Matter & Energy Resources: Types & Concepts

tutorial by Paul Rich

Outline

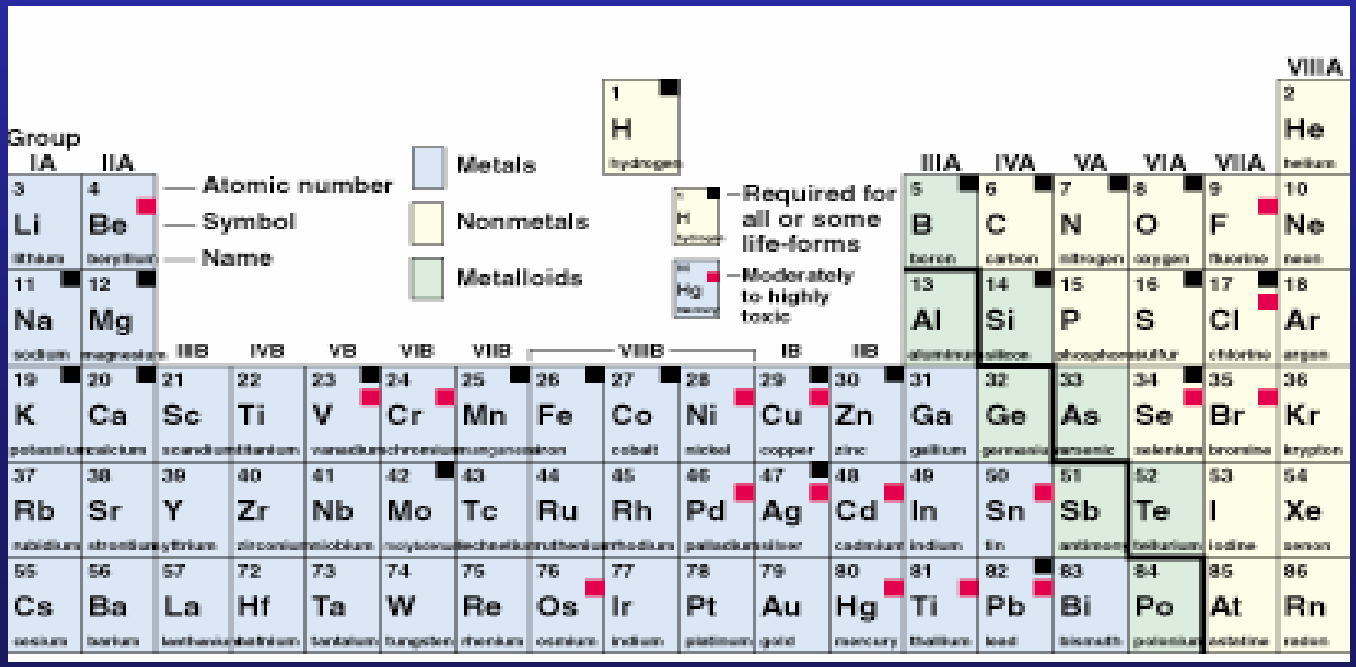
1. Matter (a primer about chemistry)
   - What is matter?
   - inorganic compounds, organic compounds, matter quality
2. Energy
   - What is energy?
   - energy quality
3. Changes of Matter
   - physical vs. chemical changes, conservation of matter
   - nuclear changes
4. Energy Laws
   - first law, second law

1. Matter

matter: anything that has mass & takes up space.

forms:

1)elements: the distinct building blocks that form matter; made up of a single type of **atom**, the smallest unit of matter unique to an element



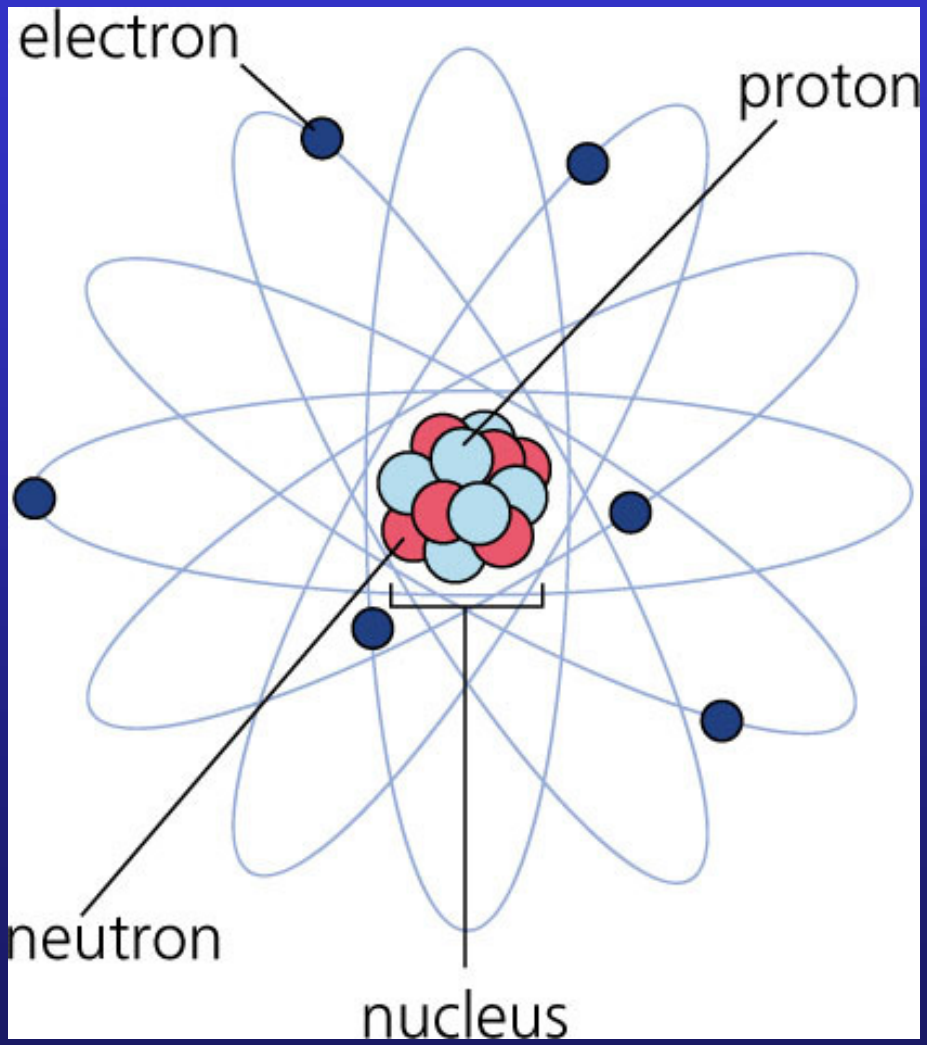
112 known elements
(92 natural,
20 synthesized)

