[Template:About](/wiki/Template:About" \o "Template:About) [Template:Pp-semi-protected](/wiki/Template:Pp-semi-protected) [Template:Use dmy dates](/wiki/Template:Use_dmy_dates) [Template:Infobox iron](/wiki/Template:Infobox_iron)

**Iron** is a [chemical element](/wiki/Chemical_element) with symbol **Fe** (from [Template:Lang-la](/wiki/Template:Lang-la), ultimately from *ferre* to bear or carry) and [atomic number](/wiki/Atomic_number) 26. It is a [metal](/wiki/Metal) in the [first transition series](/wiki/First_transition_series).[[1]](#cite_note-1)<ref name=corr>[Template:Cite book](/wiki/Template:Cite_book)</ref> !Material !TS   
(MPa) !BH   
([Brinell](/wiki/Brinell_scale)) |- |[Iron whiskers](/wiki/Monocrystalline_whisker) |11000 | |- |Ausformed (hardened)   
steel |2930 |850–1200 |- |[Martensitic steel](/wiki/Martensite) |2070 |600 |- |[Bainitic steel](/wiki/Bainite) |1380 |400 |- |[Pearlitic steel](/wiki/Pearlite) |1200 |350 |- |Cold-worked iron |690 |200 |- |Small-grain iron |340 |100 |- |Carbon-containing iron |140 |40 |- |Pure, single-crystal iron |10 |3 |}

The mechanical properties of iron and its alloys can be evaluated using a variety of tests, including the [Brinell test](/wiki/Brinell_scale), [Rockwell test](/wiki/Rockwell_scale) and the [Vickers hardness test](/wiki/Vickers_hardness_test). The data on iron is so consistent that it is often used to calibrate measurements or to compare tests.<ref name=corr/>[[3]](#cite_note-3) However, the mechanical properties of iron are significantly affected by the sample's purity: pure, single crystals of iron are actually softer than aluminium,<ref name=pure/> and the purest industrially produced iron (99.99%) has a hardness of 20–30 Brinell.[[4]](#cite_note-4) An increase in the carbon content will cause a significant increase in the iron's hardness and tensile strength. Maximum hardness of [65 Rc](/wiki/Rockwell_scale) is achieved with a 0.6% carbon content, although the alloy has low tensile strength.[[5]](#cite_note-5)[thumb|right|240px|Molar volume vs. pressure for α iron at room temperature](/wiki/File:Iron-alpha-pV.svg) Because of its significance for planetary cores, the physical properties of iron at high pressures and temperatures have also been studied extensively. The form of iron that is stable under standard conditions can be subjected to pressures up to ca. 15 GPa before transforming into a high-pressure form, as described in the next section.

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### Phase diagram and allotropes[[edit](/index.php?title=(none)&action=edit&section=3)]

[Template:Main article](/wiki/Template:Main_article) Iron represents an example of [allotropy](/wiki/Allotropy) in a metal. There are at least four allotropic forms of iron, known as α, γ, δ, and ε; at very high pressures, some controversial experimental evidence exists for a phase β stable at very high pressures and temperatures.[[6]](#cite_note-6)[thumb|left|240px|Low-pressure](/wiki/File:Pure_iron_phase_diagram_(EN).png) [phase diagram](/wiki/Phase_diagram) of pure iron As molten iron cools it crystallizes at 1538 °C into its δ allotrope, which has a [body-centered cubic](/wiki/Body-centered_cubic) (bcc) [crystal structure](/wiki/Crystal_structure). As it cools further to 1394 °C, it changes to its γ-iron allotrope, a [face-centered cubic](/wiki/Face-centered_cubic) (fcc) crystal structure, or [austenite](/wiki/Austenite). At 912 °C and below, the crystal structure again becomes the bcc α-iron allotrope, or [ferrite](/wiki/Ferrite_(iron)). Finally, at 770 °C (the [Curie point](/wiki/Curie_point), Tc) iron becomes [magnetic](/wiki/Magnetic). As the iron passes through the Curie temperature there is no change in crystalline structure, but there is a change in "domain structure", where each domain contains iron atoms with a particular electronic spin. In unmagnetized iron, all the electronic spins of the atoms within one domain have the same axis orientation; however, the electrons of neighboring domains have other orientations with the result of mutual cancellation and no unmagnetic field. In magnetized iron, the electronic spins of the domains are aligned and the magnetic effects are reinforced. Although each domain contains billions of atoms, they are very small, about 10 micrometres across.[[7]](#cite_note-7) At pressures above approximately 10 GPa and temperatures of a few hundred kelvin or less, α-iron changes into a [hexagonal close-packed](/wiki/Hexagonal_close-packed) (hcp) structure, which is also known as [ε-iron](/wiki/Hexaferrum); the higher-temperature γ-phase also changes into ε-iron, but does so at higher pressure. The [β-phase](/wiki/Beta_ferrite), if it exists, would appear at pressures of at least 50 GPa and temperatures of at least 1500 K and have an orthorhombic or a double hcp structure.[[6]](#cite_note-6) Iron is of greatest importance when mixed with certain other metals and with carbon to form steels. There are many types of steel, all with different properties, and an understanding of the properties of the [allotropes of iron](/wiki/Allotropes_of_iron) is key to the manufacture of good quality steels.

α-iron, also known as ferrite, is the most stable form of iron at normal temperatures. It is a fairly soft metal that can dissolve only a small concentration of carbon (no more than 0.021% by mass at 910 °C).[[8]](#cite_note-8) Above 912 °C and up to 1400 °C α-iron undergoes a [phase transition](/wiki/Phase_transition) from bcc to the fcc configuration of γ-iron, also called [austenite](/wiki/Austenite). This is similarly soft and metallic but can dissolve considerably more carbon (as much as 2.04% by mass at 1146 °C). This form of iron is used in the type of [stainless steel](/wiki/Stainless_steel) used for making cutlery, and hospital and food-service equipment.[[7]](#cite_note-7) The high-pressure phases of iron are important as endmember models for the solid parts of planetary cores. The [inner core](/wiki/Inner_core) of the [Earth](/wiki/Earth) is generally presumed to be an iron-[nickel](/wiki/Nickel) [alloy](/wiki/Alloy) with ε (or β) structure.

The melting point of iron is experimentally well defined for pressures less than 50 GPa. For greater pressures, studies put the γ-ε-liquid [triple point](/wiki/Triple_point) at pressures that differ by tens of gigapascals and 1000 K in the melting point. Generally speaking, [molecular dynamics](/wiki/Molecular_dynamics) computer simulations of iron melting and shock wave experiments suggest higher melting points and a much steeper slope of the melting curve than static experiments carried out in [diamond anvil cells](/wiki/Diamond_anvil_cell).[[9]](#cite_note-9)

### Isotopes[[edit](/index.php?title=(none)&action=edit&section=4)]

[Template:Main article](/wiki/Template:Main_article)

Naturally occurring iron consists of four stable [isotopes](/wiki/Isotope): 5.845% of 54Fe, 91.754% of [56Fe](/wiki/Iron-56), 2.119% of 57Fe and 0.282% of 58Fe. Of these stable isotopes, only 57Fe has a nuclear [spin](/wiki/Spin_(physics)) (−[Template:Frac](/wiki/Template:Frac)). The [nuclide](/wiki/Nuclide) 54Fe theoretically undergoes [double beta decay](/wiki/Double_beta_decay), but the process had never been observed and only the lower limit on the half-life is established: t1/2>3.1×1022 years.

60Fe is an [extinct radionuclide](/wiki/Extinct_radionuclide) of long [half-life](/wiki/Half-life) (2.6 million years).[[10]](#cite_note-10) It is not found on Earth, but its ultimate decay product is the stable nuclide [nickel-60](/wiki/Nickel-60).

