Key Take-Home Assignment 01

Approximately 10-12 times during the semester you will complete a take-home assigment that builds on one or more quantitative topics from class. You are encouraged to work with classmates on these problems as the conversations that develop during this sort of collaborative effort is a good way to strengthen your understanding of tricky concepts. If you do work with others you will see that although each of you has the same general problem, the data within your problem is unique; although you cannot simply compare answers with each other, you can compare approaches. The id numbers included within each problem is not relevant to your work; it simply is a code that helps me determine the correct answer.

This assignment consists of two problems. Place your neatly worked solutions in the available space or attach your neatly worked solutions to this handout.

Problem 1

At several points during the semester you will determine the concentration of a reagent in lab using a technique called a titration. In a titration a known amount of a pure compound, which we call the standard, is added to a flask and, if necessary, brought into solution using water. The reagent is added drop-by-drop until a signal tells us that the amount of reagent added is stoichiometrically equivalent to the amount of standard initially present. We call this the equivalence point. Knowing the amount of standard used, the amount of the reagent used to reach the equivalence point, and the balanced reaction between the two is sufficient to determine the reagent's concentration. For example, we can determine the concentration of HCl by titrating it against Na_2CO_3

$$\mathrm{Na_2CO_3}(aq) + 2\,\mathrm{HCl}(aq) \rightleftharpoons 2\,\mathrm{NaCl}(aq) + \mathrm{H_2CO_3}(aq)$$

In one trial, you dissolve 0.1988 g of Na_2CO_3 in approximately 25 mL of water. Titrating with your solution of HCl requires 14.95 mL to reach the equivalence point. Report the molar concentration of HCl to the correct number of significant figures. Your solution of HCl is lot number D4.

Answer. To find the moles of HCl that react with the Na_2CO_3 we use the stoichiometry of the titration reaction; thus

$$0.1988 \text{ g } \mathrm{Na_2CO_3} \times \frac{1 \text{ mol } \mathrm{Na_2CO_3}}{105.99 \text{ g } \mathrm{Na_2CO_3}} \times \frac{2 \text{ mol HCl}}{\text{mol } \mathrm{Na_2CO_3}} = 3.751 \times 10^{-3} \text{ mol HCl}$$

To find the molarity of the HCl we divide the moles of HCl by the volume used in the titration.

$$\frac{3.751 \times 10^{-3} \text{ mol HCl}}{0.01495 \text{ L}} = 0.2509 \text{ M HCl}$$

Note that we do need to account for the 25 mL of water used to dissolve the Na_2CO_3; indeed if you use this value to calculate the concentration of Na_2CO_3 by dividing the moles of Na_2CO_3 by the volume, then you must immediately multiply by the same volume to get back to moles and to complete the calculation.

With four significant figures for mass and volume, we can report the molarity to four significant figures.

Problem 2

Later in the semester you will encounter problems that take the following general form

$$a = b + \log \frac{c - x}{d + x}$$

If $a = 4.21$, $b = 4.35$, $c = 0.56$, and $d = 0.30$, then what is the value for x to the correct number of significant figures? The id for this problem is 49.

Answer. First we isolate the log term on one side of the equation by subtracting 4.35 from both sides of the equation

$$4.21 - 4.35 = -0.14 = \log \frac{0.56 - x}{0.30 + x}$$

Next, we take the inverse log of both sides of the equation

$$10^{-0.14} = 10^{\log \frac{0.56 - x}{0.30 + x}}$$

$$0.724 = \frac{0.56 - x}{0.30 + x}$$

Finally, we solve for x by mulitiplying both sides by $0.30 + x$

$$0.724 \times (0.30 + x) = 0.56 - x$$

$$0.217 + 0.724x = 0.56 - x$$

and then gather terms with x on one side of the equation, and gather the remaining terms on the other side

$$x + 0.724x = 0.56 - 0.217$$

$$1.724x = 0.343$$

$$x = 0.199 \approx 0.20$$