Podcast Script – Periodic Trends.

Hello,

This podcast comes to you today from Dhahran, Saudi Arabia, sponsored by Scramling Science. Today’s topic is Periodic Trends.

We have already learned what a fantastic tool the Periodic Chart is for the chemist. However, it has even more uses than you have learned so far.

Due to its arrangement we are able to easily see trends in some properties by using the chart. For this podcast, it would be helpful to have a periodic chart handy for reference.

We are going to discuss several properties of elements and show how the chart can be used to learn the patterns of how they change. We will explore the properties as we go from top to bottom down a column and also from left to right along a row or series.

The first property is atomic number. This is the number of protons in the atom. Since the periodic chart is based on atomic number, the pattern is extremely easy to see. As we go from left to right the atomic number increases and as we go from top to bottom, the atomic number also increases.

Next is atomic weight. The weight (or mass) of the atom is similar in trend to the atomic number. As the atom is gaining protons, it is also gaining neutrons and getting heavier. So once again, as we go from left to right the atomic weight increases and as we go from top to bottom, the atomic weight also increases.

The third property is that of Atomic Radii, which is sometimes called Atomic Size. Naturally as we go from the top to the bottom of the chart, we are moving from one energy level to the next biggest, so the atoms are getting larger. Going from left to right is a bit trickier. It would be logical to surmise that since the atoms are getting heavier as we go from left to right on the periodic chart, that they would also be getting bigger. This is not the case. Let’s explore the second series of elements, which are the ones from Lithium to Neon. We see from reference material that Lithium has an atomic radii of 152 picometers, (which, by the way is 152 trillionths of a meter), now as we go to Beryllium, and see it has an atomic radii of 105 picometers. To see why this occurs, we need to recall a bit about our electron configurations. Lithium has an electron configuration of 1s2 2s1 and now Beryllium has an additional electron but it is found in the 2s orbital to give it the following electron configuration 1s2 2s2 .

Since the additional electron is being put in the same orbital, it really isn’t increasing the atomic radii, so we might even expect for Lithium and Beryllium to have the same atomic radii, but Beryllium is significantly smaller. Here is why. The Beryllium is also adding another proton in addition to the electron that is being added. This proton increases the electronic pull that the nucleus is exerting on the electrons so it is pulling the electrons closer to it, especially in light that the additional electron being discussed in Beryllium is at the same beginning distance as the other electron and so the radii decreases. Boron’s additional electron does go into a higher energy 2p orbital but while this orbital might have more energy, it is still in the 2nd energy level and so it is no further from the nucleus so it gets the pull of an additional proton, causing the Boron atom to be smaller than the Beryllium atom. This trend continues until we reach Neon.

Continuing the discussion of Atomic Radii, let’s skip down to the 4th series, starting with Potassium. We follow across the period and we seem to see the expected pattern but then there is an unexpected jump. The reason for this is that as we go from left to right in this period we start with 4s orbitals and then start to fill the 3d set of orbitals. The increase starts when we complete the 3d set of orbitals and start to fill the 4p orbitals. Notice that within a set of orbitals the pattern remains.

This is a good time to introduce some concepts that we will use on occasion throughout the year. It is a set of 4 ideas and depending on the application, some will be more of a factor than others.

1. Distance from the nucleus. The closer the electron is from the nucleus, the greater the pull from the nucleus that the electron will experience.

2. Proton to electron ratio. As an electron gets removed from an atom to form an ion, the ratio of protons to electrons gets bigger and so there is more of an attraction between the nucleus and the electrons which pulls the electrons in toward the nucleus making the radii decrease.

3. Shielding effect. This idea is best visualized if you think about magnets. Magnetic attraction can’t go through magnetic material. If it could, you can use your refrigerator magnets to move the jar of pickles inside. While that would be highly entertaining, we know that it doesn’t work that way. We do know that if we have two magnets on each side of a piece of paper, the magnetic attraction will go through the piece of paper. So the attraction between the nucleus and the electrons in the outer shell are sometimes diminished when the inner electrons get in the way. This is called the shielding effect. So, the larger the atom, the bigger the amount of shielding effect.

4. Filled and half – filled sets of orbitals. We learned previously that filled and half-filled orbitals are particularly stable. This means that more energy is going to be needed to break apart either filled or half-filled orbitals.

The 4th trend we will look at is electronegativity. Electronegativity is the ability for an atom to attract shared electrons in a bond. Linus Pauling, often described as the greatest chemist of the last century came up with the values for Electronegativity that are still used. Pauling won two Noble Prizes, one for peace and the other for his work on Chemical Bonds, which included his work on Electronegativity. On a side note, if you take Vitamin C supplements, Linus Pauling was the person that popularized the taking of large amounts of Vitamin C as a dietary supplement.

