[This is a good article. Follow the link for more information.](https://en.wikipedia.org/wiki/Wikipedia:Good_articles)

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**Carbon**

From Wikipedia, the free encyclopedia

[Jump to navigation](https://en.wikipedia.org/wiki/Carbon#mw-head) [Jump to search](https://en.wikipedia.org/wiki/Carbon#p-search)

This article is about the chemical element. For other uses, see [Carbon (disambiguation)](https://en.wikipedia.org/wiki/Carbon_(disambiguation)).

"Element 6" redirects here. For the company, see [Element Six](https://en.wikipedia.org/wiki/Element_Six).

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| --- | --- |
| Carbon,  6C | |
| [Graphite-and-diamond-with-scale.jpg](https://en.wikipedia.org/wiki/File:Graphite-and-diamond-with-scale.jpg)  Graphite (left) and diamond (right), two allotropes of carbon | |
| **General properties** | |
| [**Allotropes**](https://en.wikipedia.org/wiki/Allotropy) | [graphite](https://en.wikipedia.org/wiki/Graphite), [diamond](https://en.wikipedia.org/wiki/Diamond) |
| **Appearance** | graphite: black diamond: clear |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | [12.0096, 12.0116] conventional: 12.011 |
| **Carbon in the** [**periodic table**](https://en.wikipedia.org/wiki/Periodic_table) | |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 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[Sodium](https://en.wikipedia.org/wiki/Sodium) | [Magnesium](https://en.wikipedia.org/wiki/Magnesium) |  | | | | | | | | | | | | | | | | | | | | | | | | [Aluminium](https://en.wikipedia.org/wiki/Aluminium) | [Silicon](https://en.wikipedia.org/wiki/Silicon) | [Phosphorus](https://en.wikipedia.org/wiki/Phosphorus) | [Sulfur](https://en.wikipedia.org/wiki/Sulfur) | [Chlorine](https://en.wikipedia.org/wiki/Chlorine) | [Argon](https://en.wikipedia.org/wiki/Argon) | | [Potassium](https://en.wikipedia.org/wiki/Potassium) | [Calcium](https://en.wikipedia.org/wiki/Calcium) | [Scandium](https://en.wikipedia.org/wiki/Scandium) |  | | | | | | | | | | | | | | [Titanium](https://en.wikipedia.org/wiki/Titanium) | [Vanadium](https://en.wikipedia.org/wiki/Vanadium) | [Chromium](https://en.wikipedia.org/wiki/Chromium) | [Manganese](https://en.wikipedia.org/wiki/Manganese) | [Iron](https://en.wikipedia.org/wiki/Iron) | [Cobalt](https://en.wikipedia.org/wiki/Cobalt) | [Nickel](https://en.wikipedia.org/wiki/Nickel) | [Copper](https://en.wikipedia.org/wiki/Copper) | [Zinc](https://en.wikipedia.org/wiki/Zinc) | [Gallium](https://en.wikipedia.org/wiki/Gallium) | [Germanium](https://en.wikipedia.org/wiki/Germanium) | [Arsenic](https://en.wikipedia.org/wiki/Arsenic) | [Selenium](https://en.wikipedia.org/wiki/Selenium) | [Bromine](https://en.wikipedia.org/wiki/Bromine) | [Krypton](https://en.wikipedia.org/wiki/Krypton) | | [Rubidium](https://en.wikipedia.org/wiki/Rubidium) | [Strontium](https://en.wikipedia.org/wiki/Strontium) | [Yttrium](https://en.wikipedia.org/wiki/Yttrium) |  |  | | | | | | | | | | | | | [Zirconium](https://en.wikipedia.org/wiki/Zirconium) | [Niobium](https://en.wikipedia.org/wiki/Niobium) | [Molybdenum](https://en.wikipedia.org/wiki/Molybdenum) | [Technetium](https://en.wikipedia.org/wiki/Technetium) | [Ruthenium](https://en.wikipedia.org/wiki/Ruthenium) | [Rhodium](https://en.wikipedia.org/wiki/Rhodium) | [Palladium](https://en.wikipedia.org/wiki/Palladium) | [Silver](https://en.wikipedia.org/wiki/Silver) | [Cadmium](https://en.wikipedia.org/wiki/Cadmium) | [Indium](https://en.wikipedia.org/wiki/Indium) | [Tin](https://en.wikipedia.org/wiki/Tin) | [Antimony](https://en.wikipedia.org/wiki/Antimony) | [Tellurium](https://en.wikipedia.org/wiki/Tellurium) | [Iodine](https://en.wikipedia.org/wiki/Iodine) | [Xenon](https://en.wikipedia.org/wiki/Xenon) | | [Caesium](https://en.wikipedia.org/wiki/Caesium) | [Barium](https://en.wikipedia.org/wiki/Barium) | [Lanthanum](https://en.wikipedia.org/wiki/Lanthanum) | [Cerium](https://en.wikipedia.org/wiki/Cerium) | [Praseodymium](https://en.wikipedia.org/wiki/Praseodymium) | [Neodymium](https://en.wikipedia.org/wiki/Neodymium) | [Promethium](https://en.wikipedia.org/wiki/Promethium) | [Samarium](https://en.wikipedia.org/wiki/Samarium) | [Europium](https://en.wikipedia.org/wiki/Europium) | [Gadolinium](https://en.wikipedia.org/wiki/Gadolinium) | [Terbium](https://en.wikipedia.org/wiki/Terbium) | [Dysprosium](https://en.wikipedia.org/wiki/Dysprosium) | [Holmium](https://en.wikipedia.org/wiki/Holmium) | [Erbium](https://en.wikipedia.org/wiki/Erbium) | [Thulium](https://en.wikipedia.org/wiki/Thulium) | [Ytterbium](https://en.wikipedia.org/wiki/Ytterbium) | [Lutetium](https://en.wikipedia.org/wiki/Lutetium) | [Hafnium](https://en.wikipedia.org/wiki/Hafnium) | [Tantalum](https://en.wikipedia.org/wiki/Tantalum) | [Tungsten](https://en.wikipedia.org/wiki/Tungsten) | [Rhenium](https://en.wikipedia.org/wiki/Rhenium) | [Osmium](https://en.wikipedia.org/wiki/Osmium) | [Iridium](https://en.wikipedia.org/wiki/Iridium) | [Platinum](https://en.wikipedia.org/wiki/Platinum) | [Gold](https://en.wikipedia.org/wiki/Gold) | [Mercury (element)](https://en.wikipedia.org/wiki/Mercury_(element)) | [Thallium](https://en.wikipedia.org/wiki/Thallium) | [Lead](https://en.wikipedia.org/wiki/Lead) | [Bismuth](https://en.wikipedia.org/wiki/Bismuth) | [Polonium](https://en.wikipedia.org/wiki/Polonium) | [Astatine](https://en.wikipedia.org/wiki/Astatine) | [Radon](https://en.wikipedia.org/wiki/Radon) | | [Francium](https://en.wikipedia.org/wiki/Francium) | [Radium](https://en.wikipedia.org/wiki/Radium) | [Actinium](https://en.wikipedia.org/wiki/Actinium) | [Thorium](https://en.wikipedia.org/wiki/Thorium) | [Protactinium](https://en.wikipedia.org/wiki/Protactinium) | [Uranium](https://en.wikipedia.org/wiki/Uranium) | [Neptunium](https://en.wikipedia.org/wiki/Neptunium) | [Plutonium](https://en.wikipedia.org/wiki/Plutonium) | [Americium](https://en.wikipedia.org/wiki/Americium) | [Curium](https://en.wikipedia.org/wiki/Curium) | [Berkelium](https://en.wikipedia.org/wiki/Berkelium) | [Californium](https://en.wikipedia.org/wiki/Californium) | [Einsteinium](https://en.wikipedia.org/wiki/Einsteinium) | [Fermium](https://en.wikipedia.org/wiki/Fermium) | [Mendelevium](https://en.wikipedia.org/wiki/Mendelevium) | [Nobelium](https://en.wikipedia.org/wiki/Nobelium) | [Lawrencium](https://en.wikipedia.org/wiki/Lawrencium) | [Rutherfordium](https://en.wikipedia.org/wiki/Rutherfordium) | [Dubnium](https://en.wikipedia.org/wiki/Dubnium) | [Seaborgium](https://en.wikipedia.org/wiki/Seaborgium) | [Bohrium](https://en.wikipedia.org/wiki/Bohrium) | [Hassium](https://en.wikipedia.org/wiki/Hassium) | [Meitnerium](https://en.wikipedia.org/wiki/Meitnerium) | [Darmstadtium](https://en.wikipedia.org/wiki/Darmstadtium) | [Roentgenium](https://en.wikipedia.org/wiki/Roentgenium) | [Copernicium](https://en.wikipedia.org/wiki/Copernicium) | [Nihonium](https://en.wikipedia.org/wiki/Nihonium) | [Flerovium](https://en.wikipedia.org/wiki/Flerovium) | [Moscovium](https://en.wikipedia.org/wiki/Moscovium) | [Livermorium](https://en.wikipedia.org/wiki/Livermorium) | [Tennessine](https://en.wikipedia.org/wiki/Tennessine) | [Oganesson](https://en.wikipedia.org/wiki/Oganesson) | | – ↑ **C** ↓ [Si](https://en.wikipedia.org/wiki/Silicon) | | [boron](https://en.wikipedia.org/wiki/Boron) ← **carbon** → [nitrogen](https://en.wikipedia.org/wiki/Nitrogen) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 6 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 14 (carbon group)](https://en.wikipedia.org/wiki/Carbon_group) |
| [**Period**](https://en.wikipedia.org/wiki/Period_(periodic_table)) | [period 2](https://en.wikipedia.org/wiki/Period_(periodic_table)#Period_2) |
| [**Block**](https://en.wikipedia.org/wiki/Block_(periodic_table)) | [p-block](https://en.wikipedia.org/wiki/P-block) |
| [**Element category**](https://en.wikipedia.org/wiki/Names_for_sets_of_chemical_elements#Category) | [reactive nonmetal](https://en.wikipedia.org/wiki/Reactive_nonmetal), sometimes considered a [metalloid](https://en.wikipedia.org/wiki/Metalloid) |
| [**Electron configuration**](https://en.wikipedia.org/wiki/Electron_configuration) | [[He](https://en.wikipedia.org/wiki/Helium)] 2s2 2p2 |
| Electrons per shell | 2, 4 |
| **Physical properties** | |
| [**Phase**](https://en.wikipedia.org/wiki/Phase_(matter)) **at**[**STP**](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure) | [solid](https://en.wikipedia.org/wiki/Solid) |
| [**Sublimation point**](https://en.wikipedia.org/wiki/Sublimation_point) | 3915 K ​(3642 °C, ​6588 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | amorphous: 1.8–2.1 g/cm3[[1]](https://en.wikipedia.org/wiki/Carbon#cite_note-CRC-1)  graphite: 2.267 g/cm3  diamond: 3.515 g/cm3 |
| [**Triple point**](https://en.wikipedia.org/wiki/Triple_point) | 4600 K, ​10,800 kPa[[2]](https://en.wikipedia.org/wiki/Carbon#cite_note-triple2-2)[[3]](https://en.wikipedia.org/wiki/Carbon#cite_note-triple3-3) |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | graphite: 117 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | graphite: 8.517 J/(mol·K)  diamond: 6.155 J/(mol·K) |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | **−4**, [−3](https://en.wikipedia.org/wiki/Ethane), [−2](https://en.wikipedia.org/wiki/Methanol), [−1](https://en.wikipedia.org/wiki/Carbide), [0](https://en.wikipedia.org/wiki/Formaldehyde), +1,[[4]](https://en.wikipedia.org/wiki/Carbon#cite_note-4) +2, +3,[[5]](https://en.wikipedia.org/wiki/Carbon#cite_note-5) **+4**[[6]](https://en.wikipedia.org/wiki/Carbon#cite_note-6) (a mildly [acidic](https://en.wikipedia.org/wiki/Acidic) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 2.55 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 1086.5 kJ/mol * 2nd: 2352.6 kJ/mol * 3rd: 4620.5 kJ/mol * ([more](https://en.wikipedia.org/wiki/Molar_ionization_energies_of_the_elements#carbon)) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | sp3: 77 pm sp2: 73 pm sp: 69 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Van der Waals radius**](https://en.wikipedia.org/wiki/Van_der_Waals_radius) | 170 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Carbon_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of carbon** | |
| **Other properties** | |
| [**Crystal structure**](https://en.wikipedia.org/wiki/Crystal_structure) | graphite: ​[simple hexagonal](https://en.wikipedia.org/wiki/Hexagonal_crystal_system)  [Simple hexagonal crystal structure for graphite: carbon](https://en.wikipedia.org/wiki/File:Hexagonal.svg)  (black) |
| **Crystal structure** | diamond: ​[face-centered diamond-cubic](https://en.wikipedia.org/wiki/Diamond_cubic)  [Diamond cubic crystal structure for diamond: carbon](https://en.wikipedia.org/wiki/File:Diamond_cubic_crystal_structure.svg)  (clear) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | diamond: 18,350 m/s (at 20 °C) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | diamond: 0.8 µm/(m·K) (at 25 °C)[[7]](https://en.wikipedia.org/wiki/Carbon#cite_note-ioffe-7) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | graphite: 119–165 W/(m·K)  diamond: 900–2300 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | graphite: 7.837 µΩ·m[[8]](https://en.wikipedia.org/wiki/Carbon#cite_note-8) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | [diamagnetic](https://en.wikipedia.org/wiki/Diamagnetic)[[9]](https://en.wikipedia.org/wiki/Carbon#cite_note-9) |
| [**Magnetic susceptibility**](https://en.wikipedia.org/wiki/Magnetic_susceptibility) | −5.9·10−6 (graph.) cm3/mol[[10]](https://en.wikipedia.org/wiki/Carbon#cite_note-10) |
| [**Young's modulus**](https://en.wikipedia.org/wiki/Young%27s_modulus) | diamond: 1050 GPa[[7]](https://en.wikipedia.org/wiki/Carbon#cite_note-ioffe-7) |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | diamond: 478 GPa[[7]](https://en.wikipedia.org/wiki/Carbon#cite_note-ioffe-7) |
| [**Bulk modulus**](https://en.wikipedia.org/wiki/Bulk_modulus) | diamond: 442 GPa[[7]](https://en.wikipedia.org/wiki/Carbon#cite_note-ioffe-7) |
| [**Poisson ratio**](https://en.wikipedia.org/wiki/Poisson%27s_ratio) | diamond: 0.1[[7]](https://en.wikipedia.org/wiki/Carbon#cite_note-ioffe-7) |
| [**Mohs hardness**](https://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness) | graphite: 1–2  diamond: 10 |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-44-0 |
| **History** | |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) | [Egyptians](https://en.wikipedia.org/wiki/Ancient_Egypt) and [Sumerians](https://en.wikipedia.org/wiki/Sumer)[[11]](https://en.wikipedia.org/wiki/Carbon#cite_note-11) (3750 BCE) |
| **Recognized as an element by** | [Antoine Lavoisier](https://en.wikipedia.org/wiki/Antoine_Lavoisier)[[12]](https://en.wikipedia.org/wiki/Carbon#cite_note-12) (1789) |
| **Main** [**isotopes of carbon**](https://en.wikipedia.org/wiki/Isotopes_of_carbon) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**Iso­tope**](https://en.wikipedia.org/wiki/Isotope) | [**Abun­dance**](https://en.wikipedia.org/wiki/Natural_abundance) | [**Half-life**](https://en.wikipedia.org/wiki/Half-life) **(*t*1/2)** | [**Decay mode**](https://en.wikipedia.org/wiki/Radioactive_decay) | [**Pro­duct**](https://en.wikipedia.org/wiki/Decay_product) | | [**11C**](https://en.wikipedia.org/wiki/Carbon-11) | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 20 min | [β+](https://en.wikipedia.org/wiki/Beta_emission) | [11B](https://en.wikipedia.org/wiki/Boron-11) | | [**12C**](https://en.wikipedia.org/wiki/Carbon-12) | 98.9% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | [**13C**](https://en.wikipedia.org/wiki/Carbon-13) | 1.1% | stable | | | | [**14C**](https://en.wikipedia.org/wiki/Carbon-14) | [trace](https://en.wikipedia.org/wiki/Trace_radioisotope) | 5730 y | [β−](https://en.wikipedia.org/wiki/Beta_emission) | [14N](https://en.wikipedia.org/wiki/Nitrogen-14) | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_carbon) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_carbon) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_carbon&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Carbon** (from [Latin](https://en.wikipedia.org/wiki/Latin_language): *carbo* "coal") is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with [symbol](https://en.wikipedia.org/wiki/Symbol_(chemistry)) **C** and [atomic number](https://en.wikipedia.org/wiki/Atomic_number) 6. It is [nonmetallic](https://en.wikipedia.org/wiki/Nonmetal) and [tetravalent](https://en.wikipedia.org/wiki/Tetravalence)—making four [electrons](https://en.wikipedia.org/wiki/Electron) available to form [covalent](https://en.wikipedia.org/wiki/Covalent_bond) [chemical bonds](https://en.wikipedia.org/wiki/Chemical_bond). It belongs to group 14 of the periodic table.[[16]](https://en.wikipedia.org/wiki/Carbon#cite_note-16) Three [isotopes](https://en.wikipedia.org/wiki/Isotopes_of_carbon) occur naturally, [12C](https://en.wikipedia.org/wiki/Carbon-12) and [13C](https://en.wikipedia.org/wiki/Carbon-13) being stable, while [14C](https://en.wikipedia.org/wiki/Carbon-14) is a [radionuclide](https://en.wikipedia.org/wiki/Radionuclide), decaying with a [half-life](https://en.wikipedia.org/wiki/Half-life) of about 5,730 years.[[17]](https://en.wikipedia.org/wiki/Carbon#cite_note-isotopes-17) Carbon is one of the [few elements known since antiquity](https://en.wikipedia.org/wiki/Discoveries_of_the_chemical_elements).[[18]](https://en.wikipedia.org/wiki/Carbon#cite_note-D2-18)

