Chapter 6: The Periodic Table

This table, while awesome, is nowhere near as badass as the actual periodic table.

http://commons.wikimedia.org/wiki/File:Aalto_table.JPG

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You've probably noticed that scientists like to keep big charts full of letters on their walls to make them look smarter. Well, it turns out that the letters on those charts represent elements, and that these big charts are called the **periodic table**.

Figure 6.1: *Sodium is one of the many elements on the periodic table, and it totally blows up like whoa when you put it in water. This sample is notable because it kinda looks like a baby monster.*

Photo credit: http://commons.wikimedia.org/wiki/File:Sodium-1.jpg

Section 6.1: Making the Modern Table

For a long time, people knew there were a bunch of elements but they didn't really know how to write them down in ways that made sense, given their properties. Do you just make a big list, or do you make cool diagrams that show the elements? People were pretty sure that they wanted to make a cool diagram, but they didn't know how to draw it. Fortunately, a periodic superhero emerged: Dmitri Mendeleev.

Dmitri Mendeleev[1] came up with the first periodic table that related the atomic mass of an element to its properties. Instead of just putting the elements in a big table according to arbitrary rules, he arranged them into columns that contained elements with similar properties. The idea that the properties of elements repeat from time to time are referred to as the **periodic law**. Mendeleev is often thought of as the father of the periodic table.

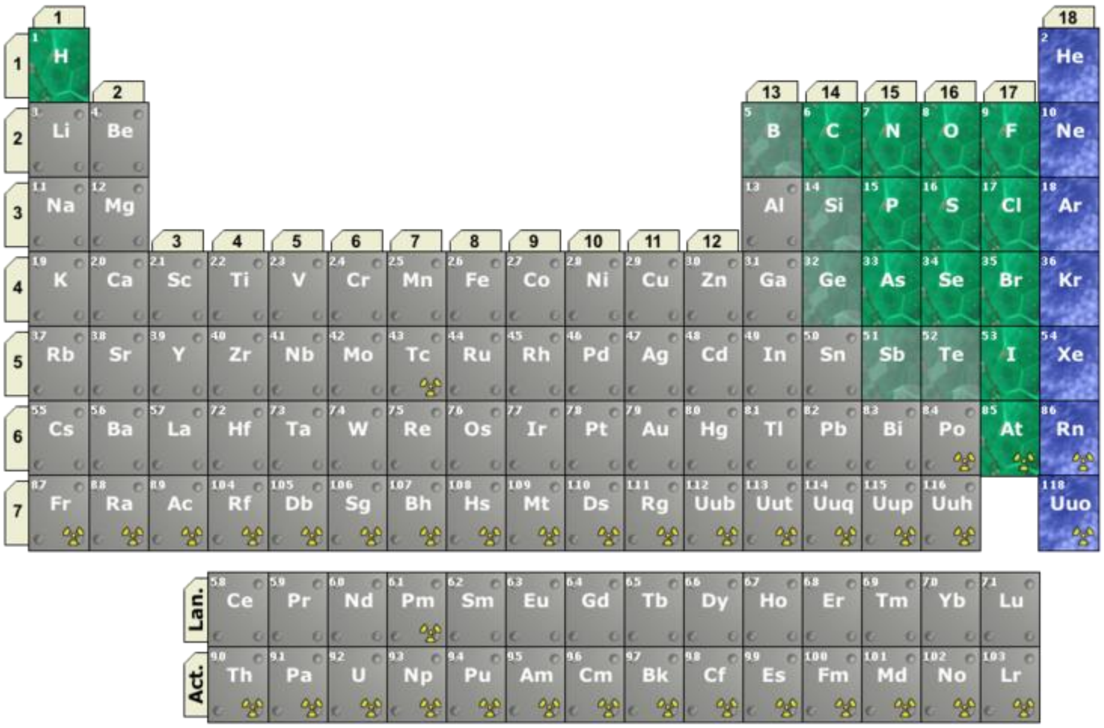
Profiles in Obscurity: Lothar Meyer and John Newlands

Lothar Meyer came up with a periodic table a lot like Mendeleev's, but since he published it later he doesn't get any credit for it. John Newlands came up with the law of octaves, which said that the properties of elements tended to repeat themselves at intervals of eight elements.

[1] Fun fact: Mendeleev was a bigamist. He also had a notably huge beard. The two are not known to be related.

Section 6.2: The current periodic table

The modern periodic table looks like this (Figure 6.2):[2,3]



The columns in the periodic table are called either **families** or **groups**. Elements in the same groups tend to have similar properties. The rows in the periodic table are called **periods**. Elements in the same period don't really have much in common with each other.

Some of the main parts of the periodic table you should probably know include the following:[4]

- Groups 1, 2, and 13-18 are called the **main block elements**.
- Groups 3-12 are called the **transition metals**[5].
- Those rows at the bottom of the periodic table are the **lanthanides**[6] and **actinides**[7, 8].

