

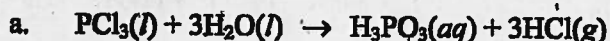
## CHAPTER 9

# Chemical Quantities

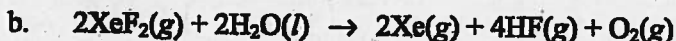
### CHAPTER ANSWERS

1. The coefficients of the balanced chemical equation for a reaction give the *relative numbers of molecules* of reactants and products that are involved in the reaction.
2. The coefficients of the balanced chemical equation for a reaction indicate the *relative numbers of moles* of each reactant that combine during the process as well as the number of moles of each product formed.
3. Although we define mass as the "amount of matter in a substance," the *units* in which we measure mass are a human invention. Atoms and molecules react on an individual particle-by-particle basis, and we have to count individual particles when doing chemical calculations.
4. Balanced chemical equations tell us in what molar ratios substances combine to form products; not, in what mass proportions they combine.

5.



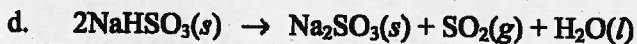
One molecule of liquid phosphorus trichloride reacts with three molecules of liquid water, producing one molecule of aqueous phosphorous acid and three molecules of gaseous hydrogen chloride. One mole of phosphorus trichloride reacts with three moles of water to produce one mole of phosphorous acid and three moles of hydrogen chloride.



Two molecules of gaseous xenon difluoride react with two molecules of liquid water, producing two gaseous xenon atoms, four molecules of gaseous hydrogen fluoride, and one molecule of oxygen gas. Two moles of xenon difluoride react with two moles of water to produce two moles of xenon, four moles of hydrogen fluoride, and one mole of oxygen.



One sulfur atom reacts with six molecules of aqueous nitric acid, producing one molecule of aqueous sulfuric acid, two molecules of water, and six molecules of nitrogen dioxide gas. One mole of sulfur reacts with six moles of nitric acid to produce one mole of sulfuric acid, two moles of water, and six moles of nitrogen dioxide.

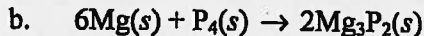


Two formula units of solid sodium hydrogen sulfite react to produce one formula unit of solid sodium sulfite, one molecule of gaseous sulfur dioxide, and one molecule of liquid water. Two moles of sodium hydrogen sulfite react to produce one mole of sodium sulfite, one mole of sulfur dioxide, and one mole of water.

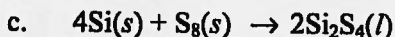
6.



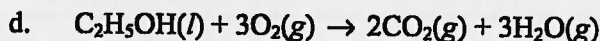
One formula unit of solid ammonium carbonate decomposes to produce two molecules of ammonia gas, one molecule of carbon dioxide gas, and one molecule of water vapor. One mole of solid ammonium carbonate decomposes into two moles of gaseous ammonia, one mole of carbon dioxide gas, and one mole of water vapor.



Six atoms of magnesium metal react with one molecule of solid phosphorus ( $\text{P}_4$ ) to make two formula units of solid magnesium phosphide. Six moles of magnesium metal react with one mole of phosphorus solid ( $\text{P}_4$ ) to produce two moles of solid magnesium phosphide.



Four atoms of solid silicon react with one molecule of solid sulfur ( $\text{S}_8$ ) to form two molecules of liquid disilicon tetrasulfide. Four moles of solid silicon react with one mole of solid sulfur ( $\text{S}_8$ ) to form two moles of liquid disilicon tetrasulfide.



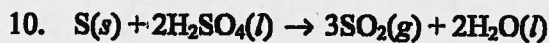
One molecule of liquid ethanol burns with three molecules of oxygen gas to produce two molecules of carbon dioxide gas and three molecules of water vapor. One mole of liquid ethanol burns with three moles of oxygen gas to produce two moles of gaseous carbon dioxide and three moles of water vapor.

7. False. The coefficients of the balanced chemical equation represent the ratios on a *mole* basis by which potassium hydroxide combines with sulfur dioxide.
8. Balanced chemical equations tell us in what molar ratios substances combine to form products; not in what mass proportions they combine. How could 2 g of reactant produce a total of 3 g of products?
9. For converting from a given number of moles of  $\text{CH}_4$  to the number of moles of oxygen needed for reaction, the correct mole ratio is

$$\left( \frac{2 \text{ mol O}_2}{1 \text{ mol CH}_4} \right)$$

For converting from a given number of moles of  $\text{CH}_4$  to the number of moles of product produced, the ratios are

$$\left( \frac{1 \text{ mol CO}_2}{1 \text{ mol CH}_4} \right) \text{ and } \left( \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol CH}_4} \right)$$

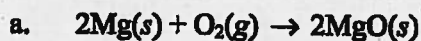


$$\text{For SO}_2, \left( \frac{3 \text{ mol SO}_2}{1 \text{ mol S}} \right)$$

$$\text{For H}_2\text{O}, \left( \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol S}} \right)$$

$$\text{For H}_2\text{SO}_4, \left( \frac{2 \text{ mol H}_2\text{SO}_4}{1 \text{ mol S}} \right)$$

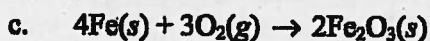
11.



$$0.15 \text{ mol Mg} \times \frac{2 \text{ mol MgO}}{2 \text{ mol Mg}} = 0.15 \text{ mol MgO}$$



$$0.15 \text{ mol O}_2 \times \frac{2 \text{ mol MgO}}{1 \text{ mol O}_2} = 0.30 \text{ mol MgO}$$

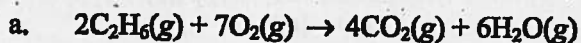


$$0.15 \text{ mol Fe} \times \frac{2 \text{ mol Fe}_2\text{O}_3}{4 \text{ mol Fe}} = 0.075 \text{ mol Fe}_2\text{O}_3$$



$$0.15 \text{ mol O}_2 \times \frac{2 \text{ mol Fe}_2\text{O}_3}{3 \text{ mol O}_2} = 0.10 \text{ mol Fe}_2\text{O}_3$$

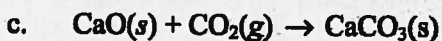
12.



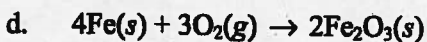
$$5.0 \text{ mol C}_2\text{H}_6 \times \frac{7 \text{ mol O}_2}{2 \text{ mol C}_2\text{H}_6} = 17.5 \text{ mol O}_2 \text{ (18 mol O}_2\text{)}$$



$$5.0 \text{ mol P}_4 \times \frac{5 \text{ mol O}_2}{1 \text{ mol P}_4} = 25 \text{ mol O}_2$$

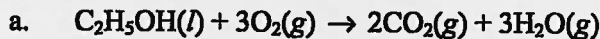


$$5.0 \text{ mol CaO} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol CaO}} = 5.0 \text{ mol CO}_2$$



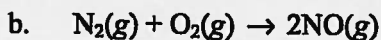
$$5.0 \text{ mol Fe} \times \frac{3 \text{ mol O}_2}{4 \text{ mol Fe}} = 3.75 \text{ mol O}_2 \text{ (3.8 mol O}_2\text{)}$$

13.

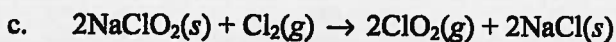


$$1.25 \text{ mol C}_2\text{H}_5\text{OH} \times \frac{2 \text{ mol CO}_2}{1 \text{ mol C}_2\text{H}_5\text{OH}} = 2.50 \text{ mol CO}_2$$

$$1.25 \text{ mol C}_2\text{H}_5\text{OH} \times \frac{3 \text{ mol H}_2\text{O}}{1 \text{ mol C}_2\text{H}_5\text{OH}} = 3.75 \text{ mol H}_2\text{O}$$



$$1.25 \text{ mol N}_2 \times \frac{2 \text{ mol NO}}{1 \text{ mol N}_2} = 2.50 \text{ mol NO}$$



$$1.25 \text{ mol NaClO}_2 \times \frac{2 \text{ mol ClO}_2}{2 \text{ mol NaClO}_2} = 1.25 \text{ mol ClO}_2$$

$$1.25 \text{ mol NaClO}_2 \times \frac{2 \text{ mol NaCl}}{2 \text{ mol NaClO}_2} = 1.25 \text{ mol NaCl}$$



$$1.25 \text{ mol H}_2 \times \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} = 0.833 \text{ mol NH}_3$$

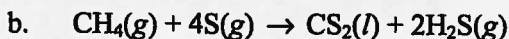
14.



molar mass of  $\text{NH}_4\text{Cl}$ , 53.49 g

$$0.50 \text{ mol NH}_3 \times \frac{1 \text{ mol NH}_4\text{Cl}}{1 \text{ mol NH}_3} = 0.50 \text{ mol NH}_4\text{Cl}$$

$$0.50 \text{ mol NH}_4\text{Cl} \times \frac{53.49 \text{ g NH}_4\text{Cl}}{1 \text{ mol NH}_4\text{Cl}} = 27 \text{ g NH}_4\text{Cl}$$



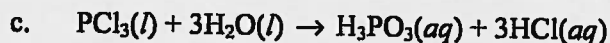
molar masses:  $\text{CS}_2$ , 76.15 g;  $\text{H}_2\text{S}$ , 34.09 g

$$0.50 \text{ mol S} \times \frac{1 \text{ mol CS}_2}{4 \text{ mol S}} = 0.125 \text{ mol CS}_2 (= 0.13 \text{ mol CS}_2)$$

$$0.125 \text{ mol CS}_2 \times \frac{76.15 \text{ g CS}_2}{1 \text{ mol CS}_2} = 9.5 \text{ g CS}_2$$

$$0.50 \text{ mol S} \times \frac{2 \text{ mol H}_2\text{S}}{4 \text{ mol S}} = 0.25 \text{ mol H}_2\text{S}$$

$$0.25 \text{ mol H}_2\text{S} \times \frac{34.09 \text{ g H}_2\text{S}}{1 \text{ mol H}_2\text{S}} = 8.5 \text{ g H}_2\text{S}$$



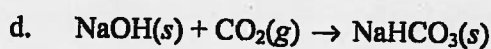
molar masses:  $\text{H}_3\text{PO}_3$ , 81.99 g;  $\text{HCl}$ , 36.46 g

$$0.50 \text{ mol PCl}_3 \times \frac{1 \text{ mol H}_3\text{PO}_3}{1 \text{ mol PCl}_3} = 0.50 \text{ mol H}_3\text{PO}_3$$

$$0.50 \text{ mol H}_3\text{PO}_3 \times \frac{81.99 \text{ g H}_3\text{PO}_3}{1 \text{ mol H}_3\text{PO}_3} = 41 \text{ g H}_3\text{PO}_3$$

$$0.50 \text{ mol PCl}_3 \times \frac{3 \text{ mol HCl}}{1 \text{ mol PCl}_3} = 1.5 \text{ mol HCl}$$

$$1.5 \text{ mol HCl} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 54.7 = 55 \text{ g HCl}$$

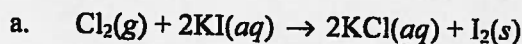


molar mass of  $\text{NaHCO}_3 = 84.01 \text{ g}$

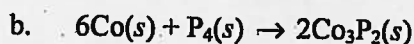
$$0.50 \text{ mol NaOH} \times \frac{1 \text{ mol NaHCO}_3}{1 \text{ mol NaOH}} = 0.50 \text{ mol NaHCO}_3$$

$$0.50 \text{ mol NaHCO}_3 \times \frac{84.01 \text{ g NaHCO}_3}{1 \text{ mol NaHCO}_3} = 42 \text{ g NaHCO}_3$$

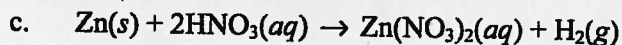
15.



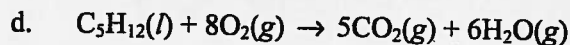
$$0.275 \text{ mol Cl}_2 \times \frac{2 \text{ mol KI}}{1 \text{ mol Cl}_2} = 0.550 \text{ mol KI}$$



$$0.275 \text{ mol Co} \times \frac{1 \text{ mol P}_4}{6 \text{ mol Co}} = 0.0458 \text{ mol P}_4$$

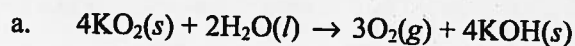


$$0.275 \text{ mol Zn} \times \frac{2 \text{ mol HNO}_3}{1 \text{ mol Zn}} = 0.550 \text{ mol HNO}_3$$

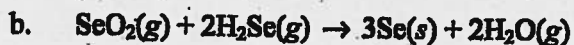


$$0.275 \text{ mol C}_5\text{H}_{12} \times \frac{8 \text{ mol O}_2}{1 \text{ mol C}_5\text{H}_{12}} = 2.20 \text{ mol O}_2$$

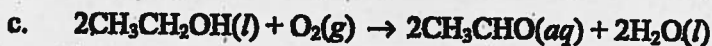
16. Before doing the calculations, the equations must be *balanced*.



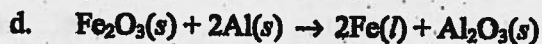
$$0.625 \text{ mol KOH} \times \frac{3 \text{ mol O}_2}{4 \text{ mol KOH}} = 0.469 \text{ mol O}_2$$



$$0.625 \text{ mol H}_2\text{O} \times \frac{3 \text{ mol Se}}{2 \text{ mol H}_2\text{O}} = 0.938 \text{ mol Se}$$



$$0.625 \text{ mol H}_2\text{O} \times \frac{2 \text{ mol CH}_3\text{CHO}}{2 \text{ mol H}_2\text{O}} = 0.625 \text{ mol CH}_3\text{CHO}$$



$$0.625 \text{ mol Al}_2\text{O}_3 \times \frac{2 \text{ mol Fe}}{1 \text{ mol Al}_2\text{O}_3} = 1.25 \text{ mol Fe}$$

17. the molar mass of the substance

18. Stoichiometry is the process of using a chemical equation to calculate the relative masses of reactants and products involved in a reaction.

