1. (a) # of O_2 molecules $= 6 \text{ molecules } C_2H_6 \times \frac{7 \text{ molecules } O_2}{2 \text{ molecules } C_2H_6}$ = **21 molecules**

   (b) # of H_2O molecules $= 12 \text{ molecules } C_2H_6 \times \frac{6 \text{ molecules } H_2O}{2 \text{ molecules } C_2H_6}$ = **36 molecules**

   (c) # of moles of $O_2 = 18 \text{ mol } CO_2 \times \frac{7 \text{ mol } O_2}{4 \text{ mol } CO_2}$ = **31.5 mol**

   (d) # of moles of $CO_2 = 13 \text{ mol } C_2H_6 \times \frac{4 \text{ mol } CO_2}{2 \text{ mol } C_2H_6}$ = **26 mol**

2. (a) # of molecules $Fe_3O_4 = 12 \text{ atoms Fe} \times \frac{1 \text{ molecule } Fe_3O_4}{3 \text{ atoms Fe}}$ = **4 molecules**

   (b) # of moles of Fe $= 16 \text{ mol } H_2 \times \frac{3 \text{ mol Fe}}{4 \text{ mol } H_2}$ = **12 mol**

   (c) # of molecules $H_2 = 40 \text{ molecules } Fe_3O_4 \times \frac{4 \text{ molecules } H_2}{1 \text{ molecule } Fe_3O_4}$ = **160 molecules**

   (d) # of moles of $H_2O = 14.5 \text{ mol Fe} \times \frac{4 \text{ mol } H_2O}{3 \text{ mol Fe}}$ = **19.3 mol**

3. # of moles of $H_2O = 9.6 \text{ mol } O_2 \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2}$ = **19 mol**

4. (a) # of moles of $I_4F_2 = 5.40 \text{ mol } F_2 \times \frac{1 \text{ mol } I_4F_2}{6 \text{ mol } F_2}$ = **0.900 mol**

   (b) # of moles of $F_2 = 4.50 \text{ mol } IF_5 \times \frac{6 \text{ mol } F_2}{2 \text{ mol } IF_5}$ = **13.5 mol**

   (c) # of moles of $I_2 = 7.60 \text{ mol } F_2 \times \frac{3 \text{ mol } I_2}{6 \text{ mol } F_2}$ = **3.80 mol**

5. Since 2 mol of reactants make a total of 3 mol of products, then O_2 represents $1/5$ of the total moles involved. Therefore:

   # of moles of $O_2 = \frac{0.125 \text{ mol}}{5}$ = **0.025 mol**

   Alternately: # of moles of $O_2 = 0.125 \text{ mol molecules} \times \frac{1 \text{ mol } O_2}{5 \text{ mol molecules}}$ = **0.025 mol**

6. (a) mass of NO $= 2.00 \text{ mol } NH_3 \times \frac{4 \text{ mol NO}}{4 \text{ mol } NH_3} \times \frac{30.0 \text{ g NO}}{1 \text{ mol NO}}$ = **60.0 g**

   (b) mass of $H_2O = 4.00 \text{ mol } O_2 \times \frac{6 \text{ mol } H_2O}{5 \text{ mol } O_2} \times \frac{18.0 \text{ g } H_2O}{1 \text{ mol } H_2O}$ = **86.4 g**

   (c) volume of $NH_3 = 3.00 \text{ mol } O_2 \times \frac{4 \text{ mol } NH_3}{5 \text{ mol } O_2} \times \frac{22.4 \text{ L } NH_3}{1 \text{ mol } NH_3}$ = **53.8 L**

   (d) volume of $NH_3 = 0.750 \text{ mol } H_2O \times \frac{4 \text{ mol } NH_3}{6 \text{ mol } H_2O} \times \frac{22.4 \text{ L } NH_3}{1 \text{ mol } NH_3}$ = **11.2 L**

7\. (a) mass of $CO_2 = 100.0\text{ g }C_5H_{12} \times \frac{1\text{ mol }C_5H_{12}}{72.0\text{ g }C_5H_{12}} \times \frac{5\text{ mol }CO_2}{1\text{ mol }C_5H_{12}} \times \frac{44.0\text{ g }CO_2}{1\text{ mol }CO_2} = \mathbf{306\ g}$

