Study of Gp 13 and Gp 14 of p-block elements

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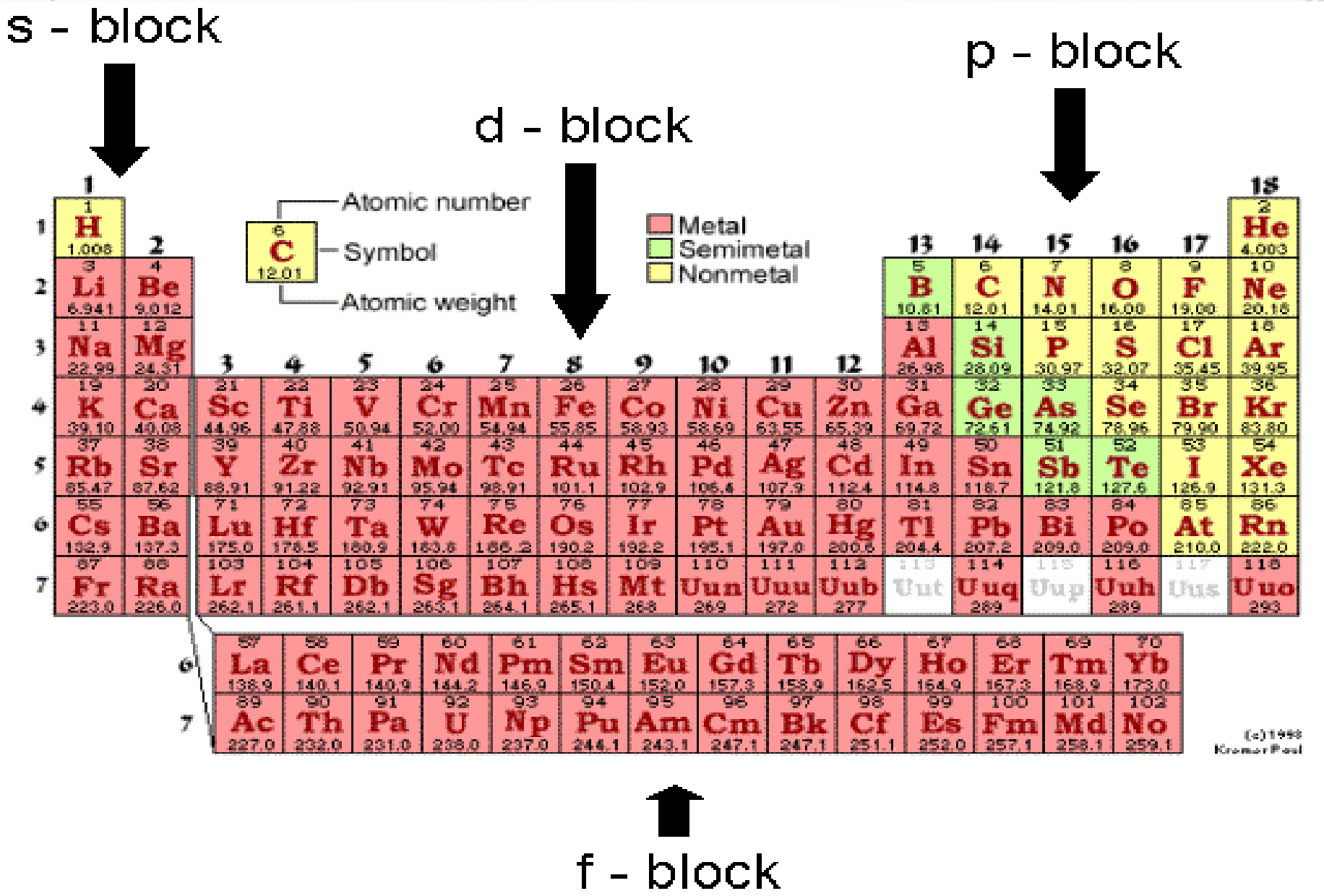
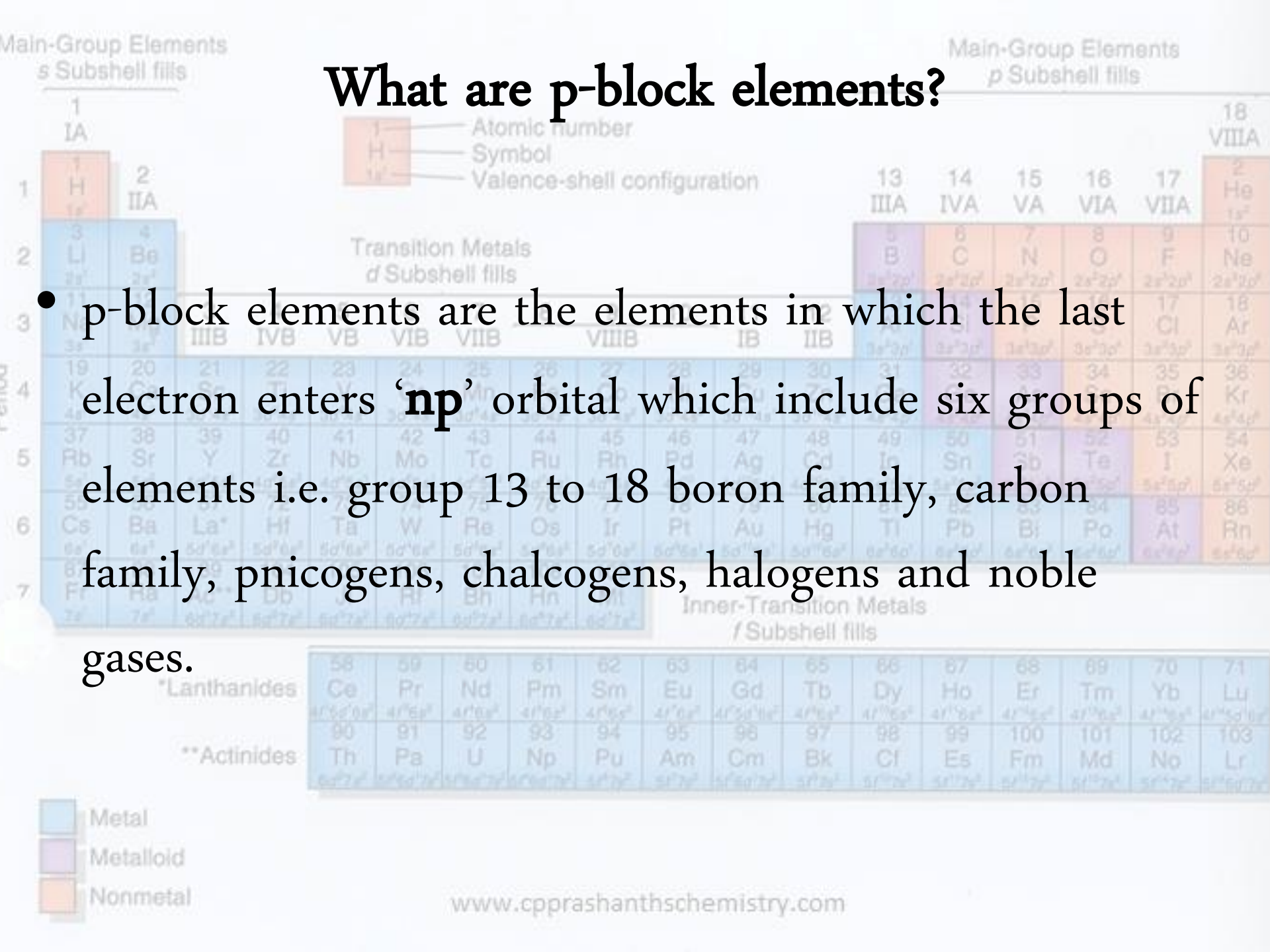
Position of p-block in periodic table



What are p-block elements?

