pH of strong acid and base

What does strong mean in terms of acids and bases?
Solubility. Basically, if you say an acid or base is strong, then it dissociates 100% in water. These types of situations are not equilibrium, when it comes to the dissociation of the acid. It does have to do with the equilibrium of the hydrogen ion, hydroxide ion, and water. In other words, you may need to track 2 different equations.

- Strength has **ABSOLUTELY NOTHING** to do with pH.
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- pH has to do with how **CONCENTRATED** the acid or base is.
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A **strong** acid/base dissociates completely. Not equilibrium. Reaction goes all the way to the right. $K = \infty$

A **weak** acid/base does not dissociate completely. Equilibrium. Reaction favors both directions. A reasonable $K$ value would be like $10^{-5}$.

A **feeble** acid/base does not dissociate very much at all. Equilibrium, but the reaction greatly favors the reactants. A typical $K$ would be like $10^{-45}$.

**Strong Acids**
hydrochloric, hydrobromic, hydroiodic, nitric, chloric, perchloric, sulfuric
HCl, HBr, HI, HNO$_3$, HClO$_3$, HClO$_4$, H$_2$SO$_4$.
Each of these acids dissociate completely, and you should be able to easily write their dissociation reactions.

$$ \text{HCl} \rightarrow \text{H}^+ + \text{Cl}^- \quad \text{or} \quad \text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^- $$

The same type of dissociation reaction would be true for all other strong acids, except sulfuric. It has 2 hydrogen atoms. However, it dissociates the hydrogens one at a time and the only dissociates the first hydrogen completely.

$$ \text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{HSO}_4^- $$

HSO$_4^-$, the hydrogen sulfate ion, is also an acid. It can dissociate to release hydrogen ion in solution. However, it is a weak acid and would reach equilibrium.

$$ \text{HSO}_4^- \leftrightarrow \text{H}^+ + \text{SO}_4^{2-} $$

You would have to use $K_{\text{eq}}$ and a RICE table to answer questions about this dissociation. Which is, another lesson.

If an acid has one hydrogen, it is called monoprotic (one proton). If it has two, diprotic. Etc.
Example. What is the pH of a 0.000042 M HBr solution?

HBr is a strong acid and dissociates completely.

\[ \text{HCl} \rightarrow \text{H}^+ + \text{Cl}^- \]

\[
\begin{array}{ccc}
0.000042 & 0.000042 & 0.000042 \\
\end{array}
\]

\[
pH = -\log_{10}[\text{H}^+] = -\log_{10}[0.000042] = 4.38
\]

4.38 is not so close to 1. Again, pH does not tell you the strength of the acid. It means this acid is dilute.

The pOH of this solution would be \(14 - 4.38 = 9.62\).

\[
[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}
\]

\[
[0.000042][\text{OH}^-] = 1 \times 10^{-14}
\]

\[
[\text{OH}^-] = 2.38 \times 10^{-10}
\]

Example. What is the pH of a 6.0 M HNO\(_3\) solution?

HBr is a strong acid and dissociates completely.

\[ \text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_3^- \]

\[
\begin{array}{ccc}
6.0 & 6.0 & 6.0 \\
\end{array}
\]

\[
pH = -\log_{10}[\text{H}^+] = -\log_{10}[6.0] = -0.778
\]

What? You didn’t know pH could be negative? This is why this molarity of acid is called CONCENTRATE and we usually wear gloves.

So which is stronger, HNO\(_3\) or HCl?

This is really a trick question. A strong acid is a strong acid. There are no degrees of strength. When we get to weak acids, there is a difference, based on which acids dissociate the greatest.

Strong Bases

Hydroxides of Group I metals, Calcium, Barium, Strontium.

Examples: NaOH, Ba(OH)\(_2\)

Each of these bases dissociate completely, and you should be able to easily write their dissociation reactions.

\[ \text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^- \]

This is the typical dissociation reaction for the group I bases. The bases of Group I metals are all \textit{monobasic}. The bases of Group II metals are all \textit{dibasic}. Aluminum hydroxide is \textit{tribasic}. Any material with two or more ionizable hydroxyl groups would be called \textit{polybasic}. Unlike sulfuric acid that could only dissociate one of its hydrogens, group II strong bases dissociate both hydroxides.

\[ \text{Ca(OH)}_2 \rightarrow \text{Ca}^{2+} + 2 \text{OH}^- \]
Example. What is the pH of a 0.005 M KOH solution?

