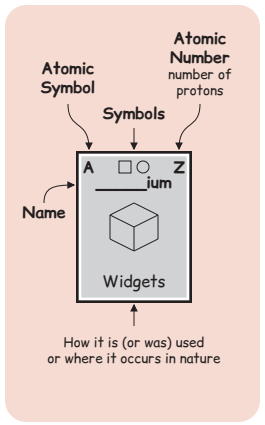
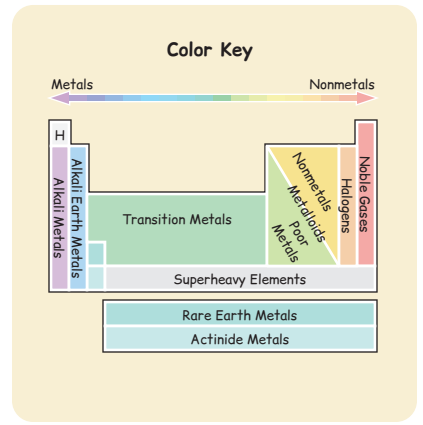


The Periodic Table of the Elements, in Pictures

Periods	Alkali Metals Group 1	Alkali Earth Metals Group 2	Transition Metals										Boron Group 13	Carbon Group 14	Nitrogen Group 15	Oxygen Group 16	Halogens Group 17	Noble Gases Group 18
1	H Hydrogen	He Helium											B Boron	C Carbon	N Nitrogen	O Oxygen	F Fluorine	Ne Neon
2	Li Lithium	Be Beryllium											Al Aluminum	Si Silicon	P Phosphorus	S Sulfur	Cl Chlorine	Ar Argon
3	Na Sodium	Mg Magnesium											Aluminum	Stone, Sand, and Soil	Bones	Eggs	Swimming Pools	Light Bulbs
4	K Potassium	Ca Calcium	Sc Scandium	Ti Titanium	V Vanadium	Cr Chromium	Mn Manganese	Fe Iron	Co Cobalt	Ni Nickel	Cu Copper	Zn Zinc	Ga Gallium	Ge Germanium	As Arsenic	Se Selenium	Br Bromine	Kr Krypton
5	Rb Rubidium	Sr Strontium	Yttrium	Zr Zirconium	Nb Niobium	Mo Molybdenum	Tc Technetium	Ru Ruthenium	Rh Rhodium	Pd Palladium	Ag Silver	Cd Cadmium	In Indium	Sn Tin	Sb Antimony	Te Tellurium	I Iodine	Xe Xenon
6	Cs Cesium	Ba Barium	Rare Earth Metals	Hf Hafnium	Ta Tantalum	W Tungsten	Re Rhenium	Os Osmium	Ir Iridium	Pt Platinum	Au Gold	Hg Mercury	Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium	At Astatine	Rn Radon
7	Fr Francium	Ra Radium	Actinide Metals	Rf Rutherfordium	Db Dubnium	Sg Seaborgium	Bh Bohrium	Hs Hassium	Mt Meitnerium	Ds Darmstadtium	Rg Roentgenium	Cn Copernicium	Nh Nihonium	Fl Flerovium	Mc Moscovium	Lv Livermorium	Ts Tennessine	Og Oganesson
8	Rare Earth Metals		Superheavy Elements															
			radioactive, never found in nature, no uses except atomic research															
	Actinide Metals		radioactive, never found in nature, no uses except atomic research															



- Solid** (square icon)
- Liquid** (teardrop icon)
- Gas** (cloud icon)
- Human Body** (person icon): top ten elements by weight
- Earth's Crust** (globe icon): top eight elements by weight
- Magnetic** (magnet icon): ferromagnetic at room temperature
- Noble Metals** (crown icon): corrosion-resistant
- Radioactive** (radiation icon): all isotopes are radioactive
- Only Traces Found in Nature** (cross icon): less than a millionth percent of earth's crust
- Never Found in Nature** (X icon): only made by people



The Periodic Table of the Elements, in Words

Hydrogen belongs to no definite group. It forms compounds by either donating an electron like an alkali metal or accepting an electron like a halogen.

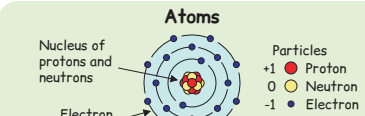
Periods

Group 1

H Hydrogen 1
lightest element; 90% of atoms in the universe, sun and stars, water (H₂O), life's organic molecules

Alkali Metals are very reactive and readily form compounds but are not found free in nature. They form salts and alkali (acid-neutralizing) compounds such as baking soda. In pure form, they are very soft metals which catch fire on contact with water.

Alkali Earth Metals are reactive and readily form compounds but are not found free in nature. Their oxides are called alkali earths. In pure form, they are soft and somewhat brittle metals.