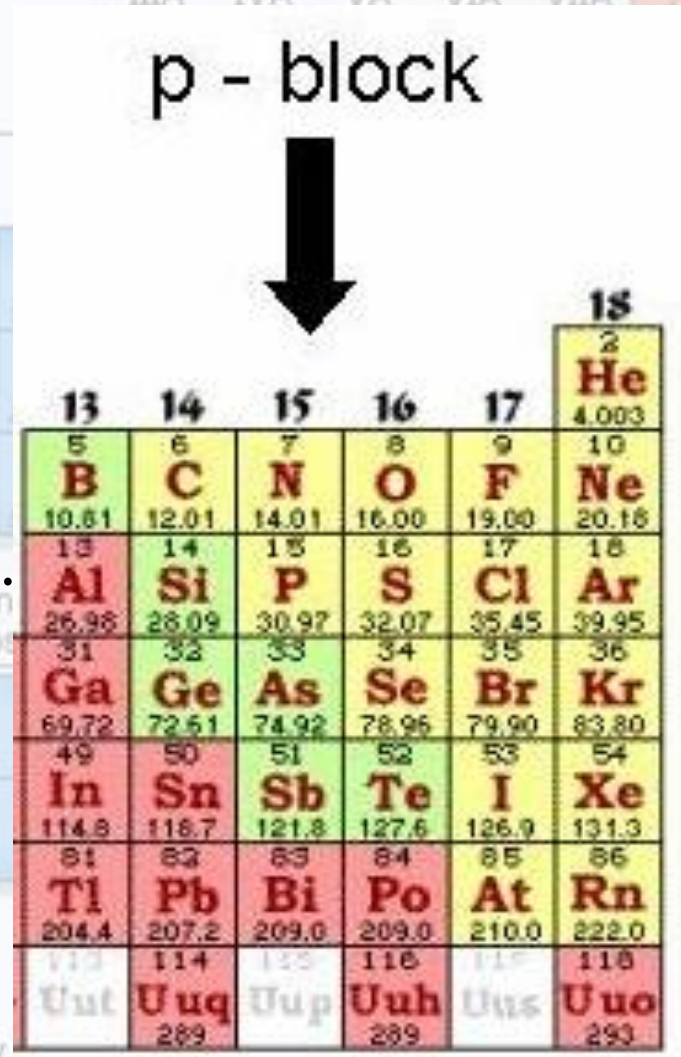
- p-block elements are the elements in which the last electron enters '**np**' orbital which include six groups of elements i.e. group 13 to 18 boron family, carbon family, pnicogens, chalcogens, halogens and noble gases.



General electronic configuration & oxidation state

Group	13	14	15	16	17	18			
G.E.C	ns^2np^1	ns^2np^2	ns^2np^3	ns^2np^4	ns^2np^5	ns^2np^6 ($1s^2$ for He)			
First G. Element	B	C	N	O	F	He			
G.O.S	+3	+4	+5	+6	+7	+8			
Other O.S	+1	+2	+3	+4	+5	+6			
		-4	-3	+2	+3	+4			
				-2	+1	+2	_		

- As metals,non-metals and metalloids exist only in p-block of periodic table.
- The heaviest element in each p-block group is mostly metallic in nature.
- Non-metallic character of down the group.



- Non metals have higher ionization enthalpy and electronegetivity than the metals.

  Hence metals form cations, and non metals form anions.

- Compounds formed between non metals are largely covalent in nature, while the compounds formed by highly reactive non-metal and metal have large difference in electronegativities.

p-block elements differ...

- Size and all the properties of size

because of this the lightest p-block elements show the same kind of differences as the lightest s-block element i.e. lithium and beryllium.

- Elements starting from boron are restricted to maximum covalence of four (using 2s and three 2p orbitals).

Group 13 elements: The boron family

Elements	At. No.	Electronic conf.
B	5	$2s^2 2p^1$ **(He)**
Al	13	$3s^2 3p^1$ **(Ne)**
Ga	31	$3d^{10} 4s^2 4p^1$ **(Ar)**
In	49	$4d^{10} 5s^2 5p^1$ **(Kr)**
Tl	81	$4f^{14} 5d^{10} 6s^2 6p^1$ (Xe)

Atomic radii

- The atomic radii increases from boron to thallium.

Element	B	Al	Ga	In	Tl
At. radius	88	143	135	167	170

- The abrupt increase in atomic radius of Al is due to greater screening effect in Al than B.

Ionization enthalpy

- Here the first ionization enthalpies of these elements are less than corresponding value of s-block element.

This is because p-electrons are less penetrating and more shielded than s-electrons.

B	Al	Ga	In	Tl
801	577	579	558	589

Electronegetivity

- Down the group, electronegetivity first decreases from B to Al and then increases till thallium.

This is because of the difference in atomic sizes of elements.

B	Al	Ga	In	Tl
2.0	1.5	1.6	1.7	1.8

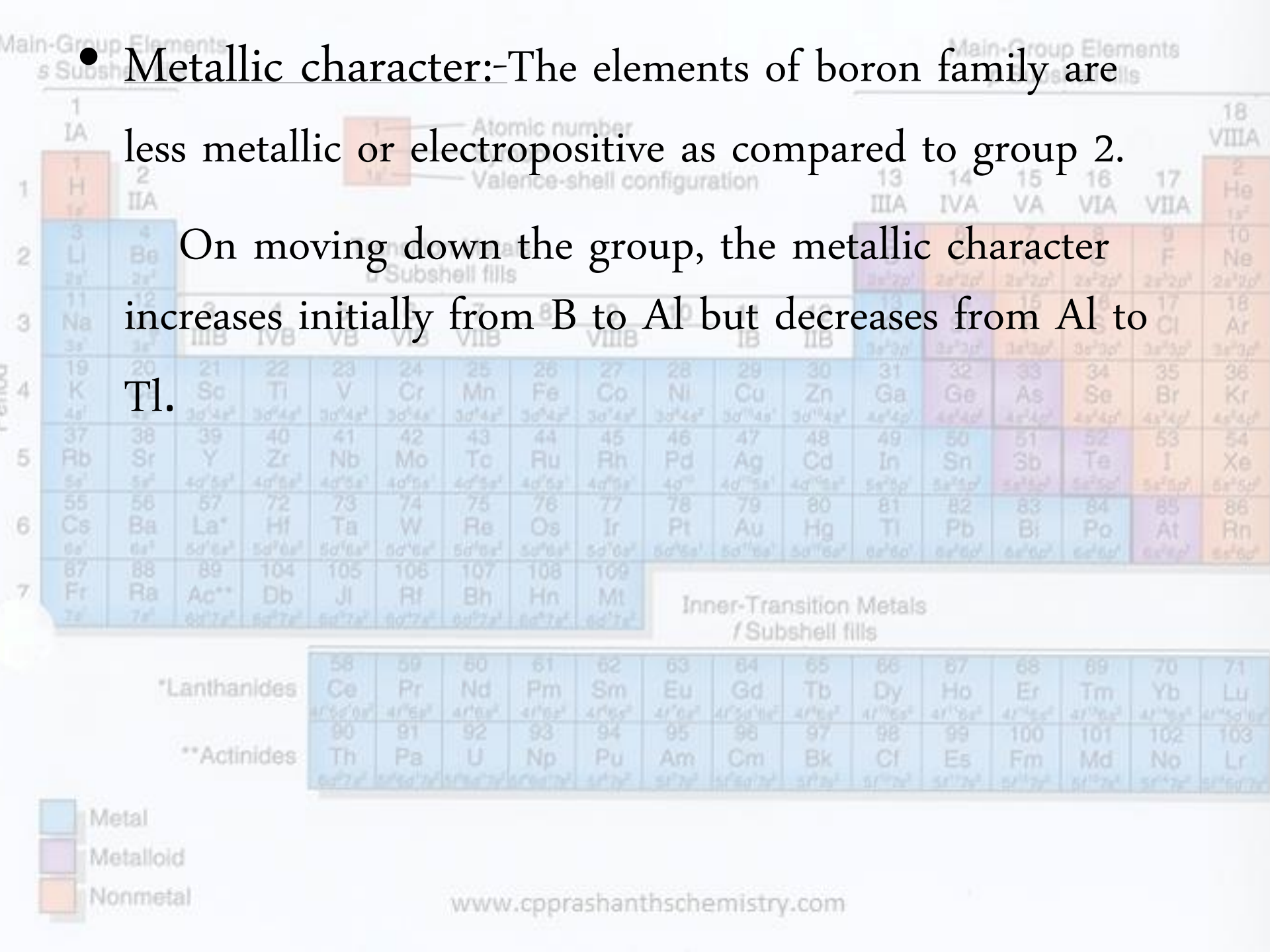
Physical properties

- Boron is extremely hard and black in colored solid which exists in many allotropic form.
- <u>Density:-</u> It increases from B to Tl due to increasing size of atom.