Much of the past work on isotopic composition of Fe has focused on the [nucleosynthesis](/wiki/Nucleosynthesis) of 60Fe through studies of [meteorite](/wiki/Meteorite)s and ore formation. In the last decade, advances in [mass spectrometry](/wiki/Mass_spectrometry) have allowed the detection and quantification of minute, naturally occurring variations in the ratios of the [stable isotopes](/wiki/Stable_isotope) of iron. Much of this work is driven by the [Earth](/wiki/Earth_science) and [planetary science](/wiki/Planetary_science) communities, although applications to biological and industrial systems are emerging.[[11]](#cite_note-11) The most abundant iron isotope 56Fe is of particular interest to nuclear scientists because it represents the most common endpoint of [nucleosynthesis](/wiki/Iron#nucleosynthesis). It is often cited, falsely, as the isotope of highest binding energy, a distinction which actually belongs to [nickel-62](/wiki/Nickel-62).[[12]](#cite_note-12) Since 56Ni is easily produced from lighter nuclei in the [alpha process](/wiki/Alpha_process) in [nuclear reactions](/wiki/Nuclear_reaction) in supernovae (see [silicon burning process](/wiki/Silicon_burning_process)), nickel-56 (14 [alpha particles](/wiki/Alpha_particle)) is the endpoint of fusion chains inside [extremely massive stars](/wiki/Population_III_stars), since addition of another alpha particle would result in zinc-60, which requires a great deal more energy. This nickel-56, which has a half-life of about 6 days, is created in quantity in these stars, but soon decays by two successive positron emissions within supernova decay products in the [supernova remnant](/wiki/Supernova_remnant) gas cloud, first to radioactive cobalt-56, and then to stable iron-56. This last nuclide is therefore common in the universe, relative to other stable [metals](/wiki/Metallicity) of approximately the same [atomic weight](/wiki/Atomic_mass).

In phases of the meteorites *Semarkona* and *Chervony Kut,* a correlation between the concentration of 60Ni, the [daughter product](/wiki/Daughter_product) of 60Fe, and the abundance of the stable iron isotopes provided evidence for the existence of 60Fe at the time of [formation of the Solar System](/wiki/Formation_and_evolution_of_the_Solar_System). Possibly the energy released by the decay of 60Fe the radionuclide 26Al contributed to the remelting and [differentiation](/wiki/Planetary_differentiation) of [asteroids](/wiki/Asteroid) after their formation 4.6 billion years ago. The abundance of 60Ni present in [extraterrestrial](/wiki/Wikt:extraterrestrial) material may bring further insight into the origin and early history of the [Solar System](/wiki/Solar_System).[[13]](#cite_note-13) Nuclei of iron atoms have some of the highest binding energies per nucleon, surpassed only by the [nickel isotope](/wiki/Isotopes_of_nickel) 62Ni. It is formed by [nuclear fusion](/wiki/Nuclear_fusion) in stars. Although a further tiny energy gain could be extracted by synthesizing 62Ni, conditions in stars are unsuitable for this process. Element production in supernovas and distribution on Earth greatly favor iron over nickel.[[14]](#cite_note-14) [Iron-56](/wiki/Iron-56) is the heaviest stable isotope produced by the alpha process in [stellar nucleosynthesis](/wiki/Stellar_nucleosynthesis); elements heavier than iron and nickel require a [supernova](/wiki/Supernova) for their formation. Iron is the most abundant element in the core of [red giants](/wiki/Red_giant), and is the most abundant metal in [iron meteorites](/wiki/Iron_meteorite) and in the dense metal [cores of planets](/wiki/Planetary_core) such as [Earth](/wiki/Earth).

### Nucleosynthesis[[edit](/index.php?title=(none)&action=edit&section=5)]

Iron is created by extremely large stars with extremely hot (over 2.5 billion kelvin) cores through the [silicon burning process](/wiki/Silicon_burning_process). It is the heaviest stable element to be produced in this manner. The process starts with the second largest stable nucleus created by silicon burning, which is calcium. One stable nucleus of calcium fuses with one helium nucleus, creating unstable titanium. Before the titanium decays, it can fuse with another helium nucleus, creating unstable chromium. Before the chromium decays, it can fuse with another helium nucleus, creating unstable iron. Before the iron decays, it can fuse with another helium nucleus, creating unstable nickel-56. Any further fusion of nickel-56 consumes energy instead of producing energy, so after the production of nickel-56, the star does not produce the energy necessary to keep the core from collapsing. Eventually, the nickel-56 decays to unstable cobalt-56, which in turn decays to stable [iron-56](/wiki/Iron-56). When the core of the star collapses, it creates a [supernova](/wiki/Supernova). Supernovas also create additional forms of stable iron via the [r-process](/wiki/R-process).

### Occurrence[[edit](/index.php?title=(none)&action=edit&section=6)]

[Template:Category see also](/wiki/Template:Category_see_also)

#### Planetary occurrence[[edit](/index.php?title=(none)&action=edit&section=7)]

[thumb| right|](/wiki/File:Widmanstatten_hand.jpg) [Iron meteorites](/wiki/Iron_meteorite), similar in composition to the Earth's inner- and outer core Iron is the sixth most [abundant element](/wiki/Abundance_of_the_chemical_elements) in the [Universe](/wiki/Universe), and the most common [refractory](/wiki/Refractory) element.<ref name=apjl717\_2\_L92>[Template:Cite journal](/wiki/Template:Cite_journal)</ref> It is formed as the final [exothermic](/wiki/Exothermic) stage of [stellar nucleosynthesis](/wiki/Stellar_nucleosynthesis), by [silicon fusion](/wiki/Silicon_burning_process) in massive stars.

Metallic or [native iron](/wiki/Native_iron) is rarely found on the surface of the Earth because it tends to oxidize, but its oxides are pervasive and represent the primary ores. While it makes up about 5% of the [Earth's crust](/wiki/Crust_(geology)), both the Earth's [inner](/wiki/Inner_core) and [outer core](/wiki/Outer_core) are believed to consist largely of an iron-[nickel](/wiki/Nickel) alloy constituting 35% of the mass of the Earth as a whole. Iron is consequently the most abundant element on Earth, but only the fourth most abundant element in the Earth's crust.[[15]](#cite_note-15)[[16]](#cite_note-16) Most of the iron in the crust is found combined with oxygen as [iron oxide](/wiki/Iron_oxide) minerals such as [hematite](/wiki/Hematite) (Fe2O3) and [magnetite](/wiki/Magnetite) (Fe3O4). Large deposits of iron are found in [banded iron formations](/wiki/Banded_iron_formations). These geological formations are a type of rock consisting of repeated thin layers of iron oxides alternating with bands of iron-poor [shale](/wiki/Shale) and [chert](/wiki/Chert). The banded iron formations were laid down in the time between [Template:Ma](/wiki/Template:Ma) and [Template:Ma](/wiki/Template:Ma)[[17]](#cite_note-17)[[18]](#cite_note-18) About 1 in 20 [meteorites](/wiki/Meteorite) consist of the unique iron-nickel minerals [taenite](/wiki/Taenite) (35–80% iron) and [kamacite](/wiki/Kamacite) (90–95% iron). Although rare, [iron meteorites](/wiki/Iron_meteorite) are the main form of natural metallic iron on the Earth's surface.[[19]](#cite_note-19) The red color of the surface of [Mars](/wiki/Mars) is derived from an iron oxide-rich [regolith](/wiki/Regolith). This has been proven by [Mössbauer spectroscopy](/wiki/Mössbauer_spectroscopy).[[20]](#cite_note-20)

#### Stocks in use in society[[edit](/index.php?title=(none)&action=edit&section=8)]

According to the [International Resource Panel's](/wiki/International_Resource_Panel) [Metal Stocks in Society report](/wiki/Metal_Stocks_in_Society_report), the global stock of iron in use in society is 2200 kg per capita. Much of this is in more-developed countries (7000–14000 kg per capita) rather than less-developed countries (2000 kg per capita).