Pauling determined that Fluorine was the atom with the highest ability to attract shared electrons, so it has the greatest electronegativity and he assigned a value of 4.0 for Fluorine. You can use this to determine trends in both directions. As long as you are moving away from Fluorine, the value must be getting smaller. Therefore, as you go from top to bottom, it is decreasing. Then as you move away from Fluorine across the chart from right to left, the value also decreases.

The next trend is Ionization Energy which is the energy needed to remove an electron. Once again, Fluorine has the highest value, which makes sense if we think about it. Fluorine has 7 electrons in the outer shell so to achieve a filled outer shell, it wants to gain an electron. The last thing it wants to do is to lose another electron to get further away from a full outer shell. We might be thinking that any of the Group 7 elements have a similar property, so what makes Fluorine have the highest Ionization Energy ? It is the fact, that the outer shell of Fluorine is closer to the nucleus than the outer shells of the other Group 7 elements. Recall our list of 4 concepts mentioned earlier. The closer the electrons are to the nucleus, the more attraction that they are going to experience.

We can follow the same ideas for the trends of Ionization Energy than we did for Electronegativity. Ionization Energy decreases as we go from top to bottom and it also decreases as we go from left to right. Like before, we notice a slight change as we go to electrons in different sets of orbitals, usually either the s – orbitals to the p – orbitals or from the d – orbitals to the p – orbitals. Within the orbital set the pattern holds.

This is a good time to discuss successive ionization energies. If we look at an ion like the Magnesium ion, we know that it has a +2 charge, meaning that it has lost two electrons. The ionization energy of Magnesium that we look up as 738 kj/mole only gives us information about the first electron that is removed. It is for this reason that Ionization Energy is often called First Ionization Energy. We must now remove a 2nd electron. There are charts that list these Successive Ionization Energies. For Magnesium in this example, the 2nd Ionization Energy is 1445 kJ/mole. We need to look at this number a bit more carefully. The main difficulty is how to interpret this number. If we had a mole of Magnesium, we would need to add 738 kJ to remove the first electron and then after that was accomplished, we would need to add an additional 1445 kJ of energy. So the total amount of energy to remove 2 electrons from a mole of Mg is 2183 kJ. The 1445 kJ is not the total amount of energy needed to remove 2 electrons. It is the amount of energy needed to remove the second electron after the first is removed. There is a bit of difference between the two.

The 6th trend is Electron Affinity. Electron Affinity is described as the Energy change that occurs when an electron is acquired by a neutral atom. The patterns for Electron Affinity are not as clear as some of the others. This is because at times when an electron is added to an atom, it results in a more stable, lower energy situation because it either has obtained a filled outer shell or it is closer to a filled outer shell. When you see a negative sign on an Electron Affinity value that means that energy is released and it has a lower energy, which results in a great stability. An example of this is once again the Fluorine atom. It has a value of -339.3 kJ/mole. So when an electron is added to the Fluorine atom to become a Fluoride Ion, it is more stable and it has released energy to become more stable.

The 7th trend is Ionic Radii. The trends for these have to be further broken down between cation and anion. As we go from top to bottom of the chart, the ion always gets larger no matter if it is an anion or a cation. As we go across the periods, we start with a cation, such as Potassium and then move to Calcium. Calcium has one more proton and one more electron. The protons as well as any neutrons added are found in the nucleus, so they don’t directly change the size of the ion. The electron that is added goes in the same orbital so it doesn’t really enlarge the ion either. It is in the orbital with the same principal quantum number as the last electron before it. Since we have added a proton, the overall strength of the pull of the nucleus is increasing and it grabs the outer electrons with more pull, drawing them closer to the nucleus and making the ion smaller. As we go to Scandium, we have the same reasoning as with Calcium, except that the electrons being added all along this row of transition metals are adding their electrons to the 3d set of orbitals, which are in a shell even closer to the nucleus. The combination of the electrons being closer to the nucleus and the increased nuclear charge result in a greater pull on those electrons creating a smaller and smaller cation.

Once we reach the end of the transition metals, other factors are coming into play and the pattern is not as strict.

When we reach the anions, the ions get much larger because we are now adding electrons instead of taking them away. The original pattern continues in the remaining anions, just like it did with the cations.

It is good to know that cations are always smaller than the original atoms because they are losing electrons. The anions are always larger than the original atoms because they are gaining electrons.

I hope you enjoyed today’s Podcast and found it entertaining and educational, and helped you with your understanding of Periodic Trends. Remember that you can get more information on this topic from the class website or you can always send me a note on either FaceBook or via email. Refer back to this topic when needed, courtesy of Scramling Science.