

Acid-Base Theory

In this lecture the theory of acids and bases will be present along with web sites which discuss acids and bases

Lecture Outline: these questions should be answered in this lecture.

- What role does water play in the world?
- What are hydrogen and hydroxide ions?
- What is the importance of acids and bases?
- How does pH measure acidity?
- What is the acid equilibrium constant?
- Are there useful web sites for acid base theory?

Water is essential for life, and it is abundant on only one planet we know



The chemistry of water (H₂O)

- In pure water there are at least three common species
- H₂O
- H₃O⁺
- OH⁻
- And they are in equilibrium with each other
- That is $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$

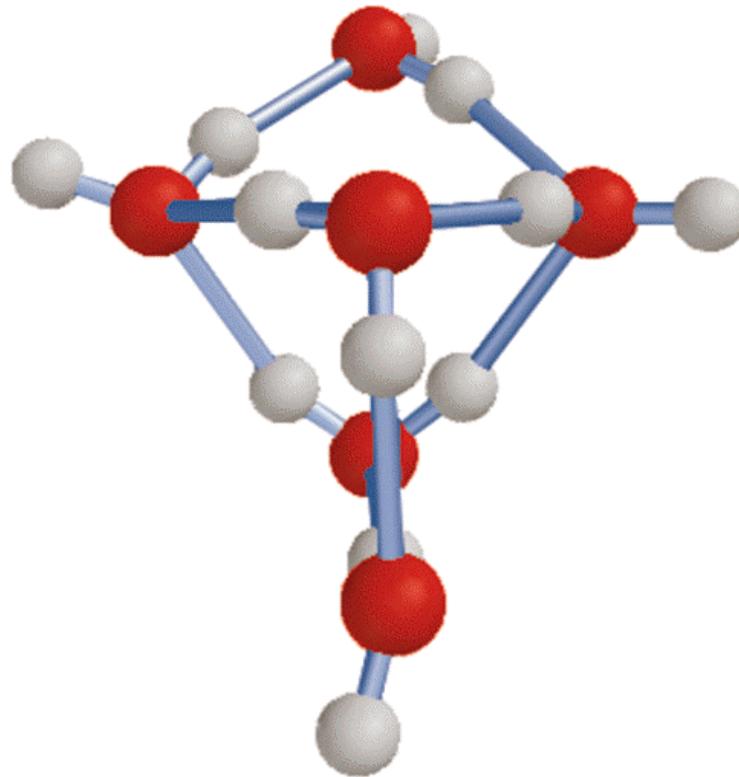
What does this mean

- The ions OH^- and H_3O^+ in pure water are present in one tenth of a part per million.
- This is equivalent to around 30 people out of the population of the United States.
- In pure water the concentrations of the ions are equal $[\text{OH}^-] = [\text{H}_3\text{O}^+]$ because they come from the reaction:
- $2\text{H}_2\text{O} \rightleftharpoons \text{OH}^- + \text{H}_3\text{O}^+$
- Yet these ions can control the chemistry of water and therefore the chemistry of life.

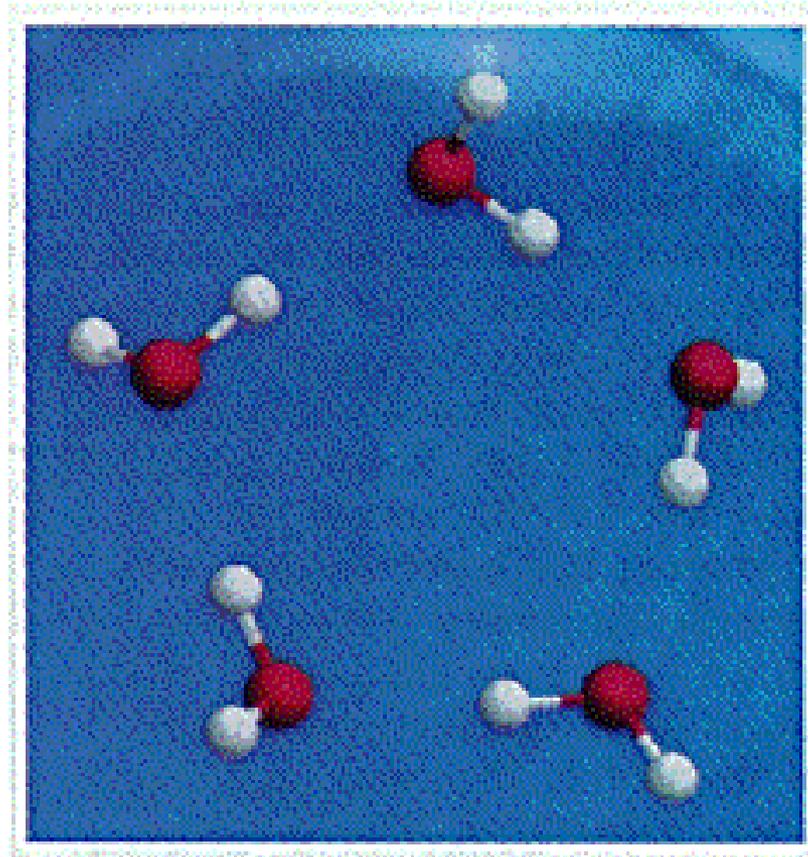
If the concentration of the hydrogen ion increases