19.

a. molar mass He = 4.003 g

$$2.62 \text{ g He} \times \frac{1 \text{ mol He}}{4.003 \text{ g He}} = 0.654 \text{ mol He}$$

b. molar mass  $\text{H}_3\text{BO}_3$  = 61.83 g

$$4.95 \text{ g H}_3\text{BO}_3 \times \frac{1 \text{ mol H}_3\text{BO}_3}{61.83 \text{ g H}_3\text{BO}_3} = 0.0801 \text{ mol H}_3\text{BO}_3$$

c. molar mass  $\text{CaF}_2$  = 78.08 g

$$8.31 \text{ g CaF}_2 \times \frac{1 \text{ mol CaF}_2}{78.08 \text{ g CaF}_2} = 0.106 \text{ mol CaF}_2$$

d. molar mass  $\text{Mg}(\text{C}_2\text{H}_3\text{O}_2)_2$  = 142.4 g

$$0.195 \text{ g Mg}(\text{C}_2\text{H}_3\text{O}_2)_2 \times \frac{1 \text{ mol Mg}(\text{C}_2\text{H}_3\text{O}_2)_2}{142.4 \text{ g Mg}(\text{C}_2\text{H}_3\text{O}_2)_2} = 0.00137 \text{ mol Mg}(\text{C}_2\text{H}_3\text{O}_2)_2$$

e. molar mass  $\text{NH}_3$  = 17.03 g

$$9.72 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.03 \text{ g NH}_3} = 0.571 \text{ mol NH}_3$$

20.

a. molar mass  $\text{Li}_2\text{CO}_3$  = 73.89 g; 2.36 mg = 0.00236 g

$$0.00236 \text{ g Li}_2\text{CO}_3 \times \frac{1 \text{ mol Li}_2\text{CO}_3}{73.89 \text{ g Li}_2\text{CO}_3} = 3.19 \times 10^{-5} \text{ mol Li}_2\text{CO}_3$$

b. molar mass U = 238.0 g

$$1.92 \times 10^{-3} \text{ g U} \times \frac{1 \text{ mol U}}{238.0 \text{ g U}} = 8.07 \times 10^{-6} \text{ mol U}$$

c. molar mass  $\text{PbCl}_2 = 278.1 \text{ g}$ ;  $3.21 \text{ kg} = 3.21 \times 10^3 \text{ g}$

$$3.21 \times 10^3 \text{ g PbCl}_2 \times \frac{1 \text{ mol}}{278.1 \text{ g}} = 11.5 \text{ mol PbCl}_2$$

d. molar mass  $\text{C}_6\text{H}_{12}\text{O}_6 = 180.2 \text{ g}$

$$4.62 \text{ g C}_6\text{H}_{12}\text{O}_6 \times \frac{1 \text{ mol C}_6\text{H}_{12}\text{O}_6}{180.2 \text{ g C}_6\text{H}_{12}\text{O}_6} = 0.0256 \text{ mol C}_6\text{H}_{12}\text{O}_6$$

e. molar mass KOH = 56.11 g

$$7.75 \text{ g KOH} \times \frac{1 \text{ mol KOH}}{56.11 \text{ g KOH}} = 0.138 \text{ mol KOH}$$

21.

a. molar mass  $\text{O}_2 = 32.00 \text{ g}$

$$4.25 \text{ mol O}_2 \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 136 \text{ g O}_2$$

b. molar mass Pt = 195.1 g; 1.27 millimol = 0.00127 mol

$$0.00127 \text{ mol Pt} \times \frac{195.1 \text{ g Pt}}{1 \text{ mol Pt}} = 0.248 \text{ g Pt}$$

c. molar mass  $\text{FeSO}_4 = 151.92 \text{ g}$

$$0.00101 \text{ mol FeSO}_4 \times \frac{151.92 \text{ g FeSO}_4}{1 \text{ mol FeSO}_4} = 0.153 \text{ g FeSO}_4$$

d. molar mass  $\text{CaCO}_3 = 100.09 \text{ g}$

$$75.1 \text{ mol CaCO}_3 \times \frac{100.09 \text{ g CaCO}_3}{1 \text{ mol CaCO}_3} = 7.52 \times 10^3 \text{ g CaCO}_3$$

e. molar mass Au = 197.0 g

$$1.35 \times 10^{-4} \text{ mol Au} \times \frac{197.0 \text{ g Au}}{1 \text{ mol Au}} = 0.0266 \text{ mol Au}$$

f. molar mass  $\text{H}_2\text{O}_2 = 34.02 \text{ g}$

$$1.29 \text{ mol H}_2\text{O}_2 \times \frac{34.02 \text{ g H}_2\text{O}_2}{1 \text{ mol H}_2\text{O}_2} = 43.9 \text{ g H}_2\text{O}_2$$

g. molar mass CuS = 95.62 g

$$6.14 \text{ mol CuS} \times \frac{95.62 \text{ g CuS}}{1 \text{ mol CuS}} = 587 \text{ g CuS}$$

22.

a. molar mass of CuI = 190.5 g

$$0.624 \text{ mol CuI} \times \frac{190.5 \text{ g CuI}}{1 \text{ mol CuI}} = 119 \text{ g CuI}$$

b. molar mass of Br<sub>2</sub> = 159.8 g

$$4.24 \text{ mol Br}_2 \times \frac{159.8 \text{ g Br}_2}{1 \text{ mol Br}_2} = 678 \text{ g Br}_2$$

c. molar mass of XeF<sub>4</sub> = 207.4 g

$$0.000211 \text{ mol XeF}_4 \times \frac{207.4 \text{ g XeF}_4}{1 \text{ mol XeF}_4} = 0.0438 \text{ g XeF}_4$$

d. molar mass of C<sub>2</sub>H<sub>4</sub> = 28.05 g

$$9.11 \text{ mol C}_2\text{H}_4 \times \frac{28.05 \text{ g C}_2\text{H}_4}{1 \text{ mol C}_2\text{H}_4} = 256 \text{ g C}_2\text{H}_4$$

e. molar mass of NH<sub>3</sub> = 17.03 g; 1.21 millimol = 0.00121 mol

$$0.00121 \text{ mol NH}_3 \times \frac{17.03 \text{ g NH}_3}{1 \text{ mol NH}_3} = 0.0206 \text{ g NH}_3$$

f. molar mass of NaOH = 40.00 g

$$4.25 \text{ mol NaOH} \times \frac{40.00 \text{ g NaOH}}{1 \text{ mol NaOH}} = 170 \text{ g NaOH}$$

g. molar mass of KI = 166.0 g

$$1.27 \times 10^{-6} \text{ mol KI} \times \frac{166.0 \text{ g KI}}{1 \text{ mol KI}} = 2.11 \times 10^{-4} \text{ g KI}$$

23. Before any calculations are done, the equations must be *balanced*.a.  $\text{CS}_2(l) + 3\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{SO}_2(g)$ masses: CS<sub>2</sub>, 76.15 g; CO<sub>2</sub>, 44.01 g; SO<sub>2</sub>, 64.07 g

$$1.55 \text{ g CS}_2 \times \frac{1 \text{ mol CS}_2}{76.15 \text{ g CS}_2} = 0.02035 \text{ mol CS}_2$$

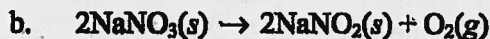
$$0.02035 \text{ mol CS}_2 \times \frac{1 \text{ mol CO}_2}{1 \text{ mol CS}_2} = 0.02035 \text{ mol CO}_2$$

$$0.02035 \text{ mol CO}_2 \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 0.896 \text{ g CO}_2$$

$$0.02035 \text{ mol CS}_2 \times \frac{2 \text{ mol SO}_2}{1 \text{ mol CS}_2} = 0.04071 \text{ mol SO}_2$$

$$0.04071 \text{ mol SO}_2 \times \frac{64.07 \text{ g SO}_2}{1 \text{ mol SO}_2} = 2.61 \text{ g SO}_2$$





molar masses:  $\text{NaNO}_3$ , 85.00 g;  $\text{NaNO}_2$ , 69.00 g;  $\text{O}_2$ , 32.00 g

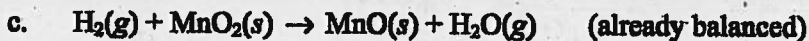
$$1.55 \text{ g NaNO}_3 \times \frac{1 \text{ mol NaNO}_3}{85.00 \text{ g NaNO}_3} = 0.01824 \text{ mol NaNO}_3$$

$$0.01824 \text{ mol NaNO}_3 \times \frac{2 \text{ mol NaNO}_2}{2 \text{ mol NaNO}_3} = 0.01824 \text{ mol NaNO}_2$$

$$0.01824 \text{ mol NaNO}_2 \times \frac{69.00 \text{ g NaNO}_2}{1 \text{ mol NaNO}_2} = 1.26 \text{ g NaNO}_2$$

$$0.01824 \text{ mol NaNO}_3 \times \frac{1 \text{ mol O}_2}{2 \text{ mol NaNO}_3} = 0.00912 \text{ mol O}_2$$

$$0.00912 \text{ mol O}_2 \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 0.292 \text{ g O}_2$$



molar masses:  $\text{MnO}_2$ , 86.94 g;  $\text{MnO}$ , 70.94 g;  $\text{H}_2\text{O}$ , 18.02 g

$$1.55 \text{ g MnO}_2 \times \frac{1 \text{ mol MnO}_2}{86.94 \text{ g MnO}_2} = 0.01783 \text{ mol MnO}_2$$

$$0.01783 \text{ mol MnO}_2 \times \frac{1 \text{ mol MnO}}{1 \text{ mol MnO}_2} = 0.01783 \text{ mol MnO}$$

$$0.01783 \text{ mol MnO} \times \frac{70.94 \text{ g MnO}}{1 \text{ mol MnO}} = 1.26 \text{ g MnO}$$

$$0.01783 \text{ mol MnO}_2 \times \frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol MnO}_2} = 0.01783 \text{ mol H}_2\text{O}$$

$$0.01783 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.321 \text{ g H}_2\text{O}$$



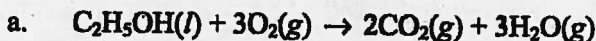
molar masses:  $\text{Br}_2$ , 159.8 g;  $\text{BrCl}$ , 115.4 g

$$1.55 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.8 \text{ g Br}_2} = 0.00970 \text{ mol Br}_2$$

$$0.00970 \text{ mol Br}_2 \times \frac{2 \text{ mol BrCl}}{1 \text{ mol Br}_2} = 0.01940 \text{ mol BrCl}$$

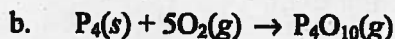
$$0.01940 \text{ mol BrCl} \times \frac{115.4 \text{ g BrCl}}{1 \text{ mol BrCl}} = 2.24 \text{ g BrCl}$$

24. Before any calculations are done, the equations must be *balanced*.



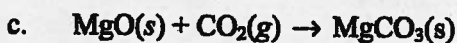
molar mass  $\text{C}_2\text{H}_5\text{OH} = 46.07 \text{ g}$

$$5.00 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol C}_2\text{H}_5\text{OH}}{46.07 \text{ g C}_2\text{H}_5\text{OH}} \times \frac{3 \text{ mol O}_2}{1 \text{ mol C}_2\text{H}_5\text{OH}} = 0.326 \text{ mol O}_2$$



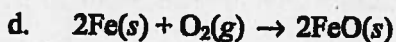
molar mass  $\text{P}_4 = 123.88 \text{ g}$

$$5.00 \text{ g P}_4 \times \frac{1 \text{ mol P}_4}{123.88 \text{ g}} \times \frac{5 \text{ mol O}_2}{1 \text{ mol P}_4} = 0.202 \text{ mol O}_2$$



molar mass  $\text{MgO} = 40.31 \text{ g}$

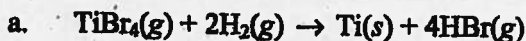
$$5.00 \text{ g MgO} \times \frac{1 \text{ mol MgO}}{40.31 \text{ g MgO}} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol MgO}} = 0.124 \text{ mol CO}_2$$



molar mass  $\text{Fe} = 55.85 \text{ g}$

$$5.00 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} \times \frac{1 \text{ mol O}_2}{2 \text{ mol Fe}} = 0.0448 \text{ mol O}_2$$

25. Before any calculations are done, the equations must be *balanced*.



molar mass  $\text{H}_2 = 2.016 \text{ g}$ ; molar mass  $\text{Ti} = 47.90 \text{ g}$ ; molar mass of  $\text{HBr} = 80.91 \text{ g}$

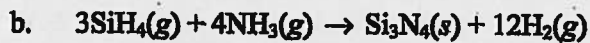
$$12.5 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} = 6.20 \text{ mol H}_2$$

$$6.20 \text{ mol H}_2 \times \frac{1 \text{ mol Ti}}{2 \text{ mol H}_2} = 3.10 \text{ mol Ti}$$

$$3.10 \text{ mol Ti} \times \frac{47.90 \text{ g Ti}}{1 \text{ mol Ti}} = 148 \text{ g Ti}$$

$$6.20 \text{ mol H}_2 \times \frac{4 \text{ mol HBr}}{2 \text{ mol H}_2} = 12.4 \text{ mol HBr}$$

$$12.4 \text{ mol HBr} \times \frac{80.91 \text{ g HBr}}{1 \text{ mol HBr}} = 1.00 \times 10^3 \text{ g HBr}$$



molar mass  $\text{SiH}_4 = 32.12 \text{ g}$ ; molar mass  $\text{Si}_3\text{N}_4 = 140.3 \text{ g}$ ; molar mass  $\text{H}_2 = 2.016 \text{ g}$

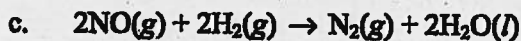
$$12.5 \text{ g SiH}_4 \times \frac{1 \text{ mol SiH}_4}{32.12 \text{ g SiH}_4} = 0.389 \text{ mol SiH}_4$$

$$0.389 \text{ mol SiH}_4 \times \frac{1 \text{ mol Si}_3\text{N}_4}{3 \text{ mol SiH}_4} = 0.130 \text{ mol Si}_3\text{N}_4$$

$$0.130 \text{ mol Si}_3\text{N}_4 \times \frac{140.3 \text{ g Si}_3\text{N}_4}{1 \text{ mol Si}_3\text{N}_4} = 18.2 \text{ g Si}_3\text{N}_4$$

$$0.389 \text{ mol SiH}_4 \times \frac{12 \text{ mol H}_2}{3 \text{ mol SiH}_4} = 1.56 \text{ mol H}_2$$

$$1.56 \text{ mol H}_2 \times \frac{2.016 \text{ g H}_2}{1 \text{ mol H}_2} = 3.14 \text{ g H}_2$$



molar mass  $\text{H}_2 = 2.016 \text{ g}$ ; molar mass  $\text{N}_2 = 28.02 \text{ g}$ ; molar mass  $\text{H}_2\text{O} = 18.02 \text{ g}$

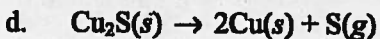
$$12.5 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} = 6.20 \text{ mol H}_2$$

$$6.20 \text{ mol H}_2 \times \frac{1 \text{ mol N}_2}{2 \text{ mol H}_2} = 3.10 \text{ mol N}_2$$

$$3.10 \text{ mol N}_2 \times \frac{28.02 \text{ g N}_2}{1 \text{ mol N}_2} = 86.9 \text{ g N}_2$$

$$6.20 \text{ mol H}_2 \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol H}_2} = 6.20 \text{ mol H}_2\text{O}$$

$$6.20 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 112 \text{ g H}_2\text{O}$$



molar mass  $\text{Cu}_2\text{S} = 159.2 \text{ g}$ ; molar mass  $\text{Cu} = 63.55 \text{ g}$ ; molar mass  $\text{S} = 32.07 \text{ g}$

$$12.5 \text{ g Cu}_2\text{S} \times \frac{1 \text{ mol Cu}_2\text{S}}{159.2 \text{ g Cu}_2\text{S}} = 0.0785 \text{ mol Cu}_2\text{S}$$

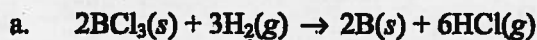
$$0.0785 \text{ mol Cu}_2\text{S} \times \frac{2 \text{ mol Cu}}{1 \text{ mol Cu}_2\text{S}} = 0.157 \text{ mol Cu}$$

$$0.157 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} = 9.98 \text{ g Cu}$$

$$0.0785 \text{ mol Cu}_2\text{S} \times \frac{1 \text{ mol S}}{1 \text{ mol Cu}_2\text{S}} = 0.0785 \text{ mol S}$$

$$0.0785 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 2.52 \text{ g S}$$

26.

