

Orbital filling diagrams

Now that you've mastered the world of electron configurations, it's time to write orbital filling diagrams. This sounds like something that would be tough, but orbital filling diagrams are really just pictures that show you the same thing as electron configurations. Mostly.

If you haven't yet learned electron configurations, you really need to go ahead and do that right now. None of the stuff on this tutorial will make any sense otherwise, so it's time to head on back and learn it. Don't worry: We'll wait here for you to finish. ([Click here to check it out](#))



For the rest of you, here's a picture of a woman eating a dog.

Great! Now that you've done that, let's get started!

What's an orbital filling diagram?

If you remember to the last tutorial (the one you just read, remember?), you'll recall that electron configurations are big lists that tell you where the electrons in an atom are located. For example, the electron configuration for oxygen, $1s^2 2s^2 2p^4$, tells you that there are two electrons in the 1s orbital, two electrons in the 2s orbital, and four electrons in the 2p orbital. So far, so good.

Orbital filling diagrams essentially just turn this big list of electron locations into a picture that shows not just what *type* of electrons an orbital resides in, but also *which* of those orbitals they're located in. Don't worry – this is easier than it seems.

The rules for orbital filling diagrams

If you want to learn how to draw orbital filling diagrams, you need to follow these handy rules. They probably won't make sense right now, but I'll explain them when the time is right. For now, trust me that these rules are handy ones:

1. **Electron configurations list the orbitals from lower to higher energy.** For example, when I show you the electron configuration for oxygen ($1s^2 2s^2 2p^4$), this means that the 1s orbital is lowest in energy, followed by the 2s orbital and 2p orbital, respectively.

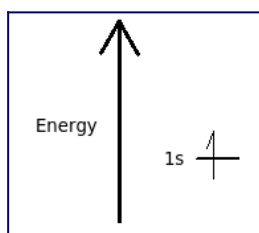
2. **1, 3, 5, 7.** This is shorthand for the rule that energy levels hold one s-orbital, three p-orbitals, five d-orbitals, and seven s-orbitals.
3. **Every orbital can hold a maximum of two electrons.** After this, they fill up and nothing else can fit.
4. **Electrons will tend to stay unpaired whenever they can, and double up only when there's no alternative.** This is called Hund's rule, and we'll talk about it in a bit.

Armed with these rules, let's get started!

The orbital filling diagram for hydrogen

As we've seen before, the electron configuration for hydrogen is: $1s^1$

Let's draw the orbital filling diagram for hydrogen:



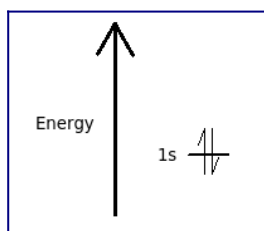
Let's go through each of the elements of this picture so we don't get confused:

- The vertical arrow on the left with the word "Energy" next to it will be in all orbital filling diagrams. All it does is tell the reader that as you move higher on the page, the orbitals will have more energy than the ones low on the page. In this example, there's only one orbital, so it doesn't really have much relevance.
- The line with "1s" written next to it represents the single 1s orbital that's present.
- The arrow that points up represents the one electron that's in the orbital. Electrons are shown as pointing up or down because they're said to be either "spin up" or "spin down" depending on their properties.¹

And that's it!

The orbital filling diagram for helium

The electron configuration for helium is $1s^2$. This means that we have two electrons in the 1s orbital, which looks like this:



This diagram is exactly the same as the one for hydrogen, except that there's a second arrow added to the 1s orbital. This represents the second electron in the 1s orbital, and is shown as "spin down" so you can tell it apart from the other one.

Why do we need to tell them apart? It's because of the...

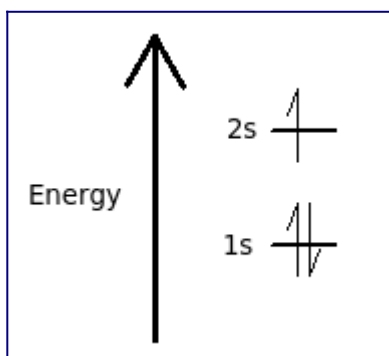
Pauli exclusion principle: No two electrons can be exactly the same

Here's the idea: The quantum numbers of an electron (hint: check the tutorial if you don't know what this means) describe the properties of that electron. Because electrons all have negative charge, they have to be different in some way to keep them from repelling each other. This happens by giving them different quantum numbers, which results in different properties. And, as you may or may not have guessed, "spin" is one of those properties. Hence, we show the two electrons in an orbital as having different spins so they can coexist.

For news about the other quantum numbers, you really should check the appropriate tutorial.

