The Elements

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The elements of the periodic table are the building blocks of the universe. Literally everything you can touch is made up of different combinations of these building blocks. From the food you eat to the people you cuddle to the technology you use, it's just the same finite set of elements combined in infinitely different and clever ways. Understanding and creating those combinations of elements is what defines the science of chemistry.

We present here 37 of those building blocks, each with their own distinctive and defining properties. A special thanks to our generous sponsors, listed below, who made this possible.

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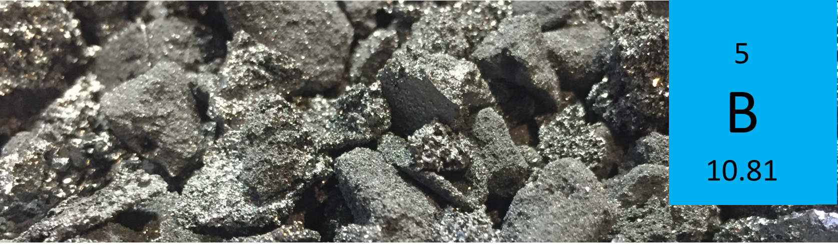


5

B

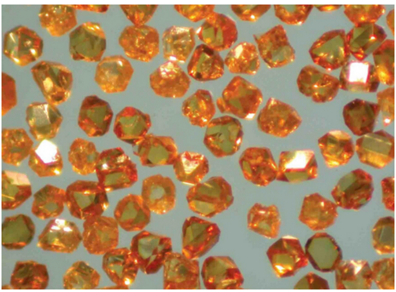
10.81

What

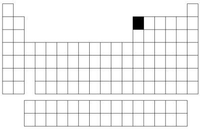
Boron is a metalloid, which means that its properties are a mix of those shown by metals and non-metals. The element has four main polymorphs but none occur naturally on Earth (though some are found in meteoroids). It is also tricky to manufacture without contaminants such as carbon. Crystalline boron is often shiny and black and, like the diamond polymorph of carbon, is extremely hard and a poor conductor of electricity.

Where

Due to the presence of a high concentration of oxygen on earth, boron is always found naturally as borate minerals. Commercially, boron appears in borosilicate glass, fibreglass insulation, detergents (borax), insecticides (boric acid), semiconductors, magnets (e.g. $Nd_2Fe_{14}B$), and materials ranging from soft playthings such as borax slime and silly putty, to superhard materials like boron nitride.



Boron



p-block metalloid
m.p.: 2077 °C
b.p.: 4000 °C
Density: 2.34 g/cm^3
[He] $2s^2$ $2p^1$
Atomic radius: 87 pm
Main isotopes:
^{10}B (20%)
^{11}B (80%)
Universe: 1.0x10^{-7} %
Earth's crust: 8.6x10^{-4} %
Human: 7.0x10^{-5} %
Year of discovery: 1808

6

C

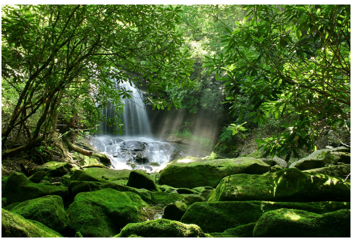
12.01

What

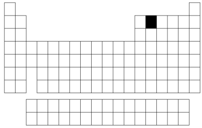
The most common forms of carbon are diamond, the hardest substance known to man and an electrical insulator, and graphite, which conducts electricity and is soft enough to rub off on a piece of paper (it's the 'lead' in a pencil). Carbon can also be made into more exotic elemental forms, including spherical fullerene molecules, carbon nanotubes, amorphous forms, and pyrolytic carbon, which floats above strong magnets. Under atmospheric pressure carbon does not melt but rather transitions straight to a gas (sublimation).

Where

Carbon is everywhere; it's the workhorse element of chemistry. Anything 'organic', by definition, contains carbon, including every living thing. Everything you eat, almost every medicine, the very air you breathe contains carbon. Plastics and polymers all contain carbon, as does coal, petroleum, and carbonate minerals such as limestone and marble.



Carbon



p-block non-metal
subl.pt.: 3652 °C
Density: 2.25 g/cm^3 (graphite)
[He] $2s^2$ $2p^2$
Atomic radius: 67 pm
Main isotopes:
^{12}C (98.9%)
^{13}C (1.1%)
^{14}C (trace)
Universe: 0.50%
Earth's crust: 0.18%
Human: 23%
Year of discovery: Ancient times

7

N

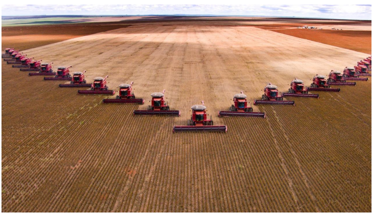
14.01

What

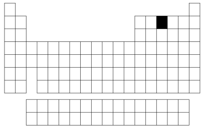
Elemental nitrogen, which makes up 78% of the atmosphere, is composed of discrete and quite unreactive molecules of two tightly bound nitrogen atoms (N_2). It becomes a liquid at -196 °C, and liquid nitrogen is widely used as a coolant across a wide range of science and industry, due to its very low temperatures, cheapness and ready availability.

Where

Like carbon, nitrogen is everywhere. Another key element of organic chemistry, it's in every living thing, most medicines, and many important plastics, polymers and other man-made materials. A key milestone in human history was the invention of industrial 'nitrogen fixation' chemistry, which converts atmospheric nitrogen into ammonia, which is then used to make the nitrate fertilisers which now underpin the world's food supply. Notable other nitrogen-containing molecules include hydrazine (rocket fuel!), nitric acid, cyanide, explosives (e.g. TNT), nitrous oxide ('laughing gas'), Kevlar, caffeine, morphine, proteins and DNA.



Nitrogen



p-block non-metal
m.p.: -210 °C
b.p.: -196 °C
Density = 1.251 g/L
[He] $2s^2$ $2p^3$
Atomic radius: 56 pm
Main isotopes:
^{14}N (99.6%)
^{15}N (0.4%)
Universe: 0.10%
Earth's crust: 0.0020%
Human: 2.6%
Year of discovery: 1772

12

Mg

24.31

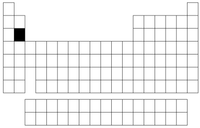
What

Magnesium is a light yet strong alkaline earth metal that, unlike the heavier alkaline earths, oxidises only slightly in air. It is, however, highly flammable and burns with a very intense flame. It will also react (usually slowly) with water, producing small bubbles of hydrogen.

Where

After sodium, magnesium is the second-most abundant cation in seawater. Its lightness and strength mean both the pure metal and its alloys are used extensively in aircraft and cars. It’s essential to life, being found in numerous enzymes in animals, and chlorophyll in plants. Its compounds are used as laxatives, antacids (e.g. milk of magnesia, magnesium hydroxide) and bath salts (Epsom salt is magnesium sulphate). It’s also found fireworks and sparklers, and was once a key component of flash powder and flashbulbs for photography.

Magnesium



s-block metal
m.p.: 650 °C
b.p.: 1090 °C
Density: 1.738 g/cm^3
[Ne] 3s^2
Atomic radius: 160 pm
Main isotopes:
^{24}Mg (79.0%)
^{25}Mg (10.0%)
^{26}Mg (11.0%)
Universe: 0.060%
Earth’s crust: 2.9%
Human: 0.027%
Year of discovery: 1755

13

Al

26.98

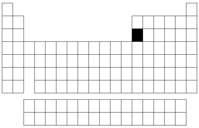
What

Aluminium's most notable properties are its lightness, strength, ductility, high reflectivity and resistance to corrosion due to the formation of a thin protective layer of oxide on its surface. It is a good thermal and electrical conductor, but is non-magnetic.

