1. (a) # of O₂ molecules = 6 molecules C₂H₆ x \( \frac{7 \text{ mol O}_2}{2 \text{ mol C}_2\text{H}_6} \) = \( 21 \) molecules

(b) # of H₂O molecules = 12 molecules C₂H₆ x \( \frac{6 \text{ mol H}_2\text{O}}{2 \text{ mol C}_2\text{H}_6} \) = \( 36 \) molecules

(c) # of moles of O₂ = 18 mol CO₂ x \( \frac{7 \text{ mol O}_2}{4 \text{ mol CO}_2} \) = \( 31.5 \) mol

(d) # of moles of CO₂ = 13 mol C₂H₆ x \( \frac{4 \text{ mol CO}_2}{2 \text{ mol C}_2\text{H}_6} \) = \( 26 \) mol

2. (a) # of molecules Fe₃O₄ = 12 atoms Fe x \( \frac{1 \text{ molecule Fe}_3\text{O}_4}{3 \text{ atoms Fe}} \) = \( 4 \) molecules

(b) # of moles of Fe = 16 mol H₂ x \( \frac{3 \text{ mol Fe}}{4 \text{ mol H}_2} \) = \( 12 \) mol

(c) # of molecules H₂ = 40 molecules Fe₃O₄ x \( \frac{4 \text{ molecules H}_2}{1 \text{ molecule Fe}_3\text{O}_4} \) = \( 160 \) molecules

(d) # of moles of H₂O = 14.5 mol Fe x \( \frac{4 \text{ mol H}_2\text{O}}{3 \text{ mol Fe}} \) = \( 19.3 \) mol

3. # of moles of H₂O = 9.6 mol O₂ x \( \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol O}_2} \) = \( 19 \) mol

4. (a) # of moles of I₂F₂ = 5.40 mol F₂ x \( \frac{1 \text{ mol I}_2\text{F}_2}{6 \text{ mol F}_2} \) = \( 0.900 \) mol

(b) # of moles of F₂ = 4.50 mol I₂F₅ x \( \frac{6 \text{ mol F}_2}{2 \text{ mol I}_2\text{F}_5} \) = \( 13.5 \) mol

(c) # of moles of I₂ = 7.60 mol F₂ x \( \frac{3 \text{ mol I}_2}{6 \text{ mol F}_2} \) = \( 3.80 \) mol

5. Since 2 mol of reactants make a total of 3 mol of products, then O₂ represents \( \frac{1}{5} \) of the total moles involved. Therefore:

\[
\text{# of moles of O}_2 = \frac{0.125 \text{ mol NO}}{5} = 0.025 \text{ mol}
\]

Alternatively:

\[
\text{# of moles of O}_2 = 0.125 \text{ mol molecules} x \frac{1 \text{ mol O}_2}{5 \text{ mol molecules}} = 0.025 \text{ mol}
\]

6. (a) mass of NO = 2.00 mol NH₃ x \( \frac{4 \text{ mol NO}}{4 \text{ mol NH}_3} \) x \( \frac{30.0 \text{ g NO}}{1 \text{ mol NO}} \) = \( 60.0 \) g

(b) mass of H₂O = 4.00 mol O₂ x \( \frac{6 \text{ mol H}_2\text{O}}{5 \text{ mol O}_2} \) x \( \frac{18.0 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} \) = \( 86.4 \) g

(c) volume of NH₃ = 3.00 mol O₂ x \( \frac{4 \text{ mol NH}_3}{5 \text{ mol O}_2} \) x \( \frac{22.4 \text{ L NH}_3}{1 \text{ mol NH}_3} \) = \( 53.8 \) L

(d) volume of NH₃ = 0.750 mol H₂O x \( \frac{4 \text{ mol NH}_3}{6 \text{ mol H}_2\text{O}} \) x \( \frac{22.4 \text{ L NH}_3}{1 \text{ mol NH}_3} \) = \( 11.2 \) L
7. (a) mass of CO₂ = \(100.0 \text{g C}_3\text{H}_12 \times \frac{1 \text{ mol C}_3\text{H}_12}{72.0 \text{g C}_3\text{H}_12} \times \frac{5 \text{ mol CO}_2}{1 \text{ mol C}_3\text{H}_12} \times \frac{44.0 \text{g CO}_2}{1 \text{ mol CO}_2} = 306 \text{ g}
\)

