Stoichiometry-Activity 3, Limiting Reagents KEY

1. Solid iron (III) oxide reacts with carbon monoxide gas to form iron solid and carbon dioxide gas. If 187 g of iron (III) oxide is allowed to react with 105.8 grams of carbon monoxide, how many grams of iron can be generated?

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3\,CO_2(g)$

$$Fe_2O_3: 187g\ Fe_2O_3 \times \frac{1\ mol\ Fe_2O_3}{159.7\ g\ Fe_2O_3} \times \frac{2\ mol\ Fe}{1\ mol\ Fe_2O_3} \times \frac{55.845\ g\ Fe}{1\ mol\ Fe} = 131\ g\ Fe$$

$$CO: 105.8\ CO \times \frac{1\ mol\ CO}{28.01\ g\ CO} \times \frac{2\ mol\ Fe}{3\ mol\ CO} \times \frac{55.845\ g\ Fe}{1\ mol\ Fe} = 140.6\ g\ Fe$$

Fe_2O_3 is the limiting reactant, so the maximum amount of Fe generated is 131 g Fe.

2. If only 99.0 g of iron is generated, what is the percent yield of iron?

$$\%\ yield = \frac{actual\ yield}{theoretical\ yield} \times 100 = \frac{99.0g\ Fe}{131g\ Fe} \times 100 = 75.6\%$$

3. The deep blue $Cu(NH_3)_4SO_4$ is made by the reaction of copper (II) sulfate with ammonia, as described by the following reaction:

$$CuSO_4(aq) + 4\ NH_3(aq) \rightarrow Cu(NH_3)_4SO_4(aq)$$

a) If you use 10.0g of ammonia and 20.0g of copper(II) sulfate, what is the theoretical yield for the reaction?

$$10.0\ g\ NH_3 \times \frac{1\ mol\ NH_3}{17.03\ g} \times \frac{1\ mol\ Cu(NH_3)_4SO_4}{4\ mol\ NH_3} \times \frac{227.756\ g\ Cu(NH_3)_4SO_4}{1\ mol} = 33.4\ g\ Cu(NH_3)_4SO_4$$

$$20.0\ g\ CuSO_4 \times \frac{1\ mol\ CuSO_4}{159.62\ g\ CuSO_4} \times \frac{1\ mol\ Cu(NH_3)_4SO_4}{1\ mol\ CuSO_4} \times \frac{227.756\ g\ Cu(NH_3)_4SO_4}{1\ mol} = 28.5\ g\ Cu(NH_3)_4SO_4$$

So, $CuSO_4$ is the limiting reagent and 28.5g of $Cu(NH_3)_4SO_4$ can be made.

b) If 18.6 g of $Cu(NH_3)_4SO_4$ is isolated at the end of the reaction, what is the percent yield for the reaction?

$$\%\ yield = \frac{actual\ yield}{theoretical\ (calculated)\ yield} \times 100\% = \frac{18.6g}{28.5g} \times 100\% = 65.3\%$$

4. Nitrogen gas can be prepared by passing gaseous ammonia over solid copper (II) oxide at high temperatures, as described by the following *balanced* equation.

$$2\ NH_3\ (g)\ +\ 3\ CuO\ (s) \rightarrow\ N_2\ (g)\ +\ 3\ Cu\ (s)\ +\ 3\ H_2O\ (g)$$

a) How many grams of N_2 are formed when 18.1 g of NH_3 are reacted with 90.4 g of CuO?

$$18.1\ g\ NH_3 \times \frac{1 mol}{17.03\ g NH_3} \times \frac{1\ mol\ N_2}{2\ mol\ NH_3} \times \frac{28.01\ g\ N_2}{1\ mol\ N_2} = 14.9\ g\ N_2$$

$$90.4\ g\ CuO \times \frac{1\ mol\ CuO}{79.55\ g\ CuO} \times \frac{1\ mol\ N_2}{3\ mol\ CuO} \times \frac{28.01\ g\ N_2}{1\ mol\ N_2} = 10.6\ g\ N_2 \leftarrow \text{Limiting Reagent!}$$

b) What starting material, if any is left over? How many grams of that material are left over?

$$10.6\ g\ N_2 \times \frac{1\ mole\ N_2}{28.02\ g\ N_2} \times \frac{2\ mole\ NH_3}{1\ mole\ N_2} \times \frac{17.03\ g\ NH_3}{1\ mole\ NH_3} = 12.9\ g\ NH_3 \text{used}$$

Thus, if 12.9 g of NH_3 is used, then 18.1g-12.9g = 5.2g NH_3 is left over.

5. Chlorine dioxide is used as a disinfectant and bleaching agent. In water, it reacts to form chloric acid ($HClO_3$), according to the following *balanced* equation:

$$6\ ClO_2\ +\ 3\ H_2O \rightarrow\ 5\ HClO_3\ +\ HCl$$

a) If 142.0 g of ClO_2 are mixed with 38.0 g of H_2O, how many grams of chloric acid are formed?

$$142.0\ g\ ClO_2 \times \frac{1\ mol\ ClO_2}{67.45\ g\ ClO_2} \times \frac{5\ mol\ HClO_3}{6\ mol\ ClO_2} \times \frac{84.46\ g\ HClO_3}{1\ mol\ HClO_3} = 148.1\ g\ HClO_3$$

$$38.0\ g\ H_2O \times \frac{1 mol\ H_2O}{18.01\ g\ H_2O} \times \frac{5\ mol\ HClO_3}{3\ mol\ H_2O} \times \frac{84.46\ g\ HClO_3}{1\ mol\ HClO_3} = 296\ g\ HClO_3$$

ClO_2 is the limiting reagent, so only 148.1 g can be formed.

b) What is the percent yield for the reaction if 120.2 g of chloric acid is actually produced?

$$\frac{120.2\ g}{148.1\ g} \times 100\% = 81.16\%$$