Answers to Learning Review

1. 6.022×10^{23} molecules is equivalent to 1 mol of molecules and 1.204×10^{24} molecules is equivalent to $2(6.022 \times 10^{23}$ molecules), so the equation can be rewritten as

$$1\text{ mol }H_2(g) + 1\text{ mol }I_2(g) \rightarrow 2\text{ mol }HI(g)$$

2. The balanced equation tells us that two moles of sodium react with two moles of water to form two moles of sodium hydroxide and ~~four~~ one mole~~s~~ of hydrogen. By using mole ratios determined from the balanced equation, we can calculate the number of moles of reactants required and products produced from 0.8 mol sodium.

$$0.8\ \cancel{\text{mol}}\text{ Na} \times \frac{2\text{ mol }H_2O}{2\ \cancel{\text{mol}}\text{ Na}} = 0.8\text{ mol }H_2O$$

0.8 mol sodium requires 0.8 mol H_2O.

$$0.8\ \cancel{\text{mol}}\text{ Na} \times \frac{2\text{ mol NaOH}}{2\ \cancel{\text{mol}}\text{ Na}} = 0.8\text{ mol NaOH}$$

0.8 mol Na produces 0.8 mol NaOH.

$$0.8\ \cancel{\text{mol}}\text{ Na} \times \frac{1\ \cancel{2}\text{ mol }H_2}{2\ \cancel{\text{mol}}\text{ Na}} = 0.4\text{ mol }H_2$$

0.8 mol Na produces 0.4 mol H_2.

We can write the molar values we have calculated in equation form.

$$0.8\text{ mol Na}(s) + 0.8\text{ mol }H_2O(l) \rightarrow 0.8\text{ mol NaOH}(aq) + 0.4\text{ mol }H_2(g)$$

3. First, make sure the equation is balanced. You should always determine whether or not an equation is balanced, and balance it if necessary. To solve this problem, we need to know the mole ratio for aluminum and aluminum oxide. The mole ratio represents the relationship between the mol of substance given in the problem and the mol of the desired substance, and is taken directly from the balanced equation. The mole ratio for aluminum oxide and aluminum is $\frac{2\text{ mol }Al_2O_3}{4\text{ mol Al}}$.

$$0.12\ \cancel{\text{mol}}\text{ Al} \times \frac{2\text{ mol }Al_2O_3}{4\ \cancel{\text{mol}}\text{ Al}} = 0.060\text{ mol }Al_2O_3$$

4. First, make sure the equation is balanced. The mole ratio for zinc and zinc chloride is taken from the balanced equation and is $\frac{1\text{ mol }ZnCl_2}{1\text{ mol Zn}}$.

$$1.38\ \cancel{\text{mol}}\text{ Zn} \times \frac{1\text{ mol }ZnCl_2}{1\ \cancel{\text{mol}}\text{ Zn}} = 1.38\text{ mol }ZnCl_2$$

Because there is a 1:1 mole ratio of $ZnCl_2$ to Zn, the number of moles of zinc equals the moles of zinc chloride produced.

5. a. First, write the formulas for reactants and products. Include the physical states. Then, balance the equation.

$$2Ag_2CO_3(s) \rightarrow 4Ag(s) + O_2(g) + 2CO_2(g)$$

b. It is <u>not</u> possible to solve this problem by converting directly from grams of Ag_2CO_3 to grams of Ag. However, the balanced equation tells us the relationship between Ag_2CO_3 and Ag in moles. If we can convert grams of Ag_2CO_3 to moles, we can use the mole ratio to tell us how many moles of Ag are produced. To convert grams of Ag_2CO_3 to moles, you can produce a conversion factor from the equivalence statement which relates number of moles to molar mass. The correct conversion factor is $\frac{1\ \text{mol}\ Ag_2CO_3}{275.75\ \text{g}\ Ag_2CO_3}$.

$$6.32\ \cancel{\text{g}}\ Ag_2CO_3 \times \frac{1\ \text{mol}\ Ag_2CO_3}{275.5\ \cancel{\text{g}}\ Ag_2CO_3} = 0.0229\ \text{mol}\ Ag_2CO_3$$

Now, we can use the mole ratio for Ag_2CO_3 and Ag to calculate the moles of Ag.

$$0.0229\ \cancel{\text{mol}}\ Ag_2CO_3 \times \frac{4\ \text{mol Ag}}{2\ \cancel{\text{mol}}\ Ag_2CO_3} = 0.0458\ \text{mol Ag}$$