## Chemistry and compounds[[edit](/index.php?title=(none)&action=edit&section=9)]

[Template:Category see also](/wiki/Template:Category_see_also)

|  |  |
| --- | --- |
| **Oxidation  state** | **Representative compound** |
| −2 | [Disodium tetracarbonylferrate](/wiki/Disodium_tetracarbonylferrate) (Collman's reagent) |
| −1 |  |
| 0 | [Iron pentacarbonyl](/wiki/Iron_pentacarbonyl) |
| 1 | [Cyclopentadienyliron dicarbonyl dimer](/wiki/Cyclopentadienyliron_dicarbonyl_dimer) ("Fp2") |
| 2 | [Ferrous sulfate](/wiki/Ferrous_sulfate), [ferrocene](/wiki/Ferrocene) |
| 3 | [Ferric chloride](/wiki/Ferric_chloride), [ferrocenium tetrafluoroborate](/wiki/Ferrocenium_tetrafluoroborate) |
| 4 | [Barium ferrate(IV)](/wiki/Barium_ferrate(IV)) |
| 5 |  |
| 6 | [Potassium ferrate](/wiki/Potassium_ferrate) |

Iron forms compounds mainly in the +2 and +3 [oxidation states](/wiki/Oxidation_state). Traditionally, iron(II) compounds are called [ferrous](/wiki/Ferrous), and iron(III) compounds [ferric](/wiki/Ferric). Iron also occurs in higher oxidation states, an example being the purple [potassium ferrate](/wiki/Potassium_ferrate) (K2FeO4) which contains iron in its +6 oxidation state. Iron(IV) is a common intermediate in many biochemical oxidation reactions.[[21]](#cite_note-21)[[22]](#cite_note-22) Numerous [organometallic](/wiki/Organometallic_chemistry) compounds contain formal oxidation states of +1, 0, −1, or even −2. The oxidation states and other bonding properties are often assessed using the technique of [Mössbauer spectroscopy](/wiki/Mössbauer_spectroscopy).[[23]](#cite_note-23)There are also many [mixed valence compounds](/wiki/Mixed_valence_compound) that contain both iron(II) and iron(III) centers, such as [magnetite](/wiki/Magnetite) and [Prussian blue](/wiki/Prussian_blue) (Fe4(Fe[CN]6)3).[[22]](#cite_note-22) The latter is used as the traditional "blue" in [blueprints](/wiki/Blueprint).[[24]](#cite_note-24)[thumb|alt=Some canary-yellow powder sits, mostly in lumps, on a laboratory watch glass.|Hydrated](/wiki/File:Iron(III)_chloride_hexahydrate.jpg) [iron(III) chloride](/wiki/Iron(III)_chloride), also known as ferric chloride

The iron compounds produced on the largest scale in industry are [iron(II) sulfate](/wiki/Iron(II)_sulfate) (FeSO4·7[H2O](/wiki/Water_of_crystallization)) and [iron(III) chloride](/wiki/Iron(III)_chloride) (FeCl3). The former is one of the most readily available sources of iron(II), but is less stable to aerial oxidation than [Mohr's salt](/wiki/Mohr's_salt) ((NH4)2Fe(SO4)2·6H2O). Iron(II) compounds tend to be oxidized to iron(III) compounds in the air.[[22]](#cite_note-22) Unlike many other metals, iron does not form amalgams with mercury. As a result, mercury is traded in standardized 76 pound flasks (34 kg) made of iron.[[25]](#cite_note-25)

### Binary compounds[[edit](/index.php?title=(none)&action=edit&section=10)]

Iron reacts with oxygen in the air to form various [oxide and hydroxide compounds](/wiki/Iron_oxide); the most common are [iron(II,III) oxide](/wiki/Iron(II,III)_oxide) (Fe3O4), and [iron(III) oxide](/wiki/Iron(III)_oxide) (Fe2O3). [Iron(II) oxide](/wiki/Iron(II)_oxide) also exists, though it is unstable at room temperature. These oxides are the principal ores for the production of iron (see [bloomery](/wiki/Bloomery) and blast furnace). They are also used in the production of [ferrites](/wiki/Ferrite_(magnet)), useful [magnetic storage](/wiki/Magnetic_storage) media in computers, and pigments. The best known sulfide is [iron pyrite](/wiki/Iron_pyrite) (FeS2), also known as fool's gold owing to its golden luster.[[22]](#cite_note-22) The binary ferrous and ferric halides are well known, with the exception of ferric iodide. The ferrous halides typically arise from treating iron metal with the corresponding binary halogen acid to give the corresponding hydrated salts.[[22]](#cite_note-22):Fe + 2 HX → FeX2 + H2 Iron reacts with fluorine, chlorine, and bromine to give the corresponding ferric halides, [ferric chloride](/wiki/Ferric_chloride) being the most common:

2 Fe + 3 X2 → 2 FeX3 (X = F, Cl, Br)

### Coordination and organometallic compounds[[edit](/index.php?title=(none)&action=edit&section=11)]

[Template:See also](/wiki/Template:See_also) [thumb|right|](/wiki/File:Prussian_blue.jpg)[Prussian blue](/wiki/Prussian_blue) Several cyanide complexes are known. The most famous example is [Prussian blue](/wiki/Prussian_blue), (Fe4(Fe[CN]6)3). [Potassium ferricyanide](/wiki/Potassium_ferricyanide) and [potassium ferrocyanide](/wiki/Potassium_ferrocyanide) are also known; the formation of Prussian blue upon reaction with iron(II) and iron(III) respectively forms the basis of a "wet" chemical test.[[22]](#cite_note-22) Prussian blue is also used as an antidote for [thallium](/wiki/Thallium) and radioactive [caesium](/wiki/Caesium) poisoning.[[26]](#cite_note-26)[[27]](#cite_note-27) Prussian blue can be used in laundry bluing to correct the yellowish tint left by ferrous salts in water.

[thumb|80px|left|](/wiki/File:Ferrocene-2D.png)[Ferrocene](/wiki/Ferrocene) Several carbonyl compounds of iron are known. The premier iron(0) compound is [iron pentacarbonyl](/wiki/Iron_pentacarbonyl), Fe(CO)5, which is used to produce [carbonyl iron](/wiki/Carbonyl_iron) powder, a highly reactive form of metallic iron. Thermolysis of iron pentacarbonyl gives the trinuclear cluster, [triiron dodecacarbonyl](/wiki/Triiron_dodecacarbonyl). Collman's reagent, [disodium tetracarbonylferrate](/wiki/Disodium_tetracarbonylferrate), is a useful reagent for organic chemistry; it contains iron in the −2 oxidation state. [Cyclopentadienyliron dicarbonyl dimer](/wiki/Cyclopentadienyliron_dicarbonyl_dimer) contains iron in the rare +1 oxidation state.[[28]](#cite_note-28) [Ferrocene](/wiki/Ferrocene) is an extremely stable complex. The first [sandwich compound](/wiki/Sandwich_compound), it contains an iron(II) center with two [cyclopentadienyl](/wiki/Cyclopentadienyl) ligands bonded through all ten carbon atoms. This arrangement was a shocking novelty when it was first discovered,[[29]](#cite_note-29) but the discovery of ferrocene has led to a new branch of organometallic chemistry. Ferrocene itself can be used as the backbone of a ligand, e.g. [dppf](/wiki/Dppf). Ferrocene can itself be oxidized to the [ferrocenium](/wiki/Ferrocenium) cation (Fc+); the ferrocene/ferrocenium couple is often used as a reference in electrochemistry.[[30]](#cite_note-30)

## History[[edit](/index.php?title=(none)&action=edit&section=12)]

[Template:Main article](/wiki/Template:Main_article)

### Wrought iron[[edit](/index.php?title=(none)&action=edit&section=13)]

[Template:Further](/wiki/Template:Further) [left|thumb|80px|alt=A circle, with a short, simple arrow shape extending diagonally upwards and rightwards from its edge|The symbol for Mars has been used since antiquity to represent iron.](/wiki/File:Mars_symbol.svg) [thumb|alt=An pillar, slightly fluted, with some ornamentation at its top. It is black, slightly weathered to a dark brown near the base. It is around](/wiki/File:QtubIronPillar.JPG) [Template:Convert](/wiki/Template:Convert) tall. It stands upon a raised circular base of stone, and is surrounded by a short, square fence.|The Iron pillar of Delhi is an example of the iron extraction and processing methodologies of early India.

