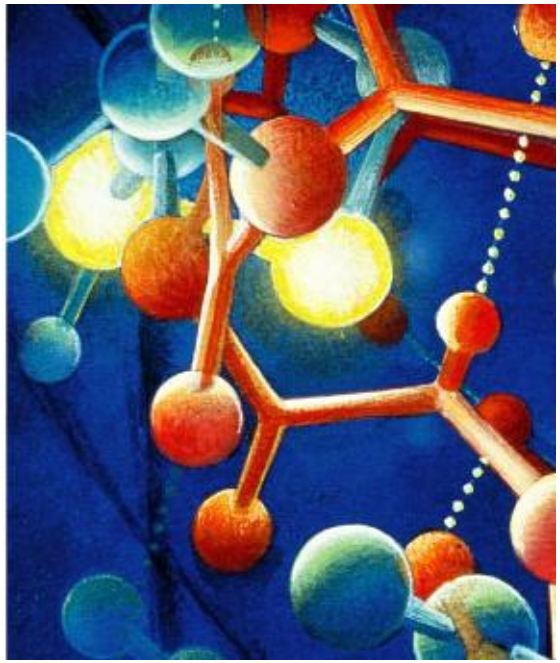
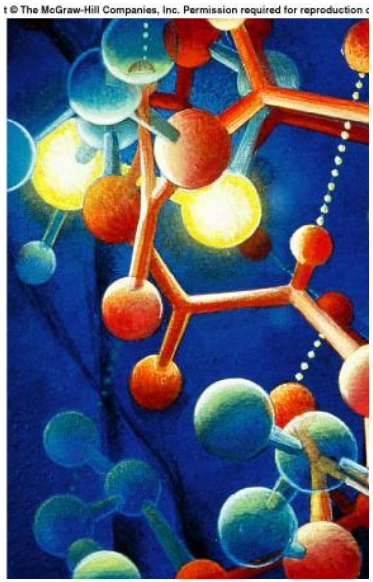
- CHAPTER 2



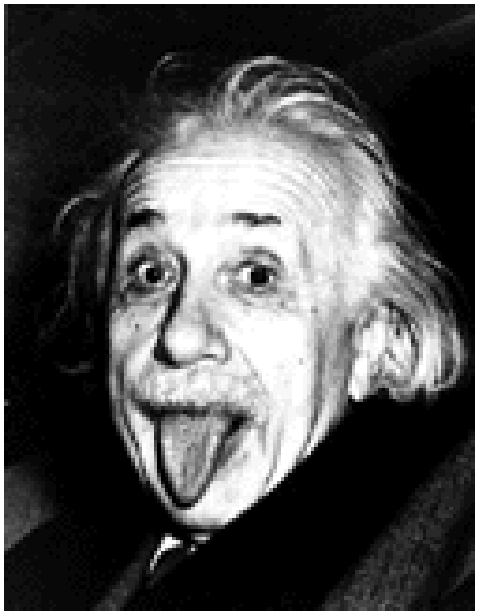
Life depends on chemical and molecular reactions

atoms and molecules



laws of physics and chemistry

Matter - takes up space has mass



Energy - capacity to do work
(move matter)

Related

$E = mc^2$ (Einstein's equation – rest energy)

E = energy

m – mass (in this case matter at rest)

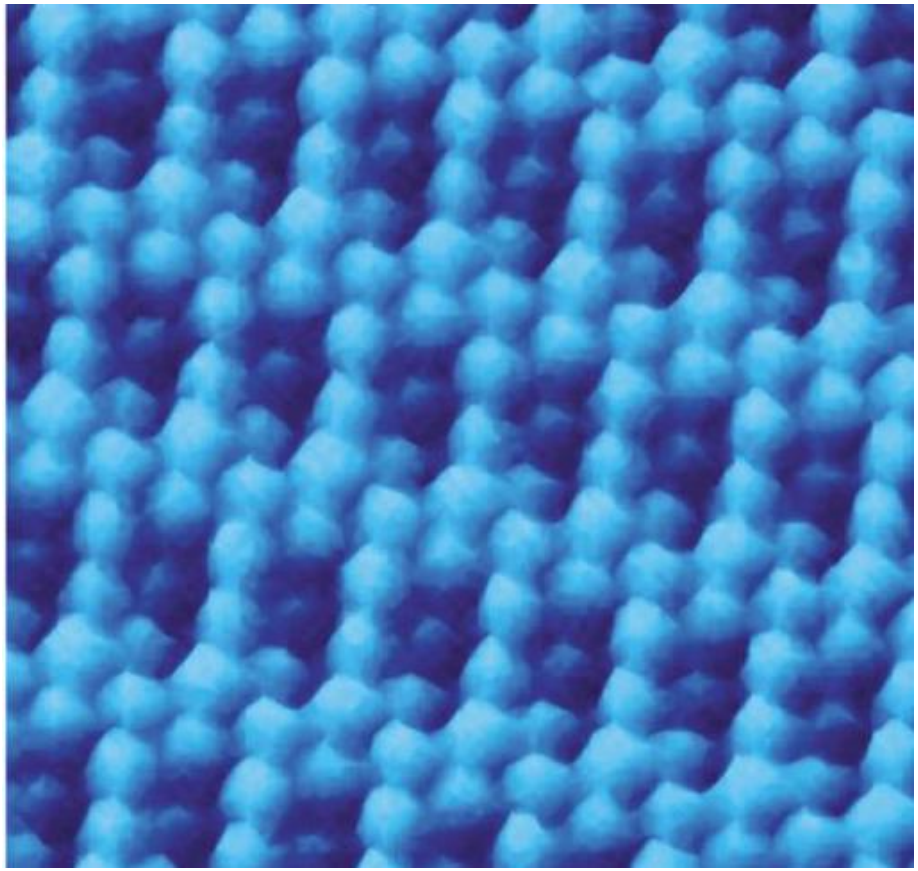
c = speed of light (299,792,458 m/s = 186,000 miles/s)

c^2 =??

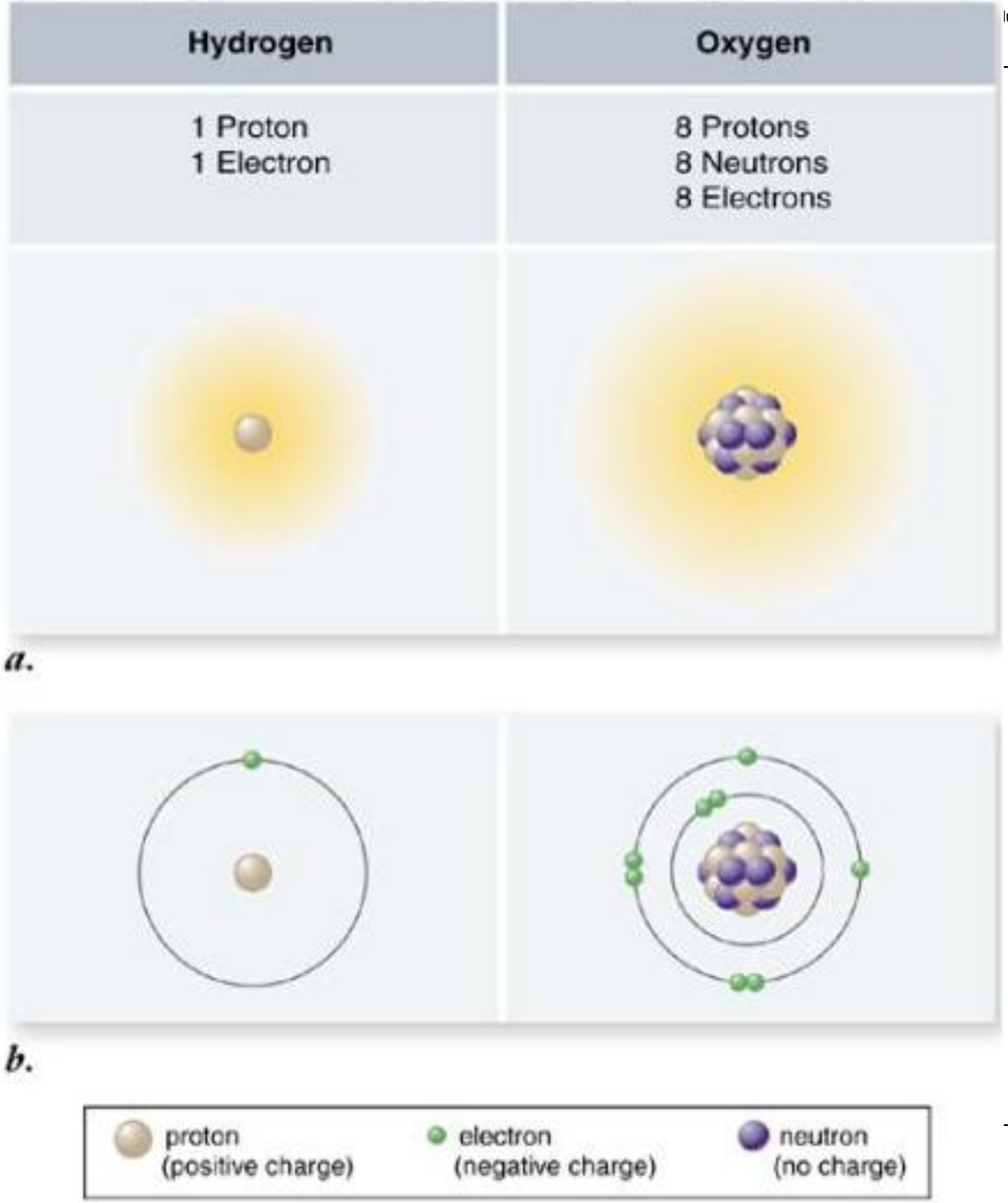
Matter consists of Atoms
Atomic structure determines behavior

- **atom** - smallest unit of matter that retains element's properties

  – composed of subatomic particles



luction or display.



neutrons and **protons** form atomic nucleus

Atoms -mostly empty space!

- **Electrons** form a cloud around the nucleus.

nucleus = golf ball 

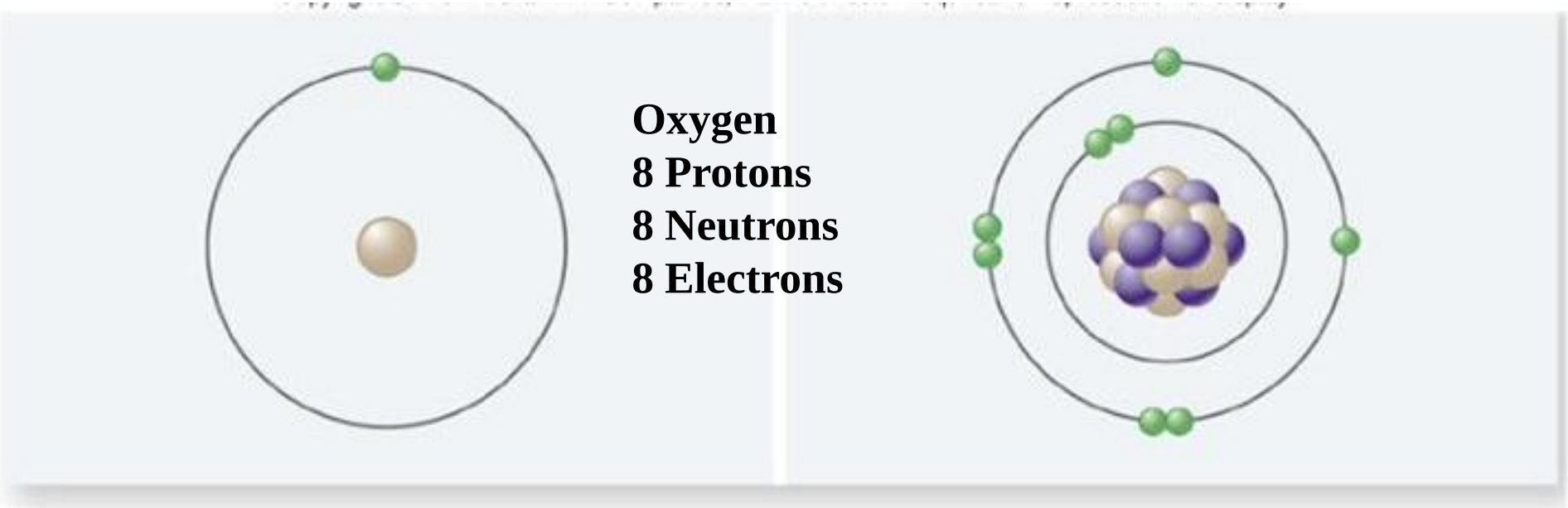
- electrons >1 kilometer (.62 miles)

schematics
useful
deceptive

mass measured in daltons

Proton, neutron = 1 dalton each

- mass of electron = about 1/1840 of neutron or proton
  - ignore when determining total mass



- **atomic weight** approximated by mass number

- all atoms of element have same number of protons in their nuclei
  - unique **atomic number**
  - subscript before symbol
  - helium ($_2$He)

    How many electrons does helium have?

