Key for Chem 170 Review

Facility with the calculations from Chem 170 is essential for Chem 260. Here are some problems to help you gauge what you remember and to help you focus your attention on topics you may wish to review.

1. Report the answer to the following to the correct number of significant figures.

$$\frac{21.15}{3.46} + 5.7$$

   For multiplication or division we round the answer to the same number of significant figures as the measurement with the fewest significant figures; thus, when we divide 21.15 by 3.46 we round the answer of 6.1127... to 6.11. For addition and subtraction we round the answer to the last significant decimal place that is common to each measurement; thus, when we add 5.7 to 6.11 we round the answer of 11.81 to 11.8. Note: When completing a multistip calculation we often carry an extra significant figure through the calculation, rounding to the correct number of significant figures at the end.

2. A portable radiator provides 2050 BTU/hour. Given that 1 BTU is equivalent to 1.055 kJ, how many megajoules are produced if the radiator is operated 24 hours per day for 90 days?

$$90 \text{ d} \times \frac{24 \text{ hr}}{\text{d}} \times \frac{2050 \text{ BTU}}{\text{hr}} \times \frac{1.055 \text{ kJ}}{\text{BTU}} \times \frac{1 \text{ MJ}}{\text{kJ}} = 4.67 \times 10^3 \text{ MJ}$$

3. How many hydrogen atoms are in 5.10 mol of NH_4S?

$$5.10\text{mol NH}_4\text{S} \times \frac{4 \text{ mol H}}{\text{mol NH}_4\text{S}} \times \frac{6.022 \times 10^{23} \text{ atoms H}}{\text{mol H}} = 1.23 \times 10^{25} \text{ atoms H}$$

4. A 30.6 g sample of the compound X_2O_3 contains 14.4 g of oxygen atoms. What is the identity of the element X?

   To determine the identity of X we need to determine its atomic mass. We know the compound contains 30.6 g − 14.4 g = 16.2 g of X; thus, the moles of X in the sample is

$$14.4 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} \times \frac{2 \text{ mol } X}{3 \text{ mol O}} = 0.600 \text{ mol } X$$

   The atomic mass for X, therefore, is 16.2 g/0.600 mol, or 27.0 g/mol, which corresponds to aluminum.

5. A compound is 54.33% carbon, 9.15% hydrogen, and 36.32% oxygen by mass. What is its empirical formula?

   If we assume a 100.0-g sample of the compound, then it contains 54.33 g C, 9.15 g H, and 36.32 g O. If we convert each of these masses to the equivalent number of moles, then we can find the simplest mole ratio between the elements.

$$54.33 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.524 \text{ mol C}$$

$$9.15 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 9.08 \text{ mol H}$$

$$36.32 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.270 \text{ mol O}$$

There are fewer moles of oxygen than of carbon or hydrogen so we used oxygen to establish the ratios. The ratio of carbon-to-oxygen is $4.524/2.270 = 2$ and the ratio of hydrogen-to-oxygen is $9.08/2.270 = 4$; thus, the compound's empirical formula is C_2H_4O.

6. When heated, $KClO_3$ decomposes to form KCl and O_2. Write a balanced chemical reaction for this process and report the mass of O_2 produced by the reaction of 20.5 g of $KClO_3$.

   The balanced chemical reaction is $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$; thus

$$20.5 \text{ g KClO}_3 \times \frac{1 \text{ mol KClO}_3}{122.55 \text{ g KClO}_3} \times \frac{3 \text{ mol O}_2}{2 \text{ mol KClO}_3} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 8.03 \text{ g O}_2$$

7. We can report the concentration of a species in many ways, a few of which are shown here:

   - molar (M) or mol/L
   - weight-to-volume (w/v) or g/mL
   - percent weight-to-volume (%w/v) or g/100 mL
   - parts-per-million (ppm) or μg/g or μg/mL

   Household solutions of hydrogen peroxide, H_2O_2, are 3.0 %w/v. Report the concentration of H_2O_2 in mol/L and in ppm.

$$\frac{3\,\text{g H}_2\text{O}_2}{100\,\text{mL}} \times \frac{1 \times 10^6 \mu\text{g}}{\text{g}} = 3.0 \times 10^4 \mu\text{g/mL} = 3.0 \times 10^4 \text{ppm}$$

8. What are the molar concentrations of Na^+, Ca^{2+}, NO_3^-, and Cl^- if you combine together 100.0 mL of 0.100 M $NaNO_3$, 50.00 mL of 0.200 M $CaCl_2$, 25.00 mL of 0.300 M NaCl, and 10.00 mL of 0.400 M $Ca(NO_3)_2$.