Where

Aluminium is the third most common element in the Earth's crust, after oxygen and silicon, and is contained in a large range of minerals. The main ore, however, is bauxite, for which Australia is the world's largest producer. Despite its great abundance, it has no known biological role, but is used extensively in cookware, foil, cans, engineering, building and aircraft construction. Sapphires, rubies and emeralds all contain aluminium, while porous aluminosilicate zeolites are used extensively as industrial catalysts.

Aluminium



p-block metal
m.p.: 660 °C
b.p.: 2467 °C
Density: 2.70 g/cm^3
[Ne] $3s^2\ 3p^1$
Atomic radius: 118 pm
Main isotopes:
^{26}Al (trace)
^{27}Al (100%)
Universe: 0.0050%
Earth's crust: 8.1%
Human: 9.0×10^{-5} %
Year of discovery: 1825

14

Si

28.09

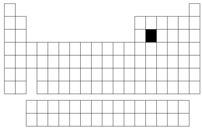
What

Silicon, a metalloid, gives crystals with a blue-grey metallic sheen. The atoms, however, are covalently bonded and arranged in the same way as the carbon atoms in diamond. But while diamond is an insulator, elemental silicon is, famously, a semiconductor. The semiconducting properties can be improved by introducing impurities such as P or N into the crystalline silicon lattice, often through irradiation with neutrons from a nuclear reactor like the one run by ANSTO in Sydney.

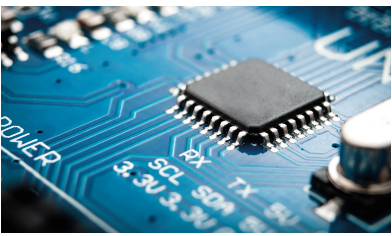
Where

While pure silicon is rare in nature, about 95% of the rocks in the earth's crust contain silicon atoms; only oxygen is more abundant. Minerals that contain silicon include beach sand and quartz (both SiO_2), silicates such as zircon, garnets and micas, and aluminosilicates such as feldspars and zeolites. As well as its wide-spread use in electronics, silicon can also be found in cements, ceramics, glass, lubricants, silicon carbide, and silicone polymers.

Silicon



p-block metalloid
m.p.: 1410 °C
b.p.: 2355 °C
Density: 2.33 g/cm^3
[Ne] $3s^2\ 3p^2$
Atomic radius: 111 pm
Main isotopes:
^{28}Si (92.2%)
^{29}Si (4.7%)
^{30}Si (3.1%)
^{32}Si (trace)
Universe: 0.070%
Earth's crust: 27%
Human: 0.026%
Year of discovery: 1824



16

S

32.06

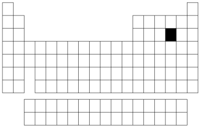
What

Sulphur, also known as brimstone in ancient times, is distinctive for its bright yellow colour. It has more than 30 allotropes, but the usual form is composed of cyclic S_8 molecules and is odourless. The infamous smell comes from impurities, and sulphur-based compounds are also responsible for other distinctive smells, including ‘rotten egg gas’ (hydrogen sulphide, H_2S), onions and garlic.

Where

Sulphur can commonly be found in its elemental form near volcanic vents. It is also a component of numerous minerals, including sulphates (e.g. gypsum, calcium sulphate) and sulphides (e.g. pyrite or ‘fool’s gold’, iron sulphide). It is essential to life, being found in the amino acids cysteine, cystine and methionine, the vitamins biotin and thiamine, and numerous proteins. The mechanical strength of skin, hair and feathers is due to the formation of S-S bonds in keratin (S-S bonds are also used to stiffen rubber in a process called vulcanisation). Many medicines (including penicillin) contain sulphur, while sulphuric acid is one of the most produced industrial inorganic chemicals worldwide.

Sulphur

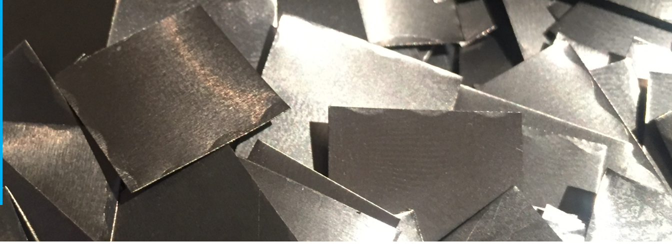


p-block non-metal
m.p.: 115 °C
b.p.: 445 °C
Density: 2.07 g/cm^3
[Ne] $3s^2$ $3p^4$
Atomic radius: 88 pm
Main isotopes:
^{32}S (94.99%)
^{33}S (0.75%)
^{34}S (4.25%)
^{35}S (trace)
^{36}S (0.01%)
Universe: 0.050%
Earth’s crust: 0.042%
Human: 0.20%
Year of discovery:
500BC

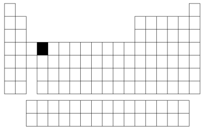
22

Ti

47.88



Titanium



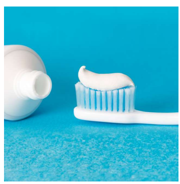
What

Titanium is a transition metal with the highest strength-to-density ratio of any metallic element. Although 60% denser than Al, it is more than twice as strong. It is also highly corrosion resistant, relatively ductile and has a high melting point. Its thermal and electrical conductivities are low for a metal. It oxidises rapidly in air, but the oxide forms a passive layer on the surface (only a few nanometres thick) that prevents further oxidation and protects it from corrosion.

Where

Titanium is found in minerals such as anatase, brookite, ilmenite, perovskite, rutile and titanite. Titanium oxide (TiO_2) is a very widely used white pigment, due to its brilliance, resistance to fading in sunlight, and chemical inertness. It is found in paints, paper, toothpaste and plastics, as well as in sunscreens. The metal and its alloys are widely used in aircraft, including the famous SR-71 “Blackbird” spy plane, boats and submarines, racing cars, pipes and equipment in chemical industry, biomedical implants, sports equipment, and laptop computers.

d-block metal
m.p.: 1660 °C
b.p.: 3287 °C
Density: 4.506 g/cm^3
[Ar] $3d^2\ 4s^2$
Atomic radius: 176 pm
Main isotopes:
^{46}Ti (8.25%)
^{47}Ti (7.44%)
^{48}Ti (73.72%)
^{49}Ti (5.41%)
^{50}Ti (5.18%)
Universe: 3.0x10^{-4} %
Earth’s crust: 0.66%
Human: none
Year of discovery: 1791



23

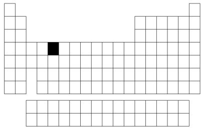
V

50.94

What

Vanadium is a hard, ductile, malleable, silver-grey transition metal. It is electrically conductive but thermally insulating. Its chemistry is notable its multiple oxidation states, which form different coloured solutions in water: lilac (II), green (III), blue (IV) and yellow (V).