Potassium hydroxide is a strong base and dissociates completely.

\[
\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^- \\
0.005 \quad 0.005 \quad 0.005
\]

Here, you could find the pOH and then subtract from 14 to get the pH since \( \text{pH} + \text{pOH} = 14 \). You can also use \( K_w \) to find the hydrogen ion concentration, then calculate pH. I’m going to do one example of each.

\[
\text{pOH} = -\log[\text{OH}^-] = -\log[0.005] = 2.3 \\
\text{pH} = 14 - 2.3 = 11.7
\]

Example. What is the pH of a 0.024 M Ba(OH)\(_2\) solution?

Barium hydroxide is a strong base and dissociates completely.

\[
\text{Ba(OH)}_2 \rightarrow \text{Ba}^{2+} + 2 \text{OH}^- \\
0.024 \quad 0.024 \quad 0.048
\]

\[
[H_3O^+][\text{OH}^-] = 1 \times 10^{-14} \\
[H_3O^+][0.048] = 1 \times 10^{-14} \\
[H_3O^+] = 2.08 \times 10^{-13}
\]

\[
\text{pH} = -\log[\text{H}^+] = -\log[2.08 \times 10^{-13}] = 12.7
\]

Some people find using diagrams easy. I think it is just more to memorize by here you go:

For a list of strong acids and bases and their dissociation reactions, see this link. This source doesn’t include francium as a strong base, but it is. Also, some sources define magnesium hydroxide as a strong base. Again, remember that “soluble” is a relative term and it depends upon where an expert draws the line on the K values. Strong means the K value is relatively big and the reaction favors the products.

http://www.chemistry.pomona.edu/chemistry/1alab/www/fall2006/powerptpresentations/5anions/acidbaset.htm
Mixing Acids and Bases

ACID-BASE NEUTRALIZATION – QUANTITATIVE STUDIES

There is a point where the acid has been completely neutralized or reacted by the base. This point is called the EQUIVALENCE POINT. At the equivalence point, the acid and base no longer exist; only the salt and water. This involves stoichiometry to determine the equivalence point in neutralization.

These are stoichiometry questions. The number of moles of hydrogen ion must equal the number of moles of hydroxide ions. So, it is important to know how to find the number of moles in a solution:

In these types of problems, you assume that even weak acids and bases dissociate to completion. Why? Look at the example of magnesium hydroxide.

\[
\text{Mg(OH)}_2 \leftrightarrow \text{Mg}^{2+} + 2 \text{OH}^-
\]

This is the milk of magnesia we looked at earlier in the year and not all of it dissolved. That is why it is in equilibrium. As you add acid, the hydrogen and hydroxide form water, removing hydroxide from the solution. Using LeChatelier’s principle, equilibrium would shift to the right and more Mg(OH)_2 would dissociate. This would continue until all of hydroxide were reacted and you would have water, magnesium ions, and the ions from the acid left in solution.

Example. What volume of 0.200 M HCl is required to neutralize 50 mL of 0.4 M Ca(OH)_2?

Look at the dissociation reactions of the acid and base.

\[
\begin{align*}
\text{Ba(OH)}_2 & \rightarrow \text{Ba}^{2+} + 2 \text{OH}^- \\
0.4 & \quad 0.4 \quad 0.8 \\
\text{HCl} & \rightarrow \text{H}^+ + \text{Cl}^- \\
0.2 & \quad 0.2 \quad 0.2 
\end{align*}
\]

So, for this problem, \([H^+] = 0.2\) and \([OH^-] = 0.8\). Then number of moles of each ion must be the same.

\[
M_aV_a = M_bV_b \\
(0.2)(V) = (0.8)(50) \\
V = 200 \text{ mL}
\]
FINDING THE pH OF TITRATIONS

In a certain experiment, 28.0 mL of 0.250 M nitric acid is titrated with 72.0 mL of 0.320 M potassium hydroxide. Assuming the volumes are additive, determine the resulting pH.

(28.0 mL)(0.250 M) = 7 mmol HNO₃.

\[
\begin{align*}
\text{HNO}_3 & \rightarrow \text{H}^+ + \text{NO}_3^- \\
7 & \quad 7 & \quad 7
\end{align*}
\]

(72.0 mL)(0.32 M) = 23.04 mmol KOH.

\[
\begin{align*}
\text{KOH} & \rightarrow \text{K}^+ + \text{OH}^- \\
23.04 & \quad 23.04 & \quad 23.04
\end{align*}
\]

The 7 mmol of H⁺ react with the 23.04 mmol OH⁻ forming 7 mmol H₂O and leaving 16.04 mmol OH⁻ in a solution with a total volume of 100 mL.

\[
[\text{OH}^-] = 0.01604 \text{ mol/0.100 L} = 0.1604 \text{ M}
\]

pOH = – log[OH⁻] = – log[0.1604] = 0.79

pH = 13.21