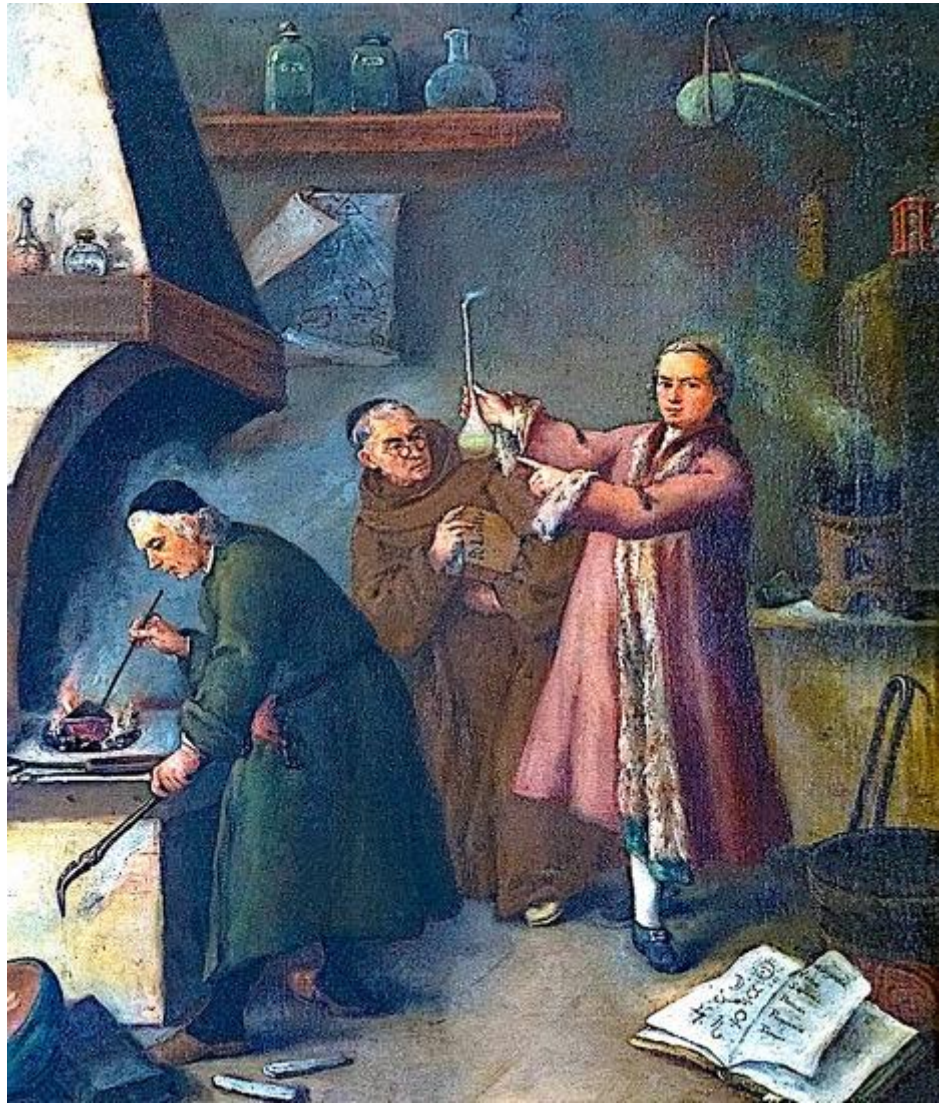
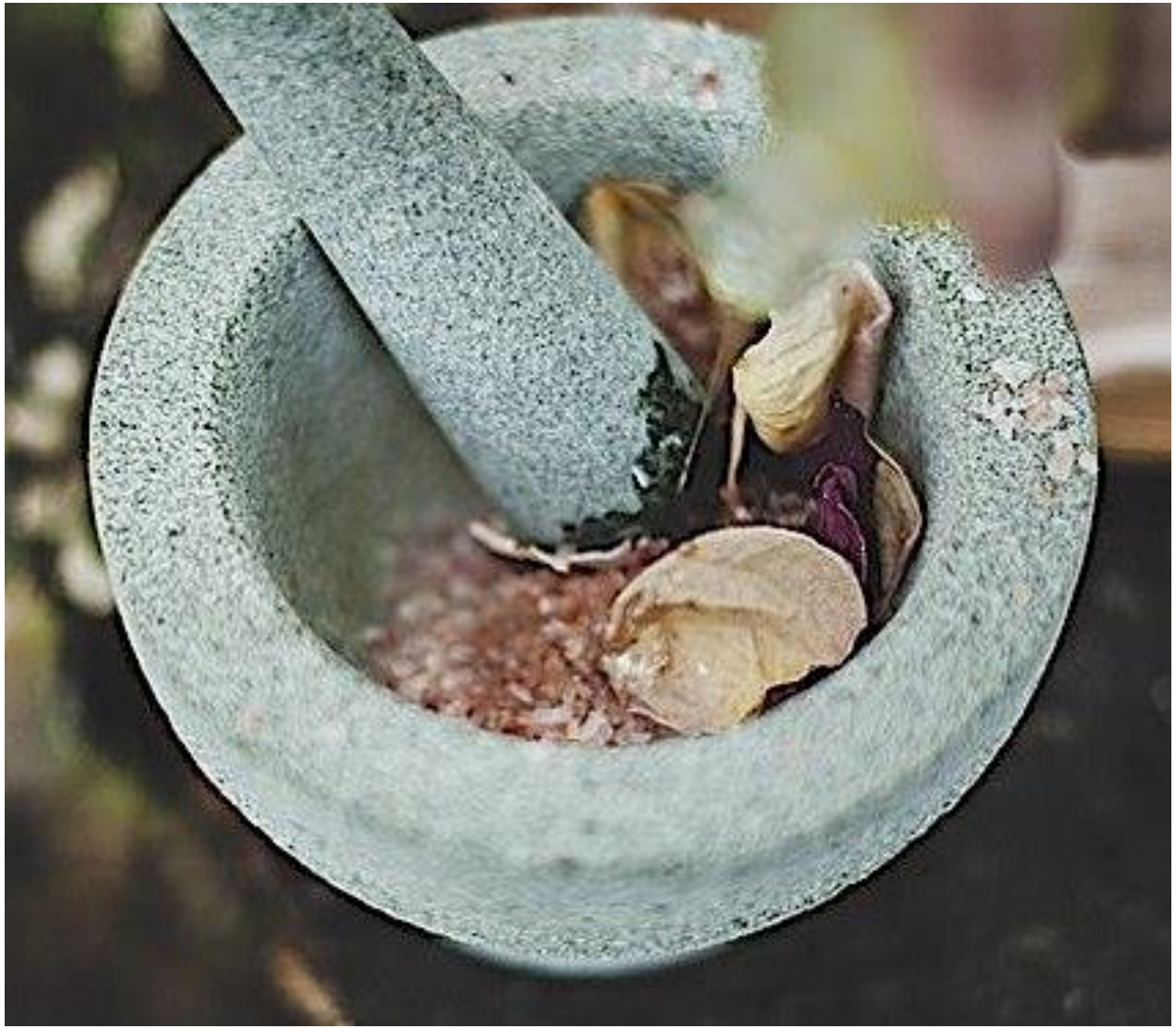
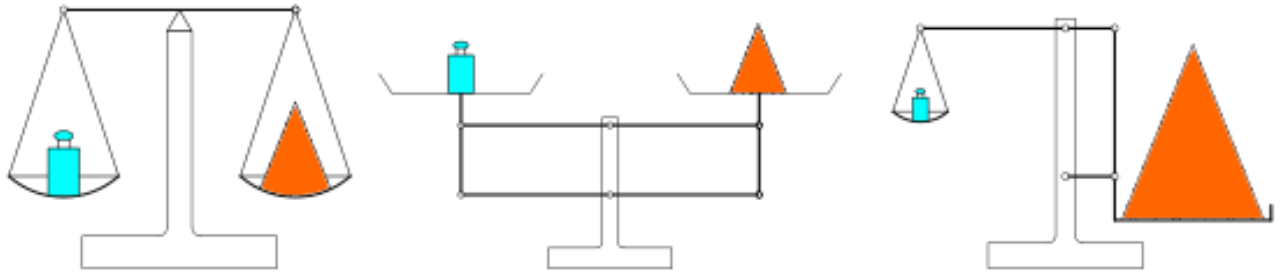
# Understanding Matter





