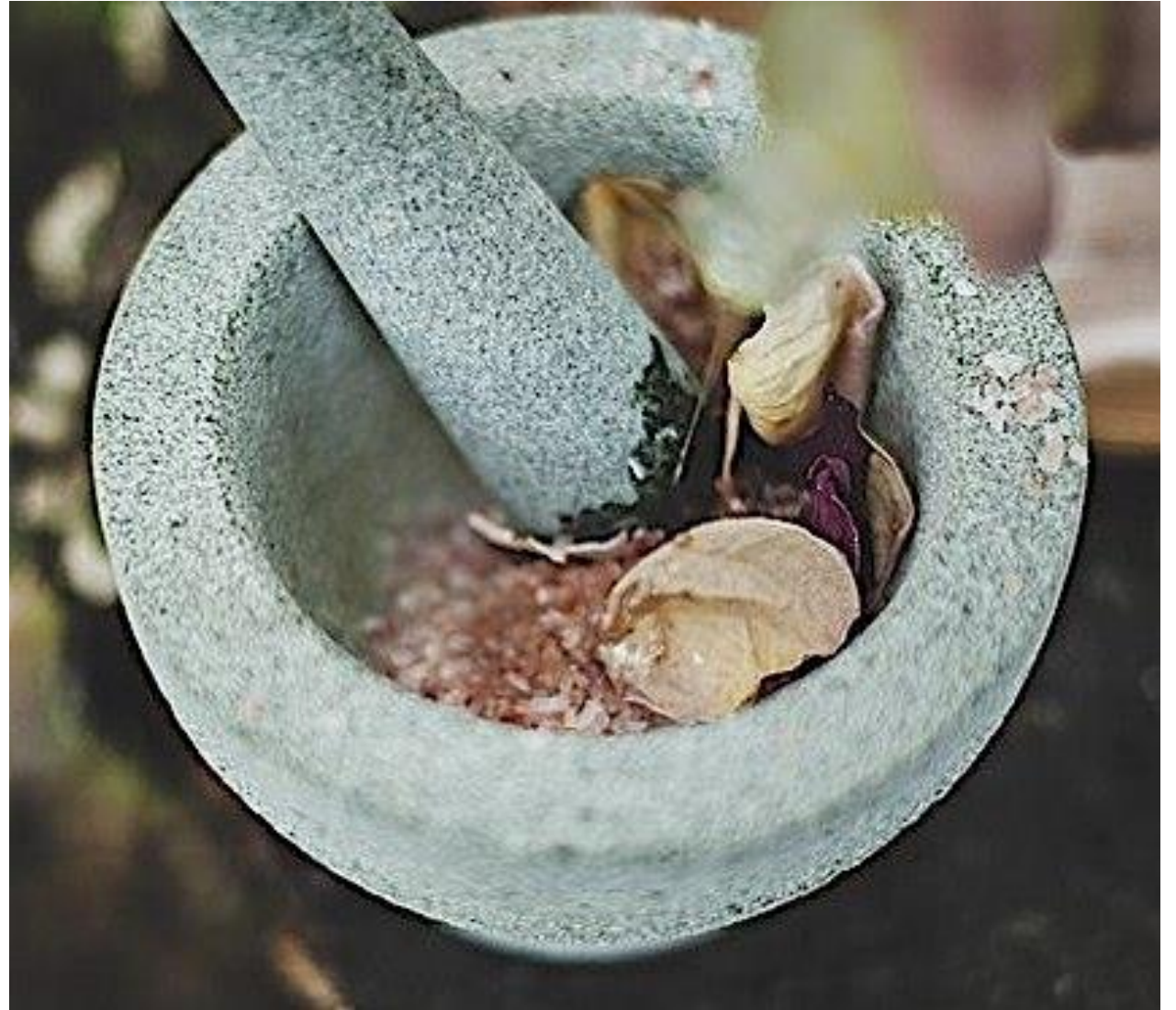
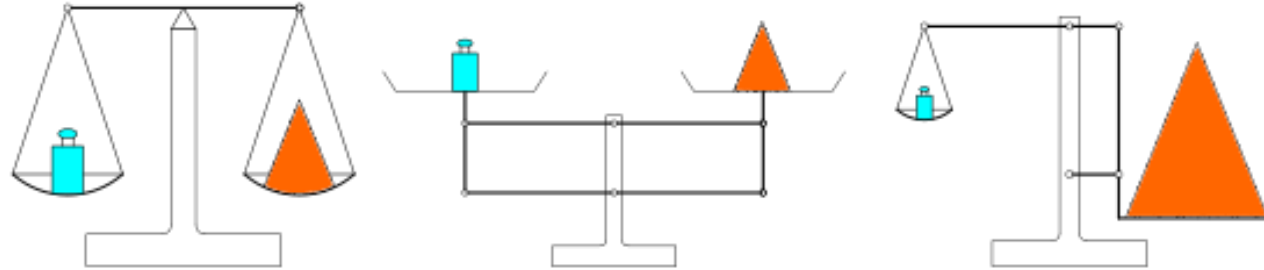


