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 (H_2O)

- In pure water there are at least three common species
- H_2O
- H_3O^+
- OH^-
- And they are in equilibrium with each other
- That is $K_w = [H_3O^+][OH^-] = 1 \times 10^{-14}$

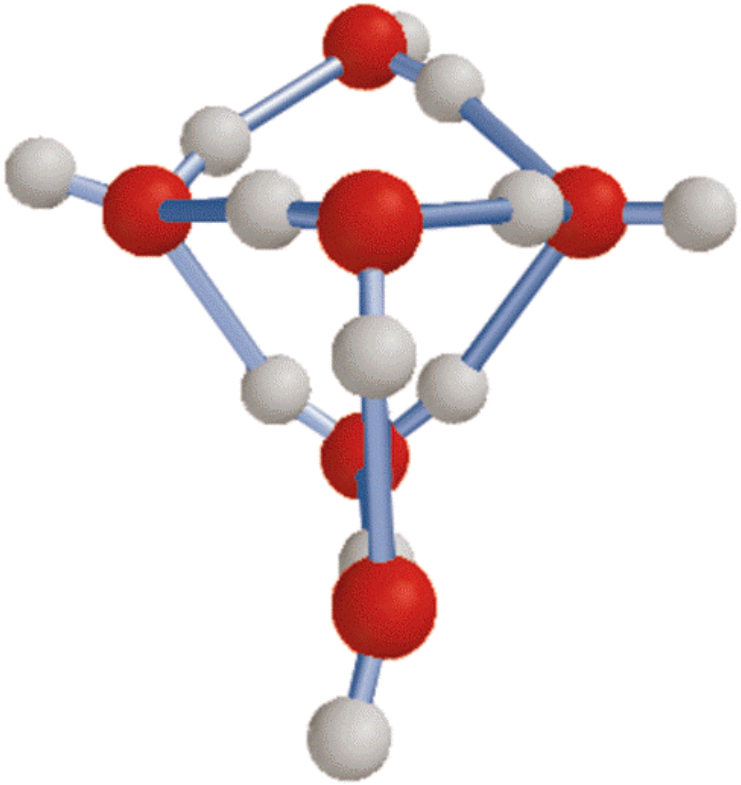
What does this mean

- 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 $[OH^-] = [H_3O^+]$ because they come from the reaction:
- $2H_2O \Leftrightarrow OH^- + H_3O^+$
- Yet these ions can control the chemistry of water and therefore the chemistry of life.

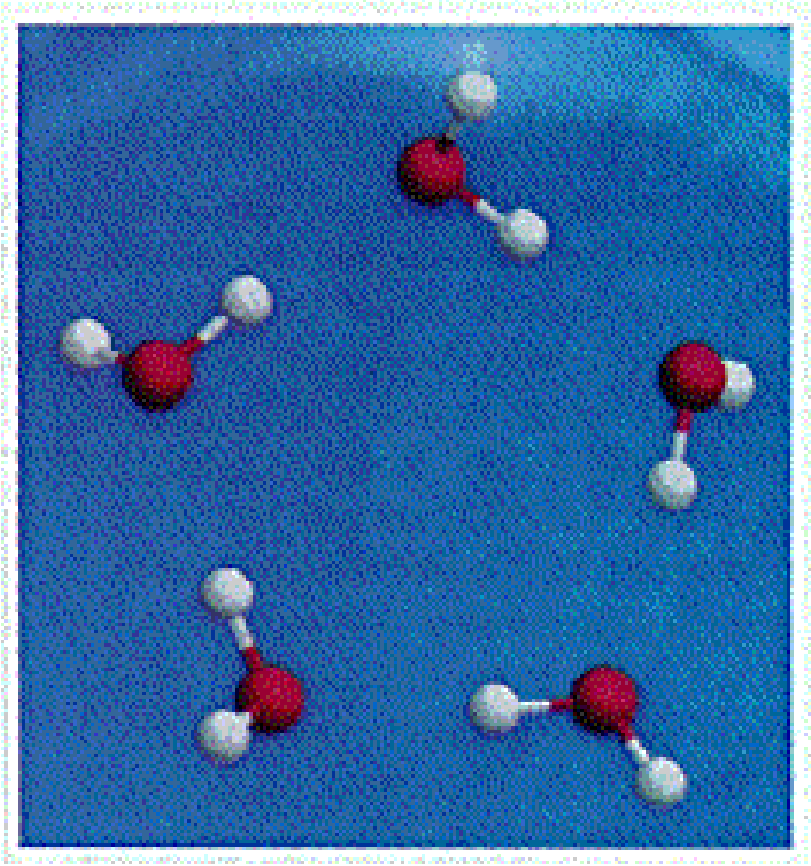
If the concentration of the hydrogen ion increases

- We call that water acidic.
- The amount of hydroxide ion decreases
- Say $[H_3O^+] = 1 \times 10^{-1}$
- Then $[OH^-] = 10^{-14}/10^{-1} = 10^{-13} \sim 0$
- The hydrogen $[H_3O^+]$ ion and the hydroxide $[OH^-]$ 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

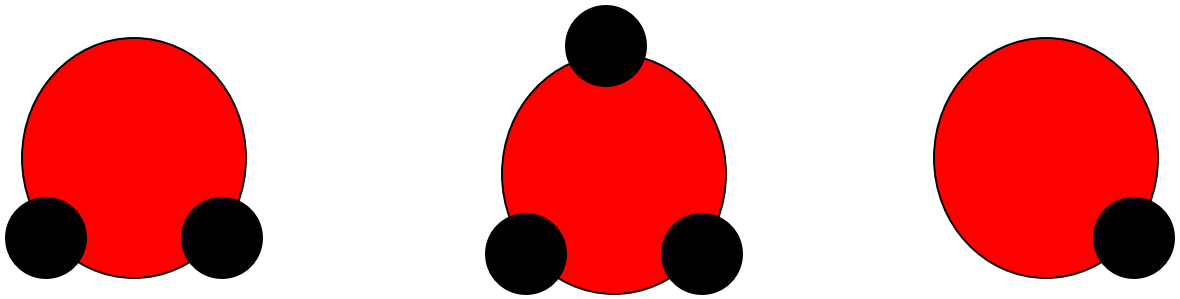


However, in this lecture we will look at the equilibrium reaction

- $2H_2O \Leftrightarrow H_3O^+ + OH^-$
- with $K = 10^{-14}$

Water (H_2O)

- Oxygen wants two additional electrons to have the stable configuration of argon.
- H_2O H_3O^+ OH^-



- 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 CH_3CO_2H is even more stable than the ion and can also exist in water

In an acetic acid solution

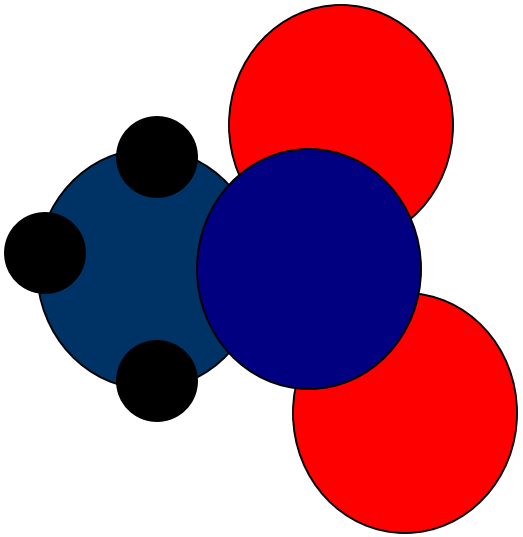
- The water molecules and the acetate ions compete for the hydrogen ion.
- Some of the hydrogen ions are taken by the water molecules increasing the number of hydronium ions H_3O^+.
- There is a corresponding decrease in the hydroxide ions, OH^-.
- This slight increase in hydronium ions make the the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