**Matter** is defined as anything that takes up space and mass.



**Elements** are substances that cannot be chemically broken down into other substances.

Carbon

Copper

Sulfur

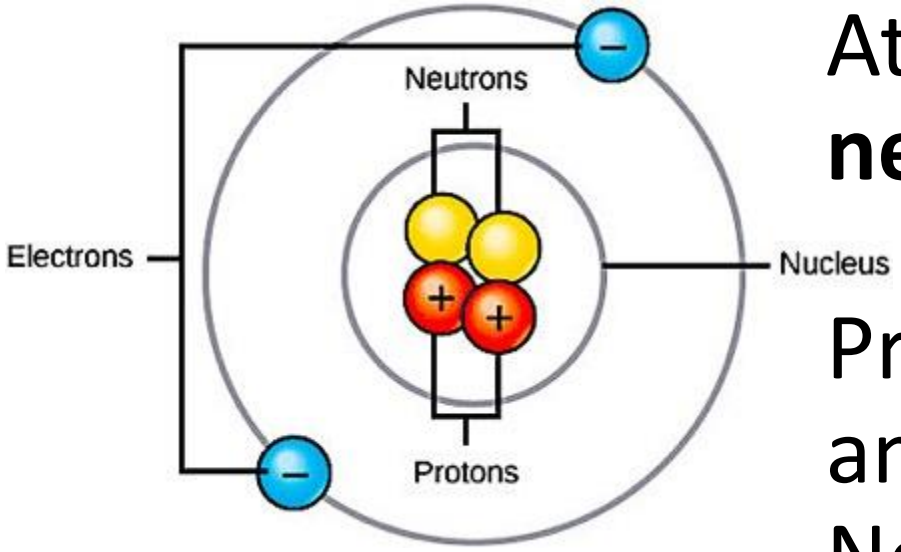
Chlorine (gas)

Western scholars up to the Middle Ages believed that the basic “elements” were Earth, water, wind, and fire.


Today we know there are more than one hundred elements!

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 He |
| 3 Li | 4 Be | | | | | | | | | | | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 11 Na | 12 Mg | | | | | | | | | | | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 19 K | 20 Ca | | | | | | | | | | | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 37 Rb | 38 Sr | | | | | | | | | | | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 55 Cs | 56 Ba | 57 La | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 87 Fr | 88 Ra | 89 Ac | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Nh | 114 Fl | 115 Mc | 116 Lv | 117 Ts | 118 Og |

