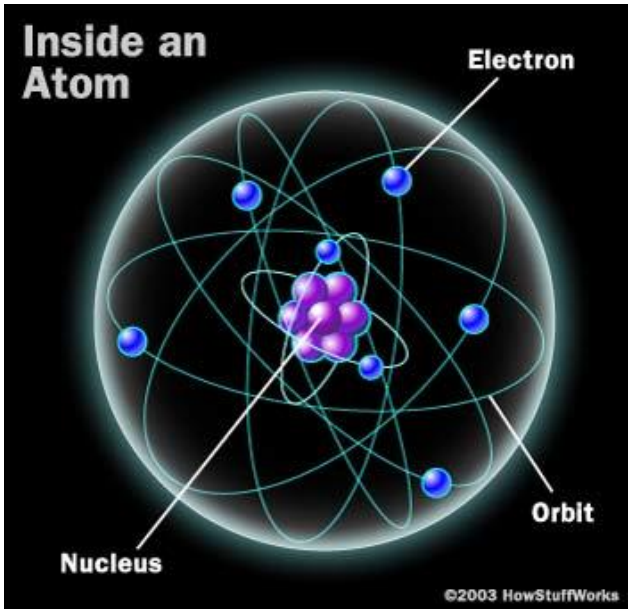
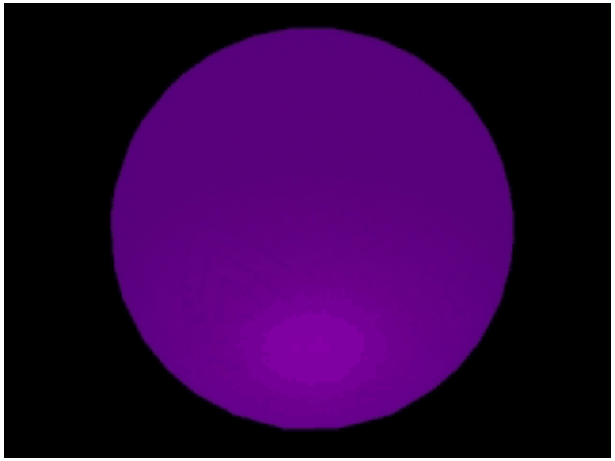
Properties of Atoms and the Periodic Table



Chapter 16 and 17

Atomic Components

- Matter – anything that has mass and takes up space
- An element is matter that is composed of one type of **atom**, which is the smallest piece of matter that still retains the property of the element.



Scientific Shorthand

- Elements are abbreviated in scientific shorthand
  - Chemical symbols consist of one capital letter or a capital letter plus one or two smaller letters.
  - Comes from elements name, sometimes in Latin or Greek. Ex: Silver (Ag = Argentium (German)
  - 1st letter is capital; 2nd letter is lower cased

Symbols of Some Elements

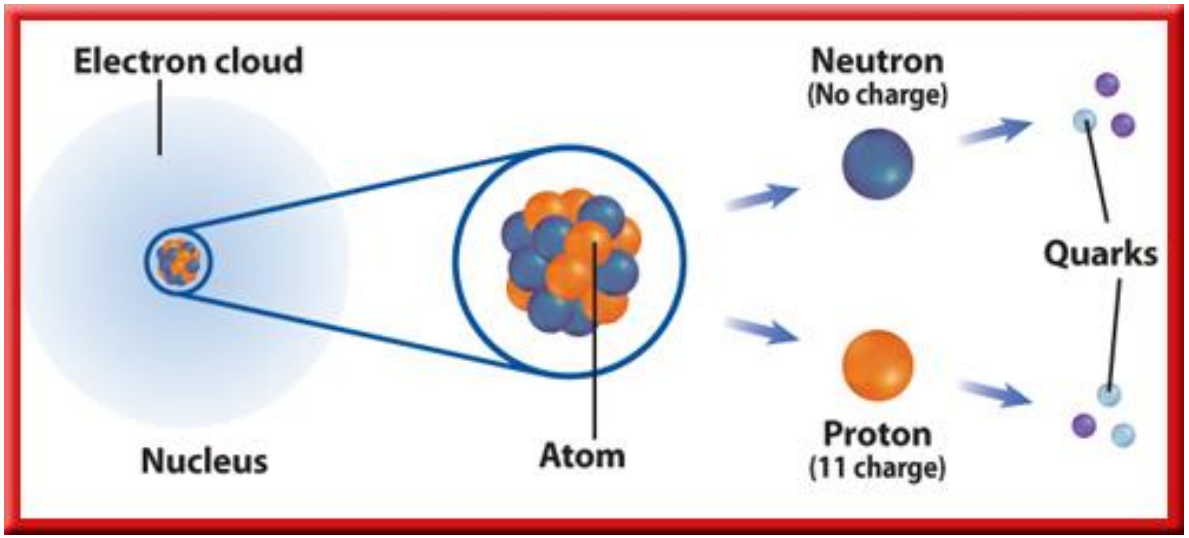
Element	Symbol	Element	Symbol
Aluminum	Al	Iron	Fe
Calcium	Ca	Mercury	Hg
Carbon	C	Nitrogen	N
Chlorine	Cl	Oxygen	O
Gold	Au	Potassium	K
Hydrogen	H	Sodium	Na

ATOMS

- Atoms are composed of particles called protons, neutrons, and electrons.
- Proton (+) and Neutrons (0) are in the nucleus
- Electrons (-) are in the electron cloud

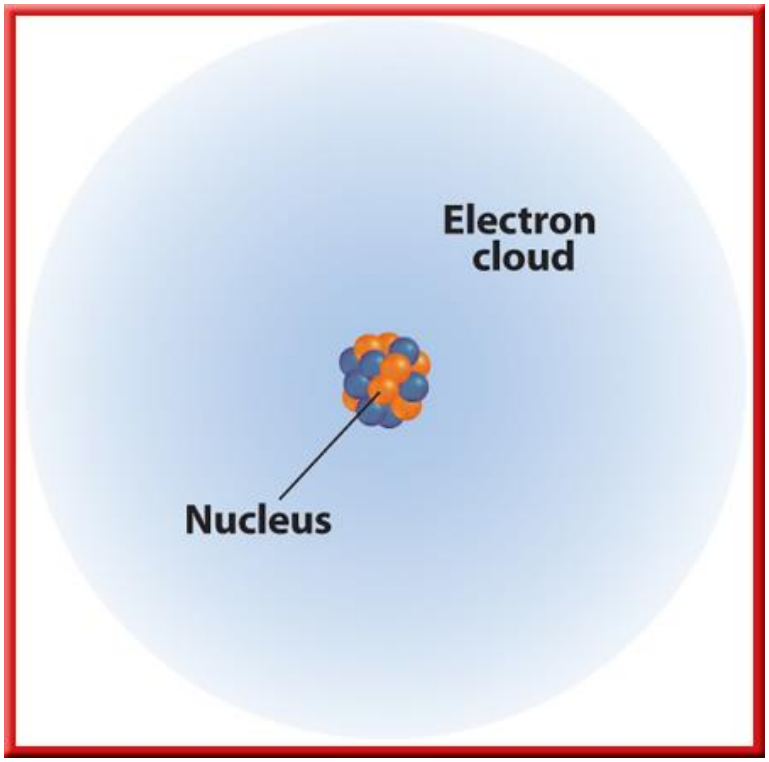
Atomic Components

- Protons and neutrons are found in a small positively charged center of the atom called the **nucleus** that is surrounded by a cloud containing electrons.