   First, we calculate the moles, n, of each compound by recalling that $n = MV$, where M is molarity and V is volume; thus

$$\text{mol NaNO}_3 = 0.1000\,\text{L} \times 0.100\,\text{mol/L} = 0.0100\,\text{mol NaNO}_3$$
$$\text{mol CaCl}_2 = 0.05000\,\text{L} \times 0.200\,\text{mol/L} = 0.0100\,\text{mol CaCl}_2$$
$$\text{mol NaCl} = 0.02500\,\text{L} \times 0.300\,\text{mol/L} = 0.00750\,\text{mol NaCl}$$
$$\text{mol Ca(NO}_3)_2 = 0.01000\,\text{L} \times 0.400\,\text{mol/L} = 0.00400\,\text{mol Ca(NO}_3)_2$$

   The total volume of the four solutions is 185 mL. To calculate the molarity of each ion we divide its total moles from all sources—adjusting for stoichiometry where necessary—by the total volume; thus

$$[\text{Na}^+] = \frac{0.0100\,\text{mol NaNO}_3 + 0.00750\,\text{mol NaCl}}{0.185\,\text{L}} = 0.0946\,\text{mol Na}^+/\text{L}$$
$$[\text{NO}_3^-] = \frac{0.0100\,\text{mol NaNO}_3 + 2 \times 0.00400\,\text{mol Ca(NO}_3)_2}{0.185\,\text{L}} = 0.0973\,\text{mol NO}_3^-/\text{L}$$
$$[\text{Ca}^{2+}] = \frac{0.0100\,\text{mol CaCl}_2 + 0.00400\,\text{mol Ca(NO}_3)_2}{0.185\,\text{L}} = 0.0757\,\text{mol Ca}^{2+}/\text{L}$$
$$[\text{Cl}^-] = \frac{2 \times 0.0100\,\text{mol CaCl}_2 + 0.00750\,\text{mol NaCl}}{0.185\,\text{L}} = 0.149\,\text{mol Cl}^-/\text{L}$$

9. Zinc reacts with hydrochloric acid to form a solution of zinc chloride and hydrogen gas. Write a balanced chemical reaction for this process and report the mL of 4.50 M HCl needed to react with 3.45 g Zn.

   The balanced chemical reaction is $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$; thus

$$3.45 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.38 \text{ g Zn}} \times \frac{1 \text{ L HCl}}{4.5 \text{ mol HCl}} \times \frac{1000 \text{ mL}}{\text{L HCl}} = 23.5 \text{ mL HCl}$$

10. Write a balanced reaction showing the precipitation of PbI_2 upon combining separate solutions of $Pb(NO_3)_2$ and NaI. What mass of PbI_2 forms when mixing 1.50 L of 0.0400 M $Pb(NO_3)_2$ and 0.600 L of 0.140 M NaI?

    The balanced reaction is $Pb(NO_3)_2\mathit{(aq)} + 2NaI\mathit{(aq)} \rightarrow PbI_2\mathit{(s)} + 2NaNO_3\mathit{(aq)}$. To determine the mass of PbI_2 we first need to determine the limiting reagent. We have

    $$1.5 \text{ L Pb(NO}_3)_2 \times \frac{0.0400 \text{ mol Pb(NO}_3)_2}{\text{L}} = 0.0600 \text{ mol Pb(NO}_3)_2$$

    $$0.600 \text{ L NaI} \times \frac{0.140 \text{ mol NaI}}{\text{L}} = 0.0840 \text{ mol NaI}$$

    Given the 2:1 stoichiometry between NaI and $Pb(NO_3)_2$, we see that NaI is the limiting reagent because the 0.0840 mol available is less than the 0.0600×2 or 0.120 mol needed to react completely with the $Pb(NO_3)_2$; thus

    $$0.0840 \text{ mol NaI} \times \frac{1 \text{ mol PbI}_2}{2 \text{ mol NaI}} \times \frac{461.0 \text{ g PbI}_2}{1 \text{ mol PbI}_2} = 19.4 \text{ g PbI}_2$$