(b) mass of $O_2 = 60.0\text{ g }H_2O \times \frac{1\text{ mol }H_2O}{18.0\text{ g }H_2O} \times \frac{8\text{ mol }O_2}{6\text{ mol }H_2O} \times \frac{32.0\text{ g }O_2}{1\text{ mol }O_2} = \mathbf{142\ g}$

(c) mass of $C_5H_{12} = 90.0\text{ L }CO_2 \times \frac{1\text{ mol }CO_2}{22.4\text{ L }CO_2} \times \frac{1\text{ mol }C_5H_{12}}{5\text{ mol }CO_2} \times \frac{72.0\text{ g }C_5H_{12}}{1\text{ mol }C_5H_{12}} = \mathbf{57.9\ g}$

(d) volume of $O_2 = 70.0\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2} \times \frac{8\text{ mol }O_2}{5\text{ mol }CO_2} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} = \mathbf{57.0\ L}$

(e) volume of $O_2 = 48.0\text{ L }CO_2 \times \frac{1\text{ mol }CO_2}{22.4\text{ L }CO_2} \times \frac{8\text{ mol }O_2}{5\text{ mol }CO_2} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} = \mathbf{76.8\ L}$

(f) mass of $H_2O = 106\text{ L }CO_2 \times \frac{1\text{ mol }CO_2}{22.4\text{ L }CO_2} \times \frac{6\text{ mol }H_2O}{5\text{ mol }CO_2} \times \frac{18.0\text{ g }H_2O}{1\text{ mol }H_2O} = \mathbf{102\ g}$

8\. (a) volume of $O_2 = 100.0\text{ g PbO} \times \frac{1\text{ mol PbO}}{223.2\text{ g PbO}} \times \frac{27\text{ mol }O_2}{2\text{ mol PbO}} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} = \mathbf{135\ L}$

(b) # of molecules of $CO_2 = 1.00 \times 10^{-6}\text{ g Pb}(C_2H_5)_4 \times \frac{1\text{ mol Pb}(C_2H_5)_4}{323.2\text{ g Pb}(C_2H_5)_4} \times \frac{16\text{ mol }CO_2}{2\text{ mol Pb}(C_2H_5)_4}$

$\times \frac{6.02 \times 10^{23}\text{ molecules }CO_2}{1\text{ mol }CO_2} = \mathbf{1.49 \times 10^{16}\ molecules}$

(c) # of molecules of $H_2O = 135\text{ molecules }O_2 \times \frac{20\text{ molecules }H_2O}{27\text{ molecules }O_2} = \mathbf{100\ molecules}$

(d) volume of $O_2 = 1.00 \times 10^{15}\text{ molec Pb}(C_2H_5)_4 \times \frac{1\text{ mol Pb}(C_2H_5)_4}{6.02 \times 10^{23}\text{ molec Pb}(C_2H_5)_4} \times \frac{27\text{ mol }O_2}{2\text{ mol Pb}(C_2H_5)_4}$

$\times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} \times \frac{1\text{ mL}}{10^{-3}\text{ L}} = \mathbf{5.02 \times 10^{-4}\ mL}$

9\. (a) mass of $H_2O = 0.150\text{ g }CH_3NO_2 \times \frac{1\text{ mol }CH_3NO_2}{61.0\text{ g }CH_3NO_2} \times \frac{6\text{ mol }H_2O}{4\text{ mol }CH_3NO_2} \times \frac{18.0\text{ g }H_2O}{1\text{ mol }H_2O} = \mathbf{0.0664\ g}$

(b) First, note that 4 mol of CH_3NO_2 produce 4 mol $CO_2(g)$ and 2 mol $N_2(g)$; that is, 6 mol of gas.

volume of gas $= 0.316\text{ g }CH_3NO_2 \times \frac{1\text{ mol }CH_3NO_2}{61.0\text{ g }CH_3NO_2} \times \frac{6\text{ mol gas}}{4\text{ mol }CH_3NO_2} \times \frac{22.4\text{ L gas}}{1\text{ mol gas}} = \mathbf{0.174\ L}$