The Electron Cloud Model

- An **electron cloud** is the area around the nucleus of an atom where its electrons are most likely found.



Atomic Mass

- The nucleus contains most of the mass of the atom because protons and neutrons are far more massive than electrons.
- The mass of a proton is about the same as that of a neutron—approximately

Subatomic Particle Masses	
Particle	**Mass (g)**
Proton	1.6726×10^{-24}
Neutron	1.6749×10^{-24}
Electron	9.1093×10^{-28}

Masses of Atoms

Protons Identify the Element

- Atomic Number = #of protons in an atom
- The sum of the number of protons and neutrons in the nucleus of an atom is the mass number

Mass Number

- The average atomic **mass number** of an atom is the sum of the number of protons and the number of neutrons in the nucleus of an atom.

Mass Numbers of Some Atoms

Element	Symbol	Atomic Number	Protons	Neutrons	Mass Number	Average Atomic Mass*
Boron	B	5	5	6	11	10.81 amu
Carbon	C	6	6	6	12	12.01 amu
Oxygen	O	8	8	8	16	16.00 amu
Sodium	Na	11	11	12	23	22.99 amu
Copper	Cu	29	29	34	63	63.55 amu

*The atomic mass units are rounded to two decimal places.

Average Atomic Mass Number

- If you know the mass number and the atomic number of an atom, you can calculate the number of neutrons.

number of neutrons = atomic mass number – atomic number

Mass Numbers of Some Atoms

Element	Symbol	Atomic Number	Protons	Neutrons	Mass Number	Average Atomic Mass*
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*The atomic mass units are rounded to two decimal places.

Isotopes

- Not all the atoms of an element have the same number of neutrons.
- Atoms of the same element that have different numbers of neutrons are called **isotopes**.
- 1) Different isotopes have different properties
- 2) name of element followed by the mass # identifies the isotope
- EX: Boron -10 or Boron -11

Identifying Isotopes

- The **average atomic mass** of an element is the weighted-average mass of the mixture of its isotopes.
- For example, four out of five atoms of boron are boron-11, and one out of five is boron-10.
- The average atomic mass is closest to its most abundant isotope

Organizing the Elements

- *Periodic* means "repeated in a pattern."
- In the late 1800s, Dmitri Mendeleev, a Russian chemist, searched for a way to organize the elements.
- When he arranged all the elements known at that time in order of increasing atomic masses, he discovered a pattern. There were blank spaces for missing elements that had not yet been discovered

Improving the Periodic Table

- In 1913, the work of Henry G.J. Moseley, a young English scientist, led to the arrangement of elements based on their increasing atomic numbers instead of an arrangement based on atomic masses.

- The current periodic table uses Moseley's arrangement of the elements.

Organizing the Elements

- The **periodic table of elements** is arranged by increasing atomic number and by changes in physical and chemical properties.

Organizing the Elements

- Groups/Families: The vertical columns in the periodic table: numbered 1 through 18.
- Elements in each group have similar properties.
- Have the same # of electrons in their outer energy level – this determines the chemical properties of the elements.
- Periods/Rows – the horizontal rows that contain increasing # of protons and electrons as you move left to right.

Periodic Table of the Elements

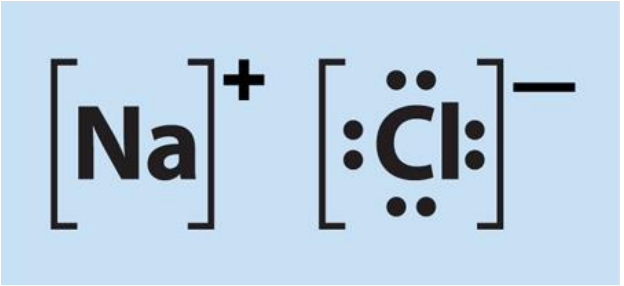
1																	18
1 H Hydrogen 1.008	2											13	14	15	16	17	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3	4	5	6	7	8	9	10	11	12	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetal | Nonmetal | Halogen | Noble Gas | Lanthanide | Actinide

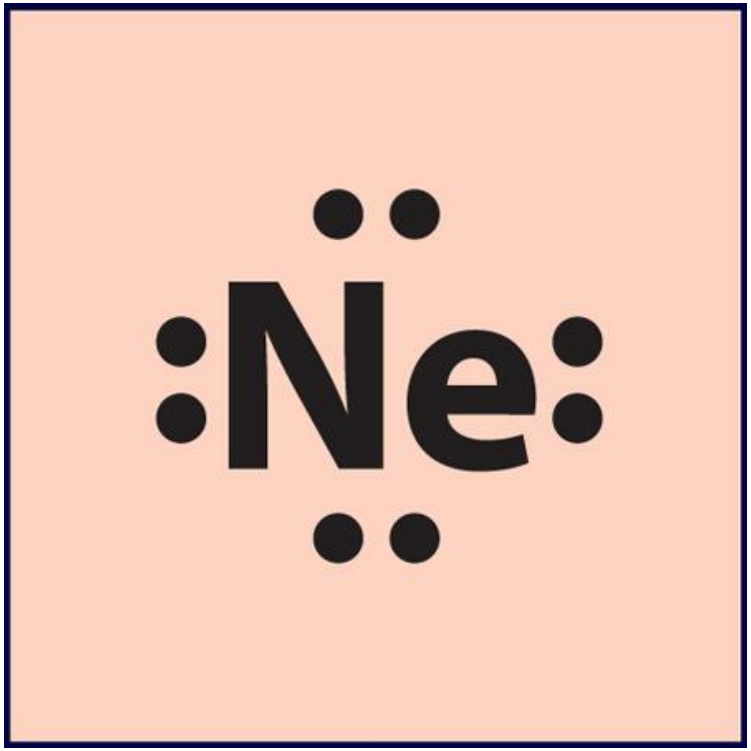
Same Group—Similar Properties

- All halogens have seven electrons in their outer energy levels.
- A common property of the halogens is the ability to form compounds readily with elements in Group 1.
- The Group 1 element, sodium, reacts easily with the Group 17 element, chlorine.
- The result is the compound sodium chloride, or NaCl—ordinary table salt.