Iron has been worked, or [wrought](/wiki/Wrought_iron), for millennia. However, iron objects of great age are much rarer than objects made of gold or silver due to the ease of corrosion of iron.[Template:Sfn](/wiki/Template:Sfn) Beads made from [meteoric iron](/wiki/Meteoric_iron) in 3500 BCE or earlier were found in Gerzah, Egypt by G. A. Wainwright.[Template:Sfn](/wiki/Template:Sfn) The beads contain 7.5% nickel, which is a signature of meteoric origin since iron found in the Earth's crust has very little to no nickel content. Meteoric iron was highly regarded due to its origin in the heavens and was often used to forge weapons and tools or whole specimens placed in churches.[Template:Sfn](/wiki/Template:Sfn) Items that were likely made of iron by Egyptians date from 2500 to 3000 BCE.[Template:Sfn](/wiki/Template:Sfn) Iron had a distinct advantage over bronze in warfare implements. It was much harder and more durable than bronze, although susceptible to rust. However, this is contested. [Hittitologist](/wiki/Hittites) [Trevor Bryce](/wiki/Trevor_Bryce) argues that before advanced iron-working techniques were developed in [India](/wiki/India), meteoritic iron weapons used by early [Mesopotamian](/wiki/Mesopotamia) armies had a tendency to shatter in combat, due to their high carbon content.[[31]](#cite_note-31) The first iron production started in the [Middle Bronze Age](/wiki/Middle_Bronze_Age) but it took several centuries before iron displaced bronze. Samples of [smelted](/wiki/Smelting) iron from [Asmar](/wiki/Asmar), Mesopotamia and Tall Chagar Bazaar in northern Syria were made sometime between 2700 and 3000 BCE.[Template:Sfn](/wiki/Template:Sfn) The [Hittites](/wiki/Hittites) appear to be the first to understand the production of iron from its ores and regard it highly in their society. They began to smelt iron between 1500 and 1200 BCE and the practice spread to the rest of the Near East after their empire fell in 1180 BCE.[Template:Sfn](/wiki/Template:Sfn) The subsequent period is called the [Iron Age](/wiki/Iron_Age). Iron smelting, and thus the Iron Age, reached Europe two hundred years later and arrived in [Zimbabwe](/wiki/Zimbabwe), Africa by the 8th century.[Template:Sfn](/wiki/Template:Sfn) In China, iron only appears circa 700–500 BCE.[[32]](#cite_note-32) Iron smelting may have been introduced into China through Central Asia.[[33]](#cite_note-33) The earliest evidence of the use of a [blast furnace](/wiki/Blast_furnace) in China dates to the 1st century AD,[[34]](#cite_note-34) and cupola furnaces were used as early as the [Warring States period](/wiki/Warring_States_period) (403–221 BCE).[[35]](#cite_note-35) Usage of the blast and cupola furnace remained widespread during the [Song](/wiki/Song_dynasty) and [Tang Dynasties](/wiki/Tang_dynasty).[[36]](#cite_note-36) Artifacts of smelted iron are found in [India](/wiki/History_of_metallurgy_in_the_Indian_subcontinent) dating from 1800 to 1200 BCE,<ref name=Tewari>[Template:Cite web](/wiki/Template:Cite_web)</ref> and in the [Levant](/wiki/Levant) from about 1500 BCE (suggesting smelting in [Anatolia](/wiki/Anatolia) or the [Caucasus](/wiki/Caucasus)).[[37]](#cite_note-37)[[38]](#cite_note-38) The [Book of Genesis](/wiki/Book_of_Genesis), fourth chapter, verse 22 contains the first mention of iron in the [Old Testament](/wiki/Old_Testament) of the [Bible](/wiki/Bible); "Tubal-cain, an instructor of every artificer in brass and iron."[Template:Sfn](/wiki/Template:Sfn) Other verses allude to iron mining (Job 28:2), iron used as a stylus (Job 19:24), furnace (Deuteronomy 4:20), chariots (Joshua 17:16), nails (I Chron. 22:3), saws and axes (II Sam. 12:31), and cooking utensils (Ezekiel 4:3).[Template:Sfn](/wiki/Template:Sfn) The metal is also mentioned in the [New Testament](/wiki/New_Testament), for example in Acts chapter 12 verse 10, "[Peter passed through] the iron gate that leadeth unto the city" of Antioch.[Template:Sfn](/wiki/Template:Sfn)

Iron working was introduced to [Greece](/wiki/Ancient_Greece) in the late 11th century BCE.[[39]](#cite_note-39) The spread of ironworking in Central and Western Europe is associated with [Celtic](/wiki/Celts) expansion. According to [Pliny the Elder](/wiki/Pliny_the_Elder), iron use was common in the [Roman](/wiki/Ancient_Rome) era.[Template:Sfn](/wiki/Template:Sfn) The annual iron output of the [Roman Empire](/wiki/Roman_Empire) is estimated at 84,750 [t](/wiki/Tonnes),[[40]](#cite_note-40) while the similarly populous Han China produced around 5,000 t.[[41]](#cite_note-41) During the Industrial Revolution in Britain, [Henry Cort](/wiki/Henry_Cort) began refining iron from [pig iron](/wiki/Pig_iron) to [wrought iron](/wiki/Wrought_iron) (or bar iron) using innovative production systems. In 1783 he patented the [puddling process](/wiki/Puddling_(metallurgy)) for refining iron ore. It was later improved by others, including [Joseph Hall](/wiki/Joseph_Hall_(metallurgist)).

### Cast iron[[edit](/index.php?title=(none)&action=edit&section=14)]

[Cast iron](/wiki/Cast_iron) was first produced in [China](/wiki/China) during 5th century BCE,[[42]](#cite_note-42) but was hardly in Europe until the medieval period.[[43]](#cite_note-43)[[44]](#cite_note-44) The earliest [cast iron](/wiki/Cast_iron) artifacts were discovered by archaeologists in what is now modern [Luhe County](/wiki/Luhe_County), [Jiangsu](/wiki/Jiangsu) in China. Cast iron was used in [ancient China](/wiki/History_of_China#Ancient_China) for warfare, agriculture, and architecture.[[45]](#cite_note-45) During the [medieval](/wiki/Medieval) period, means were found in Europe of producing wrought iron from cast iron (in this context known as [pig iron](/wiki/Pig_iron)) using [finery forges](/wiki/Finery_forge). For all these processes, [charcoal](/wiki/Charcoal) was required as fuel. [thumb|](/wiki/File:Philipp_Jakob_Loutherbourg_d._J._002.jpg)[*Coalbrookdale by Night*](/wiki/Coalbrookdale_by_Night), 1801. Blast furnaces light the iron making town of [Coalbrookdale](/wiki/Coalbrookdale). Medieval [blast furnaces](/wiki/Blast_furnaces) were about [Template:Convert](/wiki/Template:Convert) tall and made of fireproof brick; forced air was usually provided by hand-operated bellows.[[44]](#cite_note-44) Modern blast furnaces have grown much bigger.

In 1709, [Abraham Darby I](/wiki/Abraham_Darby_I) established a [coke](/wiki/Coke_(fuel))-fired blast furnace to produce cast iron. The ensuing availability of inexpensive iron was one of the factors leading to the Industrial Revolution. Toward the end of the 18th century, cast iron began to replace wrought iron for certain purposes, because it was cheaper. Carbon content in iron wasn't implicated as the reason for the differences in properties of wrought iron, cast iron, and steel until the 18th century.[Template:Sfn](/wiki/Template:Sfn)

Since iron was becoming cheaper and more plentiful, it also became a major structural material following the building of the innovative [first iron bridge](/wiki/The_Iron_Bridge) in 1778.

