Stoichiometry Worksheet #1

1. Aluminum chloride, AlCl₃, is used as a catalyst in various industrial reactions. It is prepared from hydrogen chloride gas and aluminum metal shavings.
   \[ 2\text{Al}(s) + 6\text{HCl}(g) \rightarrow 2\text{AlCl}_3(s) + 3\text{H}_2(g) \]

   **A.** How many moles of AlCl₃ can be prepared from 3.5 moles of hydrogen chloride gas with an excess of aluminum?

   \[ 3.5 \text{ mol HCl} \times \frac{2 \text{ mol AlCl}_3}{6 \text{ mol HCl}} = 1.2 \text{ mol AlCl}_3 \]

   **Ans:** 1.2 mol AlCl₃

   **B.** How many moles of hydrogen gas would be produced from the use of 8.5 moles of aluminum with an excess of hydrogen chloride?

   **Ans:** 13 mol H₂

2. When dinitrogen pentoxide, N₂O₅, a white solid, is heated, it decomposes to nitrogen dioxide and oxygen.
   \[ 2\text{N}_2\text{O}_5(s) \xrightarrow{\Delta} 4\text{NO}_2(g) + \text{O}_2(g) \]

   **A.** How many moles of nitrogen dioxide can be formed from the decomposition of 1.25 g of N₂O₅?

   **Ans:** 0.0231 mol NO₂

   **B.** How many grams of oxygen can be formed from the decomposition of 2.3 g of N₂O₅?

   \[ \frac{2.3 \text{ g N}_2\text{O}_5}{108.02 \text{ g N}_2\text{O}_5} \times \frac{1 \text{ mol N}_2\text{O}_5}{2 \text{ mol N}_2\text{O}_5} \times \frac{1 \text{ mol O}_2}{2 \text{ mol N}_2\text{O}_5} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 0.34 \text{ g O}_2 \]

3. Chlorine is prepared from sodium chloride by electrochemical decomposition. Formerly chlorine was produced by heating hydrochloric acid with pyrolusite (manganese dioxide or manganese(IV) oxide, MnO₂), a common manganese ore. Small amounts of chlorine may be prepared in the laboratory by the same reaction.
   \[ 4\text{HCl}(aq) + \text{MnO}_2(s) \rightarrow 2\text{H}_2\text{O}(l) + \text{MnCl}_2(aq) + \text{Cl}_2(g) \]

   **A.** How many grams of HCl react with 5.00 g of MnO₂, according to the equation?

   \[ \frac{5.00 \text{ g MnO}_2}{86.94 \text{ g MnO}_2} \times \frac{1 \text{ mol MnO}_2}{1 \text{ mol MnO}_2} \times \frac{4 \text{ mol HCl}}{1 \text{ mol MnO}_2} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 8.39 \text{ g HCl} \]

   **B.** If a chemist wanted to prepare 100. g of chlorine, how many grams of MnO₂ are needed, assuming there is more than enough hydrochloric acid?

   \[ \frac{100. \text{ g Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{1 \text{ mol Cl}_2}{1 \text{ mol MnO}_2} \times \frac{1 \text{ mol MnO}_2}{1 \text{ mol Cl}_2} \times \frac{86.94 \text{ g MnO}_2}{1 \text{ mol MnO}_2} = 123 \text{ g MnO}_2 \]

   **C.** How many molecules of water are produced from the reaction of 5.0 g of HCl?

   **Ans:** 4.1 x 10²² molec H₂O

4. Sodium is a soft, reactive metal that instantly reacts with water to give hydrogen gas and a solution of sodium hydroxide, NaOH.

   \[ 2\text{Na} + 2\text{H}_2\text{O} \rightarrow \text{H}_2 + 2\text{NaOH} \]

   **A.** How many grams of sodium metal are needed to give 7.81 g of hydrogen by this reaction?

   \[ \frac{7.81 \text{ g H}_2}{1} \times \frac{1 \text{ mol H}_2}{2.02 \text{ g H}_2} \times \frac{2 \text{ mol Na}}{2 \text{ mol H}_2} \times \frac{22.993 \text{ g Na}}{1 \text{ mol Na}} = 178 \text{ g Na} \]

   **Ans:** 178 g Na

   **B.** How many sodium atoms are needed to react with 1.25 x 10²⁴ molecules of water?

   **Ans:** 1.25 x 10²⁴ atoms Na
5. Hematite, Fe₂O₃, is an important ore of iron. The free metal is obtained by reacting hematite with carbon monoxide in a blast furnace. Carbon monoxide if formed in the furnace by partial combustion of carbon.