We now know the moles of Ag, but we want to know the grams of Ag. The conversion factor $\frac{107.87\ \text{g Ag}}{1\ \text{mol Ag}}$, which is derived from the molar mass of silver, will allow us to calculate grams.

$$0.0458\ \cancel{\text{mol}}\ \text{Ag} \times \frac{107.87\ \text{g Ag}}{1\ \cancel{\text{mol}}\ \text{Ag}} = 4.94\ \text{g Ag}$$

If we string together all the parts of this problem, we can see that the overall strategy is to convert grams to moles using the molar mass, then moles to moles using the mole ratio, and moles to mass using the molar mass.

$$\underset{\substack{\uparrow \\ \text{grams of} \\ \text{reactant}}}{6.32\ \cancel{\text{g}}\ \text{Ag2CO3}} \times \underset{\substack{\uparrow \\ \text{molar mass} \\ \text{of reactant}}}{\frac{1\ \cancel{\text{mol}}\ \text{Ag2CO3}}{175.75\ \cancel{\text{g}}\ \text{Ag2CO3}}} \times \underset{\substack{\uparrow \\ \text{mole ratio}}}{\frac{4\ \cancel{\text{mol}}\ \text{Ag}}{2\ \cancel{\text{mol}}\ \text{Ag2CO3}}} \times \underset{\substack{\uparrow \\ \text{molar mass} \\ \text{of product}}}{\frac{107.87\ \text{g Ag}}{1\ \cancel{\text{mol}}}} = \underset{\substack{\uparrow \\ \text{grams of} \\ \text{product}}}{4.94\ \text{g Ag}}$$

6. This question provides us with grams of reactant and asks for grams of product. Because we are told that $Pb(NO_3)_2$ is in excess, the limiting reactant must be Na_2SO_4. The amount of precipitate which can be formed is determined by the amount of Na_2SO_4 to grams $PbSO_4$. We must first calculate the moles of Na_2SO_4, then use the mole ratio derived from the balanced equation to tell us how many moles of $PbSO_4$ are produced, and finally, we can use the molar mass of $PbSO_4$ to calculate the grams of $PbSO_4$.

$$12.0\ \cancel{\text{g}}\ Na_2SO_4 \times \frac{1\ \cancel{\text{mol}}\ Na_2SO_4}{142.05\ \cancel{\text{g}}\ Na_2SO_4} \times \frac{1\ \cancel{\text{mol}}\ PbSO_4}{1\ \cancel{\text{mol}}\ Na_2SO_4} \times \frac{303.27\ \text{g}\ PbSO_4}{1\ \cancel{\text{mol}}\ PbSO_4} = 25.6\ \text{g}\ PbSO_4$$

7. First, write the balanced equation for this reaction.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

This problem gives us grams of hydrogen and asks for molecules of hydrogen chloride. There is no way to convert grams of hydrogen directly to molecules of hydrogen chloride. However, we can convert grams of hydrogen to moles of hydrogen using the molar mass of hydrogen gas. The balanced equation provide a mole ratio so that we can calculate the moles of hydrogen chloride. Converting from moles to molecules can be done because we know that 1 mole of hydrogen chloride equals 6.022 × 10^{23} molecules of hydrogen chloride.

$$20.1\ \cancel{g}\,H_2 \times \frac{1\ \text{m}\cancel{\text{o}}\text{l}\ H_2}{2.016\ \cancel{g}\,H_2} \times \frac{2\ \text{m}\cancel{\text{o}}\text{l}\ HCl}{1\ \text{m}\cancel{\text{o}}\text{l}\ H_2} \times \frac{6.022 \times 10^{23}\ \text{molecules HCl}}{1\ \text{m}\cancel{\text{o}}\text{l}\ HCl} = 1.20 \times 10^{25}\ \text{molecules}$$

8. We are given grams of kerosene and asked for grams of water vapor. Because we cannot convert directly between grams of kerosene and grams of water, we first convert grams of kerosene to moles of kerosene using the molar mass of kerosene. Then, use the mole ratio of kerosene and water from the balanced equation to determine the moles of water vapor. The molar mass of water will allow us to convert moles to grams of water.

$$15\ \cancel{g}\,C_{11}H_{24} \times \frac{1\ \text{m}\cancel{\text{o}}\text{l}\ C_{11}H_{24}}{156.30\ \cancel{g}\,C_{11}H_{24}} \times \frac{12\ \text{m}\cancel{\text{o}}\text{l}\ H_2O}{1\ \text{m}\cancel{\text{o}}\text{l}\ C_{11}H_{24}} \times \frac{18.02\ g}{1\ \text{m}\cancel{\text{o}}\text{l}\ H_2O} = 21\ g\ H_2O$$

9. a. You can prepare 4 complete copies. Copies 4 and 5 would lack page 3.

   b. Page 3 limits the number of complete reports which can be produced.

