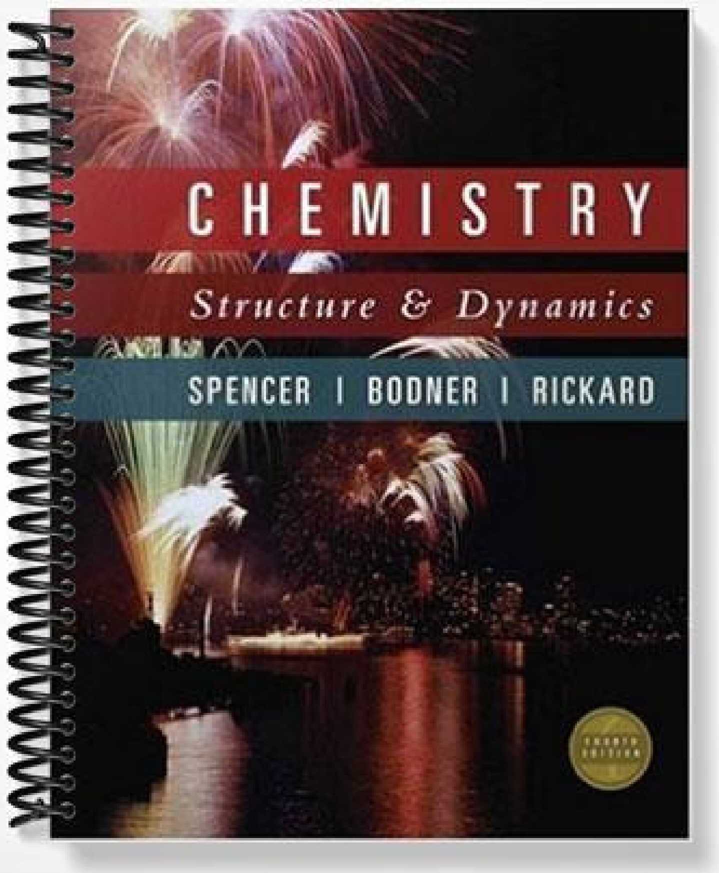
SOLUTIONS MANUAL



Chapter 2
The Mole: The Link Between the Macroscopic and the Atomic World of Chemistry

2-1 The mass of the container and the contents will not change. The same number of atoms of each element will be present after burning the candle. However, the elements will be combined differently as product molecules.

2-2 The same number of atoms will be present. The atoms which made up the molecules of liquid gasoline have been changed chemically to gaseous molecules. But the same number of atoms are still present, just in a different chemical form.

2-3 Mass is conserved because atoms are not created or destroyed in a chemical reaction. Rather their arrangement changes to form different chemical compounds.

2-4 Lavoisier observed that the mass of the products of a chemical reaction is the same as the mass of the reactants one starts with.

2-5 All the atoms which start out on the reactant side of a chemical reaction equation must be accounted for on the product side of the reaction equation.

2-6 Two gaseous hydrogen molecules and one gaseous oxygen molecule can react to form two gaseous water molecules.
This is the same reaction except that the product is liquid water: Two gaseous hydrogen molecules and one gaseous oxygen molecule can react to form two liquid water molecules.

2-7 A solid molecule of potassium iodide can react to form an aqueous plus one potassium ion and an aqueous minus one iodine ion.

2-8 One gaseous molecule of carbon dioxide and one liquid water molecule can react to form an aqueous molecule of carbonic acid.

2-9 The number of carbon and hydrogen atoms is conserved. The number of molecules is not conserved. There are two reactant molecules, but only one product molecule.

2-10 A gaseous molecule of hydrogen and a gaseous molecule of chlorine will react to give two gaseous hydrogen chloride molecules.
When chlorine and hydrogen react, one mole of each will be consumed and two moles of hydrogen chloride are formed.

2-11 Reactants: 3 Ca (3x40.078 amu) + N_2 (28.014 amu) = 134.248 amu
Products: Ca_3N_2 (3x40.078 amu+2x14.007)=134.248 amu
When using mole quantities the amu unit can be replaced with a grams unit and the numbers remain the same.

2-12 (a) $$2\text{ mol } H_2 \times \frac{2\text{ H}}{H_2} \times \frac{6.022\times10^{23}\text{ atoms}}{\text{mol}} = 2.4088\times10^{24}\text{ H atoms}$$

$$1\text{mol } O_2 \times \frac{2\text{ O}}{O_2} \times \frac{6.022\times10^{23}\text{ atoms}}{\text{mol}} = 1.2044\times10^{24}\text{ O atoms}$$

(b) $$2\text{ mol } H_2 \times \frac{6.022\times10^{23}\text{ molecules}}{\text{mol}} = 1.2044\times10^{24}\ H_2\text{ molecules}$$

$$1\text{mol } O_2 \times \frac{6.022\times10^{23}\text{ molecules}}{\text{mol}} = 6.022\times10^{23}\ O_2\text{ molecules}$$

$$\left(2\text{ mol } H_2O \times \frac{2\text{H atoms}}{H_2O\text{ molecule}} + 2\text{ mol } H_2O \times \frac{1\text{ O atom}}{H_2O\text{ molecule}}\right) \times$$

$$\frac{6.022\times10^{23}\text{ atoms}}{\text{mol}} = 3.6132\times10^{24}\text{ atoms}$$

2 moles of product water are formed

(c) $2\text{ mol }H_2O \times \frac{6.022\times10^{23}\text{ molecules}}{\text{mol}} = 1.2044\times10^{24}\ H_2O\text{ molecules}$