- We call that water acidic.
- The amount of hydroxide ion decreases
- Say $[\text{H}_3\text{O}^+] = 1 \times 10^{-1}$
- Then $[\text{OH}^-] = 10^{-14}/10^{-1} = 10^{-13} \sim 0$
- The hydrogen $[\text{H}_3\text{O}^+]$ ion and the hydroxide $[\text{OH}^-]$ can not exist together in large numbers.
- The existence of the two ions are linked together.

There are short lived cluster, but they are of low concentration



The water molecules can vibrate

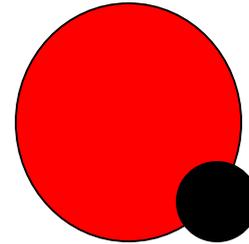
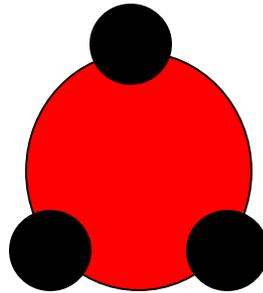
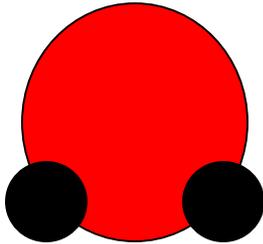


However, in this lecture we will look at the equilibrium reaction

- $2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$
- with $K = 10^{-14}$

Water (H₂O)

- Oxygen wants two additional electrons to have the stable configuration of argon.



- The hydrogen ion, H⁺, is a proton.
- Oxygen atoms can share these two extra electrons with one, two, or three hydrogen ions.
- All are stable but only the species with two hydrogen ions is uncharged.

There are other ion which can share an electron with a hydrogen ion

- An acetate ion CH_3CO_2^- also need one extra electron to be stable.
- With that extra electron, symbolized with a $-$, the ion is stable and can exist in water.
- However, it really would like a hydrogen ion to make it complete.
- The acid form $\text{CH}_3\text{CO}_2\text{H}$ is even more stable than the ion and can also exist in water

In an acetic acid solution

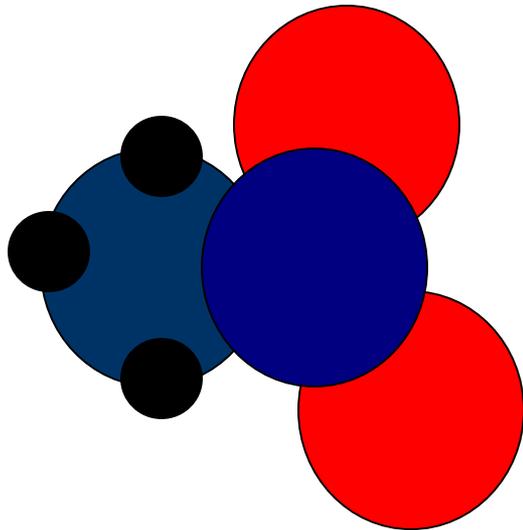
- The water molecules and the acetate ions compete for the hydrogen ion.
- Some of the hydrogen ions are taken by the water molecules increasing the number of hydronium ions H_3O^+ .
- There is a corresponding decrease in the hydroxide ions, OH^- .
- This slight increase in hydronium ions make the the solution slightly acidic.

In a hydrochloric acid solution

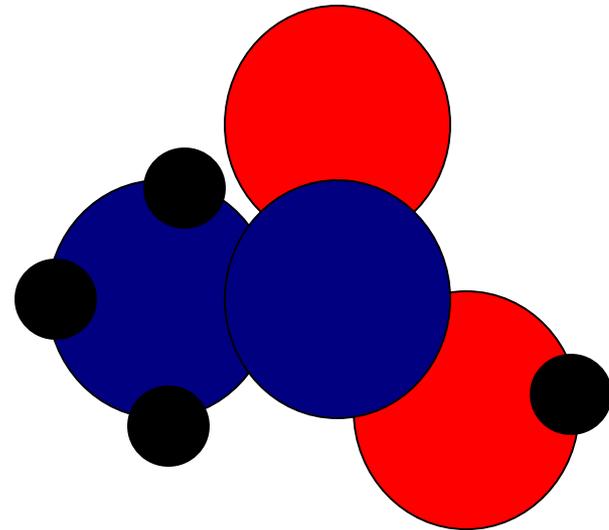
- A chlorine atom need one extra electron to form a stable species.
- The chlorine ion, Cl^- , is stable in water.
- However, this ion is not very competitive for the hydrogen ion and loses almost every time to a water molecule.
- Almost all the hydrogen ion combine with water to form a hydronium ion.