# The **atom** is the smallest distinct unit of an element.



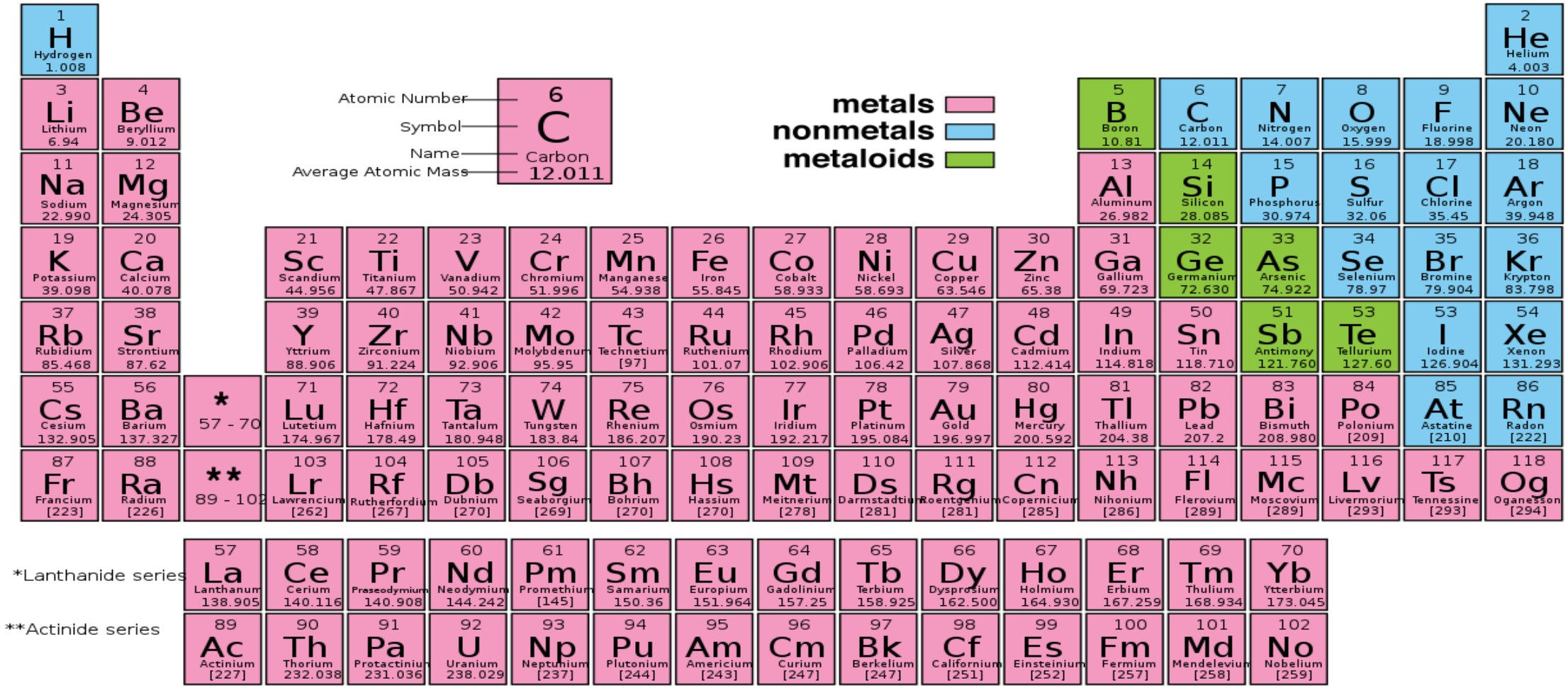

Atoms are made up of **protons**, **neutrons**, and **electrons**.

Protons and electrons have positive and negative charges respectively. Neutrons have no charge.

Protons and neutrons reside in the **nucleus** and make up almost the entirety of the element's mass.

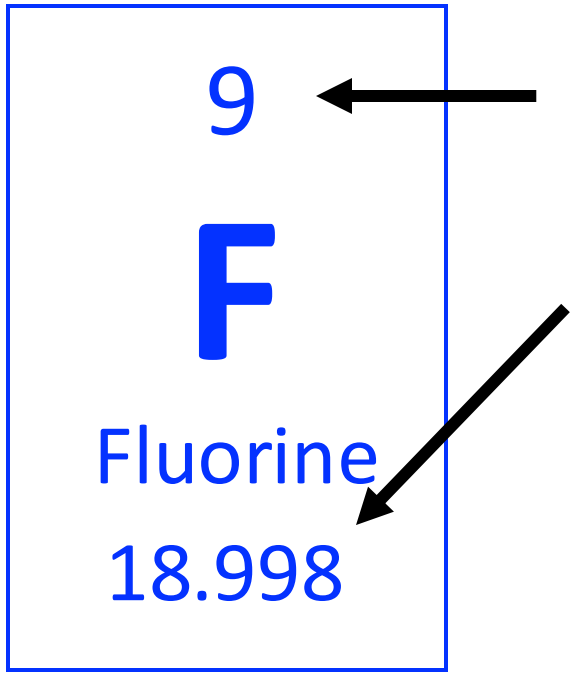
From "Environmental Issues" by Andrew Frank https://pressbooks.bccampus.ca/environmentalissues/front-matter/introduction/

Most of the known elements are metals. Note how nearly all of the nonmetals are on the upper right portion of the periodic chart




You will not be tested on these categories on the periodic chart.

The periodic chart lists elements by symbol and organizes them on the basis of their chemical properties.



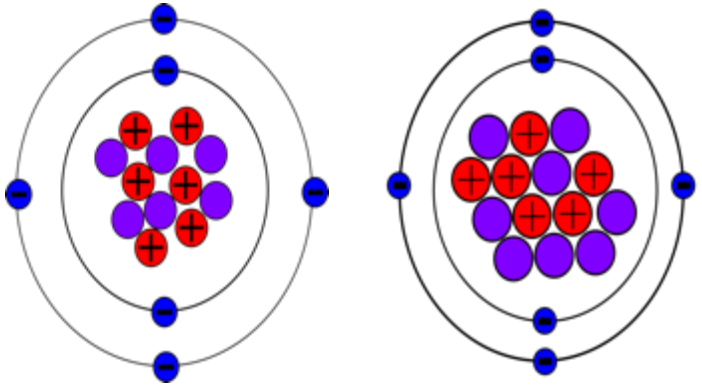

The **atomic number** indicates the number of protons in each atom.

The **atomic mass** is the average mass in atomic mass units (amu).

This is *roughly* equivalent to the **sum of protons and neutrons** in each atom.

In an atom that has not reacted with its surroundings, **the number of electrons is equal to the number of protons**.

The number of protons in a given element determines its identity because it is constant, but the same element can be made up atoms with different amounts of neutrons. These different ”versions” of the same element are called **isotopes**.





<u>Carbon-12</u>

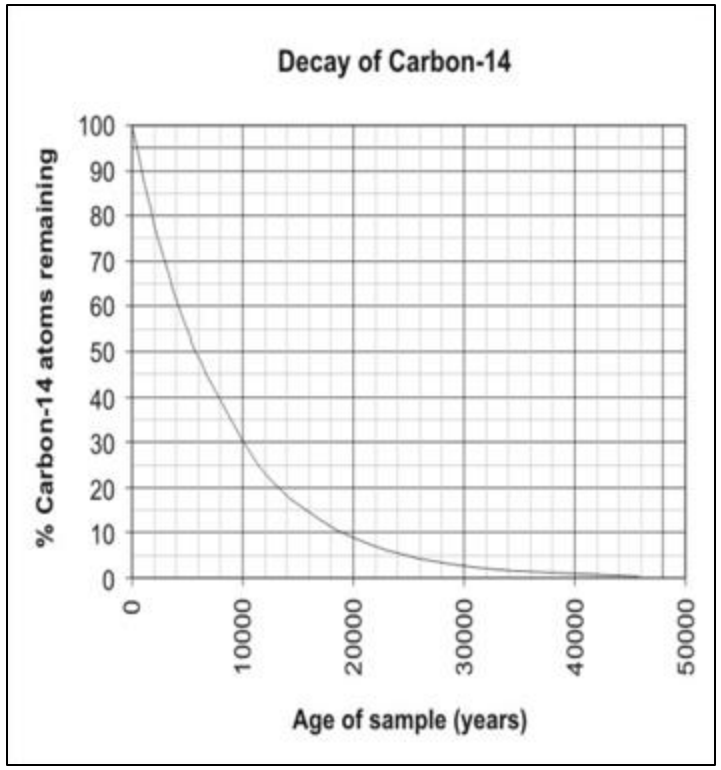
6 protons

6 neutrons

<u>Carbon-14</u>

6 protons

8 neutrons




Carbon-14 is not only rare, it is also unstable, and breaks down at a constant rate.

