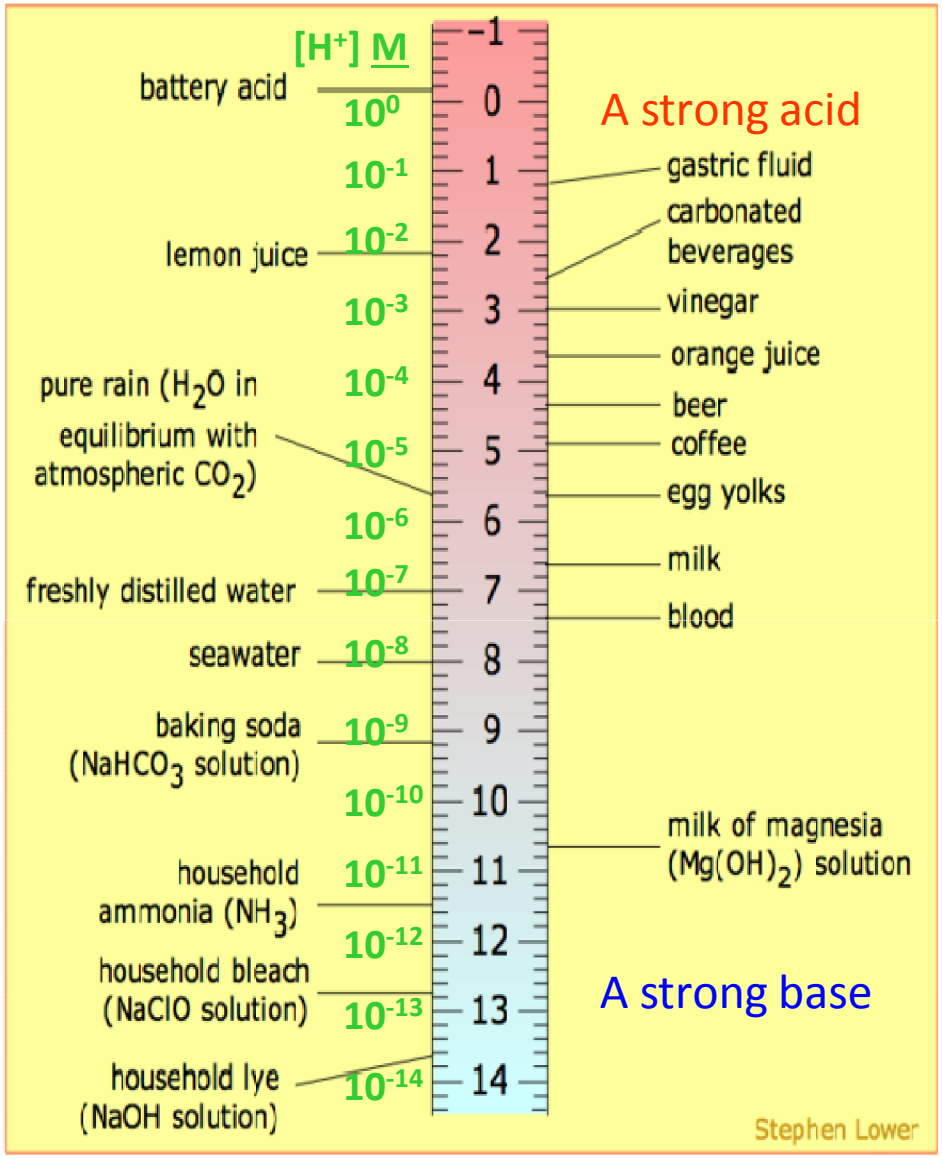
Acids, pH, and Buffers

Some Basic Chemistry for Biological Science

SOURCE: http://en.wikipedia.org/wiki/Image:PH_scale.png#file



pH definitions and maintenance

- **Most living cells have a *very* narrow range of tolerance for pH, i.e. [H^+].**
- The [H^+] concentration will be important (either explicitly or implicitly) for many other topics in biology.
- [H^+] is controlled in all biological organisms, and in virtually all biochemical experiments.
- Each pH unit represents a factor of 10 difference in [H^+].

Why is pH important in bioscience?