### Steel[[edit](/index.php?title=(none)&action=edit&section=15)]

[Template:See also](/wiki/Template:See_also) Steel (with smaller carbon content than pig iron but more than wrought iron) was first produced in antiquity by using a [bloomery](/wiki/Bloomery). Blacksmiths in [Luristan](/wiki/Luristan) in western Iran were making good steel by 1000 BCE.[Template:Sfn](/wiki/Template:Sfn) Then improved versions, [Wootz steel](/wiki/Wootz_steel) by India and [Damascus steel](/wiki/Damascus_steel) were developed around 300 BCE and 500 CE respectively. These methods were specialized, and so steel did not become a major commodity until the 1850s.[[46]](#cite_note-46) New methods of producing it by [carburizing](/wiki/Carburizing) bars of iron in the [cementation process](/wiki/Cementation_process) were devised in the 17th century AD. In the [Industrial Revolution](/wiki/Industrial_Revolution), new methods of producing bar iron without charcoal were devised and these were later applied to produce steel. In the late 1850s, [Henry Bessemer](/wiki/Henry_Bessemer) invented a new steelmaking process, involving blowing air through molten pig iron, to produce mild steel. This made steel much more economical, thereby leading to wrought iron no longer being produced.[[47]](#cite_note-47)

### Foundations of modern chemistry[[edit](/index.php?title=(none)&action=edit&section=16)]

[Antoine Lavoisier](/wiki/Antoine_Lavoisier) used the reaction of water steam with metallic iron inside an incandescent iron tube to produce [hydrogen](/wiki/Hydrogen) in his experiments leading to the demonstration of the mass conservation. Anaerobic oxidation of iron at high temperature can be schematically represented by the following reactions:

Fe + H2O → FeO + H2

2 Fe + 3 H2O → Fe2O3 + 3 H2

3 Fe + 4 H2O → Fe3O4 + 4 H2

## Production of metallic iron[[edit](/index.php?title=(none)&action=edit&section=17)]

### Industrial routes[[edit](/index.php?title=(none)&action=edit&section=18)]

[Template:See also](/wiki/Template:See_also) The production of iron or steel is a process consisting of two main stages, unless the desired product is cast iron. In the first stage pig iron is produced in a blast furnace. Alternatively, it may be directly reduced. The second stage, pig iron is converted to wrought iron or steel. [thumb|The fining process of smelting](/wiki/File:Chinese_Fining_and_Blast_Furnace.jpg) [iron ore](/wiki/Iron_ore) to make wrought iron from pig iron, with the right illustration displaying men working a blast furnace, from the *Tiangong Kaiwu* encyclopedia, published in 1637 by [Song Yingxing](/wiki/Song_Yingxing). [thumb|How iron was extracted in the 19th century](/wiki/File:Iron-Making.jpg)

For a few limited purposes like electromagnet cores, pure iron is produced by electrolysis of a [ferrous sulfate](/wiki/Ferrous_sulfate) solution

#### Blast furnace processing[[edit](/index.php?title=(none)&action=edit&section=19)]

[Template:Main article](/wiki/Template:Main_article) Industrial iron production starts with iron ores, principally [hematite](/wiki/Hematite), which has a nominal formula Fe2O3, and [magnetite](/wiki/Magnetite), with the formula Fe3O4. These ores are reduced to the metal in a [carbothermic](/wiki/Carbothermic) reaction, i.e. by treatment with carbon. The conversion is typically conducted in a blast furnace at temperatures of about 2000 °C. Carbon is provided in the form of coke. The process also contains a [*flux*](/wiki/Flux_(metallurgy)) such as [limestone](/wiki/Limestone), which is used to remove silicaceous minerals in the ore, which would otherwise clog the furnace. The coke and limestone are fed into the top of the furnace, while a massive blast of heated [air](/wiki/Earth's_atmosphere), about 4 tons per ton of iron,[[44]](#cite_note-44) is forced into the furnace at the bottom.

In the furnace, the coke reacts with oxygen in the air blast to produce [carbon monoxide](/wiki/Carbon_monoxide):

2 C + O2 → 2 CO

The carbon monoxide reduces the iron ore (in the [chemical equation](/wiki/Chemical_equation) below, hematite) to molten iron, becoming [carbon dioxide](/wiki/Carbon_dioxide) in the process:

Fe2O3 + 3 CO → 2 Fe + 3 CO2

Some iron in the high-temperature lower region of the furnace reacts directly with the coke:

2 Fe2O3 + 3 C → 4 Fe + 3 CO2

The flux present to melt impurities in the ore is principally [limestone](/wiki/Limestone) ([calcium carbonate](/wiki/Calcium_carbonate)) and [dolomite](/wiki/Dolomite) (calcium-magnesium carbonate). Other specialized fluxes are used depending on the details of the ore. In the heat of the furnace the limestone flux decomposes to [calcium oxide](/wiki/Calcium_oxide) (also known as quicklime):

CaCO3 → CaO + CO2

Then calcium oxide combines with silicon dioxide to form a liquid [slag](/wiki/Slag).

CaO + SiO2 → CaSiO3

The slag melts in the heat of the furnace. In the bottom of the furnace, the molten slag floats on top of the denser molten iron, and apertures in the side of the furnace are opened to run off the iron and the slag separately. The iron, once cooled, is called pig iron, while the slag can be used as a material in [road](/wiki/Road) construction or to improve mineral-poor soils for [agriculture](/wiki/Agriculture)[[44]](#cite_note-44)[thumb|This heap of iron ore pellets will be used in steel production.](/wiki/File:LightningVolt_Iron_Ore_Pellets.jpg)

#### Direct iron reduction[[edit](/index.php?title=(none)&action=edit&section=20)]

Owing to environmental concerns, alternative methods of processing iron have been developed. "Direct iron reduction" reduces iron ore to a powder called "sponge" iron or "direct" iron that is suitable for steelmaking.[[44]](#cite_note-44) Two main reactions comprise the direct reduction process:

Natural gas is partially oxidized (with heat and a catalyst):

2 CH4 + O2 → 2 CO + 4 H2

These gases are then treated with iron ore in a furnace, producing solid sponge iron:

Fe2O3 + CO + 2 H2 → 2 Fe + CO2 + 2 H2O

[Silica](/wiki/Silica) is removed by adding a [limestone](/wiki/Limestone) flux as described above.

#### Further processes[[edit](/index.php?title=(none)&action=edit&section=21)]

[Template:Main article](/wiki/Template:Main_article) [thumb|right|340px|Iron-carbon phase diagram, various stable](/wiki/File:Steel_pd.svg) [solid solution](/wiki/Solid_solution) forms Pig iron is not pure iron, but has 4–5% carbon dissolved in it with small amounts of other impurities like sulfur, magnesium, phosphorus and manganese. As the carbon is the major impurity, the iron (pig iron) becomes brittle and hard. This form of iron, also known as cast iron, is used to cast articles in [foundries](/wiki/Foundry) such as stoves, pipes, radiators, lamp-posts and rails.

Alternatively pig iron may be made into steel (with up to about 2% carbon) or wrought iron (commercially pure iron). Various processes have been used for this, including [finery forges](/wiki/Finery_forge), [puddling](/wiki/Puddling_(metallurgy)) furnaces, [Bessemer converters](/wiki/Bessemer_converter), [open hearth furnaces](/wiki/Open_hearth_furnace), [basic oxygen furnaces](/wiki/Basic_oxygen_furnace), and [electric arc furnaces](/wiki/Electric_arc_furnace). In all cases, the objective is to oxidize some or all of the carbon, together with other impurities. On the other hand, other metals may be added to make alloy steels.

[Annealing](/wiki/Annealing_(metallurgy)) involves the heating of a piece of steel to 700–800 °C for several hours and then gradual cooling. It makes the steel softer and more workable.