Atoms

atom: fundamental unit of matter unique to an element.

components:

- **protons** – positively charged particles in nucleus
- **neutrons** – uncharged particles in nucleus
- **electrons** – negatively charged particles orbiting nucleus
- other subatomic particles

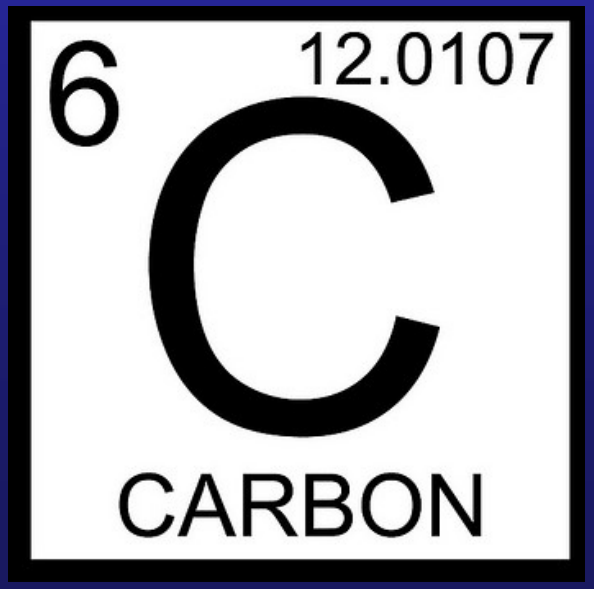


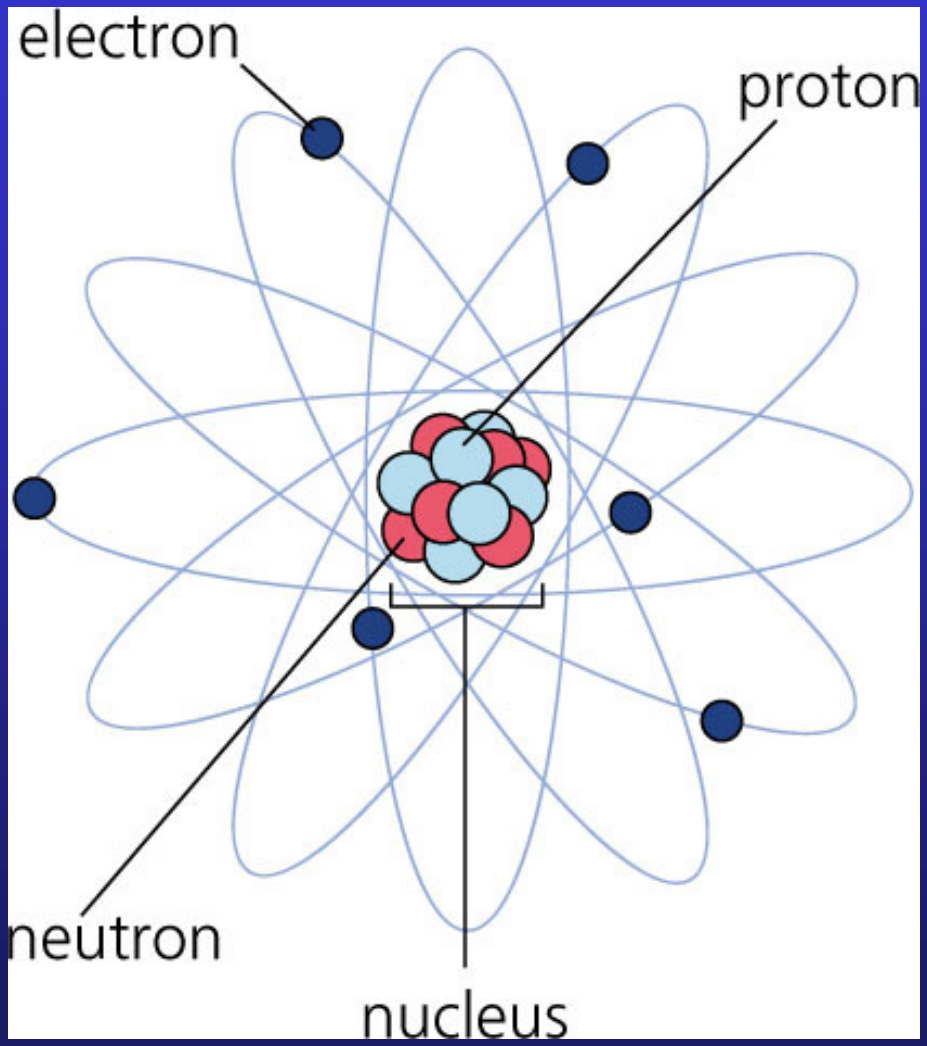
•http://www.pfscience.com/wp-content/uploads/2010/11/atom.jpg

Atoms

characteristics:

- **atomic number** – number protons in a nucleus; defines an element.
- **mass number** – total number of neutrons (mass =1) & protons (mass =1); mass of electrons near 0.