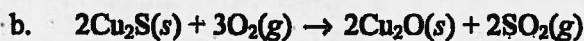


molar masses:  $\text{BCl}_3$ , 117.16 g; B, 10.81 g;  $\text{HCl}$ , 36.46 g

$$15.0 \text{ g BCl}_3 \times \frac{1 \text{ mol BCl}_3}{117.16 \text{ g BCl}_3} = 0.128 \text{ mol BCl}_3$$

$$0.128 \text{ mol BCl}_3 \times \frac{2 \text{ mol B}}{2 \text{ mol BCl}_3} \times \frac{10.81 \text{ g B}}{1 \text{ mol B}} = 1.38 \text{ g B}$$

$$0.128 \text{ mol BCl}_3 \times \frac{6 \text{ mol HCl}}{2 \text{ mol BCl}_3} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 14.0 \text{ g HCl}$$

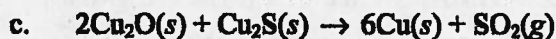


molar masses:  $\text{Cu}_2\text{S}$ , 159.17 g;  $\text{Cu}_2\text{O}$ , 143.1 g;  $\text{SO}_2$ , 64.07 g

$$15.0 \text{ g Cu}_2\text{S} \times \frac{1 \text{ mol Cu}_2\text{S}}{159.17 \text{ g Cu}_2\text{S}} = 0.09424 \text{ mol Cu}_2\text{S}$$

$$0.09424 \text{ mol Cu}_2\text{S} \times \frac{2 \text{ mol Cu}_2\text{O}}{2 \text{ mol Cu}_2\text{S}} \times \frac{143.1 \text{ g Cu}_2\text{O}}{1 \text{ mol Cu}_2\text{O}} = 13.5 \text{ g Cu}_2\text{O}$$

$$0.09424 \text{ mol Cu}_2\text{S} \times \frac{2 \text{ mol SO}_2}{2 \text{ mol Cu}_2\text{S}} \times \frac{64.07 \text{ g SO}_2}{1 \text{ mol SO}_2} = 6.04 \text{ g SO}_2$$

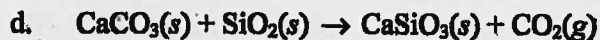


molar masses:  $\text{Cu}_2\text{S}$ , 159.17 g; Cu, 63.55 g;  $\text{SO}_2$ , 64.07 g

$$15.0 \text{ g Cu}_2\text{S} \times \frac{1 \text{ mol Cu}_2\text{S}}{159.17 \text{ g Cu}_2\text{S}} = 0.09424 \text{ mol Cu}_2\text{S}$$

$$0.09424 \text{ mol Cu}_2\text{S} \times \frac{6 \text{ mol Cu}}{1 \text{ mol Cu}_2\text{S}} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} = 35.9 \text{ g Cu}$$

$$0.09424 \text{ mol Cu}_2\text{S} \times \frac{1 \text{ mol SO}_2}{1 \text{ mol Cu}_2\text{S}} \times \frac{64.07 \text{ g SO}_2}{1 \text{ mol SO}_2} = 6.04 \text{ g SO}_2$$

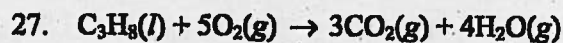


molar masses:  $\text{SiO}_2$ , 60.09 g;  $\text{CaSiO}_3$ , 116.17 g;  $\text{CO}_2$ , 44.01 g

$$15.0 \text{ g SiO}_2 \times \frac{1 \text{ mol SiO}_2}{60.09 \text{ g SiO}_2} = 0.2496 \text{ mol SiO}_2$$

$$0.2496 \text{ mol SiO}_2 \times \frac{1 \text{ mol CaSiO}_3}{1 \text{ mol SiO}_2} \times \frac{116.17 \text{ g CaSiO}_3}{1 \text{ mol CaSiO}_3} = 29.0 \text{ g CaSiO}_3$$

$$0.2496 \text{ mol SiO}_2 \times \frac{1 \text{ mol CO}_2}{1 \text{ mol SiO}_2} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 11.0 \text{ g CO}_2$$



molar mass  $\text{H}_2\text{O} = 18.02 \text{ g}$

$$3.11 \text{ mol C}_3\text{H}_8 \times \frac{4 \text{ mol H}_2\text{O}}{1 \text{ mol C}_3\text{H}_8} = 12.44 \text{ mol H}_2\text{O}$$

$$12.44 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 224 \text{ g H}_2\text{O}$$



It would make things simpler if the first equation were expressed in terms of one mole of  $\text{SO}_3$  since the second equation is expressed in terms of 1 mole of  $\text{SO}_3$ . To do this, divide the first equation by two:



By doing this, we now have the simpler relationship that one mole of S will produce one mole of  $\text{H}_2\text{SO}_4$ .

molar masses: S, 32.07 g;  $\text{H}_2\text{SO}_4$ , 98.09 g

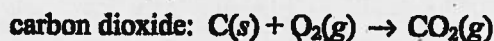
$$1.25 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.03898 \text{ mol S}$$

$$0.03898 \text{ mol S} \times \frac{1 \text{ mol H}_2\text{SO}_4}{1 \text{ mol S}} = 0.03898 \text{ mol H}_2\text{SO}_4$$

$$0.03898 \text{ mol H}_2\text{SO}_4 \times \frac{98.09 \text{ g H}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4} = 3.82 \text{ g H}_2\text{SO}_4$$

29. molar masses: C, 12.01 g; CO, 28.01 g; CO
- <sub>2</sub>
- , 44.01 g

$$5.00 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.4163 \text{ mol C}$$



$$0.4163 \text{ mol C} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol C}} = 0.4163 \text{ mol CO}_2$$

$$0.4163 \text{ mol CO}_2 \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 18.3 \text{ g CO}_2$$



$$0.4163 \text{ mol C} \times \frac{2 \text{ mol CO}}{2 \text{ mol C}} = 0.4163 \text{ mol CO}$$

$$0.4163 \text{ mol CO} \times \frac{28.01 \text{ g CO}}{1 \text{ mol CO}} = 11.7 \text{ g CO}$$

- 30.
- $2\text{NaHCO}_3(s) \rightarrow \text{Na}_2\text{CO}_3(s) + \text{H}_2\text{O}(g) + \text{CO}_2(g)$

molar masses: NaHCO<sub>3</sub>, 84.01 g; Na<sub>2</sub>CO<sub>3</sub>, 106.0 g

$$1.52 \text{ g NaHCO}_3 \times \frac{1 \text{ mol NaHCO}_3}{84.01 \text{ g NaHCO}_3} = 0.01809 \text{ mol NaHCO}_3$$

$$0.01809 \text{ mol NaHCO}_3 \times \frac{1 \text{ mol Na}_2\text{CO}_3}{2 \text{ mol NaHCO}_3} = 0.009047 \text{ mol Na}_2\text{CO}_3$$

$$0.009047 \text{ mol Na}_2\text{CO}_3 \times \frac{106.0 \text{ g Na}_2\text{CO}_3}{1 \text{ mol Na}_2\text{CO}_3} = 0.959 \text{ g Na}_2\text{CO}_3$$

- 31.
- $2\text{Fe}(s) + 3\text{Cl}_2(g) \rightarrow 2\text{FeCl}_3(s)$

millimolar masses: iron, 55.85 mg; FeCl<sub>3</sub>, 162.2 mg

$$15.5 \text{ mg Fe} \times \frac{1 \text{ mmol Fe}}{55.85 \text{ mg Fe}} = 0.2775 \text{ mmol Fe}$$

$$0.2775 \text{ mmol Fe} \times \frac{2 \text{ mmol FeCl}_3}{2 \text{ mmol Fe}} = 0.2775 \text{ mmol FeCl}_3$$

$$0.2775 \text{ mmol FeCl}_3 \times \frac{162.2 \text{ mg FeCl}_3}{1 \text{ mmol FeCl}_3} = 45.0 \text{ mg FeCl}_3$$

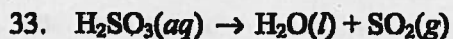


molar masses:  $C_6H_{12}O_6$ , 180.2 g;  $C_2H_5OH$ , 46.07 g

$$5.25 \text{ g } C_6H_{12}O_6 \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.2 \text{ g } C_6H_{12}O_6} = 0.02913 \text{ mol } C_6H_{12}O_6$$

$$0.02913 \text{ mol } C_6H_{12}O_6 \times \frac{2 \text{ mol } C_2H_5OH}{1 \text{ mol } C_6H_{12}O_6} = 0.5826 \text{ mol } C_2H_5OH$$

$$0.5826 \text{ mol } C_2H_5OH \times \frac{46.07 \text{ g } C_2H_5OH}{1 \text{ mol } C_2H_5OH} = 2.68 \text{ g ethyl alcohol}$$

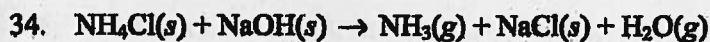


molar masses:  $H_2SO_3$ , 82.09 g;  $SO_2$ , 64.07 g

$$4.25 \text{ g } H_2SO_3 \times \frac{1 \text{ mol } H_2SO_3}{82.09 \text{ g } H_2SO_3} = 0.05177 \text{ mol } H_2SO_3$$

$$0.05177 \text{ mol } H_2SO_3 \times \frac{1 \text{ mol } SO_2}{1 \text{ mol } H_2SO_3} = 0.05177 \text{ mol } SO_2$$

$$0.05177 \text{ mol } SO_2 \times \frac{64.07 \text{ g } SO_2}{1 \text{ mol } SO_2} = 3.32 \text{ g } SO_2$$

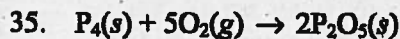


molar masses:  $NH_4Cl$ , 53.49 g;  $NH_3$ , 17.03 g

$$1.39 \text{ g } NH_4Cl \times \frac{1 \text{ mol } NH_4Cl}{53.49 \text{ g } NH_4Cl} = 0.02599 \text{ mol } NH_4Cl$$

$$0.02599 \text{ mol } NH_4Cl \times \frac{1 \text{ mol } NH_3}{1 \text{ mol } NH_4Cl} = 0.02599 \text{ mol } NH_3$$

$$0.02599 \text{ mol } NH_3 \times \frac{17.03 \text{ g } NH_3}{1 \text{ mol } NH_3} = 0.443 \text{ g } NH_3$$

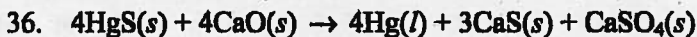


molar masses:  $P_4$ , 123.88 g;  $O_2$ , 32.00 g

$$4.95 \text{ g } P_4 \times \frac{1 \text{ mol } P_4}{123.88 \text{ g } P_4} = 0.03996 \text{ mol } P_4$$

$$0.03996 \text{ mol } P_4 \times \frac{5 \text{ mol } O_2}{1 \text{ mol } P_4} = 0.1998 \text{ mol } O_2$$

$$0.1998 \text{ mol } O_2 \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 6.39 \text{ g } O_2$$

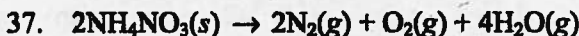


molar masses: HgS, 232.7 g Hg, 200.6 g; 10.0 kg =  $1.00 \times 10^4$  g

$$1.00 \times 10^4 \text{ g HgS} \times \frac{1 \text{ mol HgS}}{232.7 \text{ g HgS}} = 42.97 \text{ mol HgS}$$

$$42.97 \text{ mol HgS} \times \frac{4 \text{ mol Hg}}{4 \text{ mol HgS}} = 42.97 \text{ mol Hg}$$

$$42.97 \text{ mol Hg} \times \frac{200.6 \text{ g Hg}}{1 \text{ mol Hg}} = 8.62 \times 10^3 \text{ g Hg} = 8.62 \text{ kg Hg}$$



molar masses:  $\text{NH}_4\text{NO}_3$ , 80.05 g;  $\text{N}_2$ , 28.02 g;  $\text{O}_2$ , 32.00 g;  $\text{H}_2\text{O}$ , 18.02 g

$$1.25 \text{ g NH}_4\text{NO}_3 \times \frac{1 \text{ mol NH}_4\text{NO}_3}{80.05 \text{ g NH}_4\text{NO}_3} = 0.0156 \text{ mol NH}_4\text{NO}_3$$

$$0.0156 \text{ mol NH}_4\text{NO}_3 \times \frac{2 \text{ mol N}_2}{2 \text{ mol NH}_4\text{NO}_3} = 0.0156 \text{ mol N}_2$$

$$0.0156 \text{ mol N}_2 \times \frac{28.02 \text{ g N}_2}{1 \text{ mol N}_2} = 0.437 \text{ g N}_2$$

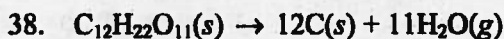
$$0.0156 \text{ mol NH}_4\text{NO}_3 \times \frac{1 \text{ mol O}_2}{2 \text{ mol NH}_4\text{NO}_3} = 0.00780 \text{ mol O}_2$$

$$0.00780 \text{ mol O}_2 \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 0.250 \text{ g O}_2$$

$$0.0156 \text{ mol NH}_4\text{NO}_3 \times \frac{4 \text{ mol H}_2\text{O}}{2 \text{ mol NH}_4\text{NO}_3} = 0.0312 \text{ mol H}_2\text{O}$$

$$0.0312 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.562 \text{ g H}_2\text{O}$$

As a check, note that  $0.437 \text{ g} + 0.250 \text{ g} + 0.562 \text{ g} = 1.249 \text{ g} = 1.25 \text{ g}$ .



molar masses:  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ , 342.3 g; C, 12.01

$$1.19 \text{ g C}_{12}\text{H}_{22}\text{O}_{11} \times \frac{1 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}}{342.3 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}} = 3.476 \times 10^{-3} \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}$$

$$3.476 \times 10^{-3} \text{ mol C}_{12}\text{H}_{22}\text{O}_{11} \times \frac{12 \text{ mol C}}{1 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}} = 0.04172 \text{ mol C}$$

$$0.04172 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 0.501 \text{ g C}$$





molar masses:  $\text{SOCl}_2$ , 119.0 g;  $\text{H}_2\text{O}$ , 18.02 g

$$35.0 \text{ g SOCl}_2 \times \frac{1 \text{ mol SOCl}_2}{119.0 \text{ g SOCl}_2} = 0.294 \text{ mol SOCl}_2$$

$$0.294 \text{ mol SOCl}_2 \times \frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol SOCl}_2} = 0.294 \text{ mol H}_2\text{O}$$

$$0.294 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 5.30 \text{ g H}_2\text{O}$$



molar masses: Mg, 24.31 g; MgO, 40.31 g

$$1.25 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}} = 5.14 \times 10^{-2} \text{ mol Mg}$$

$$5.14 \times 10^{-2} \text{ mol Mg} \times \frac{2 \text{ mol MgO}}{2 \text{ mol Mg}} = 5.14 \times 10^{-2} \text{ mol MgO}$$

$$5.14 \times 10^{-2} \text{ mol MgO} \times \frac{40.31 \text{ g MgO}}{1 \text{ mol MgO}} = 2.07 \text{ g MgO}$$

41. To determine the limiting reactant, first calculate the number of moles of each reactant present. Then determine how these numbers of moles correspond to the stoichiometric ratio indicated by the balanced chemical equation for the reaction. Specific answer depends on student response.
42. To determine the limiting reactant, first calculate the number of moles of each reactant present. Then determine how these numbers of moles correspond to the stoichiometric ratio indicated by the balanced chemical equation for the reaction.
43. The theoretical yield of a reaction represents the stoichiometric amount of product that should form if the limiting reactant for the process is completely consumed.
44. A reactant is present *in excess* if there is more of that reactant present than is needed to combine with the limiting reactant for the process. By definition, the limiting reactant cannot be present in excess. An excess of any reactant does not affect the theoretical yield for a process; the theoretical yield is determined by the limiting reactant.