[2] http://commons.wikimedia.org/wiki/File:DPS_raw.png
[3] Occasionally, somebody will come up with their own silly idea of what the periodic table should look like. These tables invariably look stupid and don't make any sense to anybody but their authors.
[4] If you want to learn about the properties of each group, check out the next chapter.
[5] They're technically the "outer transition metals", but nobody ever says that.
[6] The top one.
[7] The bottom one.
[8] These are also called the "inner transition metals", though they're never really referred to like this in real life.

- The elements at the left part of the periodic table are **metals**. Metals are shiny, good conductors, malleable[9], and ductile[10].
- The elements at the right part of the table are the **nonmetals**. These things have a whole mess of properties that vary hugely from one another: they include gases, solids, liquids… all kinds of stuff. One thing's for sure, though: They're not metals.
- The elements between the metals and the nonmetals are the **metalloids**. Metalloids have some properties of metals[11] and some properties of nonmetals.[12]

Spotlight on Technology

Metalloids are used for a bunch of different stuff. Some of the main uses include computer chips and solar cells. Actually, that's all I can think of, but I'm pretty sure they must be good for something else, too.

Section 6.3: Valence electrons

Valence electrons are the outermost s- and p- electrons in an atom. By counting across these sections in the periodic table, you can figure out how many valence electrons each atom has. For example, calcium has two valence electrons and nitrogen has five valence electrons. Elements in the same group of the periodic table have the same number of valence electrons, which explains why they have similar properties.

This is one of those reasons that electron configurations we learned in the last chapter are slightly handy. If you look at the configurations for lithium $[He]2s^1$ and sodium $[Ne]3s^1$, you can see that they have the same number of valence electrons. As a result, they act very much alike in many chemical reactions.[13]

So, why do we care about valence electrons anyway? It's the valence electrons that go wandering from atom to atom, forming and breaking chemical bonds. Since this making and breaking of bonds is something that we find interesting, we, in turn, find valence electrons to be interesting, too.[14]

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[9] Easy to dent.
[10] Easy to stretch.
[11] They can conduct electricity a little bit and they're usually solid.
[12] They're brittle and not very shiny.
[13] For example, they both blow up when you put them in water.
[14] Well, kind of interesting, anyway.

Section 6.4: Periodic Trends

One of the cool things about the periodic table[15] is that you can use it to figure out the properties of elements. The properties that change in a systematic way as you move either across a row in the periodic table or down a group are called **periodic trends**.[16]

Atomic Radii

Because atoms are more-or-less spherical, their sizes are denoted by a term called their **atomic radius**. The atomic radius of an element is defined as half the distance between two bonded atoms of the same element. So, for example, if the distance between two atoms of the same element is 120 pm, the atomic radius of that element is said to be 60 pm.[17]

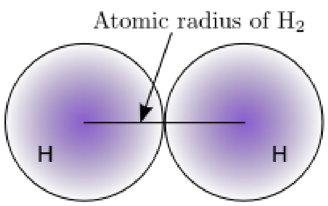

Figure 6.3: *It seemed time to put a picture in this chapter, so here's one I found online at:* *http://commons.wikimedia.org/w/index.php?title=File:Atomic_radius_of_H2.svg&page=1*

As you move left to right across the periodic table, the atomic radii of the elements decreases. This is because the nuclei of these elements pick up more protons as you move across the table, while the energies of the electrons stay the same.[18] Since the nucleus can pull harder but the electrons have the same energy, the electrons get pulled closer to the nucleus.

As you move down a group in the periodic table, the atomic radius of the elements increases. That's because the electrons are in higher energy levels, which puts them in bigger orbitals.

If you knock electrons off of an atom or add electrons, the resulting atom is referred to as an ion. **Cations** are ions with positive charge[19] and **anions** are ions with negative charge.[20] Generally, if you add electrons to an atom it makes it bigger, while taking away electrons makes it smaller. It's not exactly rocket science.

[15] A phrase you only hear from nerds.
[16] Keep in mind that these periodic trends are just that: trends. Though the elements generally follow these trends, there are exceptions to these particular rules.
[17] "pm" refers to "picometers", or 10^{-12} m.
[18] Remember, elements in the same period have nearly identical orbital energies.
[19] They lost electrons.
[20] They gained electrons.

The Octet Rule: The Single Most Important Thing You Need to Know

The **octet rule** states that the atoms tend to gain or lose electrons so they can have the same number of electrons as the nearest noble gas. Here are some things that you might want to keep in mind about this unbelievably important rule:

- The nearest noble gas may be either before the element (just as neon is before aluminum) or after the element (as argon is after phosphorus).
- If the nearest noble gas is before the element of interest, the element will lose valence electrons until it has the same number of valence electrons as that noble gas. This will give it a positive charge. As a result, aluminum will lose three electrons to become like neon, giving it a +3 charge.
- If the nearest noble gas is after the element of interest, the element will gain valence electrons until it has the same number of valence electrons as that noble gas. This will give it a negative charge. As a result, phosphorus will gain three electrons to become like argon, giving it a -3 charge.
- Ignore the d- and f-blocks when counting forwards and backwards. In this way, gallium (Ga) wants to lose three electrons to become like argon – we just ignore all of the transition elements that are between them.