2-13 (a) $4\ Cr(s) + 3\ O_2(g) \rightarrow 2\ Cr_2O_3(s)$

(b) $SiH_4(g) \rightarrow Si(s) + 2\ H_2(g)$

(c) $2\ SO_3(g) \rightarrow 2\ SO_2(g) + O_2(g)$

2-14 (a) $2\ Pb(NO_3)_2(s) \rightarrow 2\ PbO(s) + 4\ NO_2(g) + O_2(g)$

(b) $NH_4NO_2(s) \rightarrow N_2(g) + 2\ H_2O(g)$

(c) $(NH_4)_2Cr_2O_7(s) \rightarrow Cr_2O_3(s) + 4\ H_2O(g) + N_2(g)$

2-15 (a) $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$

(b) $2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ H_2O(g) + 2\ SO_2(g)$

(c) $2\ B_5H_9(g) + 12\ O_2(g) \rightarrow 5\ B_2O_3(s) + 9\ H_2O(g)$

2-16 (a) $PF_3(g) + 3\ H_2O(l) \rightarrow H_3PO_3(aq) + 3\ HF(aq)$

(b) $P_4O_{10}(s) + 6\ H_2O(l) \rightarrow 4\ H_3PO_4(aq)$

2-17 (a) $2\ C_3H_8(g) + 10\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(g)$

(b) $C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$

(c) $C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(l)$

2-18 From $5\text{ mol }O_2 \text{ x } \frac{2\text{ mol }CO_2}{1\text{ mol }O_2} = 10\text{ mol }CO_2$

2-19 Decreases; fewer moles of product than reactant

2-20 $12\text{ mol Cu x } \frac{1\text{ mol CuO}}{1\text{ mol Cu}} = 12\text{ mol CuO}$

2-21 $CS_2(l) + 3\ O_2(g) \rightarrow CO_2(g) + 2\ SO_2(g)$

A balanced chemical equation represents the molecular ratios and molar ratios of the reactants and products. Therefore,

$$500 \text{ molecules } CS_2 \times \frac{3 \text{ molecules } O_2}{1 \text{ molecule } CS_2} = 1500 \text{ molecules } O_2$$

$$5.00 \text{ mol } CS_2 \times \frac{3 \text{ mol } O_2}{1 \text{ mol } CS_2} = 15.0 \text{ mol } O_2$$

2-22 $3\ MnO_2(s) \rightarrow Mn_3O_4(s) + O_2(g)$

$$6.75 \text{ mol MnO x } \frac{1 \text{ mol } O_2}{3 \text{ mol } MnO_2} = 2.25 \text{ mol } O_2$$

2-23 $Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$

$$3.00 \text{ mol } Fe_2O_3 \times \frac{3 \text{ mol CO}}{1 \text{ mol } Fe_2O_3} = 9.00 \text{ mol CO}$$

2-24 1. Convert grams of CO reacted to moles of CO.
2. Relate moles of CO reacted to moles of CO_2 produced.
3. Convert moles CO_2 to grams.

2-25 $2\ HgO(s) \rightarrow 2\ Hg(l) + O_2(g)$

$$25 \text{ g Hg x } \frac{1 \text{ mol Hg}}{200.59 \text{ g}} \times \frac{1 \text{ mol } O_2}{2 \text{ mol Hg}} \times \frac{31.998 \text{ g } O_2}{1 \text{ mol } O_2} = 2.0 \text{ g } O_2$$

2-26 $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$

$$10.0 \text{ g } CH_4 \times \frac{1 \text{ mol } CH_4}{16.043 \text{ g}} \times \frac{2 \text{ mol } O_2}{1 \text{ mol } CH_4} \times \frac{31.998 \text{ g } O_2}{1 \text{ mol } O_2} = 39.9 \text{ g } O_2 \text{ consumed.}$$

$$10.0 \text{ g } CH_4 \times \frac{1 \text{ mol } CH_4}{16.043 \text{ g}} \times \frac{1 \text{ mol } CO_2}{1 \text{ mol } CH_4} \times \frac{44.009 \text{ g } CO_2}{1 \text{ mol } CO_2} = 27.4 \text{ g } CO_2 \text{ produced.}$$

2-27 $Zn(s) + S(s) \rightarrow ZnS(s)$

$$10.0 \text{ lb Zn x } \frac{453.6 \text{ g}}{1 \text{ lb}} \text{ x } \frac{1 \text{ mol Zn}}{65.39 \text{ g}} \text{ x } \frac{1 \text{ mol S}}{1 \text{ mol Zn}} \times \frac{32.066 \text{ g S}}{1 \text{ mol S}} \times \frac{1 \text{ lb}}{453.6 \text{ g}} = 4.90 \text{ lb S}$$

2-28 $2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(s)$

$$25.0 \text{ g } KClO_3 \times \frac{1 \text{ mol } KClO_3}{122.548 \text{ g}} \times \frac{3 \text{ mol } O_2}{2 \text{ mol } KClO_3} \times \frac{31.998 \text{ g } O_2}{1 \text{ mol } O_2} = 9.79 \text{ g } O_2$$

2-29 $$1.00 \text{ g Cr} \times \frac{1 \text{ mol Cr}}{51.996 \text{ g}} = 0.0192 \text{ mol Cr} \qquad \frac{0.0192}{0.0192} = 1.00 = 1 \text{ mol Cr}$$

$$0.923 \text{ g } O_2 \times \frac{1 \text{ mol } O_2}{31.998 \text{ g}} \times \frac{2 \text{ mol O}}{1 \text{ mol } O_2} = 0.0577 \text{ mol O} \qquad \frac{0.0577}{0.0192} = 3.00 = 3 \text{ mol O}$$

Therefore the predicted formula for the compound is CrO_3.