Fe₂O₃(s) + 3CO(g) → 2Fe(s) + 3CO₂(g)

How many grams of iron can be produced from 1.00 kg Fe₂O₃?  
Ans: 699 g Fe

6. Sphalerite is a zinc sulfide (ZnS) mineral and an important commercial source of zinc metal. The first step in the processing of the ore consists of heating the sulfide with oxygen to give zinc oxide, ZnO, and sulfur dioxide, SO₂. How many kilograms of oxygen gas combine with 5.00 x 10³ g of zinc sulfide in this reaction?

\[
\frac{5.00 \times 10^3 \text{g ZnS}}{97.46 \text{g ZnS}} \times \frac{3 \text{mol O}_2}{2 \text{mol ZnS}} \times \frac{32.00 \text{g O}_2}{1 \text{mol O}_2} \times \frac{1 \text{kg O}_2}{1000 \text{g O}_2} = 2.46 \text{ kg O}_2
\]

7. The British chemist Joseph Priestley prepared oxygen in 1774 by heating mercury(II) oxide, HgO. Mercury metal is the other product. If 6.47 g of oxygen is collected, how many grams of mercury metal are also produced?  
Ans: 81.1 g Hg

8. In a process for producing acetic acid, oxygen gas is bubbles into acetaldehyde, CH₃CHO, containing manganese(II) acetate (catalyst) under pressure at 60°C. 

\[
2\text{CH}_3\text{CHO}(l) + \text{O}_2(g) \xrightarrow{\text{Mn(C}_2\text{H}_3\text{O}_2)_2(s)} 2\text{HC}_2\text{H}_3\text{O}_2(l)
\]

If 20.0 g of acetaldehyde is reacted with an excess of oxygen, how many grams of acetic acid can be produced?  
Ans: 27.3 g HC₂H₃O₂

9. Some industrial plants for acetic acid react liquid methanol with carbon monoxide in the presence of a catalyst, 

\[
\text{CH}_3\text{OH}(l) + \text{CO}(g) \rightarrow \text{HC}_2\text{H}_3\text{O}_2(l)
\]

3.23 x 10²⁵ molecules of methanol were placed in a reaction vessel with an excess of carbon monoxide. How many grams of acetic acid can be produced?  
Ans: 32.2 g HC₃H₅O₃

10. Titanium dioxide [titanium(IV) oxide] is used as the base powder for a variety of cosmetics. Say you decide to manufacture TiO₂ in a furnace by the reaction 

\[
\text{Ti(s)} + \text{O}_2(g) \rightarrow \text{TiO}_2(s)
\]

If a company wants to produce 3.0 kg of titanium dioxide, how many grams of titanium should be reacted?  
Ans: 1.8 x 10³ g Ti

Only 2 s.f. must be scientific notation

11. Tungsten metal, W, is used to make incandescent bulb filaments. The metal is produced from the yellow tungsten(VI) oxide, WO₃, by reaction with hydrogen. 

\[
\text{WO}_3(s) + 3\text{H}_2(g) \rightarrow \text{W}(s) + 3\text{H}_2\text{O}(g)
\]

How many grams of tungsten can be obtained from 1.4 x 10²⁷ molecules of hydrogen with excess tungsten(VI) oxide?  
Ans: 1.4 x 10⁶ g W

12. Potassium superoxide, K₂O₂, is used in breathing gas masks to regenerate oxygen. 

\[
4\text{K}_2\text{O}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow 4\text{KOH}(s) + 3\text{O}_2(g)
\]

If a reaction vessel contains 0.27 mol K₂O₂, how many molecules of oxygen will be produced?  
Ans: 1.1 x 10²³ molec. O₂