### Laboratory methods[[edit](/index.php?title=(none)&action=edit&section=22)]

Metallic iron is generally produced in the laboratory by two methods. One route is electrolysis of ferrous chloride onto an iron cathode. The second method involves reduction of iron oxides with hydrogen gas at about 500 °C.[[48]](#cite_note-48)

## Applications[[edit](/index.php?title=(none)&action=edit&section=23)]

[thumb|right|250px|](/wiki/File:Iron_powder.JPG)[Iron powder](/wiki/Iron_powder)

### Metallurgical[[edit](/index.php?title=(none)&action=edit&section=24)]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Iron production 2009 (million [tonnes](/wiki/Tonnes))[[49]](#cite_note-49) | | | | |
| **Country** | [**Iron ore**](/wiki/Iron_ore) | [**Pig iron**](/wiki/Pig_iron) | [**Direct iron**](/wiki/Direct_reduced_iron) | [**Steel**](/wiki/Steel) |
| China | 1,114.9 | 549.4 |  | 573.6 |
| Australia | 393.9 | 4.4 |  | 5.2 |
| Brazil | 305.0 | 25.1 | 0.011 | 26.5 |
| Japan |  | 66.9 |  | 87.5 |
| India | 257.4 | 38.2 | 23.4 | 63.5 |
| Russia | 92.1 | 43.9 | 4.7 | 60.0 |
| Ukraine | 65.8 | 25.7 |  | 29.9 |
| South Korea | 0.1 | 27.3 |  | 48.6 |
| Germany | 0.4 | 20.1 | 0.38 | 32.7 |
| **World** | **1,594.9** | **914.0** | **64.5** | **1,232.4** |

Iron is the most widely used of all the metals, accounting for 95% of worldwide metal production.[Template:Citation needed](/wiki/Template:Citation_needed) Its low cost and high strength make it indispensable in engineering applications such as the construction of machinery and [machine tools](/wiki/Machine_tool), [automobiles](/wiki/Automobile), the [hulls](/wiki/Hull_(ship)) of large [ships](/wiki/Ship), and structural components for [buildings](/wiki/Building). Since pure iron is quite soft, it is most commonly combined with alloying elements to make steel.

Commercially available iron is classified based on purity and the abundance of additives. [Pig iron](/wiki/Pig_iron) has 3.5–4.5% carbon[[50]](#cite_note-50) and contains varying amounts of contaminants such as [sulfur](/wiki/Sulfur), silicon and [phosphorus](/wiki/Phosphorus). Pig iron is not a saleable product, but rather an intermediate step in the production of cast iron and steel. The reduction of contaminants in pig iron that negatively affect material properties, such as sulfur and phosphorus, yields cast iron containing 2–4% carbon, 1–6% silicon, and small amounts of [manganese](/wiki/Manganese). It has a [melting point](/wiki/Melting_point) in the range of 1420–1470 K, which is lower than either of its two main components, and makes it the first product to be melted when carbon and iron are heated together. Its mechanical properties vary greatly and depend on the form the carbon takes in the alloy.

"White" cast irons contain their carbon in the form of [cementite](/wiki/Cementite), or iron-carbide. This hard, brittle compound dominates the mechanical properties of white cast irons, rendering them hard, but unresistant to shock. The broken surface of a white cast iron is full of fine facets of the broken iron-carbide, a very pale, silvery, shiny material, hence the appellation.

In [gray iron](/wiki/Gray_iron) the carbon exists as separate, fine flakes of [graphite](/wiki/Graphite), and also renders the material brittle due to the sharp edged flakes of graphite that produce [stress concentration](/wiki/Stress_concentration) sites within the material. A newer variant of gray iron, referred to as [ductile iron](/wiki/Ductile_iron) is specially treated with trace amounts of [magnesium](/wiki/Magnesium) to alter the shape of graphite to spheroids, or nodules, reducing the stress concentrations and vastly increasing the toughness and strength of the material.

[Wrought iron](/wiki/Wrought_iron) contains less than 0.25% carbon but large amounts of slag that give it a fibrous characteristic.[[50]](#cite_note-50) It is a tough, malleable product, but not as fusible as pig iron. If honed to an edge, it loses it quickly. Wrought iron is characterized by the presence of fine fibers of [slag](/wiki/Slag) entrapped within the metal. Wrought iron is more corrosion resistant than steel. It has been almost completely replaced by [mild steel](/wiki/Mild_steel) for traditional "wrought iron" products and [blacksmithing](/wiki/Blacksmith).

Mild steel corrodes more readily than wrought iron, but is cheaper and more widely available. [Carbon steel](/wiki/Carbon_steel) contains 2.0% carbon or less,[[51]](#cite_note-51) with small amounts of [manganese](/wiki/Manganese), [sulfur](/wiki/Sulfur), [phosphorus](/wiki/Phosphorus), and silicon. [Alloy steels](/wiki/Alloy_steel) contain varying amounts of carbon as well as other metals, such as [chromium](/wiki/Chromium), [vanadium](/wiki/Vanadium), [molybdenum](/wiki/Molybdenum), nickel, [tungsten](/wiki/Tungsten), etc. Their alloy content raises their cost, and so they are usually only employed for specialist uses. One common alloy steel, though, is [stainless steel](/wiki/Stainless_steel). Recent developments in ferrous metallurgy have produced a growing range of microalloyed steels, also termed '[HSLA'](/wiki/HSLA_steel) or high-strength, low alloy steels, containing tiny additions to produce high strengths and often spectacular toughness at minimal cost.

[thumb|alt=A graph of attenuation coefficient vs. energy between 1 meV and 100 keV for several photon scattering mechanisms.|](/wiki/File:Ironattenuation.PNG)[Photon](/wiki/Photon) [mass attenuation coefficient](/wiki/Mass_attenuation_coefficient) for iron. Apart from traditional applications, iron is also used for protection from ionizing radiation. Although it is lighter than another traditional protection material, lead, it is much stronger mechanically. The attenuation of radiation as a function of energy is shown in the graph.

The main disadvantage of iron and steel is that pure iron, and most of its alloys, suffer badly from [rust](/wiki/Rust) if not protected in some way. [Painting](/wiki/Paint), [galvanization](/wiki/Galvanization), [passivation](/wiki/Passivation_(chemistry)), plastic coating and [bluing](/wiki/Bluing_(steel)) are all used to protect iron from rust by excluding [water](/wiki/Water) and oxygen or by [cathodic protection](/wiki/Cathodic_protection).

### Iron compounds[[edit](/index.php?title=(none)&action=edit&section=25)]

Although its metallurgical role is dominant in terms of amounts, iron compounds are pervasive in industry as well being used in many niche uses. Iron catalysts are traditionally used in the [Haber-Bosch Process](/wiki/Haber-Bosch_Process) for the production of ammonia and the [Fischer-Tropsch process](/wiki/Fischer-Tropsch_process) for conversion of carbon monoxide to [hydrocarbons](/wiki/Hydrocarbon) for fuels and lubricants.[[52]](#cite_note-52) Powdered iron in an acidic solvent was used in the [Bechamp reduction](/wiki/Bechamp_reduction) the reduction of [nitrobenzene](/wiki/Nitrobenzene) to [aniline](/wiki/Aniline).[[53]](#cite_note-53) [Iron(III) chloride](/wiki/Iron(III)_chloride) finds use in water purification and [sewage treatment](/wiki/Sewage_treatment), in the dyeing of cloth, as a coloring agent in paints, as an additive in animal feed, and as an [etchant](/wiki/Industrial_etching) for [copper](/wiki/Copper) in the manufacture of [printed circuit boards](/wiki/Printed_circuit_board).[[54]](#cite_note-54) It can also be dissolved in alcohol to form tincture of iron. The other halides tend to be limited to laboratory uses.

[Iron(II) sulfate](/wiki/Iron(II)_sulfate) is used as a precursor to other iron compounds. It is also used to [reduce](/wiki/Redox) chromate in cement. It is used to fortify foods and treat [iron deficiency anemia](/wiki/Iron_deficiency_anemia). These are its main uses. [Iron(III) sulfate](/wiki/Iron(III)_sulfate) is used in settling minute sewage particles in tank water. [Iron(II) chloride](/wiki/Iron(II)_chloride) is used as a reducing flocculating agent, in the formation of iron complexes and magnetic iron oxides, and as a reducing agent in organic synthesis.