45.



molar masses:  $\text{Na}_2\text{B}_4\text{O}_7$ , 201.2 g;  $\text{H}_2\text{SO}_4$ , 98.09 g;  $\text{H}_2\text{O}$ , 18.02 g

$$5.00 \text{ g Na}_2\text{B}_4\text{O}_7 \times \frac{1 \text{ mol}}{201.2 \text{ g}} = 0.0249 \text{ mol Na}_2\text{B}_4\text{O}_7$$

$$5.00 \text{ g H}_2\text{SO}_4 \times \frac{1 \text{ mol}}{98.09 \text{ g}} = 0.0510 \text{ mol H}_2\text{SO}_4$$

$$5.00 \text{ g H}_2\text{O} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 0.277 \text{ mol H}_2\text{O}$$

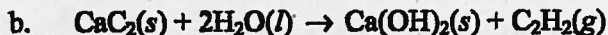
$\text{Na}_2\text{B}_4\text{O}_7$  is the limiting reactant.

$$\text{mol H}_2\text{SO}_4 \text{ remaining unreacted} = 0.0510 - 0.0249 = 0.0261 \text{ mol}$$

$$\text{mol H}_2\text{O remaining unreacted} = 0.277 - 5(0.0249) = 0.153 \text{ mol}$$

$$\text{mass of H}_2\text{SO}_4 \text{ remaining} = 0.0261 \text{ mol} \times \frac{98.09 \text{ g}}{1 \text{ mol}} = 2.56 \text{ g H}_2\text{SO}_4$$

$$\text{mass of H}_2\text{O remaining} = 0.153 \text{ mol} \times \frac{18.02 \text{ g}}{1 \text{ mol}} = 2.76 \text{ g H}_2\text{O}$$



molar masses:  $\text{CaC}_2$ , 64.10 g;  $\text{H}_2\text{O}$ , 18.02 g

$$5.00 \text{ g CaC}_2 \times \frac{1 \text{ mol}}{64.10 \text{ g}} = 0.0780 \text{ mol CaC}_2$$

$$5.00 \text{ g H}_2\text{O} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 0.277 \text{ mol H}_2\text{O}$$

$\text{CaC}_2$  is the limiting reactant; water is present in excess.

$$\text{mol of H}_2\text{O remaining} = 0.277 - 2(0.0780) = 0.121 \text{ mol H}_2\text{O}$$

$$\text{mass of H}_2\text{O remaining} = 0.121 \text{ mol} \times \frac{18.02 \text{ g}}{1 \text{ mol}} = 2.18 \text{ g H}_2\text{O}$$



molar masses:  $\text{NaCl}$ , 58.44 g;  $\text{H}_2\text{SO}_4$ , 98.09 g

$$5.00 \text{ g NaCl} \times \frac{1 \text{ mol}}{58.44 \text{ g}} = 0.0856 \text{ mol NaCl}$$

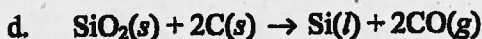
$$5.00 \text{ g H}_2\text{SO}_4 \times \frac{1 \text{ mol}}{98.09 \text{ g}} = 0.0510 \text{ mol H}_2\text{SO}_4$$

NaCl is the limiting reactant;  $\text{H}_2\text{SO}_4$  is present in excess.

$$\text{mol H}_2\text{SO}_4 \text{ that reacts} = 0.5(0.0856) = 0.0428 \text{ mol H}_2\text{SO}_4$$

$$\text{mol H}_2\text{SO}_4 \text{ remaining} = 0.0510 - 0.0428 = 0.0082 \text{ mol}$$

$$\text{mass of H}_2\text{SO}_4 \text{ remaining} = 0.0082 \text{ mol} \times \frac{98.09 \text{ g}}{1 \text{ mol}} = 0.80 \text{ g H}_2\text{SO}_4$$



molar masses:  $\text{SiO}_2$ , 60.09 g; C, 12.01 g

$$5.00 \text{ g SiO}_2 \times \frac{1 \text{ mol}}{60.09 \text{ g}} = 0.0832 \text{ mol SiO}_2$$

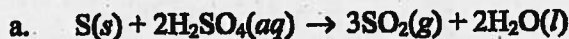
$$5.00 \text{ g C} \times \frac{1 \text{ mol}}{12.01 \text{ g}} = 0.416 \text{ mol C}$$

$\text{SiO}_2$  is the limiting reactant; C is present in excess.

$$\text{mol C remaining} = 0.416 - 2(0.0832) = 0.250 \text{ mol}$$

$$\text{mass of C remaining} = 0.250 \text{ mol} \times \frac{12.01 \text{ g}}{1 \text{ mol}} = 3.00 \text{ g C}$$

46.



Molar masses: S, 32.07 g;  $\text{H}_2\text{SO}_4$ , 98.09 g;  $\text{SO}_2$ , 64.07 g;  $\text{H}_2\text{O}$ , 18.02 g

$$5.00 \text{ g S} \times \frac{1 \text{ mol}}{32.07 \text{ g}} = 0.1559 \text{ mol S}$$

$$5.00 \text{ g H}_2\text{SO}_4 \times \frac{1 \text{ mol}}{98.09 \text{ g}} = 0.05097 \text{ mol H}_2\text{SO}_4$$

According to the balanced chemical equation, we would need twice as much sulfuric acid as sulfur for complete reaction of both reactants. We clearly have much less sulfuric acid present than sulfur; sulfuric acid is the limiting reactant. The calculation of the masses of products produced is based on the number of moles of the sulfuric acid.

$$0.05097 \text{ mol H}_2\text{SO}_4 \times \frac{3 \text{ mol SO}_2}{2 \text{ mol H}_2\text{SO}_4} \times \frac{64.07 \text{ g SO}_2}{1 \text{ mol SO}_2} = 4.90 \text{ g SO}_2$$

$$0.05097 \text{ mol H}_2\text{SO}_4 \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol H}_2\text{SO}_4} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.918 \text{ g H}_2\text{O}$$



molar masses:  $\text{MnO}_2$ , 86.94 g;  $\text{H}_2\text{SO}_4$  98.09 g;  $\text{Mn}(\text{SO}_4)_2$ , 247.1 g;  $\text{H}_2\text{O}$ , 18.02 g

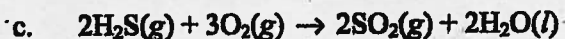
$$5.00 \text{ g MnO}_2 \times \frac{1 \text{ mol}}{86.94 \text{ g}} = 0.05751 \text{ mol MnO}_2$$

$$5.00 \text{ g H}_2\text{SO}_4 \times \frac{1 \text{ mol}}{98.09 \text{ g}} = 0.05097 \text{ mol H}_2\text{SO}_4$$

According to the balanced chemical equation, we would need twice as much sulfuric acid as manganese(IV) oxide for complete reaction of both reactants. We do not have this much sulfuric acid, so sulfuric acid must be the limiting reactant. The amount of each product produced will be based on the sulfuric acid reacting completely.

$$0.05097 \text{ mol H}_2\text{SO}_4 \times \frac{1 \text{ mol Mn}(\text{SO}_4)_2}{2 \text{ mol H}_2\text{SO}_4} \times \frac{247.1 \text{ g Mn}(\text{SO}_4)_2}{1 \text{ mol Mn}(\text{SO}_4)_2} = 6.30 \text{ g Mn}(\text{SO}_4)_2$$

$$0.05097 \text{ mol H}_2\text{SO}_4 \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol H}_2\text{SO}_4} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.918 \text{ g H}_2\text{O}$$



Molar masses:  $\text{H}_2\text{S}$ , 34.09 g;  $\text{O}_2$ , 32.00 g;  $\text{SO}_2$ , 64.07 g;  $\text{H}_2\text{O}$ , 18.02 g

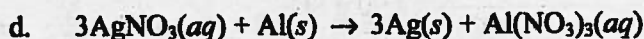
$$5.00 \text{ g H}_2\text{S} \times \frac{1 \text{ mol}}{34.09 \text{ g}} = 0.1467 \text{ mol H}_2\text{S}$$

$$5.00 \text{ g O}_2 \times \frac{1 \text{ mol}}{32.00 \text{ g}} = 0.1563 \text{ mol O}_2$$

According to the balanced equation, we would need 1.5 times as much  $\text{O}_2$  as  $\text{H}_2\text{S}$  for complete reaction of both reactants. We don't have that much  $\text{O}_2$ , so  $\text{O}_2$  must be the limiting reactant that will control the masses of each product produced.

$$0.1563 \text{ mol O}_2 \times \frac{2 \text{ mol SO}_2}{3 \text{ mol O}_2} \times \frac{64.07 \text{ g SO}_2}{1 \text{ mol SO}_2} = 6.67 \text{ g SO}_2$$

$$0.1563 \text{ mol O}_2 \times \frac{2 \text{ mol H}_2\text{O}}{3 \text{ mol O}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 1.88 \text{ g H}_2\text{O}$$



Molar masses:  $\text{AgNO}_3$ , 169.9 g;  $\text{Al}$ , 26.98 g;  $\text{Ag}$ , 107.9 g;  $\text{Al}(\text{NO}_3)_3$ , 213.0 g

$$5.00 \text{ g AgNO}_3 \times \frac{1 \text{ mol}}{169.9 \text{ g}} = 0.02943 \text{ mol AgNO}_3$$

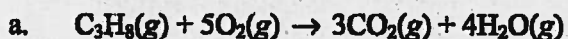
$$5.00 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 0.1853 \text{ mol Al}$$

According to the balanced chemical equation, we would need three moles of  $\text{AgNO}_3$  for every mole of  $\text{Al}$  for complete reaction of both reactants. We in fact have fewer moles of  $\text{AgNO}_3$  than aluminum, so  $\text{AgNO}_3$  must be the limiting reactant. The amount of product produced is calculated from the number of moles of the limiting reactant present:

$$0.02943 \text{ mol AgNO}_3 \times \frac{3 \text{ mol Ag}}{3 \text{ mol AgNO}_3} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}} = 3.18 \text{ g Ag}$$

$$0.02943 \text{ mol AgNO}_3 \times \frac{1 \text{ mol Al(NO}_3)_3}{3 \text{ mol AgNO}_3} \times \frac{213.0 \text{ g Al(NO}_3)_3}{1 \text{ mol Al(NO}_3)_3} = 2.09 \text{ g}$$

47. Before any calculations are attempted, the equations must be balanced.



molar masses:  $\text{C}_3\text{H}_8$ , 44.09 g;  $\text{O}_2$ , 32.00 g;  $\text{CO}_2$ , 44.01 g;  $\text{H}_2\text{O}$ , 18.02 g

$$10.0 \text{ g C}_3\text{H}_8 \times \frac{1 \text{ mol}}{44.09 \text{ g}} = 0.2268 \text{ mol C}_3\text{H}_8$$

$$10.0 \text{ g O}_2 \times \frac{1 \text{ mol}}{32.00 \text{ g}} = 0.3125 \text{ mol O}_2$$

For 0.2268 mol  $\text{C}_3\text{H}_8$ , the amount of  $\text{O}_2$  that would be needed is

$$0.2268 \text{ mol C}_3\text{H}_8 \times \frac{5 \text{ mol O}_2}{1 \text{ mol C}_3\text{H}_8} = 1.134 \text{ mol O}_2$$

Because we do not have this amount of  $\text{O}_2$ , then  $\text{O}_2$  is the limiting reactant.

$$0.3125 \text{ mol O}_2 \times \frac{3 \text{ mol CO}_2}{5 \text{ mol O}_2} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 8.25 \text{ g CO}_2$$

$$0.3125 \text{ mol O}_2 \times \frac{4 \text{ mol H}_2\text{O}}{5 \text{ mol O}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 4.51 \text{ g H}_2\text{O}$$



molar masses:  $\text{Al}$ , 26.98 g;  $\text{Cl}_2$ , 70.90 g;  $\text{AlCl}_3$ , 133.3 g

$$10.0 \text{ g Al} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 0.3706 \text{ mol Al}$$

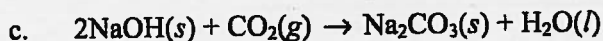
$$10.0 \text{ g Cl}_2 \times \frac{1 \text{ mol}}{70.90 \text{ g}} = 0.1410 \text{ mol Cl}_2$$

For 0.1410 mol  $\text{Cl}_2(\text{g})$ , the amount of  $\text{Al}(\text{s})$  required is

$$0.1410 \text{ mol Cl}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol Cl}_2} = 0.09400 \text{ mol Al}$$

We have far more than this amount of  $\text{Al}(s)$  present, so  $\text{Cl}_2(g)$  must be the limiting reactant that will control the amount of  $\text{AlCl}_3$  that forms.

$$0.1410 \text{ mol Cl}_2 \times \frac{2 \text{ mol AlCl}_3}{3 \text{ mol Cl}_2} \times \frac{133.3 \text{ g AlCl}_3}{1 \text{ mol AlCl}_3} = 12.5 \text{ g AlCl}_3$$



molar masses:  $\text{NaOH}$ , 40.00 g;  $\text{CO}_2$ , 44.01 g;  $\text{Na}_2\text{CO}_3$ , 106.0 g;  $\text{H}_2\text{O}$ , 18.02 g