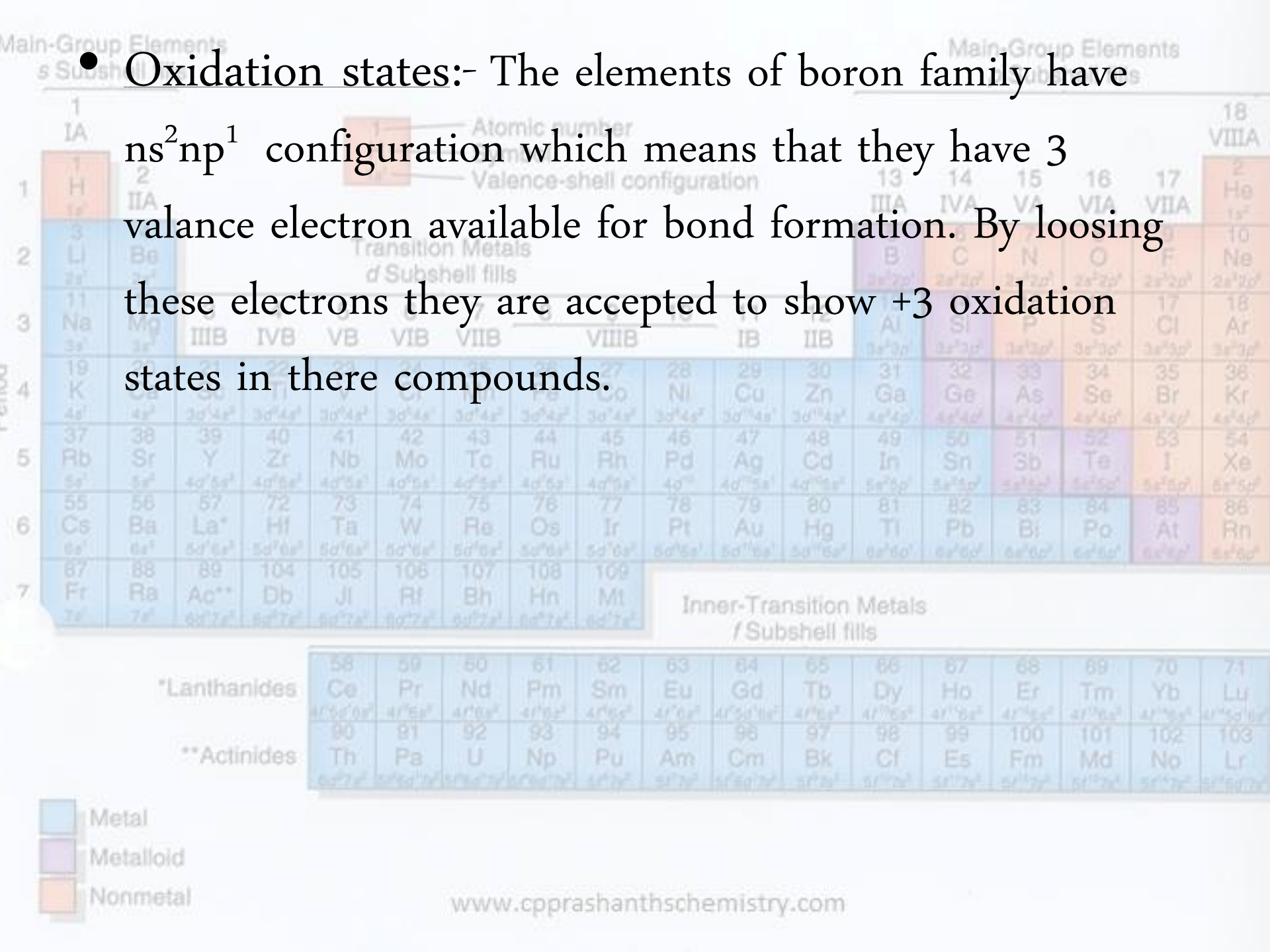
	B	Al	Ga	In	Tl
Density	2.35	2.70	5.90	7.31	11.85

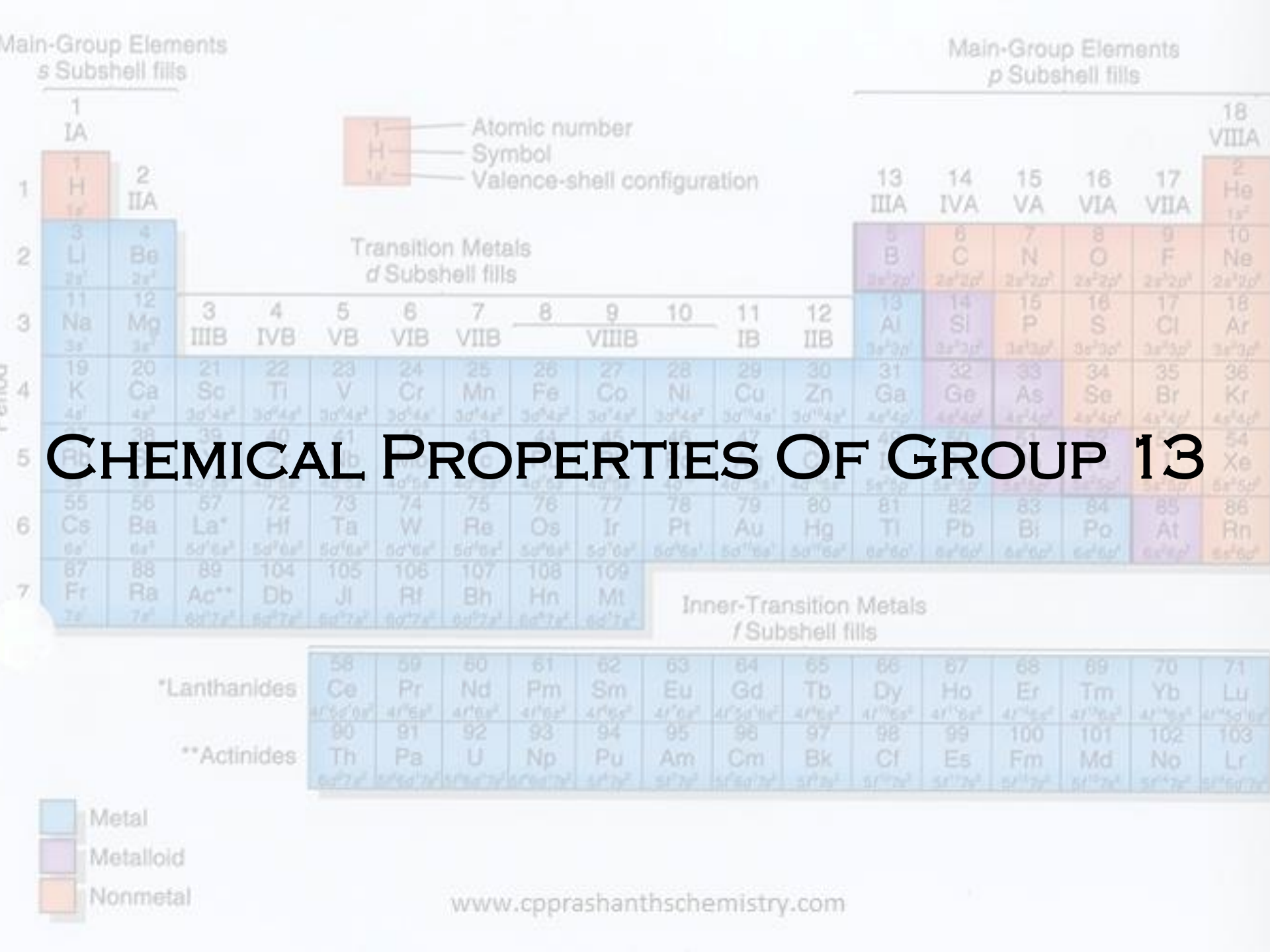
- Metallic character:-The elements of boron family are less metallic or electropositive as compared to group 2.

On moving down the group, the metallic character increases initially from B to Al but decreases from Al to Tl.



- Oxidation states:- The elements of boron family have ns^2np^1 configuration which means that they have 3 valance electron available for bond formation. By loosing these electrons they are accepted to show +3 oxidation states in there compounds.