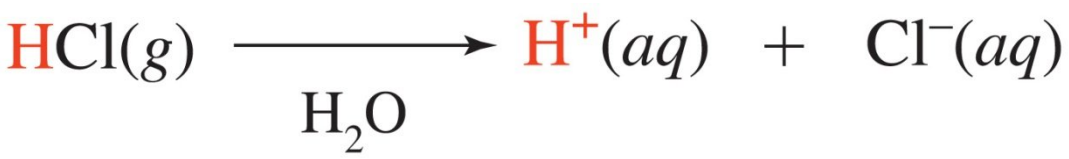
- pH affects solubility of many substances.
- pH affects structure and function of most proteins - including enzymes.
- Many cells and organisms (esp. plants and aquatic animals) can only survive in a specific pH environment.

Definitions

Acids,

- The Swedish chemist, Svante **Arrhenius**, first described ***acids*** as substances that dissociate, producing hydrogen ions (H^+) when dissolved in water.

- In the early twentieth century, ***Brønsted and Lowry*** redefined ***acids*** as a compound that donates a proton.



Dissociates into ions

Bases

- **Arrhenius** described ***bases*** as compounds that dissociate to form a metal ion and a hydroxide ion (OH^-) when dissolved in water. Arrhenius bases are formed from Group 1A and 2A metals. Hydroxide bases are characterized by a bitter taste and a slippery feel.

- The **Brønsted–Lowry** definition of a ***base*** is a compound that accepts a proton.

Buffer definition

For biological systems:

- Ionization of a strong acid is TOO BIG!
- Ionization of water itself is way TOO LITTLE!
- Ionization of a weak acid is JUST RIGHT!

Buffer uses

1. Biological systems such as blood and saliva
2. Eye drop
3. Shampoo pH 6 to prevent bacteria growth
4. Baby lotions

Homeostasis

Maintaining Physiological pH with Bicarbonate Buffer

- The bicarbonate system helps our bodies maintain its optimal physiological pH.

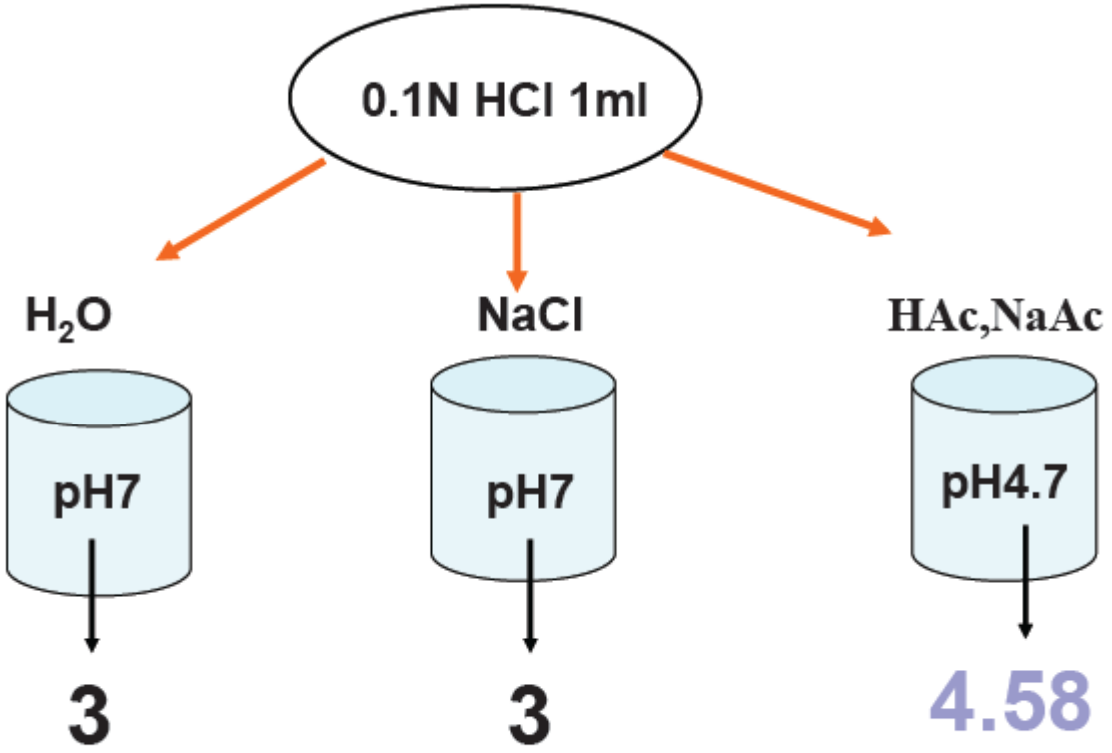
- The ability of an organism to maintain its internal environment by adjusting such factors as pH, temperature, and solute concentration is called ***homeostasis***.

