1. The reaction of calcium hydride with water can be used to prepare small quantities of hydrogen gas, as is done to fill weather-observation balloons.

$$CaH_2(s) + H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g) \text{ (not balanced)}$$

   (a) How many grams of water are consumed in the reaction of 56.2 g CaH_2?
   (b) What mass of $CaH_2(s)$ must react with an excess of water to produce 8.12 X 10^{24} molecules of H_2?

$$CaH_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + 2H_2(g)$$

a)

$$56.2\text{g } CaH_2 \times \frac{1 \text{ mol } CaH_2}{42.10 \text{ g } CaH_2} \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } CaH_2} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = \mathbf{48.1 \text{ g } H_2O}$$

b)

$$8.12\times10^{24} \text{ molec. } H_2 \times \frac{1 \text{ mol } H_2}{6.02\times10^{23} \text{ molec.}} \times \frac{1 \text{ mol } CaH_2}{2 \text{ mol } H_2} \times \frac{42.10 \text{ g } CaH_2}{1 \text{ mol } CaH_2} = \mathbf{284 \text{ g } CaH_2}$$

2. The reaction of potassium superoxide, KO_2, is used in life-support systems to replace $CO_2(g)$ in expired air with $O_2(g)$.

$$4 KO_2(s) + 2 CO_2(g) \rightarrow 2 K_2CO_3(S) + 3O_2(g)$$

   (a) How many moles of $O_2(g)$ are produced by the reaction of 156 g CO_2 with excess KO_2?
   (b) How many grams of KO_2 are consumed per 100.0 g CO_2 removed from expired air?

a)

$$156\text{g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{3 \text{ mol } O_2}{2 \text{ mol } CO_2} = \mathbf{5.32 \text{ mol } O_2}$$

b)

$$100\text{g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{4 \text{ mol } KO_2}{2 \text{ mol } CO_2} \times \frac{71.10 \text{ g } KO_2}{1 \text{ mol } KO_2} = \mathbf{323 \text{ g } KO_2}$$

3. Ammonia can be generated by heating together the solids NH_4Cl and $Ca(OH)_2$ with $CaCl_2$ and H_2O also being formed. **(a)** If a mixture containing 33.0 g each of NH_4Cl and $Ca(OH)_2$ is heated, how many grams of NH_3 will form? **(b)** Which reactant remains in excess, and in what mass?

$$2NH_4Cl + Ca(OH)_2 \rightarrow 2NH_3 + CaCl_2 + 2H_2O$$

a)
Find limiting reactant

$$33.0\text{g } NH_4Cl \times \frac{1 \text{ mol } NH_4Cl}{53.50 \text{ g } NH_4Cl} \times \frac{2 \text{ mol } NH_3}{2 \text{ mol } NH_4Cl} \times \frac{17.04 \text{ g } NH_3}{1 \text{ mol } NH_3} = 10.5 \text{ g } NH_3$$

$$33.0\text{g } Ca(OH)_2 \times \frac{1 \text{ mol } Ca(OH)_2}{74.10 \text{ g } Ca(OH)_2} \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } Ca(OH)_2} \times \frac{17.04 \text{ g } NH_3}{1 \text{ mol } NH_3} = 15.2 \text{ g } NH_3$$

Therefore NH_4Cl is the limiting reactant and 10.5 g NH_3 can be made.

b)

$$10.5 \text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.04 \text{ g } NH_3} \times \frac{1 \text{ mol } Ca(OH)_2}{2 \text{ mol } NH_3} \times \frac{74.01 \text{ g } Ca(OH)_2}{1 \text{ mol } Ca(OH)_2} = 22.8 \text{ g } Ca(OH)_2$$

Therefore 22.8 g $Ca(OH)_2$ will be consumed and (33.0 – 22.8)g = 10.2 g $Ca(OH)_2$ will remain.