Carbon is the 15th [most abundant element in the Earth's crust](https://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust), and the [fourth most abundant element in the universe by mass](https://en.wikipedia.org/wiki/Abundance_of_the_chemical_elements) after [hydrogen](https://en.wikipedia.org/wiki/Hydrogen), [helium](https://en.wikipedia.org/wiki/Helium), and [oxygen](https://en.wikipedia.org/wiki/Oxygen). Carbon's abundance, its unique diversity of [organic compounds](https://en.wikipedia.org/wiki/Organic_compound), and its unusual ability to form [polymers](https://en.wikipedia.org/wiki/Polymer) at the temperatures commonly encountered on [Earth](https://en.wikipedia.org/wiki/Earth) enables this element to serve as a common element of [all known life](https://en.wikipedia.org/wiki/Carbon-based_life). It is the second most abundant element in the [human body](https://en.wikipedia.org/wiki/Human_body) by mass (about 18.5%) after oxygen.[[19]](https://en.wikipedia.org/wiki/Carbon#cite_note-19)

The atoms of carbon can bond together in different ways, termed [allotropes of carbon](https://en.wikipedia.org/wiki/Allotropes_of_carbon). The best known are [graphite](https://en.wikipedia.org/wiki/Graphite), [diamond](https://en.wikipedia.org/wiki/Diamond), and [amorphous carbon](https://en.wikipedia.org/wiki/Amorphous_carbon).[[20]](https://en.wikipedia.org/wiki/Carbon#cite_note-therm_prop-20) The [physical properties](https://en.wikipedia.org/wiki/Physical_property) of carbon vary widely with the allotropic form. For example, graphite is [opaque](https://en.wikipedia.org/wiki/Opacity_(optics)) and black while diamond is highly [transparent](https://en.wikipedia.org/wiki/Transparency_(optics)). Graphite is soft enough to form a streak on paper (hence its name, from the [Greek](https://en.wikipedia.org/wiki/Greeks) verb "γράφειν" which means "to write"), while diamond is the hardest naturally occurring material known. Graphite is a good [electrical conductor](https://en.wikipedia.org/wiki/Electrical_conductor) while diamond has a low [electrical conductivity](https://en.wikipedia.org/wiki/Electrical_conductivity). Under normal conditions, diamond, [carbon nanotubes](https://en.wikipedia.org/wiki/Carbon_nanotube), and [graphene](https://en.wikipedia.org/wiki/Graphene) have the highest [thermal conductivities](https://en.wikipedia.org/wiki/Thermal_conductivity) of [all known materials](https://en.wikipedia.org/wiki/List_of_thermal_conductivities). All carbon allotropes are solids under normal conditions, with graphite being the most [thermodynamically stable](https://en.wikipedia.org/wiki/Thermodynamic_equilibrium) form at standard temperature and pressure. They are chemically resistant and require high temperature to react even with oxygen.

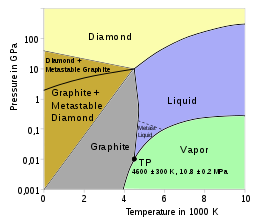
The most common [oxidation state](https://en.wikipedia.org/wiki/Oxidation_state) of carbon in [inorganic compounds](https://en.wikipedia.org/wiki/Inorganic_compound) is +4, while +2 is found in [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide) and [transition metal](https://en.wikipedia.org/wiki/Transition_metal) [carbonyl](https://en.wikipedia.org/wiki/Metal_carbonyl) complexes. The largest sources of inorganic carbon are [limestones](https://en.wikipedia.org/wiki/Limestone), [dolomites](https://en.wikipedia.org/wiki/Dolomite) and [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide), but significant quantities occur in organic deposits of [coal](https://en.wikipedia.org/wiki/Coal), [peat](https://en.wikipedia.org/wiki/Peat), [oil](https://en.wikipedia.org/wiki/Petroleum), and [methane clathrates](https://en.wikipedia.org/wiki/Methane_clathrate). Carbon forms a vast number of [compounds](https://en.wikipedia.org/wiki/Chemical_compound), more than any other element, with almost ten million compounds described to date,[[21]](https://en.wikipedia.org/wiki/Carbon" \l "cite_note-lanl-21) and yet that number is but a fraction of the number of theoretically possible compounds under standard conditions. For this reason, carbon has often been referred to as the "king of the elements".[[22]](https://en.wikipedia.org/wiki/Carbon#cite_note-22)



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**Characteristics**

[](https://en.wikipedia.org/wiki/File:Carbon-phase-diagramp.svg)

Theoretically predicted phase diagram of carbon

The [allotropes of carbon](https://en.wikipedia.org/wiki/Allotropes_of_carbon) include [graphite](https://en.wikipedia.org/wiki/Graphite), one of the softest known substances, and [diamond](https://en.wikipedia.org/wiki/Diamond), the hardest naturally occurring substance. It [bonds](https://en.wikipedia.org/wiki/Chemical_bond) readily with other small [atoms](https://en.wikipedia.org/wiki/Atom), including other carbon atoms, and is capable of forming multiple stable [covalent](https://en.wikipedia.org/wiki/Covalent) bonds with suitable multivalent atoms. Carbon is known to form almost ten million different compounds, a large majority of all [chemical compounds](https://en.wikipedia.org/wiki/Chemical_compounds).[[21]](https://en.wikipedia.org/wiki/Carbon#cite_note-lanl-21) Carbon also has the highest [sublimation](https://en.wikipedia.org/wiki/Sublimation_(phase_transition)) point of all elements. At [atmospheric pressure](https://en.wikipedia.org/wiki/Atmospheric_pressure) it has no melting point, as its [triple point](https://en.wikipedia.org/wiki/Triple_point) is at 10.8±0.2 MPa and 4,600 ± 300 K (4,330 ± 300 °C; 7,820 ± 540 °F),[[2]](https://en.wikipedia.org/wiki/Carbon#cite_note-triple2-2)[[3]](https://en.wikipedia.org/wiki/Carbon#cite_note-triple3-3) so it sublimes at about 3,900 K.[[23]](https://en.wikipedia.org/wiki/Carbon#cite_note-triple-23)[[24]](https://en.wikipedia.org/wiki/Carbon#cite_note-24) Graphite is much more reactive than diamond at standard conditions, despite being more thermodynamically stable, as its delocalised [pi system](https://en.wikipedia.org/wiki/Pi_bond) is much more vulnerable to attack. For example, graphite can be oxidised by hot concentrated [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid) at standard conditions to [mellitic acid](https://en.wikipedia.org/wiki/Mellitic_acid), C6(CO2H)6, which preserves the hexagonal units of graphite while breaking up the larger structure.[[25]](https://en.wikipedia.org/wiki/Carbon#cite_note-Greenwood289-25)

Carbon sublimes in a carbon arc, which has a temperature of about 5800 K (5,530 °C or 9,980 °F). Thus, irrespective of its allotropic form, carbon remains solid at higher temperatures than the highest-melting-point metals such as [tungsten](https://en.wikipedia.org/wiki/Tungsten) or [rhenium](https://en.wikipedia.org/wiki/Rhenium). Although thermodynamically prone to [oxidation](https://en.wikipedia.org/wiki/Redox), carbon resists oxidation more effectively than elements such as [iron](https://en.wikipedia.org/wiki/Iron) and [copper](https://en.wikipedia.org/wiki/Copper), which are weaker reducing agents at room temperature.

Carbon is the sixth element, with a ground-state [electron configuration](https://en.wikipedia.org/wiki/Electron_configuration) of 1s22s22p2, of which the four outer electrons are [valence electrons](https://en.wikipedia.org/wiki/Valence_electron). Its first four ionisation energies, 1086.5, 2352.6, 4620.5 and 6222.7 kJ/mol, are much higher than those of the heavier group-14 elements. The electronegativity of carbon is 2.5, significantly higher than the heavier group-14 elements (1.8–1.9), but close to most of the nearby nonmetals, as well as some of the second- and third-row [transition metals](https://en.wikipedia.org/wiki/Transition_metal). Carbon's [covalent radii](https://en.wikipedia.org/wiki/Covalent_radius) are normally taken as 77.2 pm (C−C), 66.7 pm (C=C) and 60.3 pm (C≡C), although these may vary depending on coordination number and what the carbon is bonded to. In general, covalent radius decreases with lower coordination number and higher bond order.[[26]](https://en.wikipedia.org/wiki/Carbon#cite_note-Greenwood276-26)

Carbon compounds form the basis of all known life on [Earth](https://en.wikipedia.org/wiki/Earth), and the [carbon–nitrogen cycle](https://en.wikipedia.org/wiki/CNO_cycle) provides some of the energy produced by the [Sun](https://en.wikipedia.org/wiki/Sun) and other [stars](https://en.wikipedia.org/wiki/Star). Although it forms an extraordinary variety of compounds, most forms of carbon are comparatively unreactive under normal conditions. At standard temperature and pressure, it resists all but the strongest oxidizers. It does not react with [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid), [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid), [chlorine](https://en.wikipedia.org/wiki/Chlorine) or any [alkalis](https://en.wikipedia.org/wiki/Alkali_metals). At elevated temperatures, carbon reacts with [oxygen](https://en.wikipedia.org/wiki/Oxygen) to form [carbon oxides](https://en.wikipedia.org/wiki/Oxocarbon) and will rob oxygen from metal oxides to leave the elemental metal. This [exothermic reaction](https://en.wikipedia.org/wiki/Exothermic_reaction) is used in the iron and steel industry to [smelt](https://en.wikipedia.org/wiki/Smelting) iron and to control the carbon content of [steel](https://en.wikipedia.org/wiki/Steel):

Fe  
3O  
4 + 4 C(s) → 3 Fe(s) + 4 CO(g)

Carbon monoxide can be recycled to smelt even more iron:

Fe  
3O  
4 + 4 CO(g) → 3 Fe(s) + 4 CO  
2(g)

with [sulfur](https://en.wikipedia.org/wiki/Sulfur) to form [carbon disulfide](https://en.wikipedia.org/wiki/Carbon_disulfide) and with steam in the coal-gas reaction:

C(s) + H2O(g) → CO(g) + H2(g).

Carbon combines with some metals at high temperatures to form metallic carbides, such as the iron carbide [cementite](https://en.wikipedia.org/wiki/Cementite) in steel and [tungsten carbide](https://en.wikipedia.org/wiki/Tungsten_carbide), widely used as an [abrasive](https://en.wikipedia.org/wiki/Abrasive) and for making hard tips for cutting tools.

The system of carbon allotropes spans a range of extremes:

|  |  |
| --- | --- |
| Graphite is one of the softest materials known. | Synthetic [nanocrystalline diamond](https://en.wikipedia.org/wiki/Aggregated_diamond_nanorod) is the hardest material known.[[27]](https://en.wikipedia.org/wiki/Carbon#cite_note-27) |
| Graphite is a very good [lubricant](https://en.wikipedia.org/wiki/Lubricant), displaying [superlubricity](https://en.wikipedia.org/wiki/Superlubricity).[[28]](https://en.wikipedia.org/wiki/Carbon#cite_note-28) | Diamond is the ultimate [abrasive](https://en.wikipedia.org/wiki/Abrasive). |
| Graphite is a [conductor](https://en.wikipedia.org/wiki/Electrical_conductor) of electricity.[[29]](https://en.wikipedia.org/wiki/Carbon#cite_note-29) | Diamond is an excellent electrical [insulator](https://en.wikipedia.org/wiki/Insulator_(electrical)),[[30]](https://en.wikipedia.org/wiki/Carbon" \l "cite_note-30) and has the highest breakdown electric field of any known material. |
| Some forms of graphite are used for [thermal insulation](https://en.wikipedia.org/wiki/Thermal_insulation) (i.e. firebreaks and heat shields), but some [other forms](https://en.wikipedia.org/wiki/Pyrolytic_graphite) are good thermal conductors. | Diamond is the best known naturally occurring [thermal conductor](https://en.wikipedia.org/wiki/List_of_thermal_conductivities) |
| Graphite is [opaque](https://en.wikipedia.org/wiki/Opacity_(optics)). | Diamond is highly transparent. |
| Graphite crystallizes in the [hexagonal system](https://en.wikipedia.org/wiki/Hexagonal_(crystal_system)).[[31]](https://en.wikipedia.org/wiki/Carbon#cite_note-31) | Diamond crystallizes in the [cubic system](https://en.wikipedia.org/wiki/Cubic_(crystal_system)). |
| Amorphous carbon is completely [isotropic](https://en.wikipedia.org/wiki/Isotropic). | Carbon nanotubes are among the most [anisotropic](https://en.wikipedia.org/wiki/Anisotropic) materials known. |

**Allotropes**

Main article: [Allotropes of carbon](https://en.wikipedia.org/wiki/Allotropes_of_carbon)

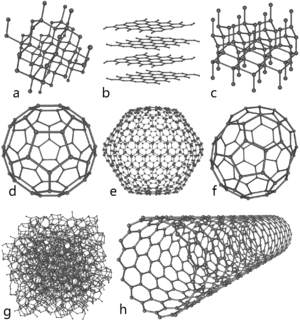
[Atomic carbon](https://en.wikipedia.org/wiki/Atomic_carbon) is a very short-lived species and, therefore, carbon is stabilized in various multi-atomic structures with different molecular configurations called [allotropes](https://en.wikipedia.org/wiki/Allotropes). The three relatively well-known allotropes of carbon are [amorphous carbon](https://en.wikipedia.org/wiki/Amorphous_carbon), [graphite](https://en.wikipedia.org/wiki/Graphite), and [diamond](https://en.wikipedia.org/wiki/Diamond). Once considered exotic, [fullerenes](https://en.wikipedia.org/wiki/Fullerene) are nowadays commonly synthesized and used in research; they include [buckyballs](https://en.wikipedia.org/wiki/Buckyball),[[32]](https://en.wikipedia.org/wiki/Carbon#cite_note-buckyballs-32)[[33]](https://en.wikipedia.org/wiki/Carbon#cite_note-nanotubes-33) [carbon nanotubes](https://en.wikipedia.org/wiki/Carbon_nanotube),[[34]](https://en.wikipedia.org/wiki/Carbon#cite_note-nanotubes2-34) [carbon nanobuds](https://en.wikipedia.org/wiki/Carbon_nanobud)[[35]](https://en.wikipedia.org/wiki/Carbon#cite_note-nanobuds-35) and [nanofibers](https://en.wikipedia.org/wiki/Carbon_nanofibers).[[36]](https://en.wikipedia.org/wiki/Carbon#cite_note-36)[[37]](https://en.wikipedia.org/wiki/Carbon#cite_note-37) Several other exotic allotropes have also been discovered, such as [lonsdaleite](https://en.wikipedia.org/wiki/Lonsdaleite),[[38]](https://en.wikipedia.org/wiki/Carbon#cite_note-lonsdaletite-38) [glassy carbon](https://en.wikipedia.org/wiki/Glassy_carbon),[[39]](https://en.wikipedia.org/wiki/Carbon#cite_note-glassy_carbon-39) [carbon nanofoam](https://en.wikipedia.org/wiki/Carbon_nanofoam)[[40]](https://en.wikipedia.org/wiki/Carbon#cite_note-40) and [linear acetylenic carbon](https://en.wikipedia.org/wiki/Linear_acetylenic_carbon) (carbyne).[[41]](https://en.wikipedia.org/wiki/Carbon#cite_note-LAC-41)

