Main Group Chemistry
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Lecture - 01
Classification of Elements and Periodic Properties

Welcome to my lecture series on main group chemistry or the chemistry of main group elements in this lecture I am going to give you some information about the periodic table and classification of elements and periodic properties to begin with let us try to understand how many people have contributed to organize the elements in the form of a table to look into the properties and also the reactivity of the elements we see in periodic table.

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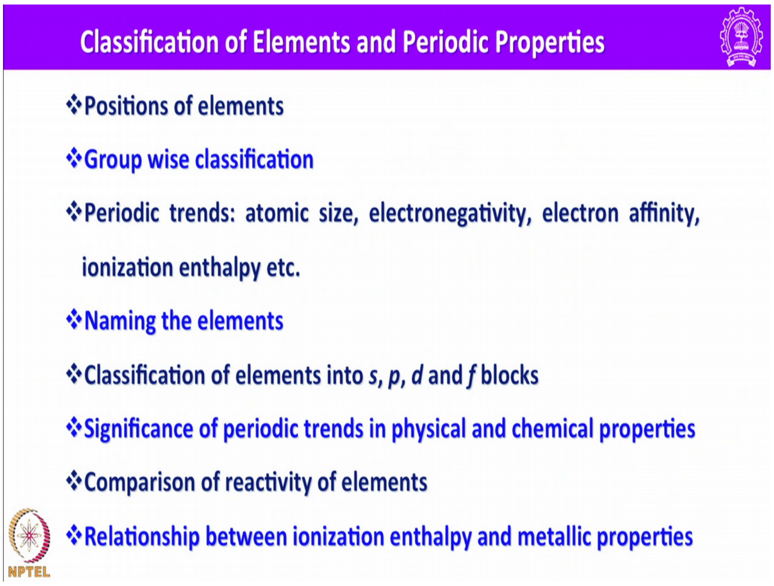

So, as a part of this one let us discuss the classification of elements and periodic properties, under this we shall try to focus on some of these points I have shown here, first of all let us try to understand the position of elements and how the elements finds a position in a particular place in the periodic table and how the classification has been carried out group wise as well as the row wise and look in to the periodic trends. When we talked about periodic trends we should look into the term such as atomic size, electronegativity, electron affinity and ionization enthalpy and then let us try to understand how to name the elements international union of pure and applied chemistry has come up with a formula to name the elements that are not known or not listed in the periodic table.

As of now we know about 118 elements all have been named and listed in the periodic table suppose in future if some elements of higher atomic number say 130,140 or 150 are discovered, we should have a proper methodology to name them. In that context let us look into the naming of elements and then it is very difficult to study all the elements under inorganic chemistry without classification of these elements. In order to make it further simplified all the elements in the periodic table are classified into 4 blocks they are s block, p block, d block, and f block and what are the criteria we used in the classification of elements into this blocked can be looked into and later let us also look into the significance of periodic trends in physical and chemical properties and once of knowing the trends in a group in a row comparison and reactivity of elements can be done in much ordered fashion.

And then once after establishing all these facts about the elements we can also try to understand relationship between ionization enthalpy and metallic properties most of these terms whatever I said atomic size, electronegativity, electron affinity and ionization enthalpy are all interrelated and how one can use this as a tool to understand the entire set of elements that are there in a periodic table.

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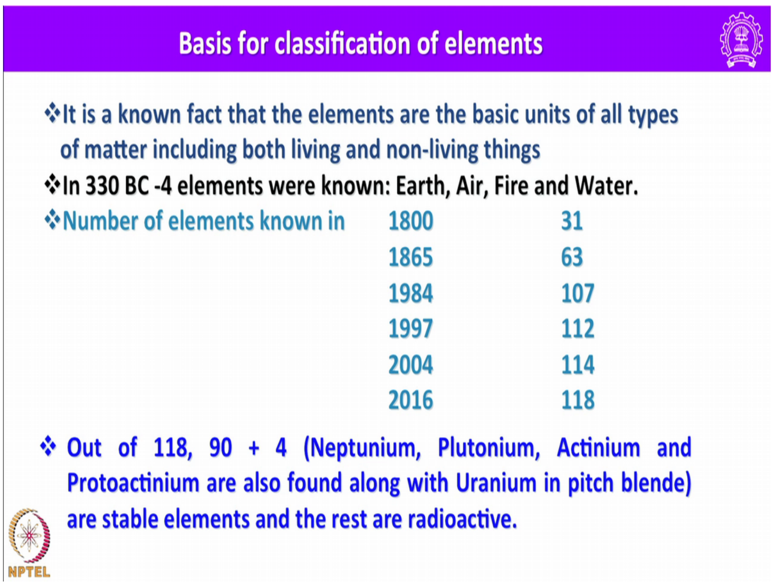

First let us look into the basis for classification of elements and we all know that the elements are the basic units of all types of matter including both living and nonliving things and in 330 BC only 4 elements were known they were earth, air, fire and water; however, in 1800, 31 elements were known and that number rose to 63 in 1865 and in 1984 that is after almost a 120 years 107 elements were known and in 1997 another 5 elements were added to make it 112, in 2004 114 elements were known and in 2016 all 118 elements were known and all of them have been named.

