Online Activity 4

Acid-Base Titration

Introduction

Acid-Base Reactions

Acid-base **neutralization** reactions are reactions where a hydrogen ion from an acid reacts with a hydroxide ion from a base to form water and a salt. An **acid** is any chemical that contains a hydrogen ion (a proton, H^+) that can dissociate and form the hydronium ion (H_3O^+) in water. In inorganic acids, the hydrogen is written first (**H**-Cl). An inorganic **base** contains the hydroxide ion (OH^-) as the anion (Na-**OH**). If you can identify these two ions in your reactants, you probably have an acid-base reaction, and the products will always be water and a salt. Thus, in the example below, the HCl is the acid and the sodium hydroxide, NaOH, is the base. A **neutralization** reaction results when the hydrogen from the acid reacts with the hydroxide ion in the base to form water. The remaining cation and anion will form a salt, such as the soluble salt NaCl in the example below. The moles of H^+ reacted in the antacid neutralization will be equal to the moles of OH^- used in the titration. Therefore, once the acid has been completely neutralized, the volume of the base used and its concentration can be used to determine the molarity of the acid present. In the example below, you have 1 mole H+ per each mole of acid and 1 mole OH- per mole of base.

$$\underline{H}Cl + Na\underline{\mathbf{OH}} \rightarrow H_2O + NaCl$$

It is very important for the acid-base reaction to be balanced, especially If either the acid or the base contains more than one hydronium ion or hydroxide ion, to ensure that the correct mole ratio is used in the titration calculation.

$$\underline{\mathbf{H_2}}SO_4 + \underline{\mathbf{2}}Na\underline{\mathbf{OH}} \rightarrow \underline{\mathbf{2}}H_2O + Na_2SO_4$$

$$\underline{\mathbf{2H}}Cl + Ca(\underline{\mathbf{OH}})_{\underline{2}} \rightarrow \underline{\mathbf{2}}H_2O + CaCl_2$$

Use the mole ratio between the acid in the base in the chemical equation to account for any **polyprotic** (more than 1 H in the acid) acids or bases with more than one hydroxide.

Molarity

In most of the stoichiometry calculations that you have seen thus far, the moles of material were calculated from the mass of a solid material that you measured using a balance. Since most acid-base reactions are carried out using solids or liquids that have been dissolved in water to form **aqueous** (dissolved in water) solutions, such mass-based calculations are less useful. When working with aqueous solutions, a unit called **molarity** is the conversion factor used to calculate the moles of the substance. Molarity is a measure of concentration that connects the amount of material to the volume of the solution, and has units of moles of compound per liter of solution (mol/L). When using aqueous solutions, molarity calculations are used instead of mass-based calculations to determine the number of moles involved in a chemical reaction.

Molarity allows you to measure out a volume of a solution and directly calculate the moles of the dissolved compound. In the case of the HCl solution used in your lab, the concentration is 3.00M, meaning there are 3.00 moles of HCl in every 1 liter of solution.

$$3.00M_{HCl\,solution} = \frac{3.00mol_{HCl}}{1L_{HCl\,soln}}$$

From this point on in the course, if you are asked to give the concentration of a compound that has been dissolved in water, and the units are not specified, you are expected to know that molarity, not density or percent volume, is what is expected for an answer.

Example 1: How much solid NaOH is needed to prepare 2.00L of 0.500M NaOH solution?

$$g_{NaOH} = \frac{0.500mol_{NaOH}}{1L_{NaOH\ soln}} x \frac{2.00L_{NaOH\ soln}}{1} x \frac{40.00g_{NaOH}}{1mol_{NaOH}} = \frac{40.00g_{NaOH}}{1}$$

You would prepare this solution by weighing out 40.00g of solid NaOH, pouring the solid into a 2L volumetric flask, and adding water until the meniscus reaches the 2L mark on the neck of the flask. The calculated concentration of the solution in the flask will be 0.500M.