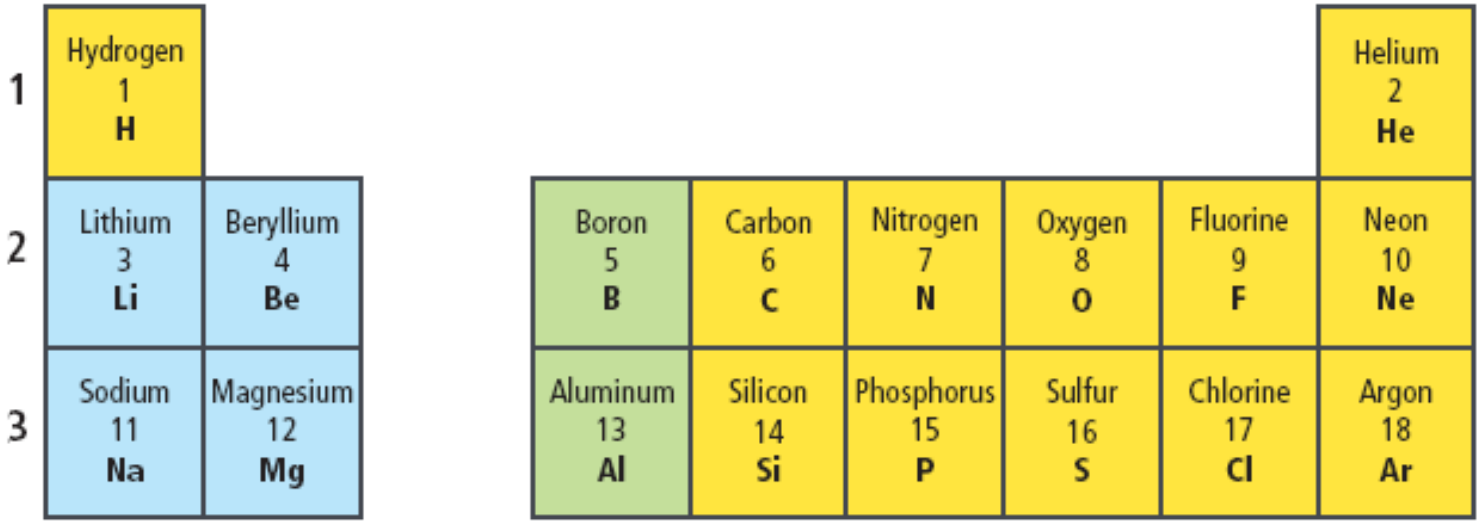
Same Group—Similar Properties

- Not all elements will combine readily with other elements.
- The elements in Group 18 have complete outer energy levels.
- This special configuration makes Group 18 elements relatively unreactive.



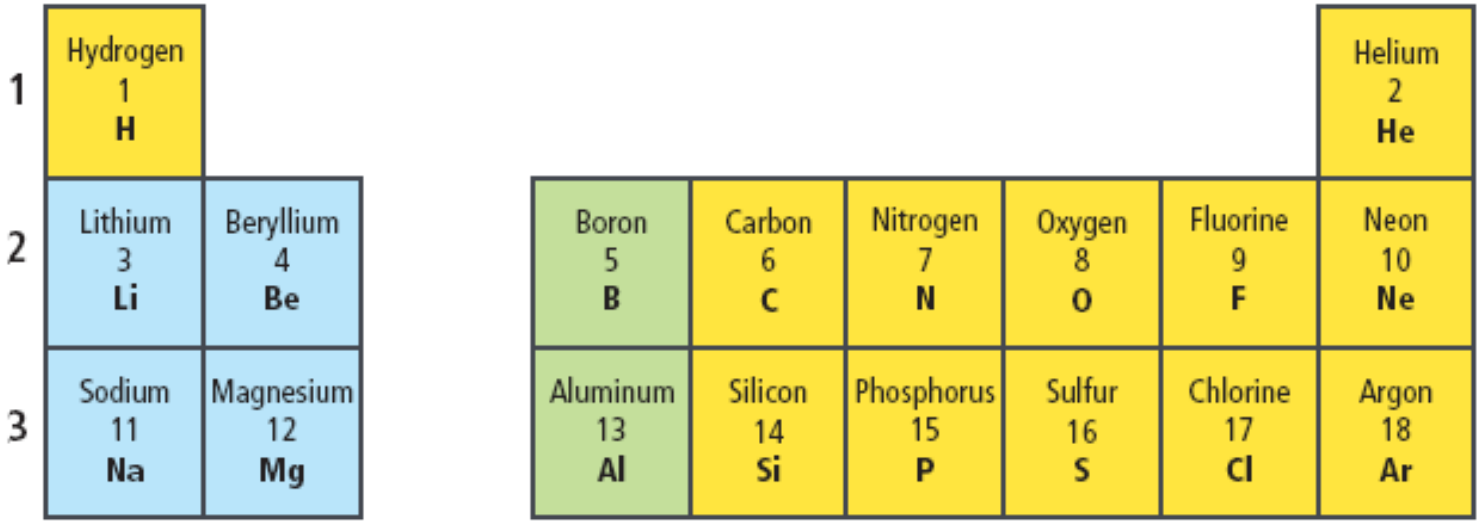
Rows on the periodic table

- Remember that the atomic number found on the periodic table is equal to the number of electrons in an atom.
- The first row has hydrogen with one electron and helium with two electrons both in energy level one.
- Energy level one can hold only two electrons. Therefore, helium has a full or complete outer energy level.