So, out of these 118 elements, 90 elements plus another 4 elements such as Neptunium, Plutonium, Actinium and Protoactinium are also found along with Uranium as trace elements in pitch blende, 30 plus this 4, 34 elements are essentially naturally occurring elements and remaining 14 elements are radioactive or manmade elements.

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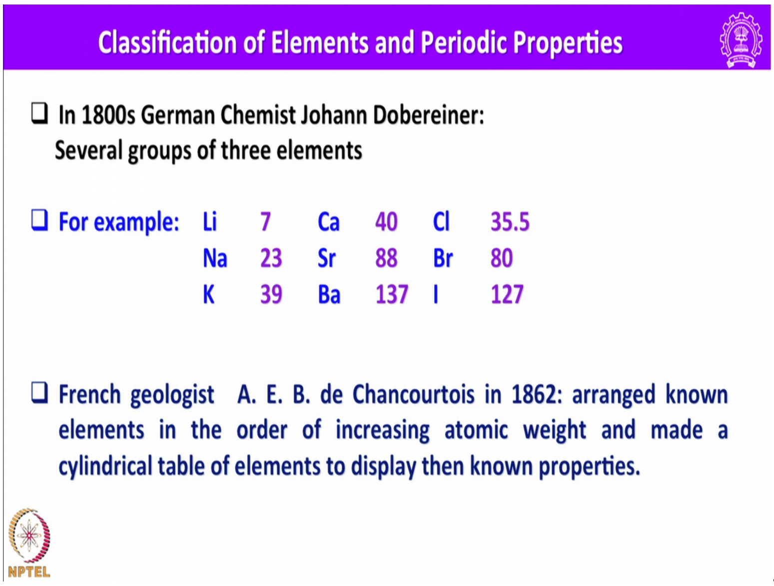

In 1800 German Chemist Johann Dobereiner he tried to understand and try to come up with a method of organizing all known elements in his attempt he made several group of 3 elements each and he called them as triads for example, I have shown some of them here you can see he made 3 or 4 such groups and the interesting thing about this group is if you just look into the atomic weight of the middle one in each triad and the atomic weight is the average of the first one and third one for example, Sodium atomic weight is 23 and that is the average of Lithium that is 7 and Potassium 13 and it is 46 divided by 2.

In the same way Strontium showed 88 midway and Bromine showed 80 that is also the average of the atomic weights of Chlorine and Iodine. So, another French geologist in 1862 de Chancourtois arranged known elements in the order of increasing atomic weight and he made a cylindrical table of elements to display the known properties and that have shown here.

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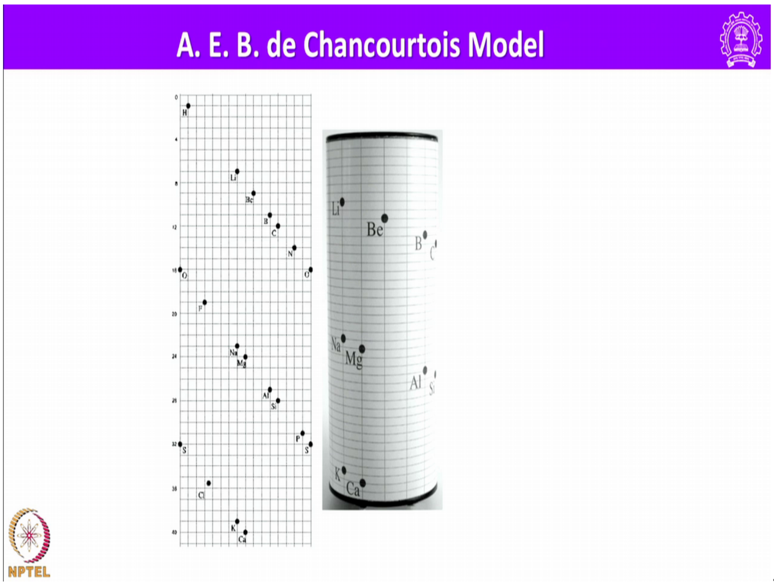

This is supposed to be the first a chart that is called de Chancourtois model to explain the known elements in one order to defeat their physical and chemical properties.