In a hydrochloric acid solution

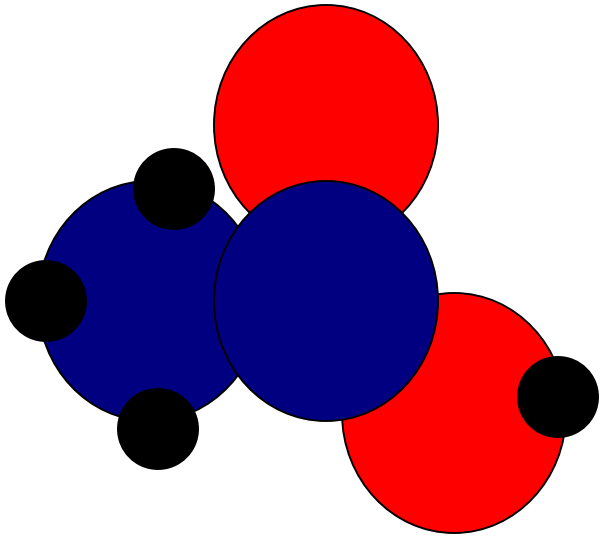
- A chlorine atom need one extra electron to form a stable species.
- The chlorine ion, Cl^-, is stable in water.
- However, this ion is not very competitive for the hydrogen ion and looses almost every time to a water molecule.
- Almost all the hydrogen ion combine with water to form a hydronium ion.

