Unit I Additional Homework Problems from Old Exams
CHM 3120

1. (***e1su11***) You were asked the following question in one of the early assignments:

   How many grams of methanol (CH_3OH, FM 32.04) are contained in 0.290 L of 1.37 M aqueous methanol (i.e., 1.37 mol CH_3OH/L solution)?

   It's a pretty straightforward calculation of the type covered early in your first general chemistry course. One approach is shown below.

$$0.290\ \text{L} \left| \frac{1.37\ \text{mol CH}_3\text{OH}}{\text{L}} \right| \frac{32.04\ \text{g}}{\text{mol}} = 12.7_3\ \text{g CH}_3\text{OH}$$

   But of course in the stark reality of an analytical chemist's world, all of those values have errors. The molar mass has an error of ±0.002 g/mol. The error in the concentration was determined to be ±0.04 mol/L. Worst of all, the volume was measured with a 1 L graduated cylinder, giving an error of ±0.01 L.

   Based on this new information, calculate the absolute error in the mass of methanol contained in the solution.

2. (***e1su11***) Lead is a neurotoxin, especially for young children whose brains are rapidly developing. Current federal standards limit the allowed amount of lead in toys to 300 ppm. (The legal limit will be lowered to 100 ppm in August 2011.)

   A. A new toy ("Factory Barbie" by Mattel®) was tested by HealthyStuff.org in the following manner. A 102 g doll was dissolved in concentrated nitric acid. The pH was increased to 9, and the solution was titrated with EDTA revealing that the doll contained 2.38×10^{-4} mol of lead.

      Calculate the amount of lead in the doll in ppm.

   B. Okay, I made up "Factory Barbie," but the consumer group HealthyStuff.org is a real organization. They test toys for toxic materials and report the results to the public.

      Suppose that a new toy is on the market. Five of these toys were purchased and tested for lead, giving the results in the table.

      The mean for this data set is $295._2$ ppm and the standard deviation is $4._4$ ppm.

      What is the 95% confidence interval for the concentration of lead in this toy?

Toy #	Pb concentration (ppm)
1	294
2	289
3	297
4	301
5	295

      Can we say with 95% confidence that the concentration is less than 300 ppm (assume 3 sig figs for this number), the federal legal standard?

3. (***e1su11***) The methoxide anion, OCH_3^-, is a very strong base used in organic syntheses. It can be generated by adding freshly-cut sodium to dry methanol, but synthetic groups often order it in bulk from Aldrich (a major supplier of reagents for synthesis) as a 25 wt% solution in methanol. However, as the solution absorbs water from the atmosphere, some of the methoxide is leveled to hydroxide, reducing the concentration of methoxide.

   A. A bottle of 25 wt% $NaOCH_3$ was ordered from Aldrich. Immediately after it was opened, the concentration of $NaOCH_3$ was measured four (4) times giving a mean of 24.6_1 wt% with a standard deviation of 0.7_4 wt%. Two weeks later, the measurement was repeated six (6) times giving a mean of 22.8_8 wt% with a standard deviation of 0.7_3 wt%.

   Did the concentration of sodium methoxide change at the 95% confidence level?

   B. Assuming the label value of 25 wt% $NaOCH_3$, what volume of this solution would be required to deliver 65 moles of $NaOCH_3$? The molar mass of $NaOCH_3$ is 54.02 g/mol, and the density of the solution is 0.945 g/mL.

4. (***e1su11***) Questions that do not require a calculator…

   A. It was later determined that one source of error in the concentration of the methanol solution from Question I on the first page of the exam was cause by a poor seal on the lid of container, allowing the methanol to evaporate. Is that a random error or a systematic error?

   How might that error have been identified?

   B. Suppose the solution in Question III.D was changed from 0.20 M NaF(aq) to 0.20 M LaF_3(aq). Would the pH increase, remain the same, or decrease?

   Explain the reasoning behind your answer.

   The experimentally determined pH of 0.20 M LaF_3(aq) turns out to be considerably different from the calculated value based on the molar concentrations of $La^{3+}(aq)$ and $F^-(aq)$, even though no math mistakes were made in the calculation. Explain why the experimental pH is different than the calculated pH.