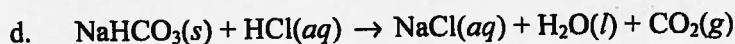
$$10.0 \text{ g NaOH} \times \frac{1 \text{ mol}}{40.00 \text{ g}} = 0.2500 \text{ mol NaOH}$$

$$10.0 \text{ g CO}_2 \times \frac{1 \text{ mol}}{44.01 \text{ g}} = 0.2272 \text{ mol CO}_2$$

Without having to calculate, according to the balanced chemical equation we would need *twice* as many moles of  $\text{NaOH}$  as  $\text{CO}_2$  for complete reaction. For the amounts calculated above, there is not nearly enough  $\text{NaOH}$  present for the amount of  $\text{Cl}_2$  used;  $\text{NaOH}$  is the limiting reactant.

$$0.2500 \text{ mol NaOH} \times \frac{1 \text{ mol Na}_2\text{CO}_3}{2 \text{ mol NaOH}} \times \frac{106.0 \text{ g Na}_2\text{CO}_3}{1 \text{ mol Na}_2\text{CO}_3} = 13.3 \text{ g Na}_2\text{CO}_3$$

$$0.2500 \text{ mol NaOH} \times \frac{1 \text{ mol H}_2\text{O}}{2 \text{ mol NaOH}} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 2.25 \text{ g H}_2\text{O}$$



molar masses:  $\text{NaHCO}_3$ , 84.01 g;  $\text{HCl}$ , 36.46 g;  $\text{NaCl}$ , 58.44 g;  $\text{H}_2\text{O}$ , 18.02 g;  $\text{CO}_2$ , 44.01 g

$$10.0 \text{ g NaHCO}_3 \times \frac{1 \text{ mol}}{84.01 \text{ g}} = 0.1190 \text{ mol NaHCO}_3$$

$$10.0 \text{ g HCl} \times \frac{1 \text{ mol}}{36.46 \text{ g}} = 0.2742 \text{ mol HCl}$$

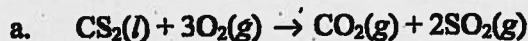
Because the coefficients of  $\text{NaHCO}_3(s)$  and  $\text{HCl}(aq)$  are both *one* in the balanced chemical equation for the reaction, there is not enough  $\text{NaHCO}_3$  present to react with the amount of  $\text{HCl}$  present: the 0.1190 mol  $\text{NaHCO}_3$  present is the limiting reactant. Because all the coefficients of the products are also each *one*, then if 0.1190 mol  $\text{NaHCO}_3$  reacts completely (with 0.1190 mol  $\text{HCl}$ ), 0.1190 mol of each product will form.

$$0.1190 \text{ mol NaCl} \times \frac{58.44 \text{ g}}{1 \text{ mol}} = 6.95 \text{ g NaCl}$$

$$0.1190 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g}}{1 \text{ mol}} = 2.14 \text{ g H}_2\text{O}$$

$$0.1190 \text{ mol CO}_2 \times \frac{44.01 \text{ g}}{1 \text{ mol}} = 5.24 \text{ g CO}_2$$

48.



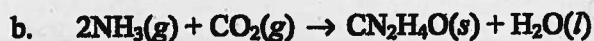
Molar masses:  $\text{CS}_2$ , 76.15 g;  $\text{O}_2$ , 32.00 g;  $\text{CO}_2$ , 44.01 g

$$1.00 \text{ g CS}_2 \times \frac{1 \text{ mol}}{76.15 \text{ g}} = 0.01313 \text{ mol CS}_2$$

$$1.00 \text{ g O}_2 \times \frac{1 \text{ mol}}{32.00 \text{ g}} = 0.03125 \text{ mol O}_2$$

From the balanced chemical equation, we would need three times as much oxygen as carbon disulfide for complete reaction of both reactants. We do not have this much oxygen, and so oxygen must be the limiting reactant.

$$0.03125 \text{ mol O}_2 \times \frac{1 \text{ mol CO}_2}{3 \text{ mol O}_2} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 0.458 \text{ g CO}_2$$



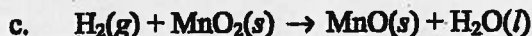
Molar masses:  $\text{NH}_3$ , 17.03 g;  $\text{CO}_2$ , 44.01 g;  $\text{H}_2\text{O}$ , 18.02 g

$$1.00 \text{ g NH}_3 \times \frac{1 \text{ mol}}{17.03 \text{ g}} = 0.05872 \text{ mol NH}_3$$

$$1.00 \text{ g CO}_2 \times \frac{1 \text{ mol}}{44.01 \text{ g}} = 0.02272 \text{ mol CO}_2$$

The balanced chemical equation tells us that we would need twice as many moles of ammonia as carbon dioxide for complete reaction of both reactants. We have *more* than this amount of ammonia present, so the reaction will be limited by the amount of carbon dioxide present.

$$0.02272 \text{ mol CO}_2 \times \frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol CO}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.409 \text{ g H}_2\text{O}$$



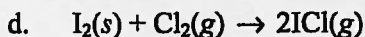
Molar masses:  $\text{H}_2$ , 2.016 g;  $\text{MnO}_2$ , 86.94 g;  $\text{H}_2\text{O}$ , 18.02 g

$$1.00 \text{ g H}_2 \times \frac{1 \text{ mol}}{2.016 \text{ g}} = 0.496 \text{ mol H}_2$$

$$1.00 \text{ g MnO}_2 \times \frac{1 \text{ mol}}{86.94 \text{ g}} = 0.0115 \text{ mol MnO}_2$$

Because the coefficients of both reactants in the balanced chemical equation are the same, we would need equal amounts of both reactants for complete reaction. Therefore manganese(IV) oxide must be the limiting reactant and controls the amount of product obtained.

$$0.0115 \text{ mol MnO}_2 \times \frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol MnO}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.207 \text{ g H}_2\text{O}$$



Molar masses:  $\text{I}_2$ , 253.8 g;  $\text{Cl}_2$ , 70.90 g;  $\text{ICl}$ , 162.35 g

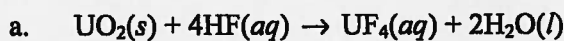
$$1.00 \text{ g I}_2 \times \frac{1 \text{ mol}}{253.8 \text{ g}} = 0.00394 \text{ mol I}_2$$

$$1.00 \text{ g Cl}_2 \times \frac{1 \text{ mol}}{70.90 \text{ g}} = 0.0141 \text{ mol Cl}_2$$

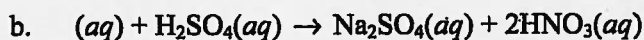
From the balanced chemical equation, we would need equal amounts of  $\text{I}_2$  and  $\text{Cl}_2$  for complete reaction of both reactants. As we have much less iodine than chlorine, iodine must be the limiting reactant.

$$0.00394 \text{ mol I}_2 \times \frac{2 \text{ mol ICl}}{1 \text{ mol I}_2} \times \frac{162.35 \text{ g ICl}}{1 \text{ mol ICl}} = 1.28 \text{ g ICl}$$

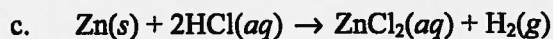
49.



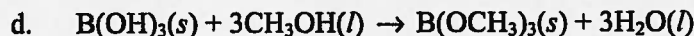
$\text{UO}_2$  is the limiting reactant; 1.16 g  $\text{UF}_4$ , 0.133 g  $\text{H}_2\text{O}$



$\text{NaNO}_3$  is the limiting reactant; 0.836 g  $\text{Na}_2\text{SO}_4$ ; 0.741 g  $\text{HNO}_3$

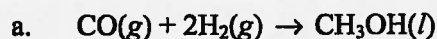


$\text{HCl}$  is the limiting reactant; 1.87 g  $\text{ZnCl}_2$ ; 0.0276 g  $\text{H}_2$

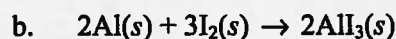


$\text{CH}_3\text{OH}$  is the limiting reactant; 1.08 g  $\text{B}(\text{OCH}_3)_3$ ; 0.562 g  $\text{H}_2\text{O}$

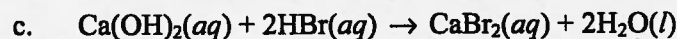
50.



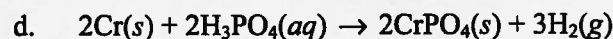
$\text{CO}$  is the limiting reactant; 11.4 mg  $\text{CH}_3\text{OH}$



$\text{I}_2$  is the limiting reactant; 10.7 mg  $\text{AlI}_3$



$\text{HBr}$  is the limiting reactant; 12.4 mg  $\text{CaBr}_2$ ; 2.23 mg  $\text{H}_2\text{O}$



$\text{H}_3\text{PO}_4$  is the limiting reactant; 15.0 mg  $\text{CrPO}_4$ ; 0.309 mg  $\text{H}_2$



molar masses:  $\text{KI}$ , 166.0 g;  $\text{Pb}(\text{NO}_3)_2$ , 331.2 g;  $\text{PbI}$ , 334.1 g

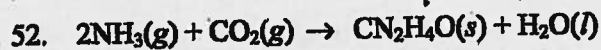
$$1.25 \text{ g KI} \times \frac{1 \text{ mol}}{166.0 \text{ g}} = 0.007530 \text{ mol KI}$$

$$2.42 \text{ g Pb}(\text{NO}_3)_2 \times \frac{1 \text{ mol}}{331.2 \text{ g}} = 0.007306 \text{ mol}$$



KI is the limiting reactant that determines the yield of product.

$$0.007530 \text{ mol KI} \times \frac{1 \text{ mol PbI}}{2 \text{ mol KI}} \times \frac{334.1 \text{ g PbI}}{1 \text{ mol PbI}} = 1.26 \text{ g PbI}$$



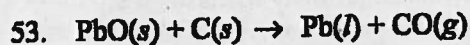
molar masses:  $\text{NH}_3$ , 17.03 g;  $\text{CO}_2$ , 44.01 g;  $\text{CN}_2\text{H}_4\text{O}$ , 60.06 g

$$100. \text{ g NH}_3 \times \frac{1 \text{ mol}}{17.03 \text{ g}} = 5.872 \text{ mol NH}_3$$

$$100. \text{ g CO}_2 \times \frac{1 \text{ mol}}{44.01 \text{ g}} = 2.272 \text{ mol CO}_2$$

$\text{CO}_2$  is the limiting reactant that determines the yield of product.

$$2.272 \text{ mol CO}_2 \times \frac{1 \text{ mol CN}_2\text{H}_4\text{O}}{1 \text{ mol CO}_2} \times \frac{60.06 \text{ g CN}_2\text{H}_4\text{O}}{1 \text{ mol CN}_2\text{H}_4\text{O}} = 136 \text{ g CN}_2\text{H}_4\text{O}$$



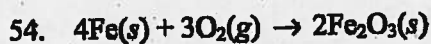
molar masses:  $\text{PbO}$ , 223.2 g;  $\text{C}$ , 12.01 g;  $\text{Pb}$ , 207.2 g

$$50.0 \times 10^3 \text{ g PbO} \times \frac{1 \text{ mol}}{223.2 \text{ g}} = 224.0 \text{ mol PbO}$$

$$50.0 \times 10^3 \text{ g C} \times \frac{1 \text{ mol}}{12.01 \text{ g}} = 4163 \text{ mol C}$$

$\text{PbO}$  is the limiting reactant.

$$224.0 \text{ mol PbO} \times \frac{1 \text{ mol Pb}}{1 \text{ mol PbO}} \times \frac{207.2 \text{ g Pb}}{1 \text{ mol Pb}} = 4.64 \times 10^4 \text{ g} = 46.4 \text{ kg Pb}$$



Molar masses:  $\text{Fe}$ , 55.85 g;  $\text{Fe}_2\text{O}_3$ , 159.7 g

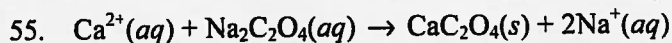
$$1.25 \text{ g Fe} \times \frac{1 \text{ mol}}{55.85 \text{ g}} = 0.0224 \text{ mol Fe present}$$

Calculate how many mol of  $\text{O}_2$  are required to react with this amount of  $\text{Fe}$

$$0.0224 \text{ mol Fe} \times \frac{3 \text{ mol O}_2}{4 \text{ mol Fe}} = 0.0168 \text{ mol O}_2$$

Because we have more  $\text{O}_2$  than this,  $\text{Fe}$  must be the limiting reactant.

$$0.0224 \text{ mol Fe} \times \frac{2 \text{ mol Fe}_2\text{O}_3}{4 \text{ mol Fe}} \times \frac{159.7 \text{ g Fe}_2\text{O}_3}{1 \text{ mol Fe}_2\text{O}_3} = 1.79 \text{ g Fe}_2\text{O}_3$$

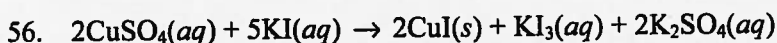


molar masses:  $\text{Ca}^{2+}$ , 40.08 g;  $\text{Na}_2\text{C}_2\text{O}_4$ , 134.0 g

$$15 \text{ g Ca}^{2+} \times \frac{1 \text{ mol}}{40.08 \text{ g}} = 0.37 \text{ mol Ca}^{2+}$$

$$15 \text{ g Na}_2\text{C}_2\text{O}_4 \times \frac{1 \text{ mol}}{134.0 \text{ g}} = 0.11 \text{ mol Na}_2\text{C}_2\text{O}_4$$

As the balanced chemical equation tells us that one oxalate ion is needed to precipitate each calcium ion, from the number of moles calculated to be present it should be clear that not nearly enough sodium oxalate ion has been added to precipitate all the calcium ion in the sample.



molar masses:  $\text{CuSO}_4$ , 159.6 g;  $\text{KI}$ , 166.0 g;  $\text{CuI}$ , 190.5 g;  $\text{KI}_3$ , 419.8 g;  $\text{K}_2\text{SO}_4$ , 174.3 g

$$0.525 \text{ g CuSO}_4 \times \frac{1 \text{ mol}}{159.6 \text{ g}} = 3.29 \times 10^{-3} \text{ mol CuSO}_4$$

$$2.00 \text{ g KI} \times \frac{1 \text{ mol}}{166.0 \text{ g}} = 0.0120 \text{ mol KI}$$

To determine the limiting reactant, let's calculate what amount of  $\text{KI}$  would be needed to react with the given amount of  $\text{CuSO}_4$  present.