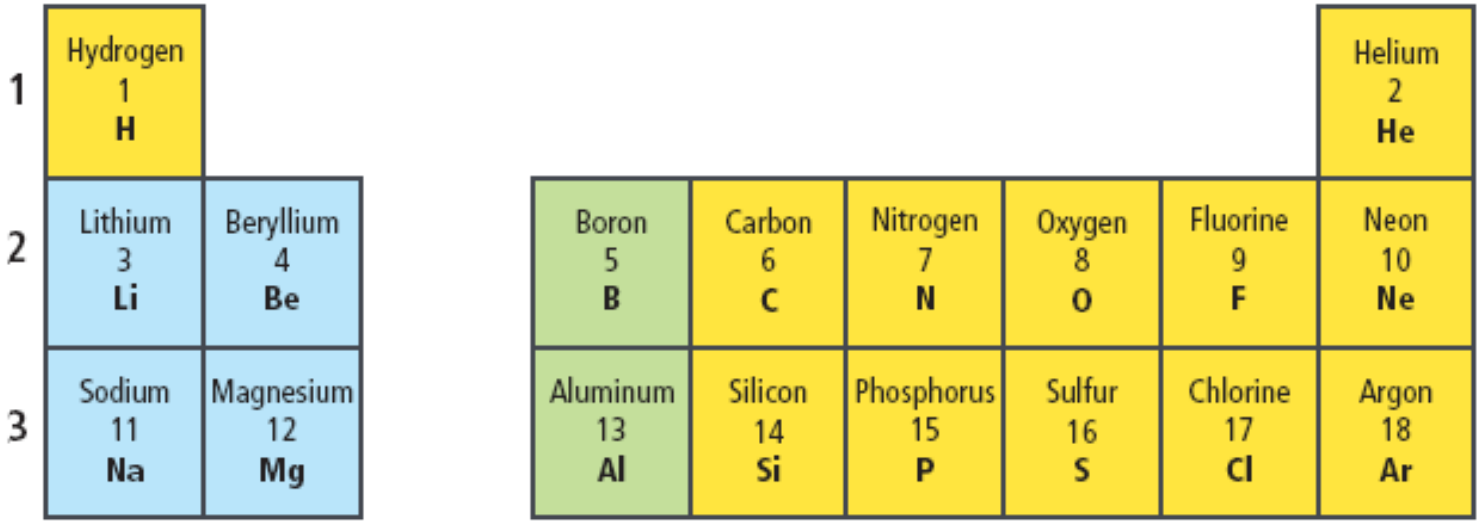
Rows on the periodic table

- The second row begins with lithium, which has three electrons—two in energy level one and one in energy level two.
- Lithium is followed by beryllium with two outer electrons, boron with three, and so on until you reach neon with eight outer electrons.



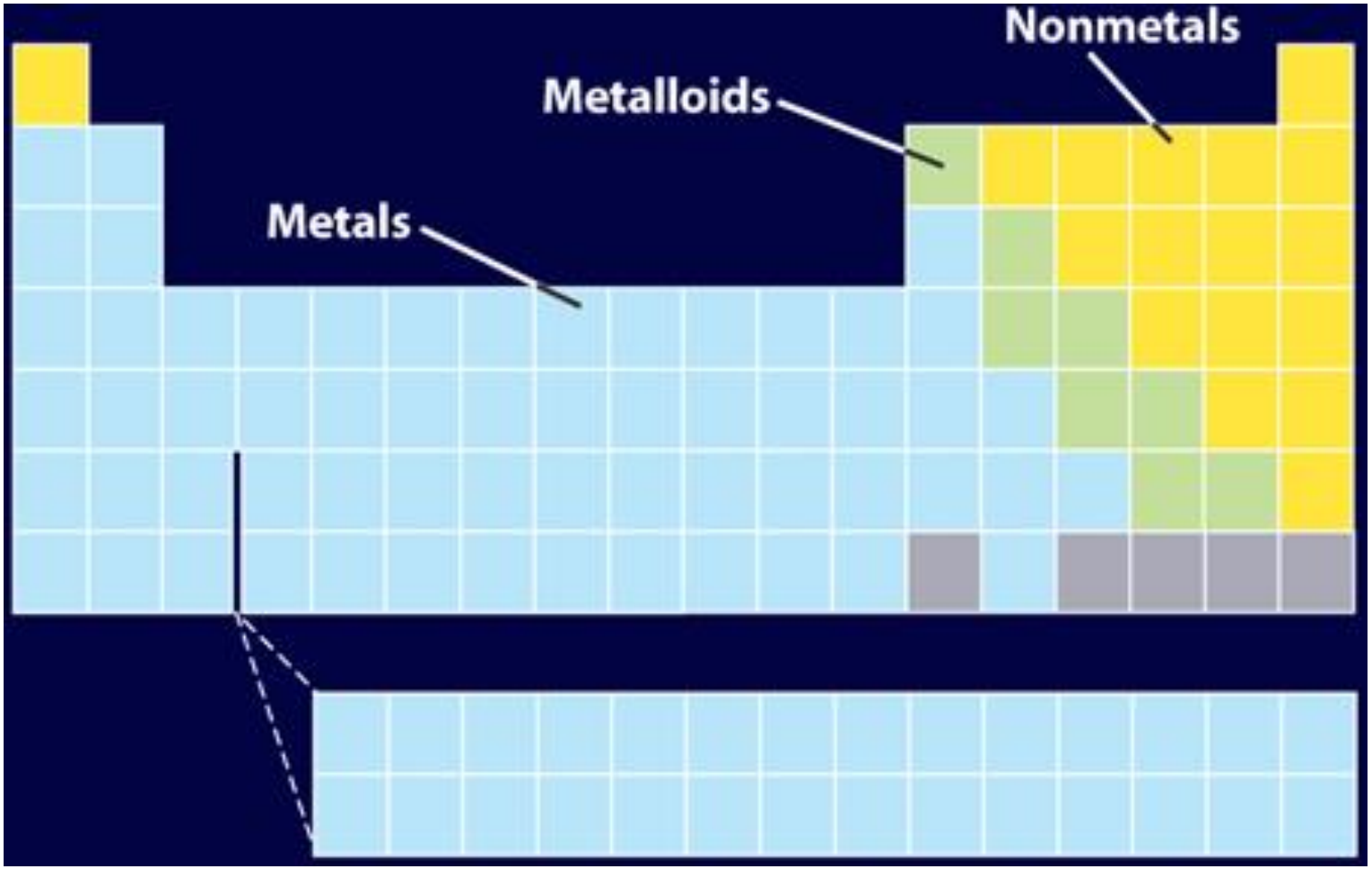
Rows on the periodic table

- Do you notice how the row in the periodic table ends when an outer level is filled?
- In the third row of elements, the electrons begin filling energy level three.
- The row ends with argon, which has a full outer energy level of eight electrons.



