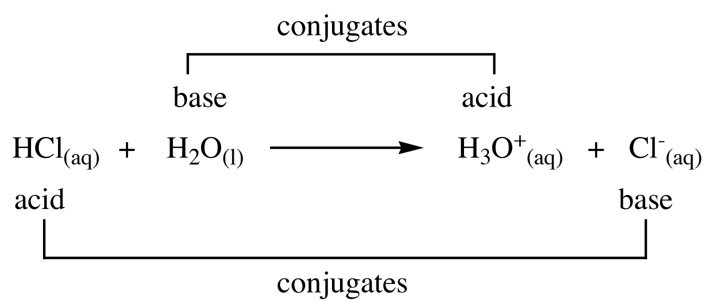
Strength of Acids and Bases: An Equilibrium Issue

Goals

- Determine the strength of acids and bases.
- Use the Brønsted-Lowry definitions of an acid and a base to identify acids and bases.
- Use the Brønsted-Lowry definition of an acid and base to identify conjugate acid-base pairs.
- Describe acid-base reactions by using hydrogen-ion (proton) transfer reactions.
- Explain the differences between strong and weak acids and bases by using equilibrium principles.

Introduction

The strength of an acid or base reflects how readily it ionizes in water. Hydrochloric acid, readily donates a proton to water to become hydronium ion and chloride ion.



Does this reaction go to completion? Are all the molecules converted into ions? In today's lab, you will use two indicators, bromthymol blue (BTB) and universal (UI), to probe acid-base strength.

Safety

Act in accordance with the laboratory safety rules of Cabrillo College.
Wear safety glasses at all times.
Avoid contact* with all chemical reagents and dispose of reactions using appropriate waste container.

Materials:

Reagent Central solutions include:

Name	Formula	Name	Formula
hydrochloric acid	HCl	sodium hydroxide	$NaOH$
nitric acid	HNO_3	potassium hydroxide	KOH
sulfuric acid	H_2SO_4	calcium hydroxide	$Ca(OH)_2$
acetic acid	$HC_2H_3O_2$	ammonia	NH_3
sodium carbonate	Na_2CO_3	ammonium hydroxide	NH_4OH
sodium dihydrogen phosphate	NaH_2PO_4	sodium hydrogen carbonate	$NaHCO_3$
sodium hydrogen sulfate	$NaHSO_4$	sodium hydrogen phosphate	Na_2HPO_4
boric acid	H_3BO_3	sodium phosphate	Na_3PO_4
citric acid	$H_3C_6H_5O_7$	sodium hydrogen sulfite	$NaHSO_3$
sodium acetate	$NaC_2H_3O_2$		

Bromthymol blue (BTB) in its green form, Universal Indicator (UI)
pH Buffer solutions (pH 1 through pH 12)

Equipment: 1×12 well strip Empty pipet for stirring Lab top reaction surface

Experimental Procedure

1. Use the 1×12 well strip and the pH buffer solutions to make a pH meter. Notice on the top of the 1×12 well strip there are small numbers corresponding to 1 – 12. Start by placing 1 drop of Universal Indicator (UI) into each well. Next place 5 drops of pH 1 buffer solution into well one, followed by 5 drops of pH 2 buffer solution into well two and so on. Compare your pH meter to your neighbor's as a check.
2. Part A and B. Mix 1 drop of each of the indicated solutions. Look carefully for similarities and differences to distinguish strong acids from weak acids and strong bases from weak bases. Record your observations. Be specific in your descriptions. In the last row test each acid/base for conductivity. Be sure to rinse the leads of the conductivity apparatus between tests. Record your observations. Use your pH meter to compare with the Universal Indicator (UI) test to determine the pH of each solution. Record the pH values.
3. Part C. Mix 5 drops of each of the solutions with one drop of indicator. Record your observations. Determine which of the species is a base and which is an acid. Use your pH

meter to compare with the Universal Indicator (UI) test to determine the pH of each solution. Record the pH values.

Reaction Guide: Insert this page into the labtop.

Part A. Acids and Indicators

1 drop ea	HCl	HNO_3	H_2SO_4	2 drops HCl + 9 drops H_2O	$HC_2H_3O_2$	Citric acid ($H_3C_6H_5O_7$)	Boric acid (H_3BO_3)
BTB							
UI							
Na_2CO_3							
Test for conductivity							

Part B. Bases and Indicators

1 drop ea	NaOH	KOH	$Ca(OH)_2$	2 drops NaOH + 9 drops H_2O	Na_3PO_4 (PO_4^{3-})	Na_2CO_3 (CO_3^{2-})	$NaC_2H_3O_2$ ($C_2H_3O_2^-$)
BTB							
UI							
Test for conductivity							

Part C. Acids, Bases, and Indicators

5 drops solution/1 drop indicator	$NaHSO_4$ (HSO_4^-)	Na_2HPO_4 (HPO_4^{2-})	$NaHCO_3$ (HCO_3^-)	NaH_2PO_4 ($H_2PO_4^-$)	$NaHSO_3$ (HSO_3^-)	NH_3
BTB						
UI						

Data Organization Suggestions

The actual amount of written data required for this lab is fairly small. Simple descriptions of color for tests with indicators, relative amounts of bubbles produced with sodium carbonate, brightness of the diode in the conductivity tests, and pH values are all that is required. This data will fit nicely in tables identical to those used in the reaction guide (provided that you add a row for the pH value). As always it is important not to crowd your data. Don't be afraid to turn your notebook page so that the data table runs along the long axis of the page (landscape format).

Data Analysis

Answer the following questions in your laboratory notebook using complete sentences.

Use your observations from Part A to answer the following questions:

1. What conclusions can you draw based upon the BTB test of the different acids?
2. What conclusions can you draw based upon the UI test of the different acids?
3. Describe the results (what you saw) in the sodium carbonate reaction with acids. Make a general conclusion about the reaction of sodium carbonate with acids.
4. Based on the results described in the above question, draw a conclusion about the acids involved. Do some seem "stronger"? Be specific.
5. Two columns include HCl. Which HCl column most closely resembles the acetic acid column? What does this tell you about acetic acid?
6. Why is conductivity used as a probe for acids?
7. Describe your results from the conductivity row in Part A and draw a conclusion.

Use your observations from Part B to answer the following questions:

8. What conclusions can you draw based upon the BTB test of the different bases?

9. What conclusions can you draw based upon the UI test of the different bases?

10. The conductivity test for bases gives conflicting information. The last three compounds, Na_3PO_4, Na_2CO_3, $NaC_2H_3O_2$ are weak bases, however the conductivity tests indicate a strongly electrolytic solution. Can you explain why these weak bases would be strong electrolytes (think solubility!)?

11. For the weak acids in section A, the weak bases in section B, and all the materials in section C, write chemical equations that describe how these materials react with water. Examples of acids and bases reacting with water are given below. The sodium cations (Na^+) in each of these reactions is a spectator ion. For simplicity we are going to focus on the net ionic equations for the weak bases in section B and all materials in section C. For these materials use the formulas of the polyatomic ions given in parenthesis to react with water. Treat each of these as single proton transfers. For those species in section C, use the BTB result to decide how the species should react with water (Yellow = Acid, Blue = Base). As shown below, label each reactant and product as either an acid or base. Additionally, draw lines to link the conjugate pairs (species which differ in their chemical formula by one proton). There are 12 reactions in all.

conjugates

base / acid

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

acid / base

conjugates

conjugates

acid / base

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + NH_4^+{}_{(aq)}$$

base / acid

conjugates