- If no net charge = equal numbers of protons and electrons

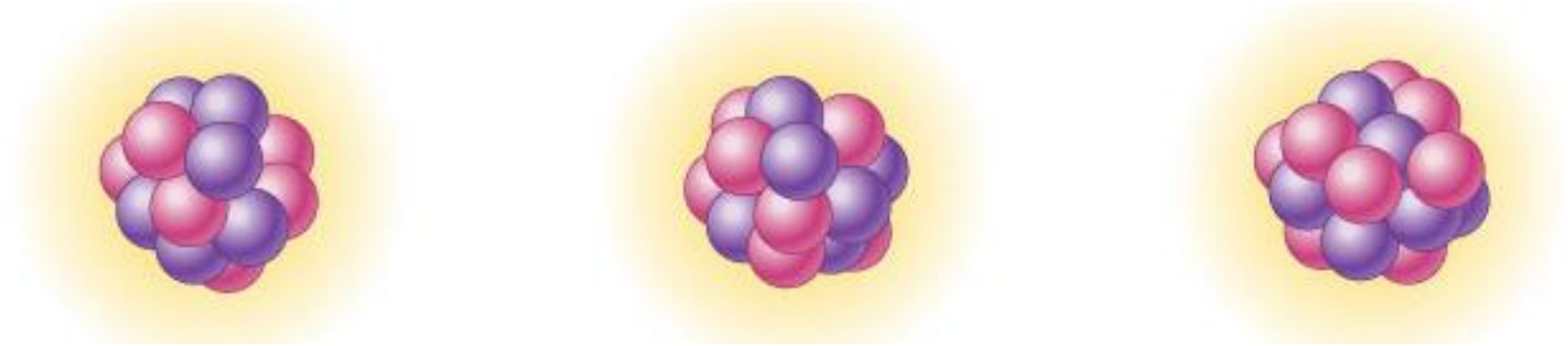
- atomic number in neutral atom depicts number of protons and electrons

- **mass number** = sum of protons and neutrons in the nucleus
  - superscript before symbol (^{4}He)
  - number of neutrons - subtract protons (the atomic number) from mass number
  - Helium 4 – atomic 2 = 2 neutrons
  - ($_{2}He$)
  - (^{4}He)

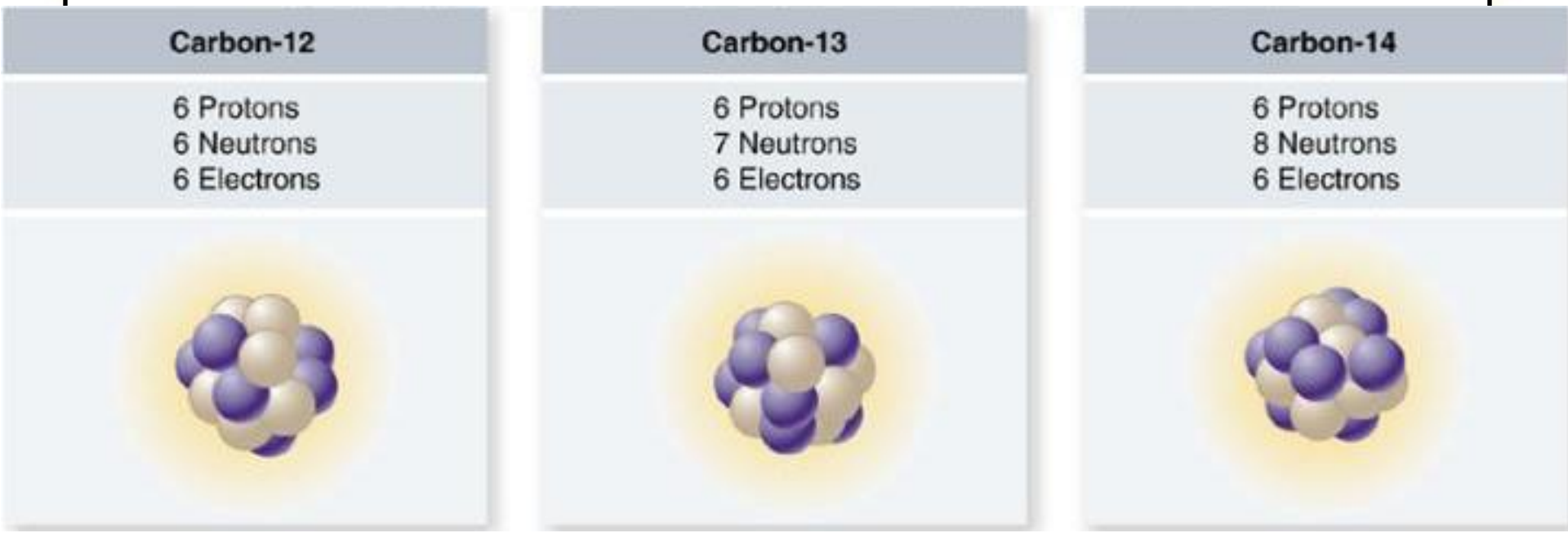
isotopes

- atoms of same element; differ in number of neutrons

- In nature, elements are mixtures



- 99% of carbon atoms have 6 neutrons (^{12}C)
  - some have 7 neutrons (^{13}C)
  - few have 8 neutrons (^{14}C)



- Most isotopes are stable (do not tend to loose particles)
- ^{12}C and ^{13}C are stable

- some isotopes are unstable - decay
- emit particles and energy.
  - ^{14}C is unstable (**radioactive)**

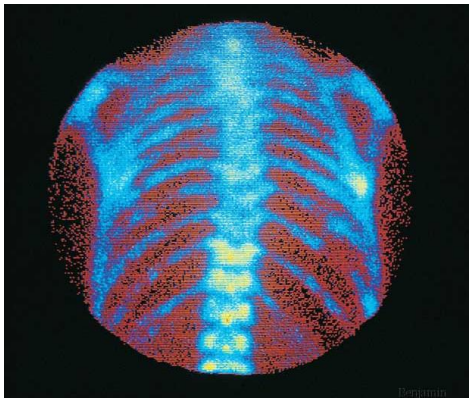
  - decay - neutron converted to proton and electron

1) Changes the identity of atom
2) Is constant
3) Can be measured – HALF LIFE

Radioactive isotopes -many applications

- ^{14}C is **radioactive isotope**
- In decay, a neutron is converted to a proton and electron.
- converts ^{14}C to ^{14}N, changing identity
- Radioactive decay rates are used to date fossils

•decay can trace cancer



(cancerous bone concentrates more isotope)

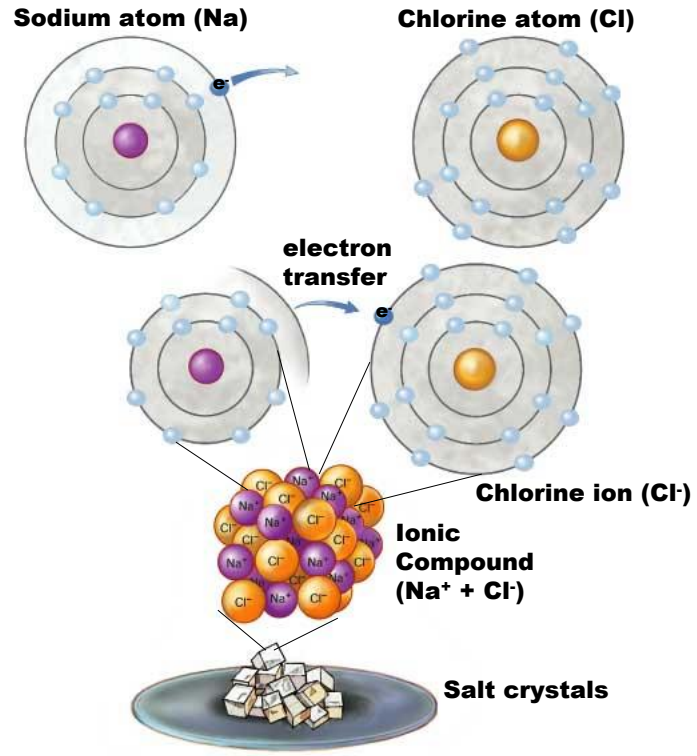
- energy emitted in decay can be hazardous
- destroys cellular molecules
  - depends on type and amount absorbed

ELECTRONS

- When two elements interact in chemical reaction

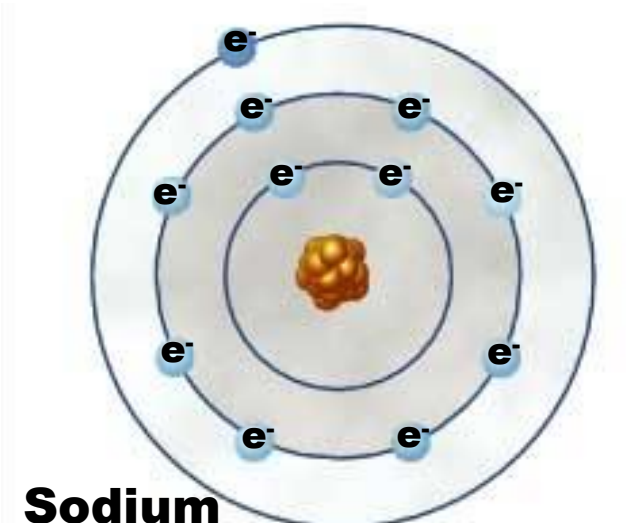
<u>electrons</u> are involved

nuclei - not even close



- Electrons have **potential energy**

position relative to the nucleus



− electrons attracted **+** nucleus

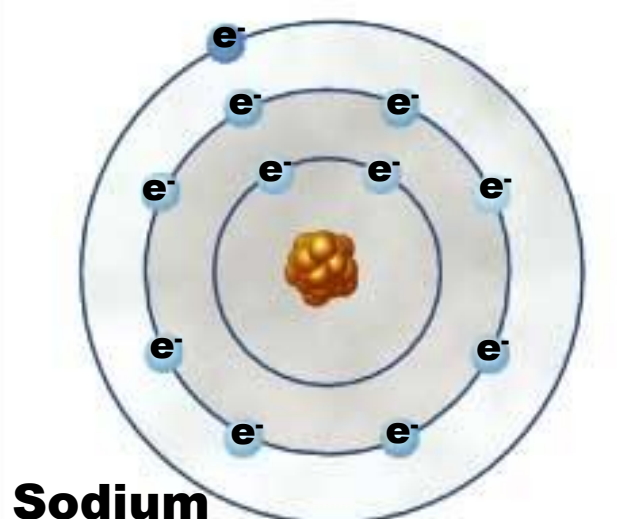
- farther from nucleus, more potential energy

- **Energy -** ability to do work

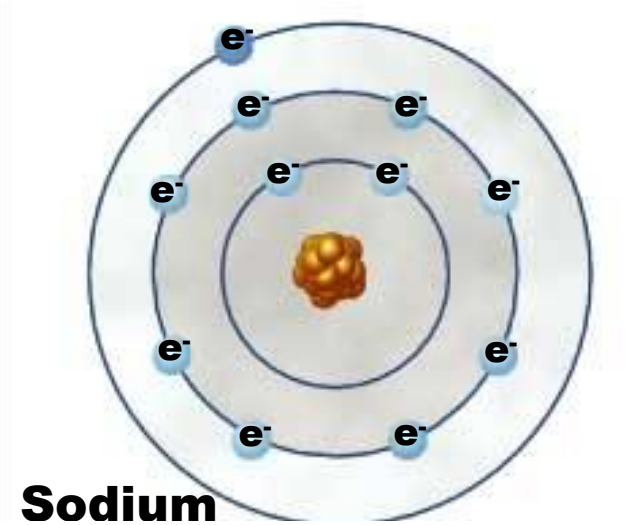
- **Potential energy -** energy that matter stores because of its position or location.