•http://www.pfscience.com/wp-content/uploads/2010/11/atom.jpg
•http://farm3.static.flickr.com/2619/4136479623_538898dcff_z.jpg

Periodic Table of Elements

Elements organized by atomic number; groups of elements in same column have similar properties.

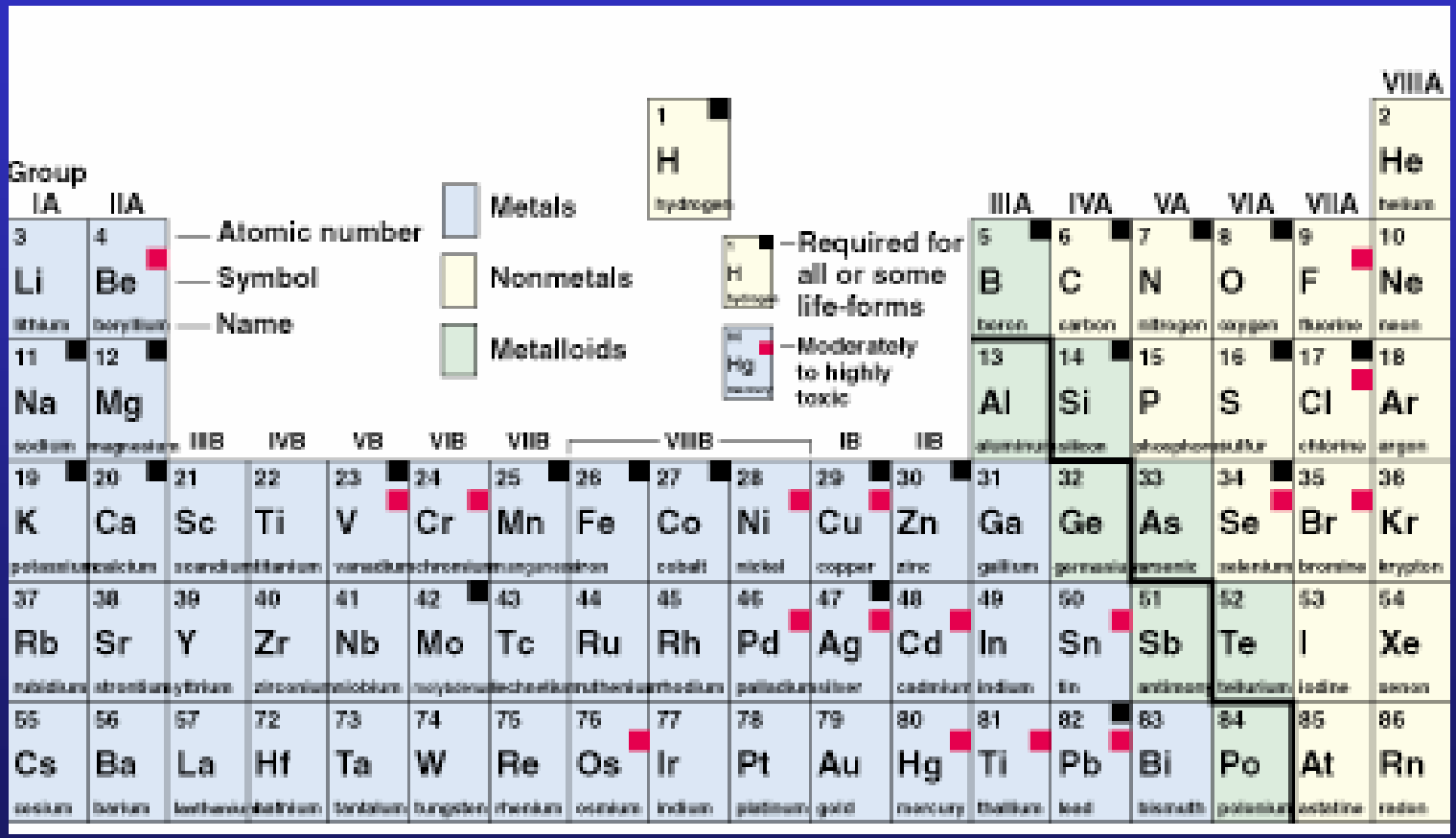


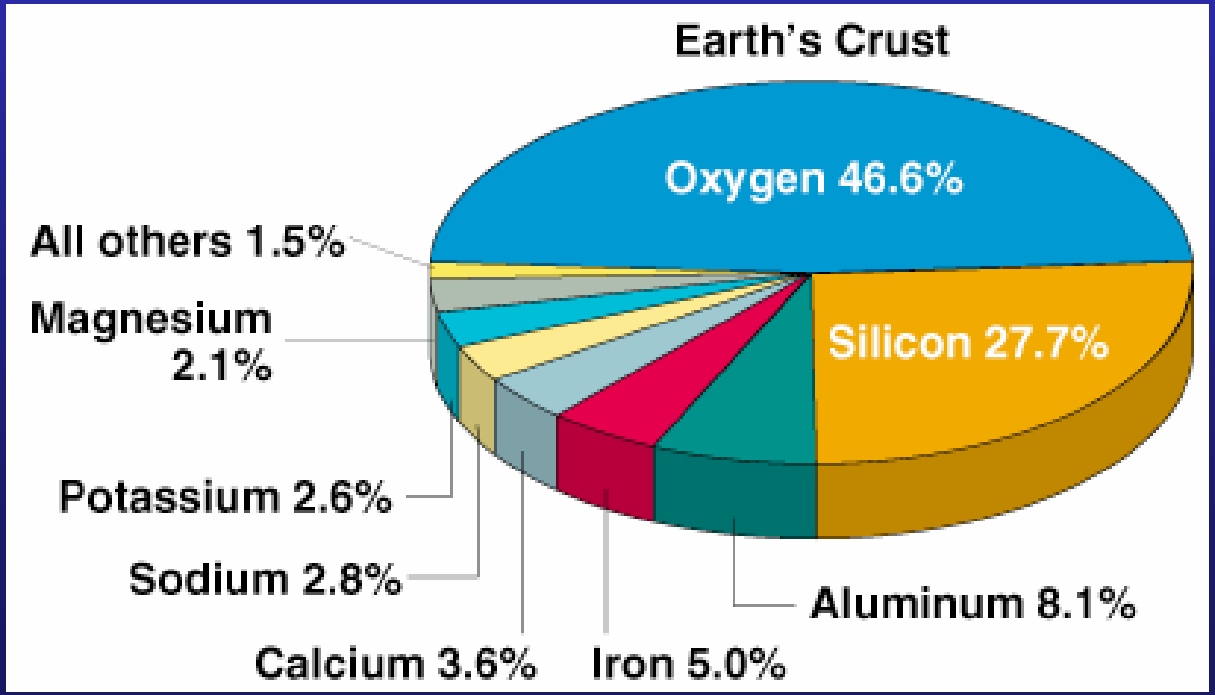
Fig. 3–4