Vanadium



Where

Vanadium is found in numerous minerals and is the 20th most abundant element in the Earth's crust. It is also abundant in seawater. Its hardness means that its major use is in increasing the strength of steel and in alloys with other metals such as iron (ferrovanadium) or titanium and aluminium. Compounds of vanadium, vanadium pentoxide (V_2O_5) in particular, are widely used as industrial catalysts. Vanadium is also found in some biomolecules, particularly in marine organisms. It can also be found in significant quantities in some fungi, though the reason is currently unknown.

d-block metal
m.p.: 1910 °C
b.p.: 3407 °C
Density: 5.96 g/cm^3
[Ar] 3d^3 4s^2
Atomic radius: 171 pm
Main isotopes:
^{50}V (0.25%)
^{51}V (99.75%)
Universe: 1.0x10^{-4} %
Earth's crust: 0.019%
Human: 3.0x10^{-6} %
Year of discovery: 1801

24

Cr

52.00

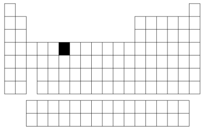
What

Chromium is the third hardest element (behind the diamond allotrope of carbon, then boron) but is also brittle. It is known for being highly reflective and tarnish resistant. Many of its compounds are brightly coloured, giving rise to the element's name (from the Greek *chrõma*, meaning colour). Compounds in the VI oxidation state are toxic and carcinogenic, while those in the III oxidation state and the metal are not.

Where

Chromium is often used to coat other metals due to its hardness, resistance to corrosion, and attractive lustre. It is also used to harden steel (to give 'stainless steel') and other alloys. Its compounds are commonly used as pigments (the mineral crocoite, $PbCrO_4$, once provided the distinctive yellow of American school buses), while rubies are red and emeralds green due to Cr impurities. Chromium salts are also used to preserve wood and tan leather, while CrO_2 is used in magnetic tape.

Chromium



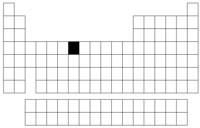
d-block metal
m.p.: 1907 °C
b.p.: 2671 °C
Density: 7.15 g/cm^3
[Ar] $3d^5$ $4s^1$
Atomic radius: 166 pm
Main isotopes:
^{50}Cr (4.35%)
^{52}Cr (83.79%)
^{53}Cr (9.50%)
^{54}Cr (2.37%)
Universe: 0.0015%
Earth's crust: 0.014%
Human: $3.0x10^{-6}$ %
Year of discovery: 1797

25

Mn

54.94

Manganese



What

Manganese in its pure state is silver-grey, but, like iron, it “rusts” (i.e. oxidises) very easily. It is hard and brittle, and displays oxidation states from -III to +VII (though II, III, IV, VI and VII are the most common).

Where

Manganese plays a key role in iron and steel production due to its readiness to react with sulphur and oxygen. Manganese compounds have been used as pigments since the Stone Age. The purple potassium permanganate ($KMnO_4$) contains Mn(VII) and is a strong and commonly used oxidiser, often used to sterilise and disinfect water supplies. Manganese dioxide (MnO_2) is a vital component of alkaline batteries. Manganese is also essential to the functioning of many important enzymes in animals and bacteria, as well as photosynthesis in plants. The human body contains approximately 12 mg of manganese.

d-block metal
m.p.: 1246 °C
b.p.: 2061 °C
Density: 7.20 g/cm^3
[Ar] $3d^5\ 4s^2$
Atomic radius: 161 pm
Main isotopes:
^{53}Mn (trace)
^{55}Mn (100%)
Universe: 8.0×10^{-4} %
Earth’s crust: 0.11%
Human: 2.0×10^{-5} %
Year of discovery: 1774

26

Fe

55.85

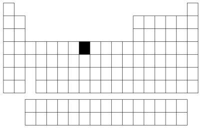
What

Pure iron is a silver-grey metal that is ferromagnetic up to 770 °C. It reacts readily with water and oxygen to give hydrated iron oxides ("rust") and unlike many other metals, where oxidation produces thin layers of oxide that protect the bulk metal, rust takes up a much larger volume, producing flakes that fall away and expose more of the bulk metal. The most common oxidation states are II and III.

Where

Iron is, by mass, the most abundant element on Earth, with the inner core of the planet thought to be an iron-nickel alloy. It is widely used across numerous fields (construction particularly) in various types of iron alloys (including wrought and cast iron) and steels (Fe+C). Its magnetic properties make it useful in ancient compasses and modern fridge magnets, and it is found in pigments such as Prussian Blue and Berlin Green. It is essential to life, being, among other things, the gas-binding centre of haemoglobin, which allows red blood cells to move oxygen and carbon dioxide between the lungs and the rest of the body.

Iron



d-block metal
m.p.: 1538 °C
b.p.: 2862 °C
Density: 7.874 g/cm^3
[Ar] 3d^6 4s^2
Atomic radius: 156 pm
Main isotopes:
^{54}Fe (5.85%)
^{56}Fe (91.75%)
^{57}Fe (2.12%)
^{58}Fe (0.28%)
^{60}Fe (trace)
Universe: 0.11%
Earth's crust: 6.3%
Human: 0.0060%
Year of discovery:
3500BC

27

Co

58.93

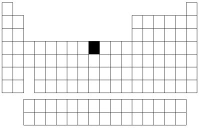
What

Cobalt is a hard, lustrous, silver-grey metal which is ferromagnetic below 1115 °C. Its common oxidation states are II and III.

Where

The majority of the world’s cobalt is currently produced by the Democratic Republic of the Congo. $LiCoO_2$ is used in lithium-ion batteries, while $SmCo_5$ alloys make very strong magnets. The colour of the “cobalt blue” pigment is distinctive of Co(II) ions in a tetrahedral geometry. Cobalt is also the key component of cobalamin coenzymes, including vitamin B_{12}. The ^{60}Co radioisotope emits high intensity gamma-rays upon decay, and has a half-life of 5.2 years. As a result, it is widely used in applications such as sterilisation of medical equipment and food, industrial radiography, and in medical radiotherapy.

Cobalt



d-block metal
m.p.: 1495 °C
b.p.: 2927 °C
Density: 8.86 g/cm^3
[Ar] $3d^7$ $4s^2$
Atomic radius: 152 pm
Main isotopes:
^{59}Co (100%)
^{60}Co (synthetic)
Universe: 3.0×10^{-4} %
Earth’s crust: 0.0030%
Human: 2.0×10^{-6} %
Year of discovery: 1735

28

Ni

58.71

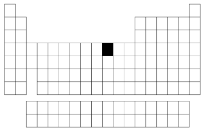
What

Nickel is a lustrous silver-white metal (with a slight golden tinge when highly polished) which is hard and ductile. It is one of only three elements that are ferromagnetic at room temperature, with the others being Fe and Co (Gd is also magnetic below 20 °C).

Where

A number of countries have used pure nickel in coins at various stages, however this practise has now been mostly discontinued in favour of cheaper alloys. However, pure nickel is corrosion resistant and thus nickel-plating of other materials is common. It also forms a number of alloys, with more than half the world's production used in stainless steel. Nickel can also be found in batteries and magnets, while "Raney nickel" is used as a catalyst to convert unsaturated oils into margarine.

Nickel



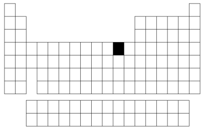
d-block metal
m.p.: 1455 °C
b.p.: 2913 °C
Density: 8.908 g/cm^3
[Ar] 3d^8 4s^2
Atomic radius: 149 pm
Main isotopes:
^{58}Ni (68.08%)
^{59}Ni (trace)
^{60}Ni (26.22%)
^{61}Ni (1.14%)
^{62}Ni (3.64%)
^{64}Ni (0.93%)
Universe: 0.0060%
Earth's crust: 0.0089%
Human: 1.0x10^{-5} %
Year of discovery: 1751

29

Cu

63.54

Copper



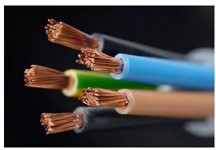
What

Pure copper is a lustrous red-orange metal, however surface oxidation can result in a brown-black appearance, and green copper carbonate can also form over time on e.g. copper roofing. It is soft, malleable and has very high thermal and electrical conductivity.