  - Water /levee has potential energy
  - Rushing water has kinetic energy

- 1st electron shell - 2 electrons
  - The two electrons fill the first shell.
- other shells - up to 8 electrons.



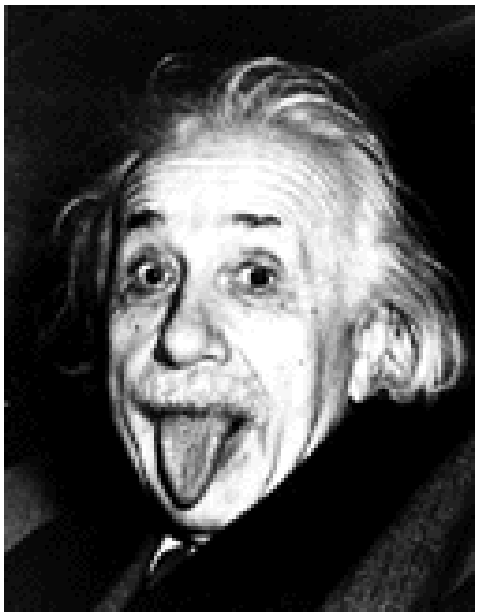
- chemical behavior - depends number of electrons in outermost shell (**valence shell)**
  - **valence electrons**



- completed valence shell -unreactive
- others - chemically reactive

excited electrons absorb energy

return to shell & release energy

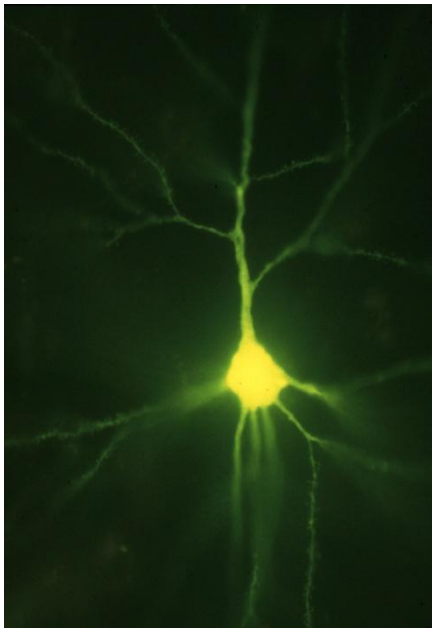


Heat

Neon gas

Fluorescing tracers

- short-lived
- Einstein



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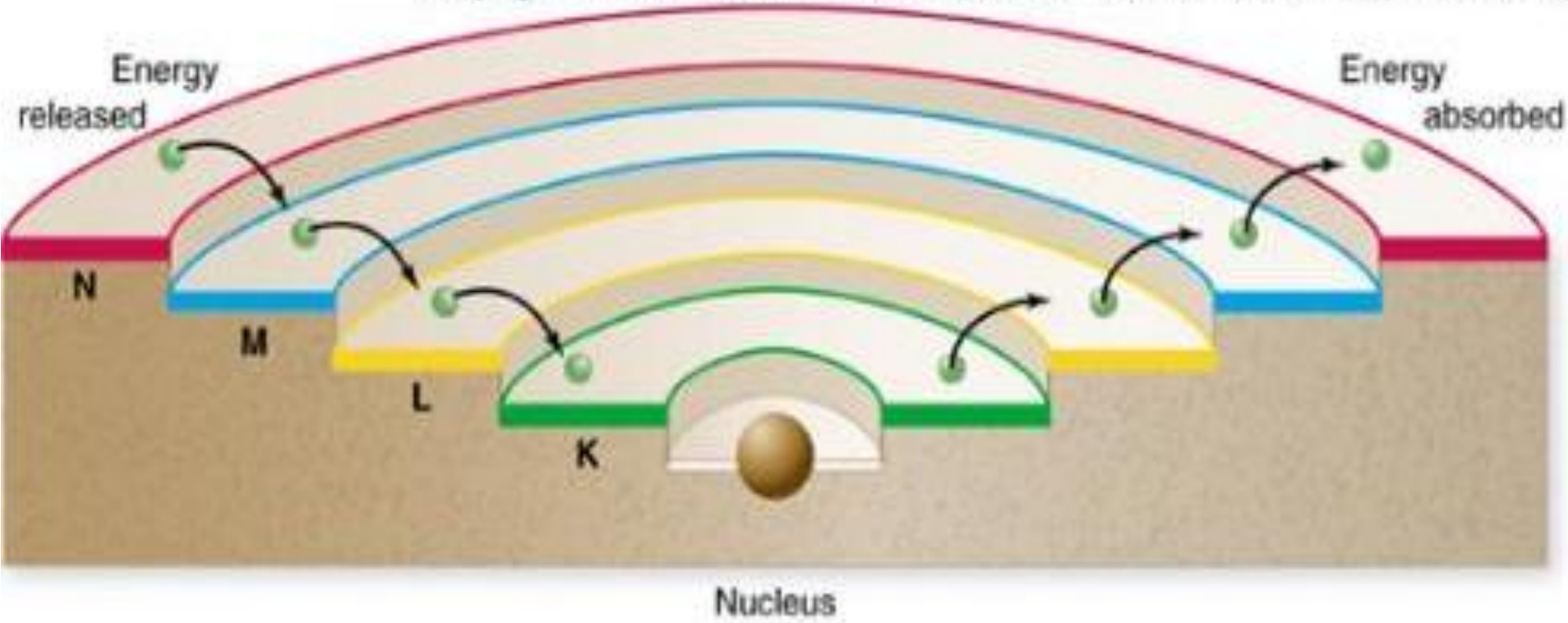
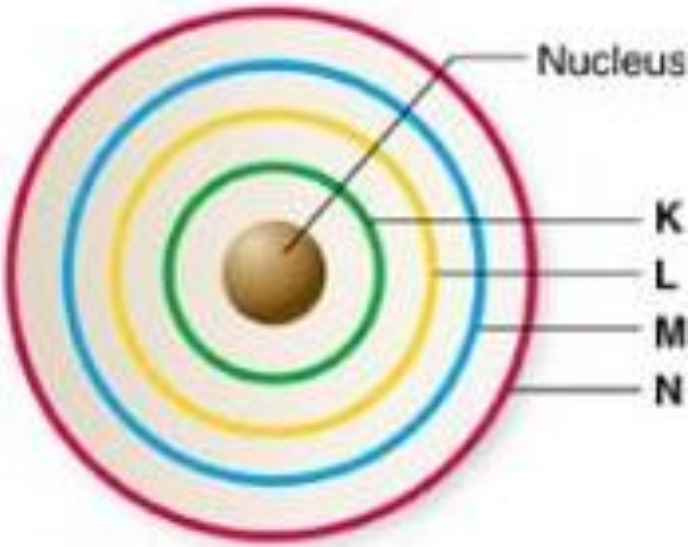
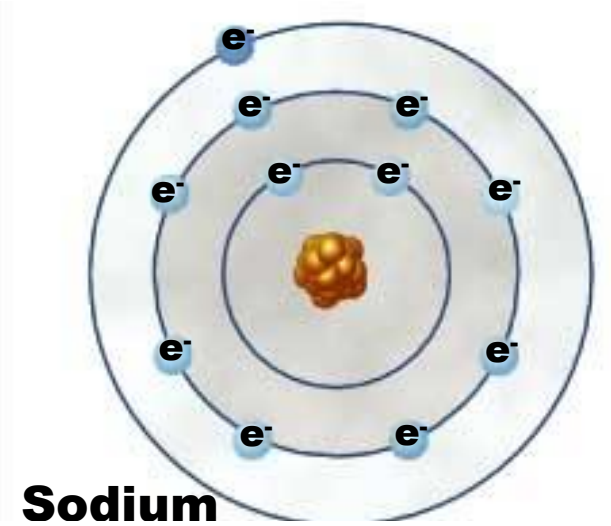




– to complete valence shells:
  - share electrons
  - transfer electrons
  - receive electrons



– interactions form <u>chemical bonds</u>

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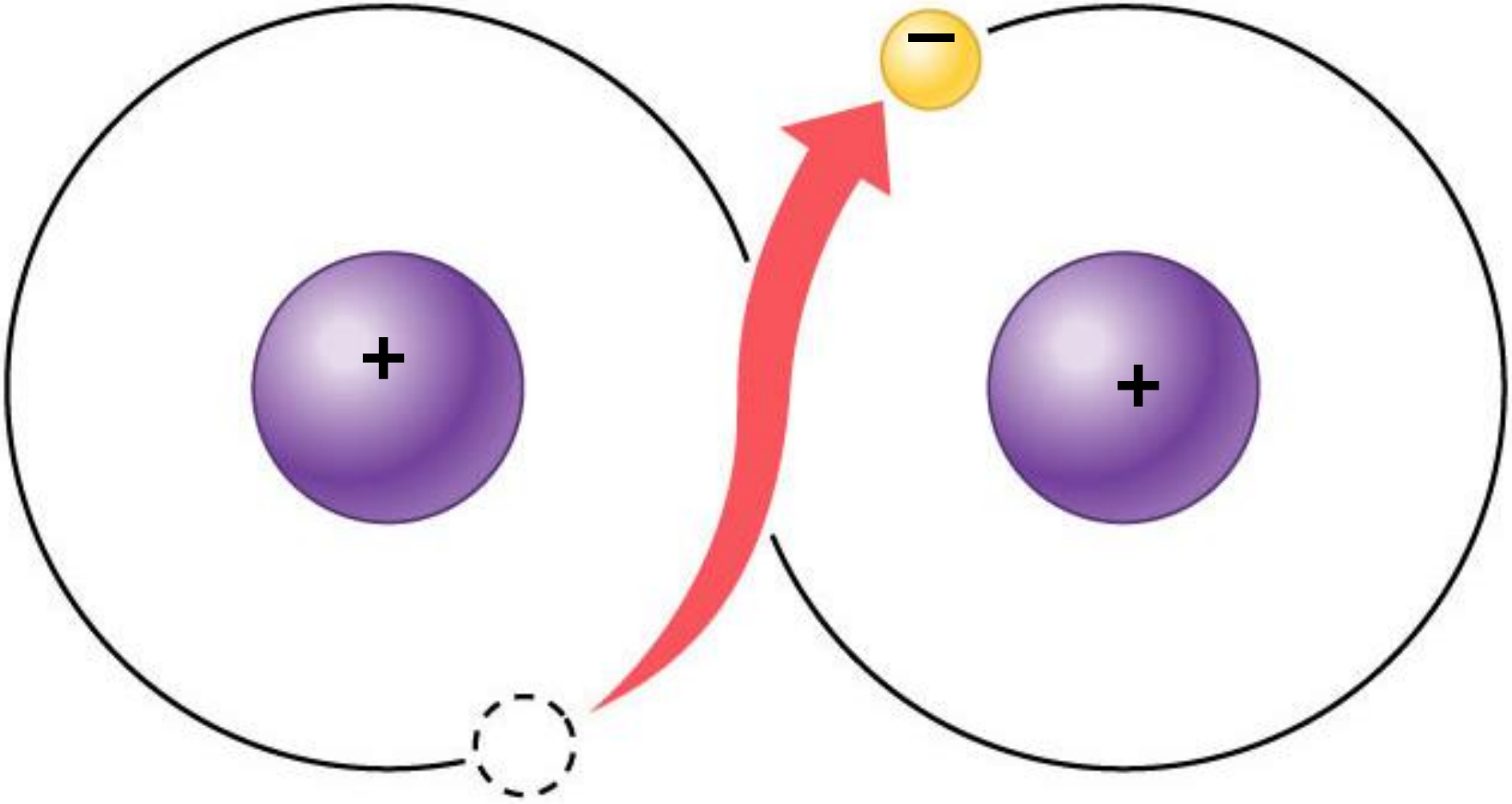
- losing electrons – oxidation
- gaining electrons - reduction



Oxidation **Reduction**

WHY??