2-30 $C_6H_{12}O_6(aq) \rightarrow 2\ C_2H_5OH(aq) + 2\ CO_2(g)$

$$1.00\text{ kg } C_6H_{12}O_6 \times \frac{1000\text{ g}}{1\text{ kg}} \times \frac{1\text{ mol } C_6H_{12}O_6}{180.155\text{ g}} \times \frac{2\text{ mol } C_2H_5OH}{1\text{ mol } C_6H_{12}O_6} \times \frac{46.068\text{ g } C_2H_5OH}{1\text{ mol } C_2H_5OH} \times \frac{1\text{ kg}}{1000\text{ g}}$$

$= 0.511\text{ kg } C_2H_5OH$

2-31 Molecular weight of bauxite, $Al_2O_3 \cdot 2\ H_2O = 137.991\ \frac{g}{mol}$

$$1\text{ ton} \times \frac{2000\text{ lb}}{1\text{ ton}} \times \frac{453.6\text{ g}}{1\text{ lb}} \times \frac{1\text{ mol } Al_2O_3 \cdot 2\ H_2O}{137.991\text{ g}} \times \frac{2\text{ mol Al}}{1\text{ mol } Al_2O_3 \cdot 2\ H_2O}$$

$$\times \frac{26.982\text{ g Al}}{1\text{ mol Al}} \times \frac{1\text{ lb Al}}{453.6\text{ g}} = 782.1\text{ lb Al}$$

2-32 $Ca_3P_2(s) + 6\ H_2O(l) \rightarrow 3\ Ca(OH)_2(aq) + 2\ PH_3(g)$

$$10.0\text{ g } Ca_3P_2 \times \frac{1\text{ mol } Ca_3P_2}{182.182\text{ g}} \times \frac{2\text{ mol } PH_3}{1\text{ mol } Ca_3P_2} \times \frac{33.998\text{ g } PH_3}{1\text{ mol } PH_3} = 3.73\text{ g } PH_3$$

2-33 $PCl_3(g) + 3\ H_2O(l) \rightarrow 3\ HCl(aq) + H_3PO_3(aq)$

$$15.0\text{ g } PCl_3 \times \frac{1\text{ mol } PCl_3}{137.333\text{ g}} \times \frac{3\text{ mol HCl}}{1\text{ mol } PCl_3} \times \frac{36.461\text{ g HCl}}{1\text{ mol HCl}} = 11.9\text{ g HCl}$$

2-34 $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$

$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$

$2\ NO(g) + O_2 \rightarrow 2\ NO_2(g)$

$3\ NO_2(g) + H_2O(l) \rightarrow 2\ HNO_3(aq) + NO(g)$

$$150\text{ g } HNO_3 \times \frac{1\text{ mol } HNO_3}{63.012\text{ g}} \times \frac{3\text{ mol } NO_2}{2\text{ mol } HNO_3} \times \frac{2\text{ mol NO}}{2\text{ mol } NO_2} \times \frac{4\text{ mol } NH_3}{4\text{ mol NO}} \times \frac{1\text{ mol } N_2}{2\text{ mol } NH_3} \times$$

$$\frac{28.014\text{ g } N_2}{1\text{ mol } N_2} = 50.0\text{ g } N_2$$

2-35 $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$

500 H_2 molecules require

$$500\text{ molecules } H_2 \times \frac{1\text{ molecule } O_2}{2\text{ molecules } H_2} = 250\text{ molecules } O_2 \text{ to react completely.}$$

Since 500 O_2 molecules are present, H_2 is the limiting reagent and based upon the stoichiometric coefficients, 500 H_2O molecules would be produced. If the amount of O_2 doubles, the yield remains 500 molecules H_2O. If the amount of H_2 doubles then the yield is 1000 molecules H_2O.

2-36 $4\ P_4(s) + 5\ S_8(s) \rightarrow 4\ P_4S_{10}(s)$

$$0.500\text{ mol } P_4 \times \frac{4\text{ mol } P_4S_{10}}{4\text{ mol } P_4} = 0.500\text{ mol } P_4S_{10}$$

$$0.500\ S_8 \times \frac{4\text{ mol } P_4S_{10}}{5\text{ mol } S_8} = 0.400\text{ mol } P_4S_{10}$$

Since S_8 produces fewer moles of P_4S_{10}, it is the limiting reagent. If P_4 is doubled, S_8 is still the limiting reagent, and the amount of P_4S_{10} produced would remain unchanged. If S_8 is doubled, then P_4 becomes the limiting reagent and the yield of P_4S_{10} would be 0.500 mol.

2-37 $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$

$$0.35 \text{ mol NO} \times \frac{2 \text{ mol } NO_2}{2 \text{ mol NO}} = 0.35 \text{ mol } NO_2$$

$$0.25 \text{ mol } O_2 \times \frac{2 \text{ mol } NO_2}{1 \text{ mol } O_2} = 0.50 \text{ mol } NO_2$$

NO produces fewer moles of NO_2, therefore it is the limiting reagent. If NO were increased the yield of NO_2 would increase. If O_2 were increased, there would be no change in the yield of NO_2.

