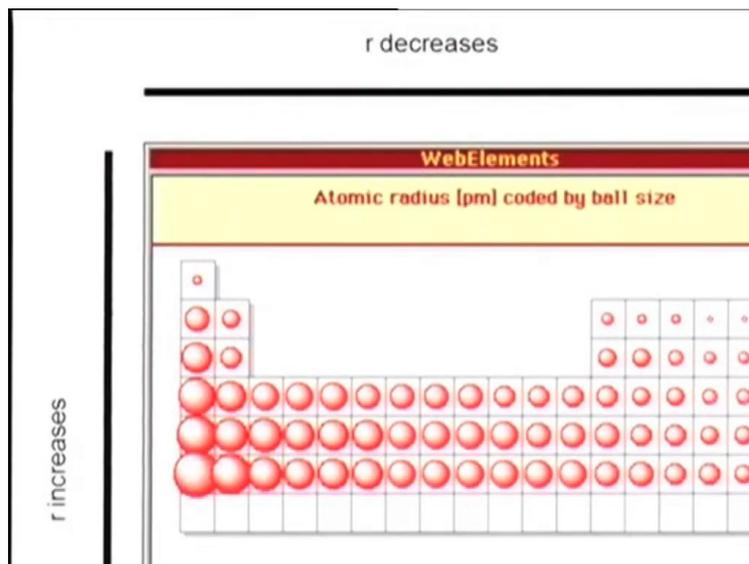


**Concepts of Chemistry for Engineering**  
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**Lecture No. 25**  
**Properties of Elements (Size IA, EA, and EN)**

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Now, let us look at the periodic table, how the periodic trends are and how can you explain very simply by what we understand so far is  $Z$  star, by  $Z$  star mainly we would like to look at the periodic trend. So, what we have learned so far from left to right  $Z$  star increases. Why  $Z$  star increases? That is because the electrons are getting incorporated in the same outer sphere electron one by one.

So, it is two  $2s_1, 2s_2, 2p_1, 2p_2, 2p_3, 2p_4, 2p_5, 2p_6$  same two shell, number principal shell 2, the electrons are getting incorporated one by one. And therefore, those electrons are not capable of neutralizing the positive charge at the nucleus. So, the shielding is going to be very less, shielding towards the outer sphere electron, shielding of the nuclear charge towards the outer sphere electron is going to be very less and therefore, this effective nuclear charge will be very high.

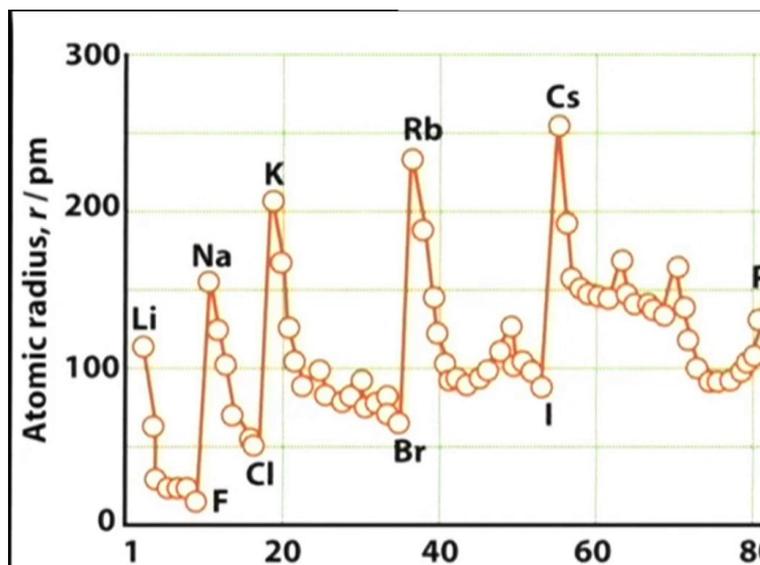
Since the effective nuclear charge is very high, the outer sphere electron or the electron will, overall all the electrons will be zoomed in or pulled in very effectively towards the nucleus and therefore size will be decreasing considerably. If you see from here, lithium, beryllium, boron

carbon, nitrogen, oxygen, fluorine, neon size is decreasing considerably, this is a representative data.

On the other hand, if you look from top to bottom, you see the size is increasing, why it is increasing, because from walking from 1s to s<sup>2</sup> to 3s to 4s to 5s, every time you are increasing a new shell, completely new shell, of course, new shell means, your size is going to increase by default, where so those electrons from going for let us say 3s to 4s more and more electrons are going to get accumulated, those inner electrons are going to neutralize the nuclear charge effectively and therefore effective nuclear charge is not increasing dramatically. It is almost remained constant from top to bottom, it is the change is very little.