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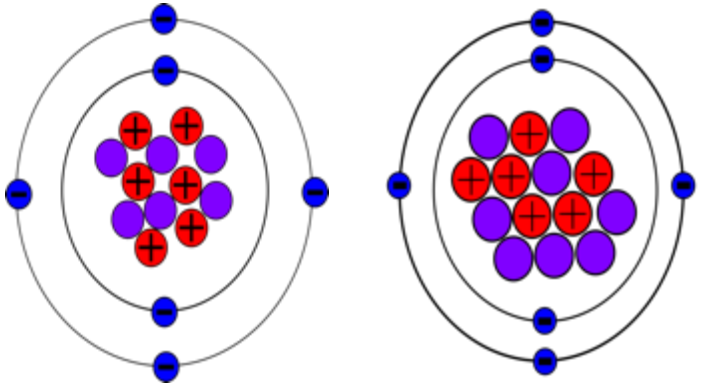



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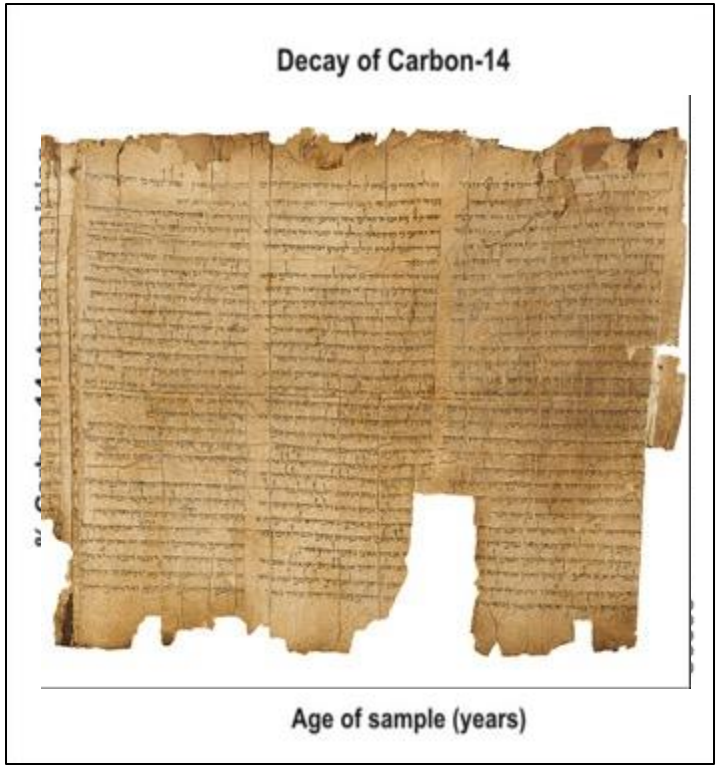



Carbon-14 is not only rare, it is also unstable, and breaks down at a constant rate.

This is why it is used to determine the age of ancient artifacts derived from previously living materials.