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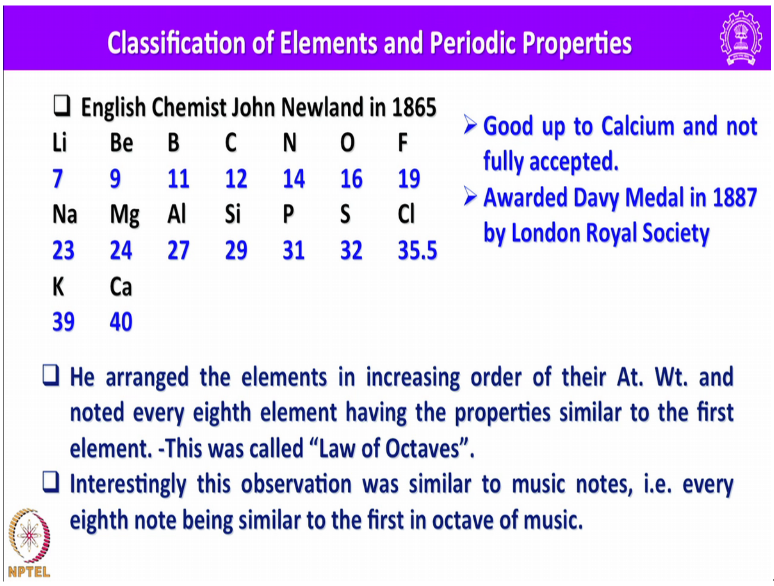

In 1865 an English chemist called John Newland he tried to arrange some of the elements then known in the increasing order of their atomic weight and he noted every 8 element having the properties similar to that of the first one and this observation he called as Law of Octaves and interesting thing is this is very similar to what we come across in music notes for example, every 8th note being similar to the first in octave of music and of course, he was recognized for this contribution and London royal society awarded Davy medal to him in 1887 and of course, this method was good up to calcium and as a reason it was not fully accepted.

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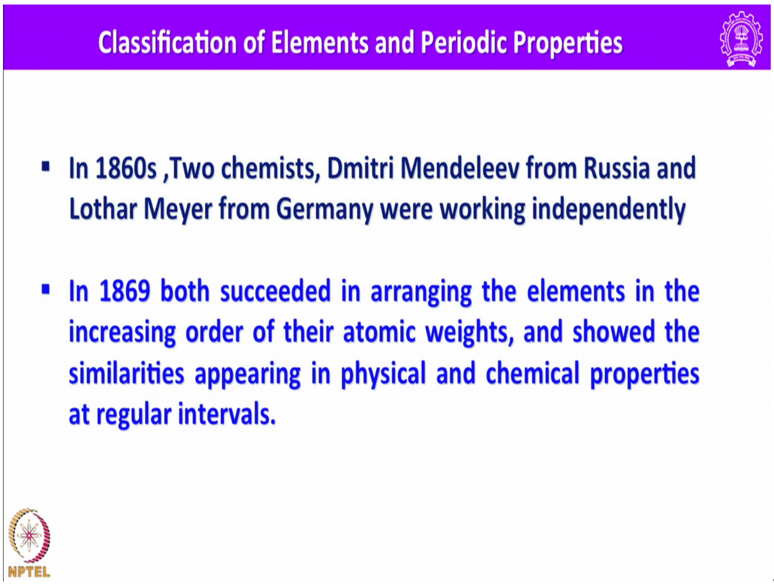

In 1862 chemists one from Russia and one from Germany that is Dmitri Mendeleev from Russia and Lothar Meyer from Germany started working independently to come up with a different organized system to include all known elements in some order and in 1869 in fact, both of them succeeded in arranging the elements in the increasing order of their atomic weight and showed the similarities appearing in physical and chemical properties at regular intervals. Lothar Meyer plotted physical properties such as atomic volume, melting point and boiling point against atomic weight and showed periodically repeating pattern.

In contrast to active format whatever proposed by John Mayer identify the change in the length of the repeating pattern and then 1868 he was ready with almost the modern periodic table; however, he did not publish his results and reasons for not noted meantime Dmitri Mendeleev published his periodic table in 1869 with an important statement the properties of the elements are the periodic functions of their atomic weight. He made an important statement I repeat again the properties of the elements are a periodic function of the atomic weight. Mendeleev arranged the known elements in horizontal rows and vertical columns in a table with increasing order of their atomic weight in such a way that the elements with similar properties occupied the same vertical groups.

The interesting and intelligent aspect is he gave importance to similarities in the empirical formula and properties and atomic weight was not strictly followed for example, despite lower attempt weight of iodine if you just try to compare the atomic weights of iodine and tellurium iodine atomic weight is lower than tellurium; however, he placed iodine in group 7 along with fluorine, chlorine and bromine that is with halogens and tellurium along with chalcogens such as oxygen, sulphur and selenium.

Also he predicted the properties of the some unknown elements and he left gap in the table at appropriate place, for example, he left gap below aluminium and silicon and called to be discovered elements as ECA aluminium and ECA silicon. So, he predicted the existence of gallium and germanium and described their general properties before they were being discovered.