# Understanding Matter



**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.

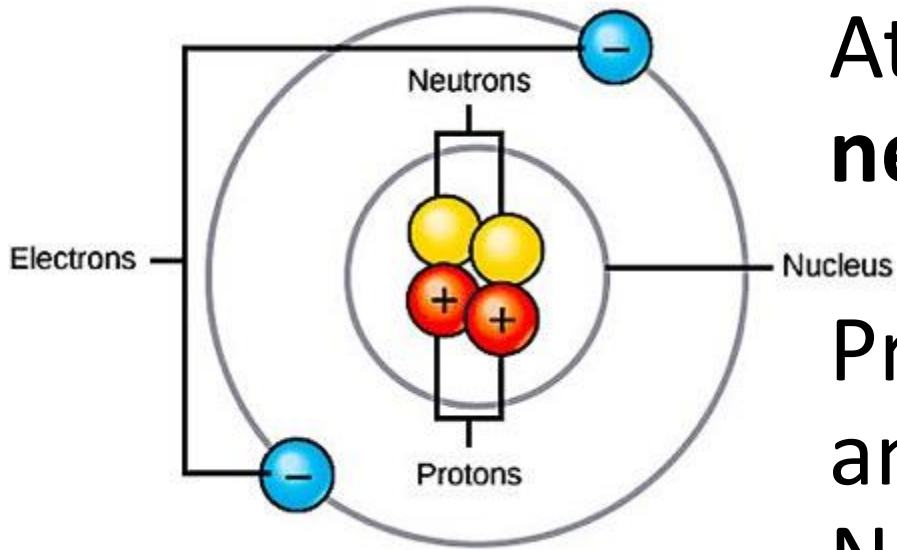
*Nomi delli caratteri delli quattro elementi .*



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

1 H Hydrogen 1.008																	2 He Helium 4.003		
3 Li Lithium 6.94	4 Be Beryllium 9.012													5 B Boron 10.81	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													13 Al Aluminum 26.982	14 Si Silicon 28.085	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	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 72.630	33 As Arsenic 74.922	34 Se Selenium 78.97	35 Br Bromine 79.904	36 Kr Krypton 83.798		
37 Rb Rubidium 85.468	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 [97]	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 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.904	54 Xe Xenon 131.293	
55 Cs Cesium 132.905	56 Ba Barium 137.327	*	71 Lu Lutetium 174.967	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 195.084	79 Au Gold 196.997	80 Hg Mercury 200.592	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]	
87 Fr Francium [223]	88 Ra Radium [226]	**	103 Lr Lawrencium [262]	104 Rf Rutherfordium [267]	105 Db Dubnium [270]	106 Sg Seaborgium [269]	107 Bh Bohrium [270]	108 Hs Hassium [270]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [281]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [293]	118 Og Oganesson [294]	
*Lanthanide series			57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium [145]	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 173.045			
**Actinide series			89 Ac Actinium [227]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium [247]	98 Cf Californium [251]	99 Es Einsteinium [252]	100 Fm Fermium [257]	101 Md Mendelevium [258]	102 No Nobelium [259]			

Atomic Number  
Symbol  
Name  
Average Atomic Mass

6  
C  
Carbon  
12.011

metals  
nonmetals  
metalloids

metals  
nonmetals  
metalloids

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.

9
F
Fluorine
18.998

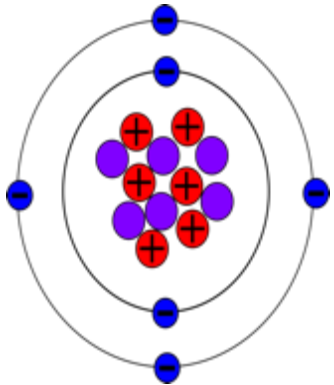
The **atomic number** indicates the number of protons in each atom.

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.

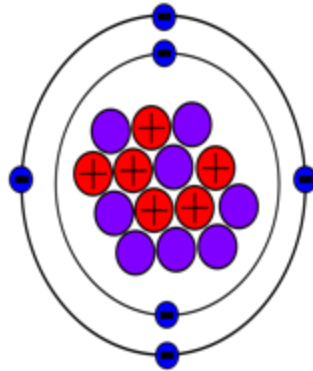
In an atom that has not reacted with its surroundings, **the number of electrons is equal to the number of protons.**

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**.