2-38 $H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$

$$10.0 \text{ g } H_2 \times \frac{1 \text{ mol } H_2}{2.0158 \text{ g}} \times \frac{2 \text{ mol HCl}}{1 \text{ mol } H_2} = 9.92 \text{ mol HCl}$$

$$10.0 \text{ g } Cl_2 \times \frac{1 \text{ mol } Cl_2}{70.906 \text{ g}} \times \frac{2 \text{ mol HCl}}{1 \text{ mol } Cl_2} = 0.282 \text{ mol HCl}$$

Cl_2 produces fewer moles of HCl, therefore it is the limiting reagent.

$$0.282 \text{ mol HCl} \times \frac{36.46\text{g}}{\text{mol}} = 10.3 \text{ g HCl}$$

To increase the amount of HCl produced, the amount of Cl_2 would have to be increased.

2-39 $3\ Ca(s) + N_2(g) \rightarrow Ca_3N_2(s)$

$$54.9 \text{ g Ca} \times \frac{1 \text{ mol Ca}}{40.078 \text{ g}} \times \frac{1 \text{ mol } Ca_3N_2}{3 \text{ mol Ca}} = 0.457 \text{ mol } Ca_3N_2,$$

$$43.2\ N_2 \times \frac{1 \text{ mol } N_2}{28.014 \text{ g}} \times \frac{2 \text{ mol N}}{1 \text{ mol } N_2} \times \frac{1 \text{ mol } Ca_3N_2}{2 \text{ mol N}} = 1.54 \text{ mol } Ca_3N_2,$$

Ca produces fewer moles of Ca_3N_2, therefore it is the limiting reagent.

The mass of Ca_3N_2 produced is $0.457 \text{ mol } Ca_3N_2 \times \frac{148.248 \ Ca_3N_2}{1 \text{ mol } Ca_3N_2} = 67.7$ g.

2-40 $2\ PF_3(g) + XeF_4(s) \rightarrow 2\ PF_5(g) + Xe(g)$

$$100.0 \text{ g } PF_3 \times \frac{1 \text{ mol } PF_3}{87.968 \text{ g}} \times \frac{2 \text{ mol } PF_5}{2 \text{ mol } PF_3} = 1.137 \text{ mol } PF_5$$

$$50.0 \text{ g } XeF_4 \times \frac{1 \text{ mol } XeF_4}{207.28 \text{ g}} \times \frac{2 \text{ mol } PF_5}{1 \text{ mol } XeF_4} = 0.482 \text{ mol } PF_5$$

XeF_4 produces fewer moles of PF_5; therefore, it is the limiting reagent and 0.482 moles of PF_5 would be produced.

2-41 $2\ Al(s) + 3\ Hg(CH_3)_2(l) \rightarrow 2\ Al(CH_3)_3(l) + 3\ Hg(l)$

$$5.00 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.982 \text{ g}} \times \frac{2 \text{ mol } Al(CH_3)_3}{2 \text{ mol Al}} = 0.185 \text{ mol } Al(CH_3)_3$$

$$25.0 \text{ g } Hg(CH_3)_2 \times \frac{1 \text{ mol } Hg(CH_3)_2}{230.66 \text{ g}} \times \frac{2 \text{ mol } Al(CH_3)_3}{3 \text{ mol } Hg(CH_3)_2}$$

$= 0.0723 \text{ mol } Al(CH_3)_3$

$Hg(CH_3)_2$ produces fewer moles of $Al(CH_3)_3$, therefore, it is the limiting reagent. The amount of $Al(CH_3)_3$ produced is

$$0.0723 \text{ mol } Al(CH_3)_3 \times \frac{72.086 \text{ g}}{1 \text{ mol } Al(CH_3)_3} = 5.21 \text{ g } Al(CH_3)_3$$

2-42 $Fe_2O_3(s) + 2\,Al(s) \rightarrow Al_2O_3(s) + 2\,Fe(l)$

$150 \text{ g Al x } \frac{1 \text{ mol Al}}{26.982 \text{ g}} \times \frac{2 \text{ mol Fe}}{2 \text{ mol Al}} = 5.56 \text{ mol Fe,}$

$250 \text{ g } Fe_2O_3 \text{ x } \frac{1 \text{ mol } Fe_2O_3}{159.691 \text{ g } Fe_2O_3} \text{ x } \frac{2 \text{ mol Fe}}{1 \text{ mol } Fe_2O_3} = 3.13 \text{ mol Fe,}$

Fe_2O_3 produces fewer moles of Fe; therefore it is the limiting reagent. The amount of Fe produced is

$3.13 \text{ mol Fe x } \frac{55.847 \text{ g}}{1 \text{ mol Fe}} = 175 \text{ g Fe.}$

2-43 $10.0 \text{ cm}^3 \text{ x } 7.9 \frac{\text{g}}{\text{cm}} = 79 \text{ g}$

$5.0 \text{ cm}^3 \text{ x } 10.5 \frac{\text{g}}{\text{cm}} = 53 \text{ g}$

The sample of iron weighs more.

2-44 $\frac{100 \text{ g}}{8.8 \text{ mL}} = 11 \frac{\text{g}}{\text{cm}}$: The first strip is Pb. $\frac{100 \text{ g}}{37.0 \text{ mL}} = 2.70 \frac{\text{g}}{\text{cm}}$: The second strip is Al.

2-45 $\frac{271 \text{ g}}{20.0 \text{ mL}} = 13.6 \frac{\text{g}}{\text{cm}}$

2-46 $5.6 \text{ mL x } 13.6 \frac{\text{g}}{\text{cm}} = 76 \text{ g}$

2-47 A **solution** is a homogeneous mixture of two or more components. The **solvent** is the component of a solution in largest relative amount. The **solute** is the component of a solution in smaller relative amount. Brine is a solution of the solute sodium chloride in the solvent water.