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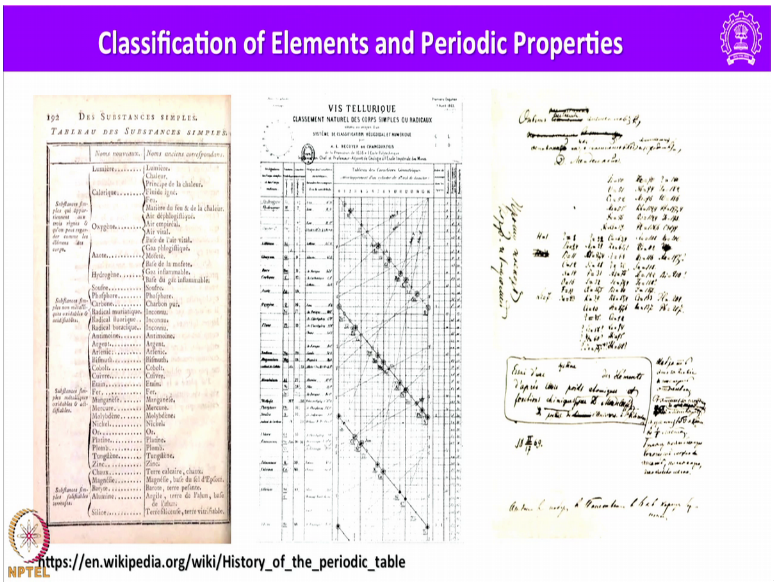

This show some of the early work of Mendeleev before he proposed the periodic table of course, this is I have taken directly from Wikipedia.

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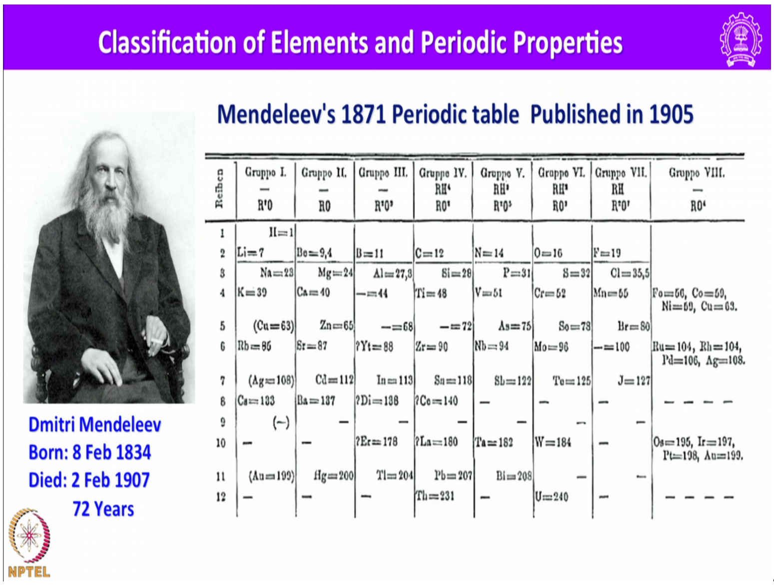

Reihen	Gruppo I. — R^2O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

And this is the Mendeleev's periodic table published in 1805 accepted in 1905 and of course, he proposed this one in 1871, let us look into some of the features of Mendeleev's discovery when Mendeleev proposed his periodic table the structure of atom and electrons were unknown of course, electrons were discovered by J J Thomson in 1897 and modern atomic theory was proposed by Niels Bohr in 1913 and work of another English physicist Henry Moseley an X ray spectra of elements and the atomic theory showed that the atomic number Z is a more fundamental property of an element and actually it is not it is atomic weight.

Mendeleev's periodic law whatever was stated based on atomic weight was modified as the physical and chemical properties of the elements or periodic functions of their atomic numbers. I repeat again the physical and chemical properties of the elements are periodic functions of their atomic numbers; that means, atomic number of an element is equal to it is nuclear charge that is in a neutral atom the number of electrons that are equal to the number of protons in the nucleus thus by simply knowing the electronic configuration it is possible to recognize the periodic variations and trends across a period or in a group. Since all this periodic law is governed by the electronic configuration the variation in electronic configuration determines the physical and chemical properties of elements and their compounds. This shows how important is to know about the electronic configuration once if you know the electronic configuration then understanding their physical and chemical properties should be rather very easy.

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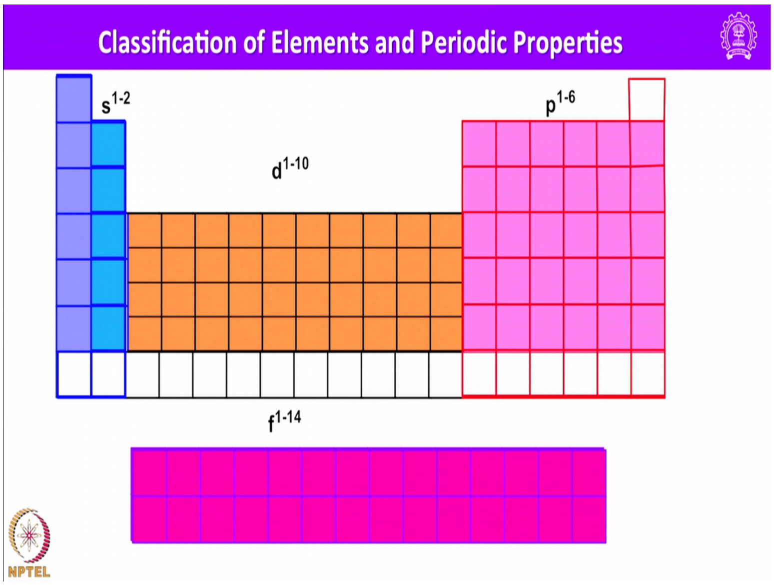

This is how the modern periodic table looks I have shown the skeleton here of the periodic table you can see I have marked in 4 different colors to indicate the blocks we have the first 2 are essentially s block, we have about 11 elements in s block including hydrogen and then in p block we have 31 elements including helium and then in d block we have 30 elements belongs to 3 d 4 d and 5 d and similarly we have f block where we have 2 rows of 15 elements each in 4 f and 5 f series..