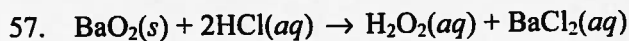
$$3.29 \times 10^{-3} \text{ mol CuSO}_4 \times \frac{5 \text{ mol KI}}{2 \text{ mol CuSO}_4} = 8.23 \times 10^{-3} \text{ mol KI}$$

As we have more  $\text{KI}$  present than the amount required to react with the  $\text{CuSO}_4$  present,  $\text{CuSO}_4$  must be the limiting reactant that will control the amount of products produced.

$$3.29 \times 10^{-3} \text{ mol CuSO}_4 \times \frac{2 \text{ mol CuI}}{2 \text{ mol CuSO}_4} \times \frac{190.5 \text{ g CuI}}{1 \text{ mol CuI}} = 0.627 \text{ g CuI}$$

$$3.29 \times 10^{-3} \text{ mol CuSO}_4 \times \frac{1 \text{ mol KI}_3}{2 \text{ mol CuSO}_4} \times \frac{419.8 \text{ g KI}_3}{1 \text{ mol KI}_3} = 0.691 \text{ g KI}_3$$

$$3.29 \times 10^{-3} \text{ mol CuSO}_4 \times \frac{2 \text{ mol K}_2\text{SO}_4}{2 \text{ mol CuSO}_4} \times \frac{174.3 \text{ g K}_2\text{SO}_4}{1 \text{ mol K}_2\text{SO}_4} = 0.573 \text{ g K}_2\text{SO}_4$$



molar masses:  $\text{BaO}_2$ , 169.3 g;  $\text{HCl}$ , 36.46 g;  $\text{H}_2\text{O}_2$ , 34.02 g

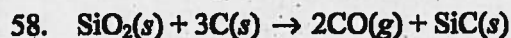
$$1.50 \text{ g BaO}_2 \times \frac{1 \text{ mol}}{169.3 \text{ g}} = 8.860 \times 10^{-3} \text{ mol BaO}_2$$

$$25.0 \text{ mL solution} \times \frac{0.0272 \text{ g HCl}}{1 \text{ mL solution}} = 0.680 \text{ g HCl}$$

$$0.680 \text{ g HCl} \times \frac{1 \text{ mol}}{36.46 \text{ g}} = 1.865 \times 10^{-2} \text{ mol HCl}$$

BaO<sub>2</sub> is the limiting reactant.

$$8.860 \times 10^{-3} \text{ mol BaO}_2 \times \frac{1 \text{ mol H}_2\text{O}_2}{1 \text{ mol BaO}_2} \times \frac{34.02 \text{ g H}_2\text{O}_2}{1 \text{ mol H}_2\text{O}_2} = 0.301 \text{ g H}_2\text{O}_2$$



molar masses: SiO<sub>2</sub>, 60.09 g; SiC, 40.10 g; 1.0 kg = 1.0 × 10<sup>3</sup> g

$$1.0 \times 10^3 \text{ g SiO}_2 \times \frac{1 \text{ mol}}{60.09 \text{ g}} = 16.64 \text{ mol SiO}_2$$

From the balanced chemical equation, if 16.64 mol of SiO<sub>2</sub> were to react completely (an excess of carbon is present), then 16.64 mol of SiC should be produced (the coefficients of SiO<sub>2</sub> and SiC are the same).

$$16.64 \text{ mol SiC} \times \frac{40.01 \text{ g}}{1 \text{ mol}} = 6.7 \times 10^2 \text{ g SiC} = 0.67 \text{ kg SiC}$$

59. The *theoretical yield* represents the yield we calculate from the stoichiometry of the reaction and the masses of reactants taken for the experiment. The *actual yield* is what is actually obtained in an experiment. The *percent yield* is the ratio of what is actually obtained to the theoretical amount that could be obtained, converted to a percent basis.
60. If the reaction is performed in a solvent, the product may have substantial solubility in the solvent and the reaction may come to equilibrium before the full yield of product is achieved (See Chapter 17.). Loss of product may occur through operator error.

61.  $\text{Percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{1.23 \text{ g}}{1.44 \text{ g}} \times 100 = 85.4\%$

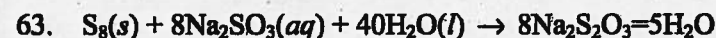


molar masses: HgO, 216.6 g; Hg, 200.6 g

$$1.25 \text{ g HgO} \times \frac{1 \text{ mol}}{216.6 \text{ g}} = 0.005771 \text{ mol HgO}$$

$$0.005771 \text{ mol HgO} \times \frac{2 \text{ mol Hg}}{2 \text{ mol HgO}} \times \frac{200.6 \text{ g Hg}}{1 \text{ mol Hg}} = 1.16 \text{ g (theoretical yield)}$$

$$\% \text{ yield} = \frac{1.09 \text{ g actual}}{1.16 \text{ g theoretical}} \times 100 = 94.0\% \text{ of theory}$$



molar masses: S<sub>8</sub>, 256.6 g; Na<sub>2</sub>SO<sub>3</sub>, 126.1 g; Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> + 5H<sub>2</sub>O, 248.2 g

$$3.25 \text{ g S}_8 \times \frac{1 \text{ mol}}{256.6 \text{ g}} = 0.01267 \text{ mol S}_8$$

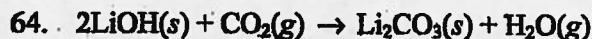
$$13.1 \text{ g Na}_2\text{SO}_3 \times \frac{1 \text{ mol}}{126.1 \text{ g}} = 0.1039 \text{ mol Na}_2\text{SO}_3$$

S<sub>8</sub> is the limiting reactant.

$$0.01267 \text{ mol S}_8 \times \frac{8 \text{ mol Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}}{1 \text{ mol S}_8} = 0.1014 \text{ mol Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$$

$$0.1014 \text{ mol Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O} \times \frac{248.2 \text{ g Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}}{1 \text{ mol Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}} = 25.2 \text{ g Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$$

$$\text{Percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{5.26 \text{ g}}{25.2 \text{ g}} \times 100 = 20.9\%$$

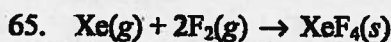


molar masses: LiOH, 23.95 g; CO<sub>2</sub>, 44.01 g

$$155 \text{ g LiOH} \times \frac{1 \text{ mol LiOH}}{23.95 \text{ g LiOH}} \times \frac{1 \text{ mol CO}_2}{2 \text{ mol LiOH}} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 142 \text{ g CO}_2$$

As the cartridge has only absorbed 102 g CO<sub>2</sub> out of a total capacity of 142 g CO<sub>2</sub>, the cartridge has absorbed

$$\frac{102 \text{ g}}{142 \text{ g}} \times 100 = 71.8\% \text{ of its capacity.}$$



molar masses: Xe, 131.3 g; F<sub>2</sub>, 38.00 g; XeF<sub>4</sub>, 207.3 g

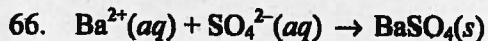
$$130. \text{ g Xe} \times \frac{1 \text{ mol}}{131.3 \text{ g}} = 0.9901 \text{ mol Xe}$$

$$100. \text{ g F}_2 \times \frac{1 \text{ mol}}{38.00 \text{ g}} = 2.632 \text{ mol F}_2$$

Xe is the limiting reactant.

$$0.9901 \text{ mol Xe} \times \frac{1 \text{ mol XeF}_4}{1 \text{ mol Xe}} \times \frac{207.3 \text{ g XeF}_4}{1 \text{ mol XeF}_4} = 205 \text{ g XeF}_4$$

$$\text{Percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{145 \text{ g}}{205 \text{ g}} \times 100 = 70.7\% \text{ of theory}$$



molar masses: SO<sub>4</sub><sup>2-</sup>, 96.07 g; BaCl<sub>2</sub>, 208.2 g; BaSO<sub>4</sub>, 233.4 g

$$1.12 \text{ g SO}_4^{2-} \times \frac{1 \text{ mol}}{96.07 \text{ g}} = 0.01166 \text{ mol SO}_4^{2-}$$

$$5.02 \text{ g BaCl}_2 \times \frac{1 \text{ mol}}{208.2 \text{ g}} = 0.02411 \text{ mol BaCl}_2 = 0.02411 \text{ mol Ba}^{2+}$$

SO<sub>4</sub><sup>2-</sup> is the limiting reactant.

$$0.01166 \text{ mol SO}_4^{2-} \times \frac{1 \text{ mol BaSO}_4}{1 \text{ mol SO}_4^{2-}} \times \frac{233.4 \text{ g BaSO}_4}{1 \text{ mol BaSO}_4} = 2.72 \text{ g BaSO}_4$$

$$\text{Percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{2.02 \text{ g}}{2.72 \text{ g}} \times 100 = 74.3\%$$

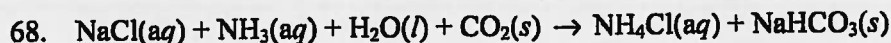


millimolar masses:  $\text{Ca}(\text{HCO}_3)_2$ , 162.1 mg;  $\text{CaCO}_3$ , 100.1 mg

$$2.0 \times 10^{-3} \text{ mg Ca}(\text{HCO}_3)_2 \times \frac{1 \text{ mmol}}{162.1 \text{ mg}} = 1.23 \times 10^{-5} \text{ mmol Ca}(\text{HCO}_3)_2$$

$$1.23 \times 10^{-5} \text{ mmol Ca}(\text{HCO}_3)_2 \times \frac{1 \text{ mmol CaCO}_3}{1 \text{ mmol Ca}(\text{HCO}_3)_2} = 1.23 \times 10^{-5} \text{ mmol CaCO}_3$$

$$1.23 \times 10^{-5} \text{ mmol} \times \frac{100.1 \text{ mg}}{1 \text{ mmol}} = 1.2 \times 10^{-3} \text{ mg} = 1.2 \times 10^{-6} \text{ g CaCO}_3$$



molar masses:  $\text{NH}_3$ , 17.03 g;  $\text{CO}_2$ , 44.01 g;  $\text{NaHCO}_3$ , 84.01 g

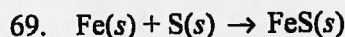
$$10.0 \text{ g NH}_3 \times \frac{1 \text{ mol}}{17.03 \text{ g}} = 0.5872 \text{ mol NH}_3$$

$$15.0 \text{ g CO}_2 \times \frac{1 \text{ mol}}{44.01 \text{ g}} = 0.3408 \text{ mol CO}_2$$

$\text{CO}_2$  is the limiting reactant.

$$0.3408 \text{ mol CO}_2 \times \frac{1 \text{ mol NaHCO}_3}{1 \text{ mol CO}_2} = 0.3408 \text{ mol NaHCO}_3$$

$$0.3408 \text{ mol NaHCO}_3 \times \frac{84.01 \text{ g}}{1 \text{ mol}} = 28.6 \text{ g NaHCO}_3$$



molar masses: Fe, 55.85 g; S, 32.07 g; FeS, 87.92 g

$$5.25 \text{ g Fe} \times \frac{1 \text{ mol}}{55.85 \text{ g}} = 0.0940 \text{ mol Fe}$$

$$12.7 \text{ g S} \times \frac{1 \text{ mol}}{32.07 \text{ g}} = 0.396 \text{ mol S}$$

Fe is the limiting reactant.

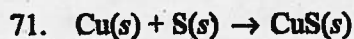
$$0.0940 \text{ mol Fe} \times \frac{1 \text{ mol FeS}}{1 \text{ mol Fe}} \times \frac{87.92 \text{ g FeS}}{1 \text{ mol FeS}} = 8.26 \text{ g FeS produced}$$

molar masses: glucose, 180.2 g;  $CO_2$ , 44.01 g

$$1.00 \text{ g glucose} \times = 5.549 \times 10^{-3} \text{ mol glucose}$$

$$5.549 \times 10^{-3} \text{ mol glucose} \times \frac{6 \text{ mol } CO_2}{1 \text{ mol glucose}} = 3.33 \times 10^{-2} \text{ mol } CO_2$$

$$3.33 \times 10^{-2} \text{ mol } CO_2 \times \frac{44.01 \text{ g}}{1 \text{ mol}} = 1.47 \text{ g } CO_2$$



molar masses: Cu, 63.55 g; S, 32.07 g; CuS, 95.62 g

$$31.8 \text{ g Cu} \times \frac{1 \text{ mol}}{63.55 \text{ g}} = 0.5004 \text{ mol Cu}$$

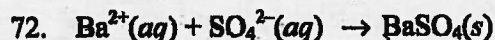
$$50.0 \text{ g S} \times \frac{1 \text{ mol}}{32.07 \text{ g}} = 1.559 \text{ mol S}$$

Cu is the limiting reactant.

$$0.5004 \text{ mol Cu} \times \frac{1 \text{ mol CuS}}{1 \text{ mol Cu}} = 0.5004 \text{ mol CuS}$$

$$0.5004 \text{ mol CuS} \times \frac{95.62 \text{ g}}{1 \text{ mol}} = 47.8 \text{ g CuS}$$

$$\% \text{ yield} = \frac{40.0 \text{ g}}{47.8 \text{ g}} \times 100 = 83.7\%$$

millimolar ionic masses:  $Ba^{2+}$ , 137.3 mg;  $SO_4^{2-}$ , 96.07 mg;  $BaCl_2$ , 208.2 mg

$$150 \text{ mg } SO_4^{2-} \times \frac{1 \text{ mmol}}{96.07 \text{ mg}} = 1.56 \text{ millimol } SO_4^{2-}$$

As barium ion and sulfate ion react on a 1:1 stoichiometric basis, then 1.56 millimol of barium ion is needed, which corresponds to 1.56 millimol of  $BaCl_2$ .

$$1.56 \text{ millimol } BaCl_2 \times \frac{208.2 \text{ mg}}{1 \text{ mmol}} = 325 \text{ milligrams } BaCl_2 \text{ needed}$$

$$73. \text{ mass of Cl}^- \text{ present} = 1.054 \text{ g sample} \times \frac{10.3 \text{ g Cl}^-}{100.0 \text{ g sample}} = 0.1086 \text{ g Cl}^-$$

molar masses:  $\text{Cl}^-$ , 35.45 g;  $\text{AgNO}_3$ , 169.9 g;  $\text{AgCl}$ , 143.4 g

$$0.1086 \text{ g Cl}^- \times \frac{1 \text{ mol}}{35.45 \text{ g}} = 3.063 \times 10^{-3} \text{ mol Cl}^-$$

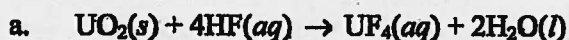
$$3.063 \times 10^{-3} \text{ mol Cl}^- \times \frac{1 \text{ mol AgNO}_3}{1 \text{ mol Cl}^-} = 3.063 \times 10^{-3} \text{ mol AgNO}_3$$

$$3.063 \times 10^{-3} \text{ mol AgNO}_3 \times \frac{169.9 \text{ g}}{1 \text{ mol}} = 0.520 \text{ g AgNO}_3 \text{ required}$$

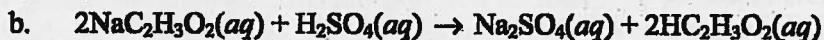
$$3.063 \times 10^{-3} \text{ mol Cl}^- \times \frac{1 \text{ mol AgCl}}{1 \text{ mol Cl}^-} = 3.063 \times 10^{-3} \text{ mol AgCl}$$

$$3.063 \times 10^{-3} \text{ mol AgCl} \times \frac{143.4 \text{ g}}{1 \text{ mol}} = 0.439 \text{ g AgCl produced}$$

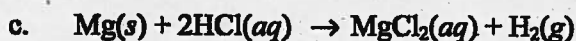
74.