Chemical Properties Of Group 13

Introduction

1)Group 13 elements and their uses

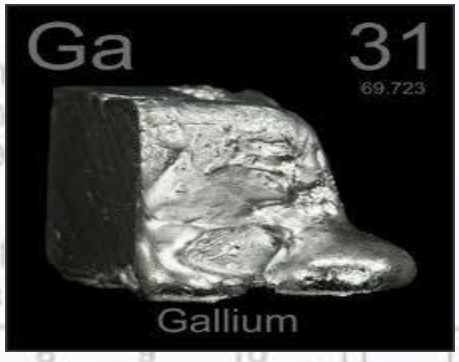
2)Boron – Electronic structure

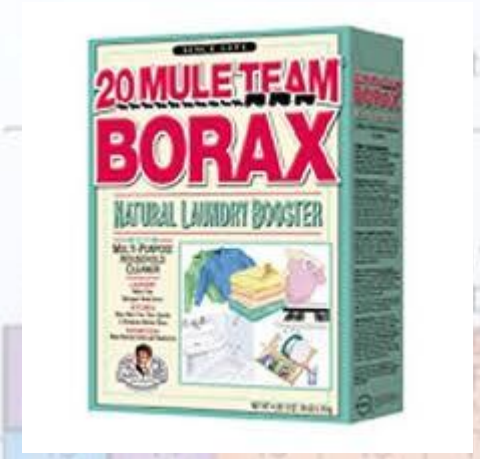
Chemical properties

3)Aluminium- Structure and properties

4) Equations

5) Concluion

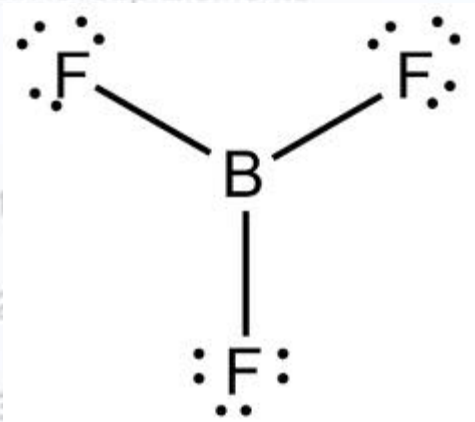


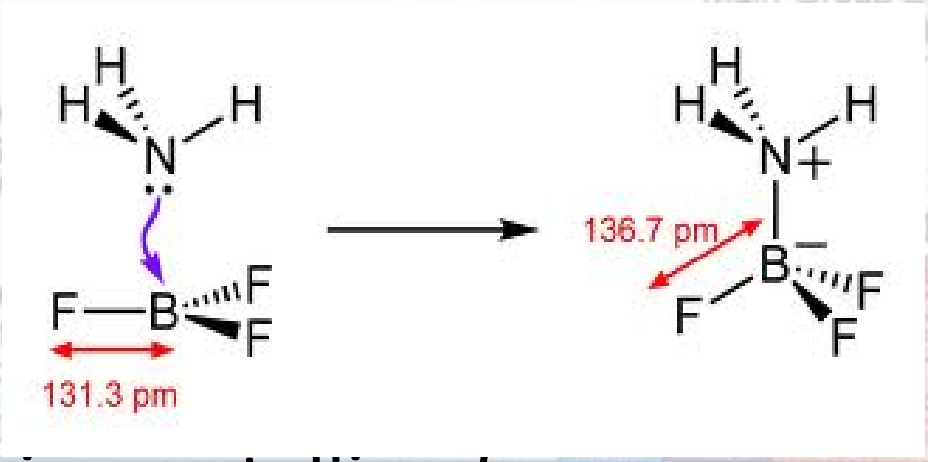


- Boron – glasses, ceramics and agriculture
- Aluminum – electrical devices and construction materials
- Gallium – amplifiers, solar cells and satellites
- Indium – coatings and alloys
- Thallium – photo electric cell, and toxics

Boron

- Electronic structure – $1s^2\ 2s^2\ 2p^1$ Atomic radius – 90 pm.
- Due to this relatively small size of boron, the sum of its first three ionization enthalpies is very high.
- This prevents it to form 3+ ions and forces it to form only covalent compounds.
- In the trivalent state, boron can be called as electron deficient as it will have only 6 electrons in its outer most orbit. Thus, Boron has a tendency to accept a lone pair of electrons from another compound to become stable.
- This property also makes the compound a Lewis acid.





- It is unreactive in crystalline form
- However, amorphous boron on heating in air forms B_2O_3.It reacts with di nitrogen at high temperatures to form nitrides.
- B_2O_3 is acidic and reacts with basic oxides forming metal borates
- It does not react with acids and alkanes.

Aluminum and other group 13 elements

- Sum of the first three ionization enthalpies is less, as compared to Boron. Thus, it due to the easy tendency to lose electrons It is able to form Al 3+.
- In the other elements, due to poor shielding effect of d and f orbitals, the nucleus holds the outer most s electrons tightly. Thus, only p bonding may be available for bonding.
- In all 3 elements, both +1 and +3 oxidation states are seen.
- The compounds in +1 state are more ionic than those in +3 state.

- Aluminum forms a very thin oxide layer. With di nitrogen at high temperatures they form nitrides.
- It dissolves in mineral acids and aqueous alkalies and thus show amphoteric character.
- All the group 13 elements except thallium show reactivity towards halogens.

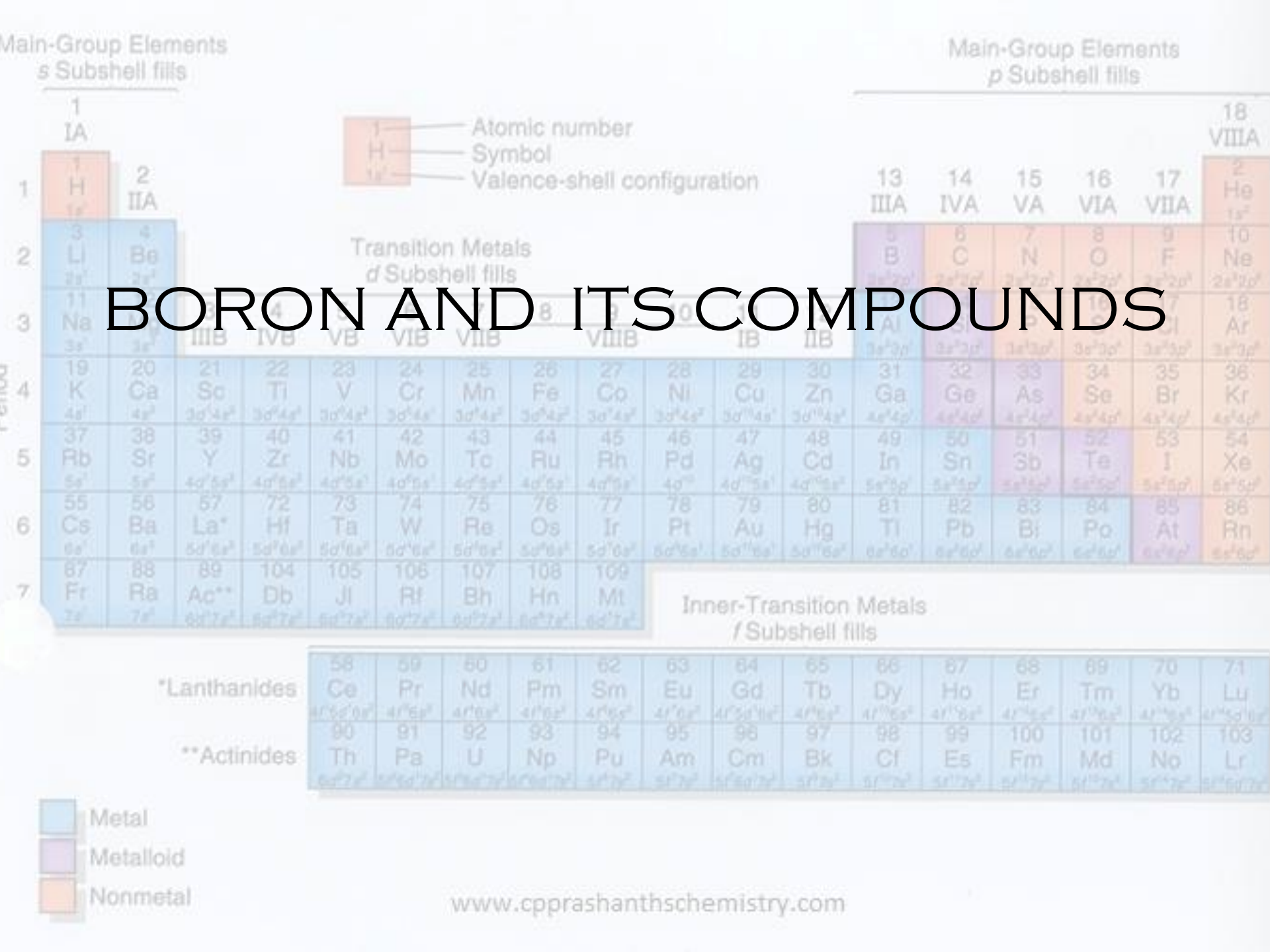
- $2E(s) + 3O_2(g) \longrightarrow 2E_2O_3(s)$
- $2E\ (s) + N_2(g) \longrightarrow 2EN(s)$

[E = element]

- $2Al(s) + 6HCl\ (aq) \longrightarrow 2Al^{3+(}aq) + 6Cl^{-}(aq) + 3H_{2(}g)$
- $2E(s) + 3X_2(g) \longrightarrow 2EX_3\ (s)$

Conclusion

- We have learnt the far and wide reaching applications of all the group 13 elements.
- We learnt the chemical properties of boron, and aluminium in detail, how they form compounds with other elements their structures; and their reactivity with certain substances.