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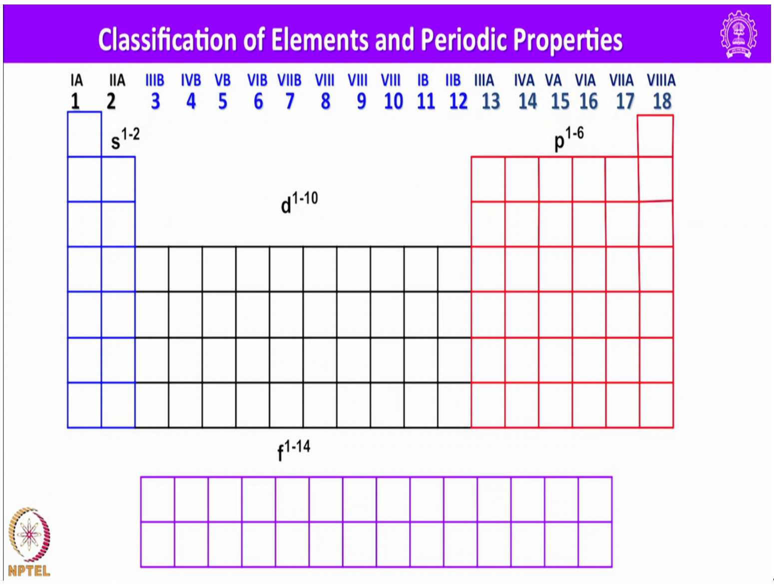

This is the entire periodic table and another important thing is you can notice all these 18 groups are numbered in the increasing order the earlier notion was little different that have listed on top that 1 a, 2 a like that and whereas, now the accepted method is to name all the groups starting from 1 to 18. Now, we have 18 groups and again the number has some significance you can see the group 1 and group 2 that means, they have 1 and 2 electron respectively in their valence shell.

Similarly, when you come to group 3 to 12 that belongs to d block here in d block also if you just look into the electronic configuration we start with d 1, s 2 to d 10, s 2; that means, the number still represent the group of the state or number of electrons present in that particular valence orbital of those elements in the group and then in the same way the p block starts from 13 and ends with 18 that represent the electronic configuration s 2 p 1 to s 2 p 6 ; that means, in 13 we have 3 electron, 14 we have 4 electron and in 17 we have 7 electrons.

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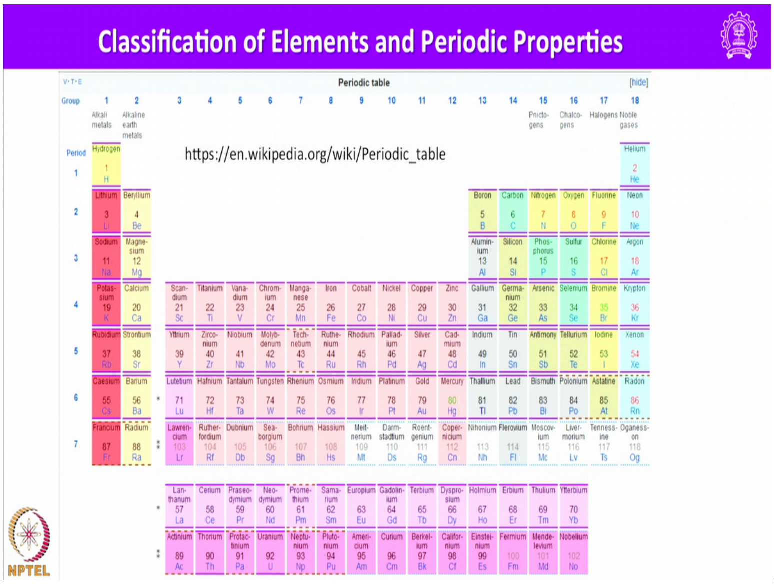

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So, still that number has some significance in denoting number of electrons in the valence shell this is the modern periodic table you can see all 118 elements have been numbered.