Where

Like silver and gold, copper can be found naturally as nuggets. Uses of the metal include electrical wiring and motors, architecture, plumbing, decorative metalwear, coins, antimicrobial applications, and in numerous alloys, including brass (Cu/Zn), bronze (Cu/Sn) and sterling silver (Ag/Cu). The Statue of Liberty contains more than 80 tonnes of copper. Copper proteins are used across a wide range of roles in the body. Notably, the blood of some animals, such as molluscs and the horseshoe crab, is blue due to the use of a copper protein as the oxygen carrier rather than the red iron-based haemoglobin molecule in other animals.

d-block metal
m.p.: 1085 °C
b.p.: 2567 °C
Density: 8.92 g/cm^3
[Ar] $3d^{10}$ $4s^1$
Atomic radius: 145 pm
Main isotopes:
^{63}Cu (69.15%)
^{64}Cu (synthetic)
^{65}Cu (30.85%)
^{67}Cu (synthetic)
Universe: 6.0x10^{-6} %
Earth's crust: 0.0068%
Human: 0.0001%
Year of discovery:
8000BC



30

Zn

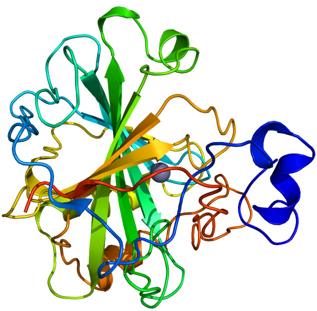
65.37

What

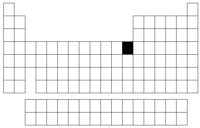
Zinc is (when oxidation is removed) a silvery-blue metal that is diamagnetic and slightly brittle. Strictly, like Cd and Hg, it is a main group metal, however they are often grouped with the transition metals due to their similar chemistry. The only oxidation state of any significance is II.

Where

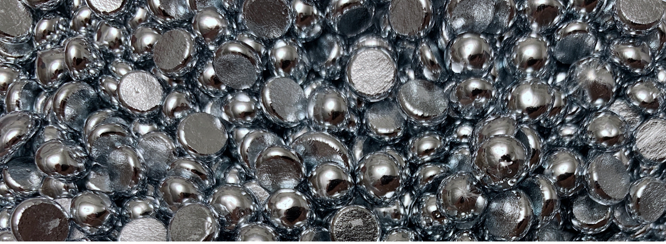
Zinc form alloys with a number of metals, including copper to give brass. It is also used to protect other metals through use as coatings (galvanisation) or as sacrificial anodes. Zinc oxide is a very popular white pigment, and also protects polymers, plastics and people from UV radiation. Numerous enzymes in plants and animals contain zinc. One example is carbonic anhydrase, which is used to remove carbon dioxide from the blood and helps regulate pH in the body.



Zinc



d-block metal
m.p.: 420 °C
b.p.: 907 °C
Density: 7.14 g/cm^3
[Ar] 3d^{10} 4s^2
Atomic radius: 142 pm
Main isotopes:
^{64}Zn (49.2%)
^{66}Zn (27.7%)
^{67}Zn (4.0%)
^{68}Zn (18.5%)
^{70}Zn (0.6%)
Universe: 3.0x10^{-5} %
Earth’s crust: 0.0078%
Human: 0.0033%
Year of discovery: 20BC



31

Ga

69.72

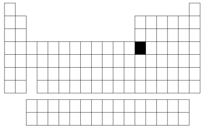
What

Gallium is a soft, silvery-blue metal that melts at just 29.76°C – low enough that it can melt in your hands. Once melted it can often form supercooled liquids, which means that it stays liquid when returned to below its freezing point (though 'seeding' can induce crystallisation). It will wet (stick to or stain) glass, skin and plastic, has no natural biological role but is non-toxic. Its existence and properties were correctly predicted by the inventor of the periodic table, Dmitri Mendeleev, four years before it was discovered.

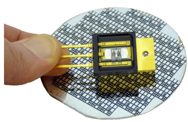
Where

Gallium arsenide, gallium nitride and indium gallium nitride are used extensively in semiconductors, including in blue LEDs and violet Blu-ray lasers. The Galinstan alloy is a mixture of gallium, indium and tin, and is a shiny metallic liquid at room temperature that is used in place of mercury in thermometers. ^{67}Ga and ^{68}Ga are used as radioisotopes in nuclear medicine.

Gallium



p-block metal
m.p.: 30 °C
b.p.: 2403 °C
Density: 5.904 g/cm^3
[Ar] $3d^{10}\ 4s^2\ 4p^1$
Atomic radius: 136 pm
Main isotopes:
^{67}Ga (synthetic)
^{68}Ga (synthetic)
^{69}Ga (60.11%)
^{71}Ga (39.89%)
Universe: 1.0x10^{-6} %
Earth's crust: 0.0019%
Human: none
Year of discovery: 1875

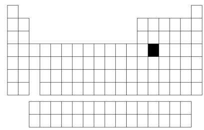


32

Ge

72.59

Germanium

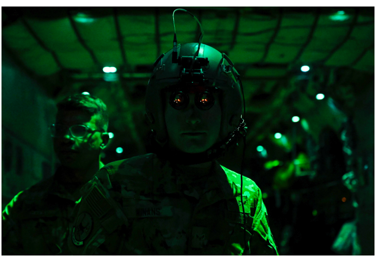


What

Germanium is a hard, shiny, grey-white metalloid. Like gallium, its existence and properties were predicted by Mendeleev 15 years before it was discovered. The common allotrope (α-Ge) has the same crystal structure as diamond (carbon) and silicon. Germanium also has the unusual property of expanding as it freezes (like water). It is also a semiconductor, like silicon.

Where

Germanium is usually produced from ores primarily mined for Zn, Ag, Pb or Cu. The main oxidation states are IV and (to a lesser extent) II. It is used in a variety of applications, including fibre optics, solar panels, semiconductors and LEDs. It is transparent to infrared wavelengths, leading to its use in thermal imaging cameras and night vision goggles. Germanium dioxide (GeO_2) is used as a catalyst in the production of polyethylene terephthalate (PET) polymer. Germanium has no biological role and generally low toxicity.



p-block metalloid
m.p.: 938 °C
b.p.: 2833 °C
Density: 5.32 g/cm^3
[Ar] $3d^{10}\ 4s^2\ 4p^2$
Atomic radius: 122 pm
Main isotopes:
- ^{68}Ge (synthetic)
- ^{70}Ge (20.5%)
- ^{71}Ge (synthetic)
- ^{72}Ge (27.4%)
- ^{73}Ge (7.76%)
- ^{74}Ge (36.5%)
- ^{76}Ge (7.75%)

Universe: 2.0x10^{-5} %
Earth’s crust: 1.4x10^{-4} %
Human: none
Year of discovery: 1886

39

Y

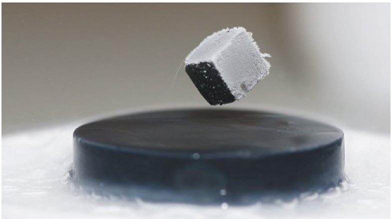
88.91

What

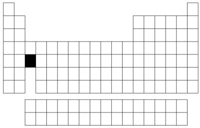
Although yttrium is a d-block transition metal, its chemical properties are similar to the lanthanoids, and thus these elements (and Sc) are commonly grouped together under the name of rare-earth elements (though many are not that rare). It is a soft, silver-coloured metal that is reasonably stable in air due to the formation of a protective oxide layer on its surface (Y_2O_3). The finely divided metal, however, is unstable and can catch fire at elevated temperatures.