10. a. By looking at the grams of MnO_2 and the grams of HCl, it is impossible to tell which is the limiting reactant. It is possible to compare moles of reactants because we know the mole ratio of reactants from the balanced equation. So, calculate the number of moles of each reactant. Then determine how many moles of product could be produced from each of the two reactants. The reactant which allows the fewest number of moles of product is the limiting reactant.

$$10.2\ \cancel{g}\,MnO_2 \times \frac{1\ \text{m}\cancel{\text{o}}\text{l}\ MnO_2}{86.94\ \cancel{g}\,MnO_2} \times \frac{1\ \text{mol}\ Cl_2}{1\ \text{m}\cancel{\text{o}}\text{l}\ MnO_2} = 0.117\ \text{mol}\ MnO_2$$

$$18.3\ \cancel{g}\,HCl \times \frac{1\ \text{m}\cancel{\text{o}}\text{l}\ HCl}{36.46\ \cancel{g}\,HCl} \times \frac{1\ \text{mol}\ Cl_2}{4\ \text{m}\cancel{\text{o}}\text{l}\ HCl} = 0.125\ \text{mol}\ Cl_2$$

From 10.2 MnO_2, 0.117 mol Cl_2 can be produced, and from 18.3 g HCl, 0.125 mol Cl_2 can be produced. So the limiting reactant is MnO_2.

   b. We already know that the most chlorine we can make is 0.117 mol. To convert from moles to grams, use the molar mass of a chlorine molecule.

$$0.117\ \text{m}\cancel{\text{o}}\text{l}\ Cl_2 \times \frac{70.90\ g\ Cl_2}{1\ \text{m}\cancel{\text{o}}\text{l}\ Cl_2} = 8.30\ g\ Cl_2$$

c. The limiting reactant is manganese(IV) oxide so we need to calculate the moles of water which can be produced from 10.2 g MnO_2. By using the mole ratio from the balanced equation we can calculate the moles of water. To convert from moles of water to the number of molecules, use Avogadro's number as a conversion factor.

$$10.2\ \cancel{g}\ MnO_2 \times \frac{1\ \cancel{mol}\ MnO_2}{86.94\ \cancel{g}\ MnO_2} \times \frac{2\ \cancel{mol}\ H_2O}{1\ \cancel{mol}\ MnO_2} \times \frac{6.022 \times 10^{23}\ \text{molecules}\ H_2O}{1\ \cancel{mol}\ H_2O}$$

$$= 1.41 \times 10^{23}\ \text{molecules}\ H_2O$$

11. First, write the balanced equation for this reaction.

$$2H_3PO_4(aq) + 3Mg(OH)_2(s) \rightarrow Mg_3(PO_4)_2(s) + 6H_2O(l)$$

When the mass is given for two reactants, and you are asked to determine the quantity of product which can be produced, you must first determine which reactant is limiting. Determine how many moles of product would be produced from each reactant. The reactant which will produce the fewest number of moles of product is the limiting reactant.

$$121.0\ \cancel{g}\ H_3PO_4 \times \frac{1\ \cancel{mol}\ H_3PO_4}{97.99\ \cancel{g}\ H_3PO_4} \times \frac{1\ \cancel{mol}\ Mg_3(PO_4)_2}{2\ \cancel{mol}\ H_3PO_4} = 0.6174\ \text{mol}\ Mg_3(PO_4)_2$$

$$89.70\ \cancel{g}\ Mg(OH)_2 \times \frac{1\ \cancel{mol}\ Mg(OH)_2}{58.33\ \cancel{g}\ Mg(OH)_2} \times \frac{1\ \cancel{mol}\ Mg_3(PO_4)_2}{3\ \cancel{mol}\ Mg(OH)_2} = 0.51\ \text{mol}\ Mg_3(PO_4)_2$$

In this reaction, the $Mg(OH)_2$ is the limiting reactant. We now know how many moles of $Mg_3(PO_4)_2$ are produced, but we want to know the number of grams. Use the molar mass of $Mg(PO_4)_2$ to convert from moles of grams.