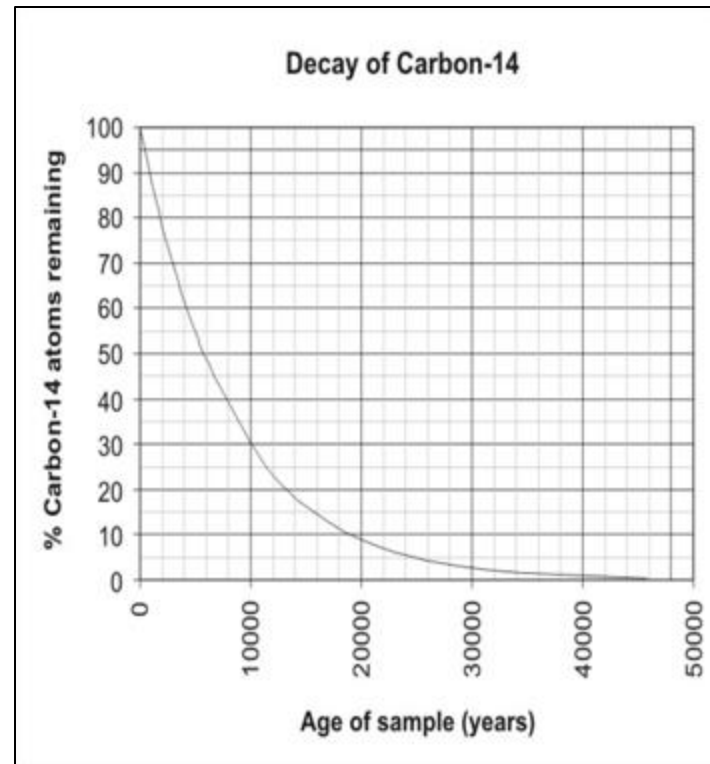
Carbon-12

6 protons  
6 neutrons



Carbon-14

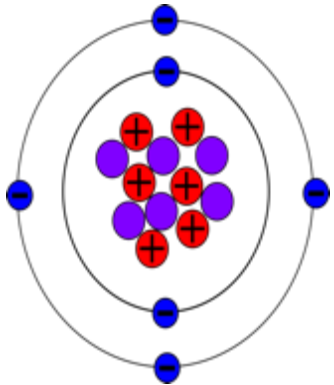
6 protons  
8 neutrons



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

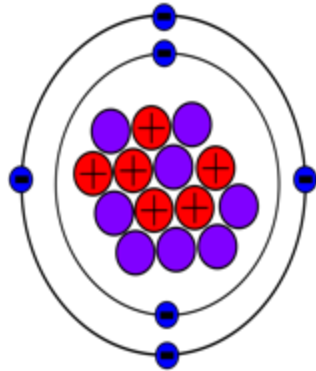


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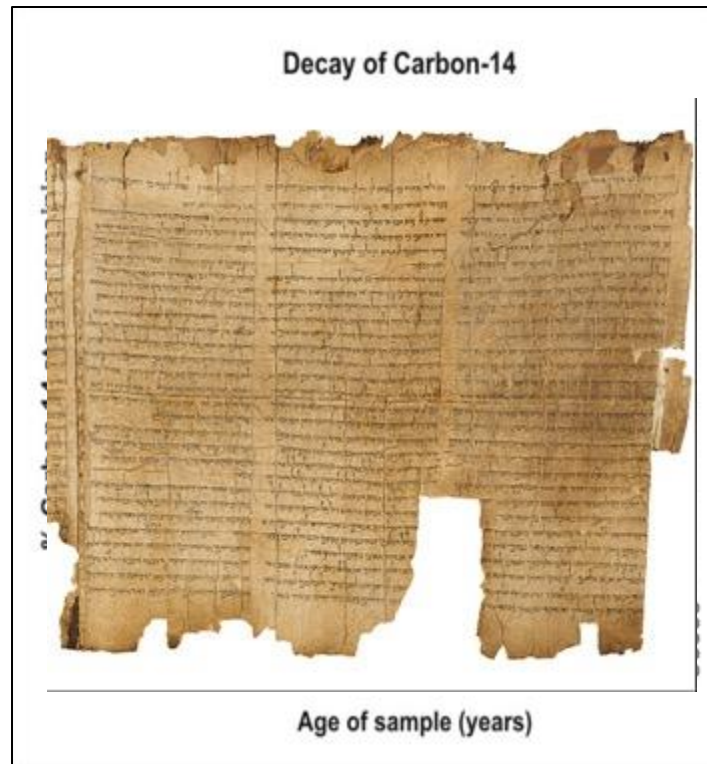
Carbon-12