Note: Use the unit, the name of the chemical, and the word "solution" or "soln" to distinguish between pure liquids and aqueous solutions. This way you can avoid confusing the different chemicals used in the calculations, and when you do dimensional analysis, you will be better able to keep track of both the chemical and the unit when canceling out units to get to your final answer.

$$0.500M_{NaOH\ solution} = \frac{0.500mol_{NaOH}}{1L_{NaOH\ soln}} \qquad Not \frac{0.500mol}{1L} or \frac{0.500mol_{NaOH}}{1L_{NaOH}}$$

Titrations

A **titration** is an analytical method that is used to determine the concentration of a solution. Titrations use a calibrated tube, called a **buret** to slowly add a solution of known concentration to a known amount of a solution with an unknown concentration. At the **endpoint**, the moles of the **titrant** (solution being added from the buret) will equal a specific number of moles of your other reactant based on the mole ratio in the chemical reaction. **You will use dimensional analysis and stoichiometry whenever you are doing titration calculations**.

In an acid-base titration the buret is used to slowly add a basic solution of known concentration into a test solution containing acid until the acid has been completely reacted (an acid of known concentration can also be added to a base of unknown concentration). We use the word "**neutralized**" in acid base reactions since once the acid has been completely used up by adding the base, the solution is no longer acidic or basic, but exactly half-way in between, or neutral. In your experiment, you will neutralize the excess HCl with a solution of NaOH. The neutralization reaction is as follows:

$HCl + NaOH \rightarrow H_2O + NaCl$ (note the 1:1 ratio between the acid and the base)

Since aqueous solutions are often colorless, you need a way to determine when the endpoint has been reached. To see the endpoint in an acid base reaction, an **indicator**, such as **phenolphthalein,** is added to the acid to determine when the endpoint of the titration is reached. Phenolphthalein is a chemical that is colorless when in an acidic solution and a very dark pink when basic. The endpoint is reached when the acid solution remains a very pale pink. At this point the solution is very slightly basic, with a negligible amount of excess NaOH.

Making Dilutions

Because of space limitations and the higher stability often seen in concentrated solutions, many aqueous solutions are prepared with a higher concentration than when normally used in the laboratory. These concentrated solutions are referred to as **"stock" solutions** and are used to prepare "**working**" solutions of lower concentrations. To obtain the solution concentration you need in the lab, you must first make a **dilution** of this stock solution.

Making a dilution involves mixing a known amount of stock solution with enough water to obtain the desired molarity of the more dilute working solution. You can use the following equation to calculate the amount of stock solution you need for the desired volume and molarity of the dilute solution. **This equation is ONLY for dilution calculations – not for titration calculations.**

$$M_{stock\ solution} \times V_{stock\ solution} = M_{dilute\ solution} \times V_{dilute\ solution}$$

M = Molarity in moles per liter
V = Volume in liters

To make a dilution, first decide how much working solution you need and its final concentration. This allows you to fill in the right side of the equation. Use the molarity of the stock solution to determine the volume of the stock solution you will need to make this dilution. You will notice that if you fill in both sides of the equation that units of volume will cancel out, leaving you with moles on both sides of the equation. Essentially when you are doing a dilution, you are working with a fixed number of moles and only manipulating the volume of water in the solutions. For example, 1L of a 0.1 M solution of HCl contains the same number moles of HCl as 100ml (0.1L) of a 1 M HCl solution. Both solutions contain 1 mole of HCl; the molecules are just more spread out in the larger container, thus the concentration, number of molecules per volume, is lower.

$M_1V_1 = M_2V_2$ SHOULD ONLY BE USED FOR DILUTION CALCULATIONS.
STOICHIOMETRY SHOULD BE USED FOR TITRATION CALCULATIONS.

DO NOT USE $M_1V_1 = M_2V_2$ FOR TITRATION CALCULATIONS

Standardization

The concentration of the titrant must be very well documented before being used. While the concentration of the stock solution of the acid remains constant, NaOH solutions are **hygroscopic**, meaning they absorb water from the atmosphere and become more dilute over time. Therefore, before using the sodium hydroxide solution in the lab, you need to check its concentration. This is called "**standardizing**" the solution. Since HCl is not hygroscopic, you use a known volume and concentration of HCl and titrate it with the NaOH solution and use dimensional analysis to solve for the molarity of the base.