(c) volume of $O_2 = 0.250\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2} \times \frac{3\text{ mol }O_2}{4\text{ mol }CO_2} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} = \mathbf{0.0955\ L}$

(d) mass of $H_2O = 0.410\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2} \times \frac{6\text{ mol }H_2O}{4\text{ mol }CO_2} \times \frac{18.0\text{ g }H_2O}{1\text{ mol }H_2O} = \mathbf{0.252\ g}$

10\. mass of $SiCl_4 = 1.00\text{ g Si} \times \frac{1\text{ mol Si}}{28.1\text{ g Si}} \times \frac{1\text{ mol }SiCl_4}{1\text{ mol Si}} \times \frac{170.1\text{ g }SiCl_4}{1\text{ mol }SiCl_4} = \mathbf{6.05\ g}$

mass of $H_2 = 1.00\text{ g Si} \times \frac{1\text{ mol Si}}{28.1\text{ g Si}} \times \frac{2\text{ mol }H_2}{1\text{ mol Si}} \times \frac{2.0\text{ g }H_2}{1\text{ mol }H_2} = \mathbf{0.14\ g}$

11\. volume of $NH_3 = 1.25 \times 10^4\text{ kg }N_2H_4 \times \frac{10^3\text{ g }N_2H_4}{1\text{ kg }N_2H_4} \times \frac{1\text{ mol }N_2H_4}{32.0\text{ g }N_2H_4} \times \frac{2\text{ mol }NH_3}{1\text{ mol }N_2H_4} \times \frac{22.4\text{ L }NH_3}{1\text{ mol }NH_3}$

$= \mathbf{1.75 \times 10^7\ L}$

12\. mass of $H_2SO_4 = 25.0\text{ mL} \times 1.84\frac{\text{g}}{\text{mL}} = 46.0\text{ g}$

mass of $P_4O_{10} = 46.0\text{ g }H_2SO_4 \times \frac{1\text{ mol }H_2SO_4}{98.1\text{ g }H_2SO_4} \times \frac{1\text{ mol }P_4O_{10}}{6\text{ mol }H_2SO_4} \times \frac{284.0\text{ g }P_4O_{10}}{1\text{ mol }P_4O_{10}} = \mathbf{22.2\ g}$

volume of $SO_3 = 46.0\text{ g }H_2SO_4 \times \frac{1\text{ mol }H_2SO_4}{98.1\text{ g }H_2SO_4} \times \frac{6\text{ mol }SO_3}{6\text{ mol }H_2SO_4} \times \frac{22.4\text{ L }SO_3}{1\text{ mol }SO_3} = \mathbf{10.5\ L}$

18\. The neutralization equation is: $HCl + NaOH \longrightarrow NaCl + H_2O$.

moles of NaOH $= 0.318\frac{\text{mol}}{\text{L}} \times 0.0250\text{ L} = 7.95 \times 10^{-3}$ mol = moles HCl

volume of HCl $= \frac{n}{c} = \frac{0.00795\text{ mol}}{0.250\text{ mol/L}} = \mathbf{0.0318\ L\ (31.8\ mL)}$

26. mass of CS_2 (based on C) = $17.5\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} \times \frac{1\ mol\ CS_2}{5\ mol\ C} \times \frac{76.2\ g\ CS_2}{1\ mol\ CS_2} = 22.2\ g$

mass of CS_2 (based on SO_2) = $39.5\ g\ SO_2 \times \frac{1\ mol\ SO_2}{64.1\ g\ SO_2} \times \frac{1\ mol\ CS_2}{2\ mol\ SO_2} \times \frac{76.2\ g\ CS_2}{1\ mol\ CS_2} = 23.5\ g$

Since C produces the least amount of CS_2, then the mass of CS_2 produced is **22.2 g.** The SO_2 is present in excess, so the mass of SO_2 used can be calculated arbitrarily based on the mass of C.