Some Important Elements

Symbols

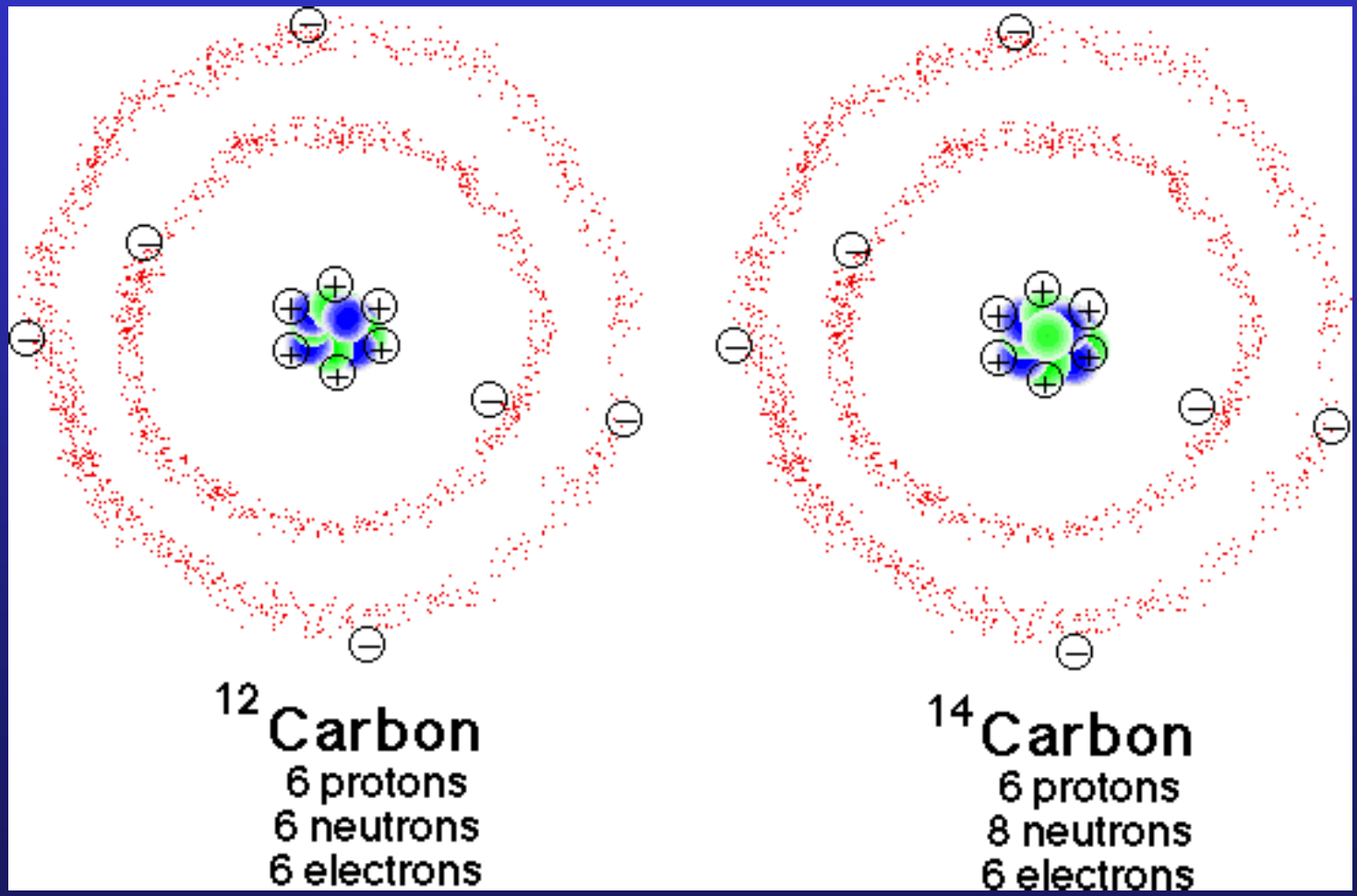
C carbon	Ca calcium	Br bromine	Al aluminum
H hydrogen	Fe iron	Cl chlorine	Hg mercury
N nitrogen	K potassium	Fl fluorine	Pb lead
O oxygen	Na sodium		Si silicon
P phosphorus	S sulfur		

Composition by weight of Earth's crust. Only eight elements make up 98.5% of the crust.



