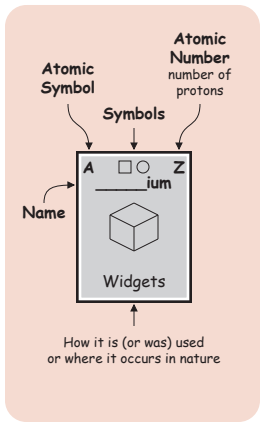
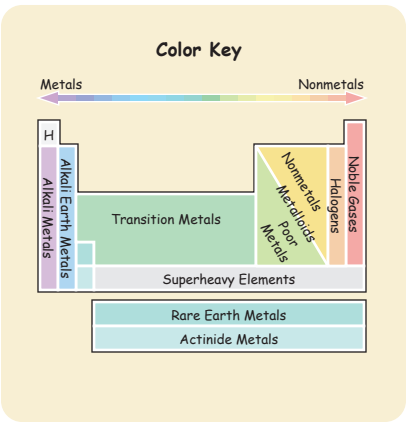


The Periodic Table of the Elements, in Pictures

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 Sun and Stars	He Helium Balloons											B Boron Sports Equipment	C Carbon Basis of Life's Molecules	N Nitrogen Protein	O Oxygen Air	F Fluorine Toothpaste	Ne Neon Advertising Signs												
2	Li Lithium Batteries	Be Beryllium Emeralds											Al Aluminum Airplanes	Si Silicon Stone, Sand, and Soil	P Phosphorus Bones	S Sulfur Egg Yolks	Cl Chlorine Swimming Pools	Ar Argon Light Bulbs												
3	Na Sodium Salt	Mg Magnesium Chlorophyll											K Potassium Fruits and Vegetables	Ca Calcium Shells and Bones	Sc Scandium Bicycles	Ti Titanium Aerospace	V Vanadium Springs	Cr Chromium Stainless Steel	Mn Manganese Earthmovers	Fe Iron Steel Structures	Co Cobalt Magnets	Ni Nickel Coins	Cu Copper Electric Wires	Zn Zinc Brass Instruments	Ga Gallium Light-Emitting Diodes (LEDs)	Ge Germanium Semiconductor Electronics	As Arsenic Poison	Se Selenium Copiers	Br Bromine Photography Film	Kr Krypton Flashlights
4	Rb Rubidium Global Navigation	Sr Strontium Fireworks	Y Yttrium Lasers	Zr Zirconium Chemical Pipelines	Nb Niobium Mag Lev Trains	Mo Molybdenum Cutting Tools	Tc Technetium Radioactive Diagnosis	Ru Ruthenium Electric Switches	Rh Rhodium Searchlight Reflectors	Pd Palladium Pollution Control	Ag Silver Jewelry	Cd Cadmium Paint	In Indium Liquid Crystal Displays (LCDs)	Sn Tin Plated Food Cans	Sb Antimony Car Batteries	Te Tellurium Thermoelectric Coolers	I Iodine Disinfectant	Xe Xenon High-Intensity Lamps												
5	Cs Cesium Atomic Clocks	Ba Barium X-Ray Diagnosis	Rare Earth Metals		Hf Hafnium Nuclear Submarines	Ta Tantalum Mobile Phones	W Tungsten Lamp Filaments	Re Rhenium Rocket Engines	Os Osmium Pen Points	Ir Iridium Spark Plugs	Pt Platinum Labware	Au Gold Jewelry	Hg Mercury Thermometers	Tl Thallium Low-Temperature Thermometers	Pb Lead Weights	Bi Bismuth Fire Sprinklers	Po Polonium Anti-Static Brushes	At Astatine Radioactive Medicine	Rn Radon Surgical Implants											
6	Fr Francium Laser Atom Traps	Ra Radium Luminous Watches	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											
7	Superheavy Elements radioactive, never found in nature, no uses except atomic research																													
8	Rare Earth Metals		La Lanthanum Telescope Lenses	Ce Cerium Lighter Flints	Pr Praseodymium Torchworkers' Eyeglasses	Nd Neodymium Electric Motor Magnets	Pm Promethium Luminous Dials	Sm Samarium Electric Motor Magnets	Eu Europium Color Televisions	Gd Gadolinium MRI Diagnosis	Tb Terbium Fluorescent Lamps	Dy Dysprosium Smart Material Actuators	Ho Holmium Laser Surgery	Er Erbium Optical Fiber Communications	Tm Thulium Laser Surgery	Yb Ytterbium Scientific Fiber Lasers	Lu Lutetium Photodynamic Medicine	Actinide Metals												
9	Actinide Metals		Ac Actinium Radioactive Medicine	Th Thorium Gas Lamp Mantles	Pa Protactinium Radioactive Waste	U Uranium Nuclear Power	Np Neptunium Radioactive Waste	Pu Plutonium Nuclear Weapons	Am Americium Smoke Detectors	Cm Curium Mineral Analyzers	Bk Berkelium Radioactive Waste	Cf Californium Mineral Analyzers	Es Einsteinium	Fm Fermium	Md Mendeleevium	No Nobelium	Lr Lawrencium	radioactive, never found in nature, no uses except atomic research												