[Graphene](https://en.wikipedia.org/wiki/Graphene) is a two-dimensional sheet of carbon with the atoms arranged in a hexagonal lattice. As of 2009, graphene appears to be the strongest material ever tested.[[42]](https://en.wikipedia.org/wiki/Carbon#cite_note-lee-42) The process of separating it from [graphite](https://en.wikipedia.org/wiki/Graphite) will require some further technological development before it is economical for industrial processes.[[43]](https://en.wikipedia.org/wiki/Carbon#cite_note-nypost-43) If successful, graphene could be used in the construction of a [space elevator](https://en.wikipedia.org/wiki/Space_elevator). It could also be used to safely store hydrogen for use in a hydrogen based engine in cars.[[44]](https://en.wikipedia.org/wiki/Carbon#cite_note-44)

[](https://en.wikipedia.org/wiki/File:Glassy_carbon_and_a_1cm3_graphite_cube_HP68-79.jpg)

A large sample of glassy carbon

The [amorphous](https://en.wikipedia.org/wiki/Amorphous) form is an assortment of carbon atoms in a non-crystalline, irregular, glassy state, not held in a crystalline macrostructure. It is present as a powder, and is the main constituent of substances such as [charcoal](https://en.wikipedia.org/wiki/Charcoal), [lampblack](https://en.wikipedia.org/wiki/Lampblack) ([soot](https://en.wikipedia.org/wiki/Soot)) and [activated carbon](https://en.wikipedia.org/wiki/Activated_carbon). At normal pressures, carbon takes the form of graphite, in which each atom is bonded trigonally to three others in a plane composed of fused [hexagonal](https://en.wikipedia.org/wiki/Hexagon) rings, just like those in [aromatic hydrocarbons](https://en.wikipedia.org/wiki/Aromatic_hydrocarbon).[[45]](https://en.wikipedia.org/wiki/Carbon#cite_note-45) The resulting network is 2-dimensional, and the resulting flat sheets are stacked and loosely bonded through weak [van der Waals forces](https://en.wikipedia.org/wiki/Van_der_Waals_force). This gives graphite its softness and its [cleaving](https://en.wikipedia.org/wiki/Cleavage_(crystal)) properties (the sheets slip easily past one another). Because of the delocalization of one of the outer electrons of each atom to form a [π-cloud](https://en.wikipedia.org/wiki/Delocalized_electron), graphite conducts [electricity](https://en.wikipedia.org/wiki/Electricity), but only in the plane of each [covalently bonded](https://en.wikipedia.org/wiki/Covalent_bond) sheet. This results in a lower bulk [electrical conductivity](https://en.wikipedia.org/wiki/Electrical_conductivity) for carbon than for most [metals](https://en.wikipedia.org/wiki/Metal). The delocalization also accounts for the energetic stability of graphite over diamond at room temperature.

[](https://en.wikipedia.org/wiki/File:Eight_Allotropes_of_Carbon.png)

Some allotropes of carbon: a) [diamond](https://en.wikipedia.org/wiki/Diamond); b) [graphite](https://en.wikipedia.org/wiki/Graphite); c) [lonsdaleite](https://en.wikipedia.org/wiki/Lonsdaleite); d–f) [fullerenes](https://en.wikipedia.org/wiki/Fullerene) (C60, C540, C70); g) [amorphous carbon](https://en.wikipedia.org/wiki/Amorphous_carbon); h) [carbon nanotube](https://en.wikipedia.org/wiki/Carbon_nanotube)

At very high pressures, carbon forms the more compact allotrope, [diamond](https://en.wikipedia.org/wiki/Diamond), having nearly twice the density of graphite. Here, each atom is bonded [tetrahedrally](https://en.wikipedia.org/wiki/Tetrahedron) to four others, forming a 3-dimensional network of puckered six-membered rings of atoms. Diamond has the same [cubic structure](https://en.wikipedia.org/wiki/Cubic_crystal_system) as [silicon](https://en.wikipedia.org/wiki/Silicon) and [germanium](https://en.wikipedia.org/wiki/Germanium), and because of the strength of the carbon-carbon [bonds](https://en.wikipedia.org/wiki/Chemical_bond), it is the hardest naturally occurring substance measured by [resistance to scratching](https://en.wikipedia.org/wiki/Mohs_scale). Contrary to the popular belief that *"diamonds are forever"*, they are thermodynamically unstable (Δf*G*°(diamond, 298 K) = 2.9 kJ/mol[[46]](https://en.wikipedia.org/wiki/Carbon#cite_note-46)) under normal conditions (298 K, 105 Pa) and transform into [graphite](https://en.wikipedia.org/wiki/Graphite).[[20]](https://en.wikipedia.org/wiki/Carbon#cite_note-therm_prop-20) Due to a high activation energy barrier, the transition into graphite is so slow at normal temperature that it is unnoticeable. The bottom left corner of the phase diagram for carbon has not been scrutinized experimentally. However, a recent computational study employing [density functional theory](https://en.wikipedia.org/wiki/Density_functional_theory) methods reached the conclusion that as *T* → 0 K and *p* → 0 Pa, diamond becomes *more stable* than graphite by approximately 1.1 kJ/mol.[[47]](https://en.wikipedia.org/wiki/Carbon#cite_note-47) Under some conditions, carbon crystallizes as [lonsdaleite](https://en.wikipedia.org/wiki/Lonsdaleite), a [hexagonal](https://en.wikipedia.org/wiki/Hexagonal) [crystal](https://en.wikipedia.org/wiki/Crystal) lattice with all atoms covalently bonded and properties similar to those of diamond.[[38]](https://en.wikipedia.org/wiki/Carbon#cite_note-lonsdaletite-38)

[Fullerenes](https://en.wikipedia.org/wiki/Fullerene) are a synthetic crystalline formation with a graphite-like structure, but in place of [hexagons](https://en.wikipedia.org/wiki/Hexagonal_crystal_system), fullerenes are formed of pentagons (or even heptagons) of carbon atoms. The missing (or additional) atoms warp the sheets into spheres, ellipses, or cylinders. The properties of fullerenes (split into buckyballs, buckytubes, and nanobuds) have not yet been fully analyzed and represent an intense area of research in [nanomaterials](https://en.wikipedia.org/wiki/Nanomaterials). The names *"fullerene"* and *"buckyball"* are given after [Richard Buckminster Fuller](https://en.wikipedia.org/wiki/Buckminster_Fuller), popularizer of [geodesic domes](https://en.wikipedia.org/wiki/Geodesic_dome), which resemble the structure of fullerenes. The buckyballs are fairly large molecules formed completely of carbon bonded trigonally, forming [spheroids](https://en.wikipedia.org/wiki/Spheroid) (the best-known and simplest is the soccerball-shaped C60 [buckminsterfullerene](https://en.wikipedia.org/wiki/Buckminsterfullerene)).[[32]](https://en.wikipedia.org/wiki/Carbon#cite_note-buckyballs-32) Carbon nanotubes are structurally similar to buckyballs, except that each atom is bonded trigonally in a curved sheet that forms a hollow [cylinder](https://en.wikipedia.org/wiki/Cylinder_(geometry)).[[33]](https://en.wikipedia.org/wiki/Carbon#cite_note-nanotubes-33)[[34]](https://en.wikipedia.org/wiki/Carbon#cite_note-nanotubes2-34) Nanobuds were first reported in 2007 and are hybrid bucky tube/buckyball materials (buckyballs are covalently bonded to the outer wall of a nanotube) that combine the properties of both in a single structure.[[35]](https://en.wikipedia.org/wiki/Carbon#cite_note-nanobuds-35)

Of the other discovered allotropes, [carbon nanofoam](https://en.wikipedia.org/wiki/Carbon_nanofoam) is a [ferromagnetic](https://en.wikipedia.org/wiki/Ferromagnetic) allotrope discovered in 1997. It consists of a low-density cluster-assembly of carbon atoms strung together in a loose three-dimensional web, in which the atoms are bonded trigonally in six- and seven-membered rings. It is among the lightest known solids, with a density of about 2 kg/m3.[[48]](https://en.wikipedia.org/wiki/Carbon#cite_note-48) Similarly, [glassy carbon](https://en.wikipedia.org/wiki/Glassy_carbon) contains a high proportion of closed [porosity](https://en.wikipedia.org/wiki/Porosity),[[39]](https://en.wikipedia.org/wiki/Carbon" \l "cite_note-glassy_carbon-39) but contrary to normal graphite, the graphitic layers are not stacked like pages in a book, but have a more random arrangement. [Linear acetylenic carbon](https://en.wikipedia.org/wiki/Linear_acetylenic_carbon)[[41]](https://en.wikipedia.org/wiki/Carbon#cite_note-LAC-41) has the chemical structure[[41]](https://en.wikipedia.org/wiki/Carbon#cite_note-LAC-41) −(C:::C)*n*−. Carbon in this modification is linear with *sp* [orbital hybridization](https://en.wikipedia.org/wiki/Orbital_hybridization), and is a [polymer](https://en.wikipedia.org/wiki/Polymer) with alternating single and triple bonds. This carbyne is of considerable interest to [nanotechnology](https://en.wikipedia.org/wiki/Nanotechnology) as its [Young's modulus](https://en.wikipedia.org/wiki/Young%27s_modulus) is 40 times that of the hardest known material – diamond.[[49]](https://en.wikipedia.org/wiki/Carbon#cite_note-49)

In 2015, a team at the [North Carolina State University](https://en.wikipedia.org/wiki/North_Carolina_State_University) announced the development of another allotrope they have dubbed [Q-carbon](https://en.wikipedia.org/wiki/Q-carbon), created by a high energy low duration laser pulse on amorphous carbon dust. Q-carbon is reported to exhibit ferromagetism, [fluorescence](https://en.wikipedia.org/wiki/Fluorescence), and a hardness superior to diamonds.[[50]](https://en.wikipedia.org/wiki/Carbon#cite_note-50)

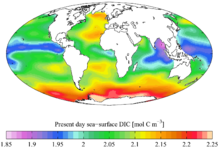
**Occurrence**

[](https://en.wikipedia.org/wiki/File:GraphiteOreUSGOV.jpg)

Graphite ore, shown with a penny for scale

[](https://en.wikipedia.org/wiki/File:Rough_diamond.jpg)

Raw diamond crystal

[](https://en.wikipedia.org/wiki/File:WOA05_GLODAP_pd_DIC_AYool.png)

"Present day" (1990s) sea surface [dissolved inorganic carbon](https://en.wikipedia.org/wiki/Total_inorganic_carbon) concentration (from the [GLODAP](https://en.wikipedia.org/wiki/Global_Ocean_Data_Analysis_Project) [climatology](https://en.wikipedia.org/wiki/Climatology))

Carbon is the [fourth most abundant chemical element](https://en.wikipedia.org/wiki/Abundance_of_the_chemical_elements) in the [observable universe](https://en.wikipedia.org/wiki/Observable_universe) by mass after hydrogen, helium, and oxygen. Carbon is abundant in the [Sun](https://en.wikipedia.org/wiki/Sun), [stars](https://en.wikipedia.org/wiki/Star), [comets](https://en.wikipedia.org/wiki/Comet), and in the [atmospheres](https://en.wikipedia.org/wiki/Celestial_body%27s_atmosphere) of most [planets](https://en.wikipedia.org/wiki/Planet).[[51]](https://en.wikipedia.org/wiki/Carbon#cite_note-NASA-20140221-51) Some [meteorites](https://en.wikipedia.org/wiki/Meteorite) contain microscopic diamonds that were formed when the [solar system](https://en.wikipedia.org/wiki/Solar_system) was still a [protoplanetary disk](https://en.wikipedia.org/wiki/Protoplanetary_disk).[[52]](https://en.wikipedia.org/wiki/Carbon#cite_note-Lauretta_McSween_2006_p._199-52) Microscopic diamonds may also be formed by the intense pressure and high temperature at the sites of meteorite impacts.[[53]](https://en.wikipedia.org/wiki/Carbon#cite_note-53)

In 2014 [NASA](https://en.wikipedia.org/wiki/NASA) announced a [greatly upgraded database](http://www.astrochem.org/pahdb/) for tracking [polycyclic aromatic hydrocarbons](https://en.wikipedia.org/wiki/Polycyclic_aromatic_hydrocarbons) (PAHs) in the [universe](https://en.wikipedia.org/wiki/Universe). More than 20% of the carbon in the universe may be associated with PAHs, complex compounds of carbon and hydrogen without oxygen.[[54]](https://en.wikipedia.org/wiki/Carbon#cite_note-54) These compounds figure in the [PAH world hypothesis](https://en.wikipedia.org/wiki/PAH_world_hypothesis) where they are hypothesized to have a role in [abiogenesis](https://en.wikipedia.org/wiki/Abiogenesis) and formation of [life](https://en.wikipedia.org/wiki/Life#Extraterrestrial_life). PAHs seem to have been formed "a couple of billion years" after the [Big Bang](https://en.wikipedia.org/wiki/Big_Bang), are widespread throughout the universe, and are associated with [new stars](https://en.wikipedia.org/wiki/Star_formation) and [exoplanets](https://en.wikipedia.org/wiki/Exoplanets).[[51]](https://en.wikipedia.org/wiki/Carbon#cite_note-NASA-20140221-51)

It has been estimated that the solid earth as a whole contains 730 [ppm](https://en.wikipedia.org/wiki/Parts_per_million) of carbon, with 2000 ppm in the core and 120 ppm in the combined mantle and crust.[[55]](https://en.wikipedia.org/wiki/Carbon#cite_note-55) Since the mass of the earth is 5.972×1024 kg, this would imply 4360 million [gigatonnes](https://en.wikipedia.org/wiki/Gigatonne) of carbon. This is much more than the amount of carbon in the oceans or atmosphere (below).

In combination with [oxygen](https://en.wikipedia.org/wiki/Oxygen) in [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide), carbon is found in the Earth's atmosphere (approximately 810 gigatonnes of carbon) and dissolved in all water bodies (approximately 36,000 gigatonnes of carbon). Around 1,900 gigatonnes of carbon are present in the [biosphere](https://en.wikipedia.org/wiki/Biosphere). [Hydrocarbons](https://en.wikipedia.org/wiki/Hydrocarbons) (such as [coal](https://en.wikipedia.org/wiki/Coal), [petroleum](https://en.wikipedia.org/wiki/Petroleum), and [natural gas](https://en.wikipedia.org/wiki/Natural_gas)) contain carbon as well. [Coal](https://en.wikipedia.org/wiki/Coal) ["reserves" (not "resources")](https://en.wikipedia.org/wiki/Mineral_resource_classification) amount to around 900 gigatonnes with perhaps 18,000 Gt of resources.[[56]](https://en.wikipedia.org/wiki/Carbon#cite_note-56) [Oil reserves](https://en.wikipedia.org/wiki/Oil_reserves) are around 150 gigatonnes. Proven sources of natural gas are about 175×1012 cubic metres (containing about 105 gigatonnes of carbon), but studies estimate another 900×1012 cubic metres of "unconventional" deposits such as [shale gas](https://en.wikipedia.org/wiki/Shale_gas), representing about 540 gigatonnes of carbon.[[57]](https://en.wikipedia.org/wiki/Carbon#cite_note-57)

Carbon is also found in [methane hydrates](https://en.wikipedia.org/wiki/Methane_hydrates) in polar regions and under the seas. Various estimates put this carbon between 500, 2500 [Gt](https://en.wikipedia.org/wiki/Gigatonne),[[58]](https://en.wikipedia.org/wiki/Carbon" \l "cite_note-58) or 3,000 Gt.[[59]](https://en.wikipedia.org/wiki/Carbon#cite_note-59)

In the past, quantities of hydrocarbons were greater. According to one source, in the period from 1751 to 2008 about 347 gigatonnes of carbon were released as carbon dioxide to the atmosphere from burning of fossil fuels.[[60]](https://en.wikipedia.org/wiki/Carbon#cite_note-60) Another source puts the amount added to the atmosphere for the period since 1750 at 879 Gt, and the total going to the atmosphere, sea, and land (such as [peat bogs](https://en.wikipedia.org/wiki/Peat_bogs)) at almost 2,000 Gt.[[61]](https://en.wikipedia.org/wiki/Carbon#cite_note-61)