Acetic acid

- Acetate ion



hydrogen acetate



Take 0.1 molar acetic acid solution

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

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

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

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

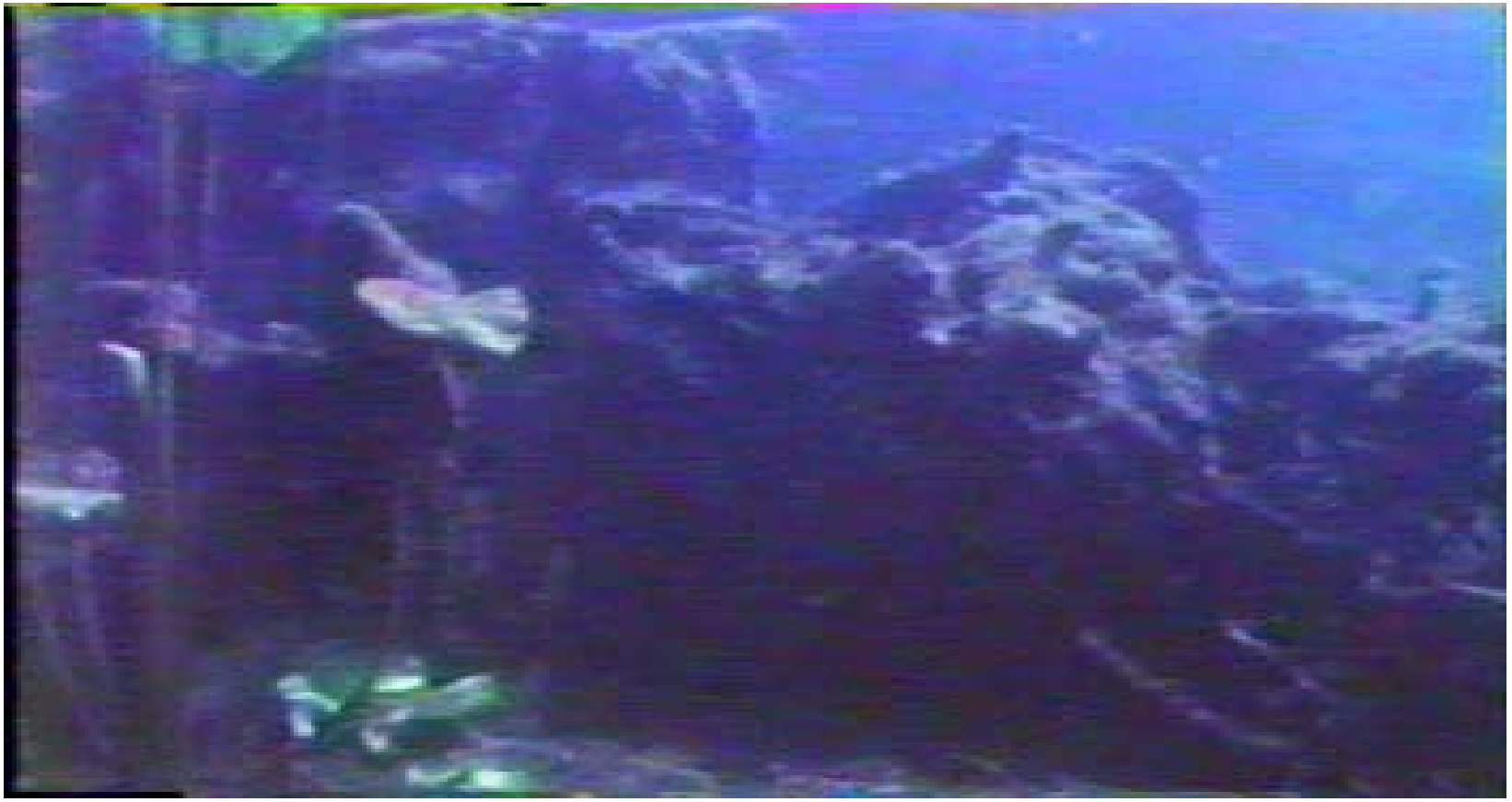
Acid Rain can causes forests to die

Power plants Emit NO_2 & SO_2

Cars Emit NO_2

Atmospheric Chemistry yields Nitric Acid, and Sulfuric Acid

Acidified lakes destroy aquatic life



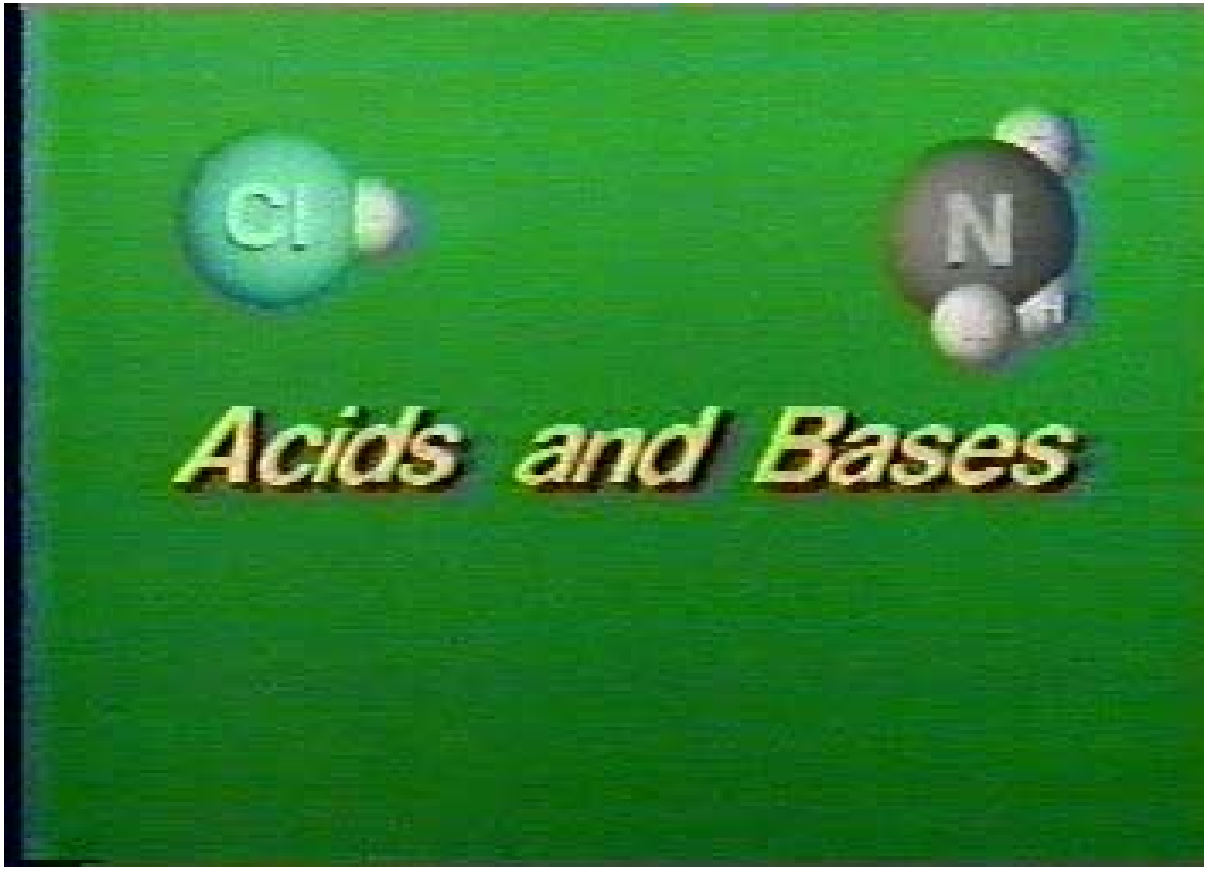
Adding Lime Stone, $CaCO_3$ to Lakes

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

A lake recovered after liming

Acid Rain Dissolves Stone

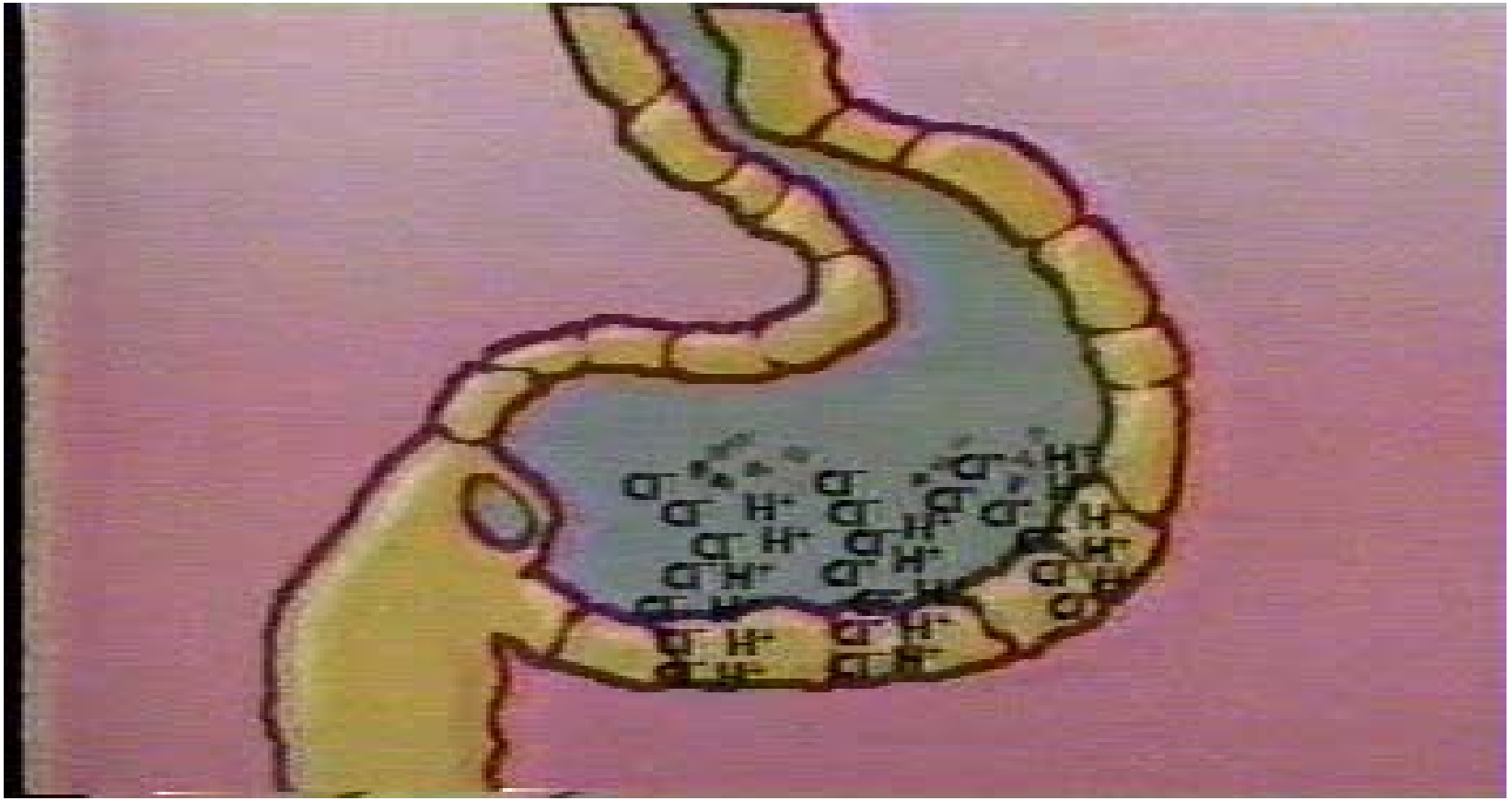
Acids and bases combine to form a salt, ammonium chloride here



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, H_2O.
- The sodium chloride would dissolve in the water to form a salt solution.

pH

- The pH is a measure of a solutions acidity.
- Definition: $pH = -\log [H^+]$.
- 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, $[H^+] = 10^{-7}$.

Hydrolysis of a salt

- The addition of a salt of a weak acid can change the pH of water.
- If sodium acetate (CH_3CO_2Na) 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.
- $H_2O + CH_3CO_2^- \Leftrightarrow CH_3CO_2H + OH^-$
- The equilibrium constant is K_a/K_w

Take a 0.1 M solution of sodium acetate

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

$$K_H = \frac{K_w}{K_a} = \frac{[CH_3CO_2H][OH^-]}{[CH_3CO_2^-]} = \frac{10^{-14}}{1.85x10^{-5}}$$