(b) mass of O₂ = \(60.0 \text{g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.0 \text{g H}_2\text{O}} \times \frac{8 \text{ mol O}_2}{2 \text{ mol H}_2\text{O}} \times \frac{32.0 \text{g O}_2}{1 \text{ mol O}_2} = 142 \text{ g}
\)

(c) mass of C₃H₁₂ = \(90.0 \text{L CO}_2 \times \frac{1 \text{ mol CO}_2}{22.4 \text{L CO}_2} \times \frac{1 \text{ mol C}_3\text{H}_12}{1 \text{ mol CO}_2} \times \frac{72.0 \text{g C}_3\text{H}_12}{1 \text{ mol C}_3\text{H}_12} = 57.9 \text{ g}
\)

(d) volume of O₂ = \(70.0 \text{g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.0 \text{g CO}_2} \times \frac{8 \text{ mol O}_2}{5 \text{ mol CO}_2} \times \frac{22.4 \text{L O}_2}{1 \text{ mol O}_2} = 57.0 \text{ L}
\)

(e) volume of O₂ = \(48.0 \text{L CO}_2 \times \frac{1 \text{ mol CO}_2}{22.4 \text{L CO}_2} \times \frac{8 \text{ mol O}_2}{5 \text{ mol CO}_2} \times \frac{22.4 \text{L O}_2}{1 \text{ mol O}_2} = 76.8 \text{ L}
\)

(f) mass of H₂O = \(106 \text{L CO}_2 \times \frac{1 \text{ mol CO}_2}{22.4 \text{L CO}_2} \times \frac{6 \text{ mol H}_2\text{O}}{5 \text{ mol CO}_2} \times \frac{18.0 \text{g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 102 \text{ g}
\)

8. (a) volume of O₂ = \(100.0 \text{g PbO} \times \frac{1 \text{ mol PbO}}{223.2 \text{g PbO}} \times \frac{27 \text{ mol O}_2}{2 \text{ mol PbO}} \times \frac{22.4 \text{L O}_2}{1 \text{ mol O}_2} = 135 \text{ L}
\)

(b) \# of molecules of CO₂ = \(1.00 \times 10^6 \text{g Pb(C}_2\text{H}_4)_4 \times \frac{1 \text{ mol Pb(C}_2\text{H}_4)_4}{323.2 \text{g Pb(C}_2\text{H}_4)_4} \times \frac{16 \text{ mol CO}_2}{2 \text{ mol Pb(C}_2\text{H}_4)_4} \times \frac{1.49 \times 10^{16} \text{molecules CO}_2}{1 \text{ mol CO}_2} = 100 \text{ molecules}
\)

(c) \# of molecules of H₂O = \(135 \text{L O}_2 \times \frac{27 \text{ mol O}_2}{1 \text{ mol O}_2} \times \frac{6 \text{ mol H}_2\text{O}}{5 \text{ mol CO}_2} \times \frac{18.0 \text{g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 5.02 \times 10^{-4} \text{ mL}
\)

9. (a) mass of H₂O = \(0.150 \text{g CH}_3\text{NO}_2 \times \frac{1 \text{ mol CH}_3\text{NO}_2}{61.0 \text{g CH}_3\text{NO}_2} \times \frac{6 \text{ mol H}_2\text{O}}{4 \text{ mol CH}_3\text{NO}_2} \times \frac{18.0 \text{g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.0664 \text{ g}
\)

(b) First, note that 4 mol of CH₃NO₂ produce 4 mol CO₂(g) and 2 mol N₂(g); that is, 6 mol of gas.

\[
\text{volume of gas} = 0.316 \text{g CH}_3\text{NO}_2 \times \frac{1 \text{ mol CH}_3\text{NO}_2}{61.0 \text{g CH}_3\text{NO}_2} \times \frac{4 \text{ mol gas}}{3 \text{ mol CH}_3\text{NO}_2} \times \frac{22.4 \text{ L gas}}{1 \text{ mol gas}} = 0.174 \text{ L}
\]

