Practice Exam for Exam 1

1. Calculate the number of chromium atoms in a sphere of a chromium alloy that is 53.84% chromium by mass. The density of the sphere is 6.83×10^3 kg m^{-3}. The radius of the sphere is 19.54 inches. The volume of sphere is $\frac{4}{3}\pi r^3$. 1 m = 39.37 in

$$\frac{4}{3}\pi r^3 = \frac{4}{3}\pi(19.54\ \text{in})^3 \times \left(\frac{1\ \text{m}}{39.37\ \text{in}}\right)^3 \times \frac{6.83\times10^3\ \text{kg}}{m^3} \times \frac{10^3\ \text{g}}{1\ \text{kg}} \times \frac{53.84\ \text{g Cr}}{100.00\ \text{g alloy}} \times \frac{1\ \text{mol Cr}}{51.996\ \text{g Cr}} \times \frac{6.022\times10^{23}\ \text{atoms}}{1\ \text{mol}}$$
$$= 2.18\times10^{28}\ \text{atoms}$$

2. 15.00 g of sodium bicarbonate reacts with 0.5250 L of 0.7658 M nitric acid to produce sodium nitrate, water and carbon dioxide gas. Write the ***balanced chemical and net ionic equations*** for the reaction. How many ***grams of sodium nitrate*** can be produced by the reaction? If only 15.00 g of sodium nitrate are made, what is the ***percent yield***?

$$NaHCO_{3\,(s)} + HNO_{3\,(aq)} \rightarrow NaNO_{3\,(aq)} + CO_{2\,(g)} + H_2O_{(l)}$$

$$HCO_3^- + H^+ \rightarrow H_2O + CO_2$$

$$15.00\ \text{g NaHCO}_3 \times \frac{1\ \text{mol NaHCO}_3}{84.0066\ \text{g NaHCO}_3} \times \frac{1\ \text{mol NaNO}_3}{1\ \text{mol NaHCO}_3} \times \frac{84.9947\ \text{g NaNO}_3}{1\ \text{mol NaNO}_3} = 15.18\ \text{g NaNO}_3$$

$$0.5250\ \text{L HNO}_3 \times \frac{0.7658\ \text{mol HNO}_3}{1\ \text{L HNO}_3} \times \frac{1\ \text{mol NaNO}_3}{1\ \text{mol HNO}_3} \times \frac{84.9947\ \text{g NaNO}_3}{1\ \text{mol NaNO}_3} = 34.17\ \text{g NaNO}_3$$

15.18 g of sodium nitrate can be produced. The percent yield is: $\frac{15.00\ \text{g NaNO}_3}{15.18\ \text{g NaNO}_3} \times 100 = 98.81\%$

3. Prozac is a common antidepressant that contains carbon, hydrogen, fluorine, nitrogen and oxygen. 0.2543 g of Prozac is analyzed by combustion analysis. There are 0.6151 g of CO_2, 0.1333 g of H_2O, 0.0666 g of OF_2 and 0.0115 g of N_2 produced. The molar mass is 309.3 g/mol.

a. What is the ***empirical formula*** of Prozac?

$$0.6151\text{ g CO}_2\times\frac{1\text{ mol CO}_2}{44.0095\text{ g CO}_2}\times\frac{1\text{ mol C}}{1\text{ mol CO}_2}=0.013977\text{ mol C}\times\frac{12.0107\text{ g C}}{1\text{ mol C}}=0.1679\text{ g C}$$

$$0.1333\text{ g H}_2\text{O}\times\frac{1\text{ mol H}_2\text{O}}{18.0153\text{ g H}_2\text{O}}\times\frac{2\text{ mol H}}{1\text{ mol H}_2\text{O}}=0.014798\text{ mol H}\times\frac{1.00794\text{ g H}}{1\text{ mol H}}=0.0149\text{ g H}$$

$$0.0666\text{ g OF}_2\times\frac{1\text{ mol OF}_2}{53.9962\text{ g OF}_2}\times\frac{2\text{ mol F}}{1\text{ mol OF}_2}=0.0024668\text{ mol F}\times\frac{18.9984032\text{ g F}}{1\text{ mol F}}=0.0469\text{ g F}$$

