GROUP 14 ELEMENTS: THE CARBON FAMILY

The elements belonging to Group 14 represent the second group within the p-block of the periodic table and are commonly referred as the carbon group.

Silicon holds the position of being the second most prevalent element in the Earth's crust, accounting for approximately 27.7% of its composition. On the other hand, carbon ranks as the seventeenth most abundant element in the Earth's crust but is of paramount importance in the constitution of all living organisms. The organic chemistry realm has witnessed the discovery of over 5 million compounds to date, with a continuous exploration leading to the identification of approximately 40,000 new organic compounds annually.

The versatile applications of silicon include its use in the manufacturing of cement, glass, transistors, and semiconductors. Tin finds application in various alloys, contributing to its significance in different industrial processes. Tin predominantly occurs as cassiterite (SnO), while lead is commonly found in the form of galena (PbS).

Germanium plays a crucial role in the field of electronics, particularly in the production of transistors. Lead, besides its presence in galena, is extensively utilized in the manufacturing of glass, paints, and varnish. Each element within this diverse set contributes uniquely to various industries, showcasing the wide-ranging applications and significance of these elements in our daily lives.

Element	Element Name	Atomic number	Electronic configuration	Group Number	Period number
C	Carbon	6	[He] $2s^2$ $2p^2$	14	1
Si	Silicon	14	[Ne] $3s^2$ $3p^2$	14	2
Ge	Germanium	32	[Ar] $3d^{10}$ $4s^2$ $4p^2$	14	3
Sn	Tin	50	[Kr] $4d^{10}$ $5s^2 5p^2$	14	4
pb	Lead	82	[Xe] $4f^{14}$ $5d^{10}$ $6s^2$ $6p^2$	14	5

Atomic Properties of Carbon Family

- Atomic Number: Carbon possesses an atomic number of 6, signifying the number of protons found in its nucleus.
- Atomic Mass: The atomic mass of carbon is measured at 12.011 grams per mole (g mol-1), representing the average mass of carbon atoms.
- Electronegativity: As per Pauling's scale, the electronegativity of carbon is determined to be 2.5, indicating its relative ability to attract and share electrons in a chemical bond.
- Atomic Radii: In comparison to the elements in Group 13, the atomic radii of Group 14 elements are smaller. Nonetheless, as one progresses down the group, there is an observable increase in atomic radii.
- Ionization Energies: The heightened ionization energies observed in Group 14 elements, as opposed to those in Group 13, can be attributed to the combination of a greater nuclear charge and the smaller size of the atoms within Group 14. The trend in ionization energies follows a decrease as one moves down the group, illustrated by the order C > Si > Ge > Sn < Pb.

Physical Properties of Carbon Family

- Every member of group 14 exists in a solid state.
- Carbon and silicon are non-metals, germanium falls into the metalloid category, while tin and lead are characterized as malleable metals with relatively low melting points.
- The elevated melting and boiling points observed in group 14 elements, as compared to their counterparts in group 13, can be attributed to the presence of stronger metallic bonds.
- Carbon stands out as a unique element, exhibiting itself in diverse forms.

Examples of carbon in its pure state include substances like coal and soot.

- Carbon, characterized by its softness, possesses a dull grey or black coloration.
- An integral carbon compound is charcoal, formed through the process of heating carbon in the absence of air.
- Carbon exists in various allotropic forms, where allotropes represent different manifestations of the element, each possessing distinct physical and chemical properties.
- The density of different carbon forms is contingent upon their origin. Some carbon forms are entirely pure, while others, such as coal, constitute a mixture of both carbon and hydrogen.

Chemical Properties

1. Reactivity towards Air

All members within this group exhibit the formation of monoxides with the general formula MO, including compounds like CO, SiO, SnO, and PbO. Additionally, they produce dioxides with the molecular formula MO_2, such as CO_2, SiO_2, GeO_2, SnO_2, and PbO_2. While CO_2 remains monomeric, SiO_2 adopts a 3-dimensional network solid structure. On the other hand, GeO_2, SnO_2, and PbO_2 all exhibit network solids with octahedral coordination. Dioxides, including CO_2, SiO_2, and GeO_2, demonstrate acidic properties, whereas dioxides (SnO_2 and PbO_2) and monoxides (SnO and PbO) display amphoteric behavior. CO, a monoxide, is neutral, while GeO, another monoxide, exhibits distinct acidity.

2. Reactivity towards Water

Within this group, carbon, silicon, and germanium react with water, whereas lead is unaffected due to the formation of a protective oxide film. Tin, however, decomposes in the presence of steam, resulting in the formation of tin dioxide and hydrogen gas.

3. Reactivity towards Halogen

Element in pure state	Type of bonding	Melting Point
C	Covalent	4100 deg C
Si	Covalent	1420 deg C
Ge	Covalent	945 deg C
Sn	Metallic	232 deg C
Pb	Metallic	327 deg C

- Reactivity refers to an atom's capacity to either lose or gain electrons, allowing it to actively engage in various chemical reactions.
- The elements located within Group 17 or VIIA of the periodic table are commonly known as halogens. This group comprises Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), Astatine (At), and Tennessine (Ts).
- As one descends the halogen group, the atomic size of the constituent atoms expands due to an increase in the number of electron shells. This enlargement in atomic size diminishes the nucleus' attraction for incoming electrons, resulting in decreased reactivity. Consequently, the reactivity of halogens experiences a decline down the group.
- Within Group 17, Fluorine (F) occupies the highest position, succeeded by Chlorine, Bromine, Iodine, Astatine, and Tennessine.
- Owing to the diminishing reactivity observed down the halogen group, Fluorine emerges as the most reactive halogen, trailed by Chlorine, Bromine, Iodine, Astatine, and Tennessine in sequence.

4. **Hydrolysis of Halides**

The chlorides, with the exception of CCl_4, readily undergo hydrolysis when exposed to water. The reaction involving $SiCl_4$ and H_2O yields silicic acid ($Si(OH)_4$) and releases 4 HCl molecules:

$$SiCl_4 + H_2O \rightarrow \underset{\text{Silicic acid}}{Si(OH)_4} + 4HCl$$

Similarly, the hydrolysis of silicon tetrafluoride results in the formation of silica and fluor silicic acid:

$$3SiF_4 + 2H_2O \rightarrow \underset{\text{Silica}}{SiO_2} + \underset{\text{Fluorosilicic acid}}{2H_2SiFF_6}$$

This process highlights that silicon tetrafluoride reacts with water to produce Silica (SiO_2) along with Fluor silicic acid ($2H_2SiF_6$):

$$3SiF_4 + 2H_2O \rightarrow \underset{\text{Silica}}{SiO_2} + \underset{\text{Fluorosilicic acid}}{2H_2SiFF_6}$$

Furthermore, carbon tetrahalides, lacking available vacant d-orbitals, are incapable of increasing their coordination number, and consequently, they do not form complexes. In contrast, compounds with accessible vacant d-orbitals have the capability to form complexes.

Ex: Provide the accurate sequence of ascending first ionization energy within the carbon family.

Sol: The correct order is as follows:

Carbon (C) > Silicon (Si) > Germanium (Ge) > Lead (Pb) > Tin (Sn).