4. How many grams of acetic acid must be allowed to react with an excess of PCl_3 to produce 75 g of acetyl chloride (C_2H_3OCl), if the reaction has a 78.2% yield?

$$C_2H_4O_2 + PCl_3 \rightarrow C_2H_3OCl + H_3PO_3 \text{ (not balanced)}$$

We need the theoretical yield to do the calculation:

$$3C_2H_4O_2 + PCl_3 \rightarrow 3C_2H_3OCl + H_3PO_3$$

Theoretical yield = actual yield/0.782 = 75g/0.782 = 95.9 g

$$95.9\text{ g } C_2H_3OCl \times \frac{1\text{ mol } C_2H_3OCl}{78.50\text{ g } C_2H_3OCl} \times \frac{3\text{ mol } C_2H_4O_2}{3\text{ mol } C_2H_3OCl} \times \frac{60.06\text{ g } C_2H_4O_2}{1\text{ mol } C_2H_4O_2} = \mathbf{73.4\text{ g } C_2H_4O_2}$$

5. Azobenzene ($(C_6H_5N)_2$), an intermediate in the manufacture of dyes, can be prepared from nitrobenzene ($C_6H_5NO_2$) by reaction with triethylene glycol ($C_6H_{14}O_4$). In one reaction, 0.10 L of nitrobenzene *(d* = 1.20 g/mL) and 0.30 L of triethylene glycol *(d* = 1.12 g/mL) yields 55 g azobenzene. What are the (a) theoretical yield, (b) actual yield, and (c) percent yield of this reaction?

$$2\ C_6H_5NO_2 + 4\ C_6H_{14}O_4 \rightarrow (C_6H_5N)_2 + 4\ C_6H_{12}O_4 + 4\ H_2O$$

a)

$$100\text{ mL } C_6H_5NO_2 \times \frac{1.20\text{ g } C_6H_5NO_2}{1\text{ mL } C_6H_5NO_2} \times \frac{1\text{ mol } C_6H_5NO_2}{123.1\text{ g } C_6H_5NO_2} \times \frac{1\text{ mol } (C_6H_5N)_2}{2\text{ mol } C_6H_5NO_2} = 0.487\text{ mol } (C_6H_5N)_2$$

$$300\text{ mL } C_6H_{14}O_4 \times \frac{1.12\text{ g } C_6H_{14}O_4}{1\text{ mL } C_6H_{14}O_4} \times \frac{1\text{ mol } C_6H_{14}O_4}{150.2\text{ g } C_6H_{14}O_4} \times \frac{1\text{ mol } (C_6H_5N)_2}{4\text{ mol } C_6H_{14}O_4} = 0.559\text{ mol } (C_6H_5N)_2$$

So, $C_6H_5NO_2$ is our limiting reactant and our theoretical yield is:

$$0.487\text{ mol } (C_6H_5N)_2 \times \frac{182.26\text{g } (C_6H_5N)_2}{1\text{ mol } (C_6H_5N)_2} = \mathbf{88.8\text{ g } (C_6H_5N)_2}$$

b) The actual yield is **55 g**

c)

$$\%\text{ yield} = \frac{55\text{ g}}{89\text{ g}} \times 100\% = \mathbf{62\ \%\ yield}$$

6. Suppose that reactions (a) and (b) have a 92% yield. Starting with 112 g CH_4 in reaction (a) and an excess of Cl_2(g), how many grams of CH_2Cl_2 are formed in reaction (b)?
   (a) $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
   (b) $CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$

$$112\text{ g } CH_4 \times \frac{1\text{ mol } CH_4}{16.05\text{ g } CH_4} \times \frac{1\text{ mol } CH_3Cl}{1\text{ mol } CH_4} = 6.98\text{ mol } CH_3Cl$$

So, the theoretical yield of reaction (a) is 6.98 mol, but the% yield is 92%, so the actual yield is 6.98 mol x 0.92 = 6.42 mol CH_3Cl. This quantity continues to reaction (b)

$$6.42\text{ mol } CH_3Cl \times \frac{1\text{ mol } CH_2Cl_2}{1\text{ mol } CH_3Cl} \times \frac{84.93\text{ g } CH_2Cl_2}{1\text{ mol } CH_2Cl_2} = 545.2\text{ g } CH_2Cl_2$$

So, the theoretical yield of reaction (b) is 545.2 g CH_2Cl_2, but the% yield is 92%, so the actual yield is 545.2 g CH_2Cl_2 x 0.92 = **502 g CH_2Cl_2.**