mass of SO_2 used = $17.5\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} \times \frac{2\ mol\ SO_2}{5\ mol\ C} \times \frac{64.1\ g\ SO_2}{1\ mol\ SO_2} = 37.4\ g$

mass of SO_2 in excess = 39.5 – 37.4 = **2.1 g**

27. mass of NO (based on Cu) = $87.0\ g\ Cu \times \frac{1\ mol\ Cu}{63.5\ g\ Cu} \times \frac{2\ mol\ NO}{3\ mol\ Cu} \times \frac{30.0\ g\ NO}{1\ mol\ NO} = 27.4\ g$

mass of NO (based on HNO_3) = $225\ g\ HNO_3 \times \frac{1\ mol\ HNO_3}{63.0\ g\ HNO_3} \times \frac{2\ mol\ NO}{8\ mol\ HNO_3} \times \frac{30.0\ g\ NO}{1\ mol\ NO} = 26.8\ g$

Since HNO_3 produces the least amount of NO, then the mass of NO produced is **26.8 g.**
Now find the mass of Cu in excess, based on the amount of HNO_3 used.

mass of Cu used = $225\ g\ HNO_3 \times \frac{1\ mol\ HNO_3}{63.0\ g\ HNO_3} \times \frac{3\ mol\ Cu}{8\ mol\ HNO_3} \times \frac{63.5\ g\ Cu}{1\ mol\ Cu} = 85.0\ g$

mass of Cu in excess = 87.0 – 85.0 = **2.0 g**

28. mass of P_4 [based on $Ca_3(PO_4)_2$] = $41.5\ g\ Ca_3(PO_4)_2 \times \frac{1\ mol\ Ca_3(PO_4)_2}{310.3\ g\ Ca_3(PO_4)_2} \times \frac{1\ mol\ P_4}{2\ mol\ Ca_3(PO_4)_2}$

$\times \frac{124.0\ g\ P_4}{1\ mol\ P_4} = 8.29\ g$

mass of P_4 (based on SiO_2) = $26.5\ g\ SiO_2 \times \frac{1\ mol\ SiO_2}{60.1\ g\ SiO_2} \times \frac{1\ mol\ P_4}{6\ mol\ SiO_2} \times \frac{124.0\ g\ P_4}{1\ mol\ P_4} = 9.11\ g$

mass of P_4 (based on C) = $7.80\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} \times \frac{1\ mol\ P_4}{10\ mol\ C} \times \frac{124.0\ g\ P_4}{1\ mol\ P_4} = 8.06\ g$

Since C produces the least amount of P_4, then the mass of P_4 produced is **8.06 g.**
Next, calculate the masses of both $Ca_3(PO_4)_2$ and SiO_2 used by the C:

mass of $Ca_3(PO_4)_2$ used = $7.80\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} \times \frac{2\ mol\ Ca_3(PO_4)_2}{10\ mol\ C} \times \frac{310.3\ g\ Ca_3(PO_4)_2}{1\ mol\ Ca_3(PO_4)_2} = 40.3\ g$

mass of $Ca_3(PO_4)_2$ in excess = 41.5 – 40.3 = **1.2 g**

mass of SiO_2 used = $7.80\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} \times \frac{6\ mol\ SiO_2}{10\ mol\ C} \times \frac{60.1\ g\ SiO_2}{1\ mol\ SiO_2} = 23.4\ g$

mass of SiO_2 in excess = 26.5 – 23.4 = **3.1 g**

29. mass of Br_2 (based on $K_2Cr_2O_7$) = $25.0\ g\ K_2Cr_2O_7 \times \frac{1\ mol\ K_2Cr_2O_7}{294.2\ g\ K_2Cr_2O_7} \times \frac{3\ mol\ Br_2}{1\ mol\ K_2Cr_2O_7} \times \frac{159.8\ g\ Br_2}{1\ mol\ Br_2}$

= 40.7 g

mass of Br_2 (based on KBr) = $55.0\ g\ KBr \times \frac{1\ mol\ KBr}{119.0\ g\ KBr} \times \frac{3\ mol\ Br_2}{6\ mol\ KBr} \times \frac{159.8\ g\ Br_2}{1\ mol\ Br_2} = 36.9\ g$

mass of Br_2 (based on H_2SO_4) = $60.0\ g\ H_2SO_4 \times \frac{1\ mol\ H_2SO_4}{98.1\ g\ H_2SO_4} \times \frac{3\ mol\ Br_2}{7\ mol\ H_2SO_4} \times \frac{159.8\ g\ Br_2}{1\ mol\ Br_2}$

