Carbon (C) – The Element of Life and the Backbone of Organic Chemistry

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# 1. General Information

- Symbol: C
- Atomic Number: 6
- Atomic Mass: 12.01 u
- Group: 14 (Carbon Group)
- Period: 2
- Block: p-block
- Electron Configuration: $1s^2\ 2s^2\ 2p^2$
- Valence Electrons: 4
- Phase at Room Temperature: Solid

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## 2. Isotopes of Carbon

| Isotope | Protons | Neutrons | Abundance | Notes |
|---|---|---|---|---|
| $^{12}C$ | 6 | 6 | 98.9% | Stable (most common). |
| $^{13}C$ | 6 | 7 | 1.1% | Stable, used in NMR spectroscopy. |
| $^{14}C$ | 6 | 8 | Trace | Radioactive (used in carbon dating). |

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## 3. Allotropes of Carbon

| Allotrope | Structure | Properties | Uses |
|---|---|---|---|
| Diamond | Tetrahedral (3D lattice) | Hard, transparent, non-conductive. | Jewelry, cutting tools, electronics. |
| Graphite | Layered (2D sheets) | Soft, conducts electricity. | Pencils, lubricants, batteries. |
| Graphene | Single-layer of graphite | Strong, lightweight, conductive. | Electronics, composites. |
| Fullerenes ($C_{60}$) | Spherical (Buckyballs) | Hollow, high strength. | Nanotechnology, medicine. |
| Carbon Nanotubes | Cylindrical tubes | Extremely strong and conductive. | Electronics, materials, space tech. |
| Amorphous Carbon | Disordered structure | Varies in hardness and conductivity. | Activated carbon, carbon black. |

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## 4. Physical Properties

- Color: Black (graphite), Clear (diamond).
- Density:
  - Diamond: 3.51 $g/cm^3$
  - Graphite: 2.26 $g/cm^3$
- Melting Point: Sublimes at 3,642°C.
- Boiling Point: 4,827°C.

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## 5. Chemical Properties

- Valency: 4 (can form 4 covalent bonds).
- Reactivity:
  - At High Temperatures: Reacts with oxygen, producing CO or $CO_2$.
  - Forms Compounds with Hydrogen, Oxygen, and Halogens.
- Combustion:

$C + O_2 \rightarrow CO_2$ (Complete Combustion)
$C + \frac{1}{2}O_2 \rightarrow CO$ (Incomplete Combustion)

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## 6. Occurrence and Abundance

- Fourth most abundant element in the universe.
- Found in:
  - Atmosphere: As $CO_2$.
  - Earth's Crust: In carbonates (limestone).
  - Organic Compounds: In all living organisms (proteins, fats, carbohydrates).
  - Fossil Fuels: Coal, oil, and natural gas.

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## 7. The Carbon Cycle

- Key Process: Movement of carbon between the atmosphere, oceans, plants, animals, and fossil fuels.
- Stages:
  - Photosynthesis: $CO_2 \rightarrow$ Glucose (by plants).
  - Respiration: Glucose $\rightarrow CO_2$ (by animals/plants).
  - Combustion: Fossil fuels $\rightarrow CO_2$.
  - Decomposition: Organic matter $\rightarrow$ Carbon in soil.

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## 8. Industrial Uses of Carbon

| Application | Description |
|---|---|
| Steel Production | Carbon is a key component in steel alloys. |
| Electronics | Graphene and nanotubes in advanced tech. |
| Energy Storage | Graphite in lithium-ion batteries. |
| Filtration | Activated carbon for water and air purification. |
| Fuel | Coal, oil, natural gas. |
| Medical | Fullerenes and carbon nanotubes for drug delivery. |

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## 9. Important Carbon Compounds

| Compound | Formula | Use |
|---|---|---|
| Carbon Dioxide | $CO_2$ | Greenhouse gas, used in beverages. |
| Carbon Monoxide | CO | Poisonous gas, produced by combustion. |
| Methane | $CH_4$ | Natural gas, fuel. |
| Calcium Carbonate | $CaCO_3$ | Chalk, limestone, antacids. |
| Carbon Tetrachloride | $CCl_4$ | Used as a solvent (now restricted). |

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## 10. Biological Importance of Carbon

- Basis of Organic Chemistry – Forms the backbone of DNA, proteins, fats, and carbohydrates.
- Essential for Life – Present in all known life forms.
- Carbon Bonds: Can form single, double, and triple bonds with other elements.

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## 11. Safety and Toxicity

- Graphite and Diamond – Non-toxic and safe.
- Carbon Monoxide (CO): Highly toxic, binds to hemoglobin and reduces oxygen transport.

- Carbon Dust (Amorphous Carbon): Can cause lung disease if inhaled in large quantities.

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## Fun Facts About Carbon:

- Diamonds are formed from carbon under extreme heat and pressure deep within the Earth.
- Graphene is 200 times stronger than steel but incredibly lightweight.
- Carbon dating (using $^{14}C$) can determine the age of ancient fossils and artifacts.
- All living organisms are carbon-based, making it the building block of life.