$$0.5126\ \cancel{mol}\ Mg_3(PO_4)_2 \times \frac{262.87\ \cancel{g}\ Mg_3(PO_4)_2}{1\ \cancel{mol}\ Mg_3(PO_4)_2} = 134.7\ g\ Mg_3(PO_4)_2$$

12. In this problem we are given quantities of two reactants, one expressed in grams and the other in molecules. Before we can calculate grams of product, we need to know which reactant limits the amount of product which can be produced. Convert the grams of KI to moles using the molar mass of KI and calculate the moles of I_2 from the mole ratio.

$$85.6\ \cancel{g}\ KI \times \frac{1\ \cancel{mol}\ KI}{166.0\ \cancel{g}\ KI} \times \frac{1\ \cancel{mol}\ I_2}{2\ \cancel{mol}\ KI} = 0.258\ \text{mol}\ I_2$$

The quantity of the other reactant, Cl_2, is given in molecules, not grams. We can convert molecules of Cl_2 to moles of Cl_2 using Avogadro's number. 1 mol Cl_2 = 6.022×10^{23} molecules Cl_2.

$$2.41 \times 10^{24}\ \cancel{\text{molecules}}\ Cl_2 \times \frac{1\ \text{mol}\ Cl_2}{6.022 \times 10^{23}\ \cancel{\text{molecules}}\ Cl_2} = 4.00\ \text{mol}\ Cl_2$$

So 2.41×10^{24} molecules is equivalent to 4.00 moles of Cl_2. Now we can find the moles of I_2 which can be produced from 4.00 moles of Cl_2.

$$4.00\ \text{mol}\ Cl_2 \times \frac{1\ \text{mol}\ I_2}{1\ \text{mol}\ Cl_2} = 4.00\ \text{mol}\ I_2$$

KI limits the amount of I_2 which can be produced, so it is the limiting reactant. We can calculate the grams of I_2 using the molar mass of I_2.

$$0.258\ \text{m}\cancel{\text{o}}\text{l I}_2 \times \frac{253.8\ \text{g I}_2}{\text{m}\cancel{\text{o}}\text{l I}_2} = 65.5\ \text{g Cl}_2$$

13. a. First, balance the equation.

$$2\ \text{NaI} + \text{Pb(NO}_3)_2 \rightarrow \text{PbI}_2 + 2\ \text{NaNO}_3$$

This problem first asks for the theoretical yield of PbI_2 when 2 quantities of reactants are mixed. Before we can calculate the amount of product, we need to know which reactant is limiting. Use the molar mass for each product and the mole ratio for the balanced equation to calculate the moles of PbI_2 which could be produced.

$$125.5\ \cancel{\text{g}}\ \text{NaI} \times \frac{1\ \text{m}\cancel{\text{o}}\text{l NaI}}{149.89\ \cancel{\text{g}}\ \text{NaI}} \times \frac{1\ \text{mol PbI}_2}{2\ \text{m}\cancel{\text{o}}\text{l NaI}} = 0.4186\ \text{mol PbI}_2$$

$$205.6\ \cancel{\text{g}}\ \text{Pb(NO}_3)_2) \times \frac{1\ \text{m}\cancel{\text{o}}\text{l Pb(NO}_3)_2}{331.22\ \cancel{\text{g}}\ \text{Pb(NO}_3)_2} \times \frac{1\ \text{mol PbI}_2}{1\ \text{m}\cancel{\text{o}}\text{l Pb(NO}_3)_2} = 0.6207\ \text{mol PbI}_2$$

The limiting reactant is NaI. Now we can answer the question about theoretical yield. Theoretical is the amount of product we calculate can be produced, that is, 0.4186 mol PbI_2. In real life, the actual yield might be less than the calculated yield. The theoretical yield of PbI_2 can be calculated from the number of moles of PbI_2, if we know the molar mass.

$$0.4186\ \text{m}\cancel{\text{o}}\text{l PbI}_2 \times \frac{461.00\ \text{g PbI}_2}{1\ \text{m}\cancel{\text{o}}\text{l PbI}_2} = 193.0\ \text{g}$$

b. In part a we calculated the theoretical yield of lead(II) iodide, which is 193.0 g. We are told that the actual yield from this reaction was found to be 164.5 g. The percent yield is equal to the actual yield divided by the theoretical yield, multiplied by 100 percent. So the percent yield of lead(II) iodide is

$$\frac{164.5\ \text{g PbI}_2}{193.0\ \text{g PbI}_2} \times 100\% = 85.23\%$$