# Many elements can chemically combine to form **compounds.**

Sodium

+

Chlorine

→

Sodium Chloride

Carbon

+

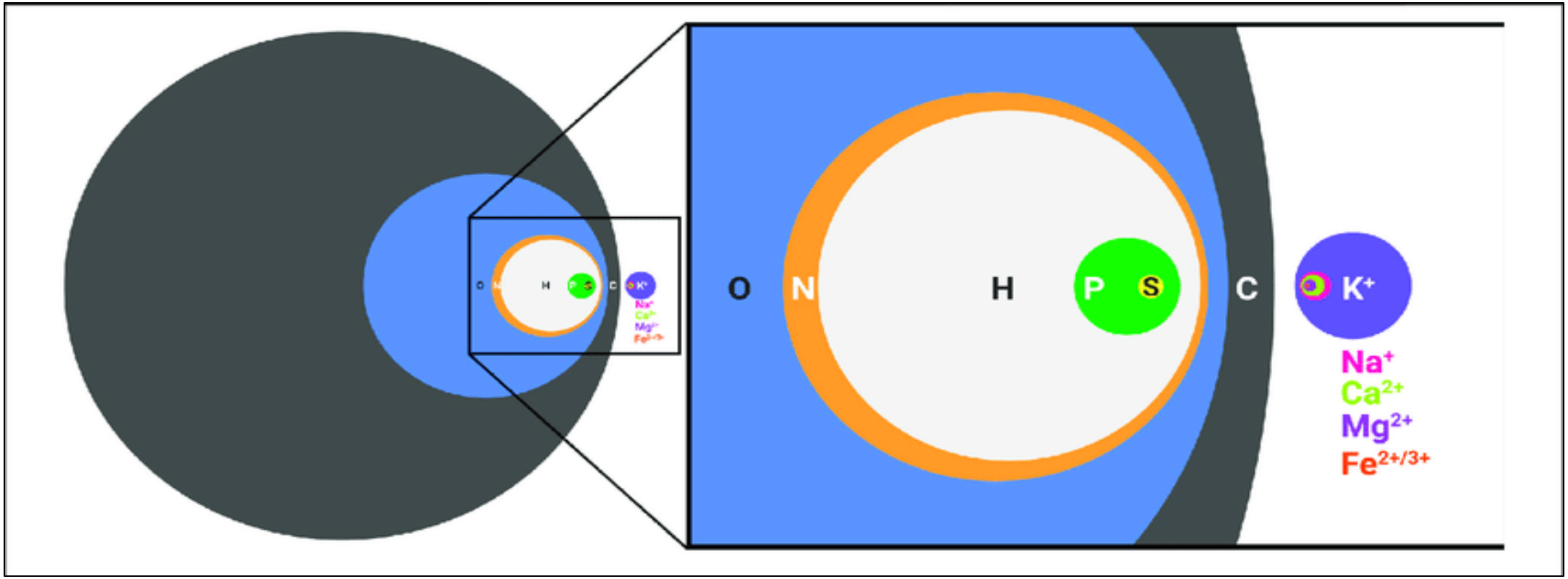
Oxygen

→

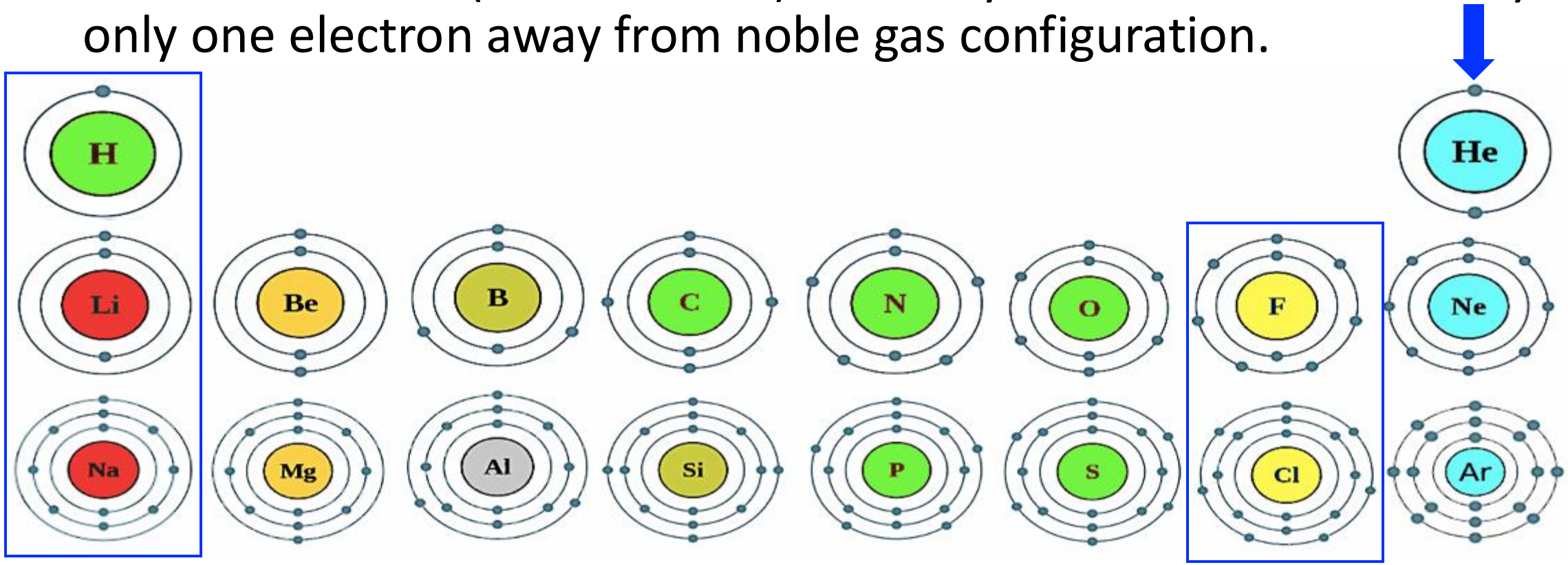
Carbon Dioxide

**Carbon**, **nitrogen**, **oxygen**, and **hydrogen** are the main elements involved the compounds of life.

**Phosphorous (P)**, **sulfur (S)**, **potassium (K)**, **sodium (Na)**, **magnesium (Mg)**, **iron (Fe),** and other micronutrients also occur in much lesser amounts. This shows their dry weight ratios in the compounds that make up living cells.