Understanding biological buffers
By: Dr Mehdi Imani

Factors in choosing a buffer

1. Be sure it covers the pH range you need
   - Generally: pK_a of acid $\pm$ 1 pH unit
   - Consult tables for ranges or pK_a values
2. Be sure it is not toxic to the cells or organisms you are working with.
3. Be sure it would not confound the experiment (e.g. avoid phosphate buffers in experiments on plant mineral nutrition).
4. Calculation using the Henderson-Hasselbach equation.

How a Buffer Works



How a Buffer Works (cont.)

$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

relative concs. HIGH LOW LOW

NB A strong acid can't be used as it is fully dissociated and cannot remove $H^+(aq)$

$HCl(aq) \longrightarrow Cl^-(aq) + H^+(aq)$

Adding acid

Any H^+ is removed by reacting with CH_3COO^- ions to form CH_3COOH via the equilibrium. Unfortunately, the concentration of CH_3COO^- is small and only a few H^+ can be "mopped up". A much larger concentration of CH_3COO^- is required.

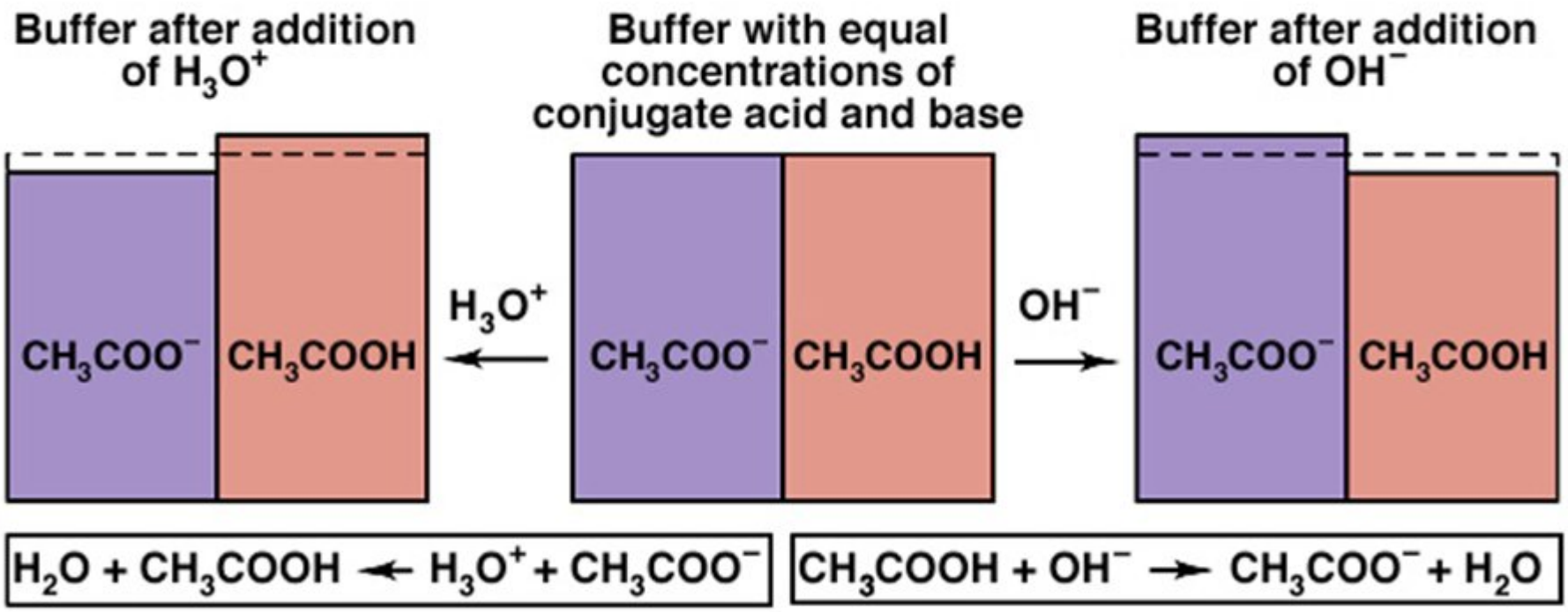
To build up the concentration of CH_3COO^- ions, sodium ethanoate is added, which dissociates completely.