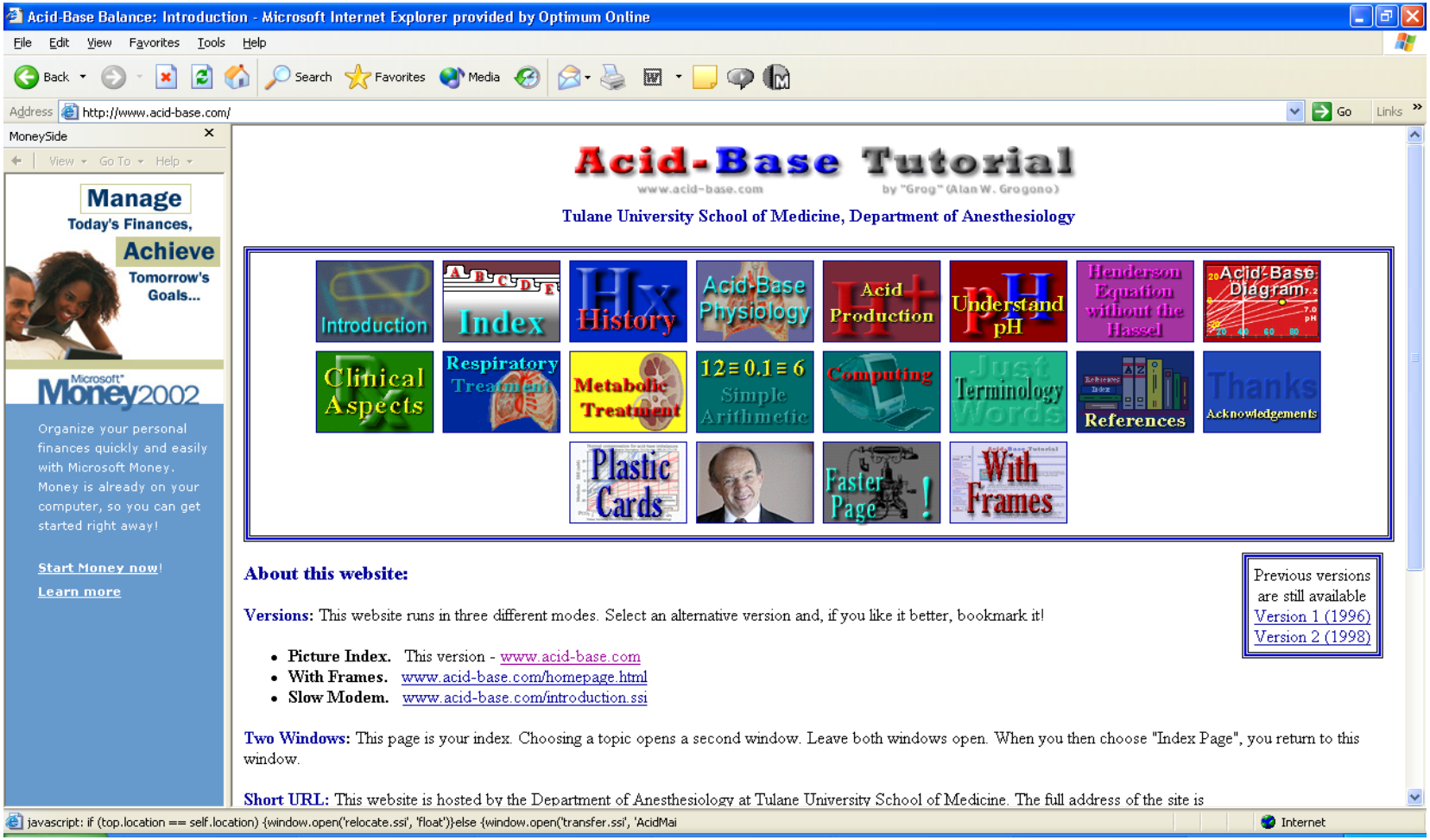
$$= \frac{[x][x]}{[c_s - x]}$$

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

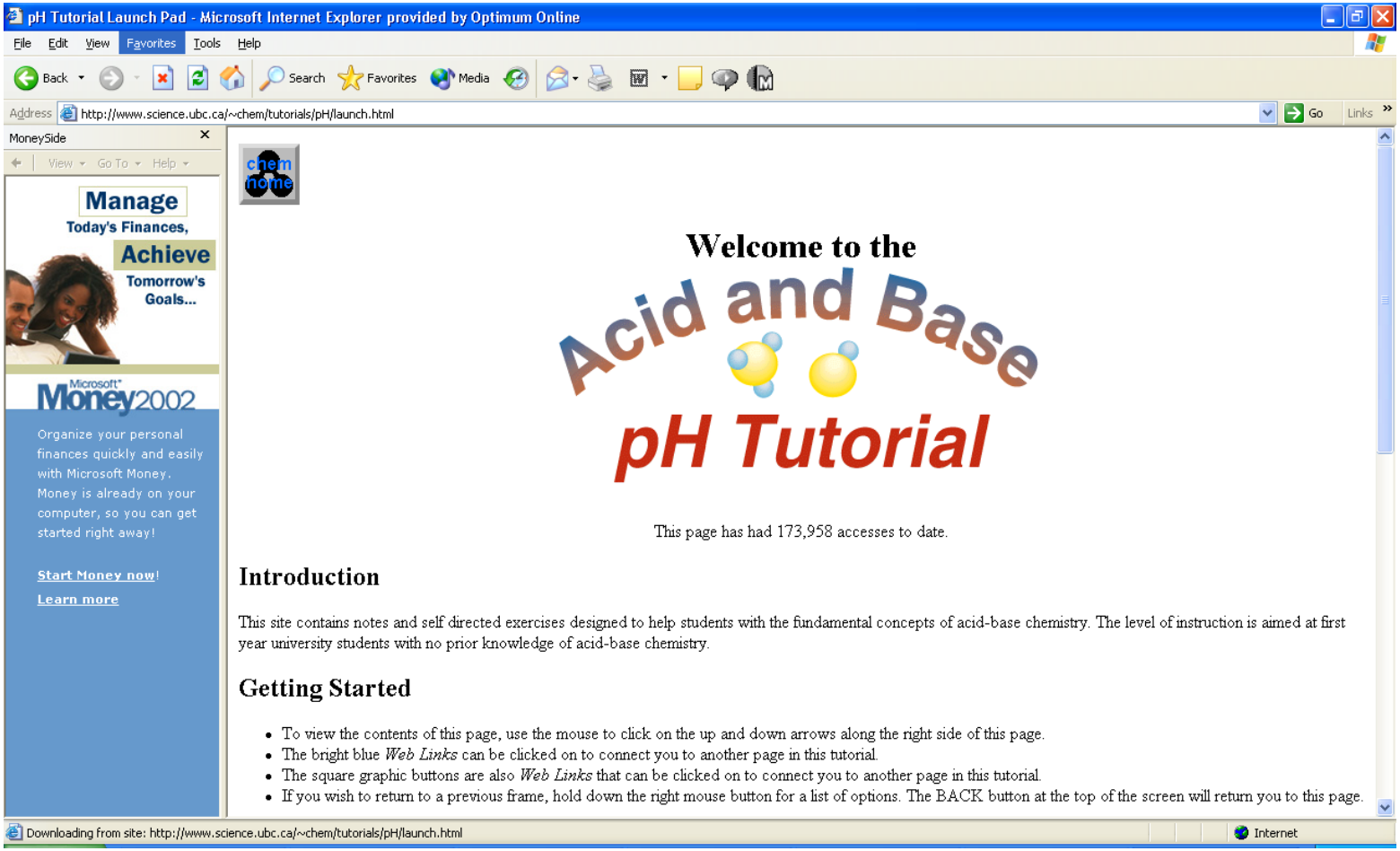
There are many Web Sites which discuss Acid-Base Theory

- 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.