2-48 Both (b) and (c) are homogeneous mixtures.

2-49 $H_2C_2O_4 \cdot 2\,H_2O$ MW=126.063 $\frac{\text{g}}{\text{mol}}$

1. Calculate the number of moles oxalic acid needed

$0.125 \text{ L x } \frac{0.745 \text{ mol oxalic acid}}{1 \text{ L}} = 0.0931 \text{ mol}$

2. Find what chemical is available.

Oxalic acid dihydrate, $H_2C_2O_4 \cdot 2\,H_2O$, FW=126.154 $\frac{\text{g}}{\text{mol}}$

3. Weigh out the quantity needed.

$0.0931 \text{ mol x } 126.154 \frac{\text{g}}{\text{mol}} = 11.7 \text{ g oxalic acid dihydrate}$

4. Quantitavely transfer this amount of oxalic acid to a 250 mL volumetric flask and dissolve it in deionized water. Mix well. Dilute to 250 mL in the volumetric flask.

2-50 $27.3 \text{ g HCl x } \frac{1 \text{ mol HCl}}{36.461 \text{ g HCl}} = 0.749 \text{ mol HCl}$

$M = \frac{\text{moles}}{\text{liter}} = \frac{0.749 \text{ mol}}{0.125 \text{ L}} = 5.99 \text{ M}$

2-51 $0.00019 \text{ g AgCl} \times \frac{1 \text{ mol AgCl}}{143.32 \text{ g}} = 1.3 \times 10^{-6} \text{ mol AgCl}$

$M = \frac{\text{moles}}{\text{liter}} = \frac{1.3 \times 10^{-6} \text{ mol}}{0.100 \text{ L}} = 1.3 \times 10^{-5} \text{ M}$

2-52 $252 \text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.031 \text{ g}} = 14.8 \text{ mol } NH_3$

$$M = \frac{\text{moles}}{L} = \frac{14.8 \text{ mol}}{1 \text{ L}} = 14.8 \text{ M}$$

2-53 $1.60 \text{ mg} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol cholesterol}}{386.67 \text{ g}} = 4.14 \times 10^{-6} \text{ mol}$

$$M = \frac{\text{mol}}{L} = \frac{4.14 \times 10^{-6} \text{ mol}}{0.100 \text{ L}} = 4.14 \times 10^{-5} \text{ M}$$

2-54 $5.77 \text{ g } Cl_2 \times \frac{1 \text{ mol } Cl_2}{70.906 \text{ g}} = 0.0814 \text{ mol } Cl_2$

$$M = \frac{\text{mol}}{L} = \frac{0.0814 \text{ mol}}{1.00 \text{ L}} = 0.0814 \text{ M}$$

2-55 $\frac{0.150 \text{ mol}}{1 \text{ L}} \times 0.500 \text{ L} = 0.0750 \text{ mol } Na_2SO_4$ needed

$$0.0750 \text{ mol } Na_2SO_4 \times \frac{142.042 \text{ g } Na_2SO_4}{1 \text{ mol } Na_2SO_4} = 10.7 \text{ g } Na_2SO_4$$

2-56 1.00 L of water plus 1.00 mol of K_2CrO_4 may not be 1.00 L of solution. The student probably made more than 1.00 L of solution, so the solution was less than 1.00 M. A 1.00 liter sample of a 1.00 mol solute per liter solution must be prepared by placing the solute in a container calibrated to hold 1.000 liter. Add water to the container (volumetric flask) to dissolve the solute. Thoroughly mix the solution. Continue to add more water (solvent) until the liquid level has been brought to the calibration mark.

2-57 Assuming the volumes in solution preparation are additive then 458 mL+800 mL= 1.258L

$$\frac{92 \text{ g } Na_2Cr_2O_7 \cdot 2\,H_2O}{1.258 \text{ L}} \times \frac{1 \text{ mol } Na_2Cr_2O_7 \cdot 2\,H_2O}{297.995 \text{ g } Na_2Cr_2O_7 \cdot 2\,H_2O} \times \frac{1 \text{ mol } Cr_2O_7^{2-}}{1 \text{ mol } Na_2Cr_2O_7 \cdot 2\,H_2O}$$

$$= \frac{0.25 \text{ mol } Cr_2O_7^{2-}}{1 \text{ L soln}} = 0.25 \text{ M } Cr_2O_7^{2-}$$

2-58 $\frac{20 \text{ ng}}{\text{ml}} \times \frac{10^{-9} \text{ g}}{\text{ng}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{1 \text{ mol}}{315 \text{ g}} = 6.3 \text{ x } 10^{-8} \text{ M}$

2-59 $\frac{1.25 \text{ g KCl}}{0.500 \text{ L}} \times \frac{1 \text{mol KCl}}{74.551 \text{ g KCl}} = 0.0335 \text{ M KCl}$. To make it twice as concentrated either add twice as much KCl or use half as much water.

2-60 $\frac{2.75 \text{ g } AgNO_3}{0.250 \text{ L}} \times \frac{1 \text{mol } AgNO_3}{169.87 \text{ g } AgNO_3} = 0.0648 \text{ M } AgNO_3$. To make it half as concentrated either add half as much KCl or use twice as much water.