$CH_3COO^-Na^+(aq) \longrightarrow CH_3COO^-(aq) + Na^+(aq)$

relative concs. LOW HIGH HIGH

.

How a Buffer Works (cont.)



Henderson-Hasselbalch Approximation

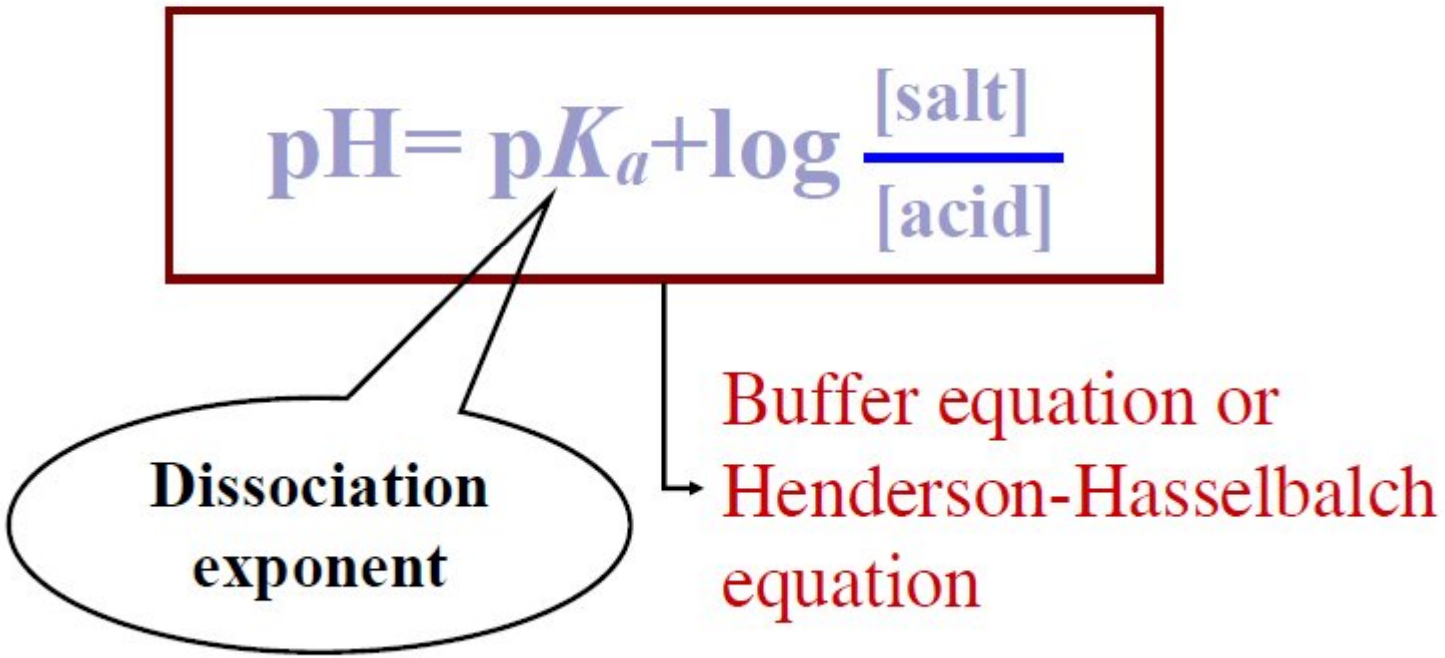
$$K_1 = \frac{[A^-][H^+]}{[HA]} \quad \Rightarrow \quad [H^+] = K_1 \frac{[HA]}{[A^-]}$$