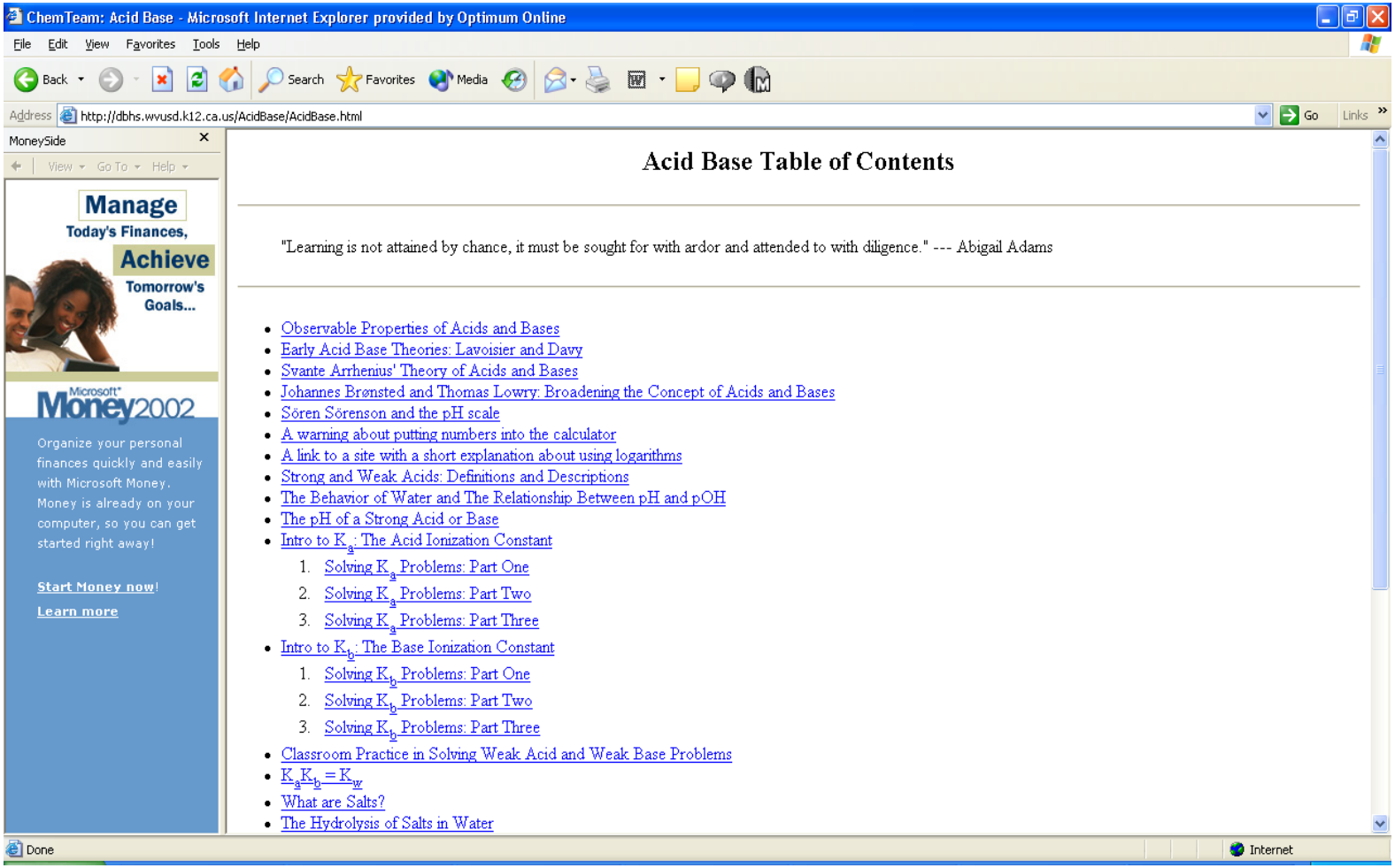
http://www.acid-base.com/



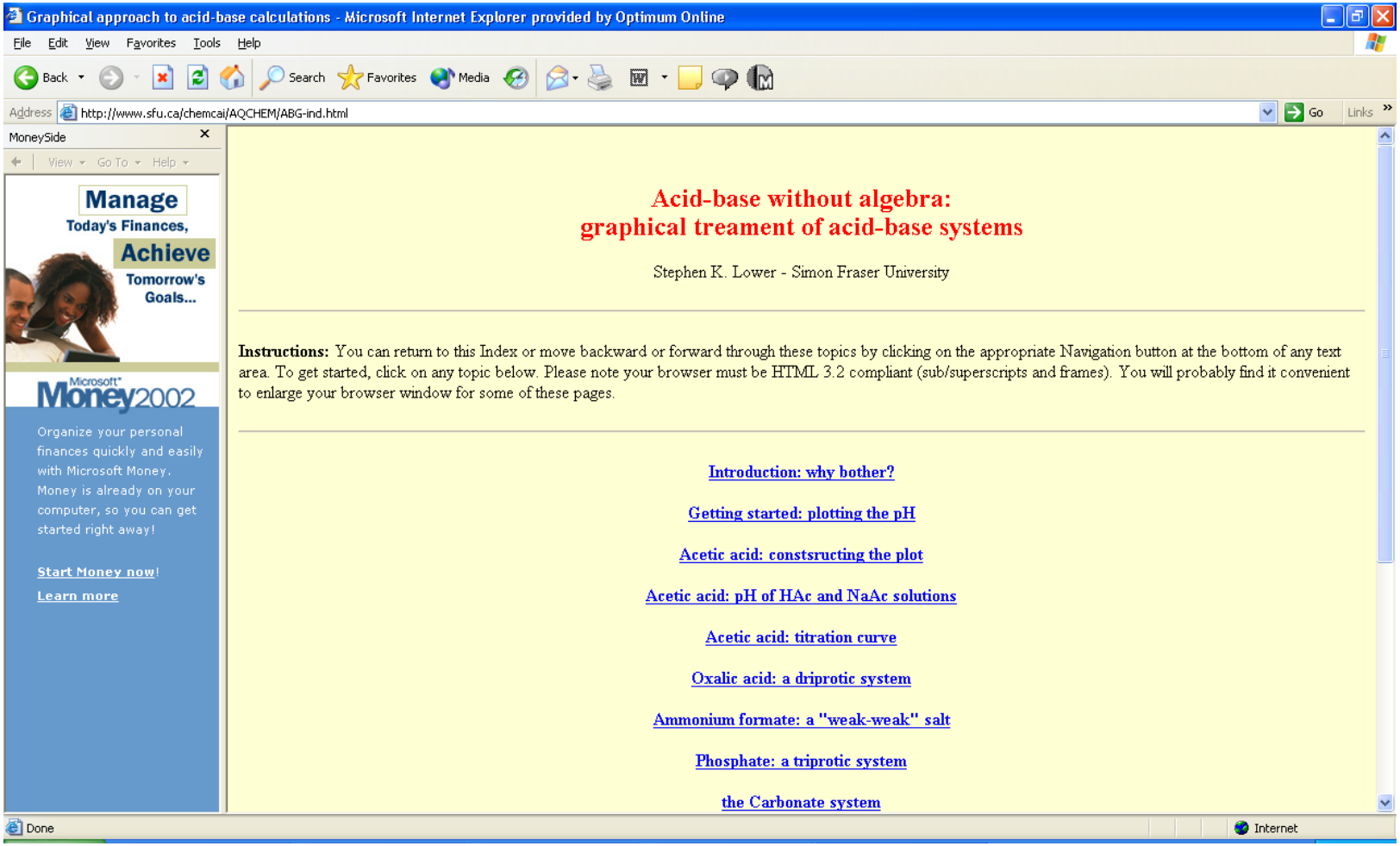
http://www.science.ubc.ca/~chem/tutorials/pH/launch.html



