

Acid and base basics

You've heard of acids and bases before. Acids are those things that burn stuff, and bases have something to do with hip-hop music. You're a bright person, and you haven't missed much when it comes to this topic.



Though her experimentation with acid started off well enough, Sunflower eventually found that her lack of knowledge led to some very bad decisions.

So let's learn more about our little chemical friends, shall we?

What are acids and bases?

You'd think this would be easy to define, but it's not all that simple. The answer to this question isn't all that definite, but rather "which definition would you like to use?" Because of this odd situation, I'll have to give you three definitions of acids and bases...

Definition 1: Arrhenius acids and bases

This is the definition you've probably heard your entire life up to now. Using the Arrhenius definition:

Acids are compounds that give off H^+ ions (called "hydronium ions" and sometimes shown as H_3O^+) when you put them in water.

- Their formulas start with H (for example HBr), so they're easy to identify.
- The pH of an acidic solution is less than 7.
- The names of acids always end with the word "acid", which makes it pretty easy to figure them out.

Bases are compounds that give off OH^- ions ("hydroxide ions") when you put them in water.

- They're always hydroxides, so if you see an OH at the end of the formula of an ionic compounds (for example, NaOH), you've got a base.
- The pH of a basic solution is greater than 7.

- Bases are always ionic compounds, because they're the only things that give off OH⁻ ions in water.

Neutral compounds don't give off either H⁺ or OH⁻ ions in water.

- They have a pH of exactly 7. Water is the most common example.

Simple, right?



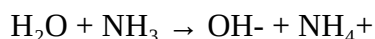
The professors voted against giving James his PhD when they realized that his chemistry dissertation involved “dropping the bass” rather than anything pH related.

Definition 2: Brønsted-Lowry acids and bases

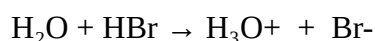
The big difference between Arrhenius acids and bases and Brønsted-Lowry acids and bases is that Arrhenius acids describe what a compound *is*, while Brønsted-Lowry describes what a compound *does*. As a result, when you put two compounds in a beaker, whatever compound acts as an acid in this case will give one or more H⁺ ion to the base. Which leads to this definition:

In a chemical reaction, the Brønsted-Lowry acid is the compound that gives one or more H⁺ ions to the Brønsted-Lowry base.

Most compounds will act differently when combined with different things. For example, if you put water in a beaker with ammonia, it acts like an acid by giving H⁺ to ammonia:

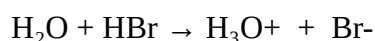


However, put water together with HBr and water acts as a base by taking H⁺ from HBr:



Which is the whole point of the Brønsted-Lowry thing. Compounds aren't naturally acids or bases – instead, they *behave* as acids or bases depending on the circumstances in which you put them. As a result, water can be either an acid or a base, depending on what else is in the beaker.

Another handy feature: Brønsted-Lowry acid-base reactions result in the formation of Brønsted-Lowry conjugate acid-base pairs. Let's go back to this reaction:



If you look at this reaction as going from forwards to backwards, water is a base and HBr is an acid. When water grabs that H^+ ion, it becomes the hydronium ion on the right side of the equation, and when HBr gives off H^+ it becomes the Br^- ion on the right.

If you look at the reaction from the other direction, the hydronium ion is acting as an acid by giving H^+ to the bromide ion (which, by definition, means it's acting like a base). This reforms the original water and HBr that we started with.

The relationship between reagent and product leads to the idea of conjugate acid-base pairs. Let's have a look:

- When water grabs H^+ (i.e. water acts like a base), it forms the hydronium ion, which will want to give its H^+ to the bromide ion (i.e. hydronium will act like an acid). As a result, we would say that water acts like a base, and the hydronium ion is its conjugate acid.
- Likewise, when HBr gives H^+ to water (i.e. HBr acts like an acid), it forms the Br^- ion which will act like a base when it reacts with the hydronium ion. This makes HBr an acid and Br^- its conjugate base.

If you want to figure out whether something will act like an acid when you combine it with something else, look at their K_a values. The compound with the larger K_a value will act as the acid, while the one with the lower K_a value will act as the base. Or at least, that's what that smooth talker Brønsted will tell you:



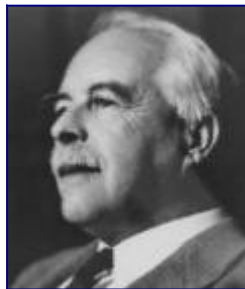
Hello, ladies.

An aside: Why wasn't the Arrhenius definition good enough?

The reason that Brønsted and Lowry came up with their definition is to account for compounds like ammonia. You see, ammonia doesn't have any OH^- ions in it, but it behaves like a base when you put it in water. Because the Arrhenius definition didn't quite cut it, they came up with a somewhat broader definition that would take this into account.

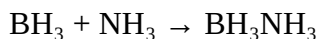
Definition 3: Lewis acids and bases

If you're wondering whether this Lewis is the same guy who came up with the idea of Lewis structures, wonder no more. This is the guy.



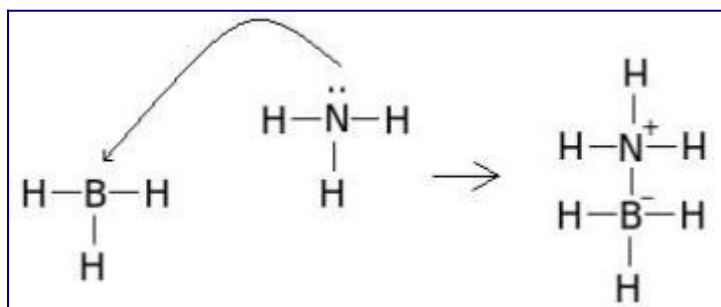
Hello, ladies.

In any case, he came up with a definition of acids and bases that's even broader than the earlier ones. Consider the reaction of BH_3 and NH_3 :

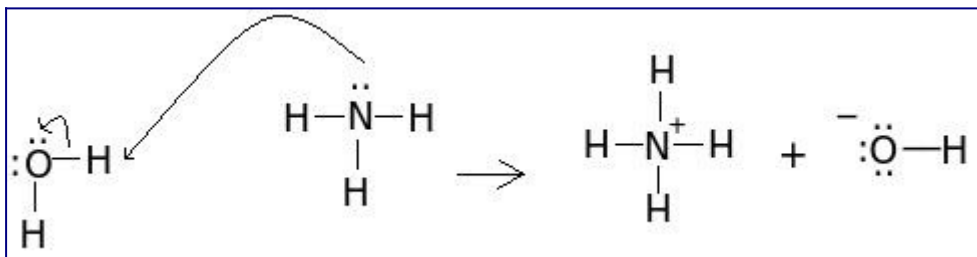


Isn't that something? If you don't think so, don't be offended. This reaction involves the lone pair electrons on NH_3 attaching to BH_3 in order to form a complex as shown below:

According to the Lewis definition, a Lewis acid is something that accepts electrons, while a Lewis base donates electrons. In this example, the ammonia is giving electrons to BH_3 , which is how this reaction works.



This definition also works for moving H^+ ions around, except we usually don't use it for that reason very much. Consider what happens when ammonia reacts with water:



Which means that the Lewis definition is really just a super-complicated version of what we've been saying all along. Hooray for complicated explanations!

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