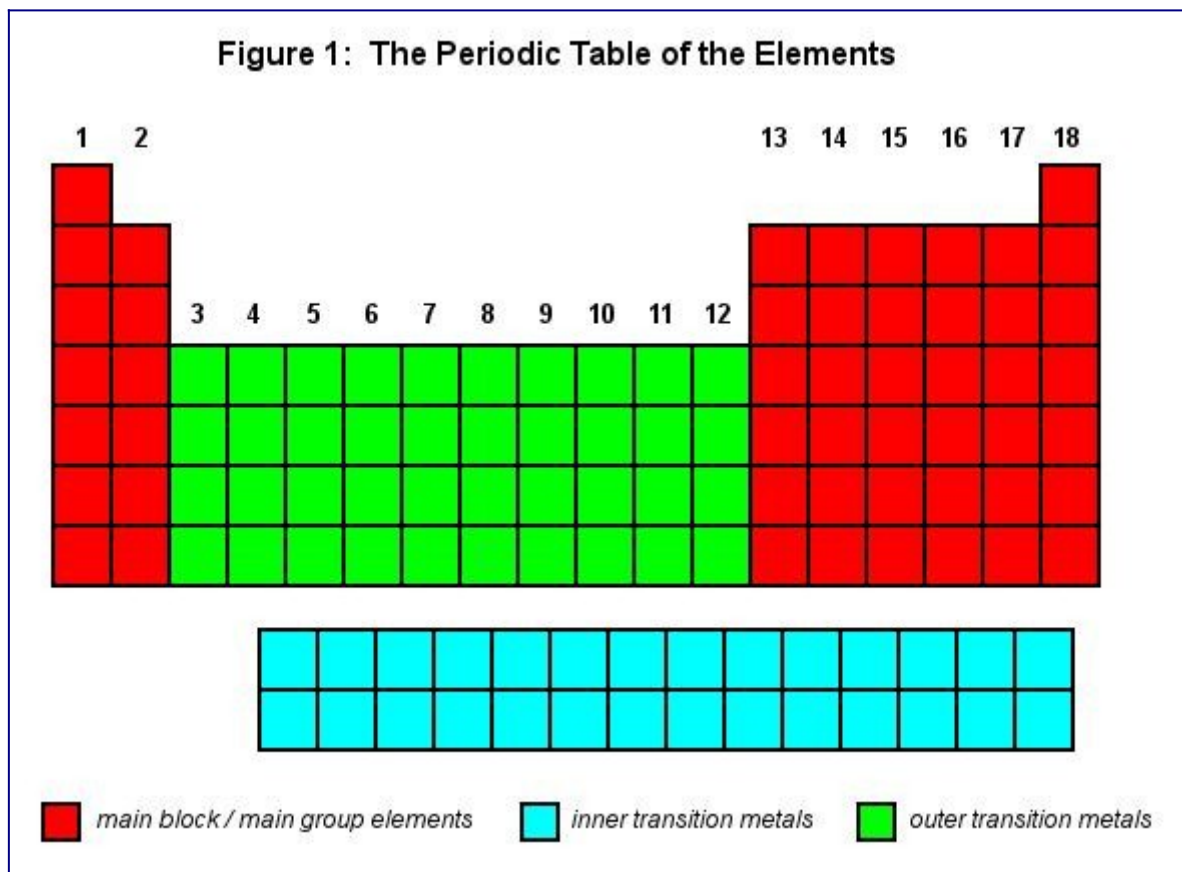


Periodic table

There's a slight chance that if you've spent any time in a science classroom, you may have seen a great big thing on the wall with a lot of boxes on it. No, I'm not talking about the [cages](#) where they keep the bad kids: I'm talking about the periodic table. In this tutorial, we'll talk all about the periodic table and the periodic trends.

What's the periodic table?