2-61 $1.25 \frac{\text{mol}}{\text{L}} \times 0.250 \text{ L} \times \frac{39.997 \text{ g NaOH}}{1 \text{mol NaOH}} = 12.5 \text{g NaOH}$

2-62 $0.50 \frac{\text{mol}}{\text{L}} \times 0.500 \text{ L} = 0.25 \text{ mol}$

2-63 $0.50\ \frac{mol}{L} \times 0.500\ L \times \frac{39.997\ g\ NaOH}{1 mol\ NaOH} = 10.g\ NaOH$

2-64 The 0.25 M solution is more concentrated since it is the higher molarity; more moles per liter.

2-65 $\frac{0.25\ g\ CuSO_4}{0.125\ L} \times \frac{1 mol\ CuSO_4}{159.608\ g\ CuSO_4} = 0.0125\ M\ CuSO_4$. The solution is prepared by weighing out 0.25 grams and placing into a 125 mL flask. The flask is then filled with water until the 125 mL mark is reached.

2-66 (a) $\frac{0.275\ g\ AgNO_3}{0.500\ L} \times \frac{1 mol\ AgNO_3}{169.87\ g\ AgNO_3} = 0.00324\ M\ AgNO_3$

(b) $0.00324\ \frac{mol}{L}\ AgNO_3 \times \frac{0.0100\ L}{0.500\ L} = 6.48x10^{-5}\ M\ AgNO_3$

(c) $6.48x10^{-5}\ \frac{mol}{L}\ AgNO_3 \times \frac{0.0100\ L}{0.250\ L} = 2.60x10^{-6}\ M\ AgNO_3$

2-67 $0.10\ \frac{mol}{L}\ HCl \times 0.500\ L \times \frac{1L}{12.0\ mol\ HCl} = 0.0042\ L$. 4.2 mL of 12.0 M HCl would be diluted to 500 mL. The resulting solution will be 0.10 M HCl.

2-68 $0.050\ \frac{mol}{L}\ CuSO_4 \times \frac{x\ L}{2 \cdot x\ L} = 0.025\ M\ CuSO_4$

2-69 $18.0\ \frac{mol}{L}\ H_2SO_4 \times \frac{0.100\ L}{0.500\ L} = 3.60\ M\ H_2SO_4$

2-70 $0.10\ \frac{mol}{L}\ HCl \times 0.250\ L \times \frac{1L}{6.0\ mol\ HCl} = 0.0042\ L$. 4.2 mL of 6.0 M HCl would be diluted to 250 mL. The resulting solution will be 0.10 M HCl.

2-71 $0.050\ \frac{mol}{L}\ NaCl \times \frac{0.100\ L}{0.250\ L} = 0.020\ M\ NaCl$

2-72 $1.20\ \frac{mol}{L}\ KF \times 0.100\ L = 0.120\ mol\ KF$ are present in the initial solution. If you want a final concentration of 0.45 M, what volume must contain the 0.120 mol? $0.120\ mol \times \frac{1L}{0.45\ mol} = .267\ L$ is the final volume that the 100 mL is diluted to.

2-73 $1.0\ \frac{mol}{L} \times \frac{1.0\ L}{1.75\ L} = 0.57\ M$

2-74 $M_1V_1 = M_2V_2$

(1.00 L)(3.00 M)=(x L)(17.4 M)

$\frac{(1.00\ L)(3.00\ M)}{(17.4\ M)}$=0.172 L=172 mL of 17.4 M acetic acid is needed.

2-75 $\frac{(15.0\ \text{ml})(6.00\ \text{M})}{(25.0 + 15.0)\ \text{ml}} = 2.25\ \text{M HCl}$

2-76 (0.200 L)(1.25 M)=(x L)(5.94 M)

$\frac{(0.200\ \text{L})(1.25\ \text{M})}{5.94\ \text{M}} = \text{x L} = 0.0421\ \text{L} = 42.1\ \text{mL}$

Take about 150 mL distilled water and slowly add 42.1 mL of the HNO_3 with mixing. Bring the solution to a final volume of 200 mL with distilled water and mix. The resulting solution is 1.25 M HNO_3.

2-77 $KCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + KNO_3(aq)$

$0.430\ \text{g AgCl} \times \frac{1\ \text{mol AgCl}}{143.32\ \text{g}} \times \frac{1\ \text{mol KCl}}{1\ \text{mol AgCl}} = 3.00 \times 10^{-3}\ \text{mol KCl}$

$\text{M} = \frac{\text{mol}}{\text{L}} = \frac{3.00 \times 10^{-3}\ \text{mol}}{0.02500\ \text{L}} = 0.120\ \text{M KCl}$

2-78 $2\ NaI(aq) + Hg(NO_3)_2(aq) \rightarrow HgI_2(s) + NaNO_3(aq)$

$0.045\ \text{L} \times \frac{0.10\ \text{mol Hg(NO}_3)_2}{1\ \text{L}} = 4.5 \times 10^{-3}\ \text{mol Hg(NO}_3)_2$

$4.5 \times 10^{-3}\ \text{mol Hg(NO}_3)_2 \times \frac{2\ \text{mol NaI}}{1\ \text{mol Hg(NO}_3)_2} = 9.00 \times 10^{-3}\ \text{mol NaI}$

$\frac{9.00 \times 10^{-3}\ \text{mol NaI}}{0.25\ \frac{\text{mol NaI}}{\text{L}}} = 3.6 \times 10^{-2}\ \text{L} \times \frac{1000\ \text{mL}}{1\ \text{L}} = 36\ \text{mL NaI}$

