Transcript: The Periodic Table

Unit 3, Video 1 – History of the Periodic Table

This is Rebecca from ChemistryIsMyJam.com. This is Unit 3 about the periodic table. This unit is going to review the history of the periodic table, we'll look at the parts of the periodic table, we'll take a look at the differences between metals and nonmetals, we'll learn to draw valence dot diagrams, illustrate trends in the periodic table, and those trends will include ionization energy, electronegativity, and atomic size. Let's get started with the history of the periodic table.

Early civilizations were aware of many of the common metals like silver and gold, but there was a large gap in time before new elements began to be discovered.

During that time, not much scientific experimentation was taking place. It wasn't until 1669 when phosphorus became the first element since ancient times to be discovered. And its an interesting story. Hennig Brand discovered phosphorus trying to turn human urine into gold. I'll put a link to an article about it in the description, but basically he was burning human urine and trying to distill gold out of it.

Move forward into the 1700s and many of the elemental gases were beginning to be discovered. In the early 1800s a lot of the common elements like sodium and calcium were discovered. And in the late 1800s, there was a lot of work going on surrounding the radioactive elements.

We continue to discover new elements today. Scientists are working to synthesize some of the larger elements and fill in some of the gaps at the bottom of the periodic table.

Chemistry has really exploded over the last couple of centuries. In that time it became necessary to somehow organize these elements and that's where the periodic table came into place.

Suggested Question (Time 2:08)
True or False: The periodic table has not changed in the last 200 years.

One of the first stabs at the periodic table is credited to John Newland in 1863. He arranged the elements by weight and then noticed that every 8 elements had similar properties. He proposed the law of octaves. This divided the elements into 11 groups.

While chemists continue to recognize the number 8 as an important number in chemistry, these 11 groups are no longer sufficient to organize all of the elements that we are aware of. The periodic table had to change some.

Suggested Question (Time 2:47)
John Newland noticed that there was a repeating pattern in the properties of elements every ____ elements.

Our modern periodic table is credited to 2 scientists: Dmitri Mendeleev from Russia and Lothar Meyer from Germany. These 2 scientists were working separately on the same idea, however Mendeleev published his work first, so he receives the majority of the credit for the periodic table.

Mendeleev was also able to use his periodic table to predict the properties of some elements that had not been discovered yet, which gave a lot of credibility to him within the scientific community.

Suggested Question (Time 3:24)
True or False: Dmitri Mendeleev is given most of the credit for the development of the periodic table.

Mendeleev’s periodic table arranged the elements according to atomic weight. The current periodic table arranges the elements according to atomic number. Even though they are arranged by different numbers, you will find very few differences in the order of elements between Mendeleev’s periodic table and the current periodic table.

When he arranged this elements according to atomic weight, the groups that the elements fell into had similar properties. This allowed him to leave gaps in the table for elements that had not been discovered yet. He almost received the Nobel Prize for this work.

Suggested Question (Time 4:08)
How was Mendeleev's periodic table arranged?

Mendeleev's periodic table looked something like this, and you can see where he left these gaps that I have highlighted for elements that had not been discovered yet. He correctly predicted that gallium, scandium, and germanium would be discovered and he left a space on the table for them.

He took this a step further and predicted the properties of those elements.

Suggested Question (Time 4:33)
True or False: Sodium is in roughly the same place on Mendeleev's periodic table as it is on our current periodic table.

Here you can see what Mendeleev predicted for gallium in 1871. Gallium was not discovered until 1875 and its actual properties are listed here.

Mendeleev predicted that gallium would have an atomic mass of 68. The actual atomic mass was 69.72. Pretty close.

He predicted a density of 6.0. The actual was 5.9.

He predicted a low melting point. The actual was 29.78 which is not much above room temperature in Celsius, so that is a low melting point.

He also made a prediction about how this element would react with oxygen. He said there would be 2 of this element for every 3 oxygens, which is spot on for how gallium reacts with oxygen. He also go the density of that compound correct and the solubility of that compound.

Mendeleev's predictions about gallium were very accurate and they were totally based on the patterns that he was seeing in the properties on his periodic table. This gave so much credibility and really validated Mendeleev's periodic table.