$$-\log[H^+] = -\log(K_1 \frac{[HA]}{[A^-]}) \Rightarrow \; -\log[\mathrm{H}^+] = -\log \mathrm{K} - \log \frac{[\mathrm{HA}]}{[\mathrm{A}^-]}$$

$$-\log\frac{[\mathrm{HA}]}{[\mathrm{A}^-]} = +\log\frac{[\mathrm{A}^-]}{[\mathrm{HA}]} = \log\frac{\text{باز (نمك اسيد)}}{\text{اسيد}}$$

$$pH = pK + \log\frac{[A^-]}{[HA]}$$

- **A Weak Acid and Its Salt**



In vivo buffer systems

- **Blood**

  ① Primary buffers : Plasma ;

  $NaHCO_3$-- H_2CO_3, $NaHPO_4$--NaH_2PO_4, protein

  ② Secondary buffers : Erythrocytes ;

  hemoglobin-oxyhemoglobin, K_2Hpo_4-KH_2PO_4

- **Lacriminal fluid**

  - pH: 7.4 (range 7 – 8 or slightly higher)

- **Urine**

  - pH: 6.0 (range 4.5 – 7.8)

  - below normal…hydrogen ions are excreted by the kidney.

  - above pH 7.4…hydrogen ions are retained by action of the kidney.

Steps for buffer development

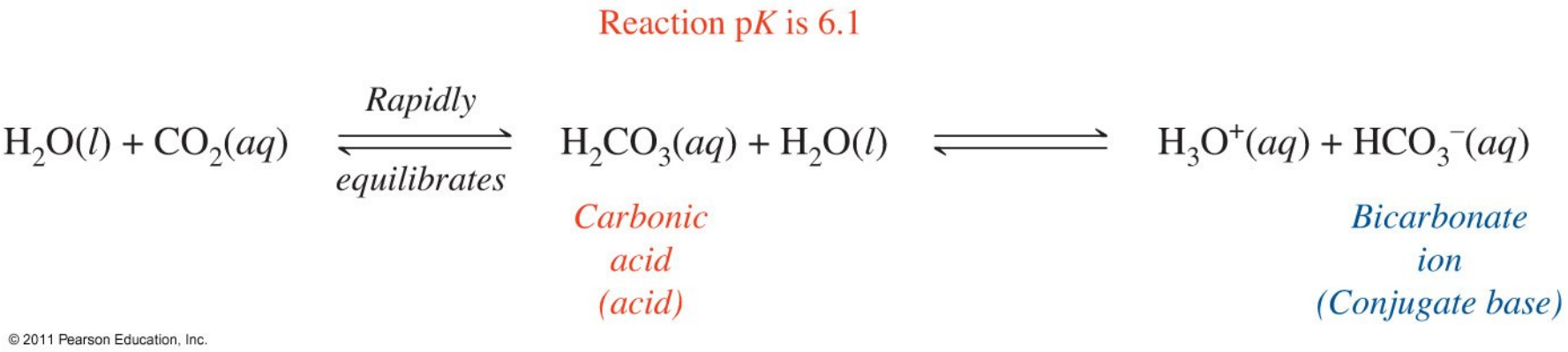
① Select a weak acid having a pK_a approximately equal to the pH at which the buffer is to be used.

② Calculate the ratio of salt & weak acid required to obtain the desired pH.