Carbon is a constituent (about 12% by mass) of the very large masses of [carbonate](https://en.wikipedia.org/wiki/Carbonate) rock ([limestone](https://en.wikipedia.org/wiki/Limestone), [dolomite](https://en.wikipedia.org/wiki/Dolomite), [marble](https://en.wikipedia.org/wiki/Marble) and so on). [Coal](https://en.wikipedia.org/wiki/Coal) is very rich in carbon ([anthracite](https://en.wikipedia.org/wiki/Anthracite) contains 92–98%)[[62]](https://en.wikipedia.org/wiki/Carbon#cite_note-62) and is the largest commercial source of mineral carbon, accounting for 4,000 gigatonnes or 80% of [fossil fuel](https://en.wikipedia.org/wiki/Fossil_fuel).[[63]](https://en.wikipedia.org/wiki/Carbon#cite_note-63)

As for individual carbon allotropes, graphite is found in large quantities in the [United States](https://en.wikipedia.org/wiki/United_States) (mostly in [New York](https://en.wikipedia.org/wiki/New_York_(state)) and [Texas](https://en.wikipedia.org/wiki/Texas)), [Russia](https://en.wikipedia.org/wiki/Russia), [Mexico](https://en.wikipedia.org/wiki/Mexico), [Greenland](https://en.wikipedia.org/wiki/Greenland), and [India](https://en.wikipedia.org/wiki/India). Natural diamonds occur in the rock [kimberlite](https://en.wikipedia.org/wiki/Kimberlite), found in ancient [volcanic](https://en.wikipedia.org/wiki/Volcano) "necks", or "pipes". Most diamond deposits are in [Africa](https://en.wikipedia.org/wiki/Africa), notably in [South Africa](https://en.wikipedia.org/wiki/South_Africa), [Namibia](https://en.wikipedia.org/wiki/Namibia), [Botswana](https://en.wikipedia.org/wiki/Botswana), the [Republic of the Congo](https://en.wikipedia.org/wiki/Republic_of_the_Congo), and [Sierra Leone](https://en.wikipedia.org/wiki/Sierra_Leone). Diamond deposits have also been found in [Arkansas](https://en.wikipedia.org/wiki/Arkansas), [Canada](https://en.wikipedia.org/wiki/Canada), the Russian [Arctic](https://en.wikipedia.org/wiki/Arctic), [Brazil](https://en.wikipedia.org/wiki/Brazil), and in Northern and Western [Australia](https://en.wikipedia.org/wiki/Australia). Diamonds are now also being recovered from the ocean floor off the [Cape of Good Hope](https://en.wikipedia.org/wiki/Cape_of_Good_Hope). Diamonds are found naturally, but about 30% of all industrial diamonds used in the U.S. are now manufactured.

Carbon-14 is formed in upper layers of the troposphere and the stratosphere at altitudes of 9–15 km by a reaction that is precipitated by [cosmic rays](https://en.wikipedia.org/wiki/Cosmic_ray).[[64]](https://en.wikipedia.org/wiki/Carbon#cite_note-64) [Thermal neutrons](https://en.wikipedia.org/wiki/Thermal_neutron) are produced that collide with the nuclei of nitrogen-14, forming carbon-14 and a proton. As such, 1.5%×10−10 of atmospheric carbon dioxide contains carbon-14.[[65]](https://en.wikipedia.org/wiki/Carbon#cite_note-65)

Carbon-rich asteroids are relatively preponderant in the outer parts of the [asteroid belt](https://en.wikipedia.org/wiki/Asteroid_belt) in our [solar system](https://en.wikipedia.org/wiki/Solar_system). These asteroids have not yet been directly sampled by scientists. The asteroids can be used in hypothetical [space-based carbon mining](https://en.wikipedia.org/wiki/Asteroid_mining), which may be possible in the future, but is currently technologically impossible.[[66]](https://en.wikipedia.org/wiki/Carbon#cite_note-66)

**Isotopes**

Main article: [Isotopes of carbon](https://en.wikipedia.org/wiki/Isotopes_of_carbon)

[Isotopes](https://en.wikipedia.org/wiki/Isotope) of carbon are [atomic nuclei](https://en.wikipedia.org/wiki/Atomic_nucleus) that contain six [protons](https://en.wikipedia.org/wiki/Proton) plus a number of [neutrons](https://en.wikipedia.org/wiki/Neutron) (varying from 2 to 16). Carbon has two stable, naturally occurring [isotopes](https://en.wikipedia.org/wiki/Isotope).[[17]](https://en.wikipedia.org/wiki/Carbon#cite_note-isotopes-17) The isotope [carbon-12](https://en.wikipedia.org/wiki/Carbon-12) (12C) forms 98.93% of the carbon on Earth, while [carbon-13](https://en.wikipedia.org/wiki/Carbon-13) (13C) forms the remaining 1.07%.[[17]](https://en.wikipedia.org/wiki/Carbon#cite_note-isotopes-17) The concentration of 12C is further increased in biological materials because biochemical reactions discriminate against 13C.[[67]](https://en.wikipedia.org/wiki/Carbon#cite_note-67) In 1961, the [International Union of Pure and Applied Chemistry](https://en.wikipedia.org/wiki/International_Union_of_Pure_and_Applied_Chemistry) (IUPAC) adopted the isotope [carbon-12](https://en.wikipedia.org/wiki/Carbon-12) as the basis for [atomic weights](https://en.wikipedia.org/wiki/Atomic_weight).[[68]](https://en.wikipedia.org/wiki/Carbon#cite_note-68) Identification of carbon in [nuclear magnetic resonance](https://en.wikipedia.org/wiki/Nuclear_magnetic_resonance) (NMR) experiments is done with the isotope 13C.

[Carbon-14](https://en.wikipedia.org/wiki/Carbon-14) (14C) is a naturally occurring [radioisotope](https://en.wikipedia.org/wiki/Radioisotope), created in the [upper atmosphere](https://en.wikipedia.org/wiki/Upper_atmosphere) (lower [stratosphere](https://en.wikipedia.org/wiki/Stratosphere) and upper [troposphere](https://en.wikipedia.org/wiki/Troposphere)) by interaction of [nitrogen](https://en.wikipedia.org/wiki/Nitrogen) with [cosmic rays](https://en.wikipedia.org/wiki/Cosmic_ray).[[69]](https://en.wikipedia.org/wiki/Carbon#cite_note-69) It is found in trace amounts on Earth of 1 part per [trillion](https://en.wikipedia.org/wiki/10%5E12) (0.0000000001%) or more, mostly confined to the atmosphere and superficial deposits, particularly of [peat](https://en.wikipedia.org/wiki/Peat) and other organic materials.[[70]](https://en.wikipedia.org/wiki/Carbon#cite_note-70) This isotope decays by 0.158 MeV [β− emission](https://en.wikipedia.org/wiki/Beta_decay). Because of its relatively short [half-life](https://en.wikipedia.org/wiki/Half-life) of 5730 years, 14C is virtually absent in ancient rocks. The amount of 14C in the [atmosphere](https://en.wikipedia.org/wiki/Atmosphere) and in living organisms is almost constant, but decreases predictably in their bodies after death. This principle is used in [radiocarbon dating](https://en.wikipedia.org/wiki/Radiocarbon_dating), invented in 1949, which has been used extensively to determine the age of carbonaceous materials with ages up to about 40,000 years.[[71]](https://en.wikipedia.org/wiki/Carbon#cite_note-71)[[72]](https://en.wikipedia.org/wiki/Carbon#cite_note-72)

There are 15 known isotopes of carbon and the shortest-lived of these is 8C which decays through [proton emission](https://en.wikipedia.org/wiki/Proton_emission) and [alpha decay](https://en.wikipedia.org/wiki/Alpha_decay) and has a half-life of 1.98739x10−21 s.[[73]](https://en.wikipedia.org/wiki/Carbon#cite_note-73) The exotic 19C exhibits a [nuclear halo](https://en.wikipedia.org/wiki/Nuclear_halo), which means its [radius](https://en.wikipedia.org/wiki/Radius) is appreciably larger than would be expected if the [nucleus](https://en.wikipedia.org/wiki/Atomic_nucleus) were a [sphere](https://en.wikipedia.org/wiki/Sphere) of constant [density](https://en.wikipedia.org/wiki/Density).[[74]](https://en.wikipedia.org/wiki/Carbon#cite_note-74)

**Formation in stars**

Main articles: [Triple-alpha process](https://en.wikipedia.org/wiki/Triple-alpha_process) and [CNO cycle](https://en.wikipedia.org/wiki/CNO_cycle)

Formation of the carbon atomic nucleus occurs within a [giant](https://en.wikipedia.org/wiki/Giant_star) or [supergiant](https://en.wikipedia.org/wiki/Supergiant) star through the [triple-alpha process](https://en.wikipedia.org/wiki/Triple-alpha_process). This requires a nearly simultaneous collision of three [alpha particles](https://en.wikipedia.org/wiki/Alpha_particle) ([helium](https://en.wikipedia.org/wiki/Helium) nuclei), as the products of further [nuclear fusion](https://en.wikipedia.org/wiki/Nuclear_fusion) reactions of helium with hydrogen or another helium nucleus produce [lithium-5](https://en.wikipedia.org/wiki/Isotopes_of_lithium) and [beryllium-8](https://en.wikipedia.org/wiki/Isotopes_of_beryllium) respectively, both of which are highly unstable and decay almost instantly back into smaller nuclei.[[75]](https://en.wikipedia.org/wiki/Carbon#cite_note-Audi-75) The triple-alpha process happens in conditions of temperatures over 100 megakelvin and helium concentration that the rapid expansion and cooling of the early universe prohibited, and therefore no significant carbon was created during the [Big Bang](https://en.wikipedia.org/wiki/Big_Bang).

According to current physical cosmology theory, carbon is formed in the interiors of stars on the [horizontal branch](https://en.wikipedia.org/wiki/Horizontal_branch).[[76]](https://en.wikipedia.org/wiki/Carbon#cite_note-Ostlie-76) When massive stars die as supernova, the carbon is scattered into space as dust. This dust becomes component material for the formation of the [next-generation star](https://en.wikipedia.org/wiki/Metallicity) systems with accreted planets.[[51]](https://en.wikipedia.org/wiki/Carbon#cite_note-NASA-20140221-51)[[77]](https://en.wikipedia.org/wiki/Carbon#cite_note-77) The [Solar System](https://en.wikipedia.org/wiki/Solar_System) is one such star system with an abundance of carbon, enabling the existence of life as we know it.

The [CNO cycle](https://en.wikipedia.org/wiki/CNO_cycle) is an additional hydrogen fusion mechanism that powers stars, wherein carbon operates as a [catalyst](https://en.wikipedia.org/wiki/Catalyst).

Rotational transitions of various isotopic forms of carbon monoxide (for example, 12CO, 13CO, and 18CO) are detectable in the [submillimeter](https://en.wikipedia.org/wiki/Submillimetre_astronomy) wavelength range, and are used in the study of [newly forming stars](https://en.wikipedia.org/wiki/Star_formation) in [molecular clouds](https://en.wikipedia.org/wiki/Molecular_clouds).[[78]](https://en.wikipedia.org/wiki/Carbon#cite_note-78)

**Carbon cycle**

Main article: [Carbon cycle](https://en.wikipedia.org/wiki/Carbon_cycle)

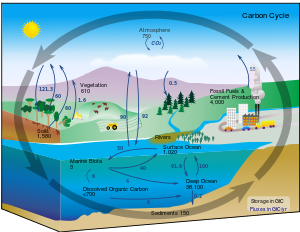
[](https://en.wikipedia.org/wiki/File:Carbon_cycle-cute_diagram.svg)

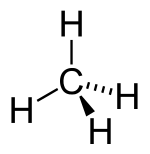
Diagram of the carbon cycle. The black numbers indicate how much carbon is stored in various reservoirs, in billions tonnes ("GtC" stands for gigatonnes of carbon; figures are circa 2004). The purple numbers indicate how much carbon moves between reservoirs each year. The sediments, as defined in this diagram, do not include the ≈70 million GtC of carbonate rock and [kerogen](https://en.wikipedia.org/wiki/Kerogen).

Under terrestrial conditions, conversion of one element to another is very rare. Therefore, the amount of carbon on Earth is effectively constant. Thus, processes that use carbon must obtain it from somewhere and dispose of it somewhere else. The paths of carbon in the environment form the [carbon cycle](https://en.wikipedia.org/wiki/Carbon_cycle). For example, [photosynthetic](https://en.wikipedia.org/wiki/Photosynthesis) plants draw [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide) from the atmosphere (or seawater) and build it into biomass, as in the [Calvin cycle](https://en.wikipedia.org/wiki/Calvin_cycle), a process of [carbon fixation](https://en.wikipedia.org/wiki/Carbon_fixation). Some of this biomass is eaten by animals, while some carbon is exhaled by animals as carbon dioxide. The carbon cycle is considerably more complicated than this short loop; for example, some carbon dioxide is dissolved in the oceans; if bacteria do not consume it, dead plant or animal matter may become [petroleum](https://en.wikipedia.org/wiki/Petroleum) or [coal](https://en.wikipedia.org/wiki/Coal), which releases carbon when burned.[[79]](https://en.wikipedia.org/wiki/Carbon#cite_note-79)[[80]](https://en.wikipedia.org/wiki/Carbon#cite_note-80)

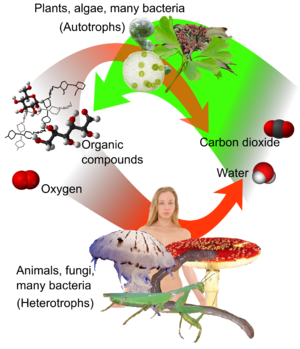
**Compounds**

Main article: [Compounds of carbon](https://en.wikipedia.org/wiki/Compounds_of_carbon)

**Organic compounds**

[](https://en.wikipedia.org/wiki/File:Methane-2D-stereo.svg)

Structural formula of [methane](https://en.wikipedia.org/wiki/Methane), the simplest possible organic compound.

[](https://en.wikipedia.org/wiki/File:Auto-and_heterotrophs.png)

Correlation between the *carbon cycle* and formation of organic compounds. In plants, carbon dioxide formed by carbon fixation can join with water in [photosynthesis](https://en.wikipedia.org/wiki/Photosynthesis) (green) to form organic compounds, which can be used and further converted by both plants and animals.

Carbon can form very long chains of interconnecting [carbon–carbon bonds](https://en.wikipedia.org/wiki/Carbon%E2%80%93carbon_bond), a property that is called [catenation](https://en.wikipedia.org/wiki/Catenation). Carbon-carbon bonds are strong and stable. Through catenation, carbon forms a countless number of compounds. A tally of unique compounds shows that more contain carbon that those that do not.[[81]](https://en.wikipedia.org/wiki/Carbon#cite_note-Burrows_Holman_Parsons_Pilling_2017_p._70-81) A similar claim can be made for hydrogen because most organic compounds also contain hydrogen.[*[citation needed](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed" \o "Wikipedia:Citation needed)*]

The simplest form of an organic molecule is the [hydrocarbon](https://en.wikipedia.org/wiki/Hydrocarbon)—a large family of [organic molecules](https://en.wikipedia.org/wiki/Organic_molecule) that are composed of [hydrogen](https://en.wikipedia.org/wiki/Hydrogen) atoms bonded to a chain of carbon atoms. A hydrocarbon backbone can be substituted by other atoms, known as heteroatoms. Common heteroatoms that appear in organic compounds include oxygen, nitrogen, sulfur, phosphorus, and the nonradioactive halogens, as well as the metals lithium and magnesium. Organic compounds containing bonds to metal are known as organometallic compounds (*see below*). Certain groupings of atoms, often including heteroatoms, recur in large numbers of organic compounds. These collections, known as [*functional groups*](https://en.wikipedia.org/wiki/Functional_group), confer common reactivity patterns and allow for the systematic study and categorization of organic compounds. Chain length, shape and functional groups all affect the properties of organic molecules.

In most stable compounds of carbon (and nearly all stable *organic* compounds), carbon obeys the [octet rule](https://en.wikipedia.org/wiki/Octet_rule) and is *tetravalent*, meaning that a carbon atom forms a total of four covalent bonds (which may include double and triple bonds). Exceptions include a small number of stabilized *carbocations* (three bonds, positive charge), *radicals* (three bonds, neutral), *carbanions* (three bonds, negative charge) and *carbenes* (two bonds, neutral), although these species are much more likely to be encountered as unstable, reactive intermediates.