Ionization Energy

Imagine that you're at a party with all of your friends. You're all having a good time when suddenly, one of your friends gets out an atom of sulfur and tries to knock electrons off of it by putting it over the stove. What do you think you would do?[21]

Figure 6.4: *A really bad picture of a sample of sulfur.*

http://commons.wikimedia.org/wiki/File:S,16.jpg

Assuming your friend wasn't overcome with chemical fumes, he[22] would find that after adding some energy, an electron would come off of the atom forming a cation. The **ionization energy** of an element is the amount of energy it takes to pull one electron off of an atom.

[21] Burned sulfur smells like the aftermath of a chili party, so I'm guessing you'd leave.
[22] Girls are usually too smart to pull dumb stunts like this.

So, what's the periodic trend for ionization energy?

- As you move left to right across the periodic table, the ionization energies of elements increase. Consider this: Elements on the left side of the periodic table *want* to lose electrons because their nearest noble gases have fewer electrons than they do, so it doesn't take much energy to make this happen. Elements on the right side of the periodic table want to gain electrons to be like the nearest noble gas, so it takes a lot of energy to pull off electrons.

- As you move down a group, the ionization energies of elements decrease. This is due to the **shielding effect**, which states that electrons in orbitals near the nucleus shove electrons further from the nucleus away from them. Because elements at the bottom of their periods have more energy levels, there are more electrons pushing on the outer electrons. This enhanced push makes it easier to pull off electrons (i.e. it takes less energy to pull an electron off).

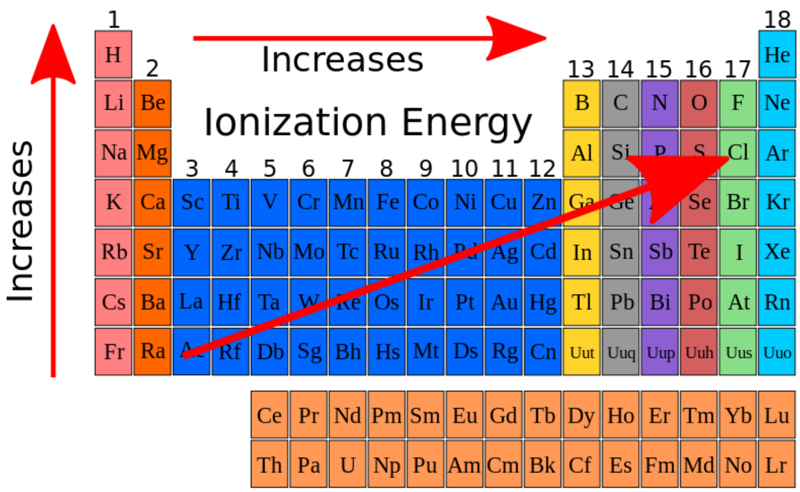

Figure 6.5: *Every textbook has some version of this figure in it, so I figured I'd put one in, too.*

http://commons.wikimedia.org/wiki/File:Ionization_energy_periodic_table.svg

> ***Multiple Ionization Energies***
>
> If you want to pull off more than one electron, more energy is required than to pull off just one. This is particularly true if you're trying to pull electrons away from an element that has the same number of electrons as its nearest noble gas. For example, it takes only 522 kJ/mol of energy to remove one electron from lithium (which gives it the same number of electrons as helium), but 7,301 kJ/mol to remove a second (which takes it away from its happy helium configuration). Yet again, the octet rule is the cause of something amazing.

Electronegativity

The electronegativity of an element measures how hard it tries to pull electrons away from other atoms it is bonded to. Elements on the right side of the periodic table really want to grab electrons[23] and have high electronegativities (they want to grab electrons). Elements on the left side of the periodic table really want to lose electrons[24] and have low electronegativities (i.e. they don't want to gain electrons very much). The noble gases, on the other hand, don't really care about picking up electrons so have no noticeable electronegativities at all.

Famous Hippies of Science

Dr. Linus Pauling was one of the greatest scientists of the 20th century. In addition to his work describing electronegativity (the most-commonly used electronegativity scale is named for him), he also did work characterizing chemical bonding and the atomic nucleus. In addition to winning a Nobel Prize for the above awesomeness, he also got involved in the nuclear disarmament movement and won a Nobel Peace Prize for that.

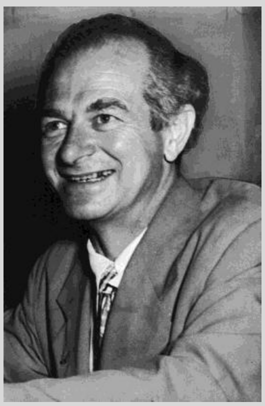

Figure 6.6: *Groundbreaking scientist and anti-nuclear hippie Linus Pauling, two-time Nobel Laureate.*

Chapter Summary

- Mendeleev gets credit for inventing the periodic table.
- The periodic table has a ton of groups and regions and stuff on it. You're stuck memorizing all of them, so get used to it.
- Valence electrons do all of the interesting chemistry that we're interested in.
- There are a bunch of periodic trends. Most of them involve the octet rule, which says that all elements want to gain or lose electrons to be like the nearest noble gas.

[23] You should be thinking of the octet rule right now.
[24] Octet rule!

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