   C. Why is the pH of 1×10^{-8} M HNO_3 not equal to 8? Do not simply say that it is because a solution of nitric acid cannot be basic. Why does $pH = -\log(1 \times 10^{-8})$ not give you the correct pH?

   D. A small data set contains a value you believe to be significantly off from the other measurements. Name three things you can do to address your concern.

5. (***e1sp11***) Scientists at the University of Nottingham have created "the world's smallest periodic table" on a human hair using a gallium ion beam in a scanning electron microscope (*Chemistry and Engineering News*, January 24, 2011). The dimensions of the periodic table are 100 μm by 50 μm. For the purposes of this problem, let's assume the following errors in those dimensions: 100 ± 8 μm by 50 ± 6 μm.

   A. Of course we recall from our middle school math class that the perimeter of a rectangle is given by the equation

      perimeter = length + length + width + width

      So the perimeter of the world's smallest periodic table in μm would be

      perimeter = 100 (± 8) + 100 (± 8) + 50 (± 6) + 50 (± 6) μm

      Calculate the perimeter and its absolute error (i.e. absolute uncertainty), and give your answers in the boxes provided below.

      perimeter = [ ] ± [ ] μm

   B. The area of the periodic table in μm^2 would be given by

      area = length × width = 100 (± 8) μm × 50 (± 6) μm

      Calculate the area and its absolute error, and give your answers in the boxes provided below.

      area = [ ] ± [ ] μm^2

6. (***e1sp11***) HMG-CoA reductase inhibitors (commonly called statins) are a class of drug used to lower cholesterol. Lipitor and Zocor are two common examples of statin drugs, but there are many others. A common dose for statins is 20.0 mg of the active ingredient per tablet (in reality the mass of active ingredient per table would probably not be known to this precision, but we are assuming three significant figures for this problem).

   A. Following the release of a new generic form of Lipitor, some concerns were raised about its potency. A sample of seven tablets taken from one batch of the generic gave the following results:

      Sample 1 (lot #2011-01-12a)

mean mass	19.4 mg
standard deviation	0.3 mg

      Calculate the 95% confidence limits for the mean mass of the drug.

      Does the sample differ from the expected value of 20.0 mg at the 95% confidence level? (To receive credit you must explain how you arrived at your answer.)

B. A second sample of five generic tablets was taken from a different lot off the production line and analyzed, giving the following results:

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Sample 2 (lot #2011-01-18c)	
mean mass	20.1 mg
standard deviation	0.3 mg

Do the two samples differ from each other at the 95% confidence level?

7. (***e1fa12***) The fuel used in most "gas" grills is LP gas, where "LP" stands for liquid propane. The formula of propane is C_3H_8, and the balance chemical equation for the combustion of propane is given below.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

We want to know the "carbon footprint" of a standard LP gas tank.

A. First you need to model the shape of the tank. What shape are you going to use? Equations to calculate volume for various shapes are given in the info pack.

B. Now estimate the dimension(s) you need to calculate the volume and the absolute uncertainty (best guess) in the estimated dimension(s). Give the values in cm. (In case you are better at estimating in inches, remember that 1 in ≡ 2.54 cm.

C. Calculate the volume of the tank using the dimension(s) you provided in Part B.

D. Calculate the absolute uncertainty in for the volume you calculated in Part C using the uncertainties you provided in Part B.

E. Now use that volume to estimate the mass of propane in a full tank. The density of liquid propane at room temperature is 0.49 g/mL.*

F. So finally, what is the carbon footprint of a standard LP gas tank. In other words, how many grams of carbon dioxide would be produced if you burned a full tank of LP gas?

*Why so low? Rhetorical question, so you do not need to answer it, but 0.49 g/mL is a surprisingly low density for a "liquid" hydrocarbon.

8. (***e1fa12***) A rural town decided to add fluoride to its drinking water to reduce tooth decay in the community. The decision was very controversial, however, as too much fluoride can stain or even etch teeth in a process termed dental fluorosis, and some folks even claimed that fluoridation of water was a communist plot. After a heated city council meeting, it was finally decided to maintain a fluoride concentration of 1.6 ppm (same value recommended in Q10 from HW 00), and that the concentration of fluoride would be monitored on a monthly basis.