Effective nuclear charge remained almost constant and the principal shell is increasing. And therefore, you have no control in size, size is going to increase since the principal shell is increasing. From left to right it is the same principle shell where electrons are getting in again and again, the penetration of these electrons or the neutralization of this electron neutralizes in a positive charge by these electrons are not that match and therefore, the effective nuclear charge increasing and pulling in the electrons, our overall size will be decreasing from left to right, from top to bottom size is going to dramatically increase.

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So, this is the atomic number versus your atomic radius plot which you can justify from top from left to right you see size increases and then lithium to sodium; lithium, sodium, potassium, rubidium, cesium you see size increases dramatically, left to right size decreases.

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**Metallic Radius**

Metallic radii of **5d**- block elements are expected to be larger than that of the **4d**-elements, **but these are not larger**. Of course they are larger than **3d**- block elements.

**Lanthanide Contraction**

**f-orbitals** have **poor shielding** properties; low penetrating power.

So  $Z_{\text{eff}}$  ( $Z^*$ ) **increases (more significantly)** from left to right (**for 5d**) across the period leading to more contraction.

Of course, these are something, this is something you do understand that is metallic radii of 5d block elements are expected to be larger than that of 4d. So, 4d to 5d you should have, if you look from, go down from 4d to 5d, 5d should be having, as you discuss should be having larger size, larger size compared to 4d, of course compared to 3d. But in reality what we find that these are not larger, 5d elements are not larger compared to 4d, which is kind of contradicting in the last slide whatever we were trying to discuss. Why is that? This is mainly due to the fact that 4f is coming into the picture.

So, since 4f is not almost very least penetrating or have the very little ability to neutralize the positive charge what will happen then, overall you see the penetration of 4f is little, so the  $Z^*$  is going to get more and more because the neutralization of the shielding is not effective. And therefore, although 4d to 5d you see a principal shell increases  $Z^*$  also increases and therefore, you will be able to contract or you will be able to mitigate that effect of the (increasing), effect of increasing this atomic size by the  $Z^*$ .

So, overall, you see the size of 4d and 5d will remain same or similar. So, once again although 4d to 5d, one of the shell is increasing, but at this point you are bringing in the f orbitals, f

orbitals being less or least penetrating,  $Z_{\text{star}}$  or the effective nuclear charge is going to be much more felt at this point penetration of f electrons are less and therefore, shielding is going to be less,  $Z_{\text{star}}$  is going to be much more effective.

And what we will see is although the (n)(7:05) principal shell is increasing due to the increased  $Z_{\text{star}}$ , the size will remain constant, 4d and 5d elements will have similar size overall. This is what is called lanthanide contraction. So, f orbitals have poor shielding properties, low penetrating power, that is what we were trying to say. So,  $Z_{\text{effective}}$  that means  $Z_{\text{star}}$  increases more significantly from left to right for 5d across the period leading to more compact atoms.

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### Ionisation Energy (IE)

The minimum **energy** needed to **remove an elec**  
gas phase atom

**Depends on:**

- (a) **Size**, IE decreases as the size of the atom inc
- (b) **Nuclear Charge (NC)**, IE increases with increa
- (c) The type of electron **Shielding effect**

**1st IE:**    **H = 1312 KJ mol<sup>-1</sup>**      **Li = 520 K**

**Reasons:**

- (1) Average **distance** of **2s** electron is greater than
- (2) **Penetration effect**

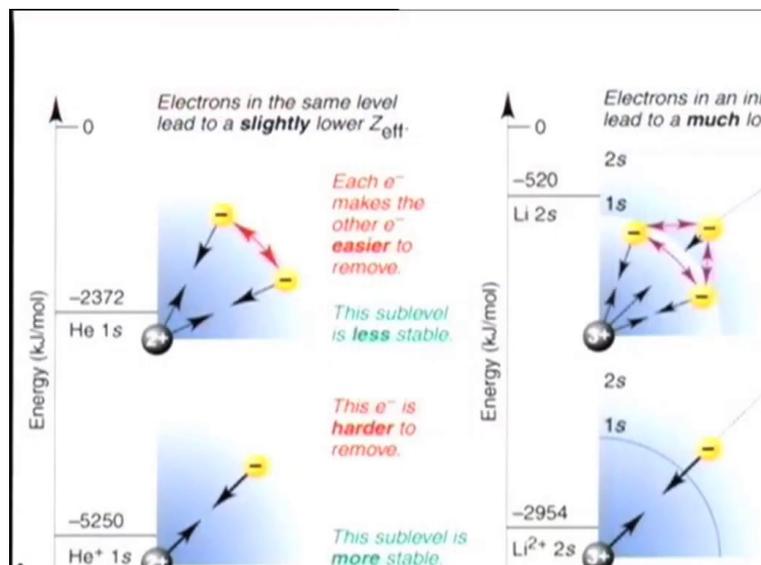
What about ionization energy? What do we have seen so far, from left to right in the periodic table we see that size is decreasing and from top to bottom size is increasing. What is the ionization energy? Ionization energy is the minimum energy that is required to remove an electron from a gas phase atom. If the size from left to right is decreasing and you have really strong attraction between nucleus and your outer sphere electrons, I think removing electron is going to be very difficult.