BORON AND ITS COMPOUNDS

1.Borax

It is the most important compound of boron. It is a white crystalline solid of formula $Na_2B_4O_7 \cdot 10H_2O$. Borax dissolves in water to give an alkaline solution.

$$Na_2B_4O_7 + 7H_2O \rightarrow 2NaOH + 4H_3BO_3$$

Orthoboric acid

On heating, borax first loses water molecules and swells up. On further heating it turns into a transparent liquid, which solidifies into glass like material known as borax bead.

$$Na_2B_4O_7.10H_2O \xrightarrow{\Delta} Na_2B_4O_7 \xrightarrow{\Delta} 2NaBO_2 + B_2O_3$$

sodium metaborate

2.Orthoboric acid

Orthoboric acid, H_3BO_3 is a white crystalline solid, with soapy touch. It is sparingly soluble in water but highly soluble in hot water.

It can be prepared by acidifying an aqueous solution of borax.

$$Na_2B_4O_7 + 2HCl + 5H_2O \rightarrow 2NaCl + 4B(OH)_3$$

It has a layer structure in which planar BO_3 units are joined by hydrogen bonds .

Boric acid is a weak monobasic acid. It is not a protonic acid but acts as a Lewis acid by accepting electrons from a hydroxyl ion:

$$B(OH)_3 + 2HOH \rightarrow [B(OH)_4]^- + H_3O^+$$

On heating, orthoboric acid above 370K forms metaboric acid , HBO_2 which on further heating yields boric oxide, B_2O_3.

$$H_3BO_3 \xrightarrow{-\Delta} HBO_2 \xrightarrow{-\Delta} B_2O_3$$

3.Diborane, B_2H_6

The simplest boron hydride known, is diborane. It is prepared by treating boron trifluoride with $LiAlH_4$ in diethyl ether .

$$4BF_3 + 3\ LiAlH_4 \rightarrow 2B_2H_6 + 3LiF + 3AlF_3$$

A convenient laboratory method for the preparation of diborane involves the oxidation of sodium boron hydride with iodine

$$2NaBH_4 + I_2 \rightarrow B_2H_6 + 2NaI + H_2$$

Diborane is produced on an industrial scale by the reaction of BF_3 with sodium hydride.

$$2BF + 6NaH \xrightarrow{-4-50K} B\ H + 6NaF$$

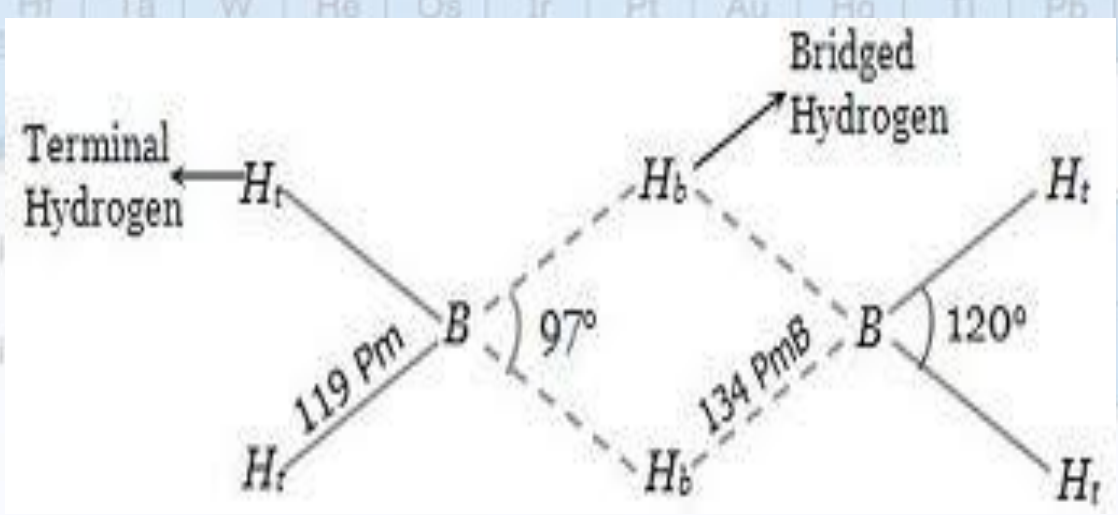
PROPERTIES OF DIBORANE.

1.Diborane is a colourless, highly toxic gas with a b.p. of 180 K.

2.Diborane catches fire spontaneously upon exposure to air. It burns in oxygen releasing an enormous amount of energy.

3.Reaction of ammonia with diborane gives initially $B_2H_6.2NH_3$, further heating gives borazine, $B_3N_3H_6$ known as “inorganic benzene” .

The structure of diborane is shown below . The four terminal hydrogen atoms and the two boron atoms lie in one plane. Above and below this plane, there are two bridging hydrogen atoms. The four terminal B-H bonds are regular two centre-two electron bonds while the two bridge (B-H-B) bonds are different and can be described in terms of three centre two Electron bond.



USES OF BORON AND ALUMINIUM AND THEIR COMPOUNDS

BORON

Boron has low density and very low electrical conductivity, finds many applications.

1.Boron fibres are used in making bullet-proof vest and light material for aircraft .

2.The boron-10 isotope has high ability to absorb neutrons and there f metal borides are used in nuclear industry as protective shields and control rods.

3. The main industrial application of borax and boric acid is in the manufacture of heat resistant glasses like glass-wool and fibreglass.

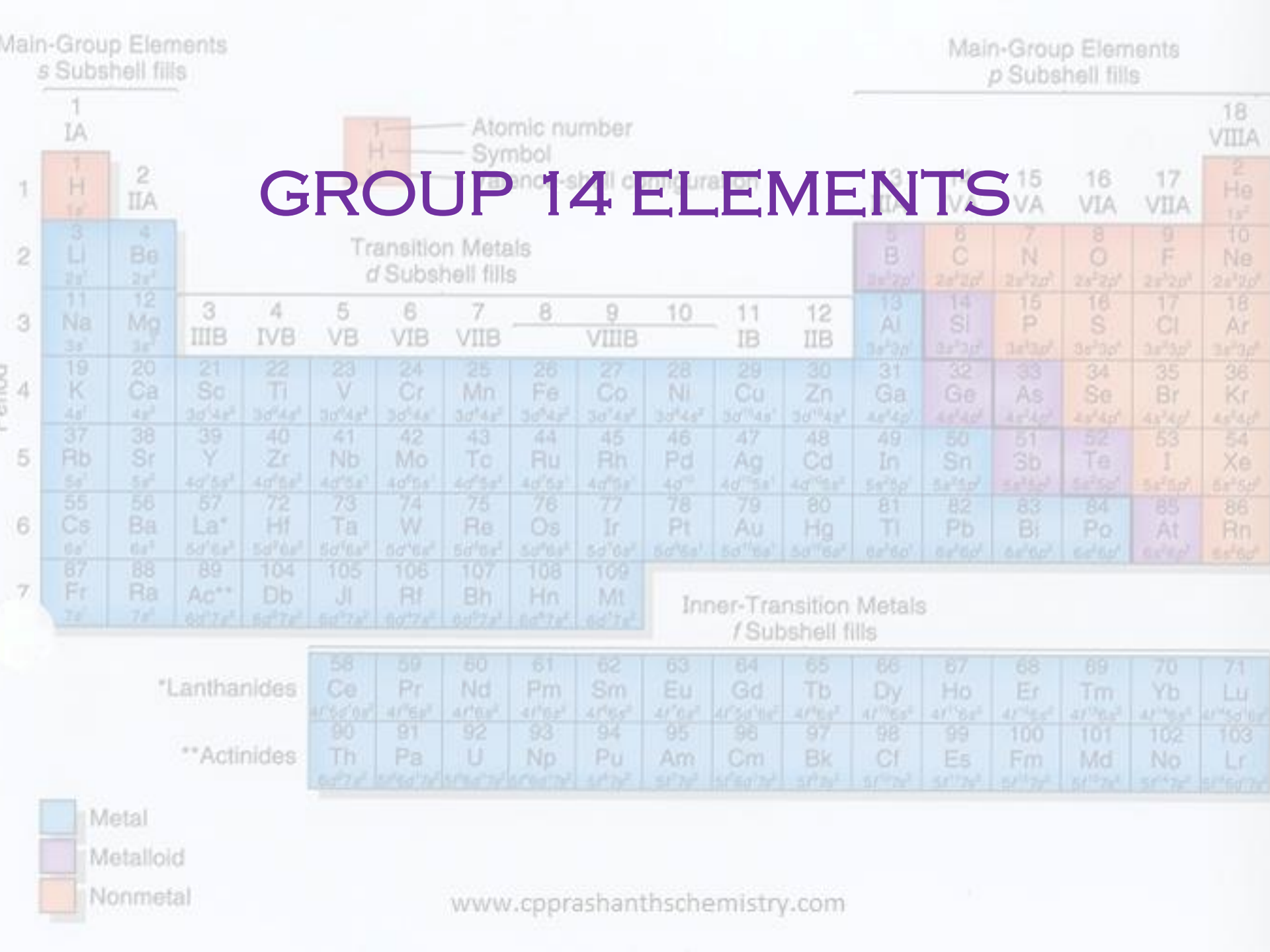
4.Borax is used as a constituent of medicinal soaps. An aqueous solution of orthoboric acid is generally used as a mild antiseptic.