One molecule (formula unit) of uranium(IV) oxide will combine with four molecules of hydrofluoric acid, producing one uranium(IV) fluoride molecule and two water molecules. One mole of uranium(IV) oxide will combine with four moles of hydrofluoric acid to produce one mole of uranium(IV) fluoride and two moles of water.



Two molecules (formula units) of sodium acetate react exactly with one molecule of sulfuric acid, producing one molecule (formula unit) of sodium sulfate and two molecules of acetic acid. Two moles of sodium acetate will combine with one mole of sulfuric acid, producing one mole of sodium sulfate and two moles of acetic acid.



One magnesium atom will react with two hydrochloric acid molecules (formula units) to produce one molecule (formula unit) of magnesium chloride and one molecule of hydrogen gas. One mole of magnesium will combine with two moles of hydrochloric acid, producing one mole of magnesium chloride and one mole of gaseous hydrogen.

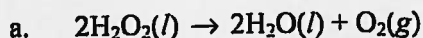


One molecule of diboron trioxide will react exactly with three molecules of water, producing two molecules of boron trihydroxide (boric acid). One mole of diboron trioxide will combine with three moles of water to produce two moles of boron trihydroxide (boric acid).

75. False. For 0.40 mol of  $\text{Mg}(\text{OH})_2$  to react, 0.80 mol of  $\text{HCl}$  will be needed. According to the balanced equation, for a given amount of  $\text{Mg}(\text{OH})_2$ , twice as many moles of  $\text{HCl}$  is needed.

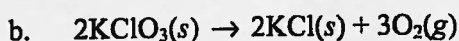
$$76. \text{ For O}_2: \left( \frac{5 \text{ mol O}_2}{1 \text{ mol C}_3\text{H}_8} \right) \quad \text{For CO}_2: \left( \frac{3 \text{ mol CO}_2}{1 \text{ mol C}_3\text{H}_8} \right) \quad \text{For H}_2\text{O}: \left( \frac{4 \text{ mol H}_2\text{O}}{1 \text{ mol C}_3\text{H}_8} \right)$$

77.



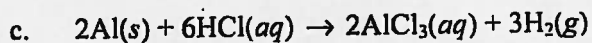
$$0.50 \text{ mol H}_2\text{O}_2 \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol H}_2\text{O}_2} = 0.50 \text{ mol H}_2\text{O}$$

$$0.50 \text{ mol H}_2\text{O}_2 \times \frac{1 \text{ mol O}_2}{2 \text{ mol H}_2\text{O}_2} = 0.25 \text{ mol O}_2$$



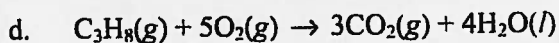
$$0.50 \text{ mol KClO}_3 \times \frac{2 \text{ mol KCl}}{2 \text{ mol KClO}_3} = 0.50 \text{ mol KCl}$$

$$0.50 \text{ mol KClO}_3 \times \frac{3 \text{ mol O}_2}{2 \text{ mol KClO}_3} = 0.75 \text{ mol O}_2$$



$$0.50 \text{ mol Al} \times \frac{2 \text{ mol AlCl}_3}{2 \text{ mol Al}} = 0.50 \text{ mol AlCl}_3$$

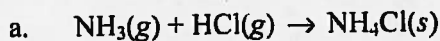
$$0.50 \text{ mol Al} \times \frac{3 \text{ mol H}_2}{2 \text{ mol Al}} = 0.75 \text{ mol H}_2$$



$$0.50 \text{ mol C}_3\text{H}_8 \times \frac{3 \text{ mol CO}_2}{1 \text{ mol C}_3\text{H}_8} = 1.5 \text{ mol CO}_2$$

$$0.50 \text{ mol C}_3\text{H}_8 \times \frac{4 \text{ mol H}_2\text{O}}{1 \text{ mol C}_3\text{H}_8} = 2.0 \text{ mol H}_2\text{O}$$

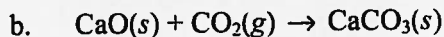
78.



molar mass of  $\text{NH}_3 = 17.01 \text{ g}$

$$1.00 \text{ g NH}_3 \times \frac{1 \text{ mol}}{17.01 \text{ g}} = 0.0588 \text{ mol NH}_3$$

$$0.0588 \text{ mol NH}_3 \times \frac{1 \text{ mol NH}_4\text{Cl}}{1 \text{ mol NH}_3} = 0.0588 \text{ mol NH}_4\text{Cl}$$



molar mass  $\text{CaO} = 56.08 \text{ g}$

$$1.00 \text{ g CaO} \times \frac{1 \text{ mol}}{56.08 \text{ g}} = 0.0178 \text{ mol CaO}$$

$$0.0178 \text{ mol CaO} \times \frac{1 \text{ mol CaCO}_3}{1 \text{ mol CaO}} = 0.0178 \text{ mol CaCO}_3$$





molar mass Na = 22.99 g

$$1.00 \text{ g Na} \times \frac{1 \text{ mol}}{22.99 \text{ g}} = 0.0435 \text{ mol Na}$$

$$0.0435 \text{ mol Na} \times \frac{2 \text{ mol Na}_2\text{O}}{4 \text{ mol Na}} = 0.0217 \text{ mol Na}_2\text{O}$$



molar mass P = 30.97 g

$$1.00 \text{ g P} \times \frac{1 \text{ mol}}{30.97 \text{ g}} = 0.0323 \text{ mol P}$$

$$0.0323 \text{ mol P} \times \frac{2 \text{ mol PCl}_3}{2 \text{ mol P}} = 0.0323 \text{ mol PCl}_3$$

79.

a. molar mass  $\text{CuSO}_4 = 159.6 \text{ g}$

$$4.21 \text{ g CuSO}_4 \times \frac{1 \text{ mol}}{159.6 \text{ g}} = 0.0264 \text{ mol CuSO}_4$$

b. molar mass  $\text{Ba}(\text{NO}_3)_2 = 261.3 \text{ g}$

$$7.94 \text{ g Ba}(\text{NO}_3)_2 \times \frac{1 \text{ mol}}{261.3 \text{ g}} = 0.0304 \text{ mol Ba}(\text{NO}_3)_2$$

c. molar mass water = 18.02 g; 1.24 mg = 0.00124 g

$$0.00124 \text{ g} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 6.88 \times 10^{-5} \text{ mol H}_2\text{O}$$

d. molar mass W = 183.9 g

$$9.79 \text{ g W} \times \frac{1 \text{ mol}}{183.9 \text{ g}} = 5.32 \times 10^{-2} \text{ mol W}$$

e. molar mass S = 32.07 g; 1.45 lb = 1.45(454) = 658 g

$$658 \text{ g S} \times \frac{1 \text{ mol}}{32.07 \text{ g}} = 20.5 \text{ mol S}$$

f. molar mass  $\text{C}_2\text{H}_5\text{OH} = 46.07 \text{ g}$

$$4.65 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol}}{46.07 \text{ g}} = 0.101 \text{ mol C}_2\text{H}_5\text{OH}$$

g. molar mass C = 12.01 g

$$12.01 \text{ g C} \times \frac{1 \text{ mol}}{12.01 \text{ g}} = 1.00 \text{ mol C}$$

80.

a. molar mass  $\text{HNO}_3 = 63.0 \text{ g}$ 

$$5.0 \text{ mol HNO}_3 \times \frac{63.0 \text{ g}}{1 \text{ mol}} = 3.2 \times 10^2 \text{ g HNO}_3$$

b. molar mass  $\text{Hg} = 200.6 \text{ g}$ 

$$0.000305 \text{ mol Hg} \times \frac{200.6 \text{ g}}{1 \text{ mol}} = 0.0612 \text{ g Hg}$$

c. molar mass  $\text{K}_2\text{CrO}_4 = 194.2 \text{ g}$ 

$$2.31 \times 10^{-5} \text{ mol K}_2\text{CrO}_4 \times \frac{194.2 \text{ g}}{1 \text{ mol}} = 4.49 \times 10^{-3} \text{ g K}_2\text{CrO}_4$$

d. molar mass  $\text{AlCl}_3 = 133.3 \text{ g}$ 

$$10.5 \text{ mol AlCl}_3 \times \frac{133.3 \text{ g}}{1 \text{ mol}} = 1.40 \times 10^3 \text{ g AlCl}_3$$

e. molar mass  $\text{SF}_6 = 146.1 \text{ g}$ 

$$4.9 \times 10^4 \text{ mol SF}_6 \times \frac{146.1 \text{ g}}{1 \text{ mol}} = 7.2 \times 10^6 \text{ g SF}_6$$

f. molar mass  $\text{NH}_3 = 17.01 \text{ g}$ 

$$125 \text{ mol NH}_3 \times \frac{17.01 \text{ g}}{1 \text{ mol}} = 2.13 \times 10^3 \text{ g NH}_3$$

g. molar mass  $\text{Na}_2\text{O}_2 = 77.98 \text{ g}$ 

$$0.01205 \text{ mol Na}_2\text{O}_2 \times \frac{77.98 \text{ g}}{1 \text{ mol}} = 0.9397 \text{ g Na}_2\text{O}_2$$

81. Before any calculations are done, the equations must be *balanced*.a.  $\text{BaCl}_2(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{BaSO}_4(s) + 2\text{HCl}(aq)$ 

$$0.145 \text{ mol BaCl}_2 \times \frac{1 \text{ mol H}_2\text{SO}_4}{1 \text{ mol BaCl}_2} = 0.145 \text{ mol H}_2\text{SO}_4$$

b.  $\text{AgNO}_3(aq) + \text{NaCl}(aq) \rightarrow \text{AgCl}(s) + \text{NaNO}_3(aq)$ 

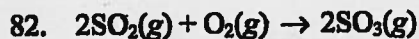
$$0.145 \text{ mol AgNO}_3 \times \frac{1 \text{ mol NaCl}}{1 \text{ mol AgNO}_3} = 0.145 \text{ mol NaCl}$$

c.  $\text{Pb}(\text{NO}_3)_2(aq) + \text{Na}_2\text{CO}_3(aq) \rightarrow \text{PbCO}_3(s) + 2\text{NaNO}_3(aq)$ 

$$0.145 \text{ mol Pb}(\text{NO}_3)_2 \times \frac{1 \text{ mol Na}_2\text{CO}_3}{1 \text{ mol Pb}(\text{NO}_3)_2} = 0.145 \text{ mol Na}_2\text{CO}_3$$

d.  $\text{C}_3\text{H}_8(g) + 5\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(g)$ 

$$0.145 \text{ mol C}_3\text{H}_8 \times \frac{5 \text{ mol O}_2}{1 \text{ mol C}_3\text{H}_8} = 0.725 \text{ mol O}_2$$

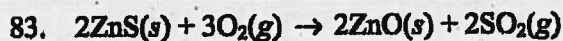


molar masses:  $\text{SO}_2$ , 64.07 g;  $\text{SO}_3$ , 80.07 g;  $150 \text{ kg} = 1.5 \times 10^5 \text{ g}$

$$1.5 \times 10^5 \text{ g SO}_2 \times \frac{1 \text{ mol}}{64.07 \text{ g}} = 2.34 \times 10^3 \text{ mol SO}_2$$

$$2.34 \times 10^3 \text{ mol SO}_2 \times \frac{2 \text{ mol SO}_3}{2 \text{ mol SO}_2} = 2.34 \times 10^3 \text{ mol SO}_3$$

$$2.34 \times 10^3 \text{ mol SO}_3 \times \frac{80.07 \text{ g}}{1 \text{ mol}} = 1.9 \times 10^5 \text{ g SO}_3 = 1.9 \times 10^2 \text{ kg SO}_3$$

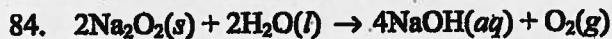


molar masses:  $\text{ZnS}$ , 97.45 g;  $\text{SO}_2$ , 64.07 g;  $1.0 \times 10^2 \text{ kg} = 1.0 \times 10^5 \text{ g}$

$$1.0 \times 10^5 \text{ g ZnS} \times \frac{1 \text{ mol}}{97.45 \text{ g}} = 1.026 \times 10^3 \text{ mol ZnS}$$

$$1.026 \times 10^3 \text{ mol ZnS} \times \frac{2 \text{ mol SO}_2}{2 \text{ mol ZnS}} = 1.026 \times 10^3 \text{ mol SO}_2$$

$$1.026 \times 10^3 \text{ mol SO}_2 \times \frac{64.07 \text{ g}}{1 \text{ mol}} = 6.6 \times 10^4 \text{ g SO}_2 = 66 \text{ kg SO}_2$$

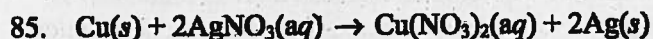


molar masses:  $\text{Na}_2\text{O}_2$ , 77.98 g;  $\text{O}_2$ , 32.00 g

$$3.25 \text{ g Na}_2\text{O}_2 \times \frac{1 \text{ mol}}{77.98 \text{ g}} = 0.0417 \text{ mol Na}_2\text{O}_2$$

$$0.0417 \text{ mol Na}_2\text{O}_2 \times \frac{1 \text{ mol O}_2}{2 \text{ mol Na}_2\text{O}_2} = 0.0209 \text{ mol O}_2$$

$$0.0209 \text{ mol O}_2 \times \frac{32.00 \text{ g}}{1 \text{ mol}} = 0.669 \text{ g O}_2$$

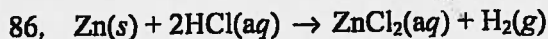


millimolar masses:  $\text{Cu}$ , 63.55 mg;  $\text{AgNO}_3$ , 169.9 mg

$$1.95 \text{ mg AgNO}_3 \times \frac{1 \text{ mmol}}{169.9 \text{ mg}} = 0.01148 \text{ mmol AgNO}_3$$

$$0.01148 \text{ mmol AgNO}_3 \times \frac{1 \text{ mmol Cu}}{2 \text{ mmol AgNO}_3} = 0.005740 \text{ mmol Cu}$$