$$0.0115\text{ g N}_2=0.0115\text{ g N}\times\frac{1\text{ mol N}}{14.0067\text{ g N}}=0.0008210\text{ mol N}$$

$$\text{g O}=0.2543-0.1679\text{ g C}-0.0149\text{ g H}-0.0469\text{ g F}-0.0115\text{ g N}=0.0131\text{ g O}$$

$$0.0131\text{ g O}\times\frac{1\text{ mol O}}{15.9994\text{ g O}}=0.0008188\text{ mol O}$$

$$\frac{0.013977\text{ mol C}}{0.0008188\text{ mol O}}=17.07\qquad\frac{0.014798\text{ mol H}}{0.0008188\text{ mol O}}=18.07\qquad\frac{0.0024668\text{ mol F}}{0.0008188\text{ mol O}}=3.01$$

$$\frac{0.0008210\text{ mol N}}{0.0008188\text{ mol O}}=1.00\qquad\frac{0.0008188\text{ mol O}}{0.0008188\text{ mol O}}=1.00$$

The empirical formula of Prozac is $C_{17}H_{18}F_3NO$

b. What is the ***molecular formula*** of Prozac?

The empirical mass is 309.3261 g mol^{-1}. Because this is the same as the molar mass the molecular formula is the same as the empirical formula, $C_{17}H_{18}F_3NO$.

4. When dinitrogen tetroxide and hydrazine react they produce water and nitrogen gas. The density of dinitrogen tetroxide is 1.44 g cm^{-3} and the density of hydrazine is 1.02 g cm^{-3}. What volume of hydrazine, in L, is needed to react completely with 15.3 L of dinitrogen tetroxide?

$$N_2O_4 + 2\ N_2H_4 \rightarrow 3\ N_2 + 4\ H_2O$$

$$15.3\ \text{L}\ N_2O_4 \times \frac{10^3\ \text{cm}^3}{1\ \text{L}} \times \frac{1.44\ \text{g}\ N_2O_4}{\text{cm}^3} \times \frac{1\ \text{mol}\ N_2O_4}{92.0110\ \text{g}\ N_2O_4} \times \frac{2\ \text{mol}\ N_2H_4}{1\ \text{mol}\ N_2O_4} \times \frac{30.0293\ \text{g}\ N_2H_4}{1\ \text{mol}\ N_2H_4} \times \frac{1\ \text{cm}^3}{1.02\ \text{g}\ N_2H_4} \times \frac{1\ \text{L}}{10^3\ \text{cm}^3}$$

$$= 14.1\ \text{L}\ N_2H_4$$

5. A stable element is discovered with an atomic number of 134. There are two naturally occurring isotopes of this element. One has an abundance of 42.63% and a relative atomic mass of 334.907863 amu. The other has a relative atomic mass of 336.916354 amu. Calculate the ***relative average atomic mass*** of the element.

$$(334.907863 \text{ amu})(0.4263)+(336.916354 \text{ amu})(0.5737)=336.\underline{0}601343 \text{ amu}$$

$$=336.1 \text{ amu}$$

6. A lab analyzes a sample of river water for the amount of mercury(I) ion present. The lab technician adds enough sodium sulfate solution to a 25.00 mL aliquot of the river water to ensure that all the mercury precipitates out. She filters and dries the precipitate and determines the mass to be 33.27 mg. What is the ***molar concentration of mercury(I) ion*** in the river water?

$$Hg_2^{2+} + SO_4^{2-} \rightarrow Hg_2SO_{4(s)}$$

$$\frac{33.27 \text{ mg } Hg_2SO_4}{25.00 \text{ mL sample}} \times \frac{1 \text{ mol } Hg_2SO_4}{497.24 \text{ g } Hg_2SO_4} \times \frac{1 \text{ mol } Hg_2^{2+}}{1 \text{ mol } Hg_2SO_4} = 0.002676 \text{ M } Hg_2^{2+}$$

7. Modern pennies are made with a core of zinc and a thin cladding of copper. The density of copper is 8.69 g cm^{-3} and the density of zinc is 7.140 g cm^{-3}. A stack of pennies has a mass of 37.500 g and a volume of 5228.68 mm^3. What is the percent by mass of copper in a penny?