Carbon occurs in all known [organic](https://en.wikipedia.org/wiki/Organic_material) life and is the basis of [organic chemistry](https://en.wikipedia.org/wiki/Organic_chemistry). When united with [hydrogen](https://en.wikipedia.org/wiki/Hydrogen), it forms various hydrocarbons that are important to industry as [refrigerants](https://en.wikipedia.org/wiki/Refrigerant), [lubricants](https://en.wikipedia.org/wiki/Lubricant), [solvents](https://en.wikipedia.org/wiki/Solvent), as chemical feedstock for the manufacture of [plastics](https://en.wikipedia.org/wiki/Plastic) and [petrochemicals](https://en.wikipedia.org/wiki/Petrochemical), and as [fossil fuels](https://en.wikipedia.org/wiki/Fossil_fuel).

When combined with oxygen and hydrogen, carbon can form many groups of important biological compounds including [sugars](https://en.wikipedia.org/wiki/Sugar), [lignans](https://en.wikipedia.org/wiki/Lignan), [chitins](https://en.wikipedia.org/wiki/Chitin), [alcohols](https://en.wikipedia.org/wiki/Alcohol), [fats](https://en.wikipedia.org/wiki/Fat), and aromatic [esters](https://en.wikipedia.org/wiki/Ester), [carotenoids](https://en.wikipedia.org/wiki/Carotenoid) and [terpenes](https://en.wikipedia.org/wiki/Terpene). With [nitrogen](https://en.wikipedia.org/wiki/Nitrogen) it forms [alkaloids](https://en.wikipedia.org/wiki/Alkaloid), and with the addition of sulfur also it forms [antibiotics](https://en.wikipedia.org/wiki/Antibiotic), [amino acids](https://en.wikipedia.org/wiki/Amino_acid), and [rubber](https://en.wikipedia.org/wiki/Rubber) products. With the addition of phosphorus to these other elements, it forms [DNA](https://en.wikipedia.org/wiki/DNA) and [RNA](https://en.wikipedia.org/wiki/RNA), the chemical-code carriers of life, and [adenosine triphosphate](https://en.wikipedia.org/wiki/Adenosine_triphosphate) (ATP), the most important energy-transfer molecule in all living cells.

**Inorganic compounds**

Commonly carbon-containing compounds which are associated with minerals or which do not contain bonds to the other carbon atoms, halogens, or hydrogen, are treated separately from classical [organic compounds](https://en.wikipedia.org/wiki/Organic_compounds); the definition is not rigid, and the classification of some compounds can vary from author to author (see reference articles above). Among these are the simple oxides of carbon. The most prominent oxide is [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide) (CO2). This was once the principal constituent of the [paleoatmosphere](https://en.wikipedia.org/wiki/Paleoatmosphere), but is a minor component of the [Earth's atmosphere](https://en.wikipedia.org/wiki/Atmosphere_of_Earth) today.[[82]](https://en.wikipedia.org/wiki/Carbon#cite_note-82) Dissolved in [water](https://en.wikipedia.org/wiki/Water_(molecule)), it forms [carbonic acid](https://en.wikipedia.org/wiki/Carbonic_acid) (H  
2CO  
3), but as most compounds with multiple single-bonded oxygens on a single carbon it is unstable.[[83]](https://en.wikipedia.org/wiki/Carbon#cite_note-83) Through this intermediate, though, resonance-stabilized [carbonate](https://en.wikipedia.org/wiki/Carbonate) [ions](https://en.wikipedia.org/wiki/Ion) are produced. Some important minerals are carbonates, notably [calcite](https://en.wikipedia.org/wiki/Calcite). [Carbon disulfide](https://en.wikipedia.org/wiki/Carbon_disulfide) (CS  
2) is similar.[[25]](https://en.wikipedia.org/wiki/Carbon#cite_note-Greenwood289-25) Nevertheless, due to its physical properties and its association with organic synthesis, carbon disulfide is sometimes classified as an *organic* solvent.[[84]](https://en.wikipedia.org/wiki/Carbon#cite_note-84)

The other common oxide is [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide) (CO). It is formed by incomplete combustion, and is a colorless, odorless gas. The molecules each contain a triple bond and are fairly [polar](https://en.wikipedia.org/wiki/Polar_molecule), resulting in a tendency to bind permanently to hemoglobin molecules, displacing oxygen, which has a lower binding affinity.[[85]](https://en.wikipedia.org/wiki/Carbon#cite_note-85)[[86]](https://en.wikipedia.org/wiki/Carbon#cite_note-86) [Cyanide](https://en.wikipedia.org/wiki/Cyanide) (CN−), has a similar structure, but behaves much like a [halide](https://en.wikipedia.org/wiki/Halide) ion ([pseudohalogen](https://en.wikipedia.org/wiki/Pseudohalogen)). For example, it can form the nitride [cyanogen](https://en.wikipedia.org/wiki/Cyanogen) molecule ((CN)2), similar to diatomic halides. Likewise, the heavier analog of cyanide, [cyaphide](https://en.wikipedia.org/wiki/Cyaphide) (CP−), is also considered inorganic, though most simple derivatives are highly unstable. Other uncommon oxides are [carbon suboxide](https://en.wikipedia.org/wiki/Carbon_suboxide) (C  
3O  
2),[[87]](https://en.wikipedia.org/wiki/Carbon#cite_note-87) the unstable [dicarbon monoxide](https://en.wikipedia.org/wiki/Dicarbon_monoxide) (C2O),[[88]](https://en.wikipedia.org/wiki/Carbon#cite_note-88)[[89]](https://en.wikipedia.org/wiki/Carbon#cite_note-89) [carbon trioxide](https://en.wikipedia.org/wiki/Carbon_trioxide) (CO3),[[90]](https://en.wikipedia.org/wiki/Carbon#cite_note-90)[[91]](https://en.wikipedia.org/wiki/Carbon#cite_note-91) [cyclopentanepentone](https://en.wikipedia.org/wiki/Cyclopentanepentone) (C5O5),[[92]](https://en.wikipedia.org/wiki/Carbon#cite_note-fatiadi-92) [cyclohexanehexone](https://en.wikipedia.org/wiki/Cyclohexanehexone) (C6O6),[[92]](https://en.wikipedia.org/wiki/Carbon#cite_note-fatiadi-92) and [mellitic anhydride](https://en.wikipedia.org/wiki/Mellitic_anhydride) (C12O9). However, mellitic anhydride is the triple acyl anhydride of mellitic acid; moreover, it contains a benzene ring. Thus, many chemists consider it to be organic.

With reactive [metals](https://en.wikipedia.org/wiki/Metal), such as [tungsten](https://en.wikipedia.org/wiki/Tungsten), carbon forms either [carbides](https://en.wikipedia.org/wiki/Carbide) (C4−) or [acetylides](https://en.wikipedia.org/wiki/Acetylide) (C2−  
2) to form alloys with high melting points. These anions are also associated with [methane](https://en.wikipedia.org/wiki/Methane) and [acetylene](https://en.wikipedia.org/wiki/Acetylene), both very weak [acids](https://en.wikipedia.org/wiki/Acid). With an electronegativity of 2.5,[[93]](https://en.wikipedia.org/wiki/Carbon" \l "cite_note-93) carbon prefers to form [covalent bonds](https://en.wikipedia.org/wiki/Covalent_bond). A few carbides are covalent lattices, like [carborundum](https://en.wikipedia.org/wiki/Silicon_carbide) (SiC), which resembles [diamond](https://en.wikipedia.org/wiki/Diamond). Nevertheless, even the most polar and salt-like of carbides are not completely ionic compounds.[[94]](https://en.wikipedia.org/wiki/Carbon#cite_note-Greenwood297-94)

**Organometallic compounds**

Main article: [Organometallic chemistry](https://en.wikipedia.org/wiki/Organometallic_chemistry)

Organometallic compounds by definition contain at least one carbon-metal covalent bond. A wide range of such compounds exist; major classes include simple alkyl-metal compounds (for example, [tetraethyllead](https://en.wikipedia.org/wiki/Tetraethyllead)), η2-alkene compounds (for example, [Zeise's salt](https://en.wikipedia.org/wiki/Zeise%27s_salt)), and η3-allyl compounds (for example, [allylpalladium chloride dimer](https://en.wikipedia.org/wiki/Allylpalladium_chloride_dimer)); [metallocenes](https://en.wikipedia.org/wiki/Metallocene) containing cyclopentadienyl ligands (for example, [ferrocene](https://en.wikipedia.org/wiki/Ferrocene)); and [transition metal carbene complexes](https://en.wikipedia.org/wiki/Transition_metal_carbene_complex). Many [metal carbonyls](https://en.wikipedia.org/wiki/Metal_carbonyl) and [metal cyanides](https://en.wikipedia.org/wiki/Cyanometalate) exist (for example, [tetracarbonylnickel](https://en.wikipedia.org/wiki/Tetracarbonylnickel) and [potassium ferricyanide](https://en.wikipedia.org/wiki/Potassium_ferricyanide)); some workers consider metal carbonyl and cyanide complexes without other carbon ligands to be purely inorganic, and not organometallic. However, most organometallic chemists consider metal complexes with any carbon ligand, even 'inorganic carbon' (e.g., carbonyls, cyanides, and certain types of carbides and acetylides) to be organometallic in nature. Metal complexes containing organic ligands without a carbon-metal covalent bond (e.g., metal carboxylates) are termed *metalorganic* compounds.

While carbon is understood to strongly prefer formation of four covalent bonds, other exotic bonding schemes are also known. An interesting compound containing an octahedral hexacoordinated carbon atom has been reported. The cation of the compound is [(Ph3PAu)6C]2+. This phenomenon has been attributed to the [aurophilicity](https://en.wikipedia.org/wiki/Aurophilicity) of the gold ligands, which provide additional stabilization of an otherwise labile species.[[95]](https://en.wikipedia.org/wiki/Carbon#cite_note-95) In nature, the iron-molybdenum cofactor ([FeMoco](https://en.wikipedia.org/wiki/FeMoco)) responsible for microbial [nitrogen fixation](https://en.wikipedia.org/wiki/Nitrogen_fixation) likewise has an octahedral carbon center (formally a carbide, C(-IV)) bonded to six iron atoms. In 2016, it was confirmed that, in line with earlier theoretical predictions, [hexamethylbenzene dication](https://en.wikipedia.org/wiki/Hexamethylbenzene) contains a carbon atom with six bonds, with the formulation [MeC(η5-C5Me5)]2+, making it an "organic [metallocene](https://en.wikipedia.org/wiki/Metallocene)". Thus, a MeC3+ fragment is bonded to a η5-C5Me5− fragment through all five of the carbons of the ring.[[96]](https://en.wikipedia.org/wiki/Carbon#cite_note-96)

It is important to note that in the cases above, each of the bonds to carbon contain less than two formal electron pairs, making them hypercoordinate, but not hypervalent. Even in cases of alleged 10-C-5 species (that is, a carbon with five ligands and a formal electron count of ten), as reported by Akiba and co-workers,[[97]](https://en.wikipedia.org/wiki/Carbon#cite_note-97) electronic structure calculations conclude that the total number of electrons around carbon is still less than eight, as in the case of other compounds described by [three-center bonding](https://en.wikipedia.org/wiki/Three-center_bond).

**History and etymology**

[](https://en.wikipedia.org/wiki/File:Antoine_lavoisier.jpg)

[Antoine Lavoisier](https://en.wikipedia.org/wiki/Antoine_Lavoisier) in his youth

The [English](https://en.wikipedia.org/wiki/English_language) name *carbon* comes from the [Latin](https://en.wikipedia.org/wiki/Latin) *carbo* for coal and charcoal,[[98]](https://en.wikipedia.org/wiki/Carbon" \l "cite_note-98) whence also comes the [French](https://en.wikipedia.org/wiki/French_language) *charbon*, meaning charcoal. In [German](https://en.wikipedia.org/wiki/German_language), [Dutch](https://en.wikipedia.org/wiki/Dutch_language) and [Danish](https://en.wikipedia.org/wiki/Danish_language), the names for carbon are *Kohlenstoff*, *koolstof* and *kulstof* respectively, all literally meaning [coal](https://en.wikipedia.org/wiki/Coal)-substance.

Carbon was discovered in prehistory and was known in the forms of [soot](https://en.wikipedia.org/wiki/Soot) and [charcoal](https://en.wikipedia.org/wiki/Charcoal) to the earliest [human](https://en.wikipedia.org/wiki/Human) [civilizations](https://en.wikipedia.org/wiki/Civilization). Diamonds were known probably as early as 2500 BCE in China, while carbon in the form of [charcoal](https://en.wikipedia.org/wiki/Charcoal) was made around Roman times by the same chemistry as it is today, by heating wood in a [pyramid](https://en.wikipedia.org/wiki/Pyramid) covered with [clay](https://en.wikipedia.org/wiki/Clay) to exclude air.[[99]](https://en.wikipedia.org/wiki/Carbon#cite_note-ancient_China-99)[[100]](https://en.wikipedia.org/wiki/Carbon#cite_note-100)

[](https://en.wikipedia.org/wiki/File:Carl_Wilhelm_Scheele_from_Familj-Journalen1874.png)

[Carl Wilhelm Scheele](https://en.wikipedia.org/wiki/Carl_Wilhelm_Scheele)

In 1722, [René Antoine Ferchault de Réaumur](https://en.wikipedia.org/wiki/Ren%C3%A9_Antoine_Ferchault_de_R%C3%A9aumur) demonstrated that iron was transformed into steel through the absorption of some substance, now known to be carbon.[[101]](https://en.wikipedia.org/wiki/Carbon#cite_note-101) In 1772, [Antoine Lavoisier](https://en.wikipedia.org/wiki/Antoine_Lavoisier) showed that diamonds are a form of carbon; when he burned samples of charcoal and diamond and found that neither produced any water and that both released the same amount of [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide) per [gram](https://en.wikipedia.org/wiki/Gram). In 1779,[[102]](https://en.wikipedia.org/wiki/Carbon#cite_note-102) [Carl Wilhelm Scheele](https://en.wikipedia.org/wiki/Carl_Wilhelm_Scheele) showed that graphite, which had been thought of as a form of [lead](https://en.wikipedia.org/wiki/Lead), was instead identical with charcoal but with a small admixture of iron, and that it gave "aerial acid" (his name for carbon dioxide) when oxidized with nitric acid.[[103]](https://en.wikipedia.org/wiki/Carbon#cite_note-103) In 1786, the French scientists [Claude Louis Berthollet](https://en.wikipedia.org/wiki/Claude_Louis_Berthollet), [Gaspard Monge](https://en.wikipedia.org/wiki/Gaspard_Monge) and C. A. Vandermonde confirmed that graphite was mostly carbon by oxidizing it in oxygen in much the same way Lavoisier had done with diamond.[[104]](https://en.wikipedia.org/wiki/Carbon#cite_note-104) Some iron again was left, which the French scientists thought was necessary to the graphite structure. In their publication they proposed the name *carbone* (Latin *carbonum*) for the element in graphite which was given off as a gas upon burning graphite. Antoine Lavoisier then listed carbon as an [element](https://en.wikipedia.org/wiki/Chemical_element) in his 1789 textbook.[[105]](https://en.wikipedia.org/wiki/Carbon#cite_note-105)

A new [allotrope](https://en.wikipedia.org/wiki/Allotrope) of carbon, [fullerene](https://en.wikipedia.org/wiki/Fullerene), that was discovered in 1985[[106]](https://en.wikipedia.org/wiki/Carbon#cite_note-106) includes [nanostructured](https://en.wikipedia.org/wiki/Nanostructure) forms such as [buckyballs](https://en.wikipedia.org/wiki/Buckyball) and [nanotubes](https://en.wikipedia.org/wiki/Carbon_nanotube).[[32]](https://en.wikipedia.org/wiki/Carbon#cite_note-buckyballs-32) Their discoverers – [Robert Curl](https://en.wikipedia.org/wiki/Robert_Curl), [Harold Kroto](https://en.wikipedia.org/wiki/Harold_Kroto) and [Richard Smalley](https://en.wikipedia.org/wiki/Richard_Smalley) – received the [Nobel Prize](https://en.wikipedia.org/wiki/Nobel_Prize) in Chemistry in 1996.[[107]](https://en.wikipedia.org/wiki/Carbon#cite_note-107) The resulting renewed interest in new forms lead to the discovery of further exotic allotropes, including [glassy carbon](https://en.wikipedia.org/wiki/Glassy_carbon), and the realization that "[amorphous carbon](https://en.wikipedia.org/wiki/Amorphous_carbon)" is not strictly [amorphous](https://en.wikipedia.org/wiki/Amorphous).[[39]](https://en.wikipedia.org/wiki/Carbon#cite_note-glassy_carbon-39)