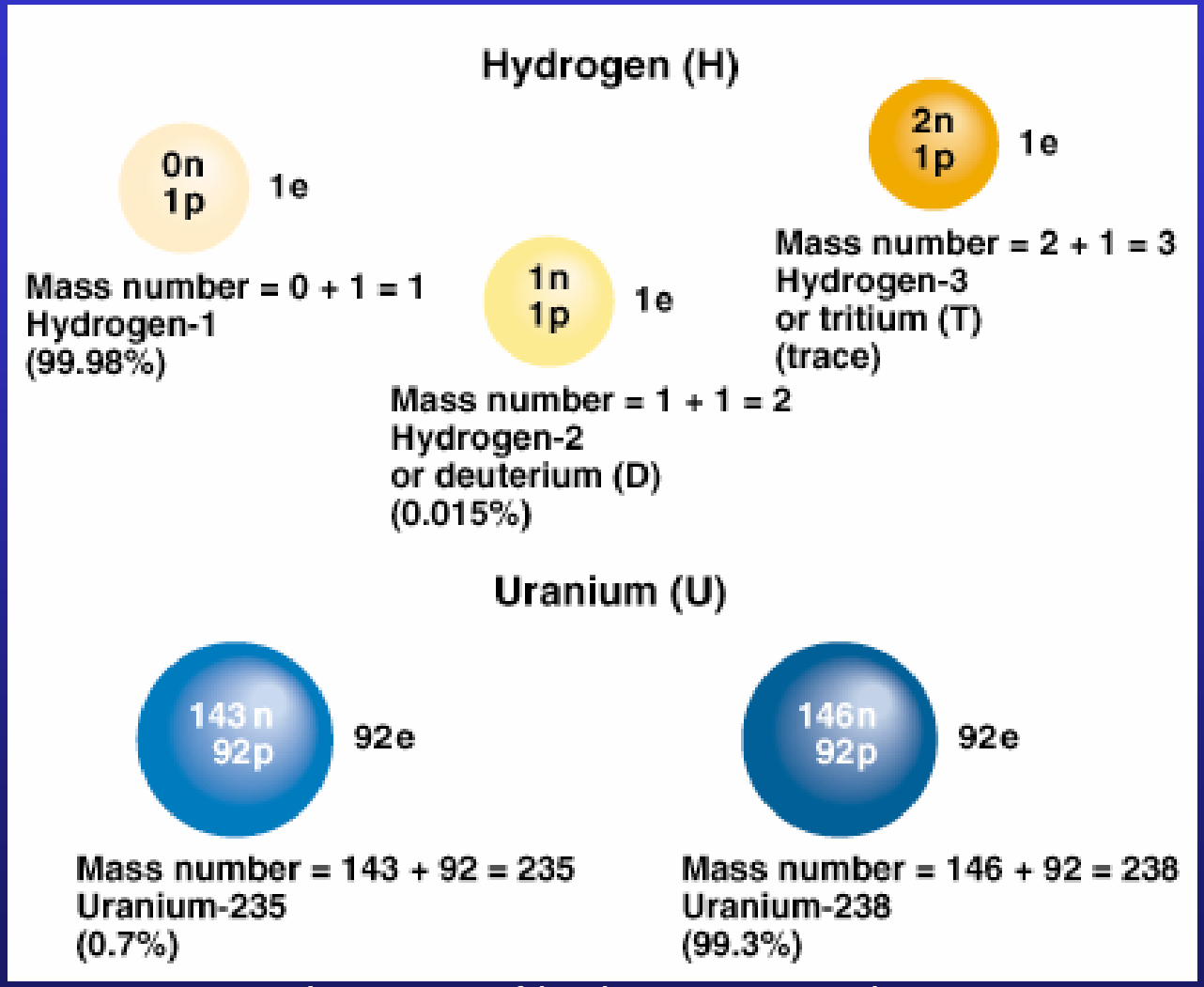
Isotopes

- **isotopes** – various forms of element that have same number of protons, but different numbers of neutrons.



•http://www.sp.uconn.edu/~terry/images/mols/C12C14.GIF

Isotopes



Isotopes of hydrogen & uranium

Ions

ions: charged molecules formed when atoms of some elements gain or lose one or more electrons.

examples of positive ions (cations):