I hope I have made the point that the periodic table is so much more than just a list of elements. Stick around as we look at the parts of the periodic table and then some of the many predictions that a chemist can make about an element completely based on where it is located on the periodic table.

Suggested Question (Time 6:19)
True or False: The periodic table lists the elements for us but little can be determined about their properties.

Unit 3, Video 2 – Parts of the Periodic Table

This is Rebecca from ChemistryIsMyJam.com. In this video, we're going to look at the parts of the periodic table.

The periodic table is so much more than just a list of elements. We can use the location of an element on the table to indicate the properties of the elements, to tell us what other elements in might react with. There is just a lot of information dealing with the arrangement of the periodic table that is so useful to a chemist.

In terms of the arrangement, you should be aware of what the rows and the columns on the periodic table are called and what they tell us.

Horizontal rows on the periodic table are called periods and the elements in the same period have the same number of energy levels. Aluminum, for example, is in the third period and it has three energy levels. All of the elements in period three have three energy levels.

The vertical columns on the periodic table are called groups. The elements in the same group tend to have similar properties. A great example of that is the group where copper is located. In the group where copper is located, you'll also find silver and gold. These are three metals that we very often make jewelry out of. They are solid at room temperature, they are shiny – which means they have luster, you can draw them into wires. They are great metals to use for jewelry. They all have similar properties and can be found in the same group on the periodic table.

Suggested Question (Time 1:44)
Which element has 4 energy levels and properties similar to lithium?

Another way that the periodic table is arranged is by metals and nonmetals. This periodic table has been color coded for you. These elements are called the metalloids. They have properties of both metals and nonmetals. Everything to the left of the metalloids is a metal, with the exception of hydrogen. Hydrogen is a nonmetal. Other than hydrogen, all of the other nonmetals are to the right of the metalloids. The majority of the elements on the periodic table are considered metals.

> Suggested Question (Time 2:22)
> True or False: Sulfur is a nonmetal.

These are the properties of metals and nonmetals. Think about aluminum foil. It is solid at room temperature. It is a good conductor of heat and electricity. It has luster, which means that it is shiny. It is malleable, which means that it is bendable, and it is ductile – meaning you can draw it into wires. Those are the common properties of metals.

While there are some exceptions, nonmetals tend to be gases at room temperature. They are poor conductors of heat and electricity and if you do find a solid nonmetal, you'll find that it is brittle – meaning that if you try to bend it it is going to break instead of bend.

> Suggested Question (Time 3:10)
> An unknown sample is analyzed and found to be solid at room temperature, shiny, and a good conductor. Is the unknown sample more likely to be carbon or titanium?

Some of the groups on the periodic table have special names and you should memorize these. These are the alkali metals found in group 1. The alkaline earth metals are in group 2. The halogens are in group 18, and the noble gases are in group 18. This center section, which is made up of groups 3-12, these are called the transition metals. And these below the table are called the inner transition metals.

You should be aware of where the inner transition metals fit into the table. If you follow the numbers, 55, 56, 57, 58 is down here through 71, and then it comes back up to here. The inner transition metals actually fit into this space here. However, we put them below the table for convenience to make the table easier to print.

Those are the major parts of the periodic table. Stick around as we look at trends in ions and try to determine how we can use the location of an element on the periodic table to determine how it will bond with other elements.

Suggested Question (Time 4:39)
What is the name of the halogen in period three?

Unit 3, Video 3 – Periodic Trends in Ions

This is Rebecca from ChemistryIsMyJam.com. Let's dive in to understanding the trend in ion charges found on the periodic table.

We will begin with the octet rule. The octet rule says that when elements form a chemical bond they do so to achieve a full outer energy level and for most of our elements, that means that they want 8 electrons, which is why we call this the octet rule.

Neon is an example of an element that is already satisfied according to the octet rule. Neon has 8 electron in its outermost energy level, meaning that it has a full outer energy level. Neon is a noble gas. This is the case for all of the noble gases. All of the noble gases have full outer energy levels which explains why they are unreactive.

Other elements are going to react in such a way that they look like a noble gas in terms of their electrons. They are going to try to achieve a full outer energy level.

> Suggested Question (Time 1:07)
> Which group of elements on the periodic table have as many electrons as possible in their outermost energy level?