Acetic acid

- Acetate ion



hydrogen acetate



Take 0.1 molar acetic acid solution

- $K_a = 1.85 \times 10^{-5}$
- $H_2O + CH_3CO_2H \rightleftharpoons H_3O^+ + CH_3CO_2^-$
- $$c_s - x \qquad \qquad x \qquad \qquad x$$

$$K_a = \frac{[H^+][CH_3CO_2^-]}{CH_3CO_2H}$$

$$K_a = \frac{x \bullet x}{c_s - x} = \frac{x^2}{0.1 - x} = \frac{(0.0013)^2}{0.1 - 0.0013}$$

- If x is small $x^2 = K_a c_s = 1.8 \times 10^{-6}$; $x \sim 0.0013$
- $pH = -\log[H^+] = -\log[0.0013] = 3$

Acid Rain can causes forests to die



Power plants Emit NO_2 & SO_2



Cars Emit NO₂



Atmospheric Chemistry yields Nitric Acid, and Sulfuric Acid



Acidified lakes destroy aquatic life



Adding Lime Stone, CaCO_3 to Lakes



Lime, CaO , is added to soil to make it less acidic.



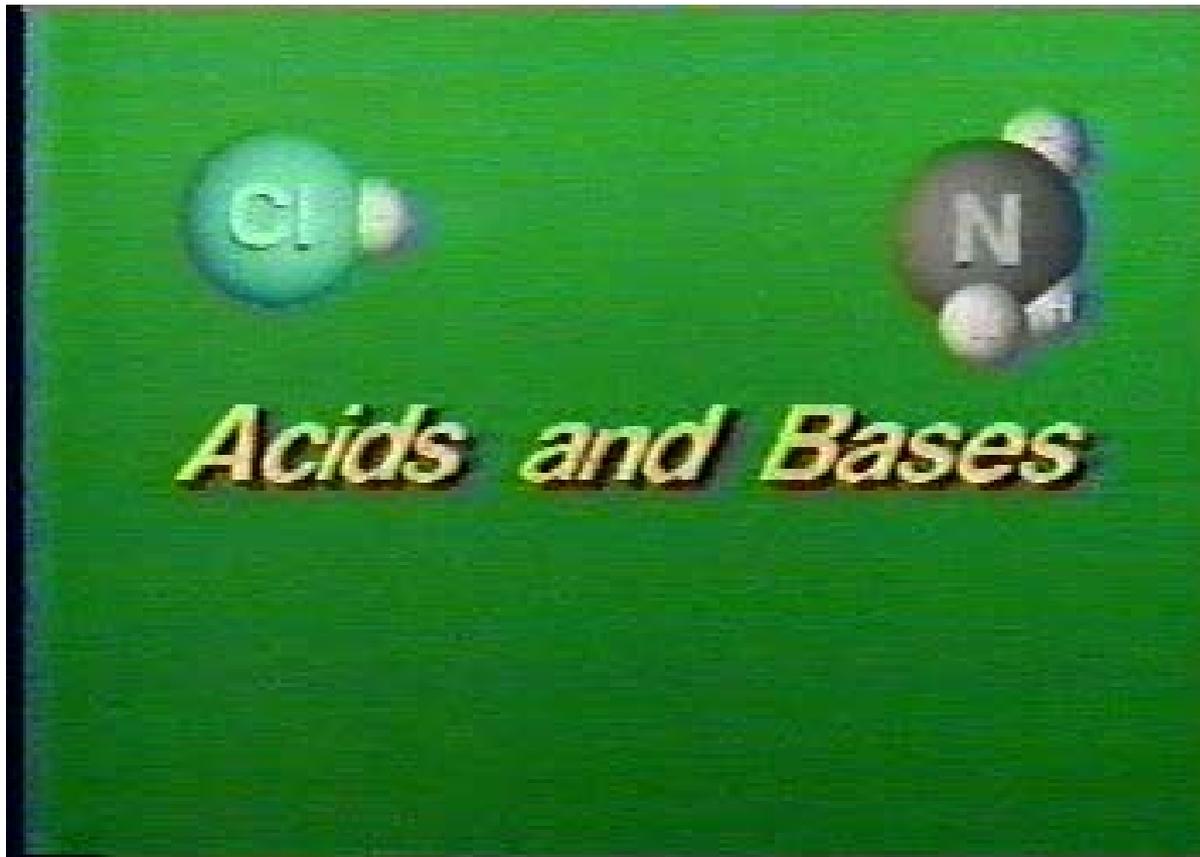
A lake recovered after liming



Acid Rain Dissolves Stone



Acids and bases combine to form a salt, ammonium chloride here



The smoke is NH_4Cl
when HCl is near NH_3



Acetic acid (vinegar) and Sodium bicarbonate (baking powder)