**Production**

**Graphite**

Main article: [Graphite](https://en.wikipedia.org/wiki/Graphite)

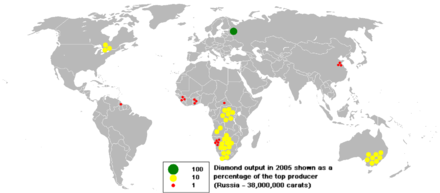
Commercially viable natural deposits of graphite occur in many parts of the world, but the most important sources economically are in [China](https://en.wikipedia.org/wiki/China), [India](https://en.wikipedia.org/wiki/India), [Brazil](https://en.wikipedia.org/wiki/Brazil) and [North Korea](https://en.wikipedia.org/wiki/North_Korea). Graphite deposits are of [metamorphic](https://en.wikipedia.org/wiki/Metamorphic_rock) origin, found in association with [quartz](https://en.wikipedia.org/wiki/Quartz), [mica](https://en.wikipedia.org/wiki/Mica) and [feldspars](https://en.wikipedia.org/wiki/Feldspar) in schists, [gneisses](https://en.wikipedia.org/wiki/Gneiss) and metamorphosed [sandstones](https://en.wikipedia.org/wiki/Sandstone) and [limestone](https://en.wikipedia.org/wiki/Limestone) as [lenses](https://en.wikipedia.org/wiki/Lens_(geology)) or [veins](https://en.wikipedia.org/wiki/Vein_(geology)), sometimes of a metre or more in thickness. Deposits of graphite in [Borrowdale](https://en.wikipedia.org/wiki/Borrowdale), [Cumberland](https://en.wikipedia.org/wiki/Cumberland), [England](https://en.wikipedia.org/wiki/England) were at first of sufficient size and purity that, until the 19th century, [pencils](https://en.wikipedia.org/wiki/Pencil) were made simply by sawing blocks of natural graphite into strips before encasing the strips in wood. Today, smaller deposits of graphite are obtained by crushing the parent rock and floating the lighter graphite out on water.[[108]](https://en.wikipedia.org/wiki/Carbon#cite_note-USGS-108)

There are three types of natural graphite—amorphous, flake or crystalline flake, and vein or lump. Amorphous graphite is the lowest quality and most abundant. Contrary to science, in industry "amorphous" refers to very small crystal size rather than complete lack of crystal structure. Amorphous is used for lower value graphite products and is the lowest priced graphite. Large amorphous graphite deposits are found in China, Europe, Mexico and the United States. Flake graphite is less common and of higher quality than amorphous; it occurs as separate plates that crystallized in metamorphic rock. Flake graphite can be four times the price of amorphous. Good quality flakes can be processed into expandable graphite for many uses, such as [flame retardants](https://en.wikipedia.org/wiki/Flame_retardant). The foremost deposits are found in Austria, Brazil, Canada, China, Germany and Madagascar. Vein or lump graphite is the rarest, most valuable, and highest quality type of natural graphite. It occurs in veins along intrusive contacts in solid lumps, and it is only commercially mined in Sri Lanka.[[108]](https://en.wikipedia.org/wiki/Carbon#cite_note-USGS-108)

According to the [USGS](https://en.wikipedia.org/wiki/USGS), world production of natural graphite was 1.1 million tonnes in 2010, to which China contributed 800,000 t, India 130,000 t, Brazil 76,000 t, North Korea 30,000 t and Canada 25,000 t. No natural graphite was reported mined in the United States, but 118,000 t of synthetic graphite with an estimated value of $998 million was produced in 2009.[[108]](https://en.wikipedia.org/wiki/Carbon#cite_note-USGS-108)

**Diamond**

Main article: [Diamond](https://en.wikipedia.org/wiki/Diamond)

[](https://en.wikipedia.org/wiki/File:Global_Diamond_Output_in_2005.png)

Diamond output in 2005

The diamond supply chain is controlled by a limited number of powerful businesses, and is also highly concentrated in a small number of locations around the world (see figure).

Only a very small fraction of the diamond ore consists of actual diamonds. The ore is crushed, during which care has to be taken in order to prevent larger diamonds from being destroyed in this process and subsequently the particles are sorted by density. Today, diamonds are located in the diamond-rich density fraction with the help of [X-ray fluorescence](https://en.wikipedia.org/wiki/X-ray_fluorescence), after which the final sorting steps are done by hand. Before the use of [X-rays](https://en.wikipedia.org/wiki/X-ray) became commonplace, the separation was done with grease belts; diamonds have a stronger tendency to stick to grease than the other minerals in the ore.[[109]](https://en.wikipedia.org/wiki/Carbon#cite_note-109)

Historically diamonds were known to be found only in alluvial deposits in [southern India](https://en.wikipedia.org/wiki/Southern_India).[[110]](https://en.wikipedia.org/wiki/Carbon#cite_note-Catelle1-110) India led the world in diamond production from the time of their discovery in approximately the 9th century BC[[111]](https://en.wikipedia.org/wiki/Carbon#cite_note-Ball-111) to the mid-18th century AD, but the commercial potential of these sources had been exhausted by the late 18th century and at that time India was eclipsed by Brazil where the first non-Indian diamonds were found in 1725.[[112]](https://en.wikipedia.org/wiki/Carbon#cite_note-112)

Diamond production of primary deposits (kimberlites and lamproites) only started in the 1870s after the discovery of the Diamond fields in South Africa. Production has increased over time and now an accumulated total of 4.5 billion carats have been mined since that date.[[113]](https://en.wikipedia.org/wiki/Carbon#cite_note-giasummer2007-113) About 20% of that amount has been mined in the last 5 years alone, and during the last ten years 9 new mines have started production while 4 more are waiting to be opened soon. Most of these mines are located in Canada, Zimbabwe, Angola, and one in Russia.[[113]](https://en.wikipedia.org/wiki/Carbon#cite_note-giasummer2007-113)

In the United States, diamonds have been found in [Arkansas](https://en.wikipedia.org/wiki/Arkansas), [Colorado](https://en.wikipedia.org/wiki/Colorado) and [Montana](https://en.wikipedia.org/wiki/Montana).[[114]](https://en.wikipedia.org/wiki/Carbon#cite_note-DGemGLorenz-114)[[115]](https://en.wikipedia.org/wiki/Carbon#cite_note-115) In 2004, a startling discovery of a microscopic diamond in the United States[[116]](https://en.wikipedia.org/wiki/Carbon#cite_note-116) led to the January 2008 bulk-sampling of [kimberlite pipes](https://en.wikipedia.org/wiki/Kimberlite_pipes) in a remote part of [Montana](https://en.wikipedia.org/wiki/Montana).[[117]](https://en.wikipedia.org/wiki/Carbon#cite_note-117)

Today, most commercially viable diamond deposits are in [Russia](https://en.wikipedia.org/wiki/Russia), [Botswana](https://en.wikipedia.org/wiki/Botswana), [Australia](https://en.wikipedia.org/wiki/Australia) and the [Democratic Republic of Congo](https://en.wikipedia.org/wiki/Democratic_Republic_of_Congo).[[118]](https://en.wikipedia.org/wiki/Carbon#cite_note-118) In 2005, Russia produced almost one-fifth of the global diamond output, reports the [British Geological Survey](https://en.wikipedia.org/wiki/British_Geological_Survey). Australia has the richest diamantiferous pipe with production reaching peak levels of 42 metric tons (41 long tons; 46 short tons) per year in the 1990s.[[114]](https://en.wikipedia.org/wiki/Carbon#cite_note-DGemGLorenz-114) There are also commercial deposits being actively mined in the [Northwest Territories](https://en.wikipedia.org/wiki/Northwest_Territories) of [Canada](https://en.wikipedia.org/wiki/Canada), [Siberia](https://en.wikipedia.org/wiki/Siberia) (mostly in [Yakutia territory](https://en.wikipedia.org/wiki/Sakha_Republic); for example, [Mir pipe](https://en.wikipedia.org/wiki/Mir_Mine) and [Udachnaya pipe](https://en.wikipedia.org/wiki/Udachnaya_pipe)), Brazil, and in Northern and Western [Australia](https://en.wikipedia.org/wiki/Australia).

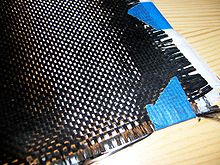
**Applications**

[](https://en.wikipedia.org/wiki/File:Mechanical_pencil_lead_spilling_out_051907.jpg)

Pencil leads for mechanical pencils are made of [graphite](https://en.wikipedia.org/wiki/Graphite) (often mixed with a clay or synthetic binder).

[](https://en.wikipedia.org/wiki/File:Charcoal_sticks_051907.jpg)

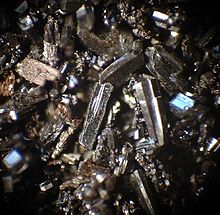
Sticks of vine and compressed [charcoal](https://en.wikipedia.org/wiki/Charcoal)

[](https://en.wikipedia.org/wiki/File:Kohlenstofffasermatte.jpg)

A cloth of woven carbon fibres

[](https://en.wikipedia.org/wiki/File:SiC_p1390066.jpg)

[Silicon carbide](https://en.wikipedia.org/wiki/Silicon_carbide) [single crystal](https://en.wikipedia.org/wiki/Single_crystal)

[](https://en.wikipedia.org/wiki/File:C60-Fulleren-kristallin.JPG)

The *C*60 fullerene in crystalline form

[](https://en.wikipedia.org/wiki/File:Tungsten_carbide.jpg)

[Tungsten carbide](https://en.wikipedia.org/wiki/Tungsten_carbide) [endmills](https://en.wikipedia.org/wiki/Endmills)

Carbon is essential to all known living systems, and without it life as we know it could not exist (see [alternative biochemistry](https://en.wikipedia.org/wiki/Alternative_biochemistry)). The major economic use of carbon other than food and wood is in the form of hydrocarbons, most notably the [fossil fuel](https://en.wikipedia.org/wiki/Fossil_fuel) [methane](https://en.wikipedia.org/wiki/Methane) gas and [crude oil](https://en.wikipedia.org/wiki/Crude_oil) (petroleum). [Crude oil](https://en.wikipedia.org/wiki/Petroleum) is [distilled](https://en.wikipedia.org/wiki/Distillation) in [refineries](https://en.wikipedia.org/wiki/Oil_refinery) by the [petrochemical industry](https://en.wikipedia.org/wiki/Petrochemical_industry) to produce [gasoline](https://en.wikipedia.org/wiki/Gasoline), [kerosene](https://en.wikipedia.org/wiki/Kerosene), and other products. [Cellulose](https://en.wikipedia.org/wiki/Cellulose) is a natural, carbon-containing polymer produced by plants in the form of [wood](https://en.wikipedia.org/wiki/Wood), [cotton](https://en.wikipedia.org/wiki/Cotton), [linen](https://en.wikipedia.org/wiki/Linen), and [hemp](https://en.wikipedia.org/wiki/Hemp). [Cellulose](https://en.wikipedia.org/wiki/Cellulose) is used primarily for maintaining structure in plants. Commercially valuable carbon polymers of animal origin include [wool](https://en.wikipedia.org/wiki/Wool), [cashmere](https://en.wikipedia.org/wiki/Cashmere_wool) and [silk](https://en.wikipedia.org/wiki/Silk). [Plastics](https://en.wikipedia.org/wiki/Plastics) are made from synthetic carbon polymers, often with oxygen and nitrogen atoms included at regular intervals in the main polymer chain. The raw materials for many of these synthetic substances come from crude oil.

The uses of carbon and its compounds are extremely varied. It can form [alloys](https://en.wikipedia.org/wiki/Alloys) with [iron](https://en.wikipedia.org/wiki/Iron), of which the most common is [carbon steel](https://en.wikipedia.org/wiki/Carbon_steel). [Graphite](https://en.wikipedia.org/wiki/Graphite) is combined with [clays](https://en.wikipedia.org/wiki/Clay) to form the 'lead' used in [pencils](https://en.wikipedia.org/wiki/Pencil) used for [writing](https://en.wikipedia.org/wiki/Writing) and [drawing](https://en.wikipedia.org/wiki/Drawing). It is also used as a [lubricant](https://en.wikipedia.org/wiki/Lubricant) and a [pigment](https://en.wikipedia.org/wiki/Pigment), as a molding material in [glass](https://en.wikipedia.org/wiki/Glass) manufacture, in [electrodes](https://en.wikipedia.org/wiki/Electrodes) for dry [batteries](https://en.wikipedia.org/wiki/Battery_(electricity)) and in [electroplating](https://en.wikipedia.org/wiki/Electroplating) and [electroforming](https://en.wikipedia.org/wiki/Electroforming), in [brushes](https://en.wikipedia.org/wiki/Brush_(electric)) for [electric motors](https://en.wikipedia.org/wiki/Electric_motors) and as a [neutron moderator](https://en.wikipedia.org/wiki/Neutron_moderator) in [nuclear reactors](https://en.wikipedia.org/wiki/Nuclear_reactors).

[Charcoal](https://en.wikipedia.org/wiki/Charcoal) is used as a drawing material in [artwork](https://en.wikipedia.org/wiki/Art), barbecue [grilling](https://en.wikipedia.org/wiki/Grilling), [iron smelting](https://en.wikipedia.org/wiki/Iron_smelting), and in many other applications. Wood, coal and oil are used as [fuel](https://en.wikipedia.org/wiki/Fuel) for production of energy and [heating](https://en.wikipedia.org/wiki/Heating). Gem quality [diamond](https://en.wikipedia.org/wiki/Diamond) is used in jewelry, and [industrial diamonds](https://en.wikipedia.org/wiki/Industrial_diamond) are used in drilling, cutting and polishing tools for machining metals and stone. Plastics are made from fossil hydrocarbons, and [carbon fiber](https://en.wikipedia.org/wiki/Carbon_fiber), made by [pyrolysis](https://en.wikipedia.org/wiki/Pyrolysis) of synthetic [polyester](https://en.wikipedia.org/wiki/Polyester) [fibers](https://en.wikipedia.org/wiki/Fiber) is used to reinforce plastics to form advanced, lightweight [composite materials](https://en.wikipedia.org/wiki/Composite_materials).

[Carbon fiber](https://en.wikipedia.org/wiki/Carbon_fiber) is made by pyrolysis of extruded and stretched filaments of [polyacrylonitrile](https://en.wikipedia.org/wiki/Polyacrylonitrile) (PAN) and other organic substances. The crystallographic structure and mechanical properties of the fiber depend on the type of starting material, and on the subsequent processing. Carbon fibers made from PAN have structure resembling narrow filaments of graphite, but thermal processing may re-order the structure into a continuous rolled sheet. The result is fibers with higher [specific tensile strength](https://en.wikipedia.org/wiki/Specific_strength) than steel.[[119]](https://en.wikipedia.org/wiki/Carbon#cite_note-cantwell-119)

[Carbon black](https://en.wikipedia.org/wiki/Carbon_black) is used as the black [pigment](https://en.wikipedia.org/wiki/Pigment) in [printing](https://en.wikipedia.org/wiki/Printing) [ink](https://en.wikipedia.org/wiki/Ink), artist's oil paint and water colours, [carbon paper](https://en.wikipedia.org/wiki/Carbon_paper), automotive finishes, [India ink](https://en.wikipedia.org/wiki/India_ink) and [laser printer](https://en.wikipedia.org/wiki/Laser_printer) [toner](https://en.wikipedia.org/wiki/Toner). [Carbon black](https://en.wikipedia.org/wiki/Carbon_black) is also used as a [filler](https://en.wikipedia.org/wiki/Filler_(materials)) in [rubber](https://en.wikipedia.org/wiki/Rubber) products such as tyres and in [plastic](https://en.wikipedia.org/wiki/Plastic) compounds. [Activated charcoal](https://en.wikipedia.org/wiki/Activated_charcoal) is used as an [absorbent](https://en.wikipedia.org/wiki/Absorption_(chemistry)) and [adsorbent](https://en.wikipedia.org/wiki/Adsorbent) in [filter](https://en.wikipedia.org/wiki/Filter_(chemistry)) material in applications as diverse as [gas masks](https://en.wikipedia.org/wiki/Gas_masks), [water purification](https://en.wikipedia.org/wiki/Water_purification), and [kitchen](https://en.wikipedia.org/wiki/Kitchen) [extractor hoods](https://en.wikipedia.org/wiki/Extractor_hood), and in medicine to [absorb](https://en.wikipedia.org/wiki/Absorption_(chemistry)) toxins, poisons, or gases from the [digestive system](https://en.wikipedia.org/wiki/Human_digestive_system). Carbon is used in [chemical reduction](https://en.wikipedia.org/wiki/Redox) at high temperatures. [Coke](https://en.wikipedia.org/wiki/Coke_(fuel)) is used to reduce iron ore into iron (smelting). [Case hardening](https://en.wikipedia.org/wiki/Case_hardening) of steel is achieved by heating finished steel components in carbon powder. [Carbides](https://en.wikipedia.org/wiki/Carbide) of [silicon](https://en.wikipedia.org/wiki/Silicon_carbide), [tungsten](https://en.wikipedia.org/wiki/Tungsten_carbide), [boron](https://en.wikipedia.org/wiki/Boron_carbide) and [titanium](https://en.wikipedia.org/wiki/Titanium_carbide), are among the hardest known materials, and are used as [abrasives](https://en.wikipedia.org/wiki/Abrasives) in cutting and grinding tools. Carbon compounds make up most of the materials used in clothing, such as natural and synthetic [textiles](https://en.wikipedia.org/wiki/Textiles) and [leather](https://en.wikipedia.org/wiki/Leather), and almost all of the interior surfaces in the [built environment](https://en.wikipedia.org/wiki/Built_environment) other than glass, stone and metal.