6 protons  
6 neutrons



Carbon-14

6 protons  
8 neutrons



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

+



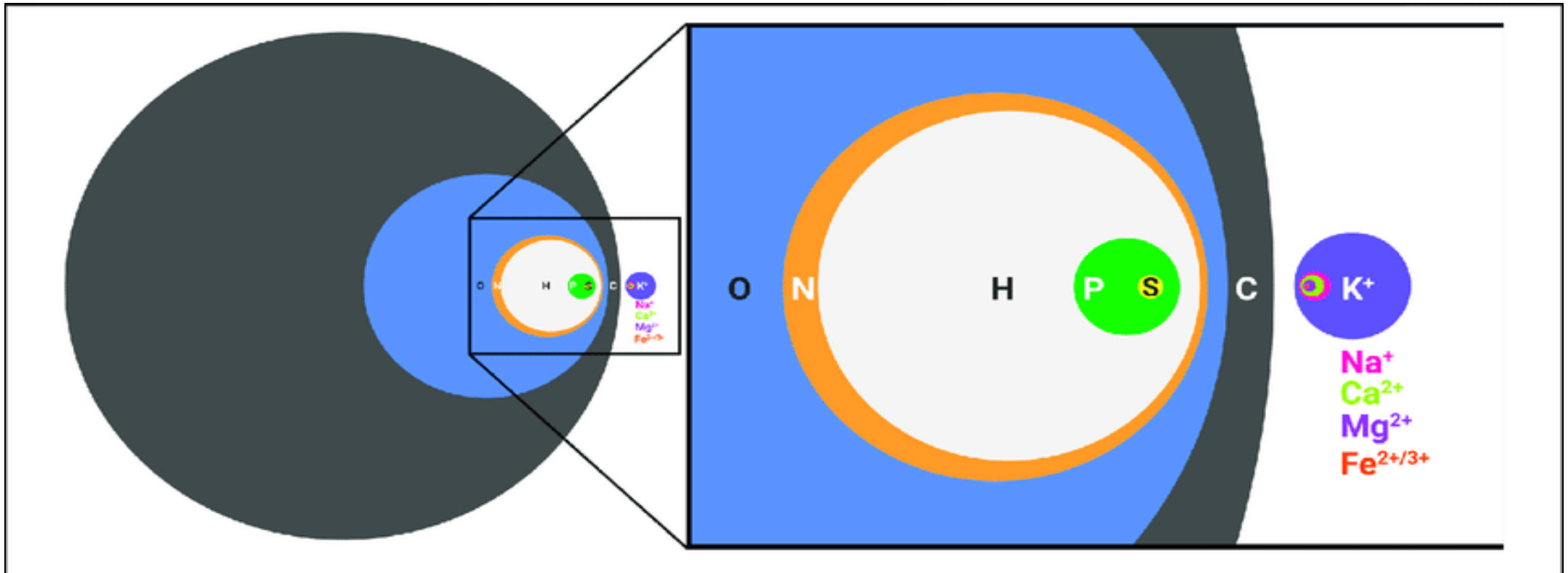
Oxygen



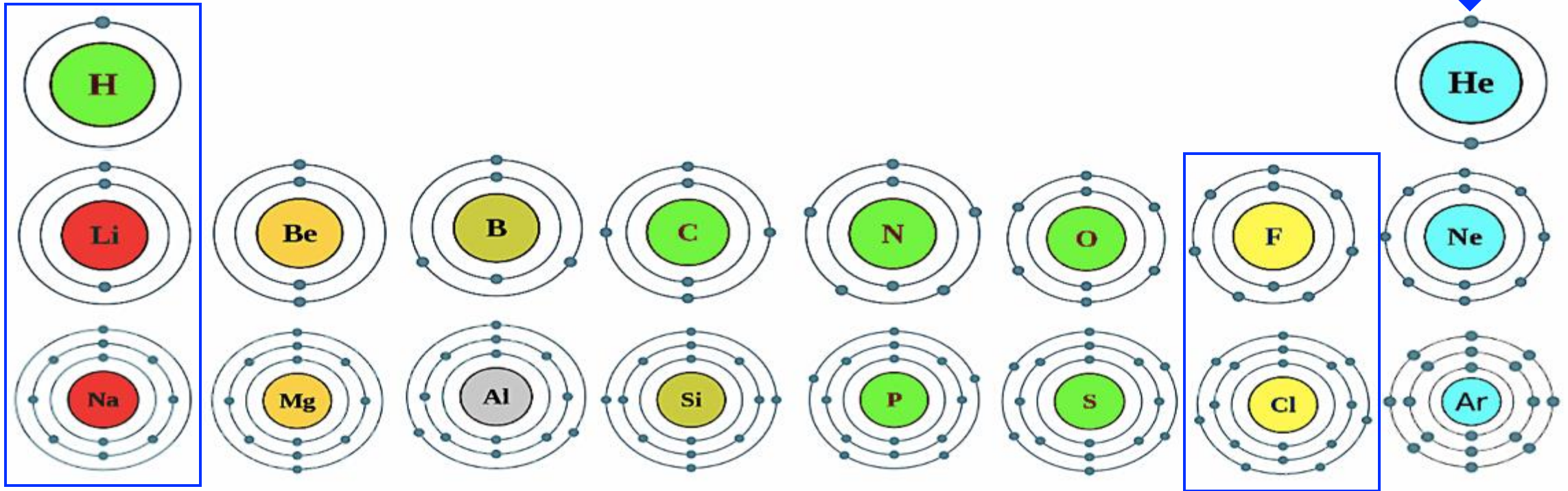
Carbon Dioxide

**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.

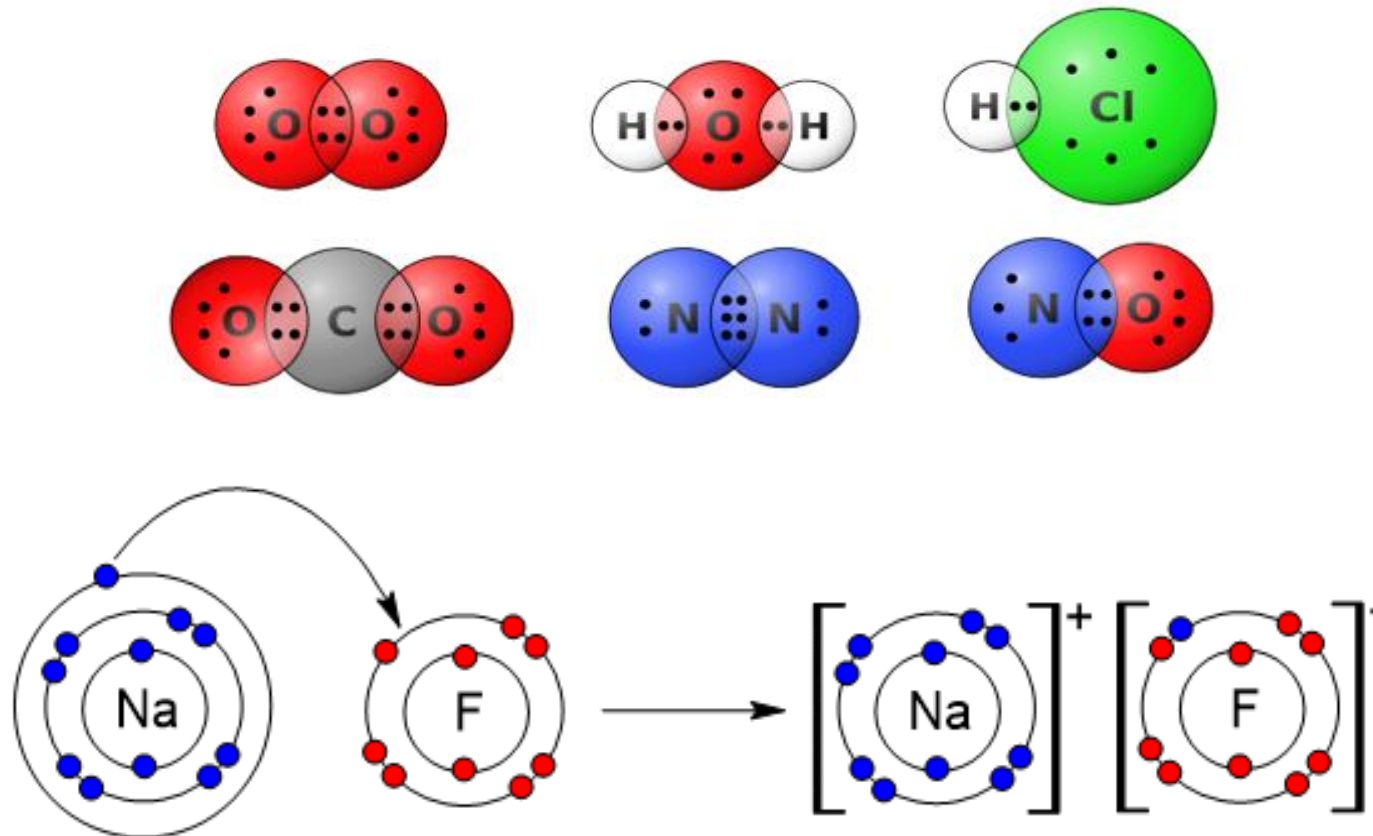


1. The outermost electrons determine chemical properties.
2. Noble gases (indicated by the arrow) do not form compounds because their outermost electron shell is “full.”
3. These elements (in the boxes) are very reactive because they are only one electron away from noble gas configuration.