- THINK NEGATIVE!!

- gaining negative electron - reduced

- losing negative electron – oxidized

OIL RIG

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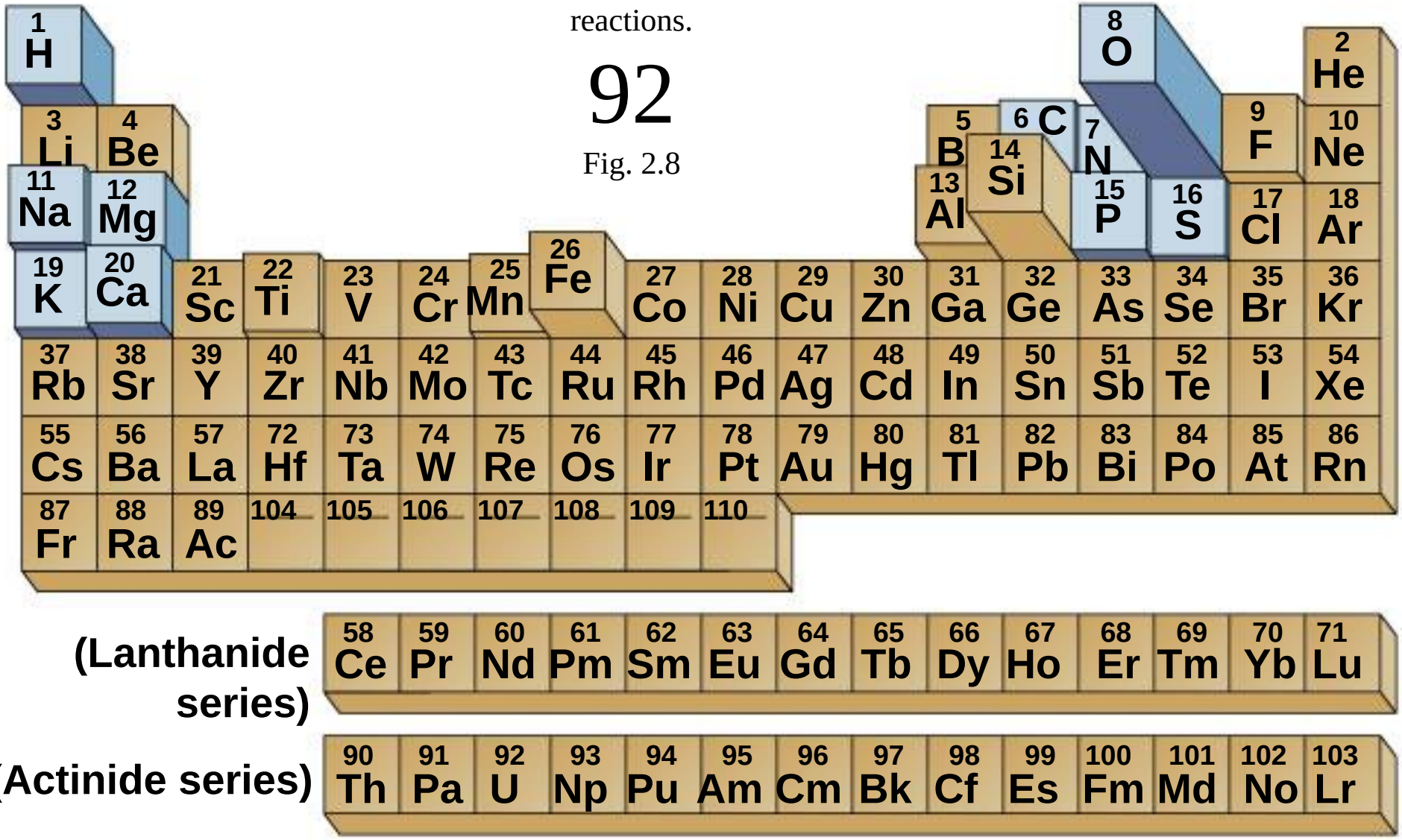
element - substance that cannot be broken down to other substances by chemical reactions.

92

Fig. 2.8

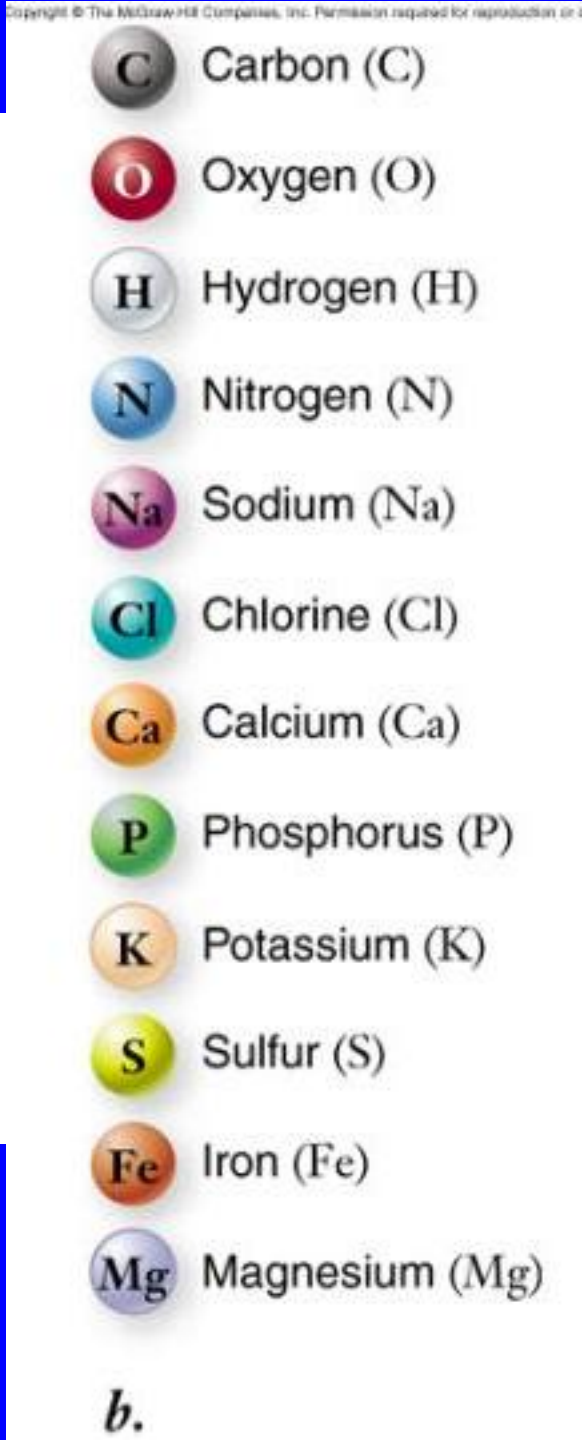


- Each element - unique atoms

- 25 of the 92 elements -essential for life

– 4 elements (96.3 %)

1. carbon (C)
2. oxygen (O)
3. hydrogen (H)
4. nitrogen (N)
   - (know these 4 well)



– H_2 hydrogen gas

2 atoms of hydrogen

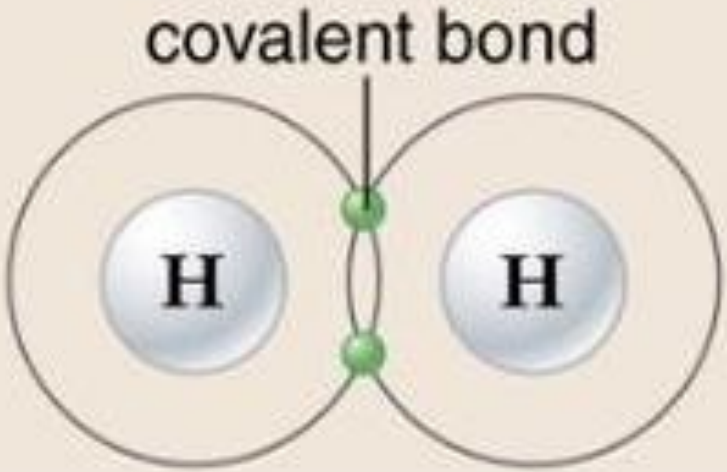
make 1 molecule

Stable (No charge, no unpaired electrons, valance shell filled)