ALUMINIUM

1.Aluminium is a bright silvery-white metal. It has a high electrical and thermal conductivity.

2.It forms alloys with Cu, Mn, Mg, Si and Zn. Aluminium and its alloys can be given shapes of pipe, tubes, rods, wires, plates or foils and, therefore, find uses in packing, utensil making,
construction, aeroplane and transportation industry.

3.The use of aluminium and its compounds for domestic purposes is now reduced considerably because of their toxic nature.



GROUP 14 ELEMENTS

PRESENTATION OVERVIEW

- MODERN PERIODIC TABLE
- GROUP 14 ELEMENTS: THE CARBON FAMILY
- CARBON & ITS USES
- SILCON & ITS USES
- GERMNIUM & USES
- TIN & ITS USES
- LEAD & ITS USES
- ATOMIC AND PHYSICAL PROPERTIES
- CHEMICAL PROPERTIES

GROUP 14 ELEMENTS: THE CARBON FAMILY

Element	symbol	electron configuration
Carbon	C	$[He]2s^2 2p^2$
Silicon	Si	$[Ne]3s^2 3p^2$
Germanium	Ge	$[Ar]3d^{10} 4s^2\ 4p^2$
Tin	Sn	$[Kr]4d^{10} 5s^2\ 5p^2$
Lead	Pb	$[Xe]4f^{14}\ 5d^{10} 6s^2\ 6p^2$

Atomic and physical properties: group 14 elements

Property	Elements				
	Carbon	Silicon	Germanium	Tin	Lead
Atomic number	6	14	32	50	82
Atomic mass(g/mol)	12.01	28.09	72.60	118.71	207.2
Electronic configuration	$[He]2s^2 2p^2$	$[Ne]3s^2 3p^2$	$[Ar]3d^{10} 4s^2 4p^2$	$[Kr]4d^{10} 5s^2 5p^2$	$[Xe]4f^{14} 5d^{10} 6 s^2 6p^2$
Covalent radius/pm	77	118	122	140	146
Ionic radiusM^{4+}/pm	_	40	53	69	78
Ionic radius M^{2+}/pm	_	_	73	118	119
Ionization enthalpy/Kjmol^{-1} ($\Delta_i H$)	1086	786	761	708	715
Electronegativity	2.5	1.8	1.8	1.8	1.9
Density/g cm-3	3.51	2.34	5.32	7.26	11.34
Melting point/K	4373	1693	1218	505	600
Boiling point/K	_	3550	3123	2896	2024
Electrical resistivity/ohm cm	10^{14}-10^{16}	50	50	10^{-5}	2 X 10^{-5}

Chemical properties

Oxidation state:-

- Carbon and silicon have +4 oxidation state.
- C & Si have very rare +2 compounds.
- Ge, Sn & Pb show both +2 and +4 oxidation states.
- The +2 state is more stable than +4 state as we go down the group.
- Fajan's rule:- "smaller is the cation, the greater is the covalent character in its compounds". Eg Sn^{4+} compounds are covalent and Sn^{2+} compounds are ionic in nature.

Chemical properties (CONT----)

Catenation:-

- The property of self linkage leading to the formation of long chains and rings is termed catenation.
- Carbon has a greater tendency of self linking than other elements.
- Catenation tendency follows follows the order,

C >> Si > Ge ≈ Sn >> Pb

Bond	C–C	Si–Si	Ge–Ge	Sn–Sn
Bond enthalpy ($Kjmol^{-1}$)	348	222	167	155
- Since, the M–M bond enthalpy decreases steadily from C to Sn. Therefore, the catenation tendency also decreases down the group.

Chemical properties (CONT----)

Formation of multiple bonds :- pi bonding

- Carbon forms stable multiple bonds with itself and with other elements.
- **>C=C< –C≡C– >C=O >C=N –C≡N >C=S**
- Other elements of this group show no tendency to form pi bonds.
- However a few compounds containing multiple bonds have been isolated.
- Effect of pi bonding on the structure may be seen in graphite.

Chemical properties (CONT---)

Hydride formation:-

- Covalent hydrides of the type MH_4 are known for all group 14 elements except lead.
- Tendency of hydride formation decreases in going from C to Pb.
- Carbon forms a large number of cyclic and acyclic hydrides known as hydrocarbons.
- Silicon and germanium form fewer hydrides of the general formula Si_nH_{2n+2} & Ge_nH_{2n+2} known as silanes and germanes respectively..

Chemical properties (CONT---)

Oxide formation:-

- Group 14 elements form three types of oxides:-
- **MO(monoxide) MO_2(Dioxide) M_2O_3(MO+MO_2)(Mixed oxide)**
- All elements of group14 expect silicon form monoxides of the formula MO.
- While CO is neutral, all other oxides are basic in character.
- Carbon monoxide(CO) is the most important monoxide.
- All group14 elements form dioxides having the formula MO_2.
- These oxides differ in their properties and structures.

Chemical properties (CONT---)

Halide formation:-

- Elements of group14 form the following types of halides,

MX_4 type eg., CCL_4 (carbon tetrachloride)

MHX_3 type eg., $CHCL_3$ (Chloroform)

MX_2 type eg., $SICL_2$ (Silicon dichloride)

- Dihalides of Ge, Sn & Pb are more ionic in nature.
- The stability of dihalides increases in going down the group
- Tetrahalides of the type MX_4 are known for all the elements of group14.
- Tetrahalides are tetradedral and covalent.
- The tetrahalides of all elements except of carbon undergo hydrolysis.

CARBON

Introduction

- **Symbol :-**C.
- **Latin word:-** "carbo" meaning"charcoal"
- **Atomic Number** = 6, **Atomic Mass** = 12.01
- **Most common element:** graphite, diamonds and coal.
- **Most common compounds:-** Hydrocarbons and Carbon dioxide.

Physical Properties

- Carbon is a soft, dull gray or black non-metal that can be scratched with a fingernail.
- The density of carbon as graphite is 2.267 g/mL, which means it will sink in water.

CARBON-Uses

Diamond

- Jewellery
- Manufacturing tools
- In making dies

Graphite

- Lubricant at high temperature
- Manufacturing lead pencils

Coal

- Fuel
- Manufacturing coal tar, coke and coal gas
- Manufacturing synthetic petrol