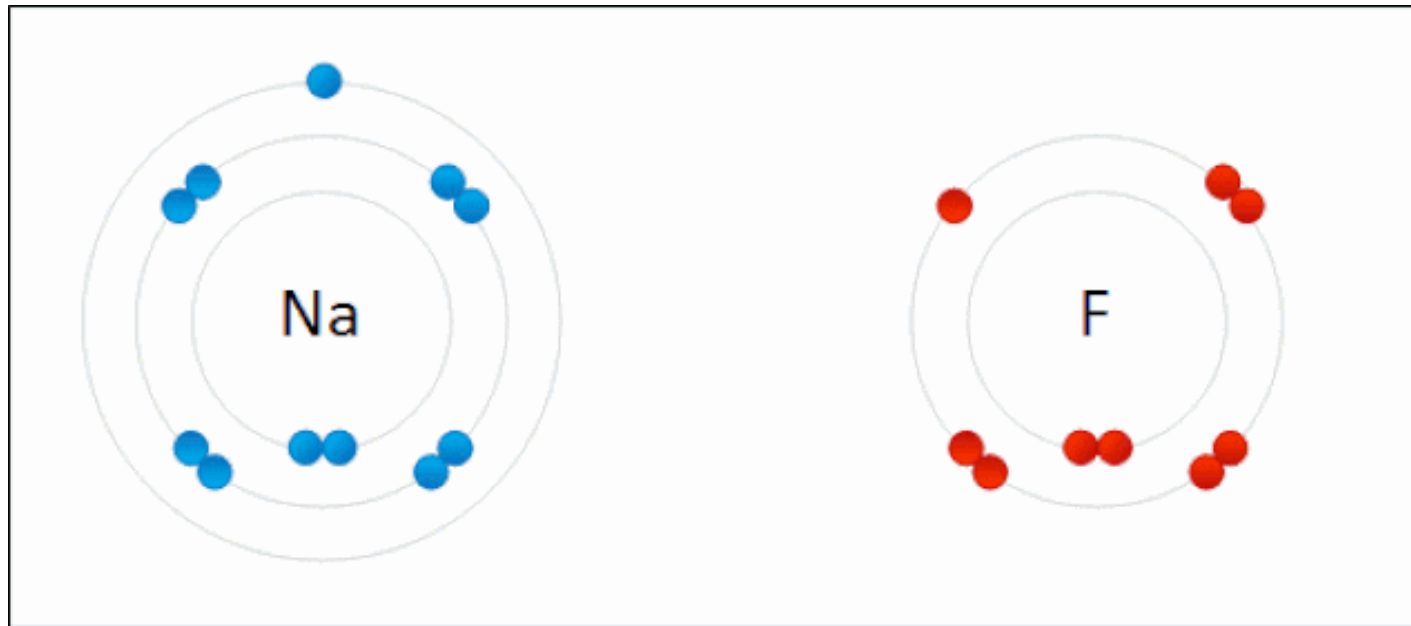
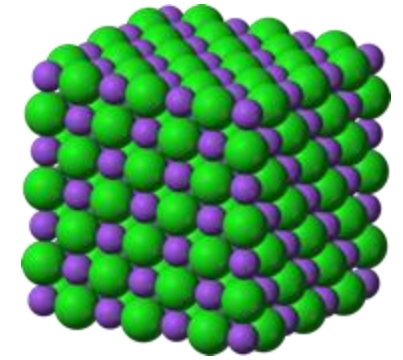
This is just to improve your understanding. You will not be tested on this.