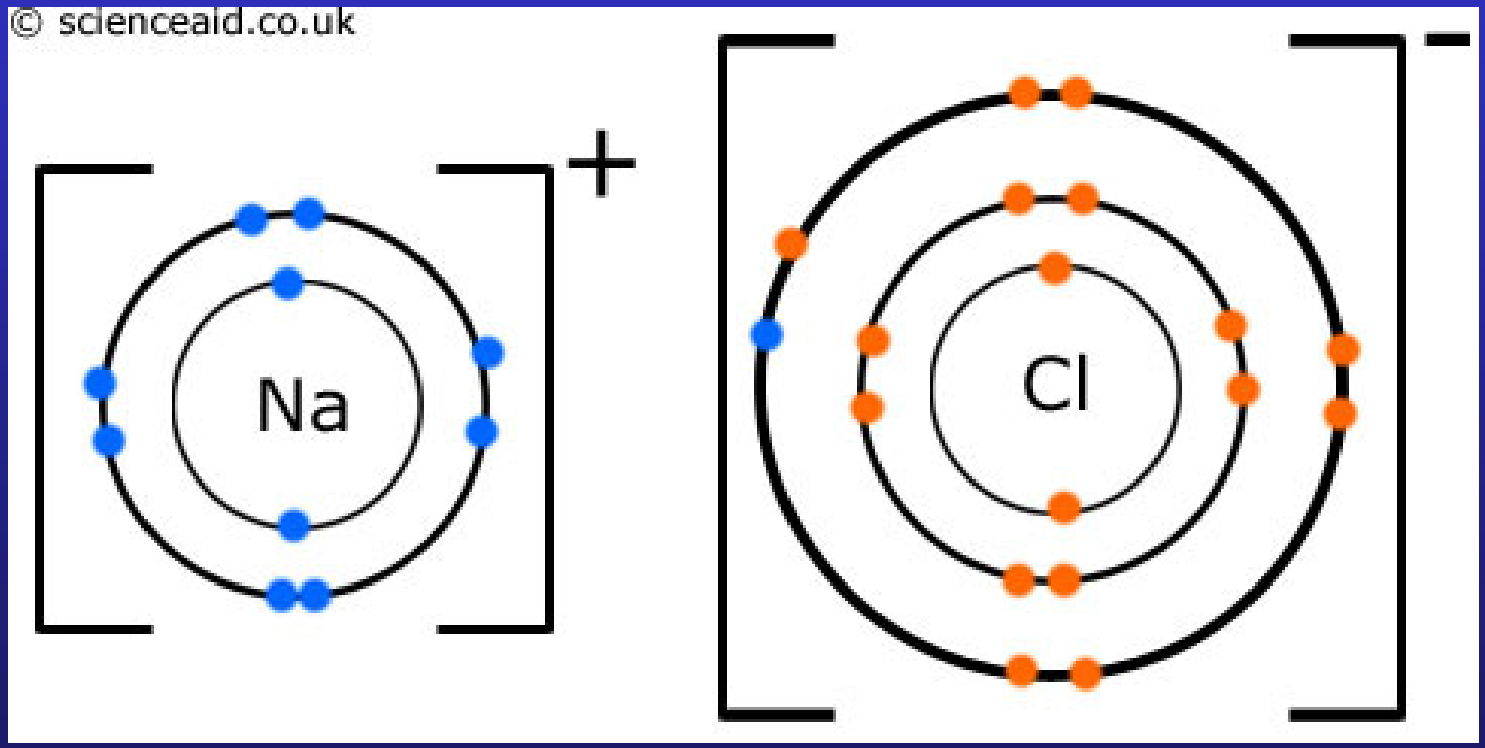
Na^{+} sodium, Ca^{2+} calcium, Fe^{+} iron, Al^{3+} aluminum

examples of negative ions (anions):

Cl^{-} chloride, PO_4^{3-} phosphate, SO_3^{-} sulfate

Matter

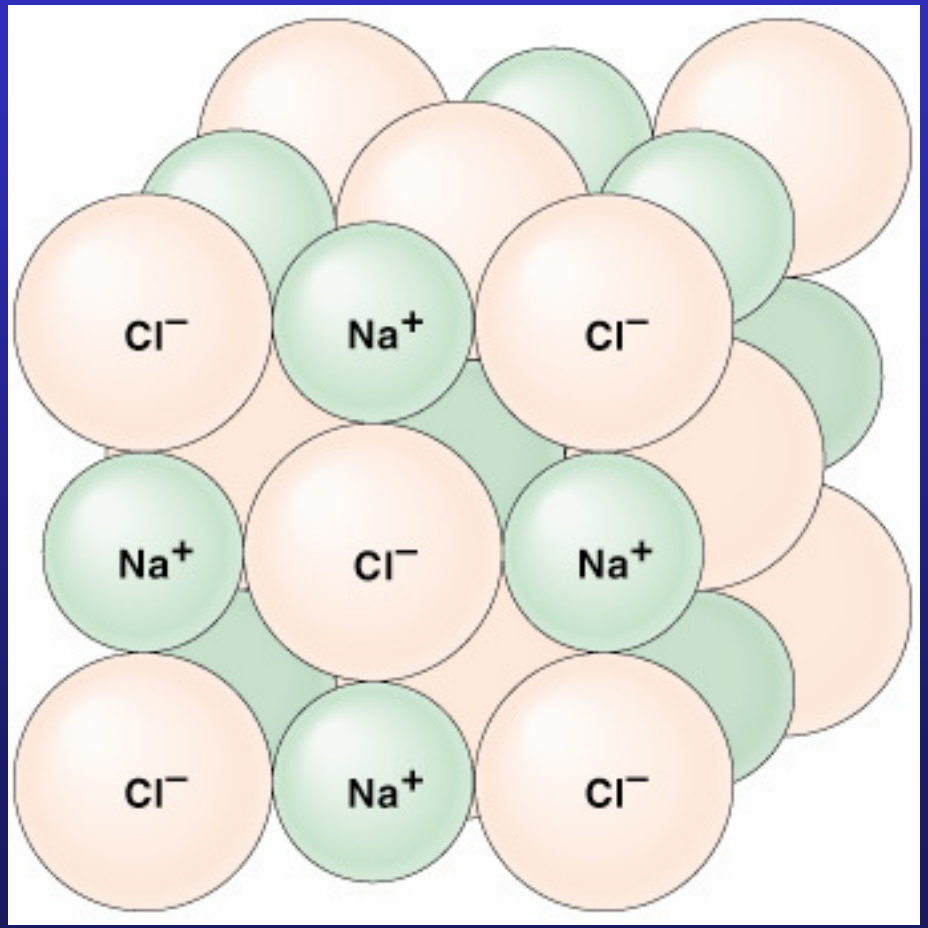
2) **compounds**: two or more different elements held together in fixed proportions by chemical bonds.



