	$3CO_{2(g)}$	$+4H_2O_{(g)}$
mole ratio	1	5		3	4
molar mass	44.11 g/mol			44.01 g/mol	
given/required	97.5 g			*m*	

$\text{Amount of } C_3H_8 = \frac{97.5 \text{ g } C_3H_8}{44.11 \text{ g/mol}} = 2.21 \text{ mol}$

$n \text{ mol } CO_2 = \frac{2.21 \text{ mol} \times 3}{1} = 6.63 \text{ mol}$

$m = 6.63 \text{ mol } CO_2 \times 44.01\text{g/mol} = 291.8 \text{ g } CO_2$

9.

	$Zn_{(s)}$	$+S_{(s)}$	→	$ZnS_{(s)}$
mole ratio	1	1		1
molar mass	65.39 g/mol	32.07 g/mol		97.46 g/mol
given/required	6.00 g	3.35 g		*m*

(a) $n \text{ mol Zn} = \frac{6.00 \text{ g Zn}}{65.39 \text{ g/mol}} = 0.0918 \text{ mol Zn}$

$n \text{ mol S} = \frac{3.35 \text{ g S}}{32.07 \text{ g/mol}} = 0.104 \text{ mol S}$

Amount of ZnS produced based on:

$\text{Zn} \rightarrow n = \frac{0.0918 \text{ mol} \times 1}{1} = 0.0918 \text{ mol}$

$\text{S} \rightarrow n = \frac{0.104 \text{ mol} \times 1}{1} = 0.104 \text{ mol}$

The limiting reactant is Zn.

10.

	$TiCl_{4(s)}$	$+2H_2O_{(\ell)}$	$\rightarrow$	$TiO_{2(s)}$	$+4HCl_{(g)}$
mole ratio	1	2		1	4
molar mass	189.67 g/mol			79.87 g/mol	
given/required	85.6 g			*m*	

Amount of $TiCl_4 = \frac{85.6 \text{ g } TiCl_4}{189.67 \text{ g/mol}} = 0.451$ mol

Amount of TiO_2 produced $= \frac{0.451 \text{ mol} \times 1}{1} = 0.451$ mol

$m = 0.451 \text{ mol } TiO_2 \times 79.87 \text{ g/mol} = 36.0 \text{ g } TiO_2$ produced

11.

	$4Ag_{(s)}$	$+2H_2S_{(g)}$	$+O_{2(g)}$	$\rightarrow$	$2Ag_2S_{(s)}$	$+2H_2O_{(g)}$
mole ratio	4	2	1		2	2
molar mass	107.87 g/mol	34.09 g/mol	32.00 g/mol		247.81 g/mol	
given/required	1.90 g	0.280 g	0.160 g		*m*	

Amount of $Ag = \frac{1.90 \text{ g Ag}}{107.87 \text{ g/mol}} = 0.0176$ mol

Amount of $H_2S = \frac{0.280 \text{ g } H_2S}{34.09 \text{ g/mol}} = 0.00821$ mol

Amount of $O_2 = \frac{0.160 \text{ g } O_2}{32.00 \text{ g/mol}} = 0.00500$ mol

Amount of Ag_2S produced based on:

$Ag \rightarrow n = \frac{0.0176 \text{ mol} \times 2}{4} = 0.00880$ mol

$H_2S \rightarrow n = \frac{0.00821 \text{ mol} \times 2}{2} = 0.00821$ mol

$O_2 \rightarrow n = \frac{0.00500 \text{ mol} \times 2}{1} = 0.0100$ mol

The limiting reactant is H_2S.

$m = 0.00821 \text{ mol } Ag_2S \times 247.81 \text{ g/mol} = 2.03 \text{ g } Ag_2S$

12.

	$2Ca_3(PO_4)_{2(s)}$	$+6SiO_{2(s)}$	$+10C_{(s)}$	$\rightarrow$	$P_{4(s)}$	$+6CaSiO_{3(s)}$	$+10CO_{(g)}$
mole ratio	2	6	10		1	6	10
molar mass	310.18 g/mol	60.09 g/mol	12.01 g/mol			116.17 g/mol	
given/required	20.8 g	13.3 g	3.90 g			*m*	

Amount of $Ca_3(PO_4)_2 = \frac{20.8 \text{ g } Ca_3(PO_4)_2}{310.18 \text{ g/mol}} = 0.0671$ mol

Amount of $SiO_2 = \frac{13.3 \text{ g } SiO_2}{60.09 \text{ g/mol}} = 0.221$ mol

Amount of $C = \frac{3.90 \text{ g C}}{12.01 \text{ g/mol}} = 0.325$ mol

Amount of $CaSiO_3$ produced based on:

$Ca_3(PO_4)_2 \rightarrow n = \frac{0.671 \text{ mol} \times 6}{2} = 0.201$ mol

$SiO_2 \rightarrow n = \frac{0.221 \text{ mol} \times 6}{6} = 0.221$ mol

$C \rightarrow n = \frac{0.325 \text{ mol} \times 6}{10} = 0.195$ mol

The limiting reactant is C.