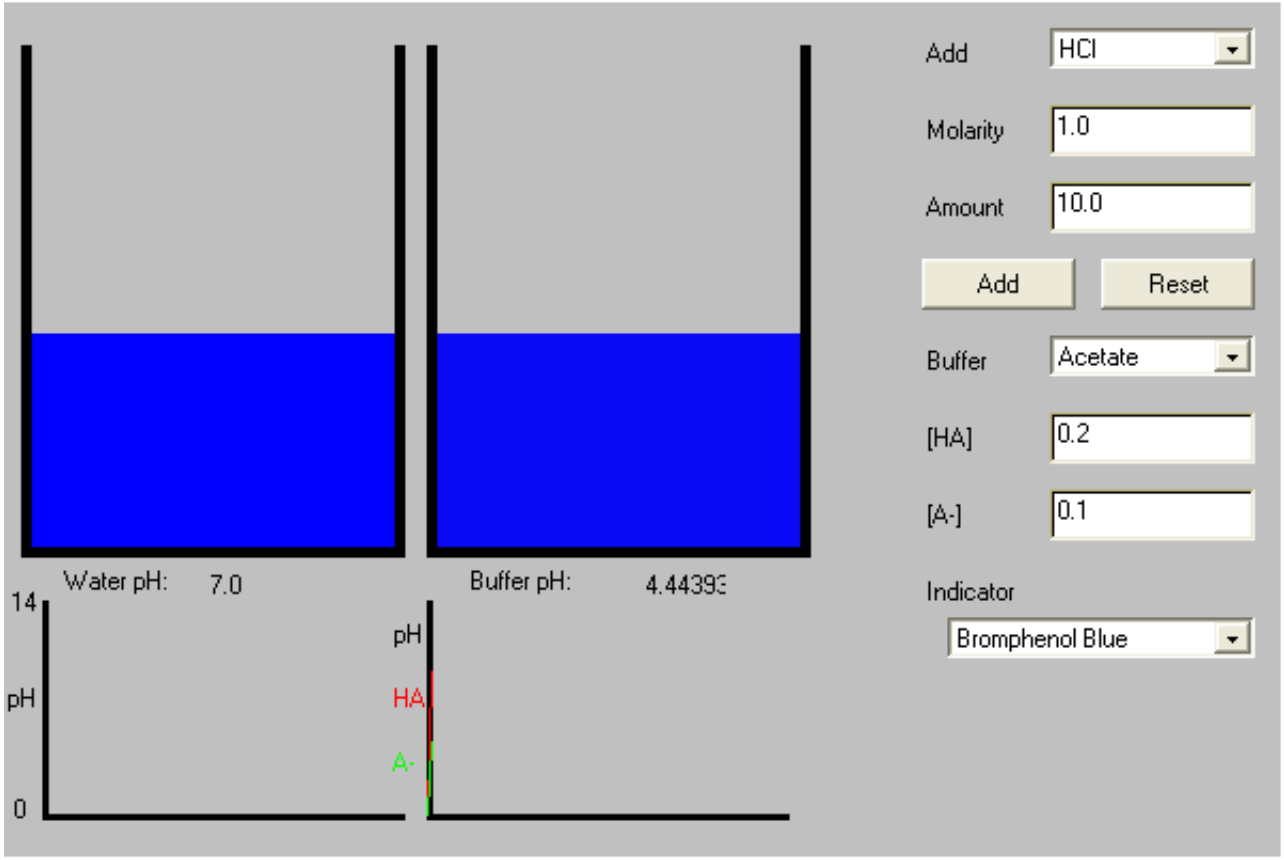
http://dbhs.wvusd.k12.ca.us/AcidBase/AcidBase.html



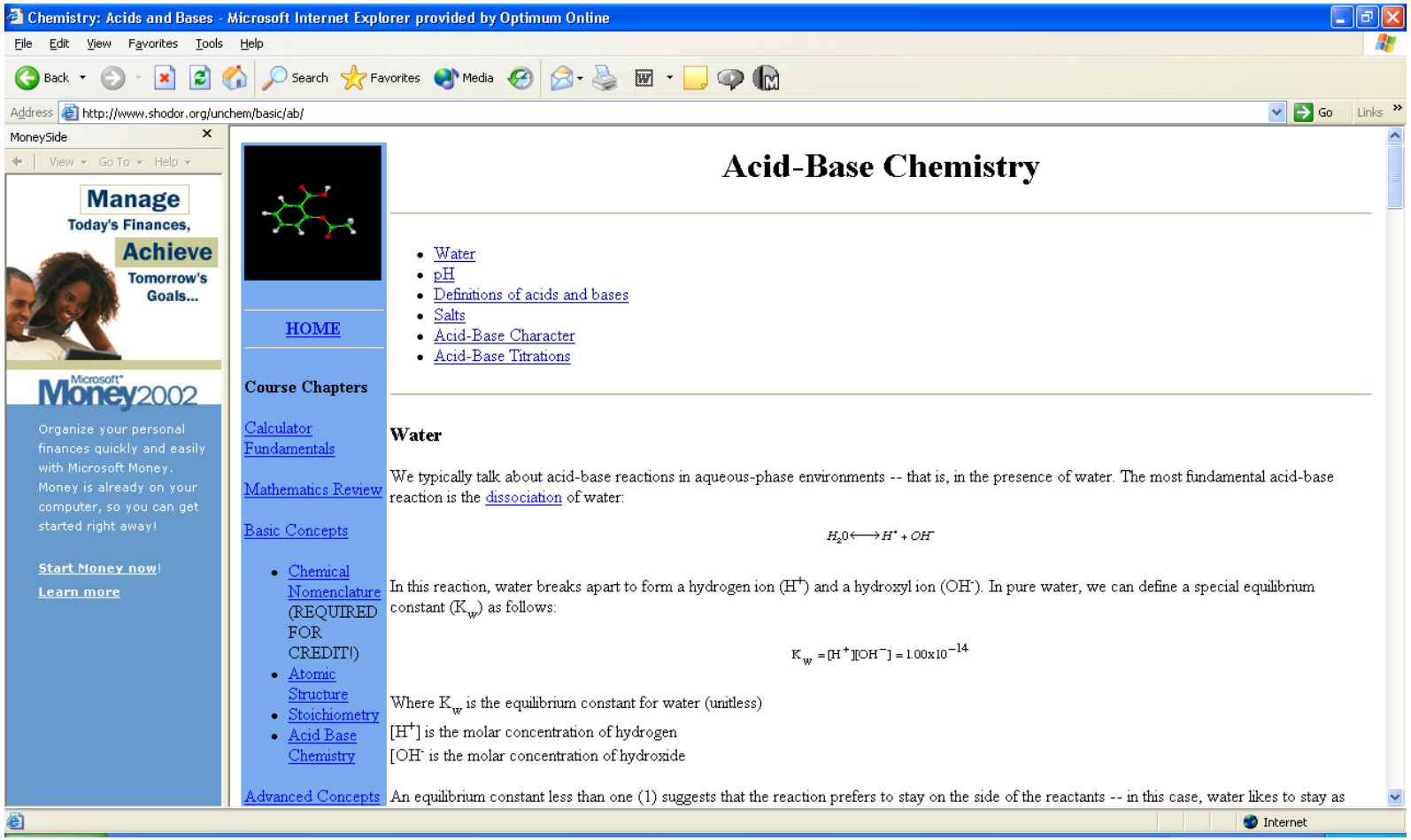
http://www.sfu.ca/chemcai/AQCHEM/ABG-ind.html