HCl in the stomach



Neutralization

- When an acid is added to a base the two neutralize each other.
- For example when sodium hydroxide, NaOH, is added to hydrogen chloride HCl.
- The salt, sodium chloride (NaCl), is formed along with water, H₂O.
- The sodium chloride would dissolve in the water to form a salt solution.

pH

- The pH is a measure of a solutions acidity.
- Definition: $\text{pH} = -\log [\text{H}^+]$.
- The pH is the negative log of the hydrogen ion concentration.
- The higher the pH, the lower the concentration of the hydrogen ion.
- The lower the pH the higher the acidity
- Pure water has a pH of 7, $[\text{H}^+] = 10^{-7}$.

Hydrolysis of a salt

- The addition of a salt of a weak acid can change the pH of water.
- If sodium acetate ($\text{CH}_3\text{CO}_2\text{Na}$) is added to water it will dissolve into sodium ions (Na^+) and acetate ions (CH_3CO_2^-).
- The acetate ion will react with the water molecule in a process call hydrolysis.
- $\text{H}_2\text{O} + \text{CH}_3\text{CO}_2^- \rightleftharpoons \text{CH}_3\text{CO}_2\text{H} + \text{OH}^-$
- The equilibrium constant is K_a/K_w

Take a 0.1 M solution of sodium acetate

- $H_2O + CH_3CO_2^- \rightleftharpoons CH_3CO_2H + OH^-$
- $c_s - x \qquad \qquad \qquad x \qquad \qquad \qquad x$
- K_a/K_w

$$K_H = \frac{K_w}{K_a} = \frac{[CH_3CO_2H][OH^-]}{[CH_3CO_2^-]} = \frac{10^{-14}}{1.85 \times 10^{-5}}$$

$$= \frac{[x][x]}{[c_s - x]}$$

- $[OH^-] = x = 1 \times 10^{-5}$; $pH = -\log[10^{-14}/10^{-5}] = 9$

There are many Web Sites which discuss Acid-Base Theory

- On the following slides are some of the many web sites on acid-base theory.
- A screen copy of the initial page of the site is given.
- To go to the site just right click your mouse in the title box.
- Then open the hyperlink
- If you have access to the internet, that site will be opened.

<http://www.acid-base.com/>

Acid-Base Balance: Introduction - Microsoft Internet Explorer provided by Optimum Online

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Address <http://www.acid-base.com/> Go Links

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Acid-Base Tutorial

www.acid-base.com by "Grog" (Alan W. Grogono)

Tulane University School of Medicine, Department of Anesthesiology

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Introduction Index History Acid-Base Physiology Acid Production pH Henderson Equation without the Hassel

Clinical Aspects Respiratory Treatment Metabolic Treatment $12 \div 0.1 = 6$ Simple Arithmetic Computing Terminology References

Plastic Cards Faster Page With Frames

20 Acid-Base Diagram 7.2 7.0 pH 6.0 4.0 8.0 10.0

Thanks Acknowledgements

Previous versions are still available
Version 1 (1996)
Version 2 (1998)

About this website:

Versions: This website runs in three different modes. Select an alternative version and, if you like it better, bookmark it!

- **Picture Index.** This version - www.acid-base.com
- **With Frames.** www.acid-base.com/homepage.html
- **Slow Modem.** www.acid-base.com/introduction.ssi

Two Windows: This page is your index. Choosing a topic opens a second window. Leave both windows open. When you then choose "Index Page", you return to this window.

Short URL: This website is hosted by the Department of Anesthesiology at Tulane University School of Medicine. The full address of the site is

javascript: if (top.location == self.location) {window.open('relocate.ssi', 'float');}else {window.open('transfer.ssi', 'AcidMai

Internet

<http://www.science.ubc.ca/~chem/tutorials/pH/launch.html>

The screenshot shows a Microsoft Internet Explorer browser window. The title bar reads "pH Tutorial Launch Pad - Microsoft Internet Explorer provided by Optimum Online". The address bar shows the URL "http://www.science.ubc.ca/~chem/tutorials/pH/launch.html". The page content includes a sidebar for Microsoft Money 2002, a main heading "Welcome to the Acid and Base pH Tutorial", a statistic "This page has had 173,958 accesses to date.", and sections for "Introduction" and "Getting Started".