The orbital filling diagram of lithium

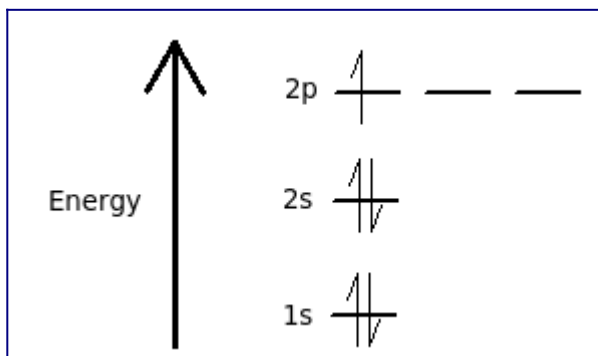
The electron configuration of lithium is $1s^2 2s^1$. This means that there are two electrons in the 1s orbital, and one electron in the higher energy 2s orbital. If you want to make a cool picture, you can do it like this:



Some students like to ask whether or not they can draw the first arrow down, or if it just has to be up. The answer: You can do it any way you'd like for a single electron, but if the orbital has two electrons one has to be up and the other down.

The orbital filling diagram of boron

I skipped past beryllium because I was getting bored. The electron configuration of boron is $1s^2 2s^2 2p^1$, which means that there are two electrons in the 1s orbital, two electrons in the 2s orbital, and one electron in the 2p orbitals. This gives us an orbital filling diagram of:

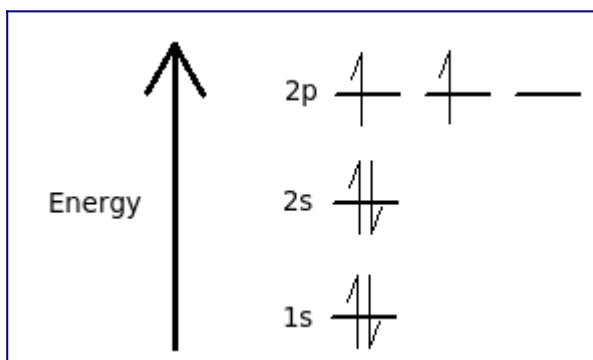


A few things to keep in mind here:

- The reason we show three p-orbitals is that p-orbitals come in groups of three. Even though two of them are completely empty, we show them anyway.
- It's standard to show the electrons as going from left-to-right and spin-up to spin-down. However, even though this is how it's usually done, it's not *wrong* to start by putting the electron as spin-down in the second orbital. It's *weird*, but it's not wrong.

The orbital filling diagram for carbon

Again, we start with the electron configuration, which is $1s^2 2s^2 2p^2$. As we've seen, this means that there are 2 electrons in the 1s orbital, two electrons in the 2s orbital, and two electrons in the 2p orbitals. This is shown like this:



Woman eating dog: Image courtesy of [imagerymajestic](#) at [FreeDigitalPhotos.net](#)

Seats: Original photo Image courtesy of [graur razvan ionut](#) at [FreeDigitalPhotos.net](#)

Creepy dude: Image courtesy of [artur84](#) at [FreeDigitalPhotos.net](#) Why, you may be asking yourself, are the two p-electrons shown in different orbitals? Isn't it allowed to put them both in the same p-orbital, with one pointing up and one pointing down?

Well, it is allowed, but it still won't happen. This is because of Hund's rule, which says that electrons will want to stay unpaired whenever possible. To think of this, consider getting on a bus with only two pairs of seats:



Clearly I haven't spent enough time practicing my photoshop.

And imagine that this guy is already sitting down at one of these seats:



Hi! My name is Steve, and I'll be your nightmare this evening.

Giving us this configuration:



I'm definitely a photoshop pro!

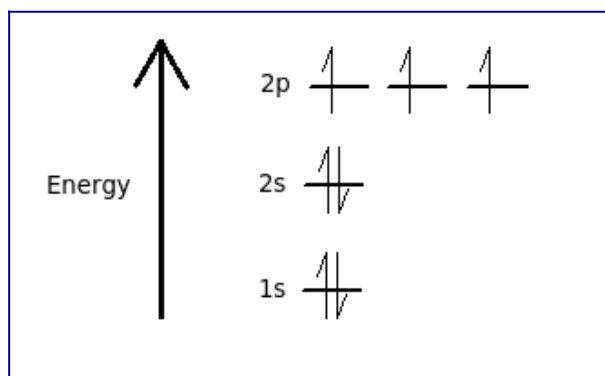
Now, where will you sit? You can either sit on the front pair of chairs, where you'll get a seat all to yourself, or you can sit on the back pair of seats, where you'll get to listen to Steve tell you about all the [ICP](#) shows he's been to.



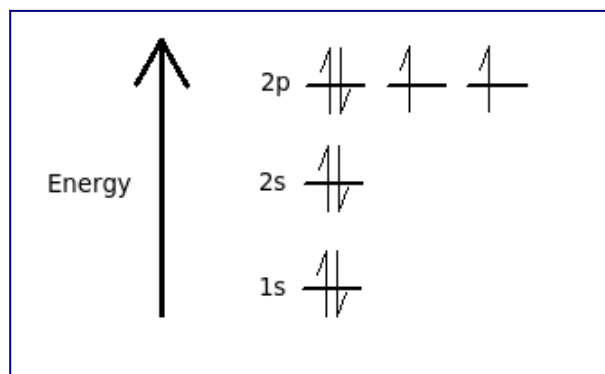
...and that's how I became the Hachetman.