Where

Yttrium is usually found in minerals containing a mixture of different rare-earth elements. It is a key component of yttrium barium copper oxide (YBCO) superconductors. YAG (yttrium aluminium garnet) crystals, often doped with other rare-earths, are used in a variety of different lasers. Yttrium compounds are used as catalysts in the production of polyethylene plastic, as components of LEDs, and as phosphors. YInMn blue was a landmark blue pigment discovered in 2008.



Yttrium



d-block metal
m.p.: 1526 °C
b.p.: 2930 °C
Density: 4.47 g/cm^3
[Kr] 4d^1 5s^2
Atomic radius: 180 pm
Main isotopes:
^{87}Y (synthetic)
^{88}Y (synthetic)
^{89}Y (100%)
^{90}Y (synthetic)
^{91}Y (synthetic)
Universe: 7.0x10^{-7} %
Earth's crust: 2.9x10^{-3} %
Human: none
Year of discovery: 1794

40

Zr

91.22

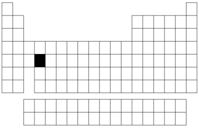
What

Zirconium is a soft, greyish-white malleable metal when pure, though impurities can make it hard and brittle. It is highly resistant to corrosion by agents such as acids, bases and salt water.

Where

The chief ore for zirconium is zircon ($ZrSiO_4$), from which it takes its name. Two-thirds of the world's mining of zircon occurs in Australia and South Africa. The most familiar use of zirconium is in cubic zirconia (ZrO_2) jewels, which are low cost yet have similar durability and visual appeal to diamond. They can also be made in a range of colours by doping the crystals with small amounts of other elements. Zirconium is also used as cladding for nuclear reactor fuels, industrial catalysis, and in medical implants such as dental implants, knee and hip replacements, and prosthetic devices. The most commonly used piezoelectric material is lead zirconate titanate ($Pb[Zr_xTi_{1-x}]O_3$, PZT).

Zirconium



d-block metal
m.p.: 1852 °C
b.p.: 4377 °C
Density: 6.511 g/cm^3
[Kr] $4d^2$ $5s^2$
Atomic radius: 206 pm
Main isotopes:
- ^{89}Zr (synthetic)
- ^{90}Zr (51.45%)
- ^{91}Zr (11.22%)
- ^{92}Zr (17.15%)
- ^{93}Zr (trace)
- ^{94}Zr (17.38%)
- ^{96}Zr (2.80%)

Universe: 5.0×10^{-6} %
Earth's crust: 0.013%
Human: 5.0×10^{-6} %
Year of discovery: 1789

41

Nb

92.91

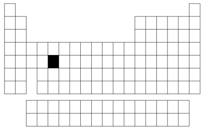
What

Niobium, once known as columbium, is a strong and ductile transition metal. It normally oxidises slowly, however the depth of the natural oxide layer can be increased using an electric current (a process known as anodizing). This changes the colour from its natural silver-grey to a range of vibrant colours which are related to the depth of the oxide layer. This process also works for a number of other metallic elements, notably Al, Ti and Ta.

Where

Niobium is hypoallergenic; this plus the iridescent colours produced through anodization mean that it's commonly used in jewellery. Niobium based superconducting magnets are used in MRI and NMR instruments, as well as at the Large Hadron Collider and in maglev trains. Lithium niobate is used widely in optics and electronics (e.g. mobile phones), while niobium capacitors offer an alternative to tantalum analogues.

Niobium



d-block metal
m.p.: 2477 °C
b.p.: 4741 °C
Density: 8.57 g/cm^3
[Kr] 4d^4 5s^1
Atomic radius: 198 pm
Main isotopes:
^{92}Nb (trace)
^{93}Nb (100%)
Universe: 2.0x10^{-7} %
Earth's crust: 0.0017%
Human: none
Year of discovery: 1801

42

Mo

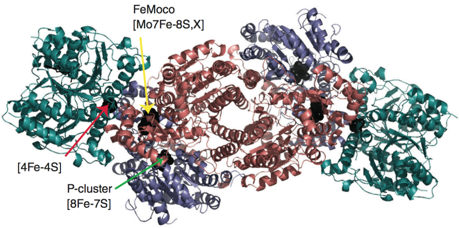
95.94

What

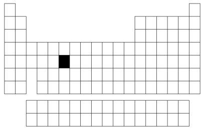
Molybdenum is a silver-grey second row transition metal which has a high melting point and a low coefficient of thermal expansion. Like Cr and W, its chemistry is notable for its large range of oxidation states, namely -II to +VI. Mo (and W) also regularly forms high nuclearity clusters and oxoanions (e.g. $Mo_6Cl_{14}^{2-}$, $Mo_8O_{26}^{4-}$).

Where

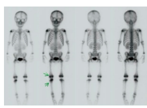
The vast majority of molybdenum produced is used in metallurgy, mostly in various steel alloys. Molybdenum is also an essential element in all plants and animals, and more than 50 molybdenum enzymes are known. The most notable are the nitrogenases, which are used by bacteria to reduce nitrogen to ammonia, a key step in nitrogen fixation, which is essential to all forms of life. The radioactive ^{99}Mo isotope is produced in nuclear reactors such as the OPAL reactor in Sydney, and decays to the short-lived ^{99m}Tc, which is the most widely-used medical radioisotope in the world.



Molybdenum



d-block metal
m.p.: 2622 °C
b.p.: 4639 °C
Density: 10.2 g/cm^3
[Kr] $4d^5\ 5s^1$
Atomic radius: 190 pm
Main isotopes:
^{92}Mo (14.65%)
^{94}Mo (9.19%)
^{95}Mo (15.87%)
^{96}Mo (16.67%)
^{97}Mo (9.58%)
^{98}Mo (24.29%)
^{99}Mo (synthetic)
^{100}Mo (9.74%)
Universe: 5.0x10^{-7} %
Earth's crust: 1.1x10^{-4} %
Human: 1.0x10^{-5} %
Year of discovery: 1781



47

Ag

107.87

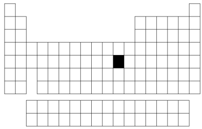
What

Silver is a soft, lustrous transition metal which has the highest electrical and thermal conductivity and reflectivity of any metal. Its chemistry is typified by insoluble, light-sensitive Ag(I) compounds.

Where

Like copper and gold, it can be found naturally as nuggets, but it is usually produced as a byproduct of mining for other metals. Apart from its important roles in currency and investment, silver can also be found in jewelry, tableware and cutlery ('silverware'), mirrors and electronics. The light sensitivity of silver compounds, particularly silver nitrate and silver halides, once led to its widespread use in film-based photography, while their antibiotic properties give rise to use in wound dressings.

Silver



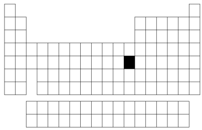
d-block metal
m.p.: 962 °C
b.p.: 2162 °C
Density: 10.5 g/cm^3
[Kr] 4d^{10} 5s^1
Atomic radius: 165 pm
Main isotopes:
^{107}Ag (51.84%)
^{109}Ag (48.16%)
Universe: 6.0x10^{-8} %
Earth's crust: 7.9x10^{-6} %
Human: none
Year of discovery:
3000BC

48

Cd

112.40

Cadmium



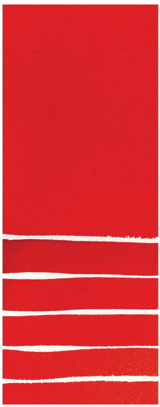
What

Cadmium is a soft, malleable silver-white metal. Its chemistry is similar to zinc, with the oxidation state II being the dominant one, though cadmium compounds are typically much more toxic.