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chem home

Welcome to the Acid and Base pH Tutorial

This page has had 173,958 accesses to date.

Introduction

This site contains notes and self directed exercises designed to help students with the fundamental concepts of acid-base chemistry. The level of instruction is aimed at first year university students with no prior knowledge of acid-base chemistry.

Getting Started

- To view the contents of this page, use the mouse to click on the up and down arrows along the right side of this page.
- The bright blue *Web Links* can be clicked on to connect you to another page in this tutorial.
- The square graphic buttons are also *Web Links* that can be clicked on to connect you to another page in this tutorial.
- If you wish to return to a previous frame, hold down the right mouse button for a list of options. The BACK button at the top of the screen will return you to this page.

Downloading from site: <http://www.science.ubc.ca/~chem/tutorials/pH/launch.html>

<http://dbhs.wvusd.k12.ca.us/AcidBase/AcidBase.html>

ChemTeam: Acid Base - Microsoft Internet Explorer provided by Optimum Online

File Edit View Favorites Tools Help

Address <http://dbhs.wvusd.k12.ca.us/AcidBase/AcidBase.html> Go Links

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Acid Base Table of Contents

"Learning is not attained by chance, it must be sought for with ardor and attended to with diligence." --- Abigail Adams

- [Observable Properties of Acids and Bases](#)
- [Early Acid Base Theories: Lavoisier and Davy](#)
- [Svante Arrhenius' Theory of Acids and Bases](#)
- [Johannes Brønsted and Thomas Lowry: Broadening the Concept of Acids and Bases](#)
- [Sören Sörenson and the pH scale](#)
- [A warning about putting numbers into the calculator](#)
- [A link to a site with a short explanation about using logarithms](#)
- [Strong and Weak Acids: Definitions and Descriptions](#)
- [The Behavior of Water and The Relationship Between pH and pOH](#)
- [The pH of a Strong Acid or Base](#)
- [Intro to \$K_a\$: The Acid Ionization Constant](#)
 1. [Solving \$K_a\$ Problems: Part One](#)
 2. [Solving \$K_a\$ Problems: Part Two](#)
 3. [Solving \$K_a\$ Problems: Part Three](#)
- [Intro to \$K_b\$: The Base Ionization Constant](#)
 1. [Solving \$K_b\$ Problems: Part One](#)
 2. [Solving \$K_b\$ Problems: Part Two](#)
 3. [Solving \$K_b\$ Problems: Part Three](#)
- [Classroom Practice in Solving Weak Acid and Weak Base Problems](#)
- [\$K_a K_b = K_w\$](#)
- [What are Salts?](#)
- [The Hydrolysis of Salts in Water](#)

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<http://www.sfu.ca/chemcai/AQCHEM/ABG-ind.html>

The screenshot shows a Microsoft Internet Explorer browser window. The title bar reads "Graphical approach to acid-base calculations - Microsoft Internet Explorer provided by Optimum Online". The address bar contains the URL "http://www.sfu.ca/chemcai/AQCHEM/ABG-ind.html". The main content area of the page has a yellow background and features the following text:

**Acid-base without algebra:
graphical treatment of acid-base systems**

Stephen K. Lower - Simon Fraser University

Instructions: You can return to this Index or move backward or forward through these topics by clicking on the appropriate Navigation button at the bottom of any text area. To get started, click on any topic below. Please note your browser must be HTML 3.2 compliant (sub/superscripts and frames). You will probably find it convenient to enlarge your browser window for some of these pages.

[Introduction: why bother?](#)

[Getting started: plotting the pH](#)

[Acetic acid: constructing the plot](#)

[Acetic acid: pH of HAc and NaAc solutions](#)

[Acetic acid: titration curve](#)

[Oxalic acid: a diprotic system](#)