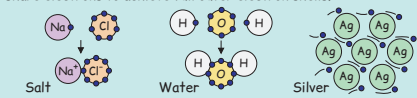
An atom has a nucleus, made of protons and neutrons, surrounded by electrons orbiting in cloud-like shells. Smaller shells are surrounded by larger shells.

The **atomic number** is the number of protons in an atom. This determines the chemical properties of the atom. Protons have positive **electric charge**, neutrons are neutral, and electrons are negative. Normally, an atom has equal numbers of protons and electrons. An **ion** is a charged atom with more or fewer electrons than protons.

The **atomic weight** of an element is the average number of protons plus neutrons. You can easily estimate the atomic weight: it is usually 2 to 2.5 times the atomic number. An **element** is a substance made from one or more atoms of the same atomic number. A **compound** is a substance made from two or more elements chemically bonded.

Chemical Bonding

Atoms form molecules by **bonding** together. Atoms give, take, or share electrons to achieve full outer electron shells.



Ionic bond
One atom takes an electron from another atom and the oppositely charged ions attract.

Covalent bond
Atoms share their outer electrons.

Metallic bond
Shared outer electrons flow, conducting heat and electricity.

Groups

Elements in the same **group**, or column, are similar because they typically have the same number of outer electrons. This table shows some easy-to-remember common numbers for each group.

Group number	1	2	3-12	13	14	15	16	17	18
Outer electrons*	1	2	2	3	4	5	6	7	8
Valence number*	+1	+2	+2	+3	+4, -4	-3	-2	-1	0

* typical
The valence number is the number of electrons given (+) or taken (-) when bonding.

Noble Gases are inactive, or inert. Each atom has exactly the number of electrons it needs to have a full outer shell, so these atoms almost never bond with other atoms. That is why these are all gases.

18

He Helium 2
inert gas, second lightest element; nuclear fusion in sun and stars, balloons, lasers, supercold refrigerant

Ne Neon 10
inert gas; orange-red neon tubes for advertising signs, lasers, supercold refrigerant

Ar Argon 18
inert gas; 1% of air, most abundant inert gas, light bulbs, "neon" tubes, lasers, welding gas

Krypton 36
inert gas; high-intensity lamps, headlights, flashlights, lanterns, "neon" tubes, lasers

Xenon 54
inert gas; high-intensity lamps, headlights, stadium lamps, projectors, strobes, lasers, spacecraft ion engines

Rn Radon 86
radioactive gas; short-lived; environmental hazard, surgical implants for cancer treatment

Li Lithium 3
lightest metal; soft, reactive; lightweight aluminum alloys, batteries, impact-resistant ceramic cookware, mood stabilizer

Be Beryllium 4
lightweight metal; non-sparking copper alloy tools, aerospace, X-ray windows, beryl gems; emeralds and aquamarines

Na Sodium 11
soft metal, reactive; salt (NaCl), nerves, baking soda, antacids, lye, soap, soda ash, glass, papermaking, street lamps

Mg Magnesium 12
lightweight metal; chlorophyll in green plants, talc, basalt, aluminum alloys, cars, planes, bikes, flares, sparklers, antacids

K Potassium 19
soft metal, reactive; salts, nerves, nutrients in fruits and vegetables, soap, fertilizer, potash, matches, gunpowder

Ca Calcium 20
soft metal; bones, teeth, milk, leaves, vegetables, shells, coral, limestone, chalk, gypsum, plaster, mortar, cement, marble, antacids

Sc Scandium 21
soft lightweight metal; aluminum alloys, racing bikes, stadium lamps, furnace bricks, aquamarines

Ti Titanium 22
strongest lightweight metal; heat-resistant; aerospace, racing bikes, artificial joints, white paint, blue sapphires

V Vanadium 23
hard metal; hard strong resilient steel, structures, vehicles, springs, driveshafts, tools, aerospace, violet sapphires

Cr Chromium 24
hard shiny metal; stainless steel (Fe-Cr-Ni), kitchenware, nichrome heaters, car trim, paints, recording tape, emeralds & rubies

Mn Manganese 25
hard metal; hard tough steel, rock crushers, rail, spools, axes, batteries, fertilizer, amethysts

Fe Iron 26
medium-hard metal; magnetic; steel alloys are mostly iron, structures, vehicles, magnets, Earth's core, red rocks, blood

Co Cobalt 27
hard metal, magnetic; hard strong steel, cutting tools, turbines, magnets (Al-Ni-Co), blue glass, ceramics, vitamin B-12

Ni Nickel 28
medium-hard metal; magnetic; stainless steel (Fe-Cr-Ni), kitchenware, nichrome heaters, nickel batteries, coins, Earth's core

Cu Copper 29
colored metal, conducts heat and electricity well; wires, cookware, brass (Cu-Zn), bronze (Cu-Sn), coins, pipes, blue crab blood

