

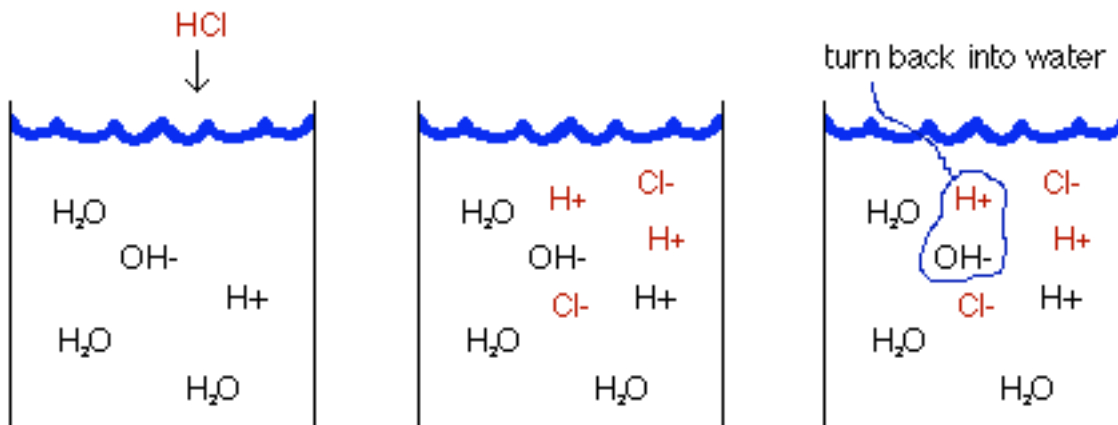
Notes on pH: What Is It and Where Did It Come From?

- Remember Arrhenius's definition of acids and bases:
 - An acid increases the hydrogen ion concentration in water.
Note: $[H^+]$ means the hydrogen ion concentration. Also don't forget that there really aren't any H^+ s in water - they combine with H_2O to form H_3O^+ .
 - A base increases the hydroxide ion concentration in water.
Note: $[OH^-]$ means the hydroxide ion concentration.
- Now consider water, which is neutral, neither an acid or a base.
 - In any sample of pure water,
 $[H^+] = 1.0 \times 10^{-7} M$ and
 $[OH^-] = 1.0 \times 10^{-7} M$

Where do they come from? Water naturally breaks up into H^+ and OH^- . When the temperature is $25^\circ C$, about two water molecules per billion split up like that. Not much.

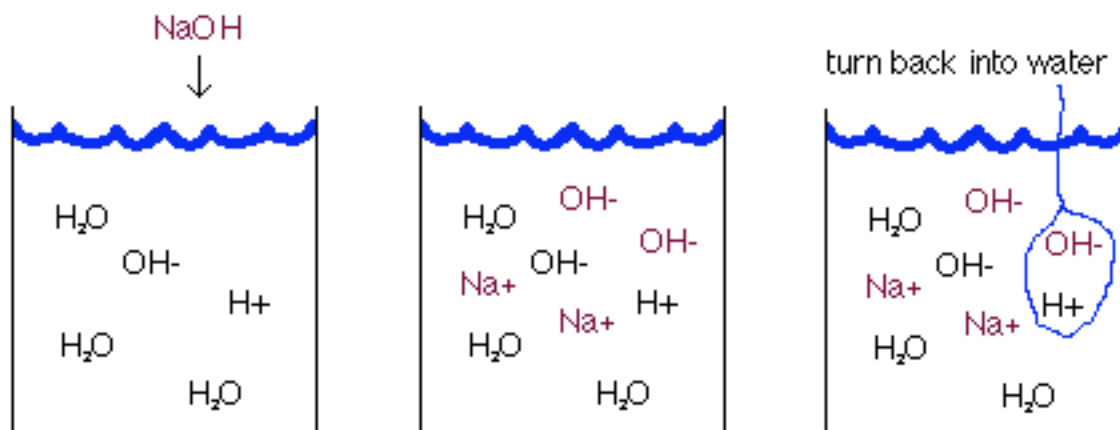
b. This means that water is both an acid and a base (this is the definition of an amphoteric substance - something that's both an acid and a base).

- So let's start with some pure water. What happens when you add an acid like HCl?



- When you add HCl to pure water it all dissociates because it's a strong acid.
 - The $[H^+]$ increases because you've thrown more H^+ s in.
 - The $[OH^-]$ decreases because some of those H^+ s you threw in combine with OH^- s that were already there and turn back into water.
- Ex: after adding some HCl,
 $[H^+] = 1.0 \times 10^{-4} M$ (increased)
 $[OH^-] = 1.0 \times 10^{-10} M$ (decreased)

4. What happens when you add a base like NaOH?



- a. When you add NaOH to pure water it all dissociates because it's a strong base.
- The $[\text{OH}^-]$ increases because you've thrown more OH^- 's in.
 - The $[\text{H}^+]$ decreases because some of those OH^- 's you threw in combine with H^+ 's that were already there and turn back into water.

- b. Ex: after adding some HCl,
- $$[\text{H}^+] = 1.0 \times 10^{-11} \text{ M (decreased)}$$
- $$[\text{OH}^-] = 1.0 \times 10^{-3} \text{ M (increased)}$$

5. The data has shown that for every case,
 $[\text{H}^+] \cdot [\text{OH}^-] = \text{a constant}$

In the case of pure water,
 $1.0 \times 10^{-7} \text{ M} \cdot 1.0 \times 10^{-7} \text{ M} = 1.0 \times 10^{-14} \text{ M}^2$

This constant, $1.0 \times 10^{-14} \text{ M}^2$, will always be the product of $[\text{H}^+] \cdot [\text{OH}^-]$.
 It's called the K_w , or "constant for water" (Konstant for water?)

How is this useful?

Ex: When we added the HCl, the new $[\text{H}^+] = 1.0 \times 10^{-4} \text{ M}$. What's the $[\text{OH}^-]$?

$$[\text{H}^+] \cdot [\text{OH}^-] = 1.0 \times 10^{-14} \text{ M}^2$$

$$(1.0 \times 10^{-4} \text{ M}) \cdot [\text{OH}^-] = 1.0 \times 10^{-14} \text{ M}^2$$

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{(1.0 \times 10^{-4} \text{ M})}$$

$$[\text{OH}^-] = 1.0 \times 10^{-10} \text{ M}$$

6. Exponents are messy, so of course chemists have come up with a shortcut for dealing with them: pH and pOH.

pH = the power or proportion of $[H^+]$

pOH = the power or proportion of $[OH^-]$

Ex: water

$$\begin{array}{ll} [H^+] = 1.0 \times 10^{-7} M & \text{pH} = 7 \\ [OH^-] = 1.0 \times 10^{-7} M & \text{pOH} = 7 \end{array}$$

$$\text{pH} + \text{pOH} = 14$$

Ex: acid

$$\begin{array}{ll} [H^+] = 1.0 \times 10^{-4} M & \text{pH} = 4 \\ [OH^-] = 1.0 \times 10^{-10} M & \text{pOH} = 10 \end{array}$$

$$\text{pH} + \text{pOH} = 14$$

Ex: base

$$\begin{array}{ll} [H^+] = 1.0 \times 10^{-11} M & \text{pH} = 11 \\ [OH^-] = 1.0 \times 10^{-3} M & \text{pOH} = 3 \end{array}$$

$$\text{pH} + \text{pOH} = 14$$

In every case, whether it's neutral, acidic, or basic, $\text{pH} + \text{pOH} = 14$. Makes it very easy.