So, effectively what we will see that ionization energy will increase from left to right. Ionization energy will increase dramatically from left to right, from top to bottom, it will be much easier to remove the electron that means ionization energy will be less because from top to bottom size is

getting higher and higher and therefore, removing electron will be very easy. So, the ionization energy depends on size, nuclear charge and the shielding effect.

Let us take an example. First, ionization energy for hydrogen is this much 1312, lithium, which  $1s^2 2s^1$ , this  $1s$  electron removal will cost you 1312 kilojoule per mole; lithium  $2s$  electron removal will same  $2s^1$  electron removal will cost you 520 kilojoule per mole. So,  $1s$  electron removal is costing much more compared to  $2s$  electron. Why is that? Of course  $1s$  is smaller in size,  $2s$  is bigger, so the distance of  $2s$  electron is greater than of  $1s$  electron, penetration effect you have to consider, electronic configuration you have to consider.

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Let us look at this one. For example, you have helium, helium you have  $1s^2$  electron, these two electrons will be repelling each other considerably and therefore removal of the first electron that is the first ionization energy will be much easier. It is a  $2+$  charge, two electron removal of first electron is easier. Once you remove the first electron you have something like this situation where  $2+$  positive charge is attracting one electron.

So, that it is  $2+$  positive charge attractive one electron, if you want to remove this electron from this system, it is going to cost you much more and further there is no repulsive energy. If you look at lithium, lithium you have  $1s^2 2s^1$ ; these three electrons are repelling each other very strongly as you can see, now, this electron being outer sphere it is easy to remove compared to let us say, you if you have let us lithium  $3+$  with, lithium  $3+$  proton with lithium  $2+$ , they

are going to attract, these three protons are going to attract this one remaining electron very effectively.

This energy well this is 520, this is you can see for the third electron removal it is going to be 2954 kilojoules per mole, that is quite a lot. So, the first electron removal is easy, second is difficult, third is even further more difficult. In the first cases, you see of course, there is repulsive energy and the electrons are outer sphere, so you will have much easier situation to deal with.

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**Ionisation Energy (IE)**

**On moving across a period**

- 1. the atomic size decreases**
- 2. nuclear charge increases**

Thus **IE increases along a period**

As I was trying to say on moving across a period, from left to right, if you are trying to go, the atomic size is decreasing, nuclear charge is increasing and therefore ionization energy increases along a period. Size is getting smaller, nuclear charge is getting increased and then therefore, ionization energy increases along a period. And from top to bottom same ionization energy, you will have lesser and lesser ionization energy as you go from top to bottom.

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## Electron affinity (EA)

The amount of **energy** associated with **gain of electrons**

The **greater the energy released** in the process of taking up the extra electron, **greater is the EA**

The EA of an atom measures the **tightness** with which it binds **an additional electron** to itself.

Electron affinity, what is electron affinity first of all? Electron affinity means, affinity means what? Love for it. If you want to have you know another electron, what is the gain in energy? The amount of energy associated with the gain of electron you want to take one electron; one atom wants to take one more electron. What is the energy gain that is what is electron affinity?

As you can understand, the greater the energy released in the process of taking up this extra electron your ionization energy or electron affinity is going to be greater, more energy released means electron affinity is greater. Now, you see from left to right, your size is decreasing your attraction between the nucleus and electron are quite high. If you want to put one more electron, electron affinity, affinity is going to be very high.

You can since the attraction of nucleus towards outer sphere electron is very high, you want to put one more electron in the outer sphere electron they are going to take it or the system is going to allow it quite easily the energy will be released quite a lot. So, the greater energy will be removed, the electron affinity of an atom measures that tightness with which it binds an additional electron to itself.