Ideally, this new concentration should be close to the original concentration that is recorded on the bottle of NaOH, but it is more accurate since any dilution due to absorption of water from the atmosphere has been addressed. Use this new concentration in calculations, not the concentration given on the bottle since the standardized concentration is more accurate.

Since this is a simulation, you do not need to standardize the NaOH, but you should be aware of the reasons why standardization is important.

Online Activity 4: Procedures and Data Sheet
(Submit as part of your Online Activity Report)

Name: ____ Date: _______ Section: _______

Record all measurements with the correct number of significant figures and units.

Directions for using the simulation:

1. Go the ChemCollective determination of an unknown strong acid simulation at: http://chemcollective.org/activities/autograded/124
2. Click on the 10.00M NaOH solution from the menu at left to add it to your work bench.
3. Click on the distilled water in the menu to add it to your workbench.
4. You will need to dilute the 10.00M NaOH solution to 5.00M using the distilled water. Use the dilution equation to calculate how much of the 10.00M solution is needed to make 100.00mL of a 5.00M solution. Show your work below:

Volume of 10.00M solution needed: ________________

5. Click on the glassware square at the top of the menu to open up the glassware options. Click on the 100.00mL volumetric flask to add that to your work bench.
6. Drag the 10.00M NaOH solution over the volumetric flask. A box should open to allow you to type in the volume that you need based on the above calculation. Type in the desired volume using 2 decimal places. Once you type in the volume, click on pour in the little box to add the NaOH to the volumetric flask.
7. Drag the distilled water over the volumetric flask. In the little box, type in the volume needed to bring the total volume in the volumetric flask up to 100.00mL. Again use 2 decimal places.
8. Click on the solutions square at the top of the menu. Click on the unknown acid and the phenolphthalein to add them to your work bench.
9. Drag the phenolphthalein over the unknown acid, and add 2.00mL of phenolphthalein to the acid. The volume of liquid in the Erlenmeyer will increase by 2.00mL.
10. Click on other in the stockroom menu and add the buret to your lab bench. Drag the volumetric flask of diluted base over the Erlenmeyer and add 40.00mL of diluted NaOH to the buret. Record the volume of liquid in the buret to two decimal places.

Initial volume of liquid in buret: ______________________

11. Drag the buret over the flask of acid. You may need to move it around a bit to get the box allowing you to enter the amount of liquid you wish to add. Enter 0.05mL in the box.
12. Click on pour to add NaOH from the buret to the unknown acid. You will want to do this very slowly so that you do not miss the endpoint. Add 0.05mL at a time until the solution turns pink. If you add the liquid too fast and miss the endpoint, you will not get the correct answer.
13. When the solution turns pink, record the volume of NaOH remaining in the buret.

Final volume of liquid in buret: ______________________

14. Subtract the initial volume in the buret from the final volume in the buret to get the volume of NaOH added to your acid.
15. Complete the calculations, and enter the concentration of your unknown acid. You have three chances to get the correct concentration for each attempt, but you can attempt the simulation as many times as is necessary. Once you get the correct concentration, either print or take a picture of the conformation page to submit with your report.

Online Activity 4: Data Rubric (20pts)

<u>Points</u>

Data are neat and legible	5pts		__________pts
Significant figures (>80% correct)	3pts		__________pts
Units (>80% correct)	2pts		__________pts
All data are present and make sense	10pts		__________pts

<u>Deductions (sliding scale based on TA discretion)</u>

Lab area left unclean	–20pts	__________pts
Improper waste disposal	–20pts	__________pts
Disruptive behavior	–20pts	__________pts
Lab coat or safety glasses removed while in lab	–20pts	__________pts
Data sheet is missing TA signature	–20pts	__________pts
Other: ____		__________pts

Comments: ____

Grade for Data Sheet __________pts

Online Activty 4: Results Table
(Submit as part of your online activity report)

Name: ______________________________ Date: ________ Section: ________

Record all results with the correct number of significant figures and units.

