

Chemistry 20L
Final Exam Study Questions Key
Winter 2007

1. Sketch the titration curves for each of the following systems. Calculate and indicate on each sketch, the equivalence point volume, the initial pH of the solution, and at least one other pH on the titration curve. Also be sure to indicate the approximate pH of the equivalence point if this is not the second point that you choose.

(a) 10.00 mL of 0.0500 M HNO₃ (beaker) titrated with 0.100 M NaOH (buret)

The titration of a strong acid (HNO₃) with a strong base (NaOH) yields a titration curve with a characteristic slow-rising, flat portion followed by a steep rise that levels off once again. The equivalence point volume for the base is 5.00 mL.

The initial pH is due to the complete dissociation of the nitric acid. [H⁺] = 0.0500 M, pH = 1.30

The equivalence point pH is 7

Calculation of other points requires more arithmetic. Any other pH can be calculated prior to the equivalence point by considering the unreacted acid in the flask. For example, at the 2.5 mL point in the titration, 5 mL of acid are unreacted in a solution volume of 12.5 mL. [H⁺] = 0.0200; pH = 1.70

After the equivalence point, you consider the concentration of the unreacted excess hydroxide.

(b) 10.00 mL of 0.0500 M benzoic acid ($K_a = 6.46 \times 10^{-5}$) (beaker) titrated with 0.100 M NaOH (buret).

The titration of a weak acid (benzoic acid) with a strong base (NaOH) yields a titration curve with a shape that resembles your titrations from the lab when you titrated vinegar with NaOH. The equivalence point volume for the base is 5.00 mL.

The initial pH is due to partial dissociation of the benzoic acid. [H⁺] = 0.00180 M, pH = 2.75

Half way through the titration, after 2.5 mL of base have been added, the pH = pK_a = 4.19. Because of the hydrolysis of the benzoate salt at the equivalence point, the pH will be greater than 7. Calculation of [OH⁻] at the equivalence point gives 5.75 x 10⁻⁶M or pOH = 5.2 and pH = 8.8

2. A Chemistry 20L student determined the sodium tripolyphosphate ($\text{Na}_5\text{P}_3\text{O}_{10}$) in a detergent by ashing a sample and then titrating the acid in the ash with NaOH assuming the following reaction:



(a) Based on the following data, calculate the percent STTP in the detergent.

Molecular weight of STTP = 371 g

| | |
|---|------------------------------|
| Weight of sample | $2.000 \pm 0.0002 \text{ g}$ |
| Concentration of standard NaOH | $0.500 \pm 0.001 \text{ M}$ |
| Volume of standard NaOH to titrate the ashed sample | $19.41 \pm 0.03 \text{ mL}$ |

(a) $\text{moles of OH}^- = \text{moles of H}_2\text{PO}_4^- = (0.500\text{M} \times 0.01941\text{L}) = 9.705 \times 10^{-3}$

$(\text{moles of H}_2\text{PO}_4^-)/3 = \text{moles of STTP} = 3.235 \times 10^{-3}$

$\text{weight of STTP in sample} = \text{moles STTP} \times \text{MW} = 3.235 \times 10^{-3} \text{ mol} \times 371 \text{ g/mol} = 1.200\text{g}$

$\% \text{ STTP in sample} = 1.200\text{g}/2.000\text{g} \times 100 = 60.0\%$

(b) Presuming that the sample was completely ashed and dissolved, and that there were no other sources of acid in the ash to react with the NaOH, calculate the percent inherent error in the phosphate determination.

(b) **Inherent error = sum of % errors in buret reading, concentration of base and weighing of original sample**

$$= \left[\left(\frac{0.0002}{2.0000} \right) + \left(\frac{0.001}{0.500} \right) + \left(\frac{0.03}{19.41} \right) \right] \times 100 = 0.36\%$$

3. (a) **The end point in a titration is when an indicator changes color signaling (one hopes) that the equivalents of acid and base that have been mixed are equivalent. The equivalence point in a titration occurs when the equivalents of acid and base that have been mixed are identical whether or not there is any indication experimentally that this is the case.**

(b) **Volumetric glassware is calibrated by the manufacturer to give a precision of 0.1% based on proper use at the temperature specified. Non-volumetric glassware may have volume indications to give an estimate of the volume contained or delivered to a precision of 1 – 5%; temperature is not a factor when the precision has these values.**

(c) **A phase diagram graphically shows the temperature, pressure, and concentrations required for equilibrium of the various phases in a system. A phase change involves the transition of a substance or a mixture between the physical states of solid, liquid and gas. Conditions at which multiple phases coexist in equilibrium are depicted as lines (or surfaces) on a phase diagram.**

(d) **Normality** is a concentration unit used in experimental work when the stoichiometry of a reaction is not known. Normality is defined as the number of equivalents of the solute/liter of solution. For acid-base reactions, an equivalent is defined as the weight of the compound that reacts with or furnishes one mole of protons. Molarity is used when the stoichiometry of the reaction is known including the molecular formula of the compounds. Molarity is a concentration unit defined as moles of solute/liter of solution.

(e) **Absorbance** is a measure of the amount of light interacting with the molecules in a solution and not passing through the solution. It is related to the transmittance by the equation $A = -\log T$. The transmittance, T , is the fraction of incident light that passes through a solution.

(f) **Accuracy** refers to the closeness of a set of results to the true value for that result. The **precision** refers to the deviation or variation of a set of results from the mean.

4. "Acid base indicators are usually weak acids, which can exist in solution as either the undissociated acid or the conjugate base. The two species have different colors. As the pH of the titration changes, the predominant form of the indicator changes from one form to the other." (*Chemistry Experiments for Physical Science and Engineering Majors*, pp58)

(a) In Assignment 4 you recorded the pH ranges for the color changes for four indicators. Based on that data, complete the following table.

SA = strong acid, SB = strong base; WA = weak acid, WB= weak base

| Indicator | pH range of color change | color of undissociated indicator | color of conjugate base | Appropriate indicator for titration of 0.1000 M reagents of acid and base (Explain below) | | |
|-------------------|--------------------------|----------------------------------|-------------------------|---|-------|-------|
| | | | | SA-SB | WA-SB | WB-SA |
| Bromocresol green | 3.8 – 5.4 | yellow | blue | | | X |
| Phenolphthalein | 8.2 – 10.0 | colorless | pink-magenta | X | X | |
| Methyl red | 4.8 – 6.0 | red | yellow | | | X |
| Methyl orange | 3.2 – 4.2 | red | yellow | | | X |

Give your reasoning for choice of titration.

The pH of the equivalence point occurs below 7 in the titration of a weak base with a strong acid due to the hydrolysis of the conjugate acid of the base. Thus, to make the end point of the indicator correspond to the equivalence point of the titration, the indicator choice must change color below pH 7. Bromocresol green, methyl red and methyl orange are appropriate indicators.