   One month the fluoride concentration averaged 1.9_6 ppm with a standard deviation of 0.1_8 ppm, based on six separate measurements of the concentration.

   What is the 95% confidence interval for the concentration of fluoride that month?

   Do the results differ from the mandated 1.6 ppm at the 95% confidence level? _____

   You are the only chemist in this rural community. The fluoride was added to the water as NaF. How you would determine the amount of NaF you would add to the water supply to achieve a concentration of 1.6 ppm, corresponding to 1.6 g of fluoride in 1000 L of drinking water. What other information do you need? Describe the calculation or set it up, but you do not carry out the calculation.

9. (***e1fa12***) As part of a routine check of water quality, a sample of seawater from Pensacola Beach was collected at 9:00 am on March 25, 2010, and analyzed for total hydrocarbons, giving the following results:

number of measurements	5
mean concentration	$37._7$ ppb
standard deviation	$5._2$ ppb

   A few months later a decision was made to repeat this analysis at 9:00 am on March 25, 2011. A sample of seawater was taken from the exact same spot and analyzed as before for total hydrocarbons:

number of measurements	9
mean concentration	$52._4$ ppb
standard deviation	$4._8$ ppb

   A. Do the data indicate that the concentration of hydrocarbon has increased compared to last year at the 95% confidence level? Be sure to show your work. You may assume that the population standard deviations are the same for both sets of measurements.

   B. *"You may assume that the population standard deviations are the same for both sets of measurements."*

      Or can you? How would you have approached the above question if you were concerned that the above assumption might not be valid? Do not do the calculation or describe the procedure in any detail. Just identify the appropriate course of action.

   C. Why is it important to repeat this measurement at the same time and on the same day?

   D. Speculate on what event prompted the decision was made to repeat the analysis a year later.

10. (***e1fa12***) The examination you are taking now is not the best way to measure what you know and what you have learned. Oral exams are better. Consider the totally made up data set below.

Student	written exam	oral exam	difference	$(d_i - \bar{d})^2$
1	83	80	3	0.64
2	96	80	16	190.44
3	65	70	−5	51.84
4	78	80	−2	17.64
5	89	90	−1	10.24
			$\bar{d} = 2.2$	$\Sigma = 270.8$

A. Based on this fake data set, do written exams and oral exams measure the same thing?

B. Show that you know how to complete the table by filling in the last two blanks below.

Student	written exam	oral exam	difference	$(d_i - \bar{d})^2$
6	72	50		

Note: you will need to calculate a new value for "d bar." Do not use the data for student #6 to answer Part A.

11. Acids and Bases

A. Identify the following compounds as strong acids, weak acids, strong bases, weak bases, or essentially neutral when dissolved in water.

1. $NaNO_3$ _____
2. HNO_3 _____
3. HF _____
4. KF _____
5. NH_4Cl _____

B. In the following chemical equilibrium

$H_2NNH_2(aq) + H_2O(l) <=> H_3NNH_2^+(aq) + OH^-(aq)$

1. What reactant is acting as the acid? _____
2. What product is acting as the conjugate acid? _____

C. Determine the pH of the following solutions:

1. 0.045 M NaOH(*aq*)

2. 7×10^{-5} M HCl(*aq*)

12. (***e1su11***) Determine the pH of the following solutions.

A. 0.057 M $HClO_4$(*aq*)

B. 0.057 M HClO(*aq*) (K_a for HClO is 3.0×10^{-8})

C. 0.20 M NaBr(*aq*)

D. 0.20 M NaF(*aq*) (K_a for HF is 3.8×10^{-4})

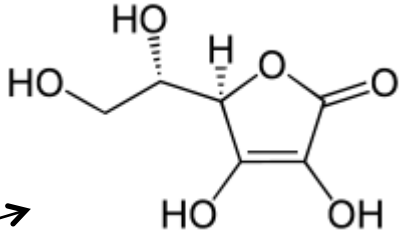
Before doing the calculation for Part D, please answer a few questions:

Do you expect the solution to be acidic or basic? Briefly explain how you arrived at your answer.