Results:

Volume of 10.00M NaOH needed to make diluted NaOH solution:	
Amount of diluted NaOH used in titration	
Moles of NaOH used in titration	
Moles of acid in unknown acid solution	
Concentration of Unknown acid solution	

Online Activity 4: Results Table Rubric (20pts)

Points

Tables are neat and legible 5pts __________pts

Significant figures (>80% correct) 3pts __________pts

Units (>80% correct) 2pts __________pts

All results are present and make sense 10pts __________pts

Deductions (sliding based on TA discretion)

Results to not match data -20pts __________pts

Plagiarism!!! Results are identical to another student -100pts __________pts

Other: ______________________________________ __________pts

Comments: ____

Grade for Results Table __________pts

Online Activity 4: Calculations

Submit as part of your online activity report. Make sure to include the notice from the simulation that you obtained the correct concentration for your unknown acid.

Dilution of NaOH

Show the calculation that you used to calculate the amount of stock NaOH solution needed for your dilution. This calculation is in your data section.

Volume of NaOH used: ______________

Titration of Unknown Acid

Remember that titration calculations are just a series of mole/molarity calculations. Never use the dilution equation for titrations. You will receive no points if you use the dilution equation for this section!

<u>Volume of NaOH used in titration</u>
Subtract the volume you initially measured on the buret from the final volume measurement.

Volume of NaOH used in titration: ________________

<u>Moles of NaOH used in titration</u>
Use the volume of NaOH used in the titration and the molarity (moles/L) of the diluted NaOH to calculate the moles of NaOH.

Moles of NaOH used in titration: ________________

<u>Moles of acid in the unknown solution</u>
Remember this is a monoprotic acid, meaning it only has one hydrogen. Therefore, there is a 1:1 relationship between the moles of base used and the moles of acid neutralized. Use this 1:1 mole ratio to calculate the number of moles of acid neutralized.

Moles of HCl neutralized: ________________

Concentration of unknown acid solution
You started with 100.00mL of your unknown acid. Use this information and the moles of acid in the sample to calculate the concentration of the unknown acid solution.

Concentration of unknown acid solution: ______________________

Online Activity 4 Additional Calculations

Include as part of your online activity report

All information needed to complete this worksheet can be found in the pre-lab information and Read this introductory material first!

- Record all values with the correct number of significant figures and units.
- Place all answers on the line when provided.
- Show calculations for any numerical answers; **work must be shown to receive credit.**
- See any 102 TA via webex if you have any questions.

Answer all questions for the following acid-base titration:

25.00mL of H_2SO_4 was titrated with 0.15M NaOH. 22.85mL of NaOH was needed to reach the endpoint of the titration.

1. Write and balance the chemical equation that results when sulfuric acid is titrated with sodium hydroxide.

   ____

2. Calculate the number of moles of base used in the titration.

   ____

3. Calculate the molarity of the acid. Show all work, including how the units cancel.

   ____

4. If you are given a 250milliliter volumetric flask, (±0.01ml) what volume of 2.00M stock solution will you need to make 250.00mL of the 0.15M NaOH titrant solution?

____

5. What mass of solid NaOH would be needed to make 250.00mL of the 0.15M NaOH solution? Show all work, including how the units cancel.

____

6. Calculate the mass of $Ca(OH)_2$ in a sample if the calcium hydroxide is neutralized by 22.50mL of 0.500M HCl according to the following equation:

$$2HCl\ (aq) + Ca(OH)_2\ (s) \rightarrow 2H_2O\ (l) + CaCl_2\ (aq)$$

Show all work, including how the units cancel.

____

7. What color is phenolphthalein in a basic solution?

____

8. What piece of equipment will you "use" to dispense the titrant in the titration (see instructions for name, it is the same equipment as you would use in an actual lab)?

____