The periodic table is a great big chart that contains a bunch of relevant information about the elements. It's organized into several sections, as seen in this handy figure:



What these elements are called:

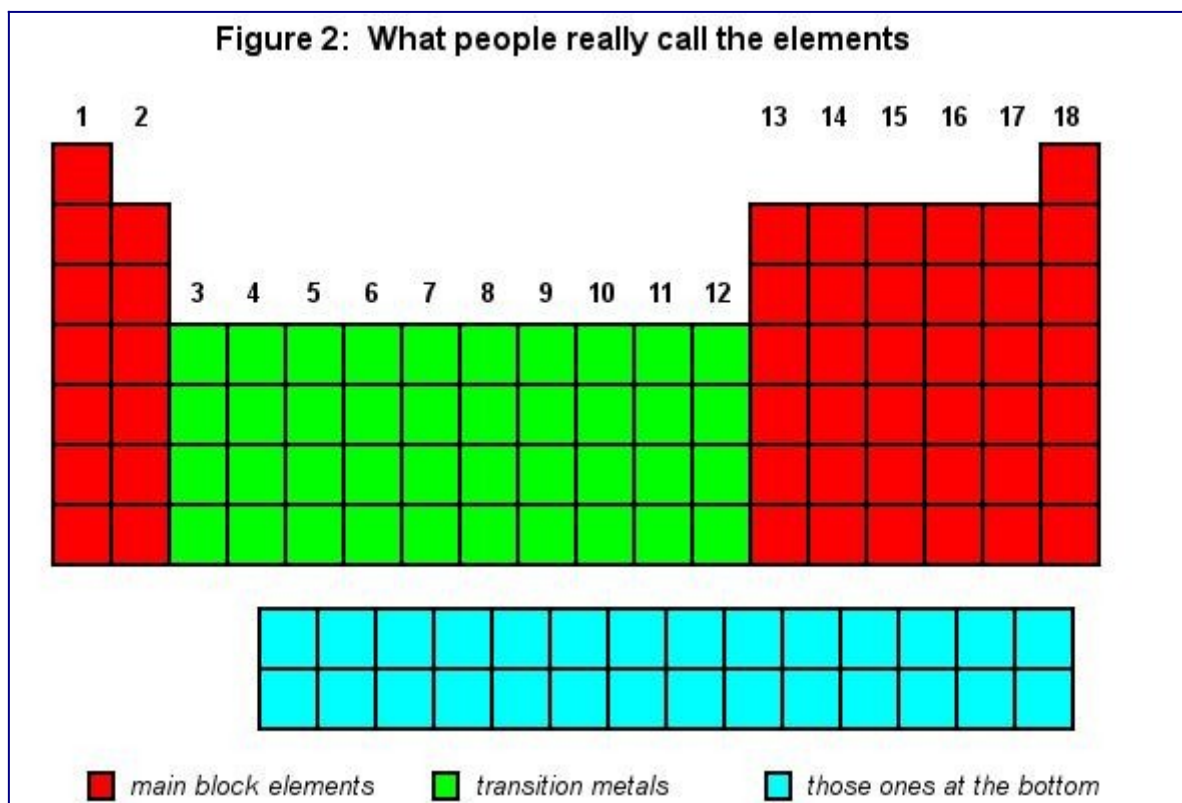
As you've seen we like to give everything fancy names. Here are the ones for the periodic table:

- **The main block elements** (also called the main group elements) consist of those red elements in Fig. 1 in which the outermost electrons are s- and p- electrons. (We talk more about that in the electron configuration tutorial). They are sometimes called the “representative elements”, though I’ve only ever read that on Wikipedia and not in real life.
- **The inner transition metals** are blue guys at the bottom, where the outermost electrons are in f-orbitals. Nobody ever actually calls them this, preferring instead to call them lanthanides and actinides after the two rows in this area. We’ll get to that.
- **The outer transition metals** are the green ones on the chart, with their outermost electrons in d-orbitals.

Together, the inner and outer transition metals comprise a larger group simply called the “transition metals.”

What these elements are actually called:

Though the above is all correct, it's also not what chemists usually say when referring to these elements. Figure 2 gives a clearer idea of the terms that are actually used:



When speaking of the elements, chemists usually use the terms above. I've never heard a chemist refer to the elements at the bottom as “inner transition metals” (I had to look it up) and there's even some disagreement as to whether the term “outer transition metals” even exists. It's almost universally the case that elements are broken into the main block, the transition metals (the green ones only), and the ones at the bottom (seriously).