$m = 0.195 \text{ mol } CaSiO_3 \times 116.17 \text{ g/mol} = 22.7 \text{ g } CaSiO_3$

13.

	$3As_2S_{3(s)}$	$+4H_2O_{(\ell)}$	$+10HNO_{3(aq)}$	$+18NaNO_{3(aq)}$	$\rightarrow$	$9Na_2SO_{4(aq)}$	$+6H_3AsO_{4(aq)}$	$+28NO_{(g)}$
mole ratio	3	4	10	18		9	6	28

Amount of $H_2O = \frac{0.140 \text{ g } H_2O}{18.02 \text{ g/mol}} = 0.00777$ mol

Amount of $HNO_3 = \frac{1.23 \text{ g } HNO_3}{63.02 \text{ g/mol}} = 0.0195$ mol

Amount of $NaNO_3 = \frac{3.50 \text{ g } NaNO_3}{85.00 \text{ g/mol}} = 0.0412$ mol

Amount of H_3AsO_4 produced based on:

$As_2S_3 \rightarrow n = \frac{0.00634 \text{ mol} \times 6}{3} = 0.01268$ mol

$H_2O \rightarrow n = \frac{0.00777 \text{ mol} \times 6}{4} = 0.01166$ mol

$HNO_3 \rightarrow n = \frac{0.0195 \text{ mol} \times 6}{10} = 0.01171$ mol

$NaNO_3 \rightarrow n = \frac{0.0412 \text{ mol} \times 6}{18} = 0.01373$ mol

The limiting reactant is H_2O.

$m = 0.01166 \text{ mol } H_3AsO_4 \times 141.95 \text{ g/mol} = 1.66 \text{ g } H_3AsO_4$

14.

	$C_5H_{12(\ell)}$	$+8O_{2(g)}$	$\rightarrow$	$5CO_{2(g)}$	$+6H_2O_{(\ell)}$
mole ratio	1	8		5	6
molar mass	72.17 g/mol	32.00 g/mol		44.01 g/mol	
given/required	2.85×10^2 g	3.00 g		*m*	

Amount of $C_5H_{12} = \frac{2.85 \times 10^2 \text{ g } C_5H_{12}}{72.17 \text{ g/mol}} = 3.95$ mol

Amount of $O_2 = \frac{3.00 \text{ g } O_2}{32.00 \text{ g/mol}} = 0.0938$ mol

Amount of CO_2 produced based on:

$C_5H_{12} \rightarrow n = \frac{3.95 \text{ mol} \times 5}{1} = 19.75$ mol

$O_2 \rightarrow n = \frac{0.0938 \text{ mol} \times 5}{8} = 0.0586$ mol

The limiting reagent is O_2.

$m = 0.0586 \text{ mol } CO_2 \times 44.01 \text{ g/mol} = 2.58 \text{ g } CO_2$

15.

	$SiO_{2(s)}$	$+4HF_{(aq)}$	$\rightarrow$	$SiF_{4(g)}$	$+2H_2O_{(g)}$
mole ratio	1	4		1	2
molar mass	60.01 g/mol			104.09 g/mol	18.02 g/mol
given/required	12.2 g				*m*

(a) Amount of of $SiO_2 = \frac{12.2 \text{ g } SiO_2}{60.01 \text{ g/mol}} = 0.203$ mol

Amount of of H_2O produced $= \frac{0.203 \text{ mol} \times 2}{1} = 0.406$ mol

Theoretical yield of $H_2O = 0.406 \text{ mol } H_2O \times 18.02 \text{ g/mol} = 7.32 \text{ g } H_2O$

(b) Percentage yield $= \frac{2.50 \text{ g}}{7.32 \text{ g}} \times 100\% = 34.2\%$

(c) Amount of of SiF_4 produced $= \frac{0.203 \text{ mol} \times 1}{1} = 0.203$ mol

Theoretical yield of $SiF_4 = 0.203 \text{ mol } SiF_4 \times 104.09 \text{ g/mol} = 21.1 \text{ g } SiF_4$

Assuming a 34.2% yield,

the actual mass of $SiF_4 = 21.13 \text{ g } SiF_4 \times 0.342 = 7.23 \text{ g } SiF_4$

16.

	$BaCl_{2(s)}$	$+Na_2SO_{4(aq)}$	$\rightarrow$	$BaSO_{4(s)}$	$+2NaCl_{(aq)}$
mole ratio	1	1		1	2
molar mass	208.23 g/mol	142.05 g/mol		233.40 g/mol	
given	4.36 g			2.62 g	

Amount of $BaSO_4 = \frac{2.62 \text{ g } BaSO_4}{\ldots} = 0.0112$ mol