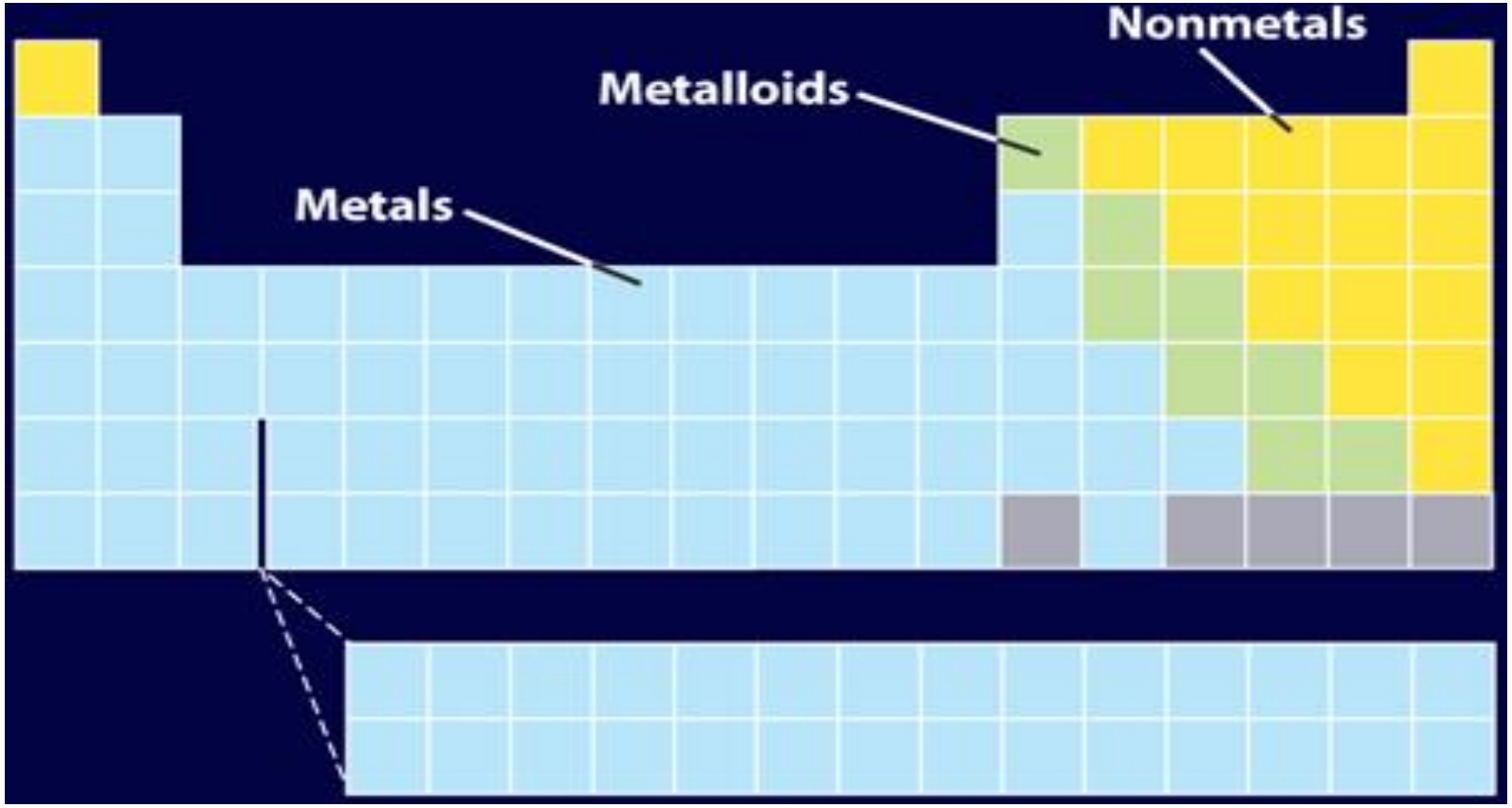
Regions on the Periodic Table

- All of the elements in the blue squares are metals.



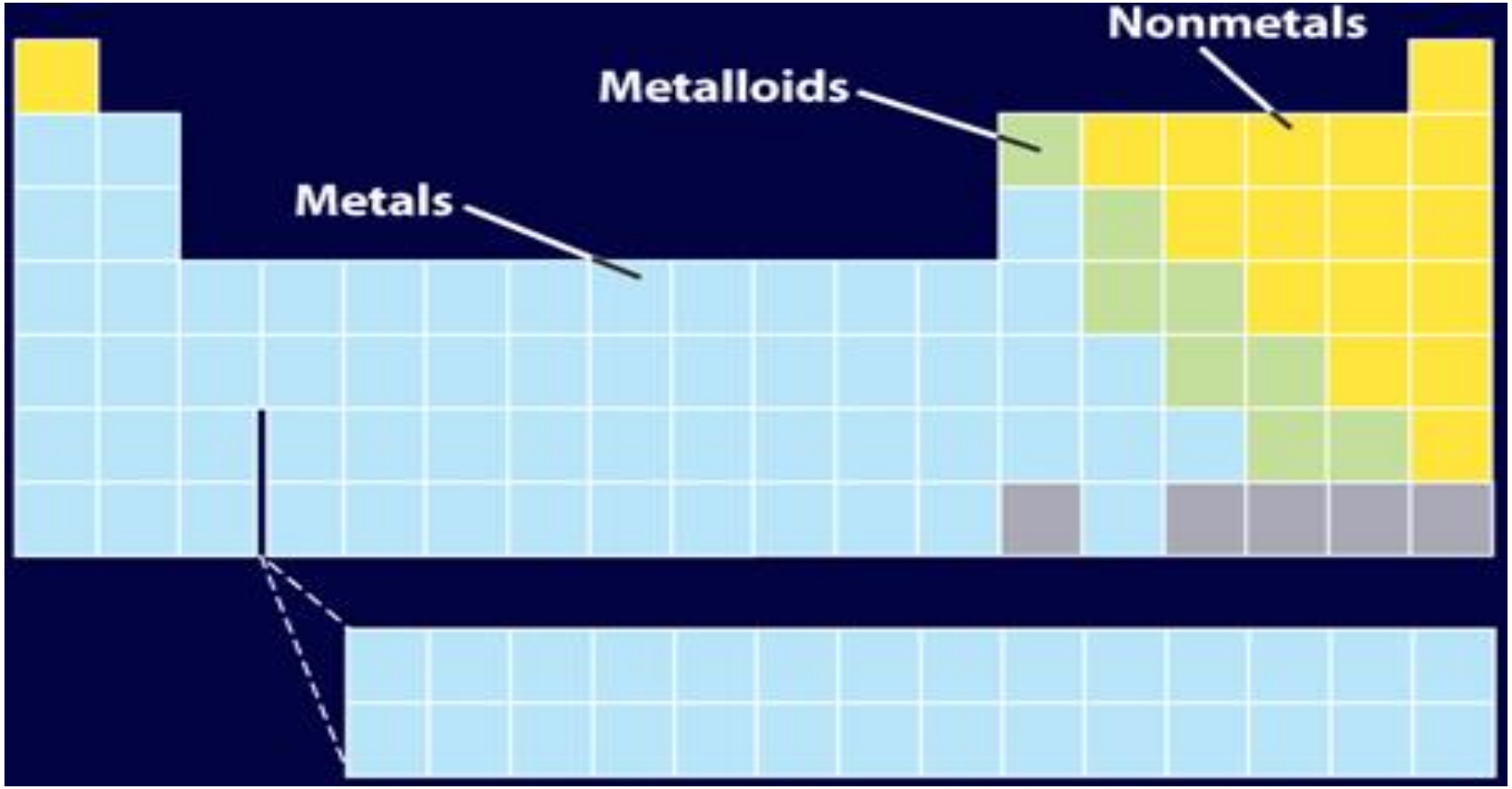
Regions on the Periodic Table

- Those elements on the right side of the periodic table, in yellow, are classified as nonmetals.