Atoms can either give away, take from other atoms, or share electrons in order to achieve a full outer energy level. We will address the sharing of electrons in a future video but for today we are talking about atoms that either give away or take from other atoms an electron, making them an ion. They will become atoms with a charge.

There is a division in how metals versus nonmetals react in order to achieve a full octet. Metals have 4 or less electrons in their outermost energy levels. They have 4 or less valence electrons, those are the electrons in the outside energy levels for an atom. Because they have 4 or less, they tend to give away electrons in order to achieve a full octet. So they give away all of the electrons in their outside energy level, causing the original outer energy level to disappear, leaving the next level full. They have given away electrons in order to have a full outer energy level.

Anytime an atom gives away electrons, it has given away something negative, leaving a positive charge for that atom. So metals tend to take a positive charge when they become ions.

Nonmetals have 4 or more electrons in their outermost energy level. They tend to take electrons from another atoms. They are going to gain electrons in order to achieve a full outer energy level. Anytime an atom gains electrons, it is gaining something negative, and it will have a negative charge when they become ions.

So we are going to find that when we look at the periodic table, that the metals tend to take a positive charge and the nonmetals tend to take a negative charge.

Suggested Question (Time 3:09)
Would you expect calcium to have a positive or negative charge when it becomes an ion?

Knowing the number of valence electrons is pretty crucial to understanding ion charges, so lets look at the trend for valence electrons on the periodic table. You are going to find that in this trend, I'm going to be skipping the transition metals. But for the main body elements on the periodic table, everything in group 1 has 1 valence electron. Everything in group 2 has 2, skip the transition metals, all of these have 3, these have 4, 5, 6, 7, and 8. So if you count from left to right for the main body elements on the periodic table, you'll be seeing the number of valence electrons – the number of electrons in the outside energy level for that atom.

If your periodic table is numbered the way mine is, then you can look at the number at the top of the column – the group number – and take off the 1. Take off the first digit and you will have the number of valence electrons.

For example, nitrogen is in group 15, take off the 1, it has 5 valence electrons.

Here you have the Bohr model for aluminum to help you picture these valence electrons. Aluminum has three energy levels. That outside, third energy level, has 3 electrons. Aluminum is right here in group 13, if you take off the 1, you see that aluminum should have 3 valence electrons.

Suggested Question (Time 4:39)
How many valence electrons does an atom of bromine have?

Which brings us to valence dot diagrams. Valence dot diagrams are simple diagrams that only show the valence electrons for an atom. Here I have drawn the valence dot diagrams for all of the elements in the third period on the periodic table.

Sodium is in group 1, it has 1 valence electron. Magnesium is in group 2 with 2 valence electrons, and you can see that the number of valence electrons increases by 1 as you go across the periodic table.

The electrons in a valence dot diagram tend to be paired. You usually find them in 2's.

These elements are color coded. You can see that the metals are in blue. The nonmetals are in pink, and silicon is a metalloid.

So how does this relate to ion charges? Sodium has 1 valence electron. In order to achieve its full octet, it is going to give away that 1 valence electron which will leave behind a sodium ion with a charge of +1. Magnesium has 2 valence electrons. It is going to give away both of those and leave behind a charge of +2. Aluminum has 3 valence electrons. It is going to give away all 3 of those and have a charge of +3.

Silicon is a little different in that it has 4 valence electrons. It can either give away or take 4, leaving with a charge of + or – 4.

Phosphorus is our first nonmetal. It has 5 valence electrons. Keep in mind that it wants 8. The easiest way for phosphorus to achieve that full outer energy level is to take 3 electrons from another atom. That will leave phosphorus with a charge of -3. Sulfur has 6 valence electrons. It is going to take 2 from another atom, leaving it with a charge of -2. Chlorine has 7 valence electrons. It is going to take 1 electron from another atom, leaving it with a charge of -1.

Argon already has a full octet. Argon is not going to give away electrons. It is not going to share electrons. And it is not going to take electrons. Argon is not going to take a charge, so we would put a zero above that one.

This creates an important trend on the periodic table. All of the elements in group 1 tend to take a charge of +1 when they become ions. The elements in group 2 are +2. These guys are +3, + or – 4, -3, -2, -1, 0. This is one of those huge trends on the periodic table that I strongly recommend that you memorize.