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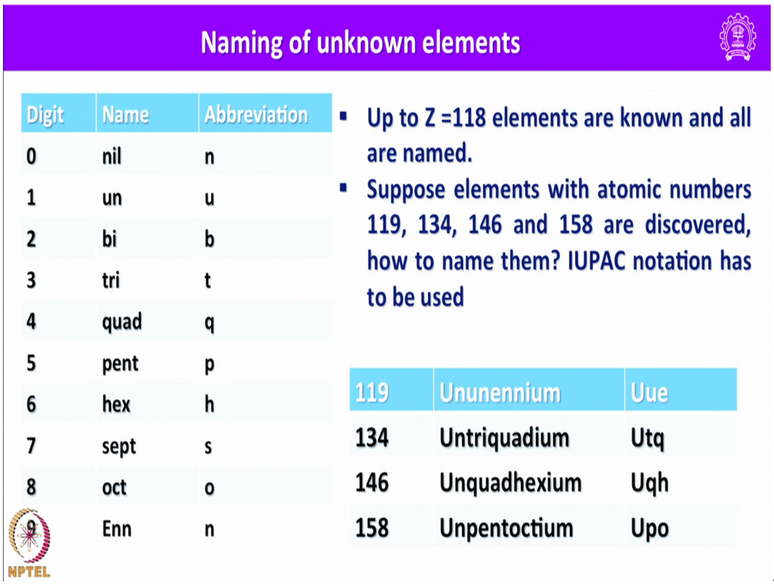

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International union of pure and applied chemistry has proposed this method in this one the digits 0 to 9 are named as nil, un, bi, tri, quad, pent, hex, sept, oct, and enn and the first letter is considered as abbreviation.

For example if you have to name let us a element with atomic number 118 it has to be named how to name it suppose of course, we know the name of the element having atomic number 118 and if suppose elements with atomic number such as 119, 134,146 or 158 are discovered. Then we can simply use this notation of IUPAC to name them and what we should do it for example, 119 I had shown there the one you should take un and another one is there second one you take un and the last one should end with ium. So, 119 can be called as un un enum and the abbreviation will be the first letter of all the 3, u u e in the same fashion one can name 134 that is atomic number 134 as in Untriquadium or atomic number with 146 can be called as Unquadhexium and element with atomic number 158 can be called as Unpentoctium, this is how we can name without any problem until they are given name in this fashion using IUPAC system.

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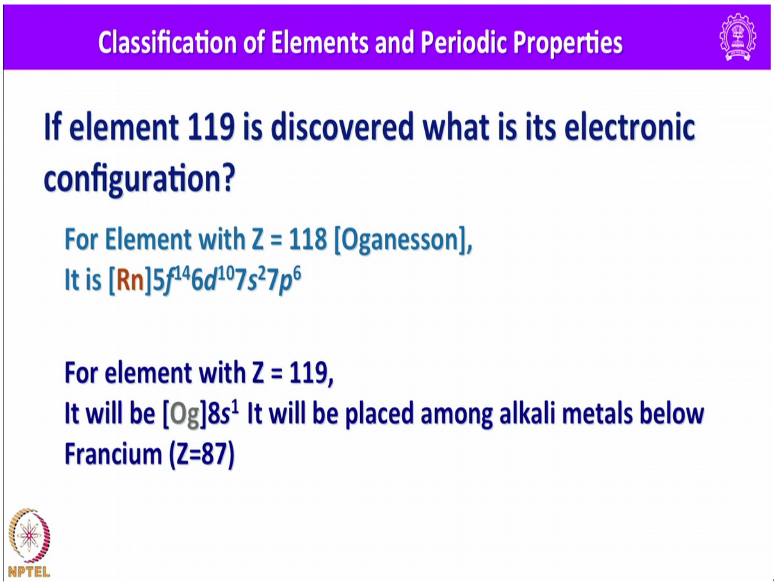

Let us look into another question if element 119 is discovered what is it is electronic configuration, let us look into this problem for element with Z equals 118 is known now, that is name is Oganesson and of course, the electronic configuration of Oganesson can be written as radon the previous inert gas element and then adding all the valence electrons that is 5f14 6d10 7s2 7p6. So, this is the electronic configuration of element with atomic number 118 to name the element 119, now this element with atomic number 118 is essential an inert gas element, that comes below radon so; that means, essentially I had to add 1 more electron to make it 119, it will be Oganesson or Og 8s1, it will be placed among alkali metal below Francium. So, here Francium atomic number is Z equals 87, another 32 elements are added you get 119 to 87.

This electronic configuration is nothing, but the distribution of electrons into the orbitals; that means, of course, atomic theory everything is described in a nice way and we are all familiar with writing the electronic configuration for any given element in the periodic table. Let us look into the electronic configuration of various groups in the periodic table all alkali metals have s 1 electronic configuration; that means, they have 1 electron in the valence shell, similarly alkaline earth metals having s 2 electronic configuration and have 2 electrons in the valence shell and p block elements have anywhere from s 2 p 1 to s 2 p 6 electronic configuration; that means, they have anywhere between 3 to 8 electrons in their valence shell and d block elements have s 2 d 1 to s 2 d 10 electronic configuration that is they have anywhere between 3 to 12 electrons in their valence shell.