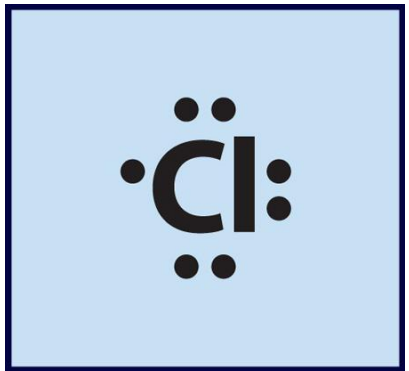
Regions on the Periodic Table

- The elements in green are metalloids or semimetals.



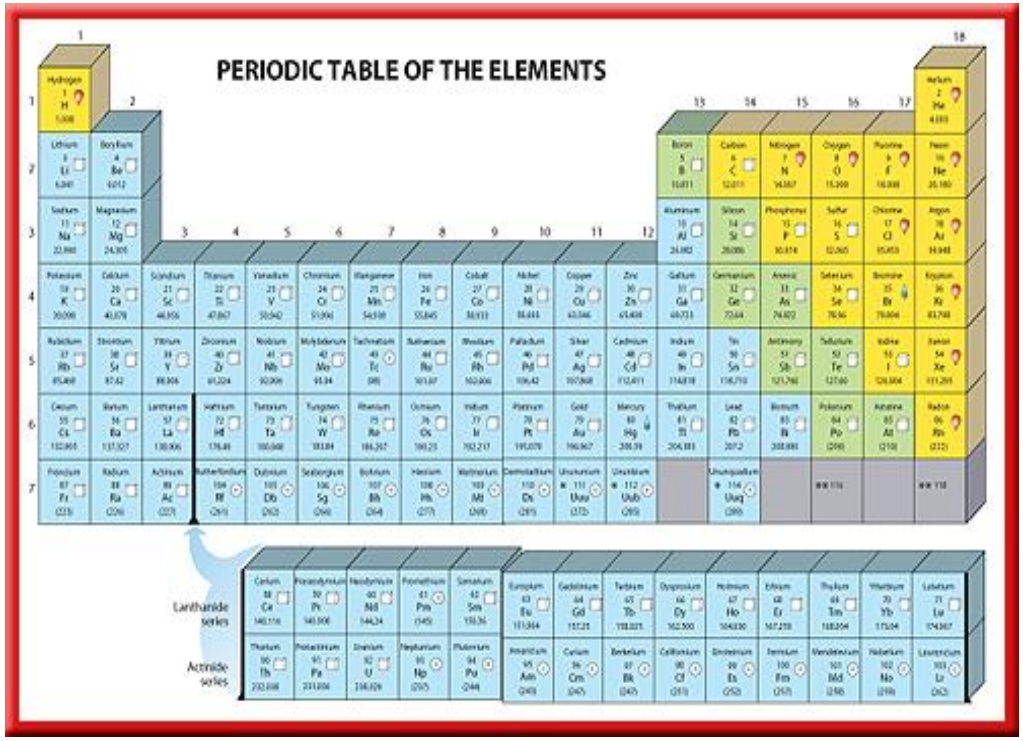
Electron Dot Diagrams

- An **electron dot diagram** uses the symbol of the element and dots to represent the electrons in the outer energy level.
- Electron dot diagrams are used also to show how the electrons in the outer energy level are bonded when elements combine to form compounds.



Properties of Metals

- Metals are good conductors of heat and electricity, and all but one are solid at room temperature.



- **Found on the left side of the stair step**

Other Properties of Metals

- Metals also reflect light (called luster)
- Metals are **malleable**, which means they can be hammered or rolled into sheets.
- Metals are also **ductile**, which means they can be drawn into wires.
- **Have high melting points and boiling points**
- **Have 1-3 electrons in outer energy level**
- **Lose electrons to become positive ions**

Group 1
the Alkali Metals
(Li, Na, K, Rb, Cs, Fr)

- 1) 1 valence electron.
- 2) Soft metals, can be cut with a knife.
- 3) VERY reactive.
- 4) Low melting points.
- 5) React quickly with the oxygen in the air.
- 6) Never found pure in nature.
- 7) React violently in water.

> Exception is **Hydrogen:** Not a member of the Alkali Metals, it is a gas (nonmetal), Lightest substance known, 93% of all atoms in the universe is hydrogen

Group 1
Alkali Metals

- loses electron easily and are found as positive ions
- combine with negative ions to form salts
- low densities
- Good conductors of heat and electricity
- Some are rare and radioactive (nucleus breaks down)
- Shiny, malleable, ductile

Group 2
the Alkaline Earth Metals
(Be, Mg, Ca, Sr, Ba, Ra)

- 1) 2 valence electrons
- 2) Highly reactive
- 3) Beryllium has such high boiling point it is used in the heat shields on the space shuttle.
- 4) Magnesium (white light of fireworks) and calcium are the most common. Ca found in cement and used in water softeners.
- 5) lose electrons to become positive charged

Group 2
Alkaline Earth Metals

- Calcium - found in bones and teeth, shells of sea animals
- Magnesium is used in planes, cars, spacecraft and ladders
- Radium is radioactive – was once used to treat cancer

Transition Elements

- **Transition elements** are those elements in Groups 3 through 12 in the periodic table. 
- They are called transition elements because they are considered to be elements in transition between Groups 1 and 2 and Groups 13 through 18.

Groups 3-12
the Transition Metals or Elements

1)**All** are similar.

2) The number of valence electrons **varies**.

3) Many elements have multiple # of **valence** electrons.