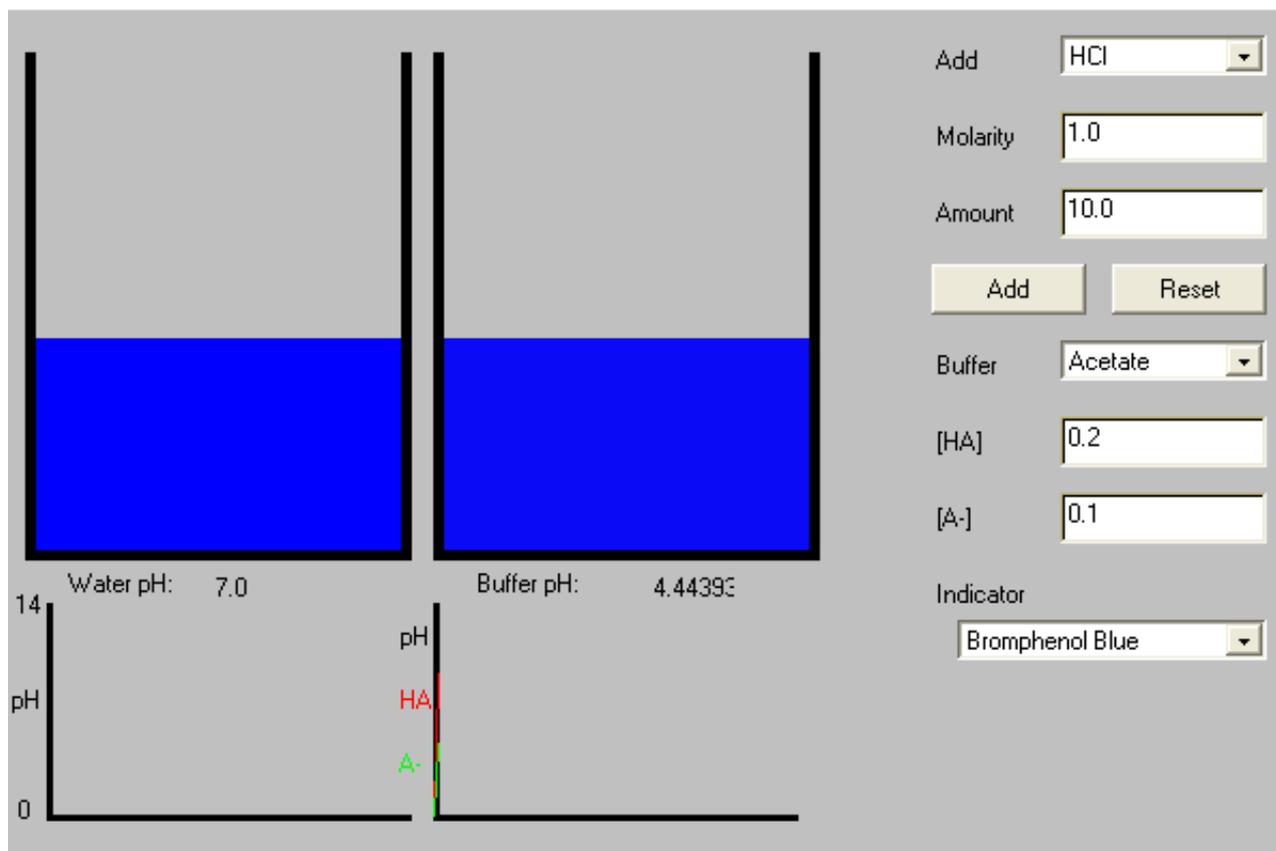
[Ammonium formate: a "weak-weak" salt](#)

[Phosphate: a triprotic system](#)

[the Carbonate system](#)

On the left side of the browser window, there is a sidebar advertisement for Microsoft Money 2002. The ad includes the text: "Manage Today's Finances, Achieve Tomorrow's Goals...", "Microsoft Money 2002", "Organize your personal finances quickly and easily with Microsoft Money. Money is already on your computer, so you can get started right away!", "Start Money now!", and "Learn more".

[http://michele.usc.edu/java/acidbase.html](http://michele.usc.edu/java/acidbase/acidbase.html)



<http://www.shodor.org/unchem/basic/ab/>

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File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media Refresh Print Mail

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Acid-Base Chemistry

- [Water](#)
- [pH](#)
- [Definitions of acids and bases](#)
- [Salts](#)
- [Acid-Base Character](#)
- [Acid-Base Titrations](#)

Course Chapters

- [Calculator](#)
- [Fundamentals](#)
- [Mathematics Review](#)
- [Basic Concepts](#)
- [Advanced Concepts](#)

Water

We typically talk about acid-base reactions in aqueous-phase environments -- that is, in the presence of water. The most fundamental acid-base reaction is the [dissociation](#) of water:

$$H_2O \rightleftharpoons H^+ + OH^-$$

In this reaction, water breaks apart to form a hydrogen ion (H^+) and a hydroxyl ion (OH^-). In pure water, we can define a special equilibrium constant (K_w) as follows:

$$K_w = [H^+][OH^-] = 1.00 \times 10^{-14}$$

Where K_w is the equilibrium constant for water (unitless)