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

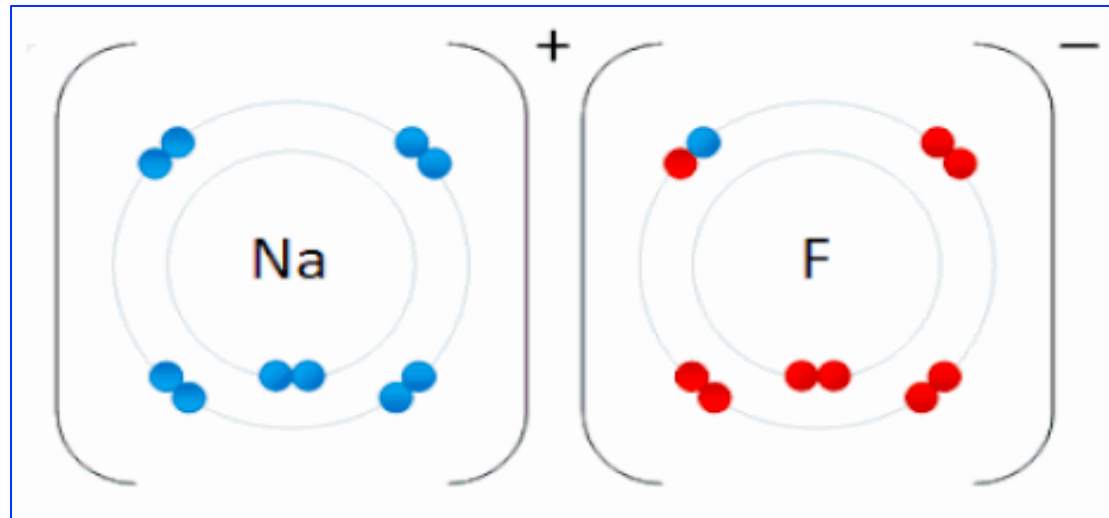
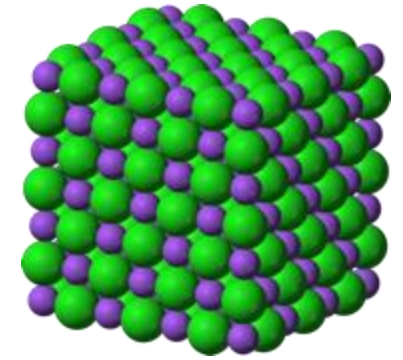




**Ionic bonds** form a continuous network of positively and negatively charged **ions**. They usually occur between metal and nonmetal.

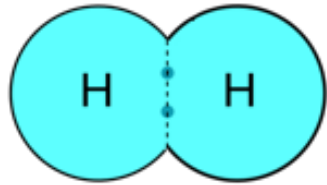


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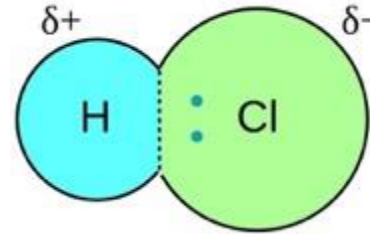


Important: This is not a molecule! These are **two ions**.

Electron sharing can be equal and unequal.