Strong Chemical Bonds

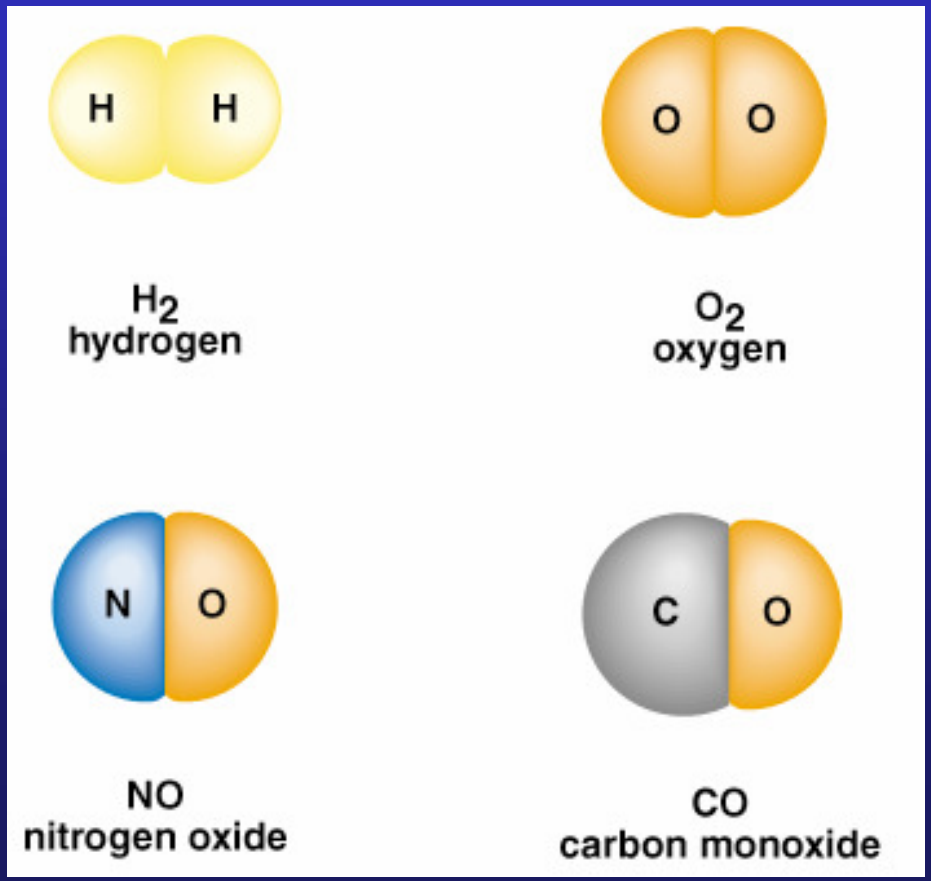
ionic bonds – strong bonds formed by joining oppositely charged ions, e.g., table salt (NaCl) is formed of Na^+ & Cl^- ions.

Solid crystals of ionic compounds, such as NaCl, consist of a three–dimensional array of oppositely charged ions held together by ionic bonds.



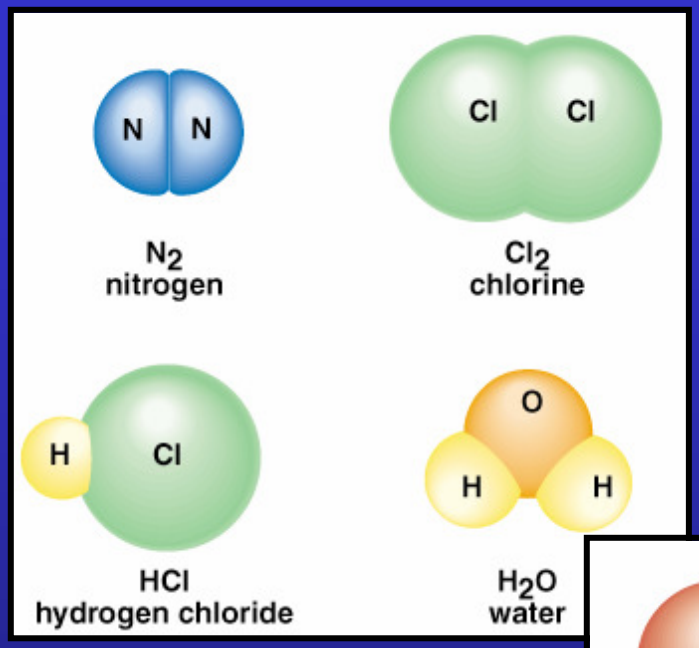
Strong Chemical Bonds

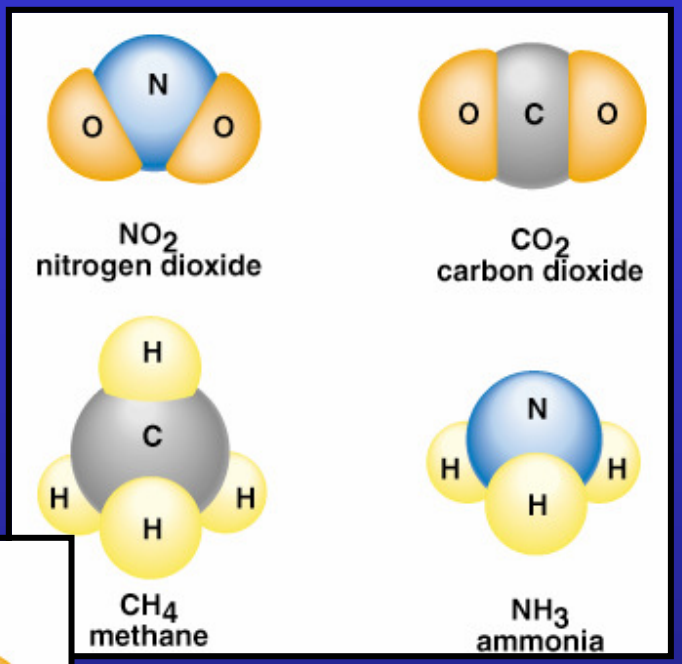
covalent bonds – strong bonds formed by joining one or more uncharged atoms into molecules by sharing of electrons, e.g., water molecules (H_2O).