$[H^+]$ is the molar concentration of hydrogen

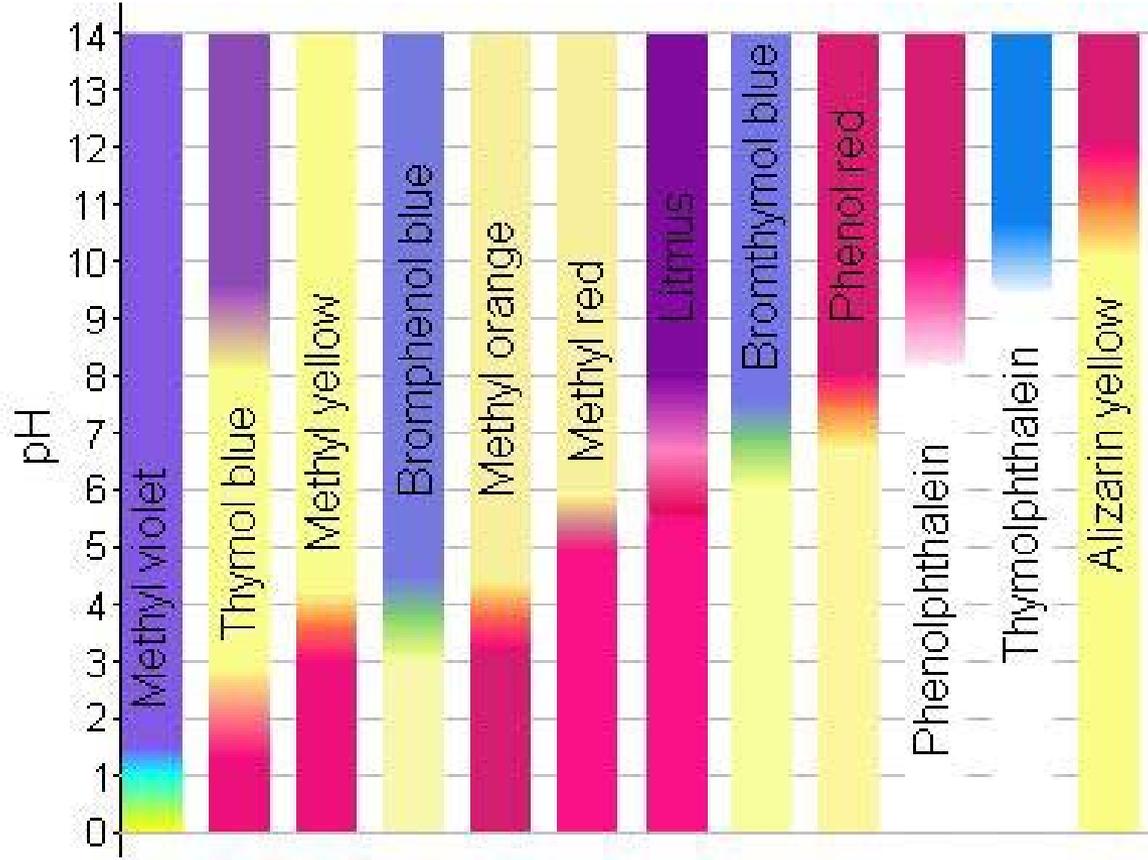
$[OH^-]$ is the molar concentration of hydroxide

An equilibrium constant less than one (1) suggests that the reaction prefers to stay on the side of the reactants -- in this case, water likes to stay as

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Internet

<http://www.carlton.paschools.pa.sk.ca/chemical/equilibrium/abindicators.htm>



http://www.usyd.edu.au/su/anaes/lectures/acidbase_mjb/acidbase.html

The screenshot shows a Microsoft Internet Explorer browser window. The title bar reads "pH of the Blood - M. J. Bookallil - Microsoft Internet Explorer provided by Optimum Online". The address bar shows the URL "http://www.usyd.edu.au/su/anaes/lectures/acidbase_mjb/acidbase.html". The webpage content includes a sidebar for Microsoft Money 2002, a main title "pH OF THE BLOOD: ACID-BASE BALANCE", author information for Michael J. Bookallil, a note about a frames version, and a table of contents.

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pH OF THE BLOOD: ACID-BASE BALANCE

[MICHAEL J. BOOKALLIL](#)
M.B., B.S., F.F.A.R.C.S., F.F.A.R.C.S.

Senior Lecturer in Anaesthetics
[Royal Prince Alfred Hospital](#)
[THE UNIVERSITY OF SYDNEY](#)

This document is available in a ['frames'](#) version for users with large screens.