Zn Zinc 30
non-corroding metal; galvanized steel, brass (Cu-Zn), batteries, white paint, phosphors in TVs and lamps, fertilizer

Ga Gallium 31
soft metal, melts on a hot day; semiconductors, light-emitting diodes (LEDs) (GaAs), signal lights, fry lasers

Ge Germanium 32
brittle metalloid; semiconductors, transistors, rectifiers, diodes, lenses, infrared windows

As Arsenic 33
brittle metalloid; poisons, semiconductors, light-emitting diodes (LEDs) (GaAs), signal lights, finy lasers

Se Selenium 34
brittle gray solid; photocopyers, laser printers, photo cells, red glass, dandruff shampoo, rubber

Rb Rubidium 37
soft metal, reactive; atomic clocks, global navigation (GPS), vacuum tube scavenger

Sr Strontium 38
soft metal; red fireworks, flares, phosphors, nuclear batteries, medical diagnostic tracer, nuclear fallout

Y Yttrium 39
soft metal; phosphors in color TVs, lasers (YAG, YLF), furnace bricks, high-temperature superconductors

Zr Zirconium 40
non-corroding neutron-resistant metal; chemical pipelines, nuclear reactors, furnace bricks, abrasives, zircon gems

Nb Niobium 41
high-melting-point non-corroding metal; chemical pipelines, superconductors, magnetic levitation trains, MRI magnets

Mo Molybdenum 42
high-melting-point metal; hard steel, cutting tools, drill bits, armor plate, gun barrels, fertilizer

Tc Technetium 43
radioactive, long-lived; first human-made element, only traces on Earth, medical diagnostic tracer

Ru Ruthenium 44
non-corroding hard metal; electric contacts, leaf switches, pen tips, hydrogen production

Rh Rhodium 45
non-corroding hard shiny metal; labware, reflectors, electric contacts, thermocouples, catalyst, pollution control

Pd Palladium 46
non-corroding hard metal; absorbs hydrogen; labware, electric contacts, dentistry, catalyst, pollution control

Ag Silver 47
soft shiny metal, conducts electricity best of all elements; jewelry, silverware, coins, dentistry, photo film

Cd Cadmium 48
non-corroding soft metal, toxic; electroplated steel, nickel batteries, red and yellow paints, fire sprinklers

In Indium 49
soft metal; solders, glass seals, glass coatings, liquid crystals (LCDs), semiconductors, diodes, photocells

Sn Tin 50
non-corroding soft metal; solders, plated food cans, bronze (Cu-Sn), pewter cups, glassmaking, fire sprinklers

Pb Lead 82
dense, soft, non-corroding metal, toxic; weights, solders, batteries, bullets, crystal glass, old plumbing, radiation shield

Bi Bismuth 83
low-melting-point brittle metal; solders, fuses, fire sprinklers (plugs melt when hot), cosmetics pigment

Cs Cesium 55
soft metal, melts on a hot day, reactive, largest stable atoms; atomic clocks, global navigation (GPS), vacuum tube scavenger

Ba Barium 56
soft metal, absorbs X-rays; stomach X-ray contrast enhancer, green fireworks, whitener and filler for paper, plastic, and rubber

89 - 103
Rare Earth Metals

Hf Hafnium 72
non-corroding metal; absorbs neutrons; nuclear reactor control rods in submarines, plasma torch electrodes

Ta Tantalum 73
high-melting-point non-corroding metal; labware, surgical tools, artificial joints, capacitors, mobile phones

W Tungsten 74
highest-melting-point metal, dense; filaments in lamps and TVs, cutting tools, abrasives, thermocouples

Re Rhenium 75
high-melting-point dense metal; rocket engines, heater coils, lab filaments, electric contacts, thermocouples, catalyst

Os Osmium 76
non-corroding high-melting-point hard metal; densest element (same as iridium); electric contacts, pen tips, needles, spark plugs, fingerprint powder

Ir Iridium 77
non-corroding hard metal, densest element (same as osmium); labware, spark plugs, pen tips, needles

Pt Platinum 78
non-corroding dense metal; labware, spark plugs, catalyst, pollution control, petroleum cracking, processing fats

Au Gold 79
most malleable element, dense non-tarnishing colored metal; jewelry, coins, ultra-thin gold leaf, electric contacts

Hg Mercury 80
liquid metal, toxic; thermometers, barometers, thermostats, street lamps, fluorescent lamps, dentistry

Tl Thallium 81
soft metal, toxic; low-melting-point mercury alloys, low-temperature thermometers, undersea lamps, photocells

Pb Lead 82
dense, soft, non-corroding metal, toxic; weights, solders, batteries, bullets, crystal glass, old plumbing, radiation shield

Bi Bismuth 83
low-melting-point brittle metal; solders, fuses, fire sprinklers (plugs melt when hot), cosmetics pigment