(c) \[
\text{volume of O}_2 = 0.250 \text{g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.0 \text{g CO}_2} \times \frac{3 \text{ mol O}_2}{4 \text{ mol CO}_2} \times \frac{22.4 \text{L O}_2}{1 \text{ mol O}_2} = 0.0955 \text{ L}
\]

(d) mass of H₂O = \(0.410 \text{g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.0 \text{g CO}_2} \times \frac{6 \text{ mol H}_2\text{O}}{4 \text{ mol CO}_2} \times \frac{18.0 \text{g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.252 \text{ g}
\)

10. mass of SiCl₄ = \(1.00 \text{g Si} \times \frac{1 \text{ mol Si}}{28.1 \text{g Si}} \times \frac{1 \text{ mol SiCl}_4}{1 \text{ mol Si}} = 6.05 \text{ g}
\)

mass of H₂ = \(1.00 \text{g Si} \times \frac{1 \text{ mol Si}}{28.1 \text{g Si}} \times \frac{2 \text{ mol H}_2}{1 \text{ mol Si}} = 0.14 \text{ g}
\)

11. volume of NH₃ = \(1.25 \times 10^4 \text{kg} \times \frac{10^3 \text{g N}_2\text{H}_4}{1 \text{ mol N}_2\text{H}_4} \times \frac{1 \text{ mol N}_2\text{H}_4}{1 \text{ kg N}_2\text{H}_4} \times \frac{32.0 \text{g N}_2\text{H}_4}{1 \text{ mol N}_2\text{H}_4} \times \frac{2 \text{ mol NH}_3}{1 \text{ mol N}_2\text{H}_4} \times \frac{22.4 \text{L NH}_3}{1 \text{ mol NH}_3} = 1.75 \times 10^7 \text{ L}
\)

12. mass of H₂SO₄ = \(25.0 \text{ mL} \times \frac{1.84 \text{g mL}^{-1}}{1 \text{ mL}} = 46.0 \text{ g}
\)

mass of P₂O₁₀ = \(46.0 \text{g H}_2\text{SO}_4 \times \frac{1 \text{ mol H}_2\text{SO}_4}{98.1 \text{g H}_2\text{SO}_4} \times \frac{1 \text{ mol P}_2\text{O}_{10}}{6 \text{ mol H}_2\text{SO}_4} \times \frac{284.0 \text{g P}_2\text{O}_{10}}{1 \text{ mol P}_2\text{O}_{10}} = 22.2 \text{ g}
\)

volume of SO₃ = \(46.0 \text{g H}_2\text{SO}_4 \times \frac{1 \text{ mol H}_2\text{SO}_4}{98.1 \text{g H}_2\text{SO}_4} \times \frac{6 \text{ mol SO}_3}{6 \text{ mol H}_2\text{SO}_4} \times \frac{22.4 \text{L SO}_3}{1 \text{ mol SO}_3} = 10.5 \text{ L}
\)

18. The neutralization equation is: HCl + NaOH \(\rightarrow\) NaCl + H₂O.

moles of NaOH = \(0.318 \text{ mol} \times 0.250 \text{ L} = 7.95 \times 10^{-3} \text{ mol} = \text{moles HCl}
\)

volume of HCl = \(\frac{n}{c} = \frac{0.00795 \text{ mol}}{0.250 \text{ mol/L}} = 0.0318 \text{ L (31.8 mL)}
\)
26. mass of $\text{CS}_2$ (based on C) = $17.5 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} \times \frac{1 \text{ mol } \text{CS}_2}{5 \text{ mol C}} \times \frac{76.2 \text{ g } \text{CS}_2}{1 \text{ mol } \text{CS}_2} = 22.2 \text{ g}$

mass of $\text{CS}_2$ (based on SO$_2$) = $39.5 \text{ g SO}_2 \times \frac{1 \text{ mol SO}_2}{64.1 \text{ g SO}_2} \times \frac{1 \text{ mol } \text{CS}_2}{2 \text{ mol SO}_2} \times \frac{76.2 \text{ g } \text{CS}_2}{1 \text{ mol } \text{CS}_2} = 23.5 \text{ g}$

Since C produces the least amount of $\text{CS}_2$, then the mass of $\text{CS}_2$ 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 = $17.5 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} \times \frac{2 \text{ mol SO}_2}{5 \text{ mol C}} \times \frac{64.1 \text{ g } \text{SO}_2}{1 \text{ mol SO}_2} = 37.4 \text{ g}$

mass of SO$_2$ in excess = 39.5 - 37.4 = 2.1 g

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

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

Since HONO 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 HONO used.