③ Consider the individual conc. Of the buffer salt & acid needed to obtain a suitable buffer capacity

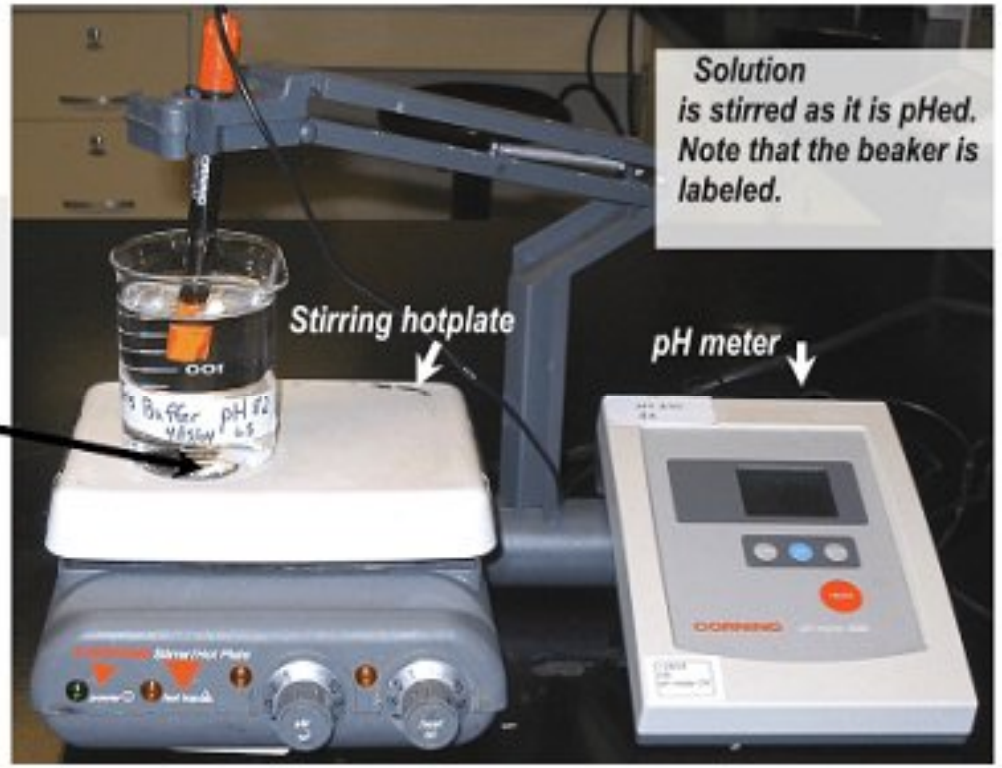
* Individual conc. : 0.05 ~ 0.5M
* buffer capacity : 0.01 ~ 0.1

The bicarbonate buffer system



- The bicarbonate buffer system can be denoted by showing the acid and its conjugate base like this: H_2CO_3/HCO_3^-. Sometimes the conjugate base is shown as an ionic compound like this: $H_2CO_3/NaHCO_3$.

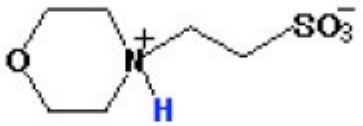
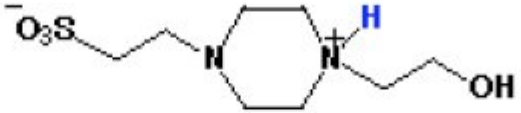
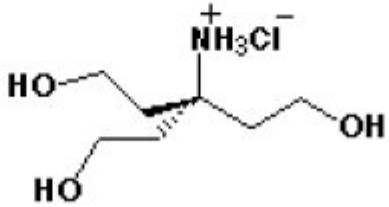
ADJUSTING THE pH OF A SOLUTION.



BE CAREFUL NOT TO CRASH THE ELECTRODE WITH THE STIR BAR.