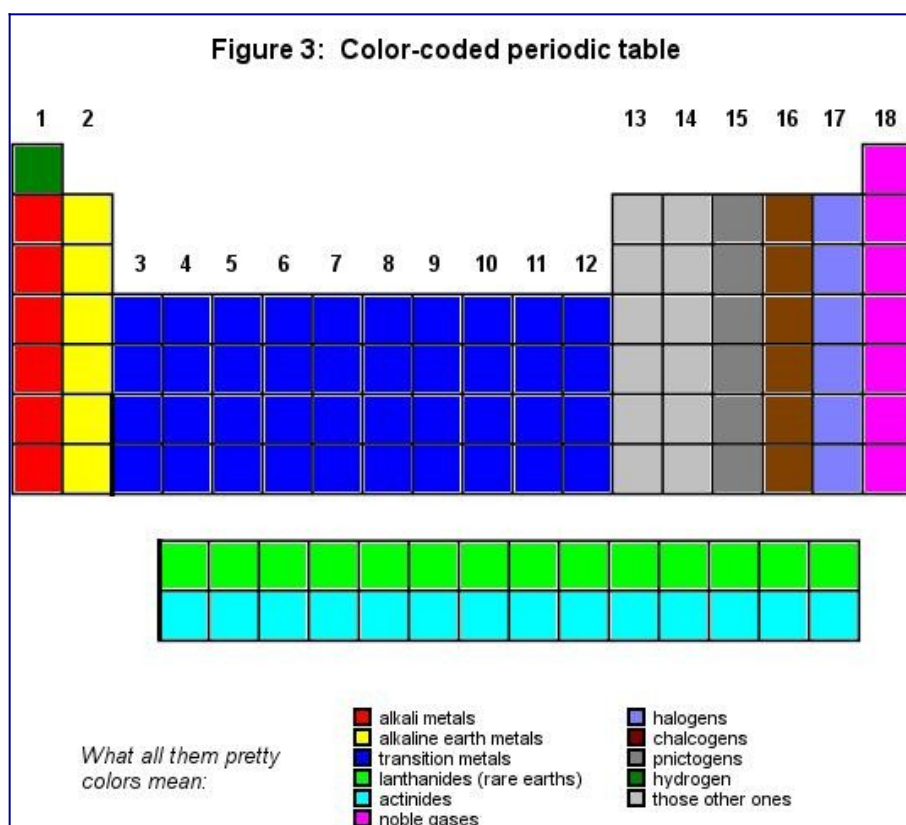
Other sections of the periodic table

In addition to the stuff that you just learned, there are lots of other ways you can divide up the periodic table. Let's look at a few:

Groups:

The groups on the periodic table (a term that's interchangeably used with “[families](#)”) consist of the elements in each column of the periodic table¹. For example, elements in group 2 are called the alkaline earth metals, while those in group 17 are the halogens. Don't worry: You don't need to know the names of every group.²

Elements in the same group of the periodic table have remarkably similar properties (particularly chemical properties) due to the fact that they have the same number of [valence electrons](#), and similar [electron configurations](#). If you're not sure what that means, you'll need to visit the tutorial that describes this. In any case, if two things have the same number of valence electrons, they'll tend to do the same things to satisfy the [octet rule](#).



Let's see some of the groups we need to think about:

- Group 1 – Alkali metals.** With the exception of hydrogen, the elements in group 1 are the alkali metals. These elements are metallic (obviously), soft, have low melting points, and are unbelievably reactive.³ This reactivity is caused by a burning desire to lose one valence electron to become like the most recent noble gas.⁴ If you want to know what the deal is with their chemistry, that's the key.
- Group 2 – Alkaline earth metals.** The alkaline earth metals are less extreme versions of the alkali metals. They're reactive, but nowhere near as reactive as the alkali metals (calcium, for example, fizzes and heats water, but doesn't start fires). They have low densities (but higher than the alkali metals). Magnesium and beryllium are used as structural materials due to their low density, but are being phased out due to other undesirable properties (extreme flammability⁵ and toxicity⁶, respectively).



Figure 4: HMS Sheffield

This image of the Royal Navy guided missile destroyer HMS Sheffield was taken three months before its crew learned that magnesium armor burns very, very well when hit with an Exocet anti-ship missile.