Let us look into the first 3 d series starts with atomic number 21 which is scandium and ends with 30 that is atomic number of zinc and 4 d series starts with atomic number 30 and 39 that is yttrium and ends with cadmium having atomic 48 and then we have 5 d series in which hafnium be the first element to start with atomic number 72 and we have mercury with atomic number 80 and similarly 4 f series starts with lanthanum 57 and it goes up to lutetium 71 and then 5 f we have actinium the first one with the atomic number 89 and the last one is lawrencium with 103. So, this is how all the elements are arranged and once we know where exactly they are located in the periodic table writing their electronic configuration will be very easy.

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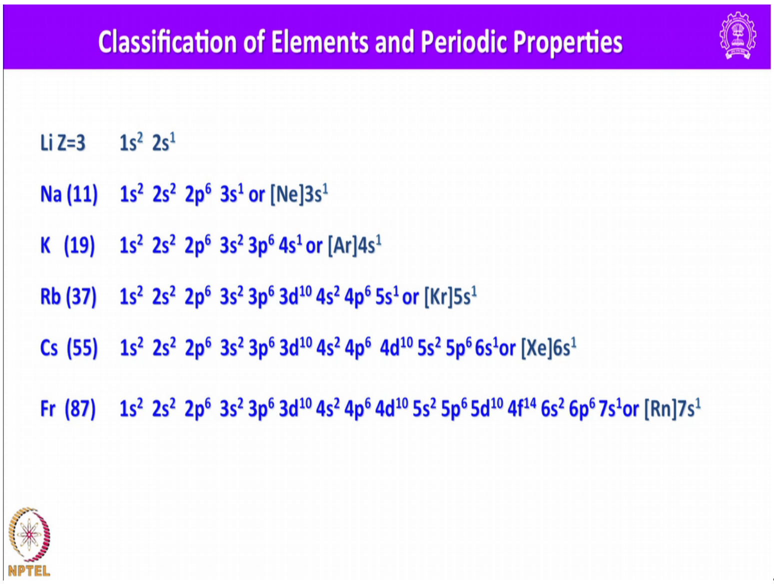

I have shown here the electronic configuration of group 1 elements starting from lithium to francium and of course, there are 2 ways one can write the electronic configuration simply you can expand and keep writing all electrons in the order in increasing their energy taking clue from of principle or one can also simply consider the previous inert gas element and then simply write the valence electron.

For example sodium atomic number 11 one can write 1s2 2s2 2p6 3s1 or one can simply write neon 3s1 the same method can be followed in all cases for simplicity one can use the last option of just including the previous electronic configuration of previous inert gas for the inner electrons and just in front of them write only the valence electron, that is much simpler and does not occupy more space while writing.

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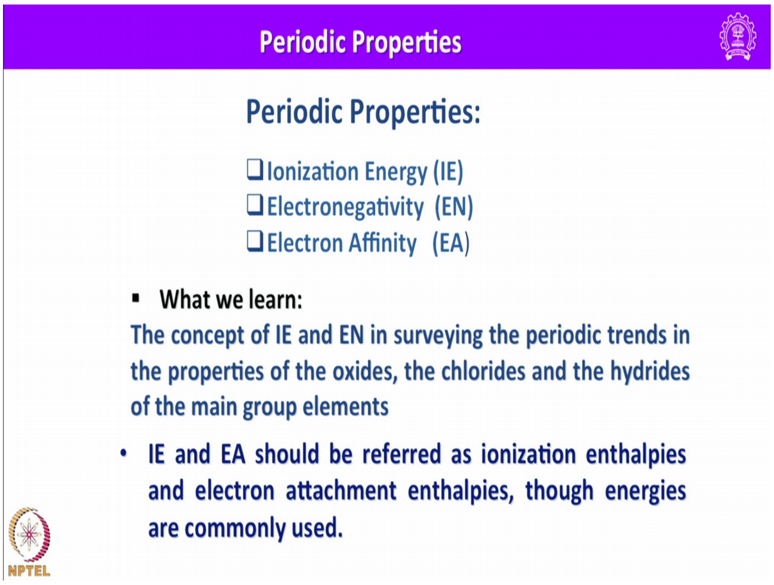

Let us look into now the periodic properties when you talk about periodic properties 3 terms comes to our mind that is Ionization Energy also known as Ionization Enthalpy and Electronegativity and Electron Affinity or electron attachment enthalpy. So, what do we will learn by knowing these terms, the concept of ionization energy and electron negativity will be very helpful when we look into the properties of main group elements compounds and ionization energy and electron affinity should be referred to as ionization enthalpies and electron attachment enthalpies though energies are commonly used. In the previous convention or in some text books they call it has ionization energy and some recent additions of a new inorganic chemistry books they are referred as ionization enthalpy; however, it is more appropriate to call ionization enthalpy rather than ionization energy similarly, electron affinity should be called as electron attachment enthalpy.

Let us try to understand the relevance of some of these terms in a compound of main group element.