Write a balanced chemical equation for the reaction showing the acid/base chemistry, if any, exhibited by this solution.

Okay, now determine the pH.

13. (***e2fa12***) Ascorbic acid (vitamin C, $H_2C_6H_6O_6$) is a utility fielder. It is a naturally occurring reducing agent that can be pressed into service for tasks from the noble (antioxidant) to the mundane (it keeps that salad bar looking fresh for days and days), but it is also a diprotic acid with $K_{a1} = 7.9 \times 10^{-5}$ ($pK_{a1} = 4.10$) and $K_{a2} = 1.6 \times 10^{-12}$ ($pK_{a2} = 11.80$).

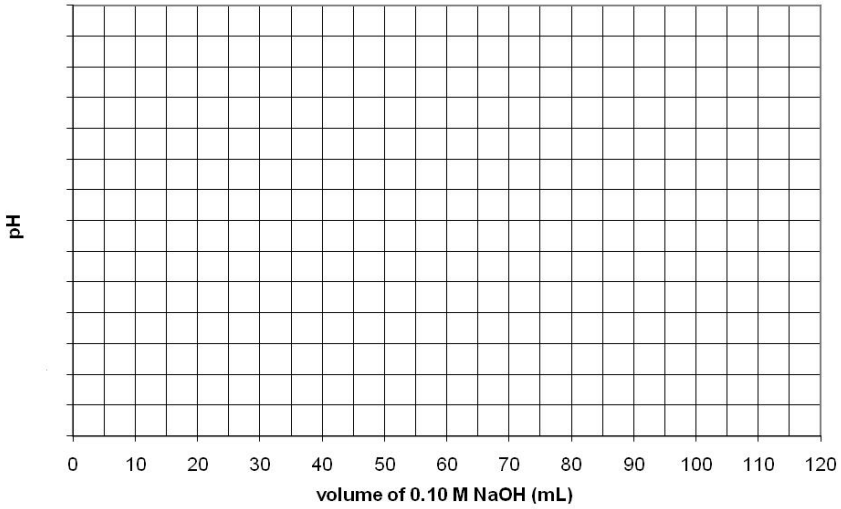


A. Circle the acidic hydrogen atoms on the structure on the right.

Account for the substantial difference between K_{a1} and K_{a2} which is even larger than most oxoacids like H_2SO_4(*aq*).

B. A 35 mL sample of 0.10 *M* $H_2C_6H_6O_6(aq)$ was titrated with 0.10 *M* NaOH(aq).

1. Sketch the expected shape of the titration curve. Annotate the curve using terms like equivalence point and give numerical values for the pH and/or volume wherever you can.



2. Determine the pH at the following volumes of added titrant:

   0 mL of 0.10 M NaOH(*aq*)

   50 mL of 0.10 M NaOH(*aq*)

   100 mL of 0.10 M NaOH(*aq*)

3. Is the solution acidic or basic at 35 mL of 0.10 M NaOH(*aq*)? _____

   Show the math you did to answer this question.

14. Trimethylamine, $N(CH_3)_3$, is a gas that responsible for the "fishy smell" as seafood starts to go bad, but when dissolved in water it acts as a weak base.

A. Write a chemical equation showing how $N(CH_3)_3$ acts as a weak base in water.

Write an equilibrium expression for that chemical equation.

B. Determine the pH of 0.25 M $N(CH_3)_3(aq)$. K_b for trimethylamine is 6.3×10^{-5}.

C. What is the conjugate acid of $N(CH_3)_3$? _____

What is the value of K_a for the conjugate acid?

15. Calculate the ionic strength of 0.025 M $MgBr_2(aq)$.

We generally assume that molar concentration is a good approximation of activity, but as we discussed in class, that is not always the case. Does that assumption get better or worse if we (circle one)

A. replace 0.025 M $MgBr_2(aq)$ with 0.025 M NaBr(aq)? better worse

Why?

B. replace 0.025 M $MgBr_2(aq)$ with 0.025 M $BeCl_2(aq)$? better worse

Why?