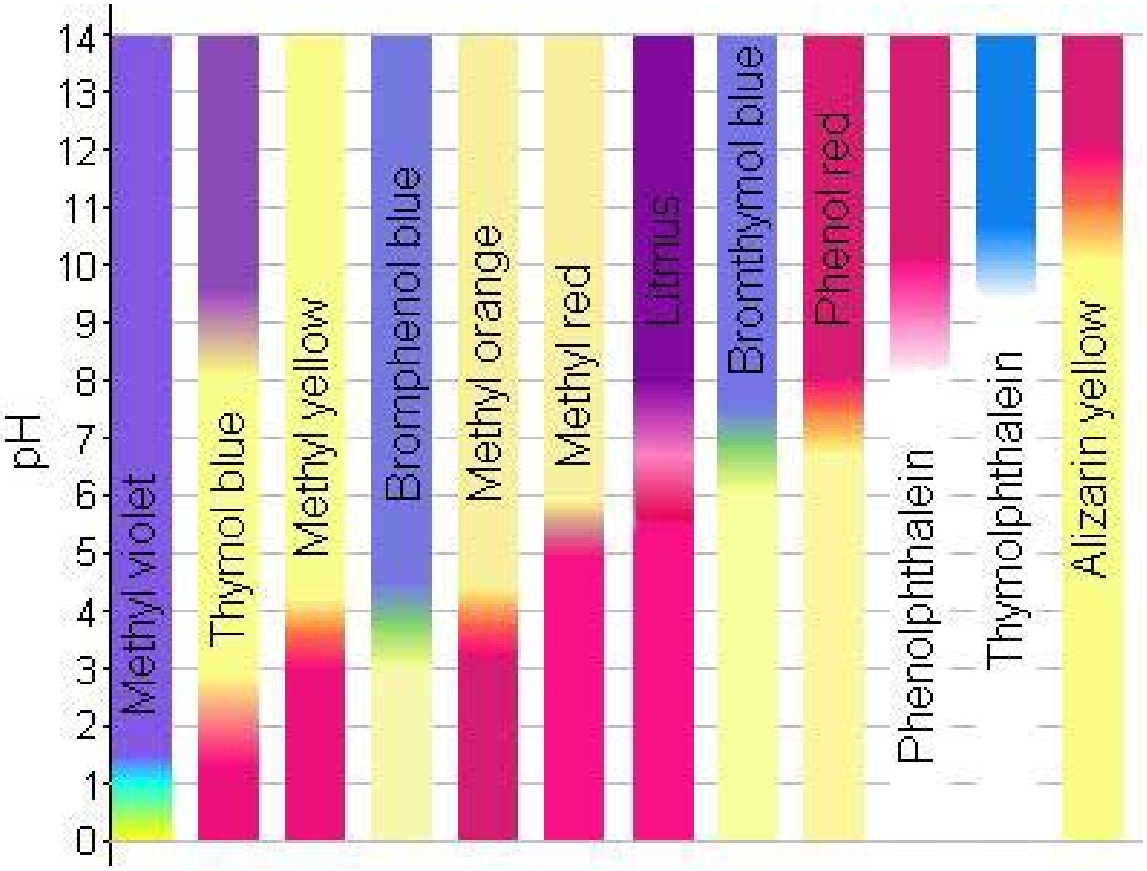
http://michele.usc.edu/java/acidbase/acidbase.html