SILICON

Introduction

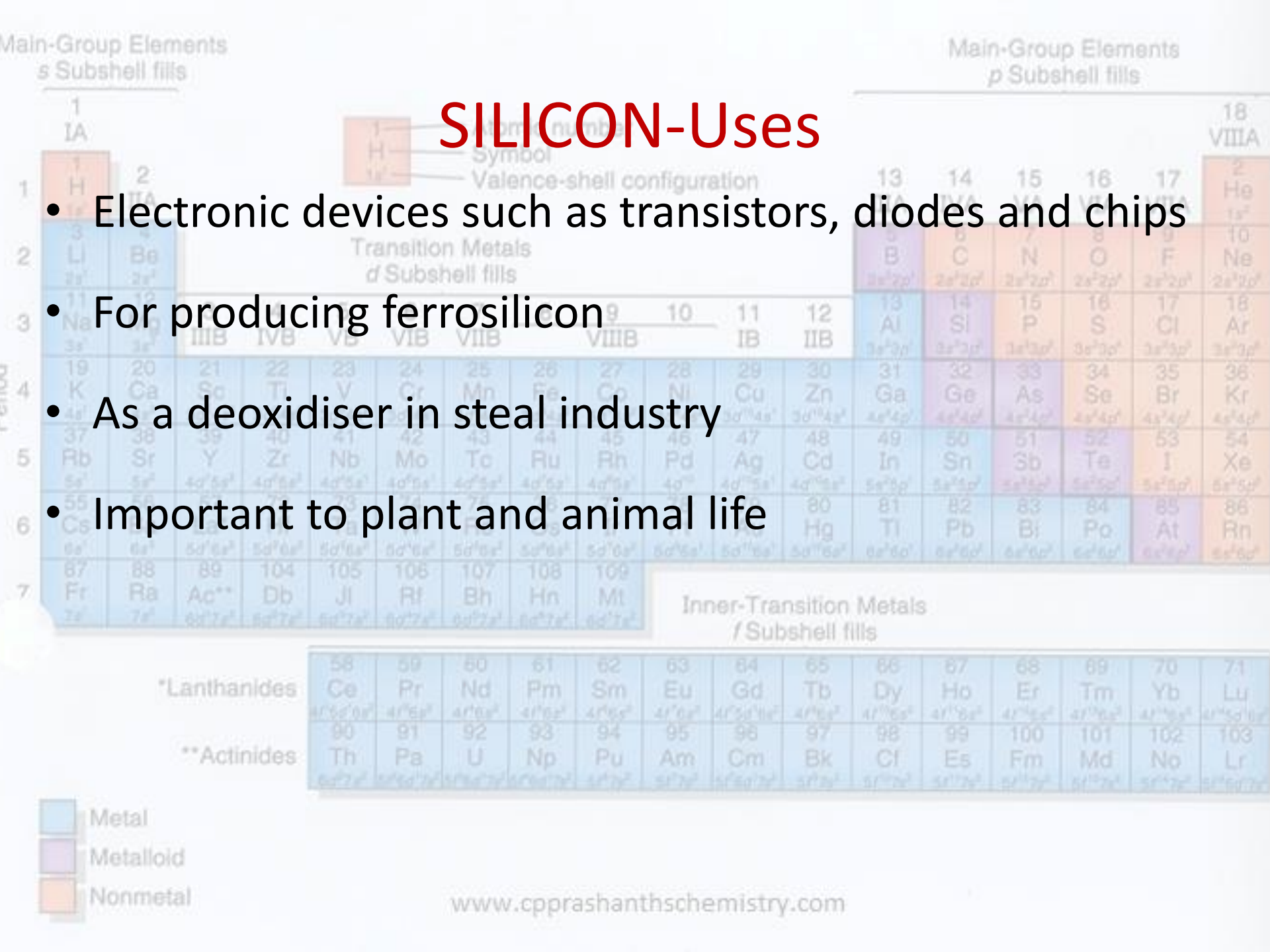
- **Symbol :-**Si.
- **Latin word:-** “Silicium”
- **Atomic Number** = 14, **Atomic Mass** = 28.09
- **Most common compounds:-**Silicon dioxide (SiO_2),Silicon carbide (SiC),Sodium silicate (Na_2SiO_3) and Silicon tetrachloride ($SiCl_4$)

Physical Properties

- Crystalline silicon has a metallic grayish color
- Silicon is relatively inert, but it is attacked by dilute alkali and by halogens
- Silicon transmits over 95% of all infrared wavelengths (1.3-6.7 mm)

SILICON-Uses

- Electronic devices such as transistors, diodes and chips
- For producing ferrosilicon
- As a deoxidiser in steal industry
- Important to plant and animal life



GERMANIUM

Introduction

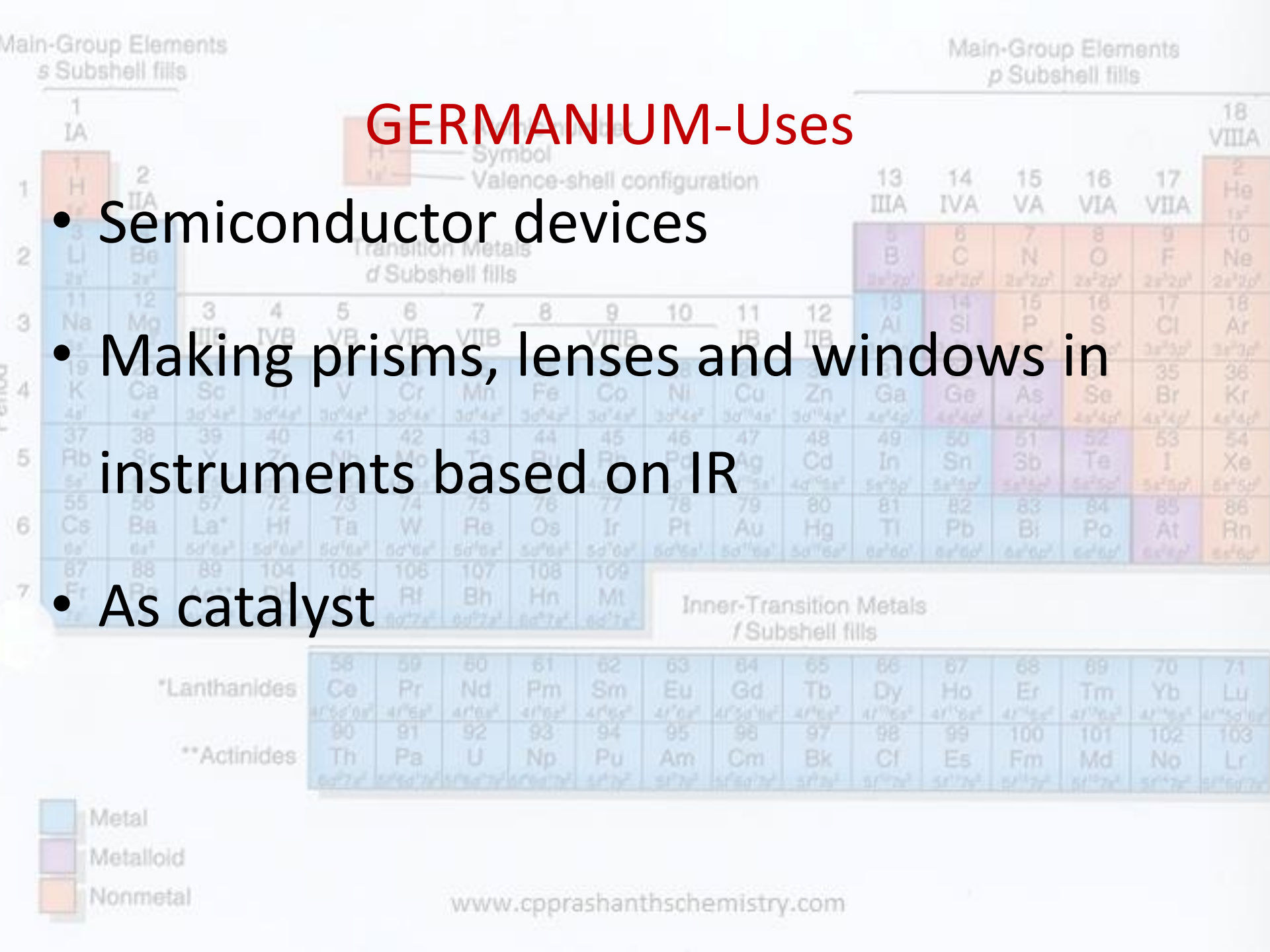
- **Symbol** :-Ge
- **Latin word:-** “Germania”
- **Atomic Number** = 32, **Atomic Mass** = 72.60
- **Most common compounds:-** Oxide(s): GeO, GeO_2 Chloride(s): $GeCl_2$, $GeCl_4$, Hydride(s): GeH_4, Ge_2H_6

Physical Properties

- Germanium is a lustrous, hard, gray-white semi-metallic element
- Germanium expands as it freezes
- It is a semiconductor
- Germanium and the oxide are transparent to infrared radiation

GERMANIUM-Uses

- Semiconductor devices
- Making prisms, lenses and windows in instruments based on IR
- As catalyst



TIN

Introduction

- **Symbol** :-Sn
- **Latin word:-** “Stannum”
- **Atomic Number** = 50, **Atomic Mass** = 118.69
- **Most common compounds**:-SnF_4, $Sncl_4$, $Snbr_4$ and $SnCl_2$

Physical Properties

- Tin is a malleable silvery-white metal which takes a high polish
- It possesses a highly crystalline structure and is moderately ductile.
- When a bar of tin is bent, the crystals break, producing a characteristic 'tin cry‘.
- Tin has a cubic structure.
- Upon warming, at 13.2°C gray tin changes to white

TIN-Uses

- For tinning of copper and brass utensils
- For making tin foils for wrapping cigarettes
- For making alloy:- solder, bronze and gun metal
- Sno_2 coated glass is scratch resistant i.e. aircraft windows
- Used in agriculture to control fungi such as potato blight