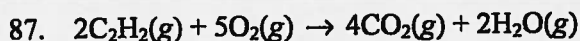
$$0.005740 \text{ mmol Cu} \times \frac{63.55 \text{ g}}{1 \text{ mol}} = 0.365 \text{ mg Cu}$$

molar masses: Zn, 65.38 g; H<sub>2</sub>, 2.016 g

$$2.50 \text{ g Zn} \times \frac{1 \text{ mol}}{65.38 \text{ g}} = 0.03824 \text{ mol Zn}$$

$$0.03824 \text{ mol Zn} \times \frac{1 \text{ mol H}_2}{1 \text{ mol Zn}} = 0.03824 \text{ mol H}_2$$

$$0.03824 \text{ mol H}_2 \times \frac{2.016 \text{ g}}{1 \text{ mol}} = 0.0771 \text{ g H}_2$$

molar masses: C<sub>2</sub>H<sub>2</sub>, 26.04 g; O<sub>2</sub>, 32.00 g; 150 g =  $1.5 \times 10^2$  g

$$1.5 \times 10^2 \text{ g C}_2\text{H}_2 \times \frac{1 \text{ mol}}{26.04 \text{ g}} = 5.760 \text{ mol C}_2\text{H}_2$$

$$5.760 \text{ mol C}_2\text{H}_2 \times \frac{5 \text{ mol O}_2}{2 \text{ mol C}_2\text{H}_2} = 14.40 \text{ mol O}_2$$

$$14.40 \text{ mol O}_2 \times \frac{32.00 \text{ g}}{1 \text{ mol}} = 4.6 \times 10^2 \text{ g O}_2$$

88.

molar masses: Na, 22.99 g; Br<sub>2</sub>, 159.8 g; NaBr, 102.9 g

$$5.0 \text{ g Na} \times \frac{1 \text{ mol}}{22.99 \text{ g}} = 0.2175 \text{ mol Na}$$

$$5.0 \text{ g Br}_2 \times \frac{1 \text{ mol}}{159.8 \text{ g}} = 0.03129 \text{ mol Br}_2$$

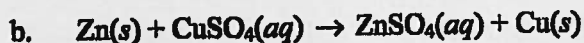
Intuitively, we would suspect that Br<sub>2</sub> is the limiting reactant because there is much less Br<sub>2</sub> than Na on a mole basis. To *prove* that Br<sub>2</sub> is the limiting reactant, the following calculation is needed:

$$0.03129 \text{ mol Br}_2 \times \frac{2 \text{ mol Na}}{1 \text{ mol Br}_2} = 0.06258 \text{ mol Na.}$$

Clearly there is more Na than this present, so Br<sub>2</sub> limits the reaction extent and the amount of NaBr formed.

$$0.03129 \text{ mol Br}_2 \times \frac{2 \text{ mol NaBr}}{1 \text{ mol Br}_2} = 0.06258 \text{ mol NaBr}$$

$$0.06258 \text{ mol NaBr} \times \frac{102.9 \text{ g}}{1 \text{ mol}} = 6.4 \text{ g NaBr}$$



molar masses: Zn, 65.38 g; Cu, 63.55 g;  $\text{ZnSO}_4$ , 161.5 g;  $\text{CuSO}_4$ , 159.6 g

$$5.0 \text{ g Zn} \times \frac{1 \text{ mol}}{65.38 \text{ g}} = 0.07648 \text{ mol Zn}$$

$$5.0 \text{ g CuSO}_4 \times \frac{1 \text{ mol}}{159.6 \text{ g}} = 0.03132 \text{ mol CuSO}_4$$

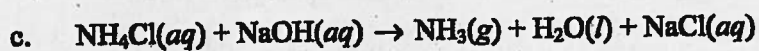
As the coefficients of Zn and  $\text{CuSO}_4$  are the *same* in the balanced chemical equation, an equal number of moles of Zn and  $\text{CuSO}_4$  would be needed for complete reaction. There is less  $\text{CuSO}_4$  present, so  $\text{CuSO}_4$  must be the limiting reactant.

$$0.03132 \text{ mol CuSO}_4 \times \frac{1 \text{ mol ZnSO}_4}{1 \text{ mol CuSO}_4} = 0.03132 \text{ mol ZnSO}_4$$

$$0.03132 \text{ mol ZnSO}_4 \times \frac{161.5 \text{ g}}{1 \text{ mol}} = 5.1 \text{ g ZnSO}_4$$

$$0.03132 \text{ mol CuSO}_4 \times \frac{1 \text{ mol Cu}}{1 \text{ mol CuSO}_4} = 0.03132 \text{ mol Cu}$$

$$0.03132 \text{ mol Cu} \times \frac{63.55 \text{ g}}{1 \text{ mol}} = 2.0 \text{ g Cu}$$



molar masses:  $\text{NH}_4\text{Cl}$ , 53.49 g; NaOH, 40.00 g;  $\text{NH}_3$ , 17.03 g;  $\text{H}_2\text{O}$ , 18.02 g; NaCl, 58.44 g

$$5.0 \text{ g NH}_4\text{Cl} \times \frac{1 \text{ mol}}{53.49 \text{ g}} = 0.09348 \text{ mol NH}_4\text{Cl}$$

$$5.0 \text{ g NaOH} \times \frac{1 \text{ mol}}{40.00 \text{ g}} = 0.1250 \text{ mol NaOH}$$

As the coefficients of  $\text{NH}_4\text{Cl}$  and NaOH are both *one* in the balanced chemical equation for the reaction, an equal number of moles of  $\text{NH}_4\text{Cl}$  and NaOH would be needed for complete reaction. There is less  $\text{NH}_4\text{Cl}$  present, so  $\text{NH}_4\text{Cl}$  must be the limiting reactant.

As the coefficients of the products in the balanced chemical equation are also all *one*, if 0.09348 mol of  $\text{NH}_4\text{Cl}$  (the limiting reactant) reacts completely, then 0.09348 mol of each product will be formed.

$$0.09348 \text{ mol NH}_3 \times \frac{17.03 \text{ g}}{1 \text{ mol}} = 1.6 \text{ g NH}_3$$

$$0.09348 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g}}{1 \text{ mol}} = 1.7 \text{ g H}_2\text{O}$$

$$0.09348 \text{ mol NaCl} \times \frac{58.44 \text{ g}}{1 \text{ mol}} = 5.5 \text{ g NaCl}$$



molar masses:  $\text{Fe}_2\text{O}_3$ , 159.7 g; CO, 28.01 g; Fe, 55.85 g;  $\text{CO}_2$ , 44.01 g

$$5.0 \text{ g Fe}_2\text{O}_3 \times \frac{1 \text{ mol}}{159.7 \text{ g}} = 0.03131 \text{ mol Fe}_2\text{O}_3$$

$$5.0 \text{ g CO} \times \frac{1 \text{ mol}}{28.01 \text{ g}} = 0.1785 \text{ mol CO}$$

Because there is considerably less  $\text{Fe}_2\text{O}_3$  than CO on a mole basis, let's see if  $\text{Fe}_2\text{O}_3$  is the limiting reactant.

$$0.03131 \text{ mol Fe}_2\text{O}_3 \times \frac{3 \text{ mol CO}}{1 \text{ mol Fe}_2\text{O}_3} = 0.09393 \text{ mol CO}$$

There is 0.1785 mol of CO present, but we have determined that only 0.09393 mol CO would be needed to react with all the  $\text{Fe}_2\text{O}_3$  present, so  $\text{Fe}_2\text{O}_3$  must be the limiting reactant. CO is present in excess.

$$0.03131 \text{ mol Fe}_2\text{O}_3 \times \frac{2 \text{ mol Fe}}{1 \text{ mol Fe}_2\text{O}_3} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 3.5 \text{ g Fe}$$

$$0.03131 \text{ mol Fe}_2\text{O}_3 \times \frac{3 \text{ mol CO}_2}{1 \text{ mol Fe}_2\text{O}_3} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 4.1 \text{ g CO}_2$$

89.



molar masses:  $\text{C}_2\text{H}_5\text{OH}$ , 46.07 g;  $\text{O}_2$ , 32.00 g;  $\text{CO}_2$ , 44.01 g

$$25.0 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol}}{46.07 \text{ g}} = 0.5427 \text{ mol C}_2\text{H}_5\text{OH}$$

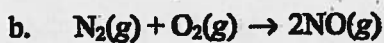
$$25.0 \text{ g O}_2 \times \frac{1 \text{ mol}}{32.00 \text{ g}} = 0.7813 \text{ mol O}_2$$

As there is less  $\text{C}_2\text{H}_5\text{OH}$  present on a mole basis, see if this substance is the limiting reactant.

$$0.5427 \text{ mol C}_2\text{H}_5\text{OH} \times \frac{3 \text{ mol O}_2}{1 \text{ mol C}_2\text{H}_5\text{OH}} = 1.6281 \text{ mol O}_2$$

From the above calculation,  $\text{C}_2\text{H}_5\text{OH}$  must *not* be the limiting reactant (even though there is a smaller number of moles of  $\text{C}_2\text{H}_5\text{OH}$  present) because more oxygen than is present would be required to react completely with the  $\text{C}_2\text{H}_5\text{OH}$  present. Oxygen is the limiting reactant.

$$0.7813 \text{ mol O}_2 \times \frac{2 \text{ mol CO}_2}{3 \text{ mol O}_2} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 22.9 \text{ g CO}_2$$



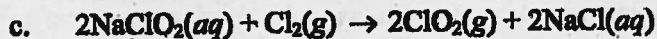
molar masses:  $\text{N}_2$ , 28.02 g;  $\text{O}_2$ , 32.00 g;  $\text{NO}$ , 30.01 g

$$25.0 \text{ g N}_2 \times \frac{1 \text{ mol}}{28.02 \text{ g}} = 0.8922 \text{ mol N}_2$$

$$25.0 \text{ g O}_2 \times \frac{1 \text{ mol}}{32.00 \text{ g}} = 0.7813 \text{ mol O}_2$$

As the coefficients of  $\text{N}_2$  and  $\text{O}_2$  are the *same* in the balanced chemical equation for the reaction, an equal number of moles of each substance would be necessary for complete reaction. There is less  $\text{O}_2$  present on a mole basis, so  $\text{O}_2$  must be the limiting reactant.

$$0.7813 \text{ mol O}_2 \times \frac{2 \text{ mol NO}}{1 \text{ mol O}_2} \times \frac{30.01 \text{ g NO}}{1 \text{ mol NO}} = 46.9 \text{ g NO}$$



molar masses:  $\text{NaClO}_2$ , 90.44 g;  $\text{Cl}_2$ , 70.90 g;  $\text{NaCl}$ , 58.44 g

$$25.0 \text{ g NaClO}_2 \times \frac{1 \text{ mol}}{90.44 \text{ g}} = 0.2764 \text{ mol NaClO}_2$$

$$25.0 \text{ g Cl}_2 \times \frac{1 \text{ mol}}{70.90 \text{ g}} = 0.3526 \text{ mol Cl}_2$$

See if  $\text{NaClO}_2$  is the limiting reactant.

$$0.2764 \text{ mol NaClO}_2 \times \frac{1 \text{ mol Cl}_2}{2 \text{ mol NaClO}_2} = 0.1382 \text{ mol Cl}_2$$

As 0.2764 mol of  $\text{NaClO}_2$  would require only 0.1382 mol  $\text{Cl}_2$  to react completely (and since we have more than this amount of  $\text{Cl}_2$ ), then  $\text{NaClO}_2$  must indeed be the limiting reactant.

$$0.2764 \text{ mol NaClO}_2 \times \frac{2 \text{ mol NaCl}}{2 \text{ mol NaClO}_2} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} = 16.2 \text{ g NaCl}$$



molar masses:  $\text{H}_2$ , 2.016 g;  $\text{N}_2$ , 28.02 g;  $\text{NH}_3$ , 17.03 g

$$25.0 \text{ g H}_2 \times \frac{1 \text{ mol}}{2.016 \text{ g}} = 12.40 \text{ mol H}_2$$

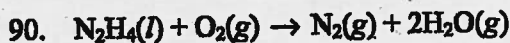
$$25.0 \text{ g N}_2 \times \frac{1 \text{ mol}}{28.02 \text{ g}} = 0.8922 \text{ mol N}_2$$

See if  $\text{N}_2$  is the limiting reactant.

$$0.8922 \text{ mol N}_2 \times \frac{3 \text{ mol H}_2}{1 \text{ mol N}_2} = 2.677 \text{ mol H}_2$$

$\text{N}_2$  is clearly the limiting reactant because there is 12.40 mol  $\text{H}_2$  present (a large excess).

$$0.8922 \text{ mol N}_2 \times \frac{2 \text{ mol NH}_3}{1 \text{ mol N}_2} \times \frac{17.03 \text{ g NH}_3}{1 \text{ mol NH}_3} = 30.4 \text{ g NH}_3$$



molar masses:  $\text{N}_2\text{H}_4$ , 32.05 g;  $\text{O}_2$ , 32.00 g;  $\text{N}_2$ , 28.02 g;  $\text{H}_2\text{O}$ , 18.02 g

$$20.0 \text{ g N}_2\text{H}_4 \times \frac{1 \text{ mol}}{32.05 \text{ g}} = 0.624 \text{ mol N}_2\text{H}_4$$

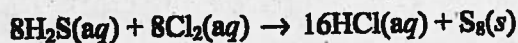
$$20.0 \text{ g O}_2 \times \frac{1 \text{ mol}}{32.00 \text{ g}} = 0.625 \text{ mol O}_2$$

The two reactants are present in nearly the required ratio for complete reaction (due to the 1:1 stoichiometry of the reaction and the very similar molar masses of the substances). We will consider  $\text{N}_2\text{H}_4$  as the limiting reactant in the following calculations.

$$0.624 \text{ mol N}_2\text{H}_4 \times \frac{1 \text{ mol N}_2}{1 \text{ mol N}_2\text{H}_4} \times \frac{28.02 \text{ g N}_2}{1 \text{ mol N}_2} = 17.5 \text{ g N}_2$$

$$0.624 \text{ mol N}_2\text{H}_4 \times \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol N}_2\text{H}_4} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 22.5 \text{ g H}_2\text{O}$$

91. Total quantity of  $\text{H}_2\text{S} = 50. \text{ L} \times \frac{1.5 \times 10^{-5} \text{ g}}{1 \text{ L}} = 7.5 \times 10^{-4} \text{ g H}_2\text{S}$



molar masses:  $\text{H}_2\text{S}$ , 34.09 g;  $\text{Cl}_2$ , 70.90 g;  $\text{S}_8$ , 256.6 g

$$7.5 \times 10^{-4} \text{ g H}_2\text{S} \times \frac{1 \text{ mol}}{34.09 \text{ g}} = 2.20 \times 10^{-5} \text{ mol H}_2\text{S}$$

$$1.0 \text{ g Cl}_2 \times \frac{1 \text{ mol}}{70.90 \text{ g}} = 1.41 \times 10^{-2} \text{ mol Cl}_2$$

There is a large excess of chlorine present compared to the amount of  $\text{Cl}_2$  that would be needed to react with all the  $\text{H}_2\text{S}$  present in the water sample:  $\text{H}_2\text{S}$  is the limiting reactant for the process.

$$2.20 \times 10^{-5} \text{ mol H}_2\text{S} \times \frac{1 \text{ mol S}_8}{8 \text{ mol H}_2\text{S}} \times \frac{256.6 \text{ g S}_8}{1 \text{ mol S}_8} = 7.1 \times 10^{-4} \text{ g S}_8 \text{ removed}$$

92.  $12.5 \text{ g theory} \times \frac{40 \text{ g actual}}{100 \text{ g theory}} = 5.0 \text{ g}$