Single covalent bond

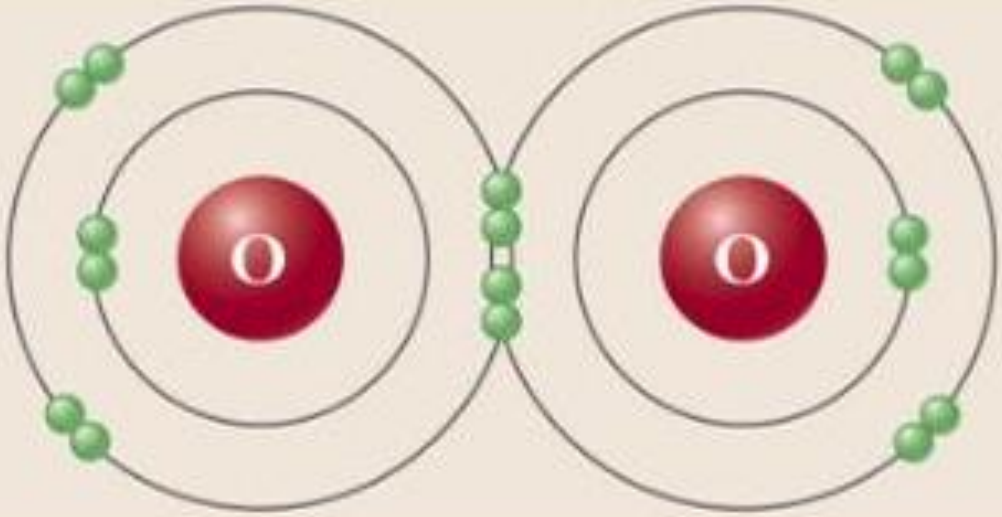
hydrogen gas

H—H H_2



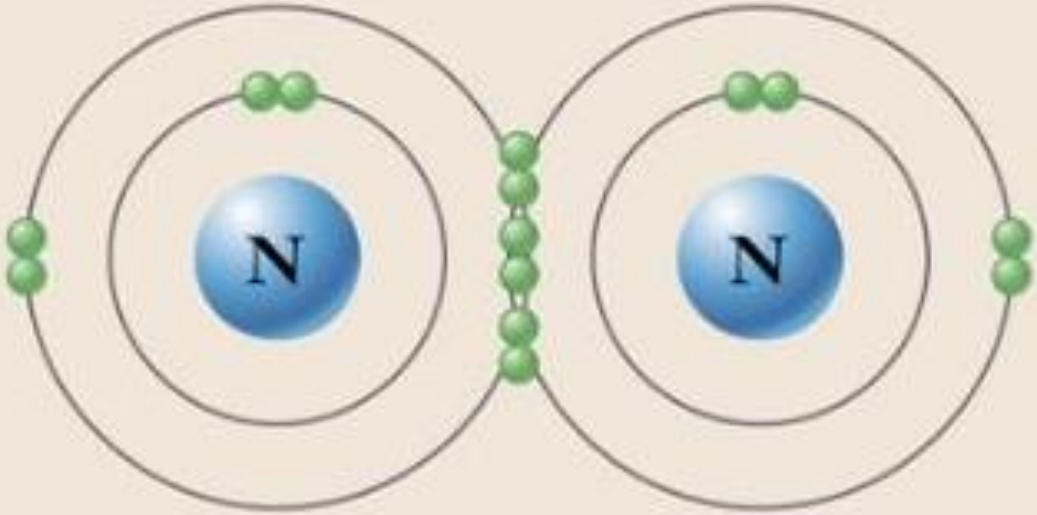
Double covalent bond
oxygen gas

$O{=}O$ O_2



Triple covalent bond
nitrogen gas

$N{\equiv}N$ N_2



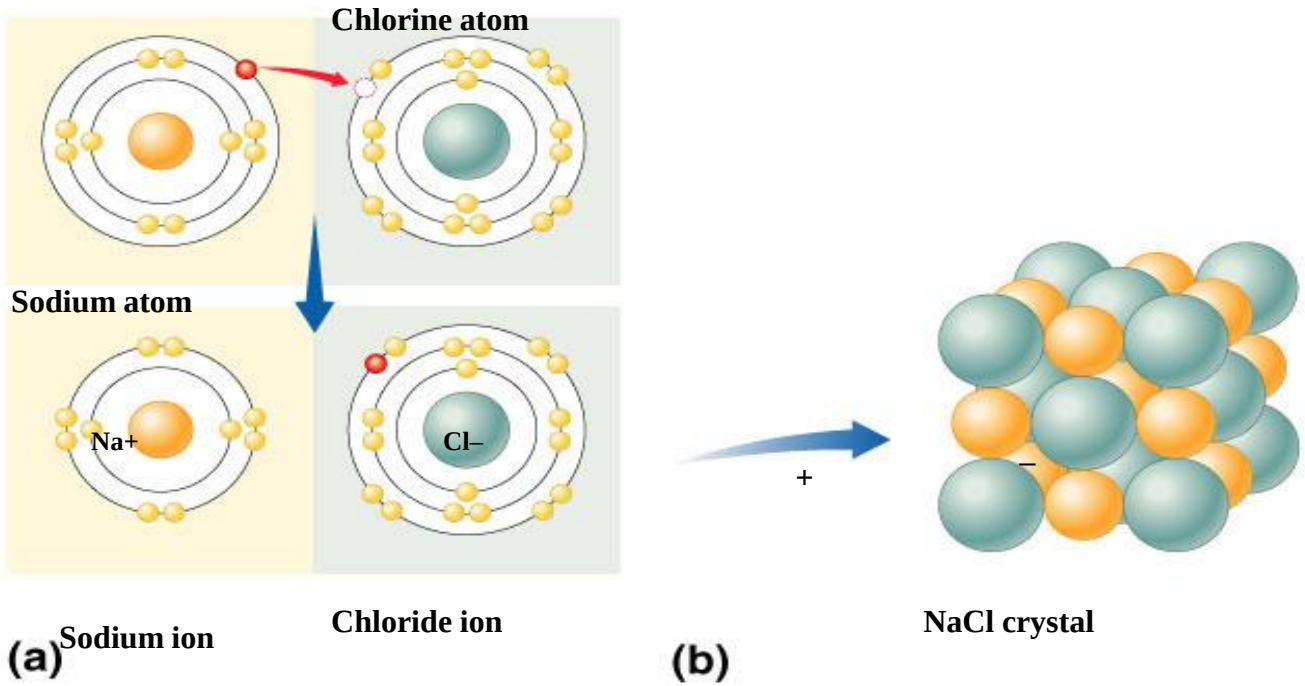
- **compound**
  - two + elements
  - fixed ratio

sodium (metal)

chlorine (gas)

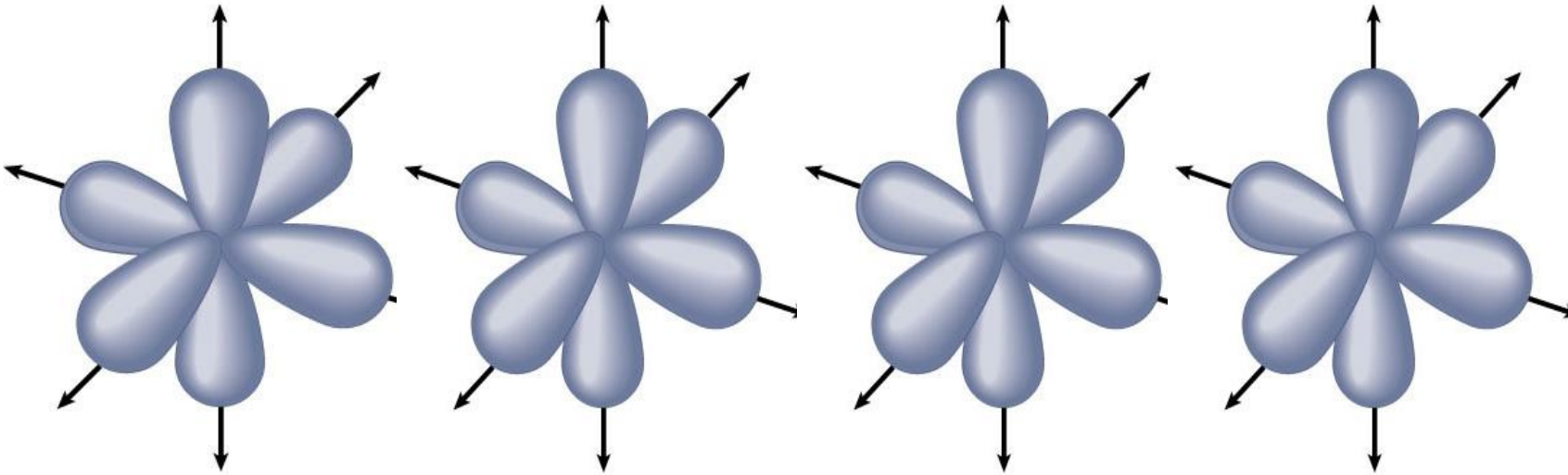
–combination?

an **emergent** property!!



biological function related to shape

- The shape determined by arrangement of shared orbitals



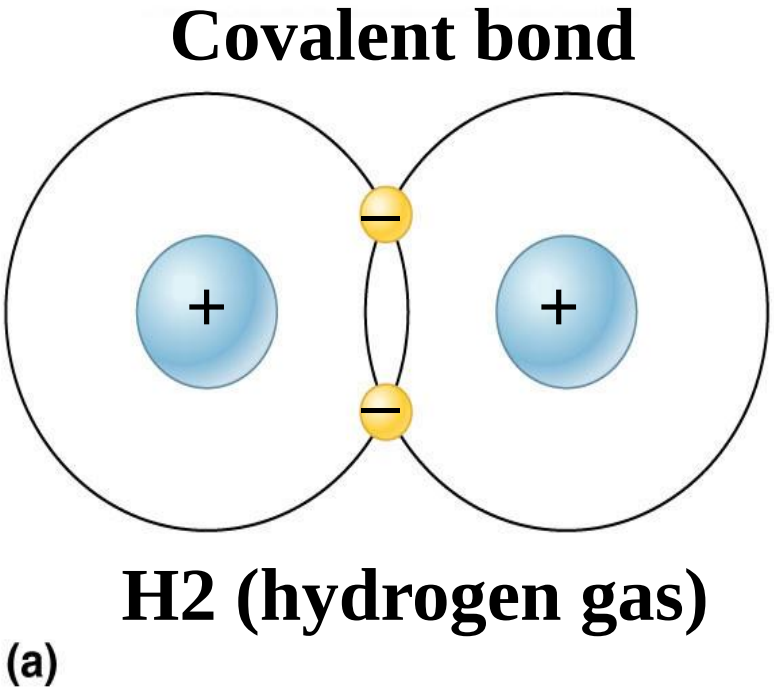
electron interactions form

- **chemical bonds**

- Strongest chemical bonds
  - **Covalent** (water)
  - **Ionic**

- Weaker (water)
  - Hydrogen bond

- 1) **covalent bond -** sharing of a pair of valence electrons by two atoms
  - hydrogen atom- 1s orbitals overlap, share their electrons



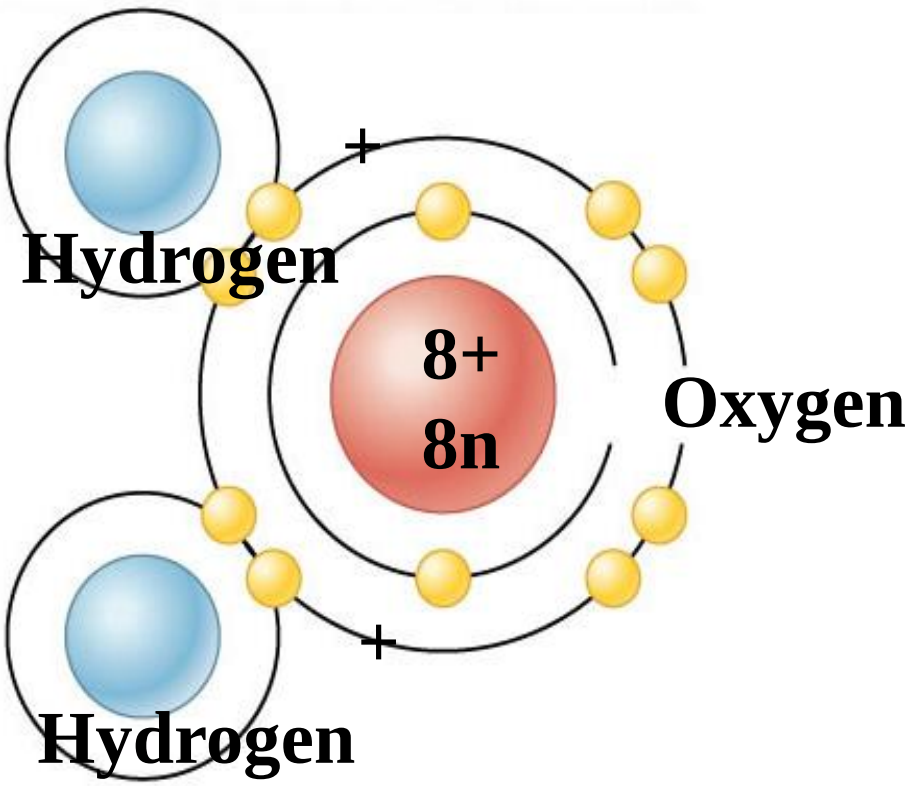
covalent = sharing

- Covalent bonds -also different elements

- What is water?

- Is bond covalent? single or double?

- Are valences satisfied?



- Oxygen add 2 electrons to 6
- complete valence shell.

– double covalent bond

covalent bonds – polar or nonpolar

POLAR????

- attraction of an atom for the electrons of a covalent bond - **electronegativity**
  - Strongly electronegative atoms try to pull shared electrons toward themselves.

  (THINK SELFISH!!)

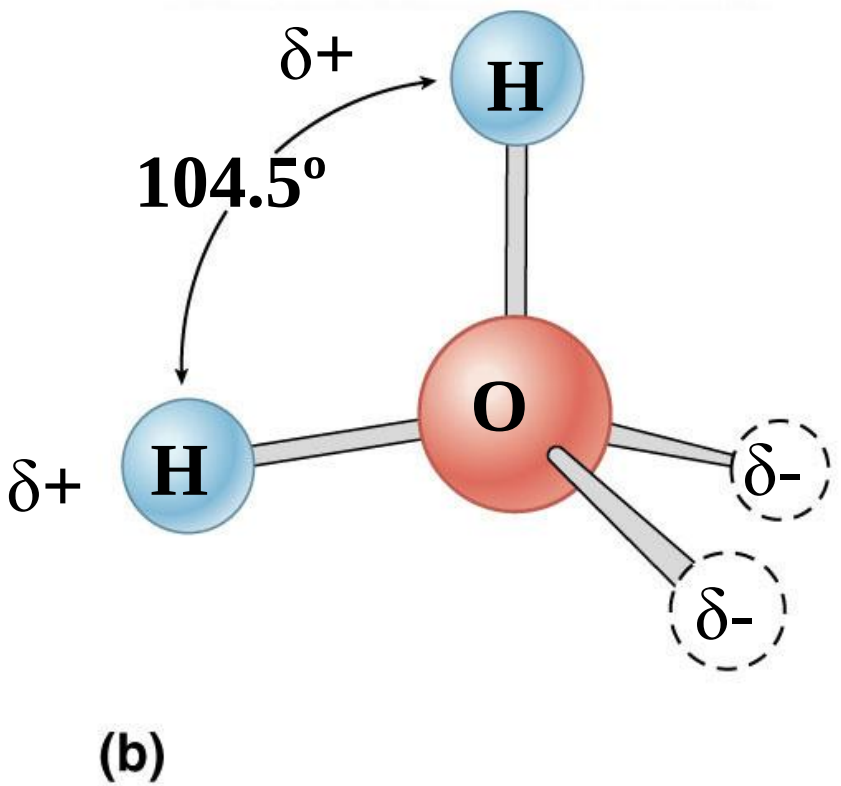
- If equally- **nonpolar covalent bond**