## Biological role[[edit](/index.php?title=(none)&action=edit&section=26)]

Iron is involved in numerous biological processes.[[55]](#cite_note-55)[[56]](#cite_note-56) Iron-proteins are found in all living organisms: [archaeans](/wiki/Archaeans), [bacteria](/wiki/Bacteria) and [eukaryotes](/wiki/Eukaryotes), including humans. For example, the color of blood is due to the hemoglobin, an iron-containing protein. As illustrated by hemoglobin, iron is often bound to [cofactors](/wiki/Cofactor_(biochemistry)), e.g. in [hemes](/wiki/Heme). The [iron-sulfur clusters](/wiki/Iron-sulfur_cluster) are pervasive and include [nitrogenase](/wiki/Nitrogenase), the enzymes responsible for biological [nitrogen fixation](/wiki/Nitrogen_fixation). Influential theories of evolution have invoked a role for iron sulfides in the [iron-sulfur world theory](/wiki/Iron-sulfur_world_theory). [thumb|Structure of](/wiki/File:Heme_b.png) [Heme b](/wiki/Heme), in the protein additional [ligand](/wiki/Ligand)(s) would be attached to Fe.

Iron is a necessary [trace element](/wiki/Trace_element) found in nearly all living organisms. Iron-containing enzymes and proteins, often containing [heme](/wiki/Heme) [prosthetic groups](/wiki/Prosthetic_group), participate in many biological oxidations and in transport. Examples of proteins found in higher organisms include hemoglobin, [cytochrome](/wiki/Cytochrome) (see [high-valent iron](/wiki/High-valent_iron)), and [catalase](/wiki/Catalase).[[57]](#cite_note-57)

### Bioinorganic compounds[[edit](/index.php?title=(none)&action=edit&section=27)]

The most commonly known and studied [bioinorganic](/wiki/Bioinorganic_chemistry) iron compounds (biological iron molecules) are the [heme proteins](/wiki/Heme_proteins): examples are [hemoglobin](/wiki/Hemoglobin), [myoglobin](/wiki/Myoglobin), and [cytochrome P450](/wiki/Cytochrome_P450). These compounds participate in transporting gases, building [enzymes](/wiki/Enzymes), and transferring [electrons](/wiki/Electrons). [Metalloproteins](/wiki/Metalloproteins) are a group of proteins with metal ion [cofactors](/wiki/Cofactor_(biochemistry)). Some examples of iron metalloproteins are [ferritin](/wiki/Ferritin) and [rubredoxin](/wiki/Rubredoxin). Many enzymes vital to life contain iron, such as [catalase](/wiki/Catalase), [lipoxygenases](/wiki/Lipoxygenases), and [IRE-BP](/wiki/IRE-BP).

### Health and diet[[edit](/index.php?title=(none)&action=edit&section=28)]

[Template:Main article](/wiki/Template:Main_article) Iron is pervasive, but particularly rich sources of dietary iron include [red meat](/wiki/Red_meat), [lentils](/wiki/Lentil), [beans](/wiki/Bean), [poultry](/wiki/Poultry), [fish](/wiki/Fish), [leaf vegetables](/wiki/Leaf_vegetable), [watercress](/wiki/Watercress), [tofu](/wiki/Tofu), [chickpeas](/wiki/Chickpea), [black-eyed peas](/wiki/Black-eyed_peas), [blackstrap molasses](/wiki/Blackstrap_molasses), fortified [bread](/wiki/Bread), and fortified [breakfast cereals](/wiki/Breakfast_cereal). Iron in low amounts is found in [molasses](/wiki/Molasses), [teff](/wiki/Teff), and [farina](/wiki/Farina_(food)). Iron in meat ([heme](/wiki/Heme) iron) is more easily absorbed than iron in vegetables.[[58]](#cite_note-58) Although some studies suggest that heme/hemoglobin from red meat has effects which may increase the likelihood of [colorectal cancer](/wiki/Colorectal_cancer),[[59]](#cite_note-59)[[60]](#cite_note-60) there is still some controversy[[61]](#cite_note-61) with a few studies suggesting that such claims are not supported by sufficient evidence.[[62]](#cite_note-62) Iron provided by [dietary supplements](/wiki/Dietary_supplement) is often found as [iron(II) fumarate](/wiki/Iron(II)_fumarate), although iron sulfate is cheaper and is absorbed equally well. Elemental iron, or reduced iron, despite being absorbed at only one third to two thirds the efficiency (relative to iron sulfate),[[63]](#cite_note-63) is often added to foods such as breakfast cereals or enriched wheat flour. Iron is most available to the body when [chelated](/wiki/Chelation) to amino acids[[64]](#cite_note-64) and is also available for use as a common [iron supplement](/wiki/Iron_supplement). [Glycine](/wiki/Glycine), the cheapest and most common amino acid is most often used to produce iron glycinate supplements.[[65]](#cite_note-65) The [Recommended Dietary Allowance](/wiki/Recommended_Dietary_Allowance) (RDA) for iron varies considerably depending on age, sex, and source of dietary iron (heme-based iron has higher [bioavailability](/wiki/Bioavailability)).[[66]](#cite_note-66) Infants may require iron supplements if they are bottle-fed cow's milk.[[67]](#cite_note-67) [Blood donors](/wiki/Blood_donation) and pregnant women are at special risk of low iron levels and are often advised to supplement their iron intake.[[68]](#cite_note-68)

### Uptake and storage[[edit](/index.php?title=(none)&action=edit&section=29)]

Iron acquisition poses a problem for aerobic organisms because ferric iron is poorly soluble near neutral pH. Thus, bacteria have evolved high-affinity [sequestering](/wiki/Wikt:sequester) agents called [siderophores](/wiki/Siderophore).[[69]](#cite_note-69)[[70]](#cite_note-70)[[71]](#cite_note-71) After uptake in [cells](/wiki/Cell_(biology)), iron storage is carefully regulated; iron ions are never "free". A major component of this regulation is the protein [transferrin](/wiki/Transferrin), which binds iron ions absorbed from the [duodenum](/wiki/Duodenum) and carries it in the [blood](/wiki/Bloodstream) to cells.[[72]](#cite_note-72) In animals, plants, and fungi, iron is often incorporated into the heme complex. Heme is an essential component of [cytochrome](/wiki/Cytochrome) proteins, which mediate [redox](/wiki/Redox) reactions, and of oxygen [carrier proteins](/wiki/Carrier_protein) such as [hemoglobin](/wiki/Hemoglobin), [myoglobin](/wiki/Myoglobin), and [leghemoglobin](/wiki/Leghemoglobin).

Inorganic iron contributes to redox reactions in the [iron-sulfur clusters](/wiki/Iron-sulfur_cluster) of many [enzymes](/wiki/Enzyme), such as [nitrogenase](/wiki/Nitrogenase) (involved in the synthesis of [ammonia](/wiki/Ammonia) from [nitrogen](/wiki/Nitrogen) and [hydrogen](/wiki/Hydrogen)) and [hydrogenase](/wiki/Hydrogenase). Non-heme iron proteins include the [enzymes](/wiki/Enzymes) [methane monooxygenase](/wiki/Methane_monooxygenase) (oxidizes [methane](/wiki/Methane) to [methanol](/wiki/Methanol)), [ribonucleotide reductase](/wiki/Ribonucleotide_reductase) (reduces [ribose](/wiki/Ribose) to [deoxyribose](/wiki/Deoxyribose); [DNA biosynthesis](/wiki/DNA_replication)), [hemerythrins](/wiki/Hemerythrin) ([oxygen](/wiki/Oxygen) transport and fixation in [marine invertebrates](/wiki/Marine_invertebrates)) and purple [acid phosphatase](/wiki/Acid_phosphatase) ([hydrolysis](/wiki/Hydrolysis) of [phosphate](/wiki/Phosphate) [esters](/wiki/Ester)).