Here is a little spoiler alert from a future video that shows why this trend in so important. I have down here calcium chloride. This trend explains why there is 1 calcium for every 2 chlorides in order to form calcium chloride.

We are going to find that compounds form in order to have neutral overall charges. Calcium has a charge of +2. Chlorine has a charge of -1. It requires 2 of these -1's to balance out 1 of these +2's. That is why the trend is so important and why I recommend that you memorize it, but we will go over that in more detail in a future video.

You likely noticed that I skipped the transition metals and the inner transition metals. The transition metals are elements that can take multiple charges in different situations. There is not just 1 particular charge that you can memorize for the transition metals.

However for the main body elements, there is a charge that you can memorize, and I suggest that you do. It is going to end up being really useful as we go forward.

Suggested Question (Time 8:53)
What charge should magnesium have when it becomes an ion?

The periodic table is also a useful tool for understanding how the electrons in an ion look. When ions form, their electrons will resemble the electrons of the closest noble gas.

For metals, that would be the gas before that element on the periodic table. Consider sodium for example. Sodium, when it becomes an ion will look like neon. That is the element up a level on the periodic table. Neon is element number 10. Sodium is element number 11. Neon is the closest noble gas to sodium.

Just what do I mean by saying it will look like the closest noble gas? Sodium starts off with 1 valence electron. It is going to give that away. This whole outer energy level is going to drop. Sodium now looks like this. It has 10 electrons and 8 of those are valence electrons. Neon has 10 electrons and 8 of those are valence electrons. Sodium's ion looks like neon, it's nearest noble gas.

For metals, that will be the noble gas in front of that ion. For nonmetals, it will be the noble gas after the ion, because nonmetals are going to gain electrons.

Look at fluorine. Fluorine has 7 valence electrons. It is going to take an electron from another atom. That is going to give it 10 total electrons, 8 of them are valence. The fluorine ion looks like neon.

Just as a reminder, the metals are going to go up a row to look like their nearest noble gas. Calcium, for example, is going to go to the left and up a row. It is going to resemble argon. Whereas nitrogen, which is a nonmetal, is going to go to the right to look like it's nearest noble gas. It will look like neon.

Understanding this concept also makes it easy if someone asks you for the number of electrons found in a certain ion. If someone were to ask me how many electrons the phosphorus ion has, well I know that it is going to look like it's nearest noble gas. I would go to the right. I see argon. Argon has 18 electrons so that is a quick way to know that the phosphorus ion would have 18 electrons.

Barium is a metal. It is going to go to the left and up to xenon. The barium ion is going to have 54 electrons.

Suggested Question (Time 11:36)
Which noble gas should magnesium look like when it becomes an ion?

While we are focusing on ions, it is also a good idea to understand how the electron configuration for ions look. Take oxygen for example. We know that oxygen, when it becomes an ion has a -2 charge. That means it has taken 2 electrons from another atom. Oxygen's original electron configuration was $1s^22s^22p^4$. That p can hold up to 6, so those 2 electrons that oxygen just took from someone else go into the 2p sublevel. So the electron configuration for oxygen now ends in $2p^6$.

This follows the rule that electrons will fill the lowest available energy level first. In the case of oxygen, the 2p sublevel was the first available energy level with space to hold those 2 extra electrons.

Electrons will be lost from the highest occupied energy level, meaning you need to look at these large numbers. That is the highest energy level. Copper, for example, ended in $4s^2 3d^9$. When copper became an ion, it lost 1 electron. Because 4 is higher than 3, copper is going to lose an electron from the 4s rather than from the 3d.

So you can't always just go by which sublevel is on the end. You need to look at which one has the higher energy level when these things are losing electrons.

We have spent a lot of time learning about ions. We have one more video in unit 3 that focuses on periodic trends.

Suggested Question (Time 13:36)
Which sublevel will copper lose electrons from when it takes a +1 charge?

Unit 3, Video 4 – Periodic Trends

This is Rebecca from ChemistryIsMyJam.com. In this video we are going to be looking at periodic trends. These are the trends on the periodic table that help us understand the behavior of elements. We are going to look at ionization energy, electronegativity, atomic radius, and then the size of ions.