Where

Cadmium is produced mainly as a byproduct of zinc, lead or copper mining. Toxicity issues are today limiting its use, with most cadmium currently being used for nickel-cadmium batteries. Another significant use is for the electroplating of steel to reduce corrosion. Cadmium compounds are also used as vibrant pigments, including ‘cadmium yellow’ (CdS), ‘cadmium red’ (CdSe), and ‘cadmium orange’ (a mixture of both).

d-block metal
m.p.: 321 °C
b.p.: 767 °C
Density: 8.642 g/cm^3
[Kr] 4d^{10} 5s^2
Atomic radius: 161 pm
Main isotopes:
^{106}Cd (1.25%)
^{108}Cd (0.89%)
^{110}Cd (12.47%)
^{111}Cd (12.80%)
^{112}Cd (24.11%)
^{113}Cd (12.23%)
^{114}Cd (28.75%)
^{116}Cd (7.51%)
Universe: 2.0x10^{-7} %
Earth’s crust: 1.5x10^{-5} %
Human: 7.0x10^{-5} %
Year of discovery: 1817



49

In

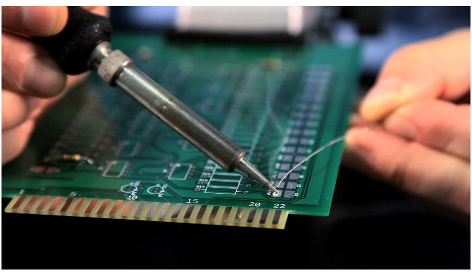
114.82

What

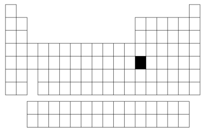
Indium is a ductile silvery-white main group metal that is soft enough to be cut with a knife. It has a relatively low melting point, and like its neighbour gallium, it is able to wet (i.e. stick to) glass. Its name comes from the indigo blue line observed in its emission spectrum, which was observed before the element was first isolated.

Where

The main consumption of indium production is in LCD displays, including televisions and computer monitors, which contain thin films of indium tin oxide. It also forms a number of low-melting alloys used as solders, as well as several other useful compounds (e.g. InSb, InP, InGaN, InGaP and $CuIn_{1-x}Ga_xSe_2$ ('CIGS')) used as semiconductors. Its ability to capture neutrons makes it a useful component of control rods in nuclear reactors.



Indium



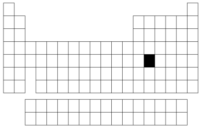
p-block metal
m.p.: 157 °C
b.p.: 2080 °C
Density: 7.31 g/cm^3
[Kr] $4d^{10}\ 5s^2\ 5p^1$
Atomic radius: 156 pm
Main isotopes:
^{111}In (synthetic)
^{113}In (4.28%)
^{115}In (95.72%)
Universe: 3.0×10^{-8} %
Earth's crust: 1.6×10^{-5} %
Human: none
Year of discovery: 1863

50

Sn

118.69

Tin



What

Tin has two important allotropes. The usual form is β-tin (‘white tin’), which is metallic, soft and malleable, however below 13°C α-tin (‘grey tin’) becomes stable; this allotrope is non-metallic and brittle. This leads to ‘tin pest’ or ‘tin disease’, where β-tin transforms into brittle α-tin in cold weather. This is thought by some to have played an important role in ill-fated historical events such as Napoleon’s 1812 Russian campaign or Robert Scott’s Antarctic expedition of 1910.

Where

About half of the tin produced each year is used as solder. Tin cans are not pure tin, but rather are composed of steel plated with tin to prevent corrosion. Tin also forms a number of important alloys, including bronze, pewter and a range of tin-lead alloys used in pipe organs. Organotin compounds are used to prevent degradation of PVC plastics, and as wood preservatives, pesticides, fungicides, algaecides, and antifouling agents.

p-block metal
m.p.: 232 °C
b.p.: 2260 °C
Density: 7.287 g/cm^3
[Kr] $4d^{10}$ $5s^2$ $5p^2$
Atomic radius: 145 pm
Main isotopes:
^{112}Sn (0.97%)
^{114}Sn (0.66%)
^{115}Sn (0.34%)
^{116}Sn (14.54%)
^{117}Sn (7.68%)
^{118}Sn (24.22%)
^{119}Sn (8.59%)
^{120}Sn (32.58%)
^{122}Sn (4.63%)
^{124}Sn (5.79%)
^{126}Sn (trace)
Universe: 4.0x10^{-7} %
Earth’s crust: 2.2x10^{-4} %
Human: 2.0x10^{-5} %
Year of discovery:
2100BC

51

Sb

121.75

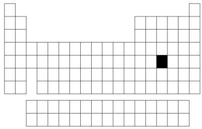
What

The most common form of the metalloid element antimony is a shiny grey metallic form which is both soft and brittle. Less common polymorphs include black and yellow forms, as well as an explosive form which is, fortunately, very rare.

Where

The mineral stibnite (Sb_2S_3) is the main source of antimony. The major use of antimony is in flame retardants, however it is also used extensively in alloys with other metals, particularly with lead and tin. These alloys include pewter, an alloy used since the Bronze Age, and others used today in lead-acid car batteries, solders, bullets and bearings. A Pb/Sn/Sb alloy was used by Johann Gutenberg for his invention of movable type in the 15th century; his printing presses made books widely available for the first time. Other uses include electronics and specialised antimony-based drugs.

Antimony



p-block metalloid
m.p.: 631 °C
b.p.: 1587 °C
Density: 6.697 g/cm^3
[Kr] $4d^{10}\ 5s^2\ 5p^3$
Atomic radius: 133 pm
Main isotopes:
^{121}Sb (57.21%)
^{123}Sb (42.79%)
Universe: 4.0×10^{-8} %
Earth's crust: 2.0×10^{-5} %
Human: none
Year of discovery:
1600BC

52

Te

127.60

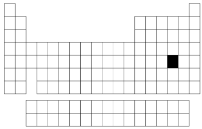
What

The crystalline allotrope of tellurium is shiny silvery-white, while the amorphous allotrope is brown or black. It is mildly toxic, with poisoning victims often having garlic-smelling breath due to the formation of dimethyl telluride gas ($(CH_3)_2Te$). The elements in this group of the periodic table (O, S, Se, Te, Po) are known as the chalcogens. The final element in this group, livermorium (Lv), is also predicted to display chalcogen-like chemistry, but its very short half-life makes it difficult to test.

Where

Tellurium is very scarce on Earth, though it can occur in Nature as the pure element. More commonly, however, it is found mixed with metals such as gold and silver. Its most significant industrial use is in compounds with metals such as zinc, cadmium and mercury, which are used in solar cells and semiconductors.

Tellurium



p-block metalloid

m.p.: 450 °C

b.p.: 988 °C

Density: 6.232 g/cm^3

[Kr] $4d^{10}\ 5s^2\ 5p^4$

Atomic radius: 123 pm

Main isotopes:

- ^{120}Te (0.09%)
- ^{122}Te (2.55%)
- ^{123}Te (0.89%)
- ^{124}Te (4.74%)
- ^{125}Te (7.07%)
- ^{126}Te (18.84%)
- ^{128}Te (31.74%)
- ^{130}Te (34.08%)

Universe: 9.0x10^{-7} %

Earth's crust: 9.9x10^{-8} %

Human: none

Year of discovery: 1783

64

Gd

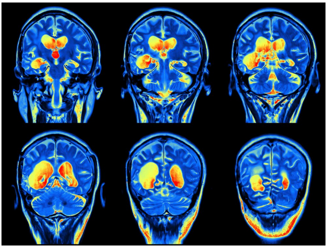
157.25

What

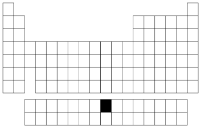
Gadolinium is a silvery-white lanthanoid metal that oxidises readily, to form black oxide coating. It is ferromagnetic (and thus attracted to a magnet) below 20 °C and highly paramagnetic above this temperature.