Po Polonium 84
radioactive, long-lived; first radioactive element found, small traces in nature, cancer medicine

Fr Francium 87
radioactive, short-lived; atoms larger than cesium; small traces in nature, studied in laser atom traps

Ra Radium 88
radioactive, long-lived; luminous watches (now banned), medical radon production, radiography, radwaste

89 - 103
Actinide Metals

Rf Rutherfordium 104

Db Dubnium 105

Sg Seaborgium 106

Bh Bohrium 107

Hs Hassium 108

Mt Meitnerium 109

Ds Darmstadtium 110

Rg Roentgenium 111

Cn Copernicium 112

Nh Nihonium 113

Fl Flerovium 114

Mc Moscovium 115

Lv Livermorium 116

Ts Tennessine 117

Og Oganesson 118

Superheavy Elements

radioactive, short-lived; never found in nature, no uses except atomic research

Rare Earth Metals are all soft metals. They are chemically similar to scandium and yttrium and are difficult to separate from each other.

Actinide Metals are all radioactive heavy metals. They are used mainly for their radioactive properties.

Radioactivity. Atoms with the same number of protons but different numbers of neutrons are called isotopes. Some isotopes are stable; others are radioactive — their nuclei eventually disintegrate. The radioactive half-life is the time for half the nuclei to disintegrate. On this chart, an element is called long-lived if the half-life of any of its isotopes is more than one year; otherwise it is called short-lived.

La Lanthanum 57 soft metal; optical glass, telescope eyepieces, camera lenses, laser flint, arc lamps	Ce Cerium 58 soft metal; most abundant rare earth metal, lighter flints, gas lamp mantles, self-cleaning ovens, glass polishing	Pr Praseodymium 59 soft metal; torchworkers' didymium eye-glasses (Pr-Nd), arc lamps, magnets, yellow glass	Nd Neodymium 60 soft metal; strong magnets (Nd-Fe-B), electric motors, speakers and headphones, lasers, lighter flints	Pm Promethium 61 radioactive, long-lived; human-made, small traces in nature, luminous dials, sheet thickness gauges	Sm Samarium 62 soft metal; magnets (Sm-Co), electric motors, speakers and headphones, infrared sensors, infrared-absorbing glass	Eu Europium 63 soft metal; phosphors in color TVs and trichromatic lamps, luminous paint, lasers	Gd Gadolinium 64 soft metal, best neutron absorber, magnetic resonance imaging (MRI) contrast enhancer, phosphors, neutron radiography	Tb Terbium 65 soft metal; phosphors in color TVs and computer disks, MRI phosphors, magnetostrictive smart materials (Terfenol-D®)	Dy Dysprosium 66 soft metal; nuclear control rods, MRI phosphors, magnetostrictive smart materials (Terfenol-D®)	Ho Holmium 67 soft metal; infrared lasers, laser surgery, eye-safe laser rangefinders, computer disks, yellow glass filters	Er Erbium 68 soft metal; fiber optic signal amplifiers, infrared lasers, laser surgery, pink glass, sunglasses, vanadium alloys	Tm Thulium 69 soft metal; rare earth metal, infrared lasers, laser surgery, phosphors	Yb Ytterbium 70 soft metal; fiber optic signal amplifiers, fiber lasers, stainless steel alloys	Lu Lutetium 71 soft metal, densest and hardest rare earth metal; cancer-fighting photodynamic (light-activated) medicine
Ac Actinium 89 radioactive, long-lived; small traces in nature, cancer medicine, neutron source, radwaste	Th Thorium 90 radioactive, long-lived; most abundant radioactive element, nuclear reactor fuel, gas lamp mantles, tungsten filaments	Pa Protactinium 91 radioactive, long-lived; small traces in nature, no uses, radwaste	U Uranium 92 radioactive, long-lived, dense; nuclear reactor fuel, nuclear weapons, counterweights, armor piercing bullets	Np Neptunium 93 radioactive, long-lived; small traces in nature, neutron detectors, dosimeters, nuclear weapons, radwaste	Pu Plutonium 94 radioactive, long-lived; small traces in nature, nuclear reactor fuel, spacecraft power, nuclear weapons	Am Americium 95 radioactive, long-lived; never found in nature, smoke detectors, sheet thickness gauges, radwaste	Cm Curium 96 radioactive, long-lived; never found in nature, scientific instruments, mineral analyzers, radwaste	Bk Berkelium 97 radioactive, long-lived; never found in nature, no uses, radwaste	Cf Californium 98 radioactive, long-lived; never found in nature, scientific instruments, mineral analyzers, radwaste	Es Einsteinium 99	Fm Fermium 100	Md Mendelevium 101	No Nobelium 102	Lr Lawrencium 103

radioactive, short-lived; never found in nature, no uses except atomic research