

Part I (52 points). Show your work on problems. Evaluation based on correctness, completeness and clarity. Use appropriate number of significant figures in your final result.

**STATISTICAL DATA ARE ON PAGE 3**

1. (14) A 2.5000 gram sample of pure oxalic acid dihydrate ( $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ , 126.1 g/mol) was dissolved in water and diluted to exactly 250 mL.

- a) A 20.00-mL aliquot was diluted to exactly 100 mL. Calculate the molar concentration of the resulting solution.

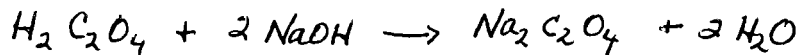
$$\text{In } 250 \text{ mL, } c_1 = \frac{n}{V} = \frac{m_{\text{H}_2\text{O}_x}}{(MW_{\text{H}_2\text{O}_x})(0.250 \text{ L})} = \frac{2.5000 \text{ g}}{(126.1 \text{ g/mol})(0.250 \text{ L})} = 0.07930 \text{ mol/L}$$

After dilution,

$$c_2 = \frac{c_1 V_1}{V_2} = (0.07930 \text{ mol/L}) \left( \frac{20}{100} \right) = 0.01586 \text{ mol/L}$$

- b) A second 20.00-mL aliquot (taken from the 250 mL) required 40.00 mL for titration with NaOH to the phenolphthalein endpoint. Both protons react.

- i) Write a balanced chemical equation for the reaction.



- ii) Calculate the molar concentration of the NaOH.

$$\text{At eq. pt, } n_{\text{NaOH}} = n_{\text{H}_2\text{O}_x} \left( \frac{2 \text{ NaOH}}{1 \text{ H}_2\text{O}_x} \right)$$

$$C_{\text{NaOH}} V_{\text{NaOH}} = C_{\text{H}_2\text{O}_x} V_{\text{H}_2\text{O}_x} (2)$$

$$C_{\text{NaOH}} = \frac{(0.07930 \text{ mol/L})(20.00 \text{ mL})(2)}{40.00 \text{ mL}}$$

$$= 0.07930 \text{ mol/L}$$

2. (6) A standard fluoride solution is prepared by dissolving 0.0180 g of calcium fluoride in water and diluting to exactly one liter. Calculate the concentration of the fluoride ion in parts per million.

Atomic weights: Ca = 40.1, F = 19.0

$$C_{\text{F}} = \frac{\text{mg F}^-}{\text{L}} ; 1 \text{ ppm} = \frac{1 \text{ mg}}{\text{L}}$$

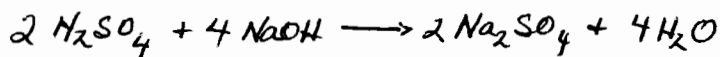
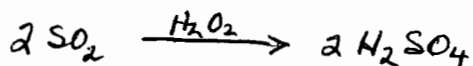
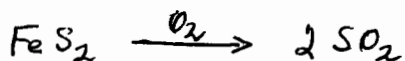
$$\cancel{m_{\text{F}}} = \cancel{m_{\text{C}}}$$

$$n_{\text{F}} = n_{\text{CaF}_2} (2) = \frac{m_{\text{CaF}_2}}{MW_{\text{CaF}_2}} (2) = \frac{0.0180 \text{ g CaF}_2}{78.1 \text{ g CaF}_2/\text{mol CaF}_2} (2) = 4.61 \times 10^{-4} \text{ mol}$$

$$m_{\text{F}} = 4.61 \times 10^{-4} \text{ mol} \times 19.0 \text{ g/mol} = 8.76 \times 10^{-3} \text{ g} = 8.76 \text{ mg}$$

$$C_{\text{F}} = \frac{8.76 \text{ mg}}{1 \text{ L}} = 8.76 \text{ ppm}$$

3. (12) Sulfur in coal may exist primarily as iron pyrite,  $\text{FeS}_2$ . The sulfur in a 1.2000-gram coal sample was analyzed by combustion. The liberated  $\text{SO}_2$  was absorbed in dilute  $\text{H}_2\text{O}_2$  to yield  $\text{H}_2\text{SO}_4$ . The  $\text{H}_2\text{SO}_4$  was titrated with 40.00 mL of 0.1000 M NaOH.
- a) Write chemical equations for the reactions to establish the stoichiometric relation between the  $\text{FeS}_2$  in the coal and the NaOH titrant. Based on these reactions, write a simple mathematical relationship between moles of  $\text{FeS}_2$  and moles of NaOH.