Where

Gadolinium is named after the mineral gadolinite, which also contains a number of other rare-earth elements, in higher abundance. Its chemistry is dominated by the oxidation state III, and while its water soluble salts are normally toxic, the use of chelating ligands to tightly bind gadolinium ions produces complexes that are widely used as magnetic contrast agents for MRI scans. Like many other rare earths, gadolinium is also used in phosphors and optical devices. It also shows the magnetocaloric effect, meaning its temperature changes entering or leaving a magnetic field, leading to significant interest in gadolinium compounds for use in refrigeration.



Gadolinium



f-block metal
m.p.: 1312 °C
b.p.: 3000 °C
Density: 7.90 g/cm^3
[Xe] $4f^7 5d^1 6s^2$
Atomic radius: 180 pm
Main isotopes:
^{148}Gd (synthetic)
^{150}Gd (synthetic)
^{152}Gd (0.2%)
^{153}Gd (synthetic)
^{154}Gd (2.18%)
^{155}Gd (14.8%)
^{156}Gd (20.5%)
^{157}Gd (15.7%)
^{158}Gd (24.8%)
^{160}Gd (21.9%)
Universe: 2.0x10^{-7} %
Earth's crust: 5.2x10^{-4} %
Human: none
Year of discovery: 1880

67

Ho

164.93

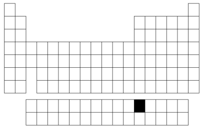
What

Holmium is a silvery lanthanoid metal that will tarnish slowly in air, forming a yellowish oxide. It is reasonably stable in dry air at room temperature, but will burn in air, react with water, and (like all lanthanoids) is not found in its pure form in nature.

Where

Holmium is usually found together with other rare-earth elements in minerals such as gadolinite and monazite. It has the highest magnetic moment of any element, and thus is used in the production of some types of permanent magnets, and in magnetic equipment such as MRI machines. It is also used as a dopant for crystals that lie in the heart of various types of medical and dental lasers. Like most lanthanoid elements, its compounds mostly contain holmium in the III oxidation state.

Holmium



f-block metal
m.p.: 1461 °C
b.p.: 2600 °C
Density: 8.79 g/cm^3
[Xe] 4f^{11} 6s^2
Atomic radius: 176 pm
Main isotopes:
^{163}Ho (synthetic)
^{164}Ho (synthetic)
^{165}Ho (100%)
^{166}Ho (synthetic)
^{166m1}Ho (synthetic)
^{167}Ho (synthetic)
Universe: 5.0x10^{-8} %
Earth's crust: 1.2x10^{-4} %
Human: none
Year of discovery: 1878

70

Yb

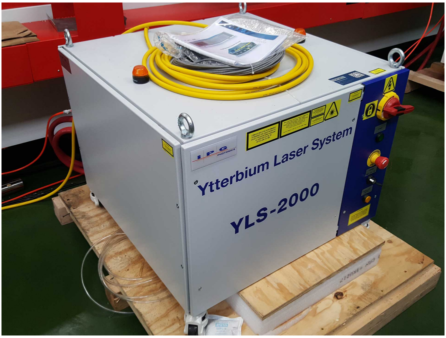
173.04

What

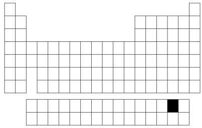
Ytterbium is soft and malleable f-block lanthanoid metal, and like most lanthanoids it will react with oxygen (though much more slowly than the early lanthanoids).

Where

Ytterbium is named after the Ytterby mine in Sweden, which produced the gadolinite ore from which it was discovered (as were six other elements, including yttrium, erbium and terbium, all named after the same mine). Unlike most lanthanoids, it readily forms divalent compounds in addition to the trivalent compounds usually favoured by these elements. The most notable current use of ytterbium is as a dopant in Yb:YAG solid-state infrared lasers.



Ytterbium



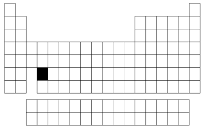
f-block metal
m.p.: 824 °C
b.p.: 1196 °C
Density: 6.965 g/cm^3
[Xe] $4f^{14}$ $6s^2$
Atomic radius: 222 pm
Main isotopes:
^{168}Yb (0.13%)
^{170}Yb (3.02%)
^{171}Yb (14.22%)
^{172}Yb (21.75%)
^{173}Yb (16.10%)
^{174}Yb (31.90%)
^{176}Yb (12.89%)
Universe: 2.0x10^{-7} %
Earth's crust: 2.8x10^{-4} %
Human: none
Year of discovery: 1878

72

Hf

178.49

Hafnium

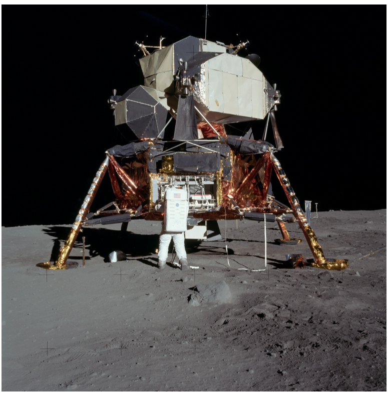


What

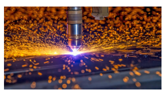
Hafnium is a lustrous, silver-grey transition metal. Its chemistry is very similar to zirconium, which can make them difficult to fully separate industrially. Indeed, much of the hafnium produced retains some level of zirconium impurities.

Where

Hafnium is mostly found as a dopant in zirconium minerals and ores. Natural zircon ($ZrSiO_4$) usually contains 1-4% Hf in place of Zr. Hafnium's high melting point and high resistance to corrosion at high temperatures are ideal for use in plasma torches. It has also been used in alloys for rocket thruster nozzles, including those on the Apollo Lunar Modules that landed the first people on the moon.



d-block metal
m.p.: 2233 °C
b.p.: 4603 °C
Density: 13.31 g/cm^3
[Xe] $4f^{14}$ $5d^2$ $6s^2$
Atomic radius: 159 pm
Main isotopes:
^{172}Hf (synthetic)
^{174}Hf (0.16%)
^{176}Hf (5.26%)
^{177}Hf (18.6%)
^{178}Hf (27.3%)
^{178m2}Hf (synthetic)
^{179}Hf (13.6%)
^{180}Hf (35.1%)
^{182}Hf (synthetic)
Universe: 7.0x10^{-8} %
Earth's crust: 3.3x10^{-4} %
Human: none
Year of discovery: 1923



73

Ta

180.95

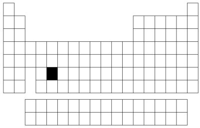
What

Tantalum is a hard, chemically inert transition metal that shows high conductivity of heat and electricity, and high resistance towards corrosion. It is chemically similar to niobium, which means that the two elements are commonly found together in most ores. It displays two crystalline phases: the more common alpha phase is relatively soft and ductile, while the beta phase is hard and brittle. The rare ^{180m}Ta isotope is 'metastable', but its decay is yet to be observed; by comparison, the ^{180}Ta isotope has a half-life of only 8 hours.