- If electrons <u>not shared equally</u> –

polar covalent bond

water

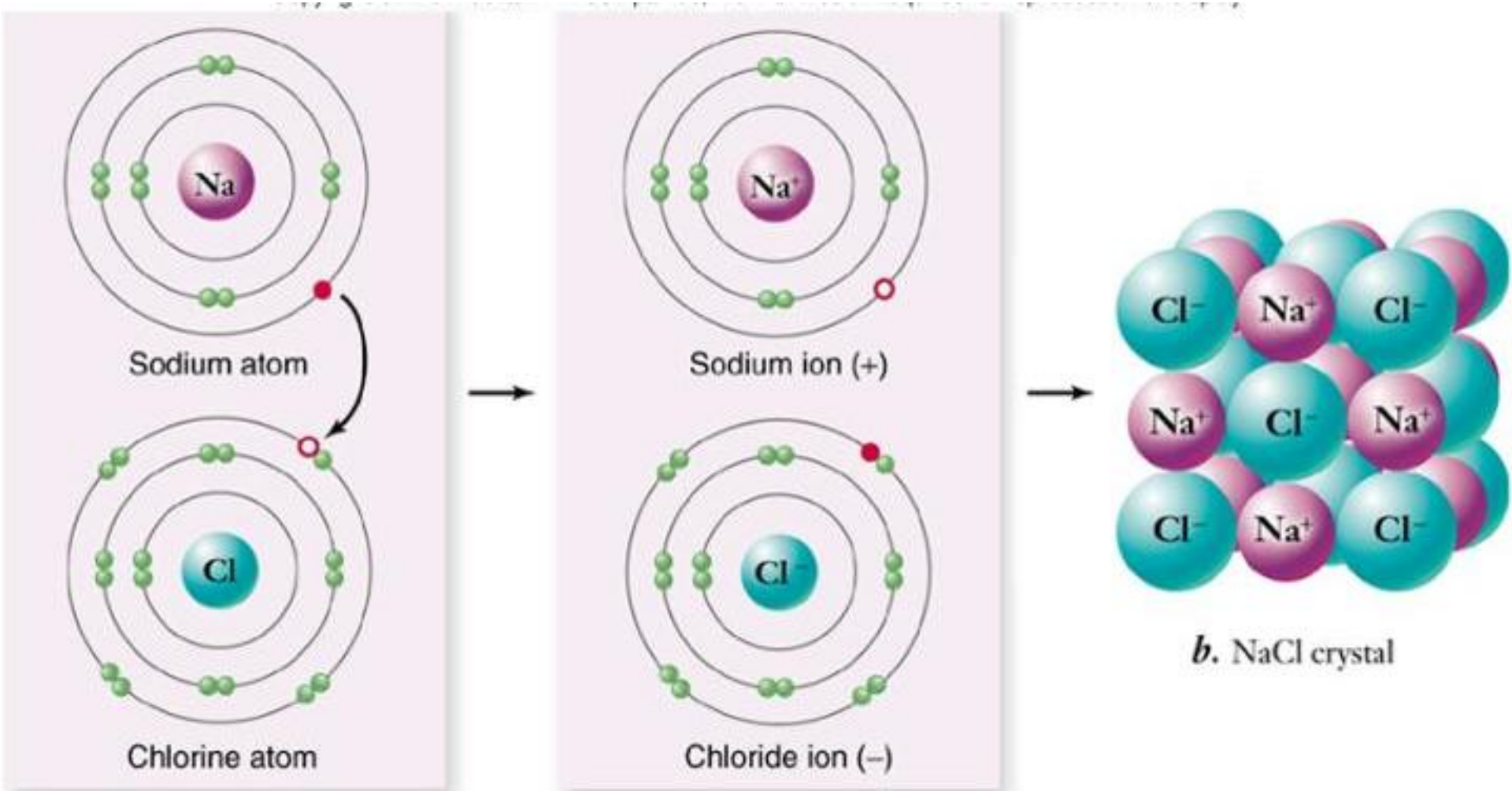
polar covalent?



oxygen higher electronegativity than hydrogen

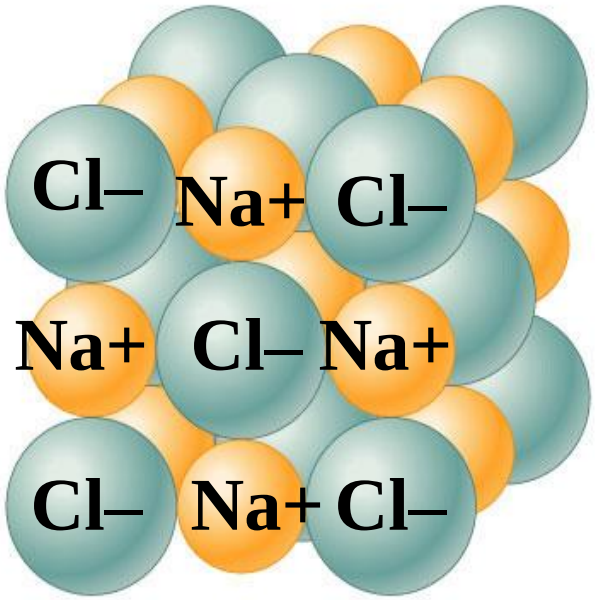
- 2) **ionic bond -** unequal attraction for valence electrons

- one atom strips electron from other



- atoms now have charges – **ions**

- Why?
- Sodium one more proton than electrons - net positive charge – **cation**



(b)

- Chlorine - one more <u>electron</u> than protons - net negative charge - **anions**

- differences in charge
- cations and anions attracted
- **ionic bond**

ionic compounds, **salts,** (NaCl)

- strength depends

<u>on environmental conditions</u>

dissociate in water?

- **3) Hydrogen bonds (weaker)**

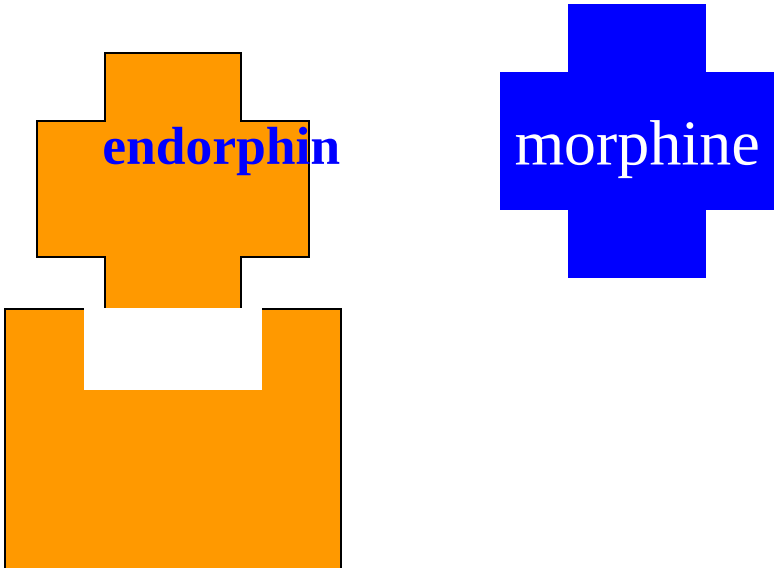
link covalently bonded hydrogen with electronegative atom

  - typically hydrogen and nitrogen or oxygen

  - important in DNA molecules

<u>weak</u> chemical - important

- Molecules -similar shapes interact similar ways
  - morphine, heroin, similar shape to natural endorphins
  - produces euphoria
  - relieves pain



WEAK Good -

signal molecules bind briefly to receptor molecules

WEAK BAD

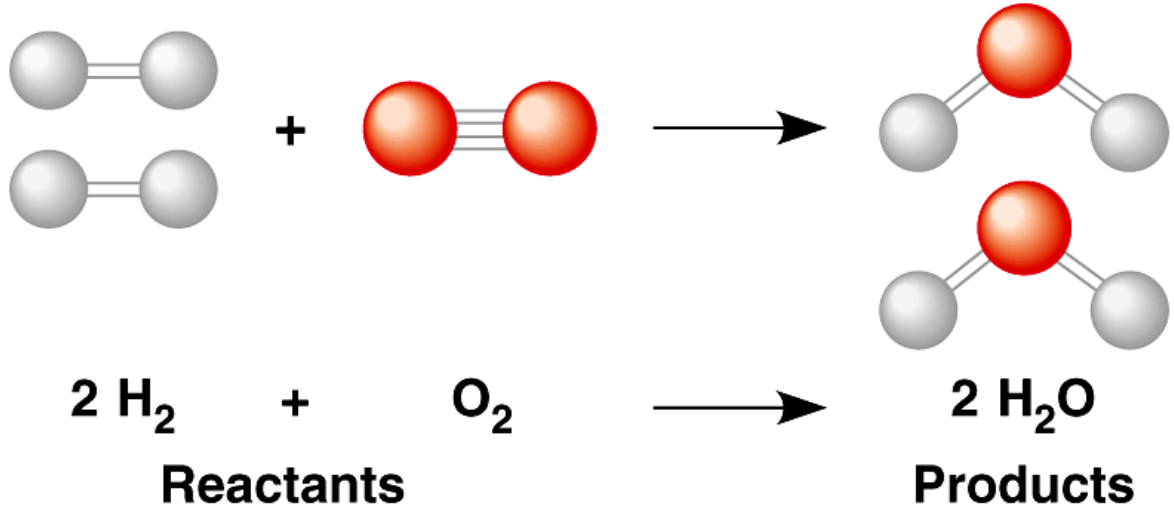
Free radicals – unpaired electrons

blood - irritate artery walls, fat deposits build up

- mutate DNA
- damage mitochondria

- producers - cigarettes, x rays, sunlight, alcohol, etc.
- scavengers – beta carotene, vitamin C, vitamin E

- **In chemical reactions** -bonds broken and reformed
- new arrangements of atoms



- starting molecules -**reactants**
- end molecules - **products**

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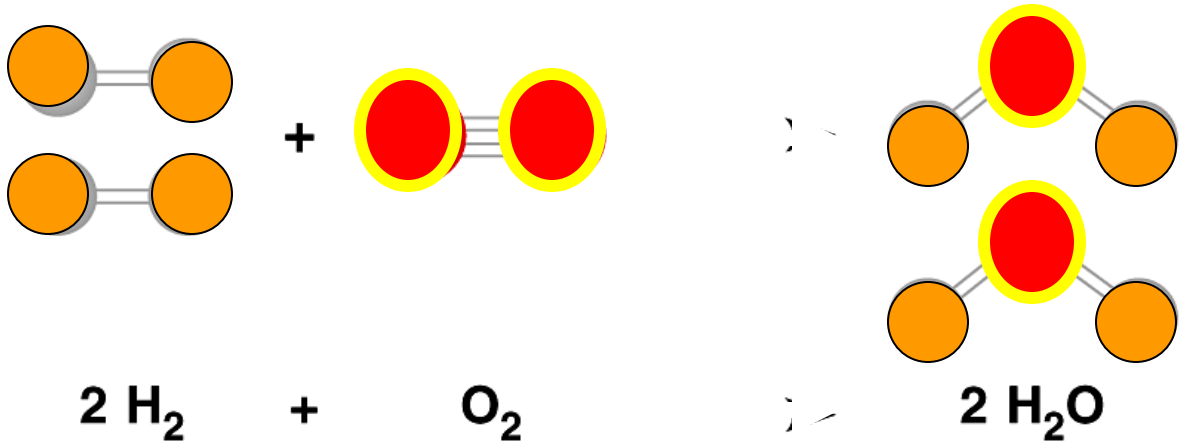
ratios - indicated by coefficients



which are reactants? which are products? balanced?????

- equilibrium???

- no new product?
- no change?
- no net change?

water

liquid

ice

vapor

life evolved in water

surface >70%

- 3 billion years in water first
  - tied to water?

solvent of life

- cells -75->85% water

- How long can we live without water?