These trends, along with much of what we see in chemistry, can be explained by forces between charged particles. You have particles with the same charge that are trying to get away from each other, and particles with opposite charges that are trying to get close together.

These forces of attraction and forces of repulsion can be increased two different ways. First of all, you can increase the number of charged particles. For us, that is going to mean increasing the number of protons and electrons within the atom.

The other way that you can increase these forces is to decrease the distance between the particles. The closer they are together, the more they are going to feel each other.

These two concepts are huge in understanding the trends that we will be looking at today.

Suggested Question (Time 1:18)
Increasing the number of charged particles within an atom means increasing the number of ________ and _________.

The first trend for us to talk about is something called ionization energy. This is the amount of energy required to remove an electron from an atom. When you remove an electron from an atom, you are creating an atom with a charge. You're creating an ion. So measuring that measures the amount of energy required to ionize the atom.

Typically when you just see the term "ionization energy," that is talking about removing the first electron from an atom, and that electron would be coming from an outside energy level. In the case of aluminum, the ionization energy would refer to how much energy is required to remove that electron from the atom.

If you were to then go further and remove a second electron from an atom, we would call it the second ionization energy. And then you could have the third, and the fourth ionization energy. But when you just see “ionization energy” you are typically talking about removing one electron from the atom.

Suggested Question (Time 2:28)
True or False: The first electron removed from an atom should come from the outside energy level.

On the periodic table, ionization energy typically increases from left to right and increases from bottom to top. The overall trend could be represented with an arrow going from the bottom left to the top right of the periodic table.

Helium has the highest ionization energy on the chart, which makes sense because helium is a very small atom. It’s electrons are very close to the nucleus. They are very attracted to that positive charge inside the nucleus, which is going to make them difficult to remove.

We saw in our last video that the atoms on the left side of the periodic table will normally give away electrons when they become ions. That makes sense because they have low ionization energies. It does not take much energy to remove those electrons.

So ionization energy increases from left to right, and increases from bottom to top.

Let’s take a look at what causes this trend. As you go from left to right across the periodic table, each element adds a proton to its nucleus. It is adding a positively charged particle to its nucleus. By having more protons in their nucleus, these elements on the right hand side of the periodic table are able to hold on tighter to their electrons. It takes more energy – more ionization energy – to remove those electrons.

Those protons in the nucleus, we call that the nuclear charge. So whenever you hear nuclear charge, that is just a way of referring to the number of protons within the nucleus.

Ionization energy decreases from top to bottom on the periodic table because each time you go down a row on the periodic table, you are adding an energy level. So you add this energy level and that causes the electrons to be farther away from that positive charge in the center. That makes them easier to remove. So the electrons that are farther away from the nucleus have a lower ionization energy. That explains why every time you go down a row on the periodic table, you are lowering the ionization energy.

Suggested Question (Time 4:51)
According to the ionization energy trend, which of the following elements would you expect to have the highest ionization energy? Sulfur, argon, oxygen, or neon?

While we are looking at the effect of energy levels on these electrons, let's look at a concept called shielding. An electron in the outside energy level is feeling two major forces. It is feeling attracted to the protons inside the nucleus of the atom. However, it is feeling repelled by the electrons that are between it and the nucleus.

This makes an electron on the outside energy level fairly easy to remove. It is farther away from the nucleus and it is being repelled by the inner electrons.

The term that is often used to describe this concept is "shielding." These electrons in the outside energy level are shielded from the nucleus by these electrons. And it makes these electrons easier to remove.

In contrast, an electron that is on a lower energy level, like this one, would be extremely difficult to remove. It is very close to the nucleus and the electrons that are farther out are actually pushing it towards the nucleus. So one that is on an inner energy level would be extremely difficult to remove.

Suggested Question (Time 6:07)
True or False: The concept of shielding makes an electron on an inner energy level easier to remove than an electron in the outermost energy level.

The second trend on the periodic table that we need to discuss is called electronegativity. Electronegativity is the ability of an atom in a molecule to attract shared electrons to itself.

We are talking about two atoms that are bonded together, one of them has the ability to hog the electrons – it pulls the electrons closer to itself. The one that is hogging the electrons is said to have a higher electronegativity.