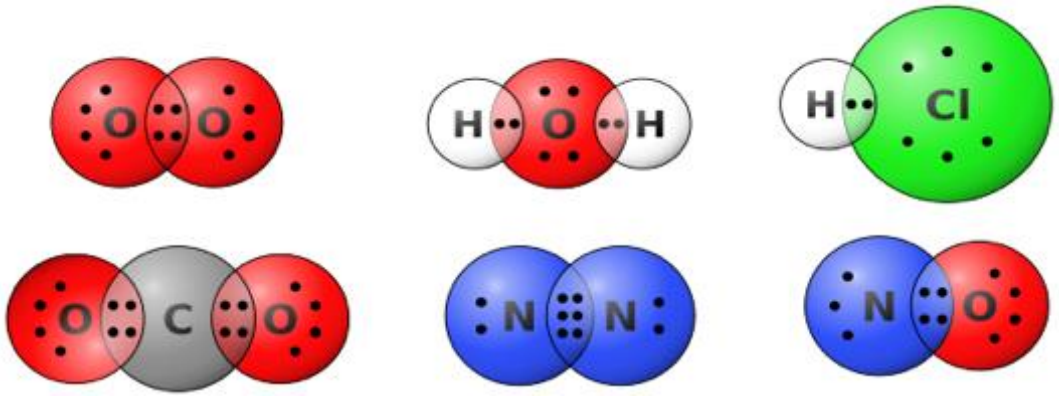


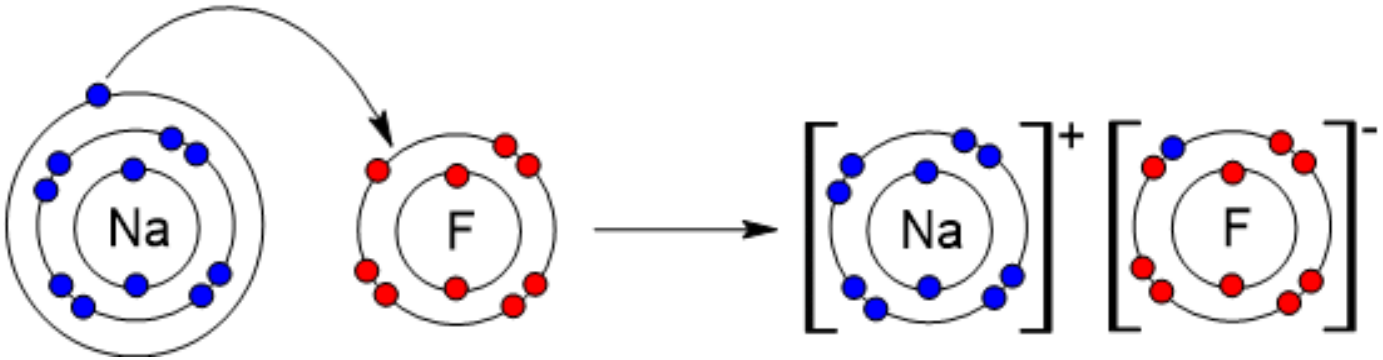
1. The outermost electrons determine chemical properties.
2. Noble gases (indicated by the arrow) do not form compounds because their outermost electron shell is “full.”
3. These elements (in the boxes) are very reactive because they are only one electron away from noble gas configuration.



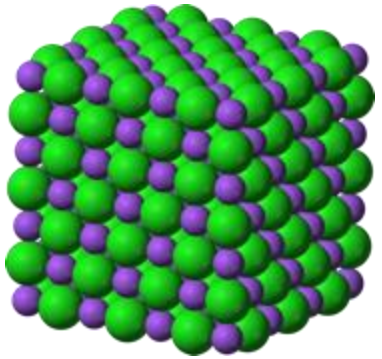

This is just to improve your understanding. You will not be tested on this.

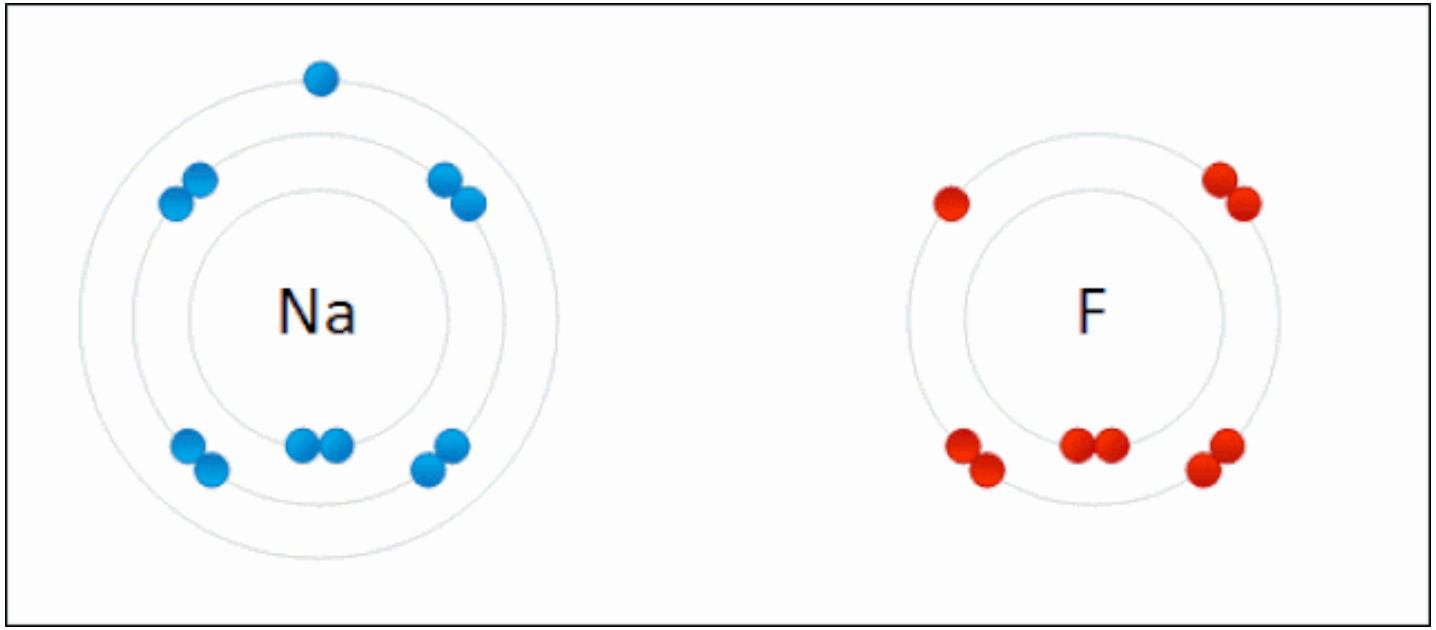
Elements form **chemical bonds** in order to obtain the configuration of noble gases. This can involve either electron sharing (**covalent**) or electron transfer (**ionic**).



**Ionic bonds** form a continuous network of positively and negatively charged **ions**. They usually occur between metal and nonmetal.





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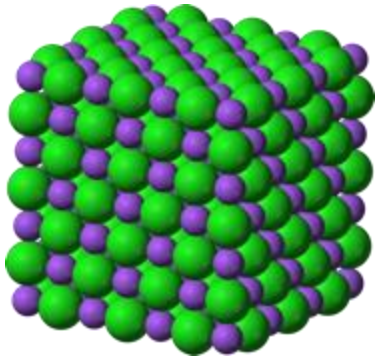
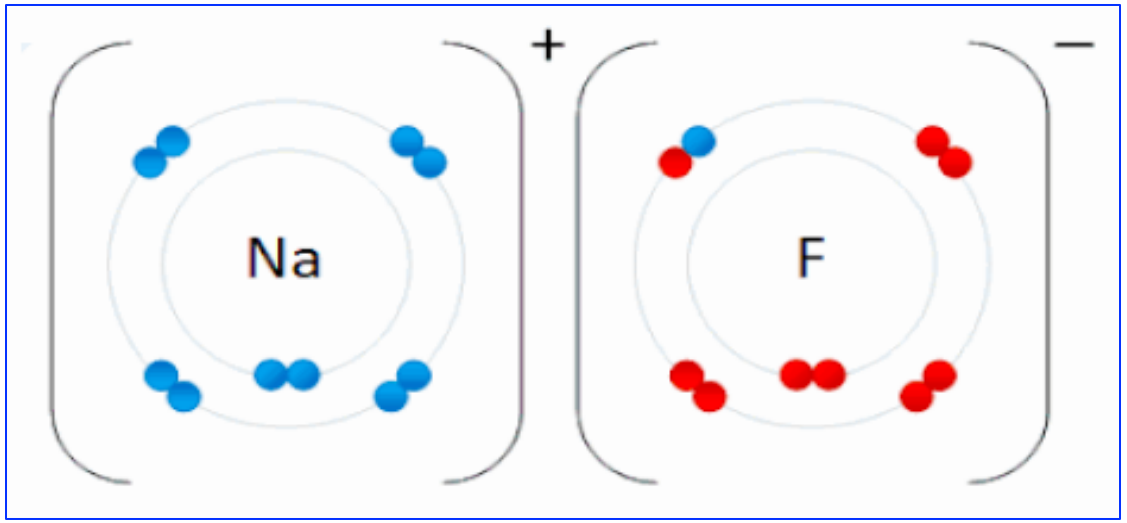
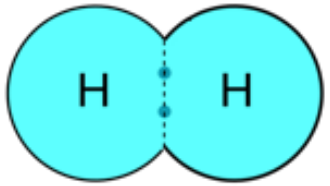