- Solid** (square icon)
 - Liquid** (teardrop icon)
 - Gas** (cloud icon)
 - Human Body** (stick figure icon)
 - Earth's Crust** (globe icon)
 - Magnetic** (magnet icon)
 - Noble Metals** (crown icon)
 - Radioactive** (radiation icon)
 - Only Traces Found in Nature** (lightning bolt icon)
 - Never Found in Nature** (X icon)
- The color of the symbol is the color of the element in its most common pure form.
- Examples: ■ metallic solid, ● red liquid, ☁ colorless gas



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

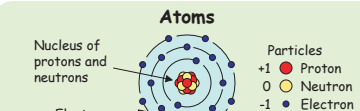
Group 1

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

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.

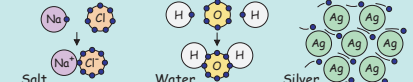
The **atomic number** is the number of protons in an atom. This determines the chemical properties of the atom. Protons have positive **electric charge**, neutrons are neutral, and electrons are negative. Normally, an atom has equal numbers of protons and electrons. An **ion** is a charged atom with 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	3	4	5	6	7	8	0
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.

Transition Metals are typical metals: they are strong, shiny, malleable (they can be hammered into shape), flexible (in thin sheets or wires), and they conduct both heat and electricity.

Poor Metals are usually soft and have low melting temperatures.

Metalloids are partly like metals and partly like nonmetals. For example, they are semiconductors, which means they conduct electricity in some conditions.

Nonmetals, in their solid state, are usually brittle (they break rather than bend) and they are insulators of both heat and electricity.

Halogens are reactive nonmetals and readily form compounds but are not found free in nature. They combine with alkali metals to form salts (halogen means salt-former).

18

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

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, eye 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, tools, 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	Ni Nickel 28 medium-hard metal, magnetic; stainless steel (Fe-Cr-Ni), kitchenware, nichrome heaters, car 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, tiny lasers	Ge Germanium 32 brittle metalloid; semiconductors, transistors, rectifiers, diodes, photocells, lenses, infrared windows	As Arsenic 33 brittle metalloid; poisons, semiconductors, light-emitting diodes (LEDs) (GaAs), signal lights, tiny lasers	Se Selenium 34 brittle gray solid; photocopyers, laser printers, photo cells, rubber, dandruff shampoo	Br Bromine 35 dark red liquid; disinfectant, pools and spas, photo film, flame retardant, leaded gasoline, sedatives	Kr Krypton 36 inert gas; high-intensity lamps, headlights, flashlights, lanterns, "neon" tubes, lasers
Rb Rubidium 37 soft metal, reactive; atomic clocks, global navigation (GPS), vacuum tube scavenger	Sr Strontium 38 soft metal; red fireworks, flares, phosphors, nuclear 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; hard steel, cutting tools, drill bits, armor plate, gun barrels, fertilizer	Mo Molybdenum 42 high-melting-point metal; hard steel, cutting tools, armor plate, gun barrels, fertilizer	Tc Technetium 43 radioactive, long-lived; first human-made element, only traces on Earth, but found in stars, medical diagnostic tracer	Ru Ruthenium 44 non-corroding hard metal; electric contacts, leaf switches, thermocouples, catalyst	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, nicad batteries, lead and yellow paints, fire sprinklers	In Indium 49 soft metal; solders, glass seals, glass coatings, liquid crystal displays (LCDs), semiconductors, diodes, photocells	Sn Tin 50 non-corroding soft metal; solders, plated food cans, bronze (Cu-Sn), pewter cups, glassmaking, fire sprinklers	Sb Antimony 51 brittle metalloid; solders, lead hardener, batteries, bullets, semiconductors, photocells, matches, flame retardant	Te Tellurium 52 brittle metalloid; alloys, semiconductors, computer disks, thermo-electric coolers and generators	I Iodine 53 violet-black solid; disinfectant for wounds and drinking water, added to salt to prevent thyroid disease, photo film	Xe Xenon 54 inert gas; high-intensity lamps, headlights, stadium lamps, projectors, strobes, lasers, spacecraft ion engines				
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	71-87 Rare Earth Metals	Hf Hafnium 72 non-corroding metal, absorbs neutrons; nuclear reactor control rods in submarines, plasma torch electrodes	Ta Tantalum 73 highest-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, 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 dense element (same as iridium); electric contacts, pen tips, needles, 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 in nature, small traces in nature, anti-static brushes, tobacco	At Astatine 85 radioactive, short-lived; small traces in nature, cancer medicine	Rn Radon 86 radioactive gas, short-lived; environmental hazard, surgical implants for cancer treatment				
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.