Iron distribution is heavily regulated in [mammals](/wiki/Mammal), partly because iron ions have a high potential for biological toxicity.[[73]](#cite_note-73)

### Regulation of uptake[[edit](/index.php?title=(none)&action=edit&section=30)]

[Template:Main article](/wiki/Template:Main_article)

[Iron uptake](/wiki/Human_iron_metabolism) is tightly regulated by the human body, which has no regulated physiological means of excreting iron. Only small amounts of iron are lost daily due to mucosal and skin epithelial cell sloughing, so control of iron levels is primarily accomplished by regulating uptake.[[74]](#cite_note-74) Regulation of iron uptake is impaired in some people as a result of a [genetic defect](/wiki/Genetic_disorder) that maps to the HLA-H gene region on chromosome 6. In these people, excessive iron intake can result in [iron overload disorders](/wiki/Iron_overload_disorder), known medically as [hemochromatosis](/wiki/Hemochromatosis). Many people have an undiagnosed genetic susceptibility to iron overload, and are not aware of a family history of the problem. For this reason, people should not take iron supplements unless they suffer from [iron deficiency](/wiki/Iron_deficiency_(medicine)) and have consulted a doctor. Hemochromatosis is estimated to be the a cause of 0.3 to 0.8% of all metabolic diseases of Caucasians.[[75]](#cite_note-75) [MRI](/wiki/MRI)fstudies show that iron accumulates in the [hippocampus](/wiki/Hippocampus) of the brains of those with [Alzheimer's disease](/wiki/Alzheimer's_disease) and in the [substantia nigra](/wiki/Substantia_nigra) of those with [Parkinson disease](/wiki/Parkinson_disease).[[76]](#cite_note-76)

### Bioremediation[[edit](/index.php?title=(none)&action=edit&section=31)]

Iron-eating bacteria live in the hulls of [sunken ships](/wiki/Sunken_ship) such as the [*Titanic*](/wiki/Titanic).[[77]](#cite_note-77) The acidophile bacteria [*Acidithiobacillus ferrooxidans*](/wiki/Acidithiobacillus), [*Leptospirillum ferrooxidans*](/wiki/Leptospirillum_ferrooxidans), [*Sulfolobus*](/wiki/Sulfolobus) spp., [*Acidianus brierleyi*](/wiki/Acidianus) and [*Sulfobacillus thermosulfidooxidans*](/wiki/Sulfobacillus_thermosulfidooxidans) can oxidize ferrous iron enzymically.[[78]](#cite_note-78) A sample of the fungus [*Aspergillus niger*](/wiki/Aspergillus_niger) was found growing from gold mining solution, and was found to contain cyano metal complexes such as gold, silver, copper iron and zinc. The fungus also plays a role in the solubilization of heavy metal sulfides.[[79]](#cite_note-79)

### Permeable reactive barriers[[edit](/index.php?title=(none)&action=edit&section=32)]

[Zerovalent iron](/wiki/Zerovalent_iron) is the main reactive material for [permeable reactive barriers](/wiki/Permeable_reactive_barriers).[[80]](#cite_note-80)

## Toxicity[[edit](/index.php?title=(none)&action=edit&section=33)]

[Template:NFPA 704](/wiki/Template:NFPA_704)

[Template:Main article](/wiki/Template:Main_article) Overdoses of ingested iron can cause excessive levels of iron in the blood. High blood levels of free ferrous iron react with [peroxides](/wiki/Peroxide) to produce highly reactive [free radicals](/wiki/Free_radical) that can damage [DNA](/wiki/DNA), [proteins](/wiki/Proteins), [lipids](/wiki/Lipids), and other cellular components. Iron toxicity occurs when the cell contains free iron, which generally occurs when iron levels exceed the availability of [transferrin](/wiki/Transferrin) to bind the iron. Damage to the cells of the [gastrointestinal tract](/wiki/Human_gastrointestinal_tract) can also prevent them from regulating iron absorption, leading to further increases in blood levels. Iron typically damages cells in the [heart](/wiki/Heart), [liver](/wiki/Liver) and elsewhere, causing adverse effects that include [coma](/wiki/Coma), [metabolic acidosis](/wiki/Metabolic_acidosis), [shock](/wiki/Shock_(circulatory)), [liver failure](/wiki/Liver_failure), [coagulopathy](/wiki/Coagulopathy), [adult respiratory distress syndrome](/wiki/Adult_respiratory_distress_syndrome), long-term organ damage, and even death.[[81]](#cite_note-81) Humans experience iron toxicity when the iron exceeds 20 milligrams for every kilogram of body mass; 60 milligrams per kilogram is considered a [lethal dose](/wiki/Lethal_dose).[[82]](#cite_note-82) Overconsumption of iron, often the result of children eating large quantities of [ferrous sulfate](/wiki/Ferrous_sulfate) tablets intended for adult consumption, is one of the most common toxicological causes of death in children under six.[[82]](#cite_note-82) The [Dietary Reference Intake](/wiki/Dietary_Reference_Intake) (DRI) sets the Tolerable Upper Intake Level (UL) for adults at 45 mg/day. For children under fourteen years old the UL is 40 mg/day.

The medical management of iron toxicity is complicated, and can include use of a specific [chelating](/wiki/Chelation) agent called [deferoxamine](/wiki/Deferoxamine) to bind and expel excess iron from the body.[[81]](#cite_note-81)[[83]](#cite_note-83)[[84]](#cite_note-84)

## See also[[edit](/index.php?title=(none)&action=edit&section=34)]

[Template:Portal](/wiki/Template:Portal)

* [El Mutún](/wiki/El_Mutún) in [Bolivia](/wiki/Bolivia), where 10% of the world's accessible iron ore is located.
* [Iron fertilization](/wiki/Iron_fertilization) – proposed fertilization of oceans to stimulate [phytoplankton](/wiki/Phytoplankton) growth
* [Iron (metaphor)](/wiki/Iron_(metaphor))
* [Iron in folklore](/wiki/Iron_in_folklore)
* [List of countries by iron production](/wiki/List_of_countries_by_iron_production)
* [Pelletising](/wiki/Pelletizing) – process of creation of iron ore pellets
* [Rustproof iron](/wiki/Rustproof_iron)
* [Steel](/wiki/Steel)

## References[[edit](/index.php?title=(none)&action=edit&section=35)]

[Template:Reflist](/wiki/Template:Reflist)

## Bibliography[[edit](/index.php?title=(none)&action=edit&section=36)]

* [Template:Cite book](/wiki/Template:Cite_book)

## Further reading[[edit](/index.php?title=(none)&action=edit&section=37)]

* H. R. Schubert, *History of the British Iron and Steel Industry... to 1775 AD* (Routledge, London, 1957)
* R. F. Tylecote, *History of Metallurgy* (Institute of Materials, London 1992).
* R. F. Tylecote, "Iron in the Industrial Revolution" in J. Day and R. F. Tylecote, *The Industrial Revolution in Metals* (Institute of Materials 1991), 200–60.

## External links[[edit](/index.php?title=(none)&action=edit&section=38)]

[Template:Wiktionary](/wiki/Template:Wiktionary) [Template:Commons](/wiki/Template:Commons)

* [It's Elemental – Iron](http://education.jlab.org/itselemental/ele026.html)
* [The Most Tightly Bound Nuclei](http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/nucbin2.html)
* [Chemistry in its element podcast](http://www.rsc.org/chemistryworld/podcast/element.asp) (MP3) from the [Royal Society of Chemistry's](/wiki/Royal_Society_of_Chemistry) [Chemistry World](/wiki/Chemistry_World): [Iron](http://www.rsc.org/images/CIIE_iron_48kbps_tcm18-120046.mp3)
* [Iron](http://www.periodicvideos.com/videos/026.htm) at [*The Periodic Table of Videos*](/wiki/The_Periodic_Table_of_Videos) (University of Nottingham)
* [Metallurgy for the non-Metallurgist](https://books.google.com/books?id=brpx-LtdCLYC&pg=frontcover&d#v=onepage&q&f=true)

[Template:Compact periodic table](/wiki/Template:Compact_periodic_table) [Template:Iron compounds](/wiki/Template:Iron_compounds) [Template:Authority control](/wiki/Template:Authority_control)

[Category:Iron](/wiki/Category:Iron) [Category:Biology and pharmacology of chemical elements](/wiki/Category:Biology_and_pharmacology_of_chemical_elements) [Category:Building materials](/wiki/Category:Building_materials) [Iron](/wiki/Category:Chemical_elements) [Category:Cubic minerals](/wiki/Category:Cubic_minerals) [Category:Dietary minerals](/wiki/Category:Dietary_minerals) [Category:Ferromagnetic materials](/wiki/Category:Ferromagnetic_materials) [Category:Pyrotechnic fuels](/wiki/Category:Pyrotechnic_fuels) [Category:Transition metals](/wiki/Category:Transition_metals)