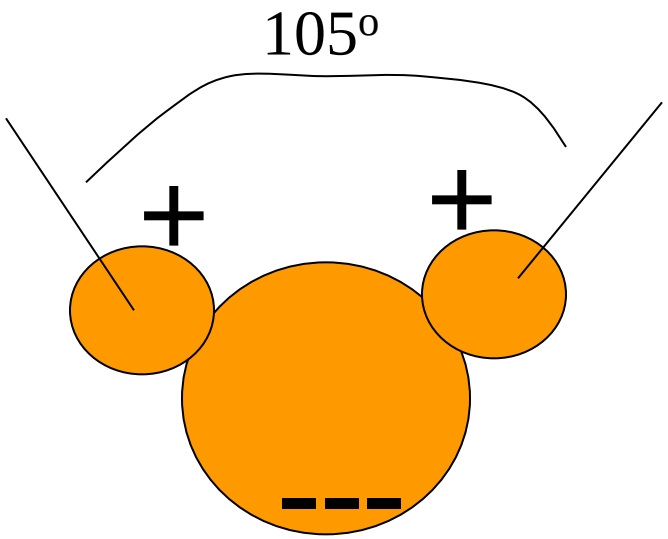
- cohesion
- adhesion
- surface tension
- temperature stabilization
- expands when frozen
- solvent

water is a polar molecule

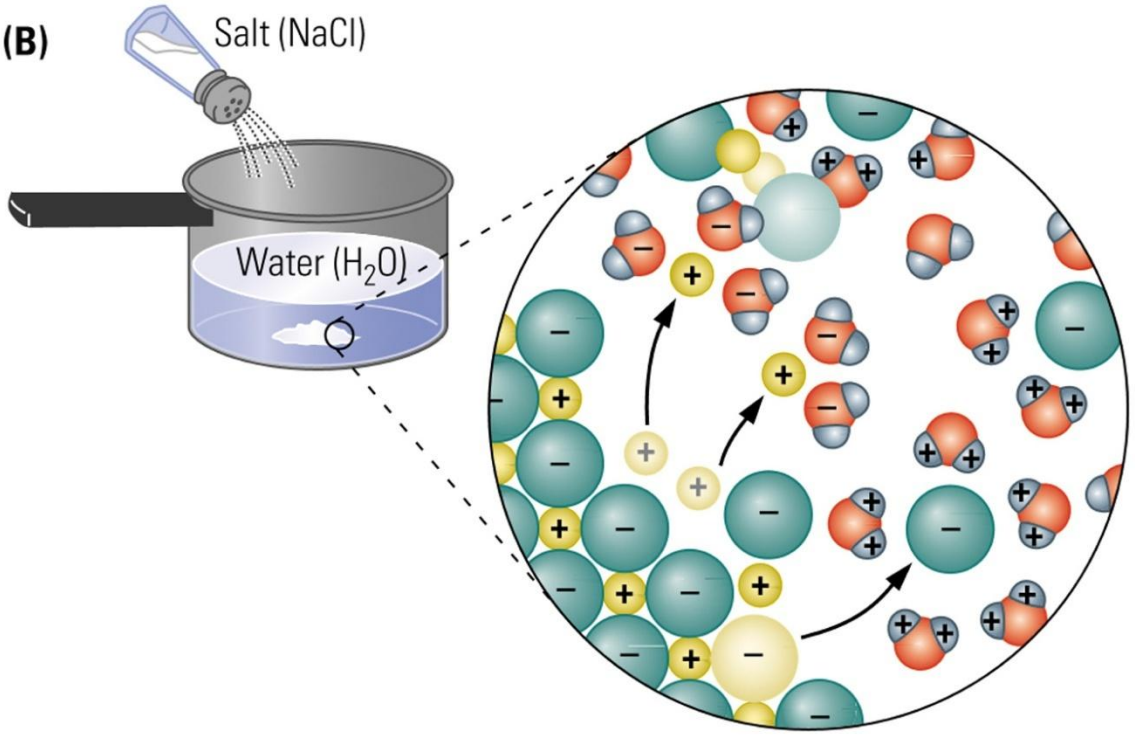
Opposite ends ; opposite charges

- oxygen more electronegative

electrons <u>not shared equally</u> **- polar covalent bond.**



Polarity = difference in electrical charge at one end of a molecule as opposed to the other



- Water Polar or non polar?
- oxygen end partial negative hydrogen end partial positive

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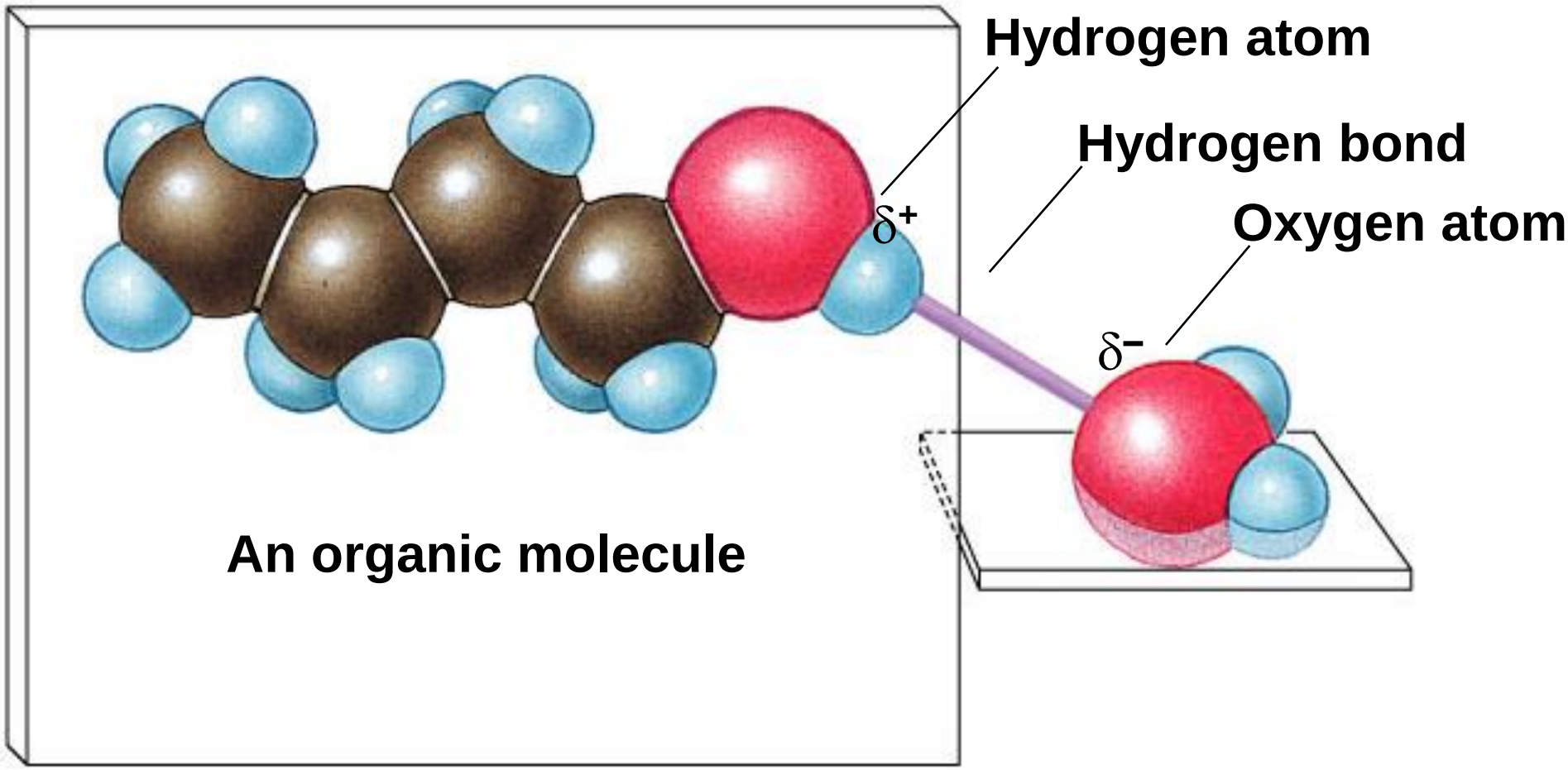
tiny magnets – poles have charges



hydrogen bonds!!!

solution salt water

solute salt

solvent water

Like dissolves like

polar - salt and water

non polar- soap and grease

Cohesion

- water molecules stick to each other

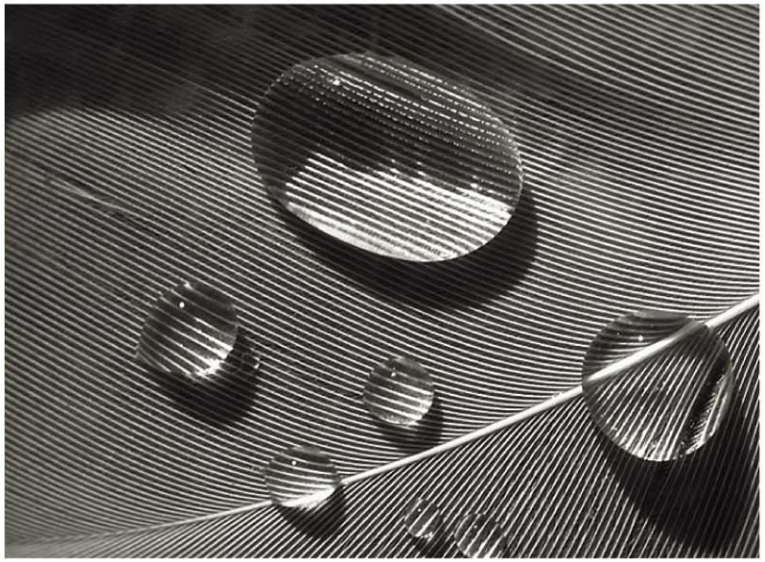
- results of H-bonds

SURFACE TENSION

Adhesion

water molecules stick to other substances

- Result of H-bonds
- meniscus



- **More Water appreciation facts**

– HIGH Specific heat

– **boil a pan of water**

- lots of energy needed to change temperature of water
- WHY???

collective effect of H-bonds

- Heat absorbed to break hydrogen bonds
- Heat released when hydrogen bonds form

- Energy used to disrupt hydrogen bonds
- not move molecules faster

  - Sweats cools - heat energy used to break H-bonds

Temperature Moderation

- absorb/release large quantities of heat

with little change in temperature

- **heat** – total kinetic energy

- **temperature** – average kinetic energy

- specific heat – amount absorbed or lost for 1 g of substance to change temp by 1 degree

- difference between a **calorie** (cal.) and "Calories" on food packages?

- calorie - amount of heat energy necessary to raise temperature of one g of water by 1^{o} C.

One mL water?

- Calorie on food packages - kilocalorie

the amount of heat energy necessary to raise the temperature of 1000g of water by 1^{o}C.