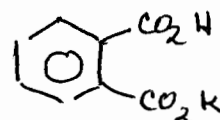
$$n_{\text{FeS}_2} = n_{\text{NaOH}} \left( \frac{1 \text{ FeS}_2}{4 \text{ NaOH}} \right)$$

- b) Report the sulfur in the coal sample as percent  $\text{FeS}_2$  (119.98 g/mol).

$$\begin{aligned} \% \text{ FeS}_2 &= \frac{\text{Wt FeS}_2 \left( \frac{\text{MW FeS}_2}{\text{MW FeS}_2} \right) 100}{\text{Wt sample}} \\ &= \frac{n_{\text{FeS}_2} (\text{MW FeS}_2) 100}{\text{Wt sample}} = \frac{M_{\text{NaOH}} \cdot V_{\text{NaOH}} \left( \frac{1}{4} \right) (\text{MW FeS}_2) 100}{\text{Wt sample}} \\ &= (0.1000 \text{ mol/L}) (40.00 \text{ mL}) \left( \frac{1}{4} \right) (0.11998 \text{ g/mmol}) 100 / 1.2000 \text{ g} \\ &= 9.998 \% \approx 10.00 \% \text{ FeS}_2. \end{aligned}$$

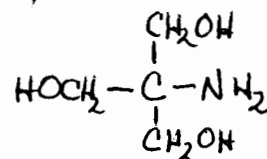
4. (8) Write the full name and structure for the following substances used in the companion laboratory course.
- a) The primary standard acid used to standardize NaOH.

KHP = Potassium acid phthalate



- b) The primary standard base used to standardize HCl.

THAM = tris(hydroxymethyl)aminomethane



5. (12) Analysis of an over-the-counter pain reliever yielded the following results for percent acetaminophen. Use the statistical tables on the following page to answer the following questions.

a) Based on these data, report the average percent acetaminophen in the sample with the 95% confidence limits.

$$\mu = \bar{x} \pm \frac{t_{\alpha, \phi} s_x}{\sqrt{N}} = 56.19 \pm \frac{(3.18)(0.11)}{\sqrt{4}}$$

$$= 56.19 \pm 0.18$$

% acetaminophen	
56.18	NN
56.12	
56.34	out
56.10	mn
Mean = <del>58.19</del>	56.19
Std dev = 0.11	
$\phi = 3$	

b) Based on extensive experience with the method, the standard deviation of the method is known to be 0.08% acetaminophen. Report the results for the analysis with the 95% confidence limits based on this information.

$$\mu = \bar{x} \pm \frac{z_{\alpha} \sigma_x}{\sqrt{N}} = 56.19 \pm \frac{(1.96)(0.08)}{\sqrt{4}}$$

$$= 56.19 \pm 0.08$$

c) Now apply the Q test to determine if a value can or should be rejected from the data set.

i) Identify the outlier

56.34

ii) Can this outlier be rejected at the 90% confidence level? Show your calculation and argument for your conclusion.

$$Q_{exp} = \frac{\text{Outlier} - \text{N.N.}}{\text{Range}} = \frac{56.34 - 56.18}{56.34 - 56.10} = \frac{0.16}{0.24} = 0.67$$

$$Q_{crit} = 0.76$$

$$Q_{exp} < Q_{crit} \Rightarrow \text{Return outlier.}$$

Values of z	
Confidence Level, %	z
90	1.64
95	1.96

Values of Student's t		
Degrees of Freedom	90% Confidence Level	95% Confidence Level
1	6.31	12.7
2	2.92	4.30
3	2.35	3.18
4	2.13	2.78
5	2.02	2.57

Critical Values for Rejection Quotient Q		
Number of Observations	Q <sub>crit</sub>	
	90% Confidence Level	95% Confidence Level
3	0.941	0.970
4	0.765	0.829
5	0.642	0.710
6	0.560	0.625

Continue to multiple choice questions