- **Groups 3-12 – Transition metals.** When you think of your stereotypical metal, you're thinking of a transition metal. Transition metals are generally hard, have high melting and boiling points, and have high density. Reactivity varies, ranging anywhere from "not all that reactive" to "hardly ever reacts." The outermost electrons in transition metals are d-electrons, so this area is sometimes called the d-block.⁷
- **The first row of elements at the bottom – Lanthanides.** Sometimes called the "rare-earth" or "lanthanoids", these elements have properties similar to those of the alkaline earth metals. They're used in small quantities in various scientific and industrial applications.
- **The second row of elements at the bottom – Actinides.** The actinides have properties similar to the alkaline earth metals, except that they're very dense and have very high melting points. All of the actinides are radioactive, and many are not found in nature and need to be artificially synthesized.⁸
- **Group 18 – Noble gases.** The main property of the noble gases is that they're stable. Like, really, really stable. You can do all sorts of stuff to noble gases and not much will happen with them. The reason they're so stable is that they want to have a full electron shell, and since they already have that, they actually resist reactions. Some people have made a few noble gas compounds, but they don't stick around long.⁹



Figure 5: This clown isn't killing children

Though it's often believed that clowns are evil monsters who live to destroy the innocent with their evil and monstrous tortures, this clown is using nonreactive helium in these balloons to entertain children. He'll probably kill them later, though.

- **Group 17: The halogens.** The halogens are really really reactive because they really really want to gain one more electron to get a filled valence shell. As you can see, they are only one element short of being like the noble gases, so they go nuts pulling electrons off of whatever they can to make this happen. Halogens are diatomic elements (they have the general formula X_2) and are used for an [unbelievable range of purposes](#).
- **Groups 15 (pnictogens) and 16 (chalcogens):** Those are the official names for these groups, but the truth of the matter is that the elements in these groups don't have much in common with one another. After all, the ones on the top are nonmetals and the ones on the bottom are metals, which doesn't exactly make for a close relationship. Most teachers don't even teach the names of these groups, so don't worry about them. The one handy thing you may need to know is that oxygen and nitrogen are diatomic, but that's about it.

- **Groups 13-14: No particular name.** I've never even heard anybody name these groups because they have so little in common among their elements. So don't sweat it.
- **Hydrogen: The weirdo.** Hydrogen, while being in group 1 like the alkali metals, doesn't really share the properties of the alkali metals. For one thing, it's a diatomic gas. For another, it tends to either lose electrons (like the alkali metals) or gain electrons (like the halogens), but is far less reactive than either. Hydrogen is generally fairly stable, but in the presence of oxygen and energy it blows up – this is one of the reactions that led to the explosion of the Hindenburg. Hydrogen is used in a wide variety of industrial chemical processes, and is also increasingly being used as a fuel source in fuel cells.