**Diamonds**

The [diamond](https://en.wikipedia.org/wiki/Diamond) industry falls into two categories: one dealing with gem-grade diamonds and the other, with industrial-grade diamonds. While a large trade in both types of diamonds exists, the two markets act in dramatically different ways.

Unlike [precious metals](https://en.wikipedia.org/wiki/Precious_metal) such as [gold](https://en.wikipedia.org/wiki/Gold) or [platinum](https://en.wikipedia.org/wiki/Platinum), gem diamonds do not trade as a [commodity](https://en.wikipedia.org/wiki/Commodity): there is a substantial mark-up in the sale of diamonds, and there is not a very active market for resale of diamonds.

Industrial diamonds are valued mostly for their hardness and heat conductivity, with the gemological qualities of clarity and color being mostly irrelevant. About 80% of mined diamonds (equal to about 100 million carats or 20 tonnes annually) are unsuitable for use as gemstones are relegated for industrial use (known as [*bort*](https://en.wikipedia.org/wiki/Bort)*)*.[[120]](https://en.wikipedia.org/wiki/Carbon#cite_note-120) [synthetic diamonds](https://en.wikipedia.org/wiki/Synthetic_diamond), invented in the 1950s, found almost immediate industrial applications; 3 billion carats (600 [tonnes](https://en.wikipedia.org/wiki/Tonne)) of synthetic diamond is produced annually.[[121]](https://en.wikipedia.org/wiki/Carbon#cite_note-usgs-121)

The dominant industrial use of diamond is in cutting, drilling, grinding, and polishing. Most of these applications do not require large diamonds; in fact, most diamonds of gem-quality except for their small size can be used industrially. Diamonds are embedded in drill tips or saw blades, or ground into a powder for use in grinding and polishing applications.[[122]](https://en.wikipedia.org/wiki/Carbon#cite_note-122) Specialized applications include use in laboratories as containment for [high pressure experiments](https://en.wikipedia.org/wiki/Pressure_experiment) (see [diamond anvil cell](https://en.wikipedia.org/wiki/Diamond_anvil_cell)), high-performance [bearings](https://en.wikipedia.org/wiki/Bearing_(mechanical)), and limited use in specialized [windows](https://en.wikipedia.org/wiki/Window).[[123]](https://en.wikipedia.org/wiki/Carbon#cite_note-123)[[124]](https://en.wikipedia.org/wiki/Carbon#cite_note-124) With the continuing advances in the production of synthetic diamonds, new applications are becoming feasible. Garnering much excitement is the possible use of diamond as a [semiconductor](https://en.wikipedia.org/wiki/Semiconductor) suitable for [microchips](https://en.wikipedia.org/wiki/Integrated_circuit), and because of its exceptional heat conductance property, as a [heat sink](https://en.wikipedia.org/wiki/Heat_sink) in [electronics](https://en.wikipedia.org/wiki/Electronics).[[125]](https://en.wikipedia.org/wiki/Carbon#cite_note-125)

**Precautions**

[](https://en.wikipedia.org/wiki/File:Worker_at_carbon_black_plant2.jpg)

Worker at [carbon black](https://en.wikipedia.org/wiki/Carbon_black) plant in [Sunray, Texas](https://en.wikipedia.org/wiki/Sunray,_Texas) (photo by [John Vachon](https://en.wikipedia.org/wiki/John_Vachon), 1942)

Pure carbon has extremely low [toxicity](https://en.wikipedia.org/wiki/Toxicity) to humans and can be handled and even ingested safely in the form of graphite or charcoal.[*[citation needed](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed" \o "Wikipedia:Citation needed)*] It is resistant to dissolution or chemical attack, even in the acidic contents of the digestive tract. Consequently, once it enters into the body's tissues it is likely to remain there indefinitely. [Carbon black](https://en.wikipedia.org/wiki/Carbon_black) was probably one of the first pigments to be used for [tattooing](https://en.wikipedia.org/wiki/Tattoo), and [Ötzi the Iceman](https://en.wikipedia.org/wiki/%C3%96tzi_the_Iceman) was found to have carbon tattoos that survived during his life and for 5200 years after his death.[[126]](https://en.wikipedia.org/wiki/Carbon#cite_note-126) Inhalation of coal dust or soot (carbon black) in large quantities can be dangerous, irritating lung tissues and causing the congestive [lung](https://en.wikipedia.org/wiki/Human_lung) disease, [coalworker's pneumoconiosis](https://en.wikipedia.org/wiki/Coalworker%27s_pneumoconiosis). Diamond dust used as an abrasive can be harmful if ingested or inhaled. Microparticles of carbon are produced in diesel engine exhaust fumes, and may accumulate in the lungs.[[127]](https://en.wikipedia.org/wiki/Carbon#cite_note-127) In these examples, the harm may result from contaminants (e.g., organic chemicals, heavy metals) rather than from the carbon itself.

Carbon generally has low toxicity to [life on Earth](https://en.wikipedia.org/wiki/Life); but carbon nanoparticles are deadly to [*Drosophila*](https://en.wikipedia.org/wiki/Drosophila).[[128]](https://en.wikipedia.org/wiki/Carbon#cite_note-128)

Carbon may burn vigorously and brightly in the presence of air at high temperatures. Large accumulations of coal, which have remained inert for hundreds of millions of years in the absence of oxygen, may [spontaneously combust](https://en.wikipedia.org/wiki/Spontaneous_combustion) when exposed to air in coal mine waste tips, ship cargo holds and coal bunkers,[[129]](https://en.wikipedia.org/wiki/Carbon#cite_note-129)[[130]](https://en.wikipedia.org/wiki/Carbon#cite_note-130) and storage dumps.

In [nuclear applications](https://en.wikipedia.org/wiki/Nuclear_reactor) where graphite is used as a [neutron moderator](https://en.wikipedia.org/wiki/Neutron_moderator), accumulation of [Wigner energy](https://en.wikipedia.org/wiki/Wigner_energy) followed by a sudden, spontaneous release may occur. [Annealing](https://en.wikipedia.org/wiki/Annealing_(metallurgy)) to at least 250 °C can release the energy safely, although in the [Windscale fire](https://en.wikipedia.org/wiki/Windscale_fire) the procedure went wrong, causing other reactor materials to combust.

The great variety of carbon compounds include such lethal poisons as [tetrodotoxin](https://en.wikipedia.org/wiki/Tetrodotoxin), the [lectin](https://en.wikipedia.org/wiki/Lectin) [ricin](https://en.wikipedia.org/wiki/Ricin) from seeds of the [castor oil plant](https://en.wikipedia.org/wiki/Castor_oil_plant) [*Ricinus communis*](https://en.wikipedia.org/wiki/Ricinus_communis), [cyanide](https://en.wikipedia.org/wiki/Cyanide) (CN−), and [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide_poisoning); and such essentials to life as [glucose](https://en.wikipedia.org/wiki/Glucose) and [protein](https://en.wikipedia.org/wiki/Protein).

**See also**

|  |  |
| --- | --- |
| https://upload.wikimedia.org/wikipedia/commons/thumb/a/a8/Office-book.svg/30px-Office-book.svg.png | * [**Book: Period 2 elements**](https://en.wikipedia.org/wiki/Book:Carbon) * [**Book: Chemical elements (sorted alphabetically)**](https://en.wikipedia.org/wiki/Book:Carbon_group) * [**Book: Chemical elements (sorted by number)**](https://en.wikipedia.org/wiki/Book:Chemical_elements_(sorted_by_number)) |

* [Carbon chauvinism](https://en.wikipedia.org/wiki/Carbon_chauvinism)
* [Carbon detonation](https://en.wikipedia.org/wiki/Carbon_detonation)
* [Carbon footprint](https://en.wikipedia.org/wiki/Carbon_footprint)
* [Carbon star](https://en.wikipedia.org/wiki/Carbon_star)
* [Low-carbon economy](https://en.wikipedia.org/wiki/Low-carbon_economy)
* [Timeline of carbon nanotubes](https://en.wikipedia.org/wiki/Timeline_of_carbon_nanotubes)
* **[Papapishu-Lab-icon-6.svg](https://en.wikipedia.org/wiki/File:Papapishu-Lab-icon-6.svg)**[**Chemistry portal**](https://en.wikipedia.org/wiki/Portal:Chemistry)

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[13](https://en.wikipedia.org/wiki/Boron_group) | [14](https://en.wikipedia.org/wiki/Carbon_group) | [15](https://en.wikipedia.org/wiki/Pnictogen) | [16](https://en.wikipedia.org/wiki/Chalcogen) | [17](https://en.wikipedia.org/wiki/Halogen) | [18](https://en.wikipedia.org/wiki/Noble_gas) | | [1](https://en.wikipedia.org/wiki/Period_1_element) | [H](https://en.wikipedia.org/wiki/Hydrogen) |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | [He](https://en.wikipedia.org/wiki/Helium) | | [2](https://en.wikipedia.org/wiki/Period_2_element) | [Li](https://en.wikipedia.org/wiki/Lithium) | [Be](https://en.wikipedia.org/wiki/Beryllium) |  | | | | | | | | | | | | | | | | | | | | | | | | [B](https://en.wikipedia.org/wiki/Boron) | C | [N](https://en.wikipedia.org/wiki/Nitrogen) | [O](https://en.wikipedia.org/wiki/Oxygen) | [F](https://en.wikipedia.org/wiki/Fluorine) | [Ne](https://en.wikipedia.org/wiki/Neon) | | [3](https://en.wikipedia.org/wiki/Period_3_element) | [Na](https://en.wikipedia.org/wiki/Sodium) | [Mg](https://en.wikipedia.org/wiki/Magnesium) |  | | | | | | | | | | | | | | | | | | | | | | | | [Al](https://en.wikipedia.org/wiki/Aluminium) | [Si](https://en.wikipedia.org/wiki/Silicon) | [P](https://en.wikipedia.org/wiki/Phosphorus) | [S](https://en.wikipedia.org/wiki/Sulfur) | [Cl](https://en.wikipedia.org/wiki/Chlorine) | [Ar](https://en.wikipedia.org/wiki/Argon) | | [4](https://en.wikipedia.org/wiki/Period_4_element) | [K](https://en.wikipedia.org/wiki/Potassium) | [Ca](https://en.wikipedia.org/wiki/Calcium) | [Sc](https://en.wikipedia.org/wiki/Scandium) |  | | | | | | | | | | | | | | [Ti](https://en.wikipedia.org/wiki/Titanium) | [V](https://en.wikipedia.org/wiki/Vanadium) | [Cr](https://en.wikipedia.org/wiki/Chromium) | [Mn](https://en.wikipedia.org/wiki/Manganese) | [Fe](https://en.wikipedia.org/wiki/Iron) | [Co](https://en.wikipedia.org/wiki/Cobalt) | [Ni](https://en.wikipedia.org/wiki/Nickel) | [Cu](https://en.wikipedia.org/wiki/Copper) | [Zn](https://en.wikipedia.org/wiki/Zinc) | [Ga](https://en.wikipedia.org/wiki/Gallium) | [Ge](https://en.wikipedia.org/wiki/Germanium) | [As](https://en.wikipedia.org/wiki/Arsenic) | [Se](https://en.wikipedia.org/wiki/Selenium) | [Br](https://en.wikipedia.org/wiki/Bromine) | [Kr](https://en.wikipedia.org/wiki/Krypton) | | [5](https://en.wikipedia.org/wiki/Period_5_element) | [Rb](https://en.wikipedia.org/wiki/Rubidium) | [Sr](https://en.wikipedia.org/wiki/Strontium) | [Y](https://en.wikipedia.org/wiki/Yttrium) |  | | | | | | | | | | | | | | [Zr](https://en.wikipedia.org/wiki/Zirconium) | [Nb](https://en.wikipedia.org/wiki/Niobium) | [Mo](https://en.wikipedia.org/wiki/Molybdenum) | [Tc](https://en.wikipedia.org/wiki/Technetium) | [Ru](https://en.wikipedia.org/wiki/Ruthenium) | [Rh](https://en.wikipedia.org/wiki/Rhodium) | [Pd](https://en.wikipedia.org/wiki/Palladium) | [Ag](https://en.wikipedia.org/wiki/Silver) | [Cd](https://en.wikipedia.org/wiki/Cadmium) | [In](https://en.wikipedia.org/wiki/Indium) | [Sn](https://en.wikipedia.org/wiki/Tin) | [Sb](https://en.wikipedia.org/wiki/Antimony) | [Te](https://en.wikipedia.org/wiki/Tellurium) | [I](https://en.wikipedia.org/wiki/Iodine) | [Xe](https://en.wikipedia.org/wiki/Xenon) | | [6](https://en.wikipedia.org/wiki/Period_6_element) | [Cs](https://en.wikipedia.org/wiki/Caesium) | [Ba](https://en.wikipedia.org/wiki/Barium) | [La](https://en.wikipedia.org/wiki/Lanthanum) | [Ce](https://en.wikipedia.org/wiki/Cerium) | [Pr](https://en.wikipedia.org/wiki/Praseodymium) | [Nd](https://en.wikipedia.org/wiki/Neodymium) | [Pm](https://en.wikipedia.org/wiki/Promethium) | [Sm](https://en.wikipedia.org/wiki/Samarium) | [Eu](https://en.wikipedia.org/wiki/Europium) | [Gd](https://en.wikipedia.org/wiki/Gadolinium) | [Tb](https://en.wikipedia.org/wiki/Terbium) | [Dy](https://en.wikipedia.org/wiki/Dysprosium) | [Ho](https://en.wikipedia.org/wiki/Holmium) | [Er](https://en.wikipedia.org/wiki/Erbium) | [Tm](https://en.wikipedia.org/wiki/Thulium) | [Yb](https://en.wikipedia.org/wiki/Ytterbium) | [Lu](https://en.wikipedia.org/wiki/Lutetium) | [Hf](https://en.wikipedia.org/wiki/Hafnium) | [Ta](https://en.wikipedia.org/wiki/Tantalum) | [W](https://en.wikipedia.org/wiki/Tungsten) | [Re](https://en.wikipedia.org/wiki/Rhenium) | [Os](https://en.wikipedia.org/wiki/Osmium) | [Ir](https://en.wikipedia.org/wiki/Iridium) | [Pt](https://en.wikipedia.org/wiki/Platinum) | [Au](https://en.wikipedia.org/wiki/Gold) | [Hg](https://en.wikipedia.org/wiki/Mercury_(element)) | [Tl](https://en.wikipedia.org/wiki/Thallium) | [Pb](https://en.wikipedia.org/wiki/Lead) | [Bi](https://en.wikipedia.org/wiki/Bismuth) | [Po](https://en.wikipedia.org/wiki/Polonium) | [At](https://en.wikipedia.org/wiki/Astatine) | [Rn](https://en.wikipedia.org/wiki/Radon) | | [7](https://en.wikipedia.org/wiki/Period_7_element) | [Fr](https://en.wikipedia.org/wiki/Francium) | [Ra](https://en.wikipedia.org/wiki/Radium) | [Ac](https://en.wikipedia.org/wiki/Actinium) | [Th](https://en.wikipedia.org/wiki/Thorium) | [Pa](https://en.wikipedia.org/wiki/Protactinium) | [U](https://en.wikipedia.org/wiki/Uranium) | [Np](https://en.wikipedia.org/wiki/Neptunium) | [Pu](https://en.wikipedia.org/wiki/Plutonium) | [Am](https://en.wikipedia.org/wiki/Americium) | [Cm](https://en.wikipedia.org/wiki/Curium) | [Bk](https://en.wikipedia.org/wiki/Berkelium) | [Cf](https://en.wikipedia.org/wiki/Californium) | [Es](https://en.wikipedia.org/wiki/Einsteinium) | [Fm](https://en.wikipedia.org/wiki/Fermium) | [Md](https://en.wikipedia.org/wiki/Mendelevium) | [No](https://en.wikipedia.org/wiki/Nobelium) | [Lr](https://en.wikipedia.org/wiki/Lawrencium) | [Rf](https://en.wikipedia.org/wiki/Rutherfordium) | [Db](https://en.wikipedia.org/wiki/Dubnium) | [Sg](https://en.wikipedia.org/wiki/Seaborgium) | [Bh](https://en.wikipedia.org/wiki/Bohrium) | [Hs](https://en.wikipedia.org/wiki/Hassium) | [Mt](https://en.wikipedia.org/wiki/Meitnerium) | [Ds](https://en.wikipedia.org/wiki/Darmstadtium) | [Rg](https://en.wikipedia.org/wiki/Roentgenium) | [Cn](https://en.wikipedia.org/wiki/Copernicium) | [Nh](https://en.wikipedia.org/wiki/Nihonium) | [Fl](https://en.wikipedia.org/wiki/Flerovium) | [Mc](https://en.wikipedia.org/wiki/Moscovium) | [Lv](https://en.wikipedia.org/wiki/Livermorium) | [Ts](https://en.wikipedia.org/wiki/Tennessine) | [Og](https://en.wikipedia.org/wiki/Oganesson) | | |
| |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | [Alkali metal](https://en.wikipedia.org/wiki/Alkali_metal) | [Alkaline earth metal](https://en.wikipedia.org/wiki/Alkaline_earth_metal) | [Lan­thanide](https://en.wikipedia.org/wiki/Lanthanide) | [Actinide](https://en.wikipedia.org/wiki/Actinide) | [Transition metal](https://en.wikipedia.org/wiki/Transition_metal) | [Post-​transition metal](https://en.wikipedia.org/wiki/Post-transition_metal) | [Metalloid](https://en.wikipedia.org/wiki/Metalloid) | [Reactive nonmetal](https://en.wikipedia.org/wiki/Reactive_nonmetal) | [Noble gas](https://en.wikipedia.org/wiki/Noble_gas) | Unknown chemical properties | | |
| * [**v**](https://en.wikipedia.org/wiki/Template:Allotropes_of_carbon) * [**t**](https://en.wikipedia.org/wiki/Template_talk:Allotropes_of_carbon) * [**e**](https://en.wikipedia.org/w/index.php?title=Template:Allotropes_of_carbon&action=edit)   [**Allotropes of carbon**](https://en.wikipedia.org/wiki/Allotropes_of_carbon) | |
| ***sp3*** [***forms***](https://en.wikipedia.org/wiki/Orbital_hybridisation) | * [**Diamond (cubic)**](https://en.wikipedia.org/wiki/Diamond) * [Lonsdaleite (hexagonal diamond)](https://en.wikipedia.org/wiki/Lonsdaleite) |
| ***sp2 forms*** | * [**Graphite**](https://en.wikipedia.org/wiki/Graphite) * [Graphene](https://en.wikipedia.org/wiki/Graphene) * [Fullerenes](https://en.wikipedia.org/wiki/Fullerene) ([*Buckminsterfullerene*](https://en.wikipedia.org/wiki/Buckminsterfullerene), [*C70*](https://en.wikipedia.org/wiki/C70_fullerene), [*Higher fullerenes*](https://en.wikipedia.org/wiki/Higher_fullerenes), [*Lower fullerenes*](https://en.wikipedia.org/wiki/Lower_fullerenes), [*Nanotubes*](https://en.wikipedia.org/wiki/Carbon_nanotube), [*Nanobuds*](https://en.wikipedia.org/wiki/Carbon_nanobud), [*Nanoscrolls*](https://en.wikipedia.org/wiki/Carbon_nanoscrolls)) * [Glassy carbon](https://en.wikipedia.org/wiki/Glassy_carbon) |
| ***sp forms*** | * [Linear acetylenic carbon](https://en.wikipedia.org/wiki/Linear_acetylenic_carbon) |
| ***mixed sp3/sp2 forms*** | * [Amorphous carbon](https://en.wikipedia.org/wiki/Amorphous_carbon) * [Carbon nanofoam](https://en.wikipedia.org/wiki/Carbon_nanofoam) * [Carbide-derived carbon](https://en.wikipedia.org/wiki/Carbide-derived_carbon) * [Q-carbon](https://en.wikipedia.org/wiki/Q-carbon) |
| ***other forms*** | * [C 1](https://en.wikipedia.org/wiki/Atomic_carbon) * [C 2](https://en.wikipedia.org/wiki/Diatomic_carbon) * [C 3](https://en.wikipedia.org/wiki/Tricarbon) |
| ***hypothetical forms*** | * [C 3](https://en.wikipedia.org/wiki/Cyclopropatriene) * [C 6](https://en.wikipedia.org/wiki/Benzotriyne) * [C 8](https://en.wikipedia.org/wiki/Prismane_C8) * [Chaoite](https://en.wikipedia.org/wiki/Chaoite) * [Haeckelites](https://en.wikipedia.org/wiki/Haeckelites) * [Cubic carbon](https://en.wikipedia.org/wiki/Allotropes_of_carbon#Other_possible_forms) * [Metallic carbon](https://en.wikipedia.org/wiki/Allotropes_of_carbon#Other_possible_forms) * [Penta-graphene](https://en.wikipedia.org/wiki/Penta-graphene) |
| ***related*** | * [Activated carbon](https://en.wikipedia.org/wiki/Activated_carbon) * [Carbon black](https://en.wikipedia.org/wiki/Carbon_black) * [Charcoal](https://en.wikipedia.org/wiki/Charcoal) * [Carbon fiber](https://en.wikipedia.org/wiki/Carbon_fibers) * [Aggregated diamond nanorod](https://en.wikipedia.org/wiki/Aggregated_diamond_nanorod) |
| * Portal[Portal](https://en.wikipedia.org/wiki/Portal:Allotropes_of_carbon) | |