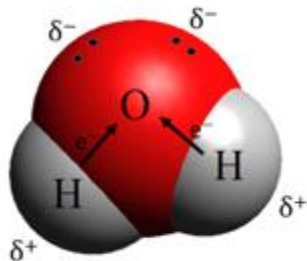


Hydrogen Molecule

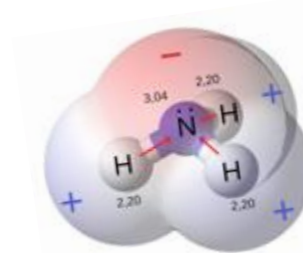


Hydrogen Chloride Molecule

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

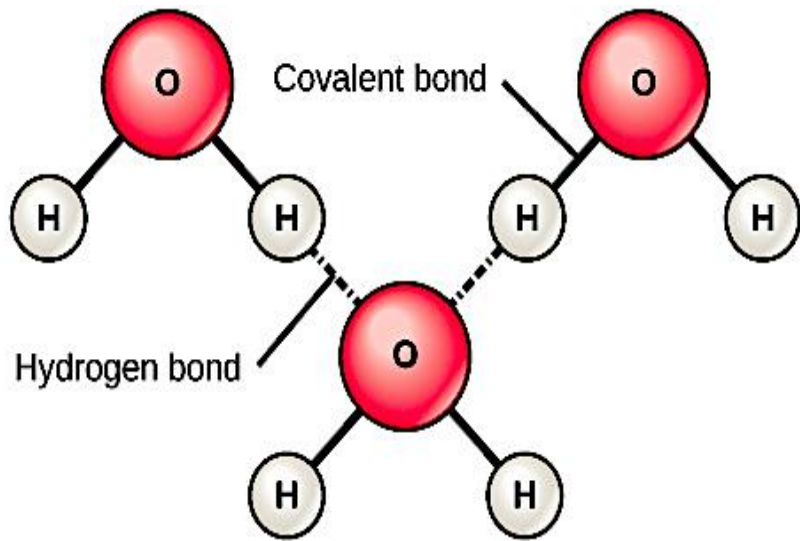


Water Molecule



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



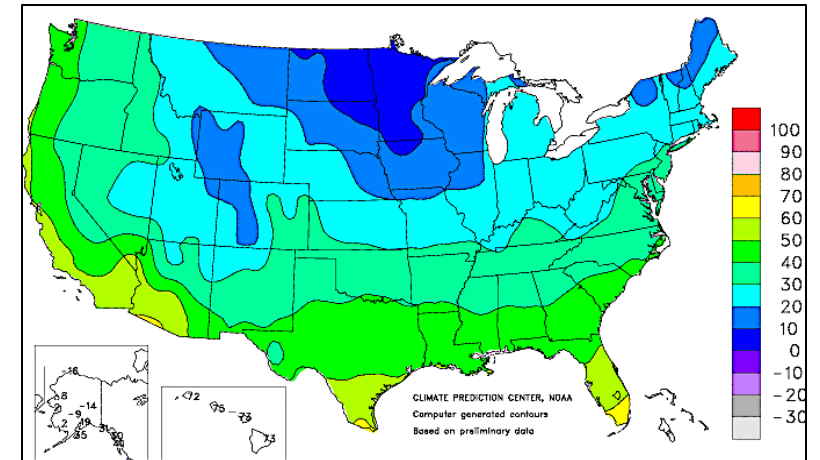
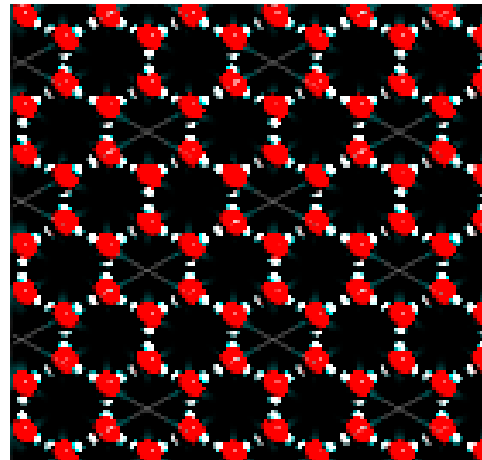
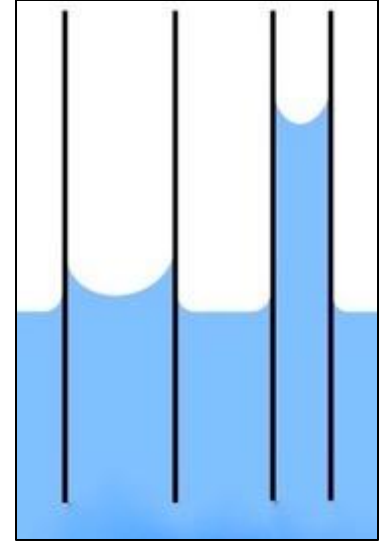
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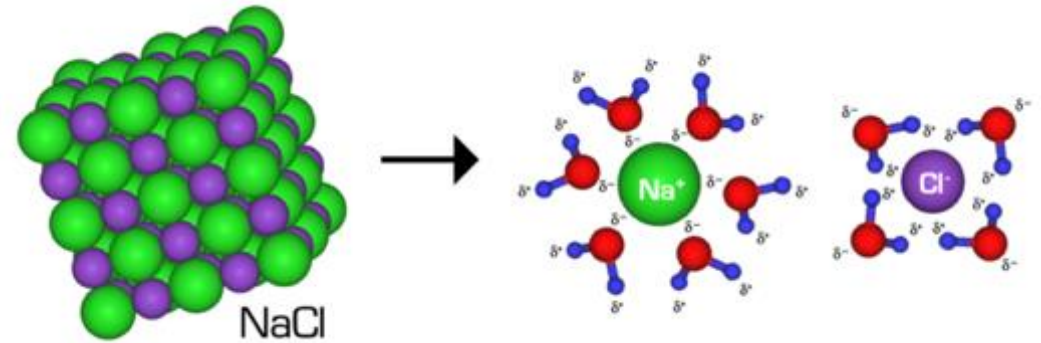


# Sugar + Oxygen $\rightarrow$ Carbon Dioxide + Water + Cellular Energy

- 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<sub>2</sub>O 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.



If pH < 7, the solution is **acidic**       $\text{OH}^- < \text{H}^+$

If pH > 7, the solution is **basic**       $\text{OH}^- > \text{H}^+$

If pH = 7, the solution is **neutral**       $\text{OH}^- = \text{H}^+$



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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 than 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 than 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  $\text{H}^+$  exceeds that of the  $\text{OH}^-$ , 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  $\text{H}^+$  exceeds that of the  $\text{OH}^-$ , 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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