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

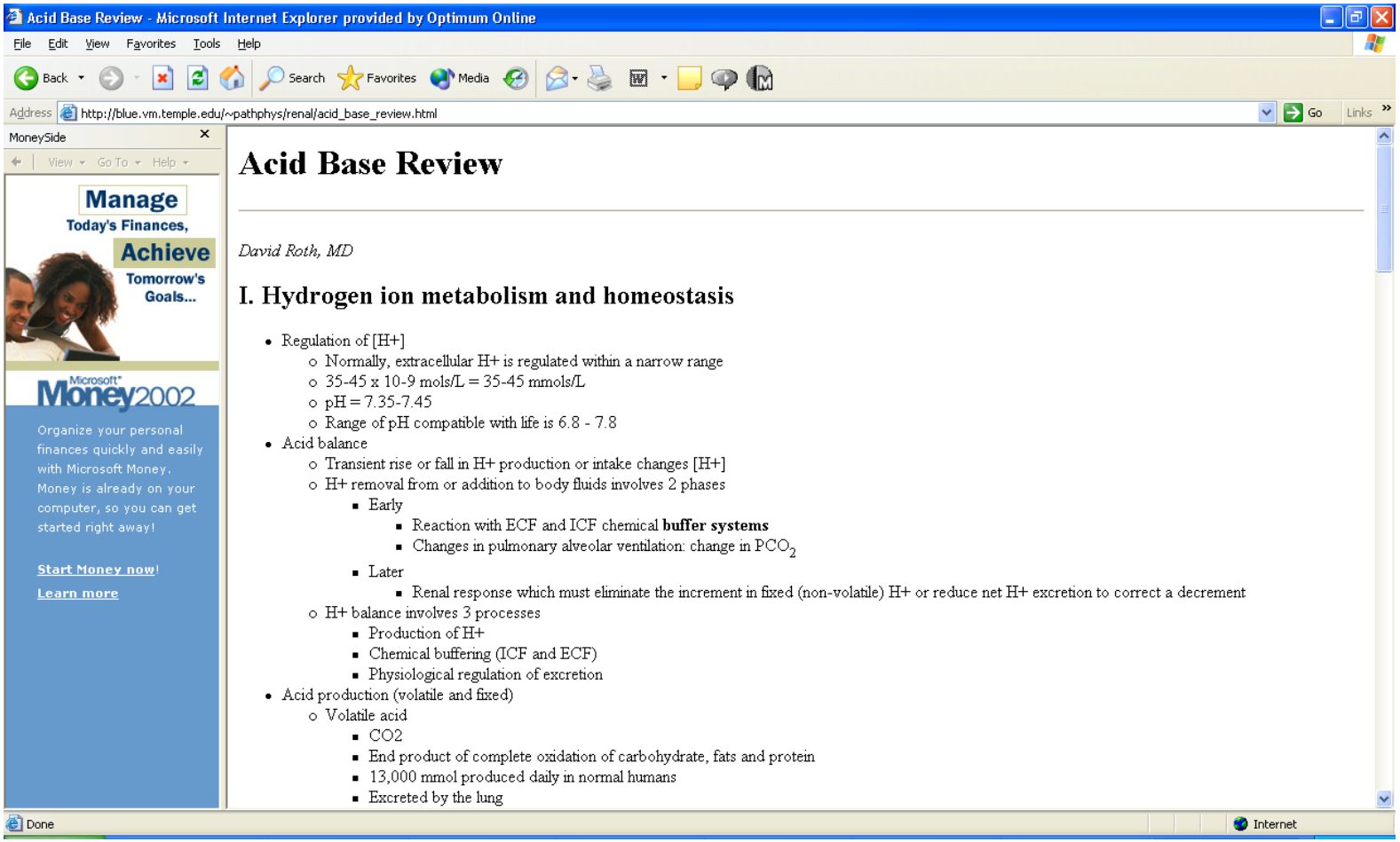


http://www.carlton.paschools.pa.sk.ca/chemical/equilibrium/abindicators.htm

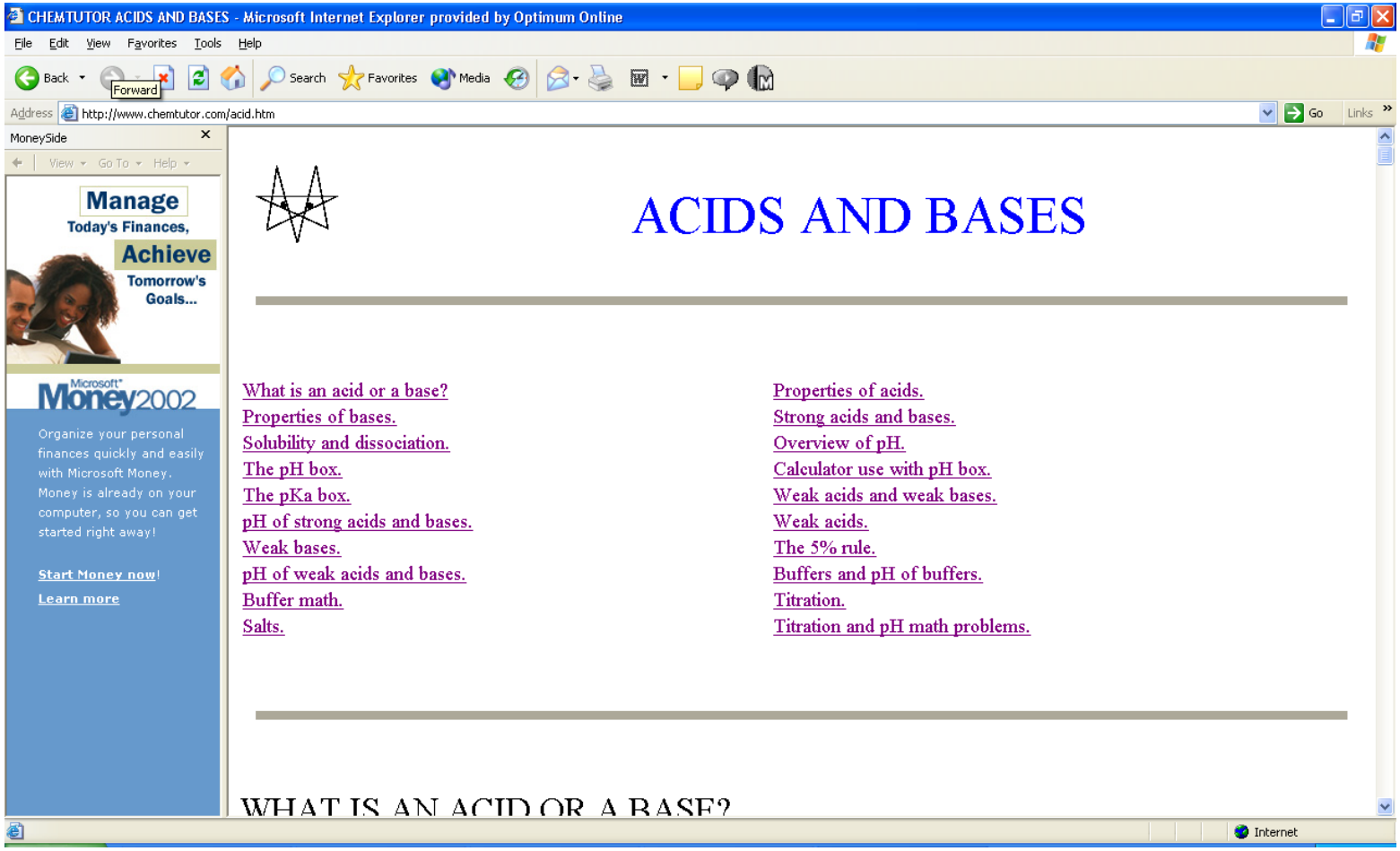


http://www.usyd.edu.au/su/anaes/lectures/acidbase_mjb/acidbase.html

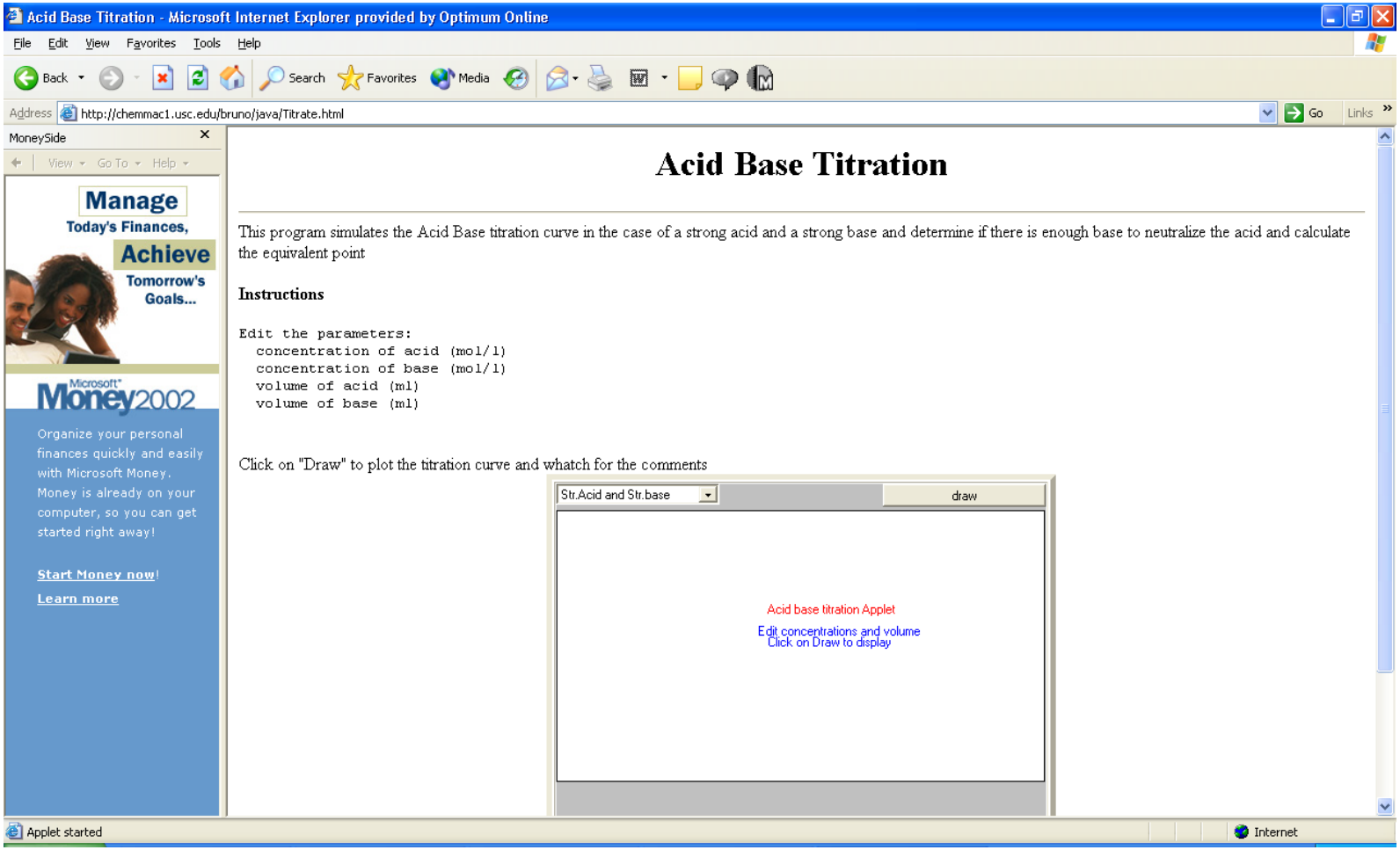
http://blue.vm.temple.edu/~pathphys/renal/acid_base_review.html



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



http://chemmac1.usc.edu/bruno/java/Titrate.html



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