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Acid/Base solutions

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What is an acid?

Bronsted-Lowry definition: An acid is a proton donor.

So, what's a base?

Bronsted-Lowry definition: A base is a proton acceptor.

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They go together…like carrots and peas, Forrest.

If you are going to donate a proton, something must accept it.

You can't really be an acid without a base.

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What's the most common acid?

Water!!

H-OH, it has a proton it can donate.

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What's the most common base?

Water!

H - O - H

It has extra electrons on the oxygen, so a proton can stick to it.

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Water is special…

…it is amphoteric: it can act as an acid or a base.

It's not the only compound that can, we'll see other's later.

It also means that most Bronsted-Lowry acids or bases can dissolve in water.

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We like water…

Acids and bases like water…

So, acids and bases are mostly found as aqueous solutions here.

Like all solutions, the concentration is a critical parameter.

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All solutions are created equal…

Like any other aqueous solution, a solution of either an acid or base is defined by its concentration.

So what's this thing called pH?

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pH is concentration

The pH scale is just a logarithmic scale for the Molarity of the protons in the solution.

The pH scale is logarithmic (the difference between pH=1 and pH=2 is a factor of 10)

pH is concentration

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Damn those logs

pH = - log [H^+]

[x] always means "concentration of x"

[H^+] should be in M.

pH is ONLY the concentration of $H^{+.}$

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Example

1 M HCl solution. What's the pH?

Implicitly, you must recognize that:

$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

Or, $HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

pH = - log [H^+] = - log [H_3O^+]

pH = - log (1 M) = 0

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Another example

2.4 M H_2SO_4. What's the pH?

In this case, you must recognize:

$H_2SO_{4\ (aq)} \rightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

So [H^+] = 2[H_2SO_4]

[H^+] = 2(2.4 M) = 4.8 M

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ICE chart

I think it is easier to see what's going on if you follow the concentrations in an "ICE" chart.

I = initial

C = change (during reaction)

E = End (or equilibrium) amounts

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$H_2SO_{4\,(aq)} \rightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

I	2.4 M	0	0
C	−1x	+2x	+1x
E	0	2x	1x

Each column is a little algebra problem:

Initial + change = End

2.4 + (-1x) = 0

X = 2.4

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$H_2SO_{4\,(aq)} \rightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

I	2.4 M	0	0
C	−2.4	+2(2.4)	+2.4
E	0	4.8	2.4

Each column is a little algebra problem:

Initial + change = End

2.4 + (-1x) = 0

X = 2.4

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The lies you were told in HS…

pH = - log $[H^+]$ = - log (4.8) = -0.68

Now, pH=-0.68 might be surprising to you.

A common "Earth Science lie" is that the pH scale goes from 0 to 14.

I am here to tell you the truth! ☺

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The Truth according to Joe

pH = - log $[H^+]$ by definition

So, pH is governed by the limits of the concentration of H^+ only.

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The Truth according to Joe

The highest $[H^+]$ is 56 M (because pure water is 56 M!) The smallest pH is, therefore -1.7

The highest pH is a little harder to define. What if you had 1 atom of H^+ in a liter of water? Then the concentration would be $1.66x10^{-24}$ and the pH=23.78 (although 16-18 is more common as the upper end of the pH scale)

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Bottom Line according to Joe

pH is simply a logarithmic concentration scale.

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New example

What is the pH of 2.4 M NaOH solution?

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New example

What is the pH of 2.4 M NaOH solution?

What is NaOH?

It’s a Base!

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New example

What is the pH of 2.4 M NaOH solution?

Where's the H^+?

What does NaOH do in solution?

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New example

What is the pH of 2.4 M NaOH solution?

$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

I still don't see the H^+?

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Autoionization of water

Water is a special molecule for many reasons:

1. Polar solvent
2. Unusually high boiling point
3. It expands when it freezes
4. It is amphiprotic

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Amphi-who?

Amphiprotic means that water can act as either an acid or a base.

What happens when you mix an acid and base together?

They neutralize each other.

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If you mix water with water…

It neutralizes itself!

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Autoionization of water

$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$

What's with the "↔"?

↔ means that the reaction goes both ways. It is an "equilibrium reaction"

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Equilibrium Reactions

Equilibrium reactions have a balance between the reactants and the products.

In the case of the autoionization of water:

$[H_3O^+][OH^-] = 1x10^{-14}$
(the equilibrium constant expression – is this familiar?)

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What does this mean?

It means that in aqueous solutions, you ALWAYS have BOTH H^+ and OH^- present.

In fact, you can define pOH similarly to pH:

$pOH = - \log [OH^-]$

And pOH and pH should be related.

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The Relationship

How are they related?

$[OH^-][H^+] = 1x10^{-14}$

$-\log([OH^-][H^+]) = - \log(1x10^{-14})$
$-\log([OH^-] + (- \log[H^+]) = - \log(1x10^{-14})$
$pOH + pH = 14$
(this is the reason for the Earth Science Lie)

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Returning to our base problem

What is the pH of 2.4 M NaOH solution?

$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

How would you solve it?

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Returning to our base problem

What is the pH of 2.4 M NaOH solution?

$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

How would you solve it?
2 ways:

- Calculate $[H^+]$ from $[OH^-]$
- Calculate pH from pOH

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$[H^+]$ from $[OH^-]$

What is the pH of 2.4 M NaOH solution?

$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

$[H^+]\,[OH^-] = 1x10^{-14}$
$[H^+]\,[2.4] = 1x10^{-14}$
$[H^+] = 4.17x10^{-15}$
$pH = -log\,(4.17x10^{-15}) = 14.38$

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pH from pOH

What is the pH of 2.4 M NaOH solution?

$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

pOH = - log (2.4) = -0.38

pH + pOH = 14

pH + (-0.38) = 14

pH = 14.38

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Why is pH important?

pH is a measure of the concentration of acid or base. Why do we care?

It's still all about the water.

- Acidic water can be corrosive to many materials.
- Life forms on Earth do all of their chemistry in water. This chemistry is optimized in certain pH ranges (usually 6-8).

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Measuring pH

There are many ways to measure pH:

- Titration – most accurate – we do this a LOT
- Electrodes – pretty accurate & easy (pH meters)
- Chemical indicators – cheap and "ballpark" (this is the pool test kit)

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Little problems

What is the pH of an aqueous solution that is 1.25 M HCl?

pH = - log [H+] = - log (1.25 M)

pH = -0.0969

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What is the pH of an aqueous solution that is 0.25 M NaOH?

pOH = - log (0.25 M) = 0.60

pH + pOH = 14

pH = 14 – pOH = 14 -0.60 = 13.4

OR

$[H+][OH-]=1x10^{-14}$

$[H+](0.25) = 1x10^{-14}$

[H+] = 4x10-14

pH = - log ($4x10^{-14}$) = 13.4