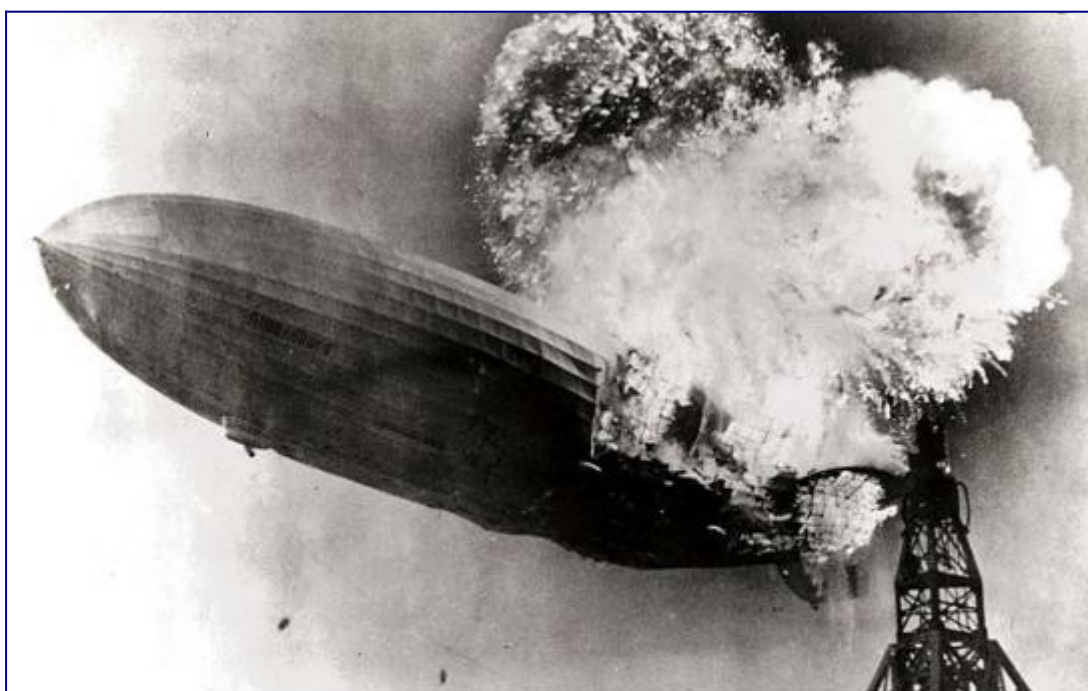
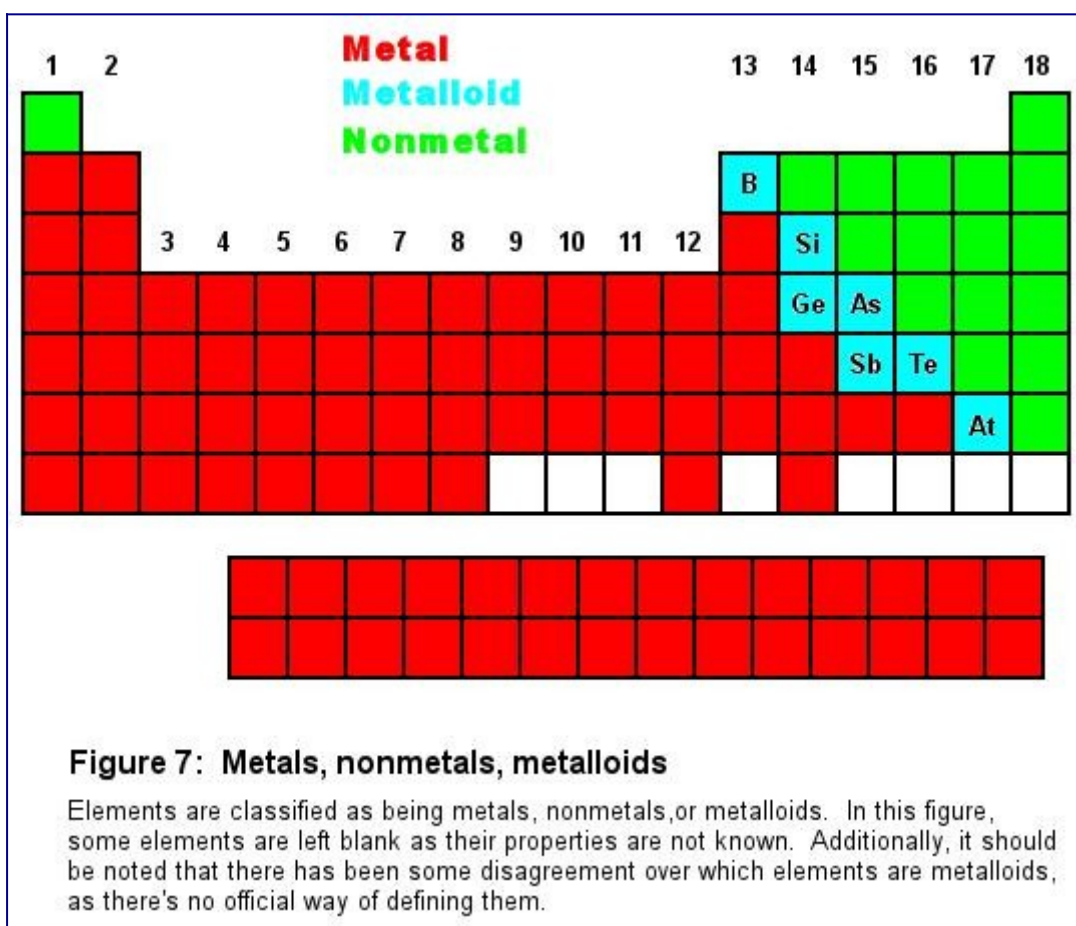


Figure 6: The destruction of the LZ Hindenburg in 1937

The zeppelin LZ Hindenburg caught fire and was completely destroyed in 34 seconds. Though the reason for the initial ignition is not clear, it's likely that the hydrogen inside of the zeppelin contributed both to the subsequent fire and the cover of the first Led Zeppelin album.