2-79 $CH_3CO_2H(aq) + NaOH(aq) \rightarrow Na^+(aq) + CH_3CO_2^-(aq) + H_2O(l)$

$25.19\ \text{mL NaOH} \times \frac{0.1025\ \text{mol NaOH}}{1000\ \text{mL}} = 2.582 \times 10^{-3}\ \text{mol NaOH}$

$2.582 \times 10^{-3}\ \text{mol NaOH} \times \frac{1\ \text{mol CH}_3\text{CO}_2\text{H}}{1\ \text{mol NaOH}} = 2.582 \times 10^{-3}\ \text{mol CH}_3\text{CO}_2\text{H}$

$\text{M} = \frac{\text{mol}}{\text{L}} = \frac{2.582 \times 10^{-3}\ \text{mol CH}_3\text{CO}_2\text{H}}{0.03457\ \text{L}} = 7.469 \times 10^{-2}\ \text{M acetic acid}$

2-80 $H_2C_2O_4(aq) + 2\ NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2\ H_2O(l)$

$25.00\ \text{mL H}_2\text{C}_2\text{O}_4 \times \frac{0.2043\ \text{mol H}_2\text{C}_2\text{O}_4}{1000\ \text{mL}} = 5.108 \times 10^{-3}\ \text{mol H}_2\text{C}_2\text{O}_4$

$5.108 \times 10^{-3}\ \text{mol H}_2\text{C}_2\text{O}_4 \times \frac{2\ \text{mol NaOH}}{1\ \text{mol H}_2\text{C}_2\text{O}_4} = 1.022 \times 10^{-2}\ \text{mol NaOH}$

$\text{M} = \frac{\text{mol}}{\text{L}} = \frac{1.022 \times 10^{-2}\ \text{mol NaOH}}{0.01042\ \text{L}} = 0.9808\ \text{M NaOH}$

2-81 $H_2SO_4(aq) + 2\ NH_3(aq) \rightarrow (NH_4)_2SO_4(aq)$

$10.89\ mL\ NH_3 \times \frac{0.01043\ mol\ NH_3}{1000\ ml} = 1.136 \times 10^{-4}\ mol\ NH_3$

$1.136 \times 10^{-4}\ mol\ NH_3 \times \frac{1\ mol\ H_2SO_4}{2\ mol\ NH_3} = 5.680 \times 10^{-5}\ mol\ H_2SO_4$

$$\frac{5.680 \times 10^{-5}\ mol\ H_2SO_4}{0.0985\ \frac{mol\ H_2SO_4}{L}} = 5.77 \times 10^{-4}\ L \times \frac{1000\ mL}{1\ L} = 0.577\ mL\ H_2SO_4$$

2-82 $C_6H_{12}O_6(aq) + 5\ IO_4^-(aq) \rightarrow 5\ IO_3^-(aq) + 5\ HCO_2H(aq) + H_2CO(aq)$

$25.0\ mL\ IO_4^- \times \frac{0.750\ mol\ IO_4^-}{1000\ mL} = 0.0188\ mol\ IO_4^-$

$0.0188\ mol\ IO_4^- \times \frac{1\ mol\ C_6H_{12}O_6}{5\ mol\ IO_4^-} = 3.75 \times 10^{-3}\ mol\ C_6H_{12}O_6$

$M = \frac{mol}{L} = \frac{3.75 \times 10^{-3}\ mol\ C_6H_{12}O_6}{0.0100\ L} = 0.375\ M\ C_6H_{12}O_6$

2-83 $3\ H_2C_2O_4(aq) + 2\ CrO_4^{2-}(aq) + 10\ H^+(aq) \rightarrow 6\ CO_2(g) + 2\ Cr^{3+}(aq) + 8\ H_2O$

$40.0\ mL\ CrO_4^{2-} \times \frac{0.0250\ mol\ CrO_4^{2-}}{1000\ mL} = 1.00 \times 10^{-3}\ mol\ CrO_4^{2-}$

$1.00 \times 10^{-3}\ mol\ CrO_4^{2-} \times \frac{3\ mol\ H_2C_2O_4}{2\ mol\ CrO_4^{2-}} = 1.50 \times 10^{-3}\ mol\ H_2C_2O_4$

$M = \frac{mol}{L} = \frac{1.50 \times 10^{-3}\ mol\ H_2C_2O_4}{0.0100\ L} = 0.150\ M\ H_2C_2O_4$

2-84 The empirical formula of the reactant compound:

$31.9\ g\ K \times \frac{1\ mol\ K}{39.098\ g} = 0.816\ mol\ K$

$28.9\ g\ Cl \times \frac{1\ mol\ Cl}{35.453\ g} = 0.815\ mol\ Cl$

$39.2\ g\ O \times \frac{1\ mol\ O}{15.999\ g} = 2.45\ mol\ O$

divide by smallest:

$\frac{0.816}{0.815} = 1\ mol\ K$ $\frac{0.815}{0.815} = 1\ mol\ Cl$ $\frac{2.45}{0.815} = 3\ mol\ O$

The empirical formula of the reactant compound is $KClO_3$.

The empirical formula of the product compound is:

$52.4\ g\ K \times \frac{1\ mol\ K}{39.098\ g} = 1.34\ mol\ K$

$47.6\ g\ Cl \times \frac{1\ mol\ Cl}{35.453\ g} = 1.34\ mol\ Cl$

Therefore, the product compound is KCl, and the balanced equation for the decomposition is $2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$.