LEAD

Introduction

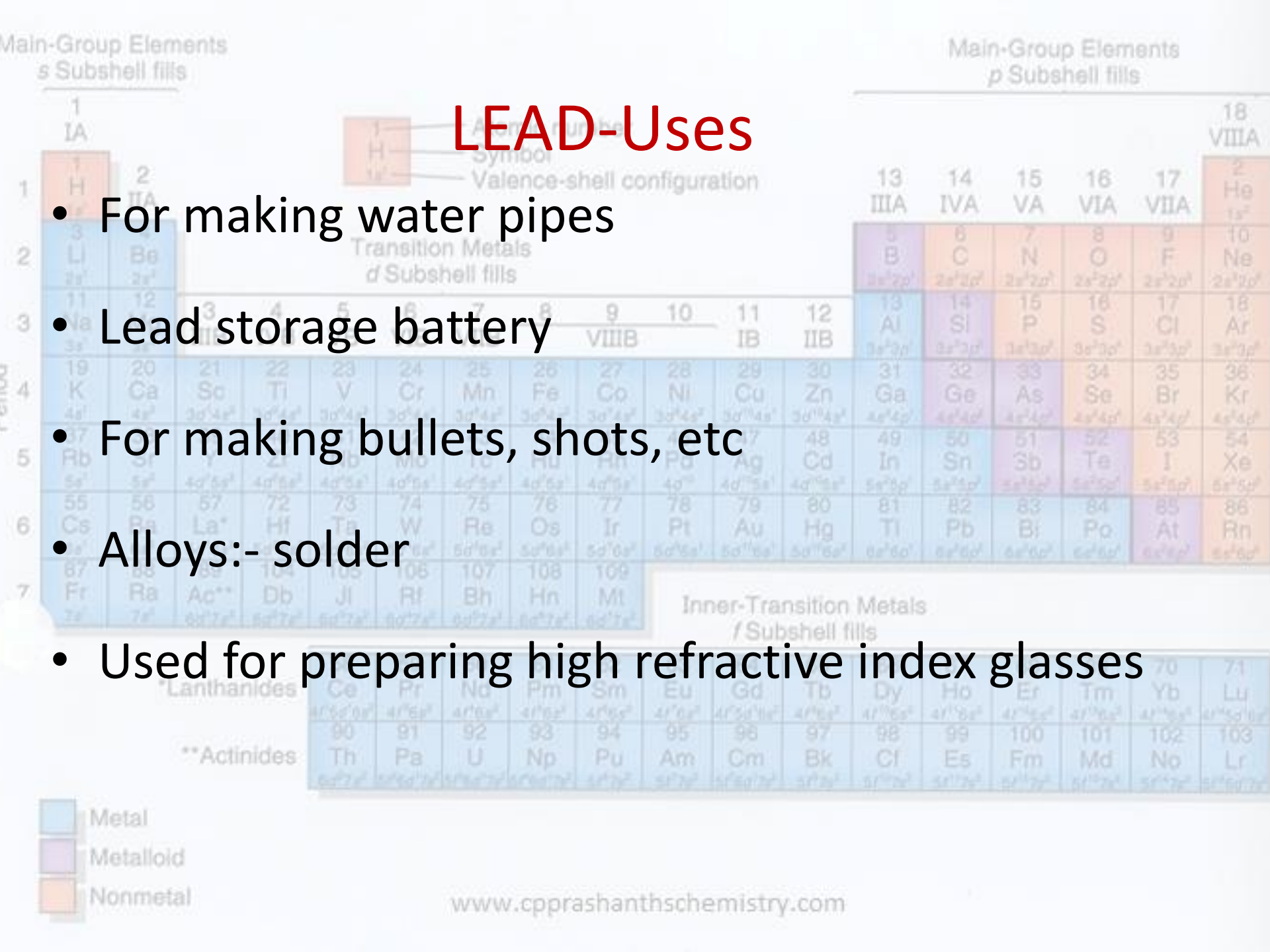
- **Symbol** :-Pb
- **Latin word:-** “plumbum”
- **Atomic Number** = 82, **Atomic Mass** = 207.19
- **Most common compounds**:- $PbCl_2$,PbO_2 ,$Pb(NO_2)_2$,Pb_3O_4 ,$Pb(CH_3)_4$

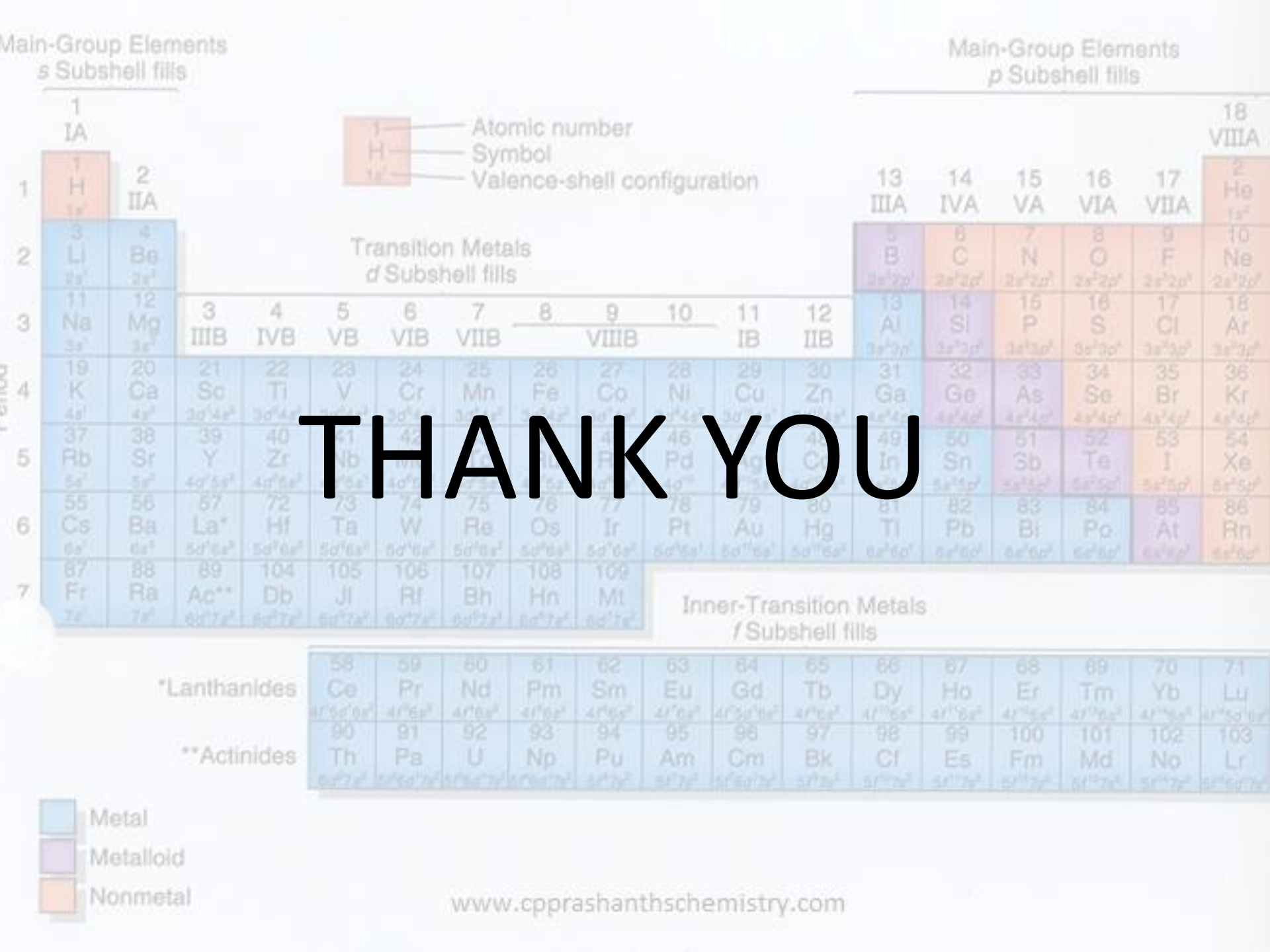
Physical Properties

- Lead is a soft, malleable and poor metal
- It is also counted as one of the heavy metals
- Metallic lead has a bluish-white color after being freshly cut, but it soon tarnishes to a dull grayish color when exposed to air
- Lead has a shiny chrome-silver luster when it is melted into a liquid

LEAD-Uses

- For making water pipes
- Lead storage battery
- For making bullets, shots, etc
- Alloys:- solder
- Used for preparing high refractive index glasses




Main-Group Elements
s Subshell fills
Main-Group Elements
p Subshell fills
Atomic number
Symbol
Valence-shell configuration
Transition Metals
d Subshell fills
Inner-Transition Metals
f Subshell fills
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