CONTENTS:

1. [Introduction](#)
2. [Definitions](#)
 1. [Balance and Status](#)
 2. [Acid and Base](#)
 3. [pH and Acid Base](#)
 4. [Buffer Solution](#)
 5. [Distinction Between Buffer and Base](#)
 6. [Respiratory, Non-Respiratory, Metabolic](#)
 7. [Acidosis and Alkalosis](#)
 8. [Nanoequivalents H+/ litre](#)
 9. [Abbreviations](#)
3. [Control of pH](#)
 1. [Normal pH](#)
 2. [Buffer Control](#)
 1. [Normal Acid Load](#)
 2. [Abnormal Acid Balance](#)
 3. [Low Buffer States](#)
 3. [Respiratory Control](#)
 1. [Normal](#)
 2. [Effect of Control of PCO₂ in Minimising pH Changes due to Non-Respiratory Acids or to Bases](#)

http://blue.vm.temple.edu/~pathphs/renal/acid_base_review.html

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Back Forward Stop Home Search Favorites Media

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Acid Base Review

David Roth, MD

I. Hydrogen ion metabolism and homeostasis

- Regulation of [H⁺]
 - Normally, extracellular H⁺ is regulated within a narrow range
 - 35-45 x 10⁻⁹ mols/L = 35-45 mmols/L
 - pH = 7.35-7.45
 - Range of pH compatible with life is 6.8 - 7.8
- Acid balance
 - Transient rise or fall in H⁺ production or intake changes [H⁺]
 - H⁺ removal from or addition to body fluids involves 2 phases
 - Early
 - Reaction with ECF and ICF chemical **buffer systems**
 - Changes in pulmonary alveolar ventilation: change in PCO₂
 - Later
 - Renal response which must eliminate the increment in fixed (non-volatile) H⁺ or reduce net H⁺ excretion to correct a decrement
 - H⁺ balance involves 3 processes
 - Production of H⁺
 - Chemical buffering (ICF and ECF)
 - Physiological regulation of excretion
- Acid production (volatile and fixed)
 - Volatile acid
 - CO₂
 - End product of complete oxidation of carbohydrate, fats and protein
 - 13,000 mmol produced daily in normal humans
 - Excreted by the lung

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<http://www.chemtutor.com/acid.htm>

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ACIDS AND BASES

[What is an acid or a base?](#)

[Properties of bases.](#)

[Solubility and dissociation.](#)

[The pH box.](#)

[The pKa box.](#)

[pH of strong acids and bases.](#)

[Weak bases.](#)

[pH of weak acids and bases.](#)

[Buffer math.](#)

[Salts.](#)

[Properties of acids.](#)

[Strong acids and bases.](#)

[Overview of pH.](#)

[Calculator use with pH box.](#)

[Weak acids and weak bases.](#)

[Weak acids.](#)

[The 5% rule.](#)

[Buffers and pH of buffers.](#)

[Titration.](#)

[Titration and pH math problems.](#)

WHAT IS AN ACID OR A BASE?

Internet

[http://chemmac1.usc.edu/bruno/j
ava/Titrate.html](http://chemmac1.usc.edu/bruno/java/Titrate.html)

The screenshot shows a Microsoft Internet Explorer browser window with the title "Acid Base Titration - Microsoft Internet Explorer provided by Optimum Online". The address bar shows the URL "http://chemmac1.usc.edu/bruno/java/Titrate.html". The page content includes a sidebar for "MoneySide" with an advertisement for "Microsoft Money 2002" and a main content area titled "Acid Base Titration".

Acid Base Titration

This program simulates the Acid Base titration curve in the case of a strong acid and a strong base and determine if there is enough base to neutralize the acid and calculate the equivalent point

Instructions

Edit the parameters:

- concentration of acid (mol/l)
- concentration of base (mol/l)
- volume of acid (ml)
- volume of base (ml)

Click on "Draw" to plot the titration curve and watch for the comments

Str.Acid and Str.base draw

Acid base titration Applet
Edit concentrations and volume
Click on Draw to display

Applet started Internet

<http://chemistry.about.com/cs/acidsandbases/>

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[Guide picks](#)

Here are lecture notes, tutorials, definitions, study guides, tables, and other resources to make those acid-base problems easier.

Acid-Base Indicators
Learn what an acid-base indicator is and how it works. A table is provided with names of indicators, pH indicator ranges, indicator concentrations in water or alcohol, and colors.

Acid and Base Definitions
Your Guide presents Arrhenius, Bronsted-Lowry, and Lewis definitions of acids and bases. Lists of properties of acids and bases and common examples are provided.

Acid and Base pH Tutorial
This tutorial from the University of British Columbia offers notes and self-directed exercises to help students with the fundamental concepts of acid-base chemistry. The tutorial is aimed at first year university students having no prior knowledge of acid-base chemistry.

Acid Base Table of Contents
ChemTeam's site explains many acid and base concepts, focusing on solving problems with acid and base ionization constants.

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