2-85 % CO_2 by mass in each of the metal carbonates= $\frac{44.009 \text{ g } CO_2}{\text{MW metal carbonate}} \times 100$

	Carbonate	MW (g/mol)	% CO_2	
(a)	Li_2CO_3	73.89	59.56	
(b)	$MgCO_3$	84.31	52.20	
(c)	$CaCO_3$	100.09	43.97	
(d)	$ZnCO_3$	125.40	35.10	*
(e)	$BaCO_3$	197.34	22.30	

2-86 % CO_2 from $CaCO_3$=43.97% (see problem 2-85)
CaO remaining is 56.03%
grams $CaCO_3$=42.670-35.351=7.319 g $CaCO_3$
grams CO_2 evolved=(0.4397)(7.319 g)=3.218 g CO_2
gram residue=7.319-3.218=4.101 g CaO residue
Theoretical mass crucible + residue=35.351+4.101=39.452 g

2-87 3 Mg(s) + N_2(g) $\rightarrow$ Mg_3N_2(s)
Mg_3N_2(s) + 6 H_2O(l) $\rightarrow$ 3 $Mg(OH)_2$(aq) + 2 NH_3(aq)

$$15.0 \text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.031 \text{ g}} \times \frac{1 \text{ mol } Mg_3N_2}{2 \text{ mol } NH_3} \times \frac{3 \text{ mol Mg}}{1 \text{ mol } Mg_3N_2} \times \frac{24.305 \text{ g Mg}}{1 \text{ mol Mg}} = 32.1 \text{ g Mg}$$

2-88 $C_4H_{10}O$(l) + 6 O_2(g) $\rightarrow$ 4 CO_2(g) + 5 H_2O(g)

In the original flask there was a total of 7 moles of reactants: 1 mole of $C_4H_{10}O$(l) and 6 moles of $O_{2(g)}$. After complete reaction, 9 moles of products formed: 4 moles of CO_2(g) and 5 moles of H_2O(g). The number of molecules increases.

2-89 CuS + 2 H_2SO_4(aq) $\rightarrow$ $CuSO_4$(aq) + SO_2(g) + 2 H_2O(l)
2 $CuSO_4$(aq) + 5 I^-(aq) $\rightarrow$ 2 CuI(s) + I_3^-(aq) + 2 SO_4^{2-}
I_3^-(aq) + 2 $S_2O_3^{2-}$(aq) $\rightarrow$ 3 I^-(aq) + $S_4O_6^{2-}$(aq)

$$31.5 \text{ mL} \times \frac{1.00 \text{ mol } S_2O_3^{2-}}{1000 \text{ ml}} = 0.0315 \text{ mol } S_2O_3^{2-}$$

$$\% \text{ Cu}=0.0315 \text{ mol } S_2O_3^{2-} \times \frac{1 \text{ mol } I_3^-}{2 \text{ mol } S_2O_3^{2-}} \times \frac{2 \text{ mol } CuSO_4}{1 \text{ mol } I_3^-} \times \frac{1 \text{ mol Cu}}{1 \text{ mol } CuSO_4}$$

$$\times \frac{63.546 \text{ g Cu}}{1 \text{ mol Cu}} \times \frac{1}{2.50 \text{ g sample}} \times 100 = 80.0\%$$

2-90 When the teaspoon of water is added to the glass of pure methanol and thoroughly stirred, a solution is formed. In this case, the water is the solute and the methanol is the solvent. A teaspoon of this new solution would consist of methanol and water. Now, add this teaspoon of solution to the original glass of water. Since this teaspoon does not contain pure methanol, the volume of methanol added to the glass of water would be less than the volume of pure water added to the glass of methanol. Answer (a) is true.

2-91 $4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$

$3\ Fe(s) + 2\ O_2(g) \rightarrow Fe_3O_4(s)$

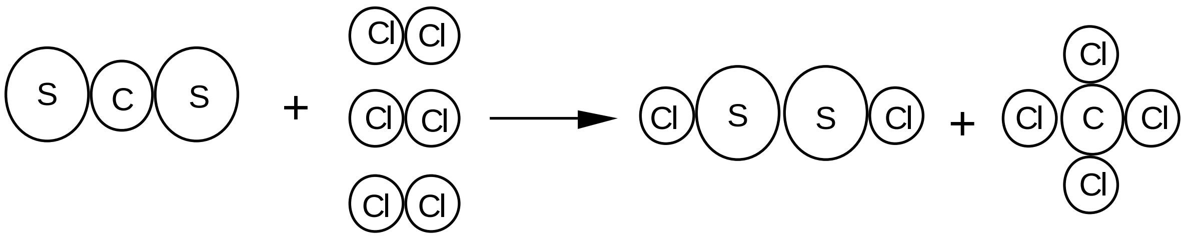
Moles of Fe reacted: $167.6\ g\ Fe \times \frac{1\ mol\ Fe}{55.847\ g} = 3.001\ mol\ Fe$

Grams of O in the iron oxide: 231.6 g - 167.6 g = 64.0 g O

Moles of O in the iron oxide: $64.0\ g\ O \times \frac{1\ mol\ O}{15.999\ g} = 4.000\ mol\ O$

The oxide formed is Fe_3O_4.

2-92



2-93 The intensity of the color red in the final solution depends on how much Br_2 is formed. In each experiment Br^- is the limiting reagent. For the first experiment 0.01 mole of Br^- react with 0.02 mole of Cl_2. In the second experiment 0.01 mole of Br^- reacts with 0.05 mole of Cl_2. Since the amount of Br^- is the same in both experiments the amount of Br_2 formed in each case will be the same. Thus, both solutions will have the same shade of red.