= 41.9 g

KBr is the limiting reactant (it produces the least amount of Br_2). $K_2Cr_2O_7$ and H_2SO_4 are in excess. Calculate the mass of $K_2Cr_2O_7$ and H_2SO_4 present in excess, arbitrarily based on the mass of KBr.

mass of $K_2Cr_2O_7$ used = $55.0\ g\ KBr \times \frac{1\ mol\ KBr}{119.0\ g\ KBr} \times \frac{1\ mol\ K_2Cr_2O_7}{6\ mol\ KBr} \times \frac{294.2\ g\ K_2Cr_2O_7}{1\ mol\ K_2Cr_2O_7} = 22.7\ g$

mass of $K_2Cr_2O_7$ in excess = 25.0 – 22.7 = **2.3 g**

mass of H_2SO_4 used = $55.0\ g\ KBr \times \frac{1\ mol\ KBr}{119.0\ g\ KBr} \times \frac{7\ mol\ H_2SO_4}{6\ mol\ KBr} \times \frac{98.1\ g\ H_2SO_4}{1\ mol\ H_2SO_4} = 52.9\ g$

mass of H_2SO_4 in excess = 60.0 – 52.9 = **7.1 g**

30. volume of CO_2 (based on C_5H_{12}) $= 0.0250\ L\ C_5H_{12} \times \frac{626.0\ g\ C_5H_{12}}{1\ L\ C_5H_{12}} \times \frac{1\ mol\ C_5H_{12}}{72.0\ g\ C_5H_{12}} \times \frac{5\ mol\ CO_2}{1\ mol\ C_5H_{12}}$

$\times \frac{22.4\ L\ CO_2}{1\ mol\ CO_2} = 24.3\ L$

volume of CO_2 (based on O_2) $= 40.0\ L\ O_2 \times \frac{1\ mol\ O_2}{22.4\ L\ O_2} \times \frac{5\ mol\ CO_2}{8\ mol\ O_2} \times \frac{22.4\ L\ CO_2}{1\ mol\ CO_2} = 25.0\ L$

Hence, the C_5H_{12} is the limiting reactant and **24.3 L** of $CO_2(g)$ will be produced.

31. moles of HCl $= 0.100\ \frac{mol}{L} \times 0.0500\ L = 5.00 \times 10^{-3}\ mol$

moles of NaCl (based on HCl) $= 5.00 \times 10^{-3}\ mol\ HCl \times \frac{1\ mol\ NaCl}{1\ mol\ HCl} = 5.00 \times 10^{-3}\ mol$

moles of NaOH $= 0.200\ \frac{mol}{L} \times 0.0300\ L = 6.00 \times 10^{-3}\ mol$

moles of NaCl (based on NaOH) $= 6.00 \times 10^{-3}\ mol\ NaOH \times \frac{1\ mol\ NaCl}{1\ mol\ NaOH} = 6.00 \times 10^{-3}\ mol$

Since the NaOH can produce more NaCl, the **NaOH** is in excess.

32. mass of $BaBr_2$ [based on $Ba(OH)_2$] $= 0.250\ g\ Ba(OH)_2 \times \frac{1\ mol\ Ba(OH)_2}{171.3\ g\ Ba(OH)_2} \times \frac{1\ mol\ BaBr_2}{1\ mol\ Ba(OH)_2}$

$\times \frac{297.1\ g\ BaBr_2}{1\ mol\ BaBr_2} = 0.434\ g$

moles of HBr $= 0.125\ \frac{mol}{L} \times 0.0150\ L = 1.875 \times 10^{-3}\ mol$

mass of $BaBr_2$ (based on HBr) $= 1.875 \times 10^{-3}\ mol\ HBr \times \frac{1\ mol\ BaBr_2}{2\ mol\ HBr} \times \frac{297.1\ g\ BaBr_2}{1\ mol\ BaBr_2} = 0.279\ g$

Since HBr is the limiting reactant, **0.279 g** of $BaBr_2$ can be formed.