So, it is a neutral condition. From there, you want to put one more electron to it. And what is the love, what is type of interaction you are going to have with the existing system that is what your electron affinity is.

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**Electron affinity (EA)**

**On moving across a period:** As the **size decreases**, the force of attraction by the nucleus increases. Consequently, the atom has a greater tendency to attract an added electron. **EA increases**

Generally the **EA's of metals are low** while those of non-metals are high. **Halogens have high EA.** This is due to their strong tendency to change their configuration to  **$ns^2np^6$**

**On moving down a group,** the **atomic size increases** and therefore, the nuclear attraction decreases and thus **EA decreases**

On moving across a period which I tried to discuss as the size decreases, size is getting smaller and smaller, the force of attraction by the nucleus increases. So, force of attraction increases from left to right. Consequently, the atom has a greater tendency to attract the added electron that is electron affinity increases, from left to right, your electron affinity going to increase.

You might generalize it in a different way, the electron affinities of metals are low, while those of non-metals are high, same thing from left side electron affinity is low, as you go to the right, your electron affinity is going to be quite high, this is where you see halogens have highest electron affinity and therefore they would like to take up the electronic configuration of  $ns^2np^6$ .

So, on moving down a group; the size is very much increasing, it is becoming more and more bigger and bigger from top to bottom, same from if you are moving from top to the bottom in the periodic table, then size is going to be bigger, they cannot hold on to their own electron, they want to release the electron pretty easily.

How come they will take up more electron from outside? It is not possible for them to really pick up more electron from outside they will be more happy to release the electron than taking up kind of. So, therefore, energy release during the process of adding electron from top to bottom will be less, so it is going to be a less favorable process. So, the electron affinity will be less from top to bottom.

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**Electronegativity**  
measure of the tendency of an element to attract  
**electrons to itself** (from its neighbour)

**On moving down the group**

- **Z increases** but  $Z^*$  almost **remains constant**
- number of shells (**n**) **increases**
- atomic **radius increases**
- force of **attraction** between added electron and nucleus **decreases**

Therefore **EA decreases down the group**

Now electronegativity, that is another very important phenomenon or there and another important topic in the periodic table discussion. So, what is electronegativity? Electronegativity is simply the measurement or measure of the tendency of an electron to attract electrons to itself. So, the atom is going to attract electron to itself. When the atom is going to attract electron to itself? When it can hold its own electron tightly.

So, you are going to attract electron towards yourself, if you can attract, if you can keep your own electron very strongly. So, once again if you walk from left to right in the periodic table, what happened? Your size decreases, so your attraction is quite good. So, from the neighbor you can really take up the electron quite or you can attract the neighbor's electron quite effectively. So, left to right in the periodic table, your electron affinity is going to be high.

From top to bottom, you cannot even hold your own electron, how can you attract from the neighbors? So, electron negativity will be less or becoming less from top to bottom right. On moving down the group, that is what I am trying to discuss;  $Z$  increases but  $Z^*$  almost remained constant. Number of shells increases, atomic radius increases, force of attraction between electron and nucleus decreases and therefore electronegativity decreases down the group.

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### Electronegativity

**On moving across a period left to right**

- $Z$  and  $Z^*$  increases
- number of shells remains constant at  
radius decreases
- force of attraction between added electron  
and nucleus increases

**Hence EN increases along a period**

On moving across a periodic table from left to right, what is happening  $Z$  and  $Z^*$  increases. That is true. Number of shells remains constant, atomic radius decreases, atomic radius becoming smaller and smaller. Force of attraction between added electron and nucleus increases and therefore electronegativity increases along a period.

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### Trends in three atomic properties

The diagram illustrates trends in three atomic properties across the periodic table:

- ATOMIC SIZE:** Indicated by a grey bar with a left-pointing arrow labeled "Increases" above it and a downward-pointing arrow labeled "Increases" to its left.
- IONIZATION ENERGY:** Indicated by a red bar with a right-pointing arrow labeled "Increases" above it and an upward-pointing arrow labeled "Increases" to its left.
- ELECTRON AFFINITY:** Indicated by a yellow bar with a right-pointing arrow labeled "Increases (with many exceptions)" above it and a downward-pointing arrow labeled "Increases (with many exceptions)" to its left.

So, this is the trends in the three atomic properties. Atomic size, as you are saying, from left to right it is decreases, from top to bottom it is increases. For ionization energy, ionization energy is going to be increasing from left to right and going to be decreasing from top to bottom. Electron

affinity, it is going to be increasing from left to right; electron affinity from top to bottom is again going to be decreasing. So that is all for today.