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| --- | --- | --- |
| * [**v**](https://en.wikipedia.org/wiki/Template:Inorganic_compounds_of_carbon) * [**t**](https://en.wikipedia.org/wiki/Template_talk:Inorganic_compounds_of_carbon) * [**e**](https://en.wikipedia.org/w/index.php?title=Template:Inorganic_compounds_of_carbon&action=edit)   [**Inorganic compounds of**](https://en.wikipedia.org/wiki/Compounds_of_carbon) **carbon and related ions** | | |
| **Compounds** | | * [CBr4](https://en.wikipedia.org/wiki/Tetrabromomethane) * [CCl4](https://en.wikipedia.org/wiki/Carbon_tetrachloride) * [CF](https://en.wikipedia.org/wiki/Carbon_monofluoride) * [CF4](https://en.wikipedia.org/wiki/Tetrafluoromethane) * [CI4](https://en.wikipedia.org/wiki/Carbon_tetraiodide) * [CO](https://en.wikipedia.org/wiki/Carbon_monoxide) * [CO2](https://en.wikipedia.org/wiki/Carbon_dioxide) * [CO3](https://en.wikipedia.org/wiki/Carbon_trioxide) * [COS](https://en.wikipedia.org/wiki/Carbonyl_sulfide) * [CS](https://en.wikipedia.org/wiki/Carbon_monosulfide) * [CS2](https://en.wikipedia.org/wiki/Carbon_disulfide) * [CSe2](https://en.wikipedia.org/wiki/Carbon_diselenide) * [C3O2](https://en.wikipedia.org/wiki/Carbon_suboxide) * [C3S2](https://en.wikipedia.org/wiki/Carbon_subsulfide) * [SiC](https://en.wikipedia.org/wiki/Silicon_carbide) |
| **Carbon ions** | | * [Carbides](https://en.wikipedia.org/wiki/Carbide) [:C≡C:]2–, [::C::]4–, [:C=C=C:]4– * [Cyanides](https://en.wikipedia.org/wiki/Cyanide) [:C≡N:]– * [Cyanates](https://en.wikipedia.org/wiki/Cyanate) [:O-C≡N:]– * [Thiocyanates](https://en.wikipedia.org/wiki/Thiocyanate) [:S-C≡N:]– * [Fulminates](https://en.wikipedia.org/wiki/Fulminate) [:C≡N-O:]– * [Thiofulminates](https://en.wikipedia.org/w/index.php?title=Thiofulminate&action=edit&redlink=1) [:C≡N-S:]– |
| **Oxides and related** | | * [Oxides](https://en.wikipedia.org/wiki/Oxocarbon) * [Metal carbonyls](https://en.wikipedia.org/wiki/Metal_carbonyl) * [Carbonic acid](https://en.wikipedia.org/wiki/Carbonic_acid) * [Bicarbonates](https://en.wikipedia.org/wiki/Bicarbonate) * [Carbonates](https://en.wikipedia.org/wiki/Carbonate) |
| * [**v**](https://en.wikipedia.org/wiki/Template:ChemicalBondsToCarbon) * [**t**](https://en.wikipedia.org/wiki/Template_talk:ChemicalBondsToCarbon) * [**e**](https://en.wikipedia.org/w/index.php?title=Template:ChemicalBondsToCarbon&action=edit)   **Compounds of carbon with other elements in the periodic table** | | |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | [CH](https://en.wikipedia.org/wiki/Carbon%E2%80%93hydrogen_bond) |  |  | | | | | | | | | | |  | | | | | He | | [CLi](https://en.wikipedia.org/wiki/Organolithium_reagent) | [CBe](https://en.wikipedia.org/wiki/Group_2_organometallic_chemistry#Organoberyllium) | [CB](https://en.wikipedia.org/wiki/Organoboron_chemistry) | [CC](https://en.wikipedia.org/wiki/Carbon%E2%80%93carbon_bond) | [CN](https://en.wikipedia.org/wiki/Carbon%E2%80%93nitrogen_bond) | [CO](https://en.wikipedia.org/wiki/Carbon%E2%80%93oxygen_bond) | [CF](https://en.wikipedia.org/wiki/Carbon%E2%80%93fluorine_bond) | Ne | | [CNa](https://en.wikipedia.org/wiki/Organosodium_chemistry) | [CMg](https://en.wikipedia.org/wiki/Group_2_organometallic_chemistry#Organomagnesium) | [CAl](https://en.wikipedia.org/wiki/Organoaluminium_chemistry) | [CSi](https://en.wikipedia.org/wiki/Organosilicon) | [CP](https://en.wikipedia.org/wiki/Organophosphorus_compound) | [CS](https://en.wikipedia.org/wiki/Organosulfur_compounds) | [CCl](https://en.wikipedia.org/wiki/Organochloride) | CAr | | [CK](https://en.wikipedia.org/wiki/Organosodium_chemistry#Organic_deriatives_of_the_heavier_alkali_metals) | [CCa](https://en.wikipedia.org/wiki/Group_2_organometallic_chemistry#Organocalcium) | [CSc](https://en.wikipedia.org/wiki/Organoscandium_chemistry) |  | [CTi](https://en.wikipedia.org/wiki/Organotitanium_compound) | [CV](https://en.wikipedia.org/wiki/Organovanadium_chemistry) | [CCr](https://en.wikipedia.org/wiki/Organochromium_chemistry) | [CMn](https://en.wikipedia.org/wiki/Organomanganese_chemistry) | [CFe](https://en.wikipedia.org/wiki/Organoiron_chemistry) | [CCo](https://en.wikipedia.org/wiki/Organocobalt_chemistry) | [CNi](https://en.wikipedia.org/wiki/Organonickel) | [CCu](https://en.wikipedia.org/wiki/Organocopper_compound) | [CZn](https://en.wikipedia.org/wiki/Organozinc_compound) | [CGa](https://en.wikipedia.org/wiki/Organogallium_chemistry) | [CGe](https://en.wikipedia.org/wiki/Organogermanium_compound) | [CAs](https://en.wikipedia.org/wiki/Organoarsenic_chemistry) | [CSe](https://en.wikipedia.org/wiki/Organoselenium_chemistry) | [CBr](https://en.wikipedia.org/wiki/Organobromine_compound) | CKr | | [CRb](https://en.wikipedia.org/wiki/Organosodium_chemistry#Organic_deriatives_of_the_heavier_alkali_metals) | [CSr](https://en.wikipedia.org/wiki/Group_2_organometallic_chemistry#Organostrontium) | [CY](https://en.wikipedia.org/wiki/Organoyttrium_chemistry) |  | [CZr](https://en.wikipedia.org/wiki/Organozirconium_chemistry) | [CNb](https://en.wikipedia.org/wiki/Organoniobium_chemistry) | [CMo](https://en.wikipedia.org/wiki/Organomolybdenum_chemistry) | [CTc](https://en.wikipedia.org/wiki/Organomanganese_chemistry#Higher_group_7_organometallics) | [CRu](https://en.wikipedia.org/wiki/Organoruthenium_chemistry) | [CRh](https://en.wikipedia.org/wiki/Organorhodium_chemistry) | [CPd](https://en.wikipedia.org/wiki/Organopalladium) | [CAg](https://en.wikipedia.org/wiki/Organosilver_chemistry) | [CCd](https://en.wikipedia.org/wiki/Organocadmium_compound) | [CIn](https://en.wikipedia.org/wiki/Organogallium_chemistry#Higher_group_13_organometallic_chemistry) | [CSn](https://en.wikipedia.org/wiki/Organotin_chemistry) | [CSb](https://en.wikipedia.org/wiki/Organoantimony_chemistry) | [CTe](https://en.wikipedia.org/wiki/Organotellurium_chemistry) | [CI](https://en.wikipedia.org/wiki/Organoiodine_compound) | [CXe](https://en.wikipedia.org/wiki/Organoxenon_compound) | | [CCs](https://en.wikipedia.org/wiki/Organosodium_chemistry#Organic_deriatives_of_the_heavier_alkali_metals) | [CBa](https://en.wikipedia.org/wiki/Group_2_organometallic_chemistry#Organobarium) | [CLa](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | 1 asterisk | [CHf](https://en.wikipedia.org/wiki/Organohafnium_chemistry) | [CTa](https://en.wikipedia.org/wiki/Organotantalum_chemistry) | [CW](https://en.wikipedia.org/wiki/Organotungsten_chemistry) | [CRe](https://en.wikipedia.org/wiki/Organorhenium_chemistry) | [COs](https://en.wikipedia.org/wiki/Organoosmium_chemistry) | [CIr](https://en.wikipedia.org/wiki/Organoiridium_compound) | [CPt](https://en.wikipedia.org/wiki/Organoplatinum) | [CAu](https://en.wikipedia.org/wiki/Organogold_chemistry) | [CHg](https://en.wikipedia.org/wiki/Organomercury) | [CTl](https://en.wikipedia.org/wiki/Organogallium_chemistry#Higher_group_13_organometallic_chemistry) | [CPb](https://en.wikipedia.org/wiki/Organolead_compound) | [CBi](https://en.wikipedia.org/wiki/Organobismuth_chemistry) | CPo | CAt | Rn | | Fr | [CRa](https://en.wikipedia.org/wiki/Group_2_organometallic_chemistry#Organoradium) | [Ac](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | 2 asterisks | Rf | Db | CSg | Bh | Hs | Mt | Ds | Rg | Cn | Nh | Fl | Mc | Lv | Ts | Og | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  | | | 1 asterisk | [CCe](https://en.wikipedia.org/wiki/Organocerium_chemistry) | [CPr](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CNd](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CPm](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CSm](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CEu](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CGd](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CTb](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CDy](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CHo](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CEr](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CTm](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CYb](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) | [CLu](https://en.wikipedia.org/wiki/Organolanthanide_chemistry) |  | |  | | | 2 asterisks | [CTh](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [CPa](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [CU](https://en.wikipedia.org/wiki/Organouranium_chemistry) | [CNp](https://en.wikipedia.org/wiki/Organoneptunium_chemistry) | [CPu](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [CAm](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [CCm](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [CBk](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [CCf](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [CEs](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [Fm](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [Md](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [No](https://en.wikipedia.org/wiki/Organoactinide_chemistry) | [Lr](https://en.wikipedia.org/wiki/Organoactinide_chemistry) |  | | | |
| **Legend** | * [Chemical bonds](https://en.wikipedia.org/wiki/Chemical_bond) to carbon * Core organic chemistry * Many uses in chemistry * Academic research, no widespread use * Bond unknown | |

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