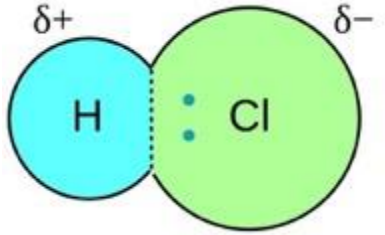



Important: This is not a molecule! These are **two ions**.

Electron sharing can be equal and unequal.

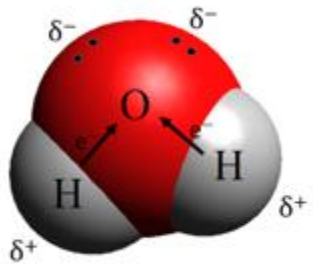



Hydrogen Molecule




Hydrogen Chloride Molecule

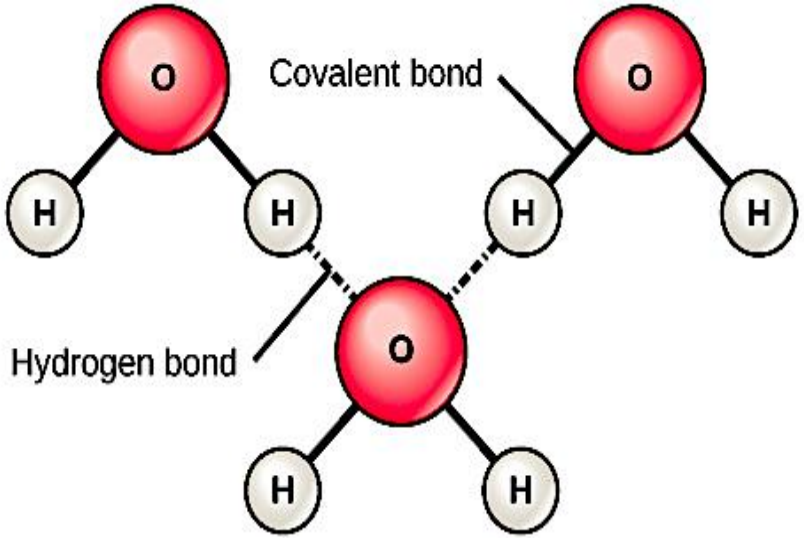
**Unequal sharing** results in **covalent bonds** that are **polar.**




Water Molecule


Ammonia Molecule

Unequal sharing of electrons between oxygen and hydrogen atoms generates strong **intermolecular forces** called **hydrogen bonds**.




Hydrogen bonding is responsible for the properties that make water conducive to life. These include:

- solvent properties
- cohesion & adhesion
- high specific heat
- crystallization of the solid

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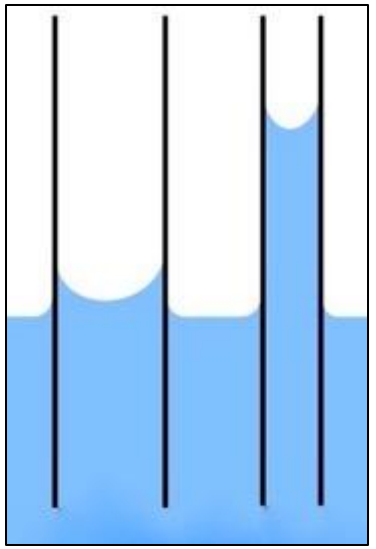
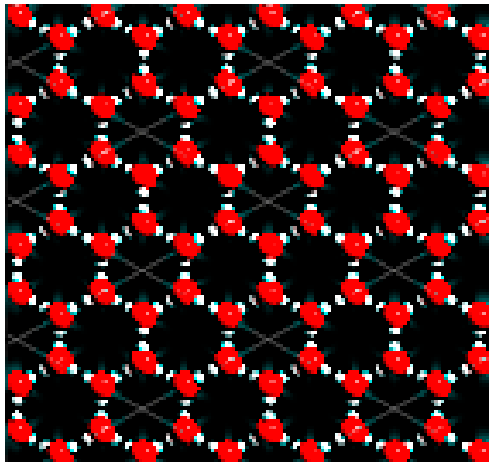
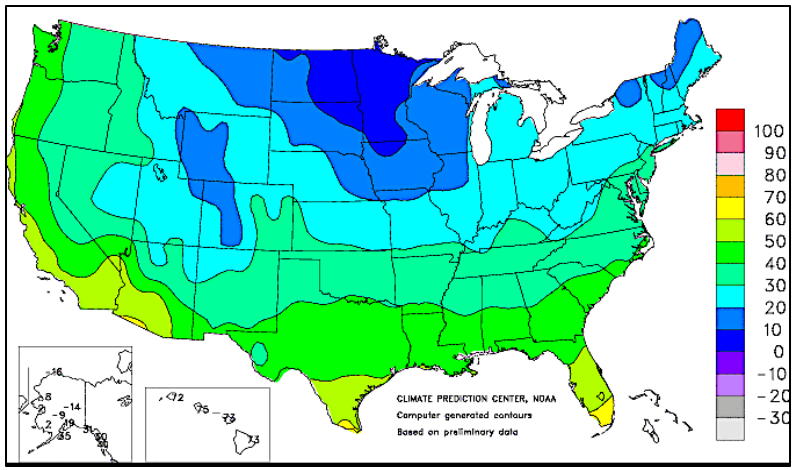
## Sugar + Oxygen ---▷ Carbon Dioxide + Water + Cellular Energy