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

mass of Cu in excess = 87.0 - 85.0 = 2.0 g

28. mass of $P_4$ [based on Ca$_3$(PO$_4$)$_2$] = $41.5 \text{ g Ca}_3(\text{PO}_4)_2 \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{310.3 \text{ g Ca}_3(\text{PO}_4)_2} \times \frac{1 \text{ mol } P_4}{2 \text{ mol Ca}_3(\text{PO}_4)_2} \times \frac{124.0 \text{ g } P_4}{1 \text{ mol } P_4} = 8.29 \text{ g}$

mass of $P_4$ (based on SiO$_2$) = $26.5 \text{ g SiO}_2 \times \frac{1 \text{ mol SiO}_2}{60.1 \text{ g SiO}_2} \times \frac{1 \text{ mol } P_4}{6 \text{ mol SiO}_2} \times \frac{124.0 \text{ g } P_4}{1 \text{ mol } P_4} = 9.11 \text{ g}$

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

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 = $7.80 \text{ g C} \times \frac{1 \text{ mol } P_4}{12.0 \text{ g C}} \times \frac{2 \text{ mol Ca}_3(\text{PO}_4)_2}{10 \text{ mol C}} \times \frac{310.3 \text{ g Ca}_3(\text{PO}_4)_2}{1 \text{ mol Ca}_3(\text{PO}_4)_2} = 40.3 \text{ g}$

mass of Ca$_3$(PO$_4$)$_2$ in excess = 41.5 - 40.3 = 1.2 g

mass of SiO$_2$ used = $7.80 \text{ g C} \times \frac{1 \text{ mol } P_4}{12.0 \text{ g C}} \times \frac{6 \text{ mol SiO}_2}{10 \text{ mol C}} \times \frac{60.1 \text{ g SiO}_2}{1 \text{ mol SiO}_2} = 23.4 \text{ g}$

mass of SiO$_2$ in excess = 26.5 - 23.4 = 3.1 g

29. mass of Br$_2$ (based on K$_2$Cr$_2$O$_7$) = $25.0 \text{ g K}_2\text{Cr}_2\text{O}_7 \times \frac{1 \text{ mol K}_2\text{Cr}_2\text{O}_7}{294.2 \text{ g K}_2\text{Cr}_2\text{O}_7} \times \frac{3 \text{ mol Br}_2}{1 \text{ mol K}_2\text{Cr}_2\text{O}_7} \times \frac{159.8 \text{ g Br}_2}{1 \text{ mol Br}_2} = 40.7 \text{ g}$

mass of Br$_2$ (based on KBr) = $55.0 \text{ g KBr} \times \frac{1 \text{ mol KBr}}{119.0 \text{ g KBr}} \times \frac{3 \text{ mol Br}_2}{6 \text{ mol KBr}} \times \frac{159.8 \text{ g Br}_2}{1 \text{ mol Br}_2} = 36.9 \text{ g}$

mass of Br$_2$ (based on H$_2$SO$_4$) = $60.0 \text{ g H}_2\text{SO}_4 \times \frac{1 \text{ mol H}_2\text{SO}_4}{98.1 \text{ g H}_2\text{SO}_4} \times \frac{3 \text{ mol Br}_2}{7 \text{ mol H}_2\text{SO}_4} \times \frac{159.8 \text{ g Br}_2}{1 \text{ mol Br}_2} = 41.9 \text{ g}$

KBr is the limiting reactant (it produces the least amount of Br$_2$). K$_2$Cr$_2$O$_7$ and H$_2$SO$_4$ are in excess. Calculate the mass of K$_2$Cr$_2$O$_7$ and H$_2$SO$_4$ present in excess, arbitrarily based on the mass of KBr.