Unless you're completely nuts you'll want to sit by yourself. Even if the guy in one seat didn't look like the product of a serial killer's nightmare, you'll probably still prefer to sit by yourself than next to him. This is because people just prefer to be apart from strangers.

Well, in the case of electrons, they're kind of like you and the skull-faced lunatic. Though you'll sit next to him if you don't have any choice, you'd much rather sit on your own. In the same way, electrons want to be apart from each other because they have the same charge. Given that things with similar charges repel, we're left with a situation where orbitals will fill halfway unless there's no alternative. In the same way, the orbital filling diagram for nitrogen will be:



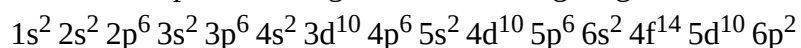
It's not until we reach oxygen, where the electrons will start to double up, just because there's no alternative:



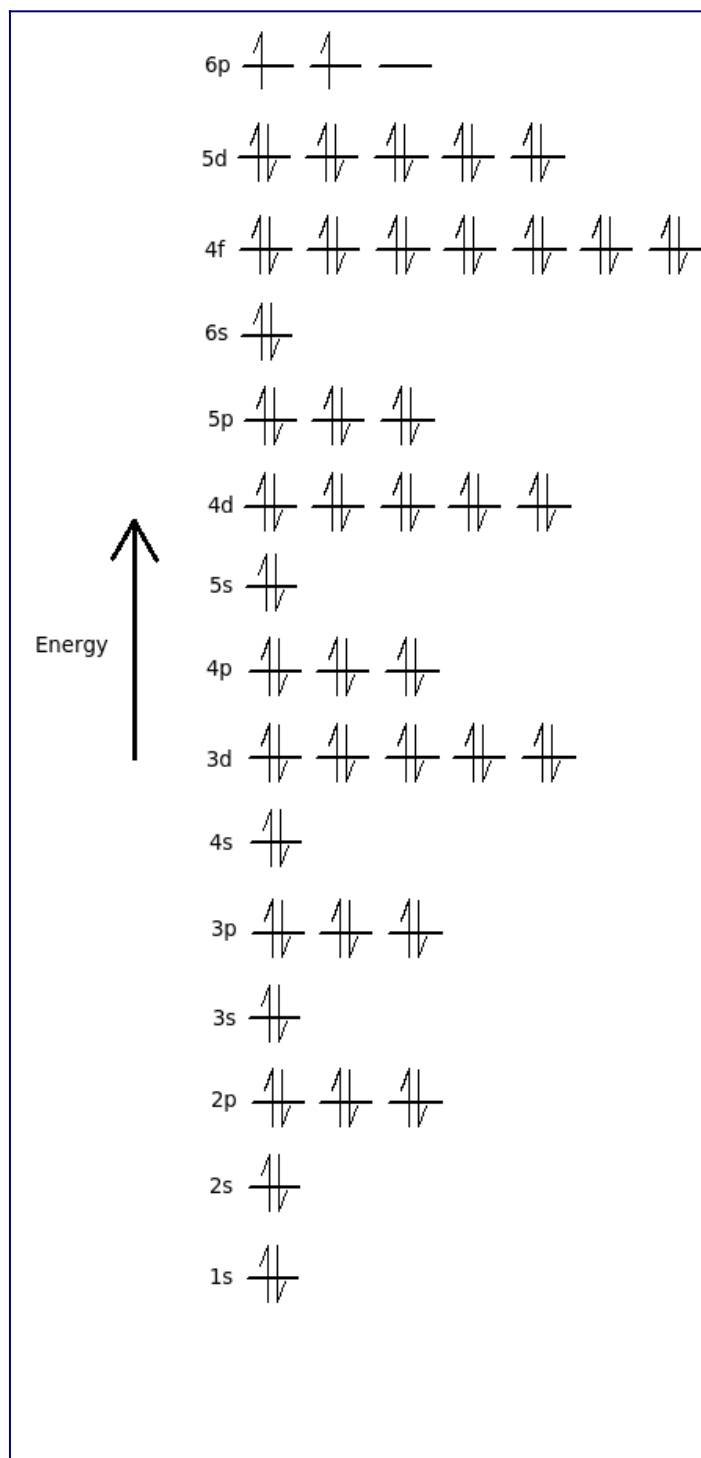
And that's the basic idea behind orbital filling diagrams!

One big example to give you an idea of what a big one looks like

Now for the pain of doing the orbital filling diagram of lead:



The rules are the same, so I'll just bite the metaphorical bullet and write it out here:



And with that, you should officially know what you're doing!

Footnotes:

1. We say electrons spin because they have magnetic properties that can be explained by their having angular momentum (i.e. they spin). Because electrons aren't classical particles that spin but quantum particles that... uh... do quantum stuff, they don't actually spin like little tops. However, the term stuck, so we talk about "spin up" and "spin down" for this reason.
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