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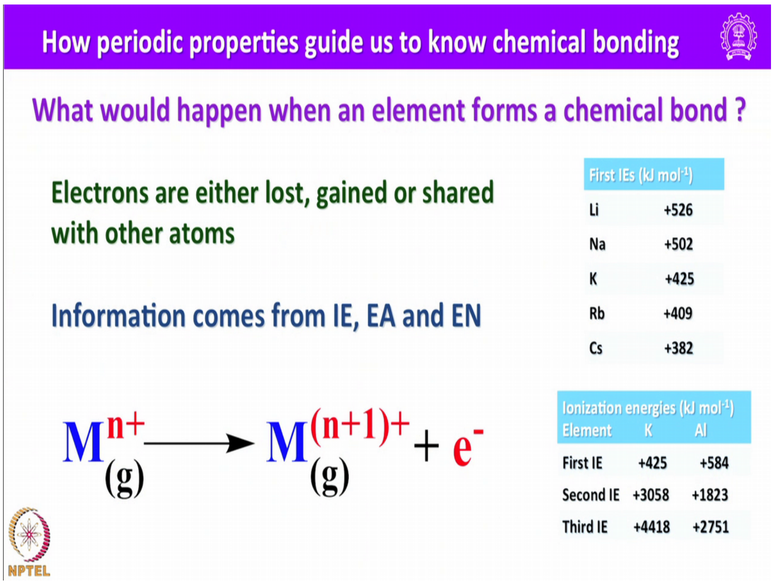

So, what would happen when an element forms a chemical bond; that means, essentially electrons are either lost electrons are gained or shared with other atoms so that means, this information which atom is losing an electron or which atom is gaining an electron or whether they are sharing all this information comes from these 3 terms that is ionization enthalpy electronegativity and electron attachment enthalpy.

For example, you look into this the equation I have given for example, you take M a gaseous atom or an ion and when you ionize it loses one electron to go to the next (Refer Time: 22:40) state when it goes to next (Refer Time: 22:43) state what would happened to that one how easy it is how difficult it is this information comes by just simply looking into the ionization energy of these elements. I have listed ionization energy of first group one element here for example, look into the first ionization energy of lithium that is plus 526 and sodium it is plus 502, in case of potassium it is plus 425, in case of rubidium it is plus 409 and case of caesium it is plus 382.

So, certainly you can observe some trend, the trend is ionization energy is decreasing down the group, why this ionization energy is decreasing down the group I will discuss that one later. Let us look into another table I have shown there in that one I have listed 3 ionization energies; that means, the electron is removed from the gaseous atom, first electron is removed that is first ionization energy and then from that one if you remove another electron that is called second ionization energy and from the valence shell if you remove the third electron it is called third ionization energy.

These first second and third ionization energies for 2 atoms I have 2 elements I have given here, the elements they are chosen I have chosen are potassium and aluminium the first ionization energy for potassium is plus 425 whereas, the same for aluminium is plus 584 and second ionization energy given for potassium is plus 3058 very high and in case of aluminium it is 1823 and similarly third ionization energy for potassium is 4418 whereas, that of aluminium it is 2751.

So, what does it say; that means, first ionization energy of potassium is very low of course, you are removing the lone electron in the valence shell so; obviously, it is less, but when you go to the aluminium you are doing the same exercise removing one electron, but; however, atomic number of aluminium is very high and effective nuclear charge is also more despite it is the lone electron of p orbital it because of nuclear charge it shows little higher value compared to potassium that is quite understandable.

When you look into the second ionization energy of potassium is very very high and it is next to impossible to remove that electron because essentially you have to remove the electron from the core not from the valence orbital whereas, in case of aluminium that electron whatever we are removing it is from the still it is valence shell and that is the reason it is 1823. In the second table what I have shown is the 3 ionization energies I have shown for 2 elements 1 is for potassium, 1 is for aluminium and first ionization energy for potassium is 425 kilojoules per mole whereas, for aluminium it is 584 kilojoules per mole so that means, essentially the valence electron the one valence electron that is present in potassium that is removed with ease that is reason value is much lower.

Whereas, in case of aluminium the situation is same we are removing 1 electron out of 3 electron that is from s to p 1 electronic configuration and here due to the increase in the atomic number and increase in the nuclear charge it is anticipated it is expected to have a little higher ionization energy, but interesting fact is looking to second ionization energy that is 3058 in case of potassium and whereas, 1823 in case of aluminium of course, we are making an attempt to remove the second electron from the valence shell again in case of aluminium as a result it can be removed with ease compared to the attempts that are made to remove second electron from the potassium cation that is essentially you are trying to remove that electron from the core shell, that would be very difficult that is the reason second ionization energy is very high and for the same reason third ionization energy is also very high in case of potassium.

Whereas, in case of aluminium second ioniz, third ionization energy is much lower compared to potassium because again you are removing the third electron from the valence shell to generate al 3 plus; that means, s2p 1 electronic configuration it has and when it becomes al 3 plus all the 3 electrons are removed, this is how ionization energy can be related to the atomic number and effective nuclear charge in my next lecture I will be discussing more about periodic properties and have a pleasant reading.

Thank you very much.