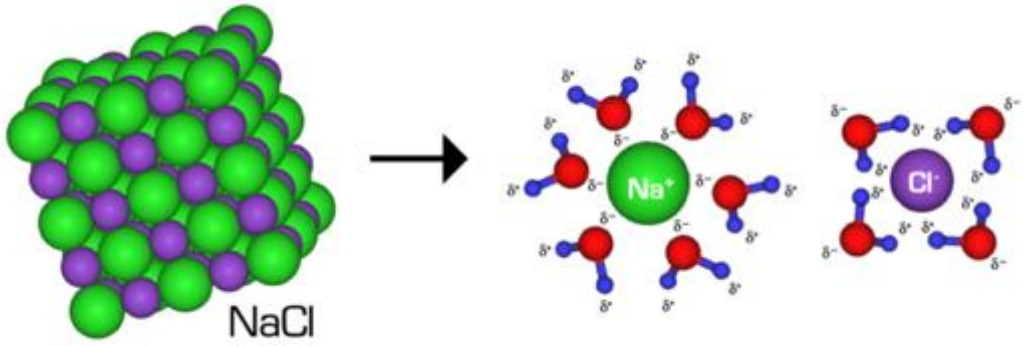
- Nearly all reactions essential to life take place in aqueous solutions.
- Cohesion and adhesion allow water to climb up the stems of plants, trees, and capillary tubes.
- This map from NOAA shows how temperatures are milder on the coast due to the high specific heat of water.
- Ice has a lower density than water due to the formation of a hexagonal lattice in the solid. Lakes do not freeze solid because ice crystals always go to the top.







# Solvent properties of water



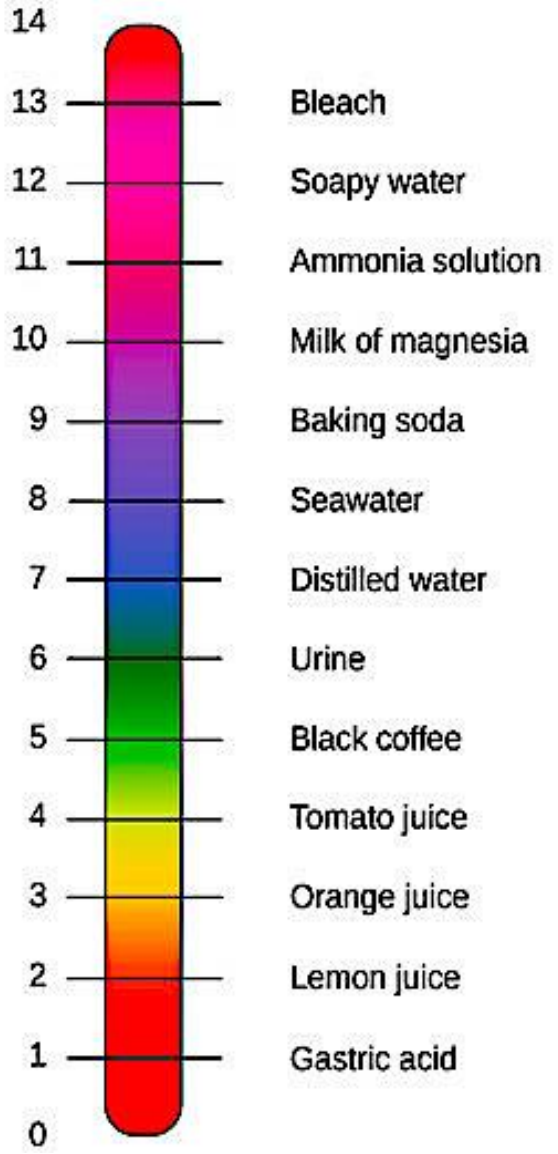

- Both sugar and ammonia **dissolve in water** because both substances are **polar**.
- Sodium chloride dissolves in water because the polar **water molecules pull the ions apart** from each other and surround them according to their ionic charges.
- Hydrocarbons like gasoline and other organic solvents **do not dissolve in water** because they are **non-polar**. This is why oil spills are cleaned up by containing the spill and using absorbent materials to remove the oil at the surface.


# The pH scale

Even pure water is never 100% $H_2O$ molecules: A small proportion of the water molecules spontaneously dissociate into **hydrogen ions** and **hydroxide ions** at a predictable concentration. The pH scale indicates which ions are higher in concentration. In pure water the pH is 7.

$$H_2O \lhd\!\!---\!\!\rhd H^+ + OH^-$$

If pH < 7, the solution is **acidic** $OH^- < H^+$
If pH > 7, the solution is **basic** $OH^- > H^+$
If pH = 7, the solution is **neutral** $OH^- = H^+$

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# Review Questions

1. Covalent bonds an (intra/inter)-molecular force.
2. Hydrogen bonds an (intra/inter)-molecular force.
3. Hydrogen bonding occurs because water molecules are (polar/non-polar).
4. Why does ice float?
5. Why are coastal climates usually milder that inland climates?

# Review Questions

1. Covalent bonds an (**intra**/inter)-molecular force.
2. Hydrogen bonds an (intra/**inter**)-molecular force.
3. Hydrogen bonding occurs because water molecules are (**polar**/non-polar).
4. Why does ice float? **It has a lower density.**
5. Why are coastal climates usually milder that inland climates? **Water has a high specific heat, so the temperature of the water and the immediate surroundings changes at a slower rate.**

# Review Questions

1. Sugar dissolves in water because it is _____.
2. Oil does not dissolve in water because it is _____.
3. If the concentration of the $H^+$ exceeds that of the $OH^-$, the solution is _____ and the pH is (above/below/equal to) 7.
4. What term is used to label the opposite situation?

# Review Questions

1. Sugar dissolves in water because it is **polar**.
2. Oil does not dissolve in water because it is **non-polar**.
3. If the concentration of the $H^+$ exceeds that of the $OH^-$, the solution is **acidic** and the pH is (above/**below**/equal to) 7.
4. What term is used to label the opposite situation?

**The solution is basic**

## Acknowledgement:


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