- vaporization or evaporation –
- transformation from liquid to a gas

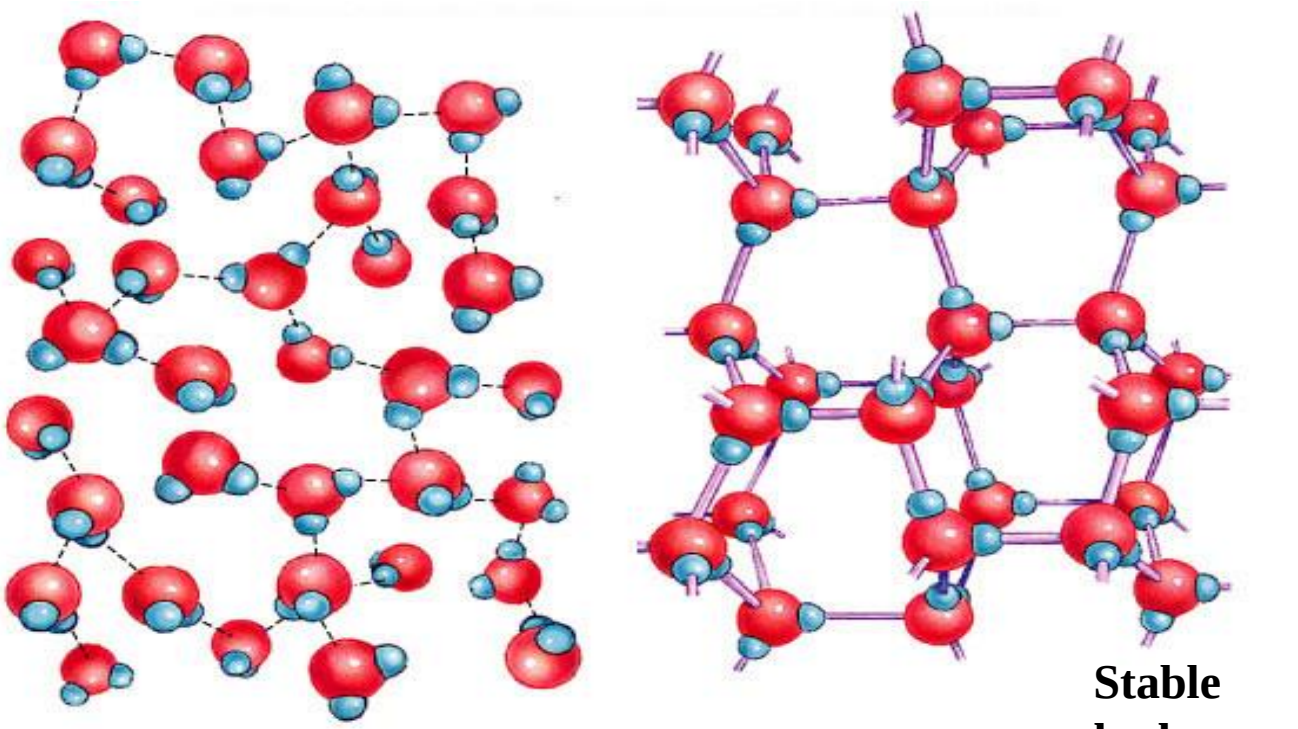
- molecule move so fast - overcome the attraction of molecules in liquid
  - Even in low temperature liquid
  - (low average kinetic energy)
  - some molecules move fast

  - even in ice! (sublimation)

- **evaporative cooling**
  - the most energetic molecules evaporate
  - lower kinetic energy molecules stay
- Evaporative cooling - moderates temperature in lakes, etc.
  - helps stop us from overheating

– at 0°C lattice

– (ice crystals and snow)



Why live by the lake?

"Heat sink"

<u>Equilibrium</u>

two objects of different temperatures meet, heat (energy) passes from warmer to cooler

Molecules in cooler object speed up at expense of kinetic energy of warmer object

Ice cools by absorbing heat

Table 2.3

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TABLE 2.3 The Properties of Water

Property	Explanation	Example of Benefit to Life
Cohesion	Hydrogen bonds hold water molecules together.	Leaves pull water upward from the roots; seeds swell and germinate.
High specific heat	Hydrogen bonds absorb heat when they break and release heat when they form, minimizing temperature changes.	Water stabilizes the temperature of organisms and the environment.
High heat of vaporization	Many hydrogen bonds must be broken for water to evaporate.	Evaporation of water cools body surfaces.
Lower density of ice	Water molecules in an ice crystal are spaced relatively far apart because of hydrogen bonding.	Because ice is less dense than water, lakes do not freeze solid, allowing fish and other life in lakes to survive the winter.
Solubility	Polar water molecules are attracted to ions and polar compounds, making them soluble.	Many kinds of molecules can move freely in cells, permitting a diverse array of chemical reactions.

Water forms bonds

dissolves **hydrophilic** molecules

Hydrophobic molecules do not

readily form bonds with water.

pH

- Occasionally, a hydrogen atom shared by two water molecules shifts from one molecule to the other.

$$\mathbf{H20} \rightarrow \mathbf{OH^-} + \mathbf{H^+}$$

water hydroxide ion hydrogen ion (proton)

– hydrogen leaves its electron behind and is transferred as a single proton **-** a **hydrogen ion** (H^+).

– The water molecule that lost a proton is now a **hydroxide ion** (OH^-)

(The water molecule with the extra proton is a hydronium ion (H_3O^+))

H20 → OH $^-$ + H$^+$

water hydroxide ion hydrogen ion (proton)

Reaction is reversible

water <=> hydrogen ion + hydroxide ion:

$H_2O <=> H^+ + OH^-$

.

At equilibrium, water molecules greatly exceed H^+ and OH^-.

In pure water only one in every 554 million is dissociated -At equilibrium (RT) conc. H^+ or OH^- is 10^{-7}M .

- hydrogen and hydroxide ions are very reactive!

- changes in concentrations drastically affect the proteins and other molecules of a cell.

- You would die if blood pH changes even a small amount!
  - IN MINUTES!

- Acids donate protons
  - (HCl, vinegar).

- Bases accept protons
  - (NaOH, lye).

- what **is** a protron?

(what happens when hydrogen loses an electron?)

SO - Acids donate hydrogen ions

- An **acid** is a substance that increases the hydrogen ion concentration in a solution.
  - When hydrochloric acid is added to water, hydrogen ions dissociate from chloride ions:
    - $HCl \rightarrow H^+ + Cl^-$
- Addition of an acid makes a solution more acidic.

Any substance that reduces the hydrogen ion concentration in a solution is a **base**.

1) Some bases reduce H^+ directly by accepting hydrogen ions.

2) Other bases reduce H^+ indirectly forming water.

- $NaOH \rightarrow Na^+ + OH^-$ $\qquad\qquad$ $OH^- + H^+ \rightarrow H_2O$

Solutions with more OH^- than H^+ are basic solutions.

Some acids and bases (HCl and NaOH) are strong

WE USE THESE IN A WET LAB

These molecules dissociate completely in water

At equilibrium there will be a fixed ratio of products to reactants

NOTE: not an EQUAL ratio

The H^+ and OH^- concentrations of solutions can vary by a factor of 100 trillion or more.

So H^+ and OH^- concentrations are expressed using **pH** scale.

The pH scale, ranging from 1 to 14, compresses the range of concentrations by employing logarithms.

- In a neutral solution
- pH = 7 (7.4 is physiologically balanced)
- Values for pH *decline* as [H+] *increase*.
- pH scale is based on [H+], but values for [OH-] can be easily calculated from the product relationship.
-

Fig. 2.16

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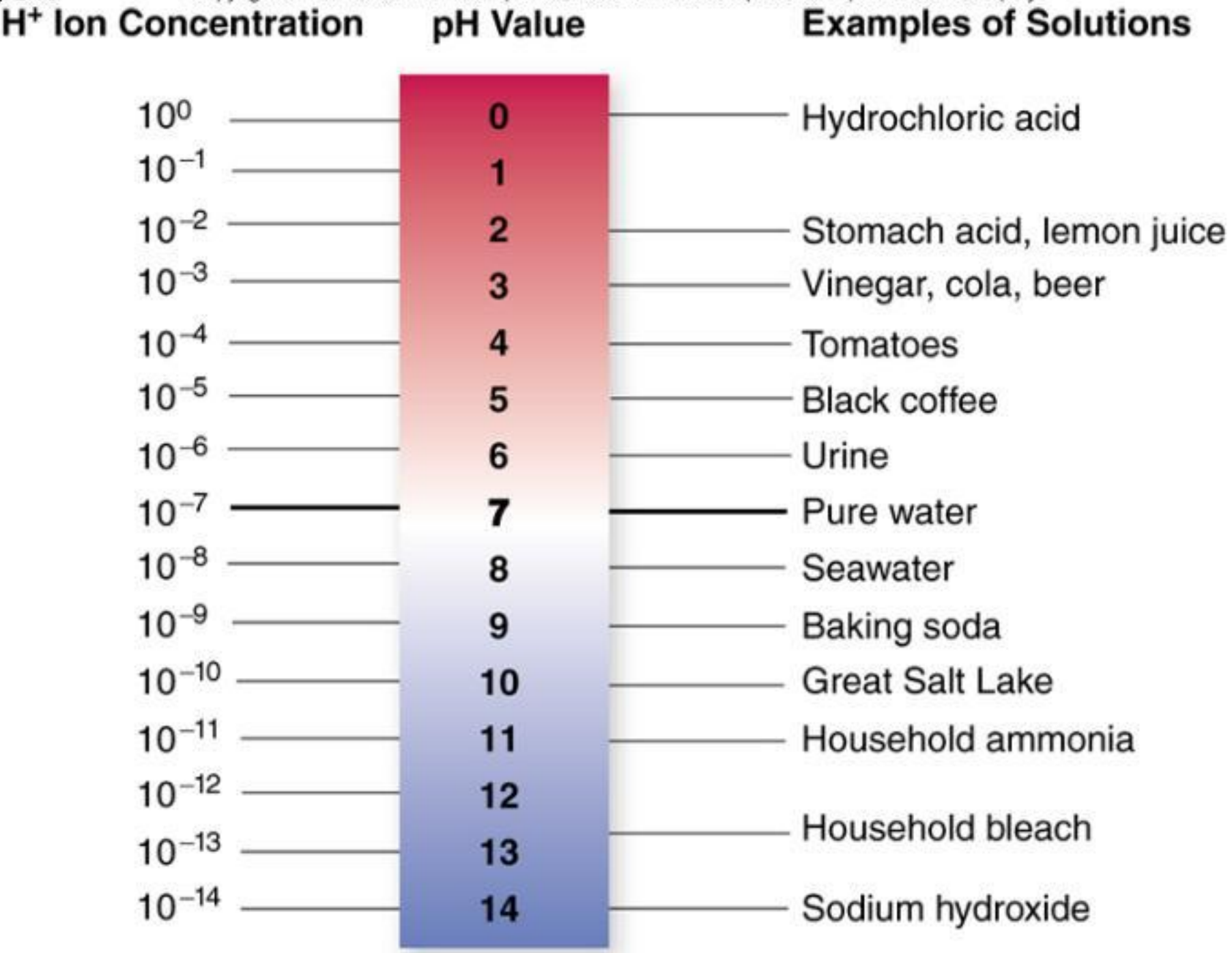
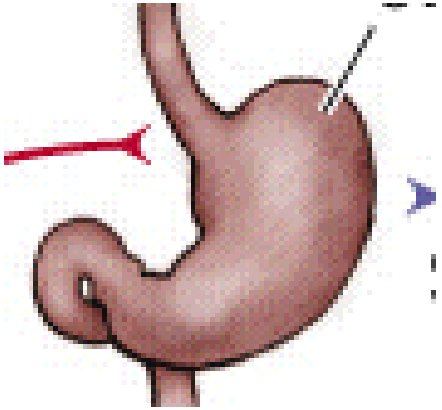


- **pH scale**
  - **Lower pH** = more acidic (MORE H)
  - **Raise pH** = less acidic, more basic, or alkaline.

  - Logarithmic scale
    - 7.4 physiological balance

pH values in the human stomach can reach 2 (is this acidic or basic?)



REMEMBER -Each pH unit represents a <u>tenfold</u> difference in H^+ and OH^- concentrations.

- A small change in pH actually indicates a substantial change in H^+ and OH^- concentrations.

To maintain cellular pH values , biological fluids have buffers.

Buffers resist changes to the pH of a solution when H^+ or OH^- is added to the solution.

Buffers accept hydrogen ions from the solution when they are in excess and donate hydrogen ions when they have been depleted.

Buffers - weak acid and corresponding base

- One important buffer in human blood carbonic acid

molecular weight -sum of the weights of <u>all</u> the atoms in a substance

a 1 molar solution (1M) is the molecular weight of a material in grams

dissolved in 1 liter (1000mL) of (usually) deionized water

- Lab
- a mole of table sugar - sucrose ($C_{12}H_{22}O_{11}$)?
  -
  - A carbon atom weighs 12 daltons, hydrogen 1 dalton, and oxygen 16 daltons
  - One molecule of sucrose = 342 daltons
  - the sum of weights of all the atoms
  - **molecular weight** of sucrose
  - one mole of sucrose we would weigh out 342 grams

solution sugar water

solute sugar

solvent water

aqueous?