Where

Currently the main source of tantalum worldwide is two mines in Western Australia. The main use of tantalum is in electrical components, such as capacitors and resistors, and it is considered a technology-critical element. Other uses include in a range of metal alloys for specialised uses, and in surgical implants and instruments, due to its chemical inertness.

Tantalum



d-block metal
m.p.: 3017 °C
b.p.: 5455 °C
Density: 16.4 g/cm^3
[Xe] $4f^{14}\ 5d^3\ 6s^2$
Atomic radius: 200 pm
Main isotopes:
^{180m}Ta (0.01%)
^{181}Ta (99.99%)
Universe: 8.0×10^{-9} %
Earth's crust: 1.7×10^{-4} %
Human: none
Year of discovery: 1802

74

W

183.85

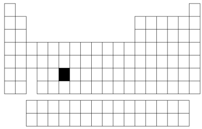
What

Tungsten, sometimes earlier known as wolfram, is a hard third-row transition metal that has the highest melting and boiling points of all the elements, as well as one of the highest densities. It also shows the lowest coefficient of thermal expansion of any pure metal. Its chemistry is notable for the formation of oxoanions such as WO_4^{2-}, $W_7O_{24}^{6-}$ and $H_2W_{12}O_{40}^{6-}$ (the 'Keggin anion').

Where

The main ores for tungsten are wolframite and scheelite. The production of hard materials accounts for about half the world's production of tungsten, including in tungsten carbide (WC), which is widely used as an abrasive and in cutting tools. Its high melting point makes it useful in arc welding and as filaments in incandescent light bulbs. Tungsten compounds are also used as industrial catalysts.

Tungsten



d-block metal
m.p.: 3414 °C
b.p.: 5555 °C
Density: 19.35 g/cm^3
[Xe] $4f^{14}$ $5d^4$ $6s^2$
Atomic radius: 193 pm
Main isotopes:
- ^{180}W (0.12%)
- ^{182}W (26.50%)
- ^{183}W (14.31%)
- ^{184}W (30.64%)
- ^{186}W (28.43%)

Universe: 5.0x10^{-8} %
Earth's crust: 1.1x10^{-4} %
Human: none
Year of discovery: 1783

79

Au

196.97

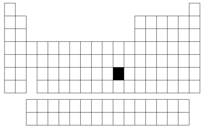
What

Gold is a soft and malleable metal, which means it's often alloyed with other metals (typically silver, copper, palladium or nickel) to make it more structurally sound when used in things like jewellery. It is generally quite unreactive (making it a 'noble metal'), and is a good conductor of heat and electricity. It is one of the densest elements, and unusually for a metal, it is not grey or silver-white in colour, but reddish-yellow.

Where

The chemical inertness of gold means that it can be found naturally as small flakes or large nuggets, often alloyed with silver. There are also significant quantities of gold dissolved in the world's oceans. Jewellery production and investment consume about 90% of the new gold produced each year, but it still finds use in areas such as electronics (a typical cell phone contains about 50mg of gold), dentistry and medicine.

Gold



d-block metal
m.p.: 1064 °C
b.p.: 2836 °C
Density: 19.3 g/cm^3
[Xe] $4f^{14}\ 5d^{10}\ 6s^1$
Atomic radius: 174 pm
Main isotope:
^{197}Au (100%)
Universe: $6.0x10^{-8}$ %
Earth's crust: $3.1x10^{-7}$ %
Human: $1.0x10^{-5}$ %
Year of discovery:
3000BC

82

Pb

207.19

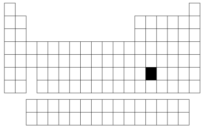
What

Lead is the heaviest non-radioactive element, and is dense, soft and highly malleable. Both its tensile strength and melting point are low relative to other metals. Freshly cut lead is silver in colour, but it then tarnishes to a dull grey (though it is resistant to corrosion). Its atomic symbol comes from the Latin word *Plumbum*, which also gives us 'plumbing'.

Where

Concerns over lead toxicity have meant that its use in many applications which stretch back thousands of years is now often discouraged, including in plumbing, construction, decorative glazes, glass, fishing sinkers and bullets. Tetraethyllead, widely used to improve petrol combustion, was phased out in the early 2000s. Lead, however, is still one of the most effective materials for shielding radiation, and lead-acid batteries continue to be widely used, including in most cars.

Lead



p-block metal
m.p.: 327 °C
b.p.: 1749 °C
Density: 11.34 g/cm^3
[Xe] $4f^{14}$ $5d^{10}$ $6s^2$ $6p^2$
Atomic radius: 154 pm
Main isotopes:
^{204}Pb (1.4%)
^{205}Pb (trace)
^{206}Pb (24.1%)
^{207}Pb (22.1%)
^{208}Pb (52.4%)
^{209}Pb (trace)
^{210}Pb (trace)
^{211}Pb (trace)
^{212}Pb (trace)
^{214}Pb (trace)
Universe: 1.0×10^{-6} %
Earth's crust: 9.9×10^{-4} %
Human: 1.7×10^{-4} %
Year of discovery:
4000BC

83

Bi

208.98

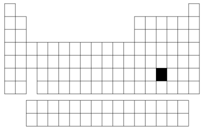
What

Bismuth is a heavy p-block metal that is actually weakly radioactive. The decay of its most common isotope, Bi-209, was only discovered in 2003, and it has a half-life that's a billion times the age of the universe. The element crystallises as highly reflective silver-grey crystals, or as beautiful multi-hued crystals when very thin layers of oxide are allowed to form on the surface (the colour is determined by the layer thickness).

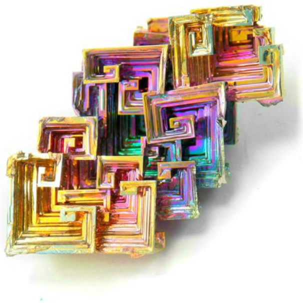
Where

Bismuth forms alloys with a number of other metals which are used for various applications, including as solders, steels, and specialised aluminium alloys. A bismuth compound, bismuth subsalicylate, is the active ingredient in Pepto-Bismol, and is also used (along with bismuth subcitrate) to treat peptic ulcers. The low melting "Wood's metal", an alloy of bismuth and cadmium, is used in automatic fire sprinklers.

Bismuth



p-block metal
m.p.: 271 °C
b.p.: 1564 °C
Density: 9.780 g/cm^3
[Xe] 4f^{14} 5d^{10} 6s^2 6p^3
Atomic radius: 143 pm
Main isotope:
^{209}Bi (100%)
Universe: 7.0x10^{-8} %
Earth's crust: 2.5x10^{-6} %
Human: none
Year of discovery: 1500



Periodic Table

	Group 1 (1A)	Group 2 (2A)	Group 3 (3B)	Group 4 (4B)	Group 5 (5B)	Group 6 (6B)	Group 7 (7B)	Group 8 (8B)	Group 9 (8B)	Group 10 (8B)	Group 11 (1B)	Group 12 (2B)	Group 13 (3A)	Group 14 (4A)	Group 15 (5A)	Group 16 (6A)	Group 17 (7A)	Group 18 (8A)
Period 1	1 **H** 1.01																	2 **He** 4.00
Period 2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
Period 3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
Period 4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.54	30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.91	36 **Kr** 83.80
Period 5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
Period 6	55 **Cs** 132.91	56 **Ba** 137.34	*	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
Period 7	87 **Fr** (223)	88 **Ra** (226)	**	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (278)	110 **Ds** (281)	111 **Rg** (282)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **Mc** (290)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

*	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
**	89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (266)