4) Occur in nature as uncombined elements and form colored compounds

Transition Metals

- **shiny**
- neighboring elements may have same properties
- **iron, cobalt and nickel** are magnetic (form Iron **Triad** – used to make steel)
- Ores - form transition metals are usually found, minerals containing large amounts of metal
- **Copper, silver, and Gold** are so stable that they are found as free elements – referred to as coinage metals

Inner Transition Metals
Lanthanide and Actinide Series
"Rare Earth elements"

- **Fits in between Groups 3 and 4 in periods 6 & 7**

Rare Earth Metals

- **Separate** rows on table
- **Lanthanide** series - period 6 - elements 58-71
- **Actinide** series-period 7-elements 90-103
- Lanthanides occur in only small amounts in the earth's crust
- Actinides are synthetic
- Lanthanides have steel-like properties, used in lasers and provide red color on TV screen

Actinide Series

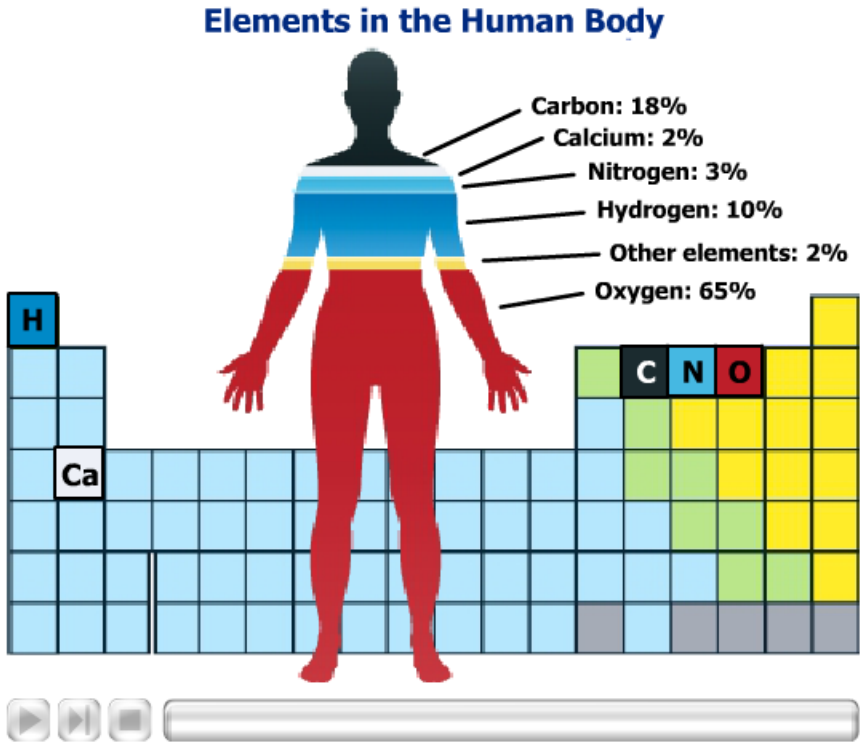
1) All **radioactive** and **unstable**
2) **Uranium** is the largest, heaviest nature element.
3) Most are man-made or **synthetic** elements.

Properties of Nonmetals

- Most of your body's mass is made of oxygen, carbon, hydrogen, and nitrogen.

MAC OSX users click here to view.

- Calcium, a metal, and other elements make up the remaining four percent of your body's mass.

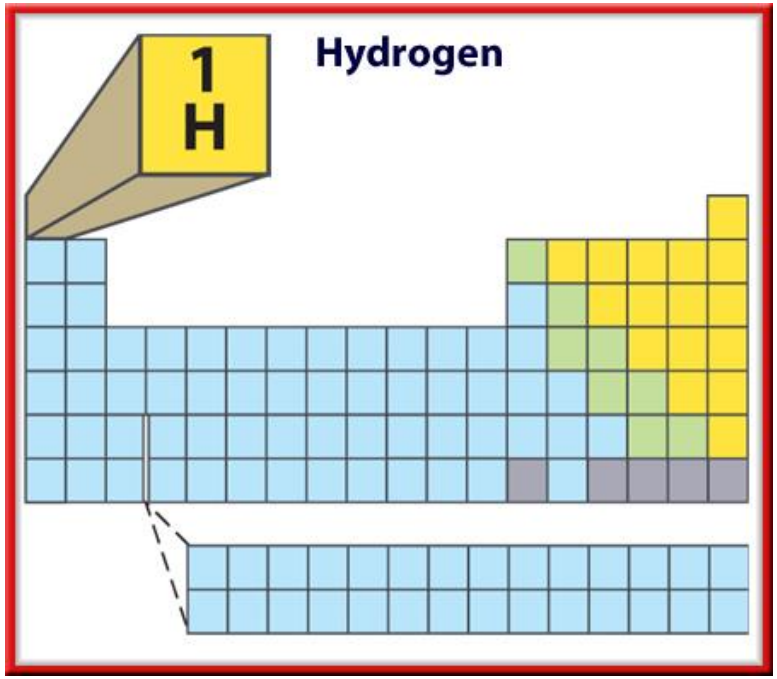


Nonmetals – elements that usually are gases or brittle solids at room temperature

1) All are Found on the **right** side of the periodic table except Hydrogen.
2) **Dull** luster. (Dull and brittle)
3) **Insulators** -> poor conductors.
4) **Brittle**, **shatter**, break under pressure.
5) **Gain** electrons when bonding to form **negative** ions.
6) Can form **covalent** bonds -> electrons are shared to form the bonds.
7) The **building** blocks of living things are nonmetals - C, N, O, S, P
8) Many are gases at room temperature
9) Many electrons in outer energy levels that are held tightly

Hydrogen

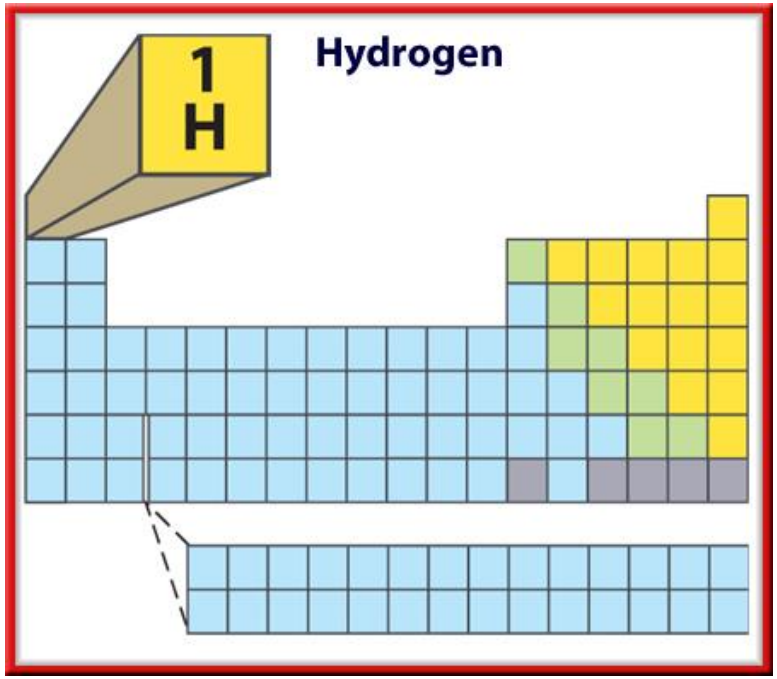
- If you could count all the atoms in the universe, you would find that about **90** percent of them are hydrogen.
- When water is broken down into its elements, hydrogen becomes a gas made up of diatomic molecules.



