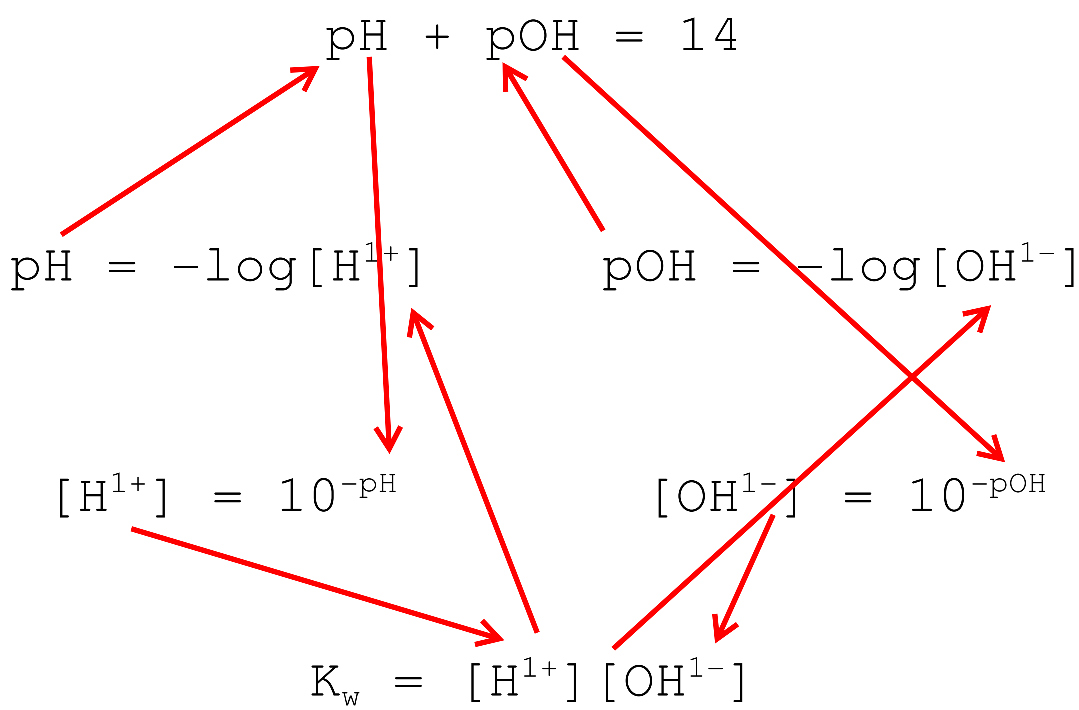
pH Relationships; Six Equations, Four Unknowns!!

(may require proofreading!!)

You home study today is to learn how to use six simple equations that relate $[H^{1+}]$ with $[OH^{1-}]$, pH, pOH and K_w. Given the circumstances you will not be required to memorize these equations for the exam. You will however need to know your way around them.

These equations centre around the pH scale, which you may know is a logarithmic scale.



$$\text{where } K_W = 1 \times 10^{-14}$$

These relationships have a cyclical property, meaning that if you know any one of $[H^{1+}]$ $[OH^{1-}]$, pH, pOH, you can find the other three, and there is more than one way to do it. *Because of the spontaneous dissociation of water equilibrium, the concentrations of $[H^{1+}]$ and $[OH^{1-}]$ always obey an equilibrium relationship. This means that both ions are alway present, even in the strongest of acid or base solutions.*

Weak vs Strong Acids and Bases

The term weak does not refer to concentration, it refers to degree of dissociation. You can have a strong concentration of a weak acid, or a weak concentration of a strong acid. On the sheet of "Relative Strengths of Acids and Bases and Selected K_A Values", the strong acids are simply those that are above the "water line". The reason that strong acids do not have a K_A value is because their dissociation is essentially 100% complete and are therefore "non-equilibrium acids" - note the reaction arrow!

$$HCl \rightarrow H^{1+} + Cl^{1-}$$

Weak acids are below the "water line" and do have a K_A value and have a partial equilibrium dissociation and are therefore "equilibrium acids" - note the equilibrium arrow

$$CH_3COOH \rightleftharpoons CH_3COO^{1-} + H^{1+}$$

The difference in reaction arrow also occurs in K_{sp} calculations when comparing slight soluble equilibrium salts with soluble non-equilibrium salts!

The six equations listed above can be used for either class of acid. The only difference is the way in which you can find the $[H^{1+}]$ and hence the other three values! We will start with strong acid and base calculations only.

eg 1 Find the $[H^{1+}]$, $[OH^{1-}]$, pH and pOH for a 6.0 M HCl solution.

Please note that this is a strong acid above the water line!

$$\underset{6.0M}{HCl} \rightarrow \underset{6.0M}{H^{1+}} + Cl^{1-}$$

$\therefore [H^{1+}] = 6.0\ M$ (Yes, it is that easy to find $[H^{1+}]$ for a strong acid)

$pH = -\log[H^{1+}]$

$pH = -\log(6.0)$

$pH = -0.778$ (Yes, that is a negative pH value. pH is after all a scale that is based on a mathematical relationship, nothing to say that pH cannot stray outside of the 1 to 14 that you know an love!)

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pOH = 14 - pH (Please note that this equation is in a rearranged form)

pOH = 14 - (-0.778)

pOH = 14.778

Although pOH can be used to find $[OH^{1-}]$, the accuracy of logarithmic calculations not as good as what can be achieved using the K_w equation.

$$[OH^{1-}] = \frac{K_w}{[H^{1+}]}$$

$$[OH^{1-}] = \frac{1 \times 10^{-14}}{6.0}$$

$$[OH^{1-}] = 1.6\dot{6} \times 10^{-15} \text{ M}$$

There you have it, four answers - fairly easy, you just need to figure out your calculator. Please note that it should be possible to verify you answers if you keep going. For example:

$[OH^{1-}] = 10^{-pOH}$

$[OH^{1-}] = 10^{-14.778}$

$[OH^{1-}] = 1.667 \times 10^{-15}$ M