$$m_{Cu} + m_{Zn} = 37.500\text{ g}$$

$V_{Cu} + V_{Zn} = 5228.68\text{ mm}^3$ which can be rewritten as $\dfrac{m_{Cu}}{d_{Cu}} + \dfrac{m_{Zn}}{d_{Zn}} = 5228.68\text{ mm}^3$

$$m_{Zn} = 37.500\text{ g} - m_{Cu}$$

$$\frac{m_{Cu}}{d_{Cu}} + \frac{(37.500\text{ g} - m_{Cu})}{d_{Zn}} = 5228.68\text{ mm}^3\left(\frac{1\text{ cm}}{10\text{ mm}}\right)^3 = 5.22868\text{ cm}^3 = \frac{m_{Cu}d_{Zn}}{d_{Cu}d_{Zn}} + \frac{(37.500\text{ g} - m_{Cu})d_{Cu}}{d_{Zn}d_{Cu}}$$

$$5.22868\text{ cm}^3 d_{Cu}d_{Zn} = m_{Cu}d_{Zn} + (37.500\text{ g} - m_{Cu})d_{Cu} = m_{Cu}d_{Zn} + 37.500\text{ g}d_{Cu} - m_{Cu}d_{Cu} = 37.500\text{ g}d_{Cu} + m_{Cu}(d_{Zn} - d_{Cu})$$

$$m_{Cu} = \frac{5.22868\text{ cm}^3 d_{Cu}d_{Zn} - 37.500\text{ g}d_{Cu}}{d_{Zn} - d_{Cu}}$$

$$m_{Cu} = \frac{5.22868\text{ cm}^3(8.69\text{ g cm}^{-3})(7.140\text{ g cm}^{-3}) - 37.500\text{ g}(8.69\text{ g cm}^{-3})}{(7.140\text{ g cm}^{-3}) - (8.69\text{ g cm}^{-3})} = 0.93\underline{7}537\text{ g}$$

$$\%\left(\tfrac{m}{m}\right)Cu = \frac{0.93\underline{7}537}{37.500} \times 100 = 2.50\%$$

8. Balance the following oxidation-reduction reactions:

a. $MnO_4^- + CN^- \rightarrow CNO^- + Mn^{2+}$ in acidic solution

+7 -2   +2 -3   +4 -3 -2   +2

$$5\,e^- + 8\,H^+ + MnO_4^- \rightarrow Mn^{2+} + 4\,H_2O$$

$$5(H_2O + CN^- \rightarrow CNO^- + 2\,H^+ + e^-)$$

~~$5\,e^-$~~ + ~~$8\,H^+$~~ + ~~5~~ $H_2O + MnO_4^- + 5\,CN^- \rightarrow Mn^{2+} + 5\,CNO^- + 2$ ~~10~~ H^+ + ~~$4\,H_2O$~~ + ~~$5\,e^-$~~

$$H_2O + MnO_4^- + 5\,CN^- \rightarrow Mn^{2+} + 5\,CNO^- + 2\,H^+$$

b. $K_2Cr_2O_7 + KI \rightarrow IO_3^- + Cr(OH)_3$ in KOH solution (write a chemical equation for this one)

+1 +6 -2   +1 -1   +5 -2   +3 -2 +1

$$6\,e^- + 8\,H_2O + K_2Cr_2O_7 \rightarrow 2\,Cr(OH)_3 + 2\,K^+ + H_2O + 8\,OH^-$$

$$6\,OH^- + 3\,H_2O + KI \rightarrow IO_3^- + K^+ + 6\,H_2O + 6\,e^-$$

~~$6\,e^-$~~ + ~~$6\,OH^-$~~ + 4 ~~11~~ $H_2O + K_2Cr_2O_7 + KI \rightarrow 2\,Cr(OH)_3 + IO_3^- + 3\,K^+$ + ~~$7\,H_2O$~~ + 2 ~~8~~ OH^- + ~~$6\,e^-$~~

$$4\,H_2O + K_2Cr_2O_7 + KI \rightarrow 2\,Cr(OH)_3 + IO_3^- + 3\,K^+ + 2\,OH^-$$

$$4\,H_2O + K_2Cr_2O_7 + KI \rightarrow 2\,Cr(OH)_3 + KIO_3 + 2\,KOH$$