Hydrogen

- A **diatomic molecule** consists of two atoms of the same element in a covalent bond.

- EX: **Hydrogen** Gas



Hydrogen

- Hydrogen is highly reactive.
- A hydrogen atom has a single electron, which the atom shares when it combines with other nonmetals.
- Hydrogen can gain an electron when it combines with alkali and alkaline earth metals.
- The compounds formed are hydrides.

Group 17
the Halogens
"salt-makers" (F, Cl, Br, I, At)

1) **7** valence electrons.

2) VERY **reactive**, **fluorine** is the most reactive of all elements.

3) Never found **pure** in nature.

4) Reactive with metals to form **salts**, for example table salt- NaCl.

- salt former EX: Sodium chloride
- Fluorine is the most reactive of all elements, used in fluoride toothpaste and the non-stick coating of pans
- Chlorine - green gas
- **Bromine** - only nonmetal that is a liquid at room temperature
- Iodine – when heated changes directly to a purple vapor (sublimation)

Group 18
the Inert or Nobel Gases
(He, Ne, Ar, Kr, Xe, Rn)

1) **8** valence electrons.

2) NON **REACTIVE** - ALWAYS found **pure** in nature.

3) **Helium** is rare on Earth, 2nd most abundant element in the universe.

4) **Neon** and **argon** is used in signs.

Noble Gases

Colorless gases

- Do not readily combine with other elements - chemically inactive
- All exist in the earth's atmosphere
- Helium - lighter than air, used in balloons

Metalloids

1) Found over and under the zigzag line.
2) Have properties of both metals and nonmetals.
3) Silicon and germanium → dull, brittle shatter and conductor.
   - Exception is Aluminum: considered a metal.
4) Shiny solids but not as much luster
5) Semiconductors – conducts electricity and heat better than nonmetals
6) Can form ionic or covalent bonds

Group 13
the Boron Family
(B, Al, Ga, In, Tl)

1) **3** valence electrons.
2) **Boron** is a metalloid used to make Borax (laundry product to soften water), all others are **metals**.
3) **Aluminum** is the third most abundant element on Earth, most abundant metal.
4) Gallium melts in your hand.

- Boron is the only nonmetal
- Aluminum - light, soft, good conductor, most abundant metal in the earth's crust

Group 14
the Carbon Family
(C, Si, Ge, Sn, Pb)

1) **4** valence electrons.
2) **Carbon** forms over 5 million compounds.
3) **Silicon** is the 2nd most abundant element in the Earth's crust.
4) Silicon and Germanium are used in electronics.
5) Lead used in water pipes before it was discovered to be poisonous.

Carbon Group

- **Carbon** is the only nonmetal
- Carbon is found in diamonds and pencil lead (graphite)
- Silicon and germanium - metalloids, silicon makes up 60 of earths crust, found in rocks
- Tin and lead - metals, steel food cans are lined with tin, lead is poisonous

The Carbon Group

- The crystal structure of silicon dioxide is similar to the structure of diamond.

- **Silicon** occurs as two allotropes. **Allotropes,** which are **different** forms of the same element, have different **molecular** structures.

Group 15
the Nitrogen Family
(N, P, As, Sb, Bi)

1) **5** valence electrons.

2) **Nitrogen** is the most abundant element in air, 78. 4th most abundant element in your body

3) **Phosphorus** used in weapons. (has 3 allotropes)

4) **Bismuth** has a low melting point used for "triggers" in automatic sprinkler systems.

Nitrogen Group

- Nitrogen and Phosphorus - **nonmetals** .
- Nitrogen is a gas, essential in the formation of proteins
- Phosphorus - in bones, teeth, and DNA, very reactive, used for matches
- Arsenic and antimony - **metalloids**
- Arsenic - pesticides
- Antimony - used to strengthen lead

Group 16
the Oxygen Family
(0, S, Se, Te, Po)

1) **6** valence electrons.

2) Highly **reactive**.

3) **Oxygen** is the most common element on Earth, 50% Earth's crust, 20% of air and 33% of water.

Oxygen Group

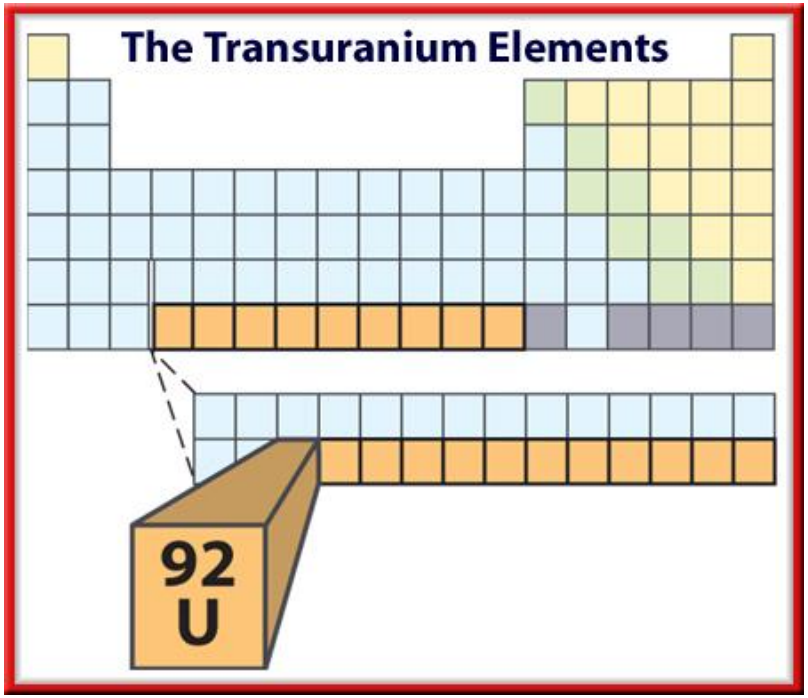
* Oxygen - most abundant element, combined with silicon in rocks, produced by plants during photosynthesis, exists in air as a diatomic molecule

» **Sulfur** - used in rubber and sulfuric acid

» **Selenium** - used in light meters, solar cells, and photocopiers

Transuranium Elements

- Elements having more than 92 protons, the atomic number of uranium, are called **transuranium elements**.
- These elements do not belong exclusively to the metal, nonmetal, or metalloid group.



Transuranium Elements

- All of the transuranium elements are synthetic and unstable, and many of them disintegrate quickly.