When we look at the trend for electronegativity, you're going to notice that it does not include the noble gases, and that is because electronegativity deals with bonded atoms, and the noble gases do not bond. So we will be ignoring the noble gases when we talk about this trend. The element with the highest electronegativity value on the chart is fluorine.

Here you can see the trend for electronegativity on the periodic table. Electronegativity increases from left to right. It increases from bottom to top. This trend ignores the noble gases because the noble gases never bond with any other atoms. And the highest value for electronegativity on the periodic table is fluorine.

The reasons behind this trend are very similar to the ones we just looked at for ionization energy. As you go from left to right across the periodic table, you are adding protons to the nucleus and those protons are able to pull electrons closer to themselves.

As you go from top to bottom on the periodic table, energy levels are being added. The electrons are getting further away from the nucleus. That is increasing the distance between one atom's nucleus and another atom's electrons. That is going to decrease the amount of pull that they can have on those electrons.

So electronegativity increases from left to right and it increases from bottom to top.

Suggested Question (Time 8:17)
According to the trend on the periodic table, which of the following elements has the highest electronegativity value? Sodium, chlorine, potassium, bromine.

The third trend on the periodic table that we need to discuss is atomic radius. We are basically looking now at the size of the atom. One thing to point out is that the atom does not have an outer barrier so this is something that is difficult to measure.

The way scientists measure this is by taking two identical atoms that are bonded together. They can tell where the nuclei are for those two atoms. They measure the distance between the two nuclei, divide that distance in half and it gives you the atomic radius. So two identical bonded atoms are used to determine the atomic radius.

Suggested Question (Time 9:01)
True or False: The atom has an outer barrier making the size easy to measure.

In general, the atomic radius increases as you go from right to left on the periodic table. It increases as you go down the periodic table. If you are looking at the main body elements on the periodic table, francium should have the largest atomic radius.

The reasons behind this trend are very similar to the reasons that we just saw. Atomic radius increases as you go down the periodic table because each time you are adding an energy level, and energy levels take up space.

Atomic radius decreases as you go from left to right across the periodic table because you are increasing the nuclear charge by having more protons in the nucleus. The protons are able to have more pull on the electrons, so they pull those electrons closer to themselves and shrink the atom as you go from left to right across the periodic table.

Suggested Question (Time 10:02)
According to the trend in atomic radius on the periodic table, which of the following elements would you expect to have the smallest radius? Magnesium, sulfur, calcium, selenium?

Reactivity is another important trend on the periodic table. This is referring to how easy it is to get an element to react with another element. The most reactive metals are on the lower left portion of the periodic table. The electrons for francium are extremely easy to remove. It is a big atom with low ionization energy. Those electrons are easy to remove making that a very reactive element.

The trend is the opposite for the nonmetals. The most reactive nonmetals are in the upper right corner. Fluorine would be the most reactive nonmetal. This trend ignores the noble gases, because they are not reactive at all.

Suggested Question (Time 10:50)
True or False: Fluorine is more reactive than bromine.

The final trend for us to discuss is ion size. This is comparing the size of an ion to the size of it's neutral atom. When you will find is that cations are smaller than their parent atoms and anions are larger than their parent atoms.

Take sodium for example. When sodium becomes an ion, it actually gives away an electron. It loses an entire energy level. So sodium, when it becomes an ion takes a positive charge, and gets smaller. Cations are smaller than their parent atoms.

The opposite of that would be something like bromine. Bromine is going to gain electrons when it becomes an ion. This is going to cause the bromine ion to actually get larger. Anions are larger than their parent atoms.

On the periodic table, ion size increases as you go down a group. It decreases from left to right across the periodic table. So you may notice that this just followed the same trend as atomic radius. The only exception is that when you switch from positive to negative charges, you should notice a sharp increase in size when you switch from those positive metals one the left side of the periodic table to those negative nonmetals on the right side of the periodic table.

I hope that this unit on the periodic table has shown you what a powerful tool that it can be. If you have found these videos helpful, please like, share, and subscribe to ChemsitryIsMyJam.com.

Suggested Question (Time 12:41)
Which would you expect to be larger? Calcium or the Calcium Ion?