Metals, nonmetals, and metalloids

If you look at the periodic table, you can easily figure out which elements are metals, which are nonmetals, and which are metalloids. Let's take a look at a color-coded version of the periodic table. Though, now that I think of it, you probably won't have a color-coded periodic table in your classroom, so you'd better tattoo this one on your hand.



Let's look at the properties of each:

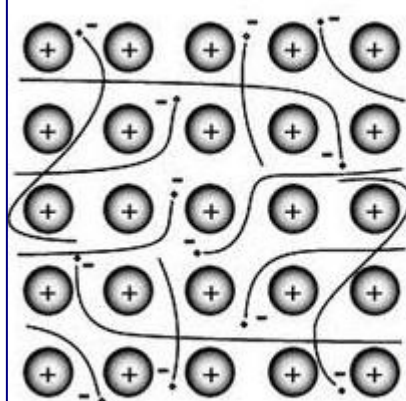
Metals: Let's be honest – you know what a metal is. When your teacher asks you what the properties of a metal are, the best way you can answer him or her is to just talk about the properties of a quarter. Of course, if you've never seen money or anything else of metal, the general properties of metals are that they're shiny, they're bendy (malleable), they're stretchy (ductile), they conduct heat and electricity well, and they tend to have high densities and melting points.¹⁰

The reason that metals have these properties is their delocalized bonding. Now, you might be asking yourself, "what's delocalized bonding?" I'm getting to it. Relax.

You have seen endless models in your schooling that show atoms stuck to each other with little sticks or straws or whatever. This portrays localized bonding, in which the electrons that hold the atoms together stay between those two atoms. If you imagine using localized bonding in a pet daycare, this is like tying every dog to its own tree – the rope stays between the two and never moves.

However, in delocalized bonding, the electrons that hold the atoms together don't just stay between two atoms. Instead, all of the electrons that do all of the bonding in the entire chunk of metal kind of float around holding everything together at once. In the pet daycare example, this would be like putting all of the dogs into a room where there were ropes strung everywhere like a giant spiderweb. The dogs still wouldn't be able to get out of the room, but there would be no one rope you could point to as the one holding each in place.¹¹

Figure 8: Bonding in metals



8a: Electron sea theory



8b: Most awesome doggie day care ever

For this reason, the delocalized bonding in metals is usually said to adhere to the “electron sea theory”, in which the metal nuclei are little islands that are held together by a big ocean of delocalized electrons. However, my example is way funnier, so feel free to call it the “electron dog day care where all the dogs are tied together theory.”

Once you’re OK with this, the rest falls into place. Metals conduct electricity because the electrons have a clear path from one side of the metal to the other. Metals are bendy because the atoms aren’t locked rigidly in place and can shift around without destroying this network of bonds. Pretty awesome, eh?¹²

Nonmetals: Nonmetals are pretty much unlike the metals in most ways. Those that are solid are brittle, hard, and don’t conduct electricity. The reason for this is that nonmetals have very rigid localized bonds in which the electrons holding the atoms together don’t move around and serve only to hold those two atoms exactly in place. As a result, any shifting around of the atoms will break these bonds and bust the whole thing apart.



Figure 9: Broken freezer

I felt like there should be an image here, so I figured I'd put a picture of a broken thing because I mentioned that nonmetals break. This isn't actually relevant to what I was talking about, but hey, at least you have a picture to look at.

Metalloids: Metalloids have bonding that's somewhere between metals and nonmetals. Rather than having totally delocalized bonds like metals or totally localized bonds like nonmetals, metalloids have bonds that are somewhere in between. Generally speaking, the bonds in metalloids become more delocalized when their temperature is increased or when high voltage electricity is applied. There's a lot of stuff about bandgaps and whatnot, but you probably won't need to know much about that, so stick with what I said before.

Because the bonding in metalloids has similarities to those with metals and nonmetals, the properties also tend to be somewhere in the middle. This includes the following:

- They're usually shiny. However, they're not shiny like metals are shiny – they look more like dark glasses than like silvery mirrors.
- They are semiconductors of electricity. Because bonding in metalloids is only kind of delocalized, the electrons have a harder time getting through the solid than they do in metals. As I mentioned before, conductivity increases when temperature and voltage increase – this allows them to be used as switches in computers.
- They're brittle. Not enough delocalization to be bendy.
- Chemically, they act more like nonmetals than metals. More about that later.