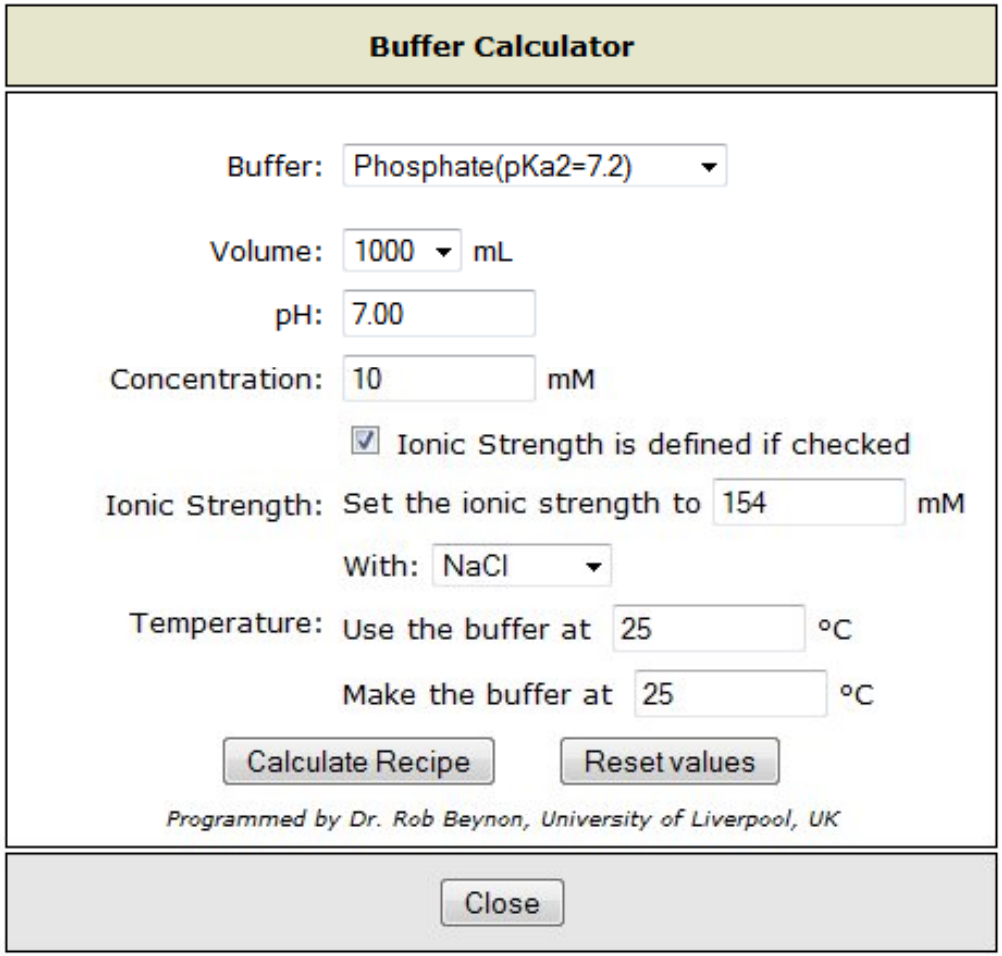
pH vs Temperature for Tris Buffer

pH of Tris Buffer (0.05 M)		
5°C	**25°C**	**37°C**
7.76	7.20	6.91
7.89	7.30	7.02
7.97	7.40	7.12
8.07	7.50	7.22
8.18	7.60	7.30
8.26	7.70	7.40
8.37	7.80	7.52
8.48	7.90	7.62
8.58	8.00	7.71
8.68	8.10	7.80
8.78	8.20	7.91

NAME	STRUCTURE	pK_a at 20^oC	ΔpK_a (^oC)
MES [2-(N-morpholino) ethanesulfonic acid]		6.15	-0.011
PIPES [piperazine-N,N'-bis (2-ethanesulfonic acid)]		6.8	-0.0085
Sodium dihydrogen phosphate	NaH_2PO_4	7.21	---
HEPES [N-2-hydroxyethyl piperazine-N'-2-ethanesulfonic acid]		7.55	-0.014
TRIS [tris(hydroxymethyl) aminoethane] hydrochloride		8.3	-0.031

Some useful links on buffer calculators!!!!

http://www.biomol.net/en/tools/buffercalculator.htm



http://dbr.csoft.net/chem/bufcalc.php

Buffer Calculator

- Input the pK_a values, the desired pH, and buffer strength
- Get recipes and other important info about your buffer

Enter pK_a values, separated by commas:

8.3

pH 7.1 Buffer Strength 10 mM Calculate

Optional: Free base name Tris Charge on H_NA 1 pKw 14 Tris HCl

Shortcuts
phosphate
citrate
phosphonate
MOPS
MES
Tris HCl
Tris acetate
carbonate
borate

Read **how it works**

By Dave Robinson

http://www.sigmaaldrich.com/life-science/core-bioreagents/biological-buffers/learning-center/Buffer-Calculator-App.html