mass of K$_2$Cr$_2$O$_7$ used = $55.0 \text{ g KBr} \times \frac{1 \text{ mol K}_2\text{Cr}_2\text{O}_7}{119.0 \text{ g KBr}} \times \frac{1 \text{ mol K}_2\text{Cr}_2\text{O}_7}{6 \text{ mol KBr}} \times \frac{294.2 \text{ g K}_2\text{Cr}_2\text{O}_7}{1 \text{ mol K}_2\text{Cr}_2\text{O}_7} = 22.7 \text{ g}$

mass of K$_2$Cr$_2$O$_7$ in excess = 25.0 - 22.7 = 2.3 g

mass of H$_2$SO$_4$ used = $55.0 \text{ g KBr} \times \frac{7 \text{ mol H}_2\text{SO}_4}{6 \text{ mol KBr}} \times \frac{98.1 \text{ g H}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4} = 52.9 \text{ g}$

mass of H$_2$SO$_4$ in excess = 60.0 - 52.9 = 7.1 g
30. volume of CO₂ (based on C₂H₂) = 0.0250 L C₂H₂ x \( \frac{62.58 \text{ g} \text{ C₂H₂}}{1 \text{ mol} \text{ C₂H₂}} \times \frac{1 \text{ mol} \text{ C₂H₂}}{5 \text{ mol} \text{ CO₂}} \times \frac{22.4 \text{ L} \text{ CO₂}}{1 \text{ mol} \text{ CO₂}} = 24.3 \text{ L} \)

volume of CO₂ (based on O₂) = \( \frac{40.0 \text{ L} \text{ O₂} \times \frac{1 \text{ mol} \text{ O₂}}{22.4 \text{ L} \text{ O₂}} \times \frac{5 \text{ mol} \text{ CO₂}}{1 \text{ mol} \text{ CO₂}}}{8 \text{ mol} \text{ O₂}} = 25.0 \text{ L} \)

Hence, the C₂H₂ is the limiting reactant and 24.3 L of CO₂(g) will be produced.

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

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

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

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

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

32. mass of BaBr₂ (based on Ba(OH)₂) = 0.250 g Ba(OH)₂ \( \times \frac{1 \text{ mol} \text{ Ba(OH)}₂}{171.3 \text{ g} \text{ Ba(OH)}₂} \times \frac{1 \text{ mol} \text{ BaBr₂}}{297.1 \text{ g} \text{ BaBr₂}} = 0.0434 \text{ g} \)

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

mass of BaBr₂ (based on HBr) = 1.875 \( \times 10^{-3} \text{ mol} \text{ HBr} \times \frac{1 \text{ mol} \text{ BaBr₂}}{2 \text{ mol} \text{ HBr}} \times \frac{297.1 \text{ g} \text{ BaBr₂}}{1 \text{ mol} \text{ BaBr₂}} = 0.279 \text{ g} \)

Since HBr is the limiting reactant, 0.279 g of BaBr₂ can be formed.

\[ \text{KClO}_4 \rightarrow 2\text{O}_2 + \text{KCl} \]

actual yield = 1.45 g

theo yield = 5.95 g \( \text{KClO}_4 \times \frac{1 \text{ mol} \text{ KClO}_4}{122.55 \text{ g} \text{ KClO}_4} \times \frac{2 \text{ O}_2}{1 \text{ KClO}_4} \times \frac{32.00 \text{ g} \text{ O}_2}{1 \text{ mol} \text{ O}_2} = 3.11 \text{ g} \text{ O}_2 \)

\[ \% \text{ Yield} = \frac{1.45 \text{ g}}{3.11 \text{ g}} \times 100\% = 46.6\% \]

34.

\[ 4\text{FeCO}_3 + \text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + 4\text{CO}_2 \]

percent purity = 62.8%

\[ \% \text{ Purity} = \frac{\text{pure}}{\text{impure}} \times 100\% \]

\[ \text{impure} = \frac{\text{pure}}{\% \text{ purity}} \times 100\% = 2.31 \times 10^3 \text{ g} \text{ FeCO}_3 \]

36. Theoretical yield: 56.9 g Cu

Percentage Yield: 75.6%

37, 83.5%
38. 82.4%
39. 92.7%
40. 74.9%