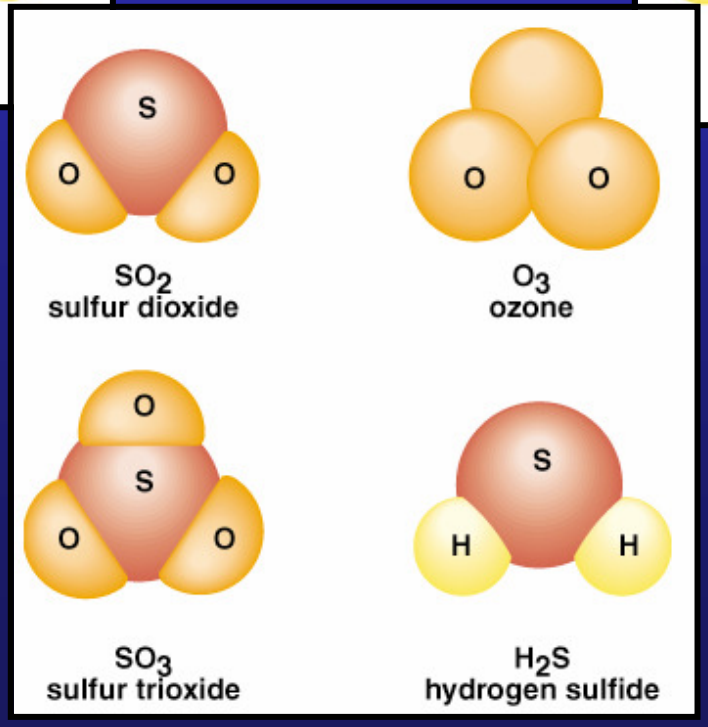


Some important molecules formed by covalent bonds.

More Important Molecules







Inorganic vs. Organic Molecules

inorganic molecule: compounds not originating from living sources; compounds lacking C–C & C–H bonds.

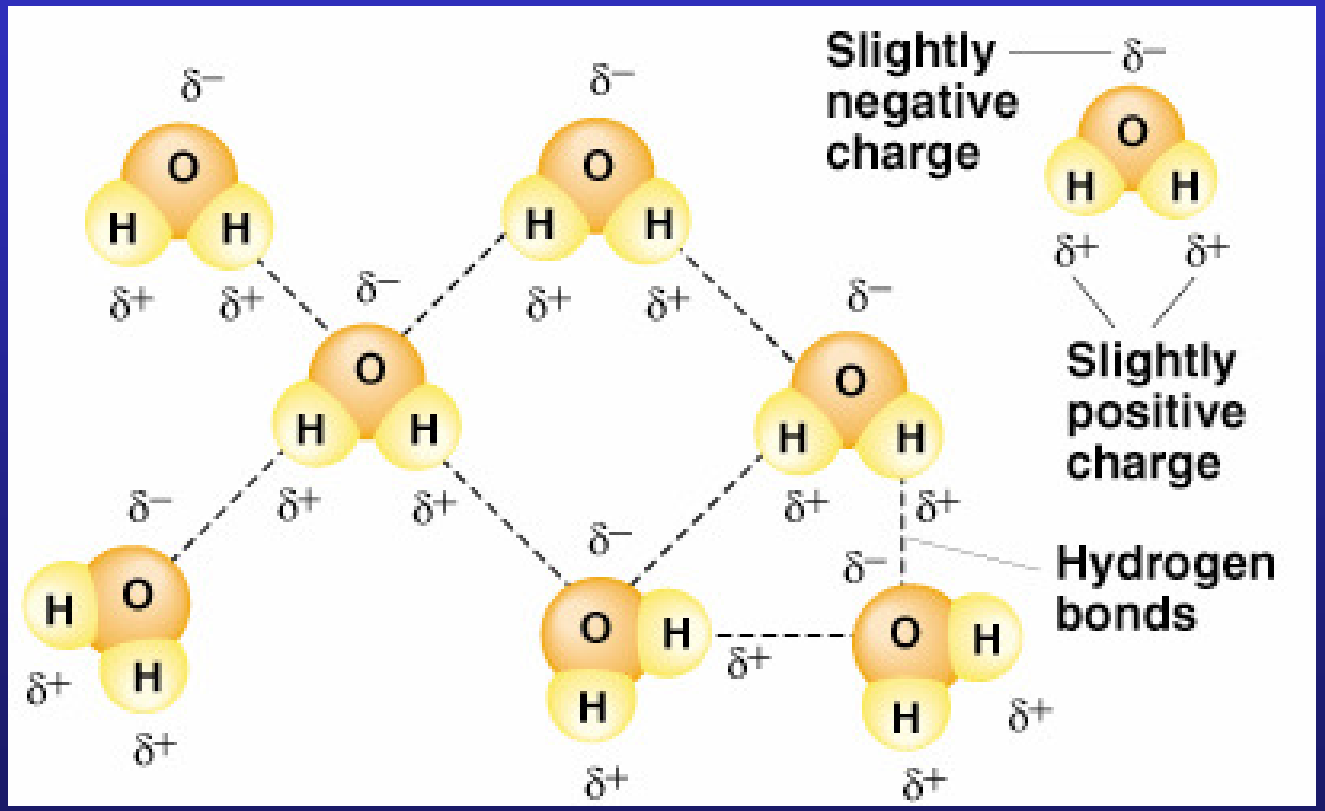
e.g., water H_2O, carbon dioxide (CO_2),
nitrogen gas (N_2), oxygen gas (O_2), ozone (O_3).

organic molecule: compounds containing C–C &/or C–H bonds (*natural* & *synthetic*).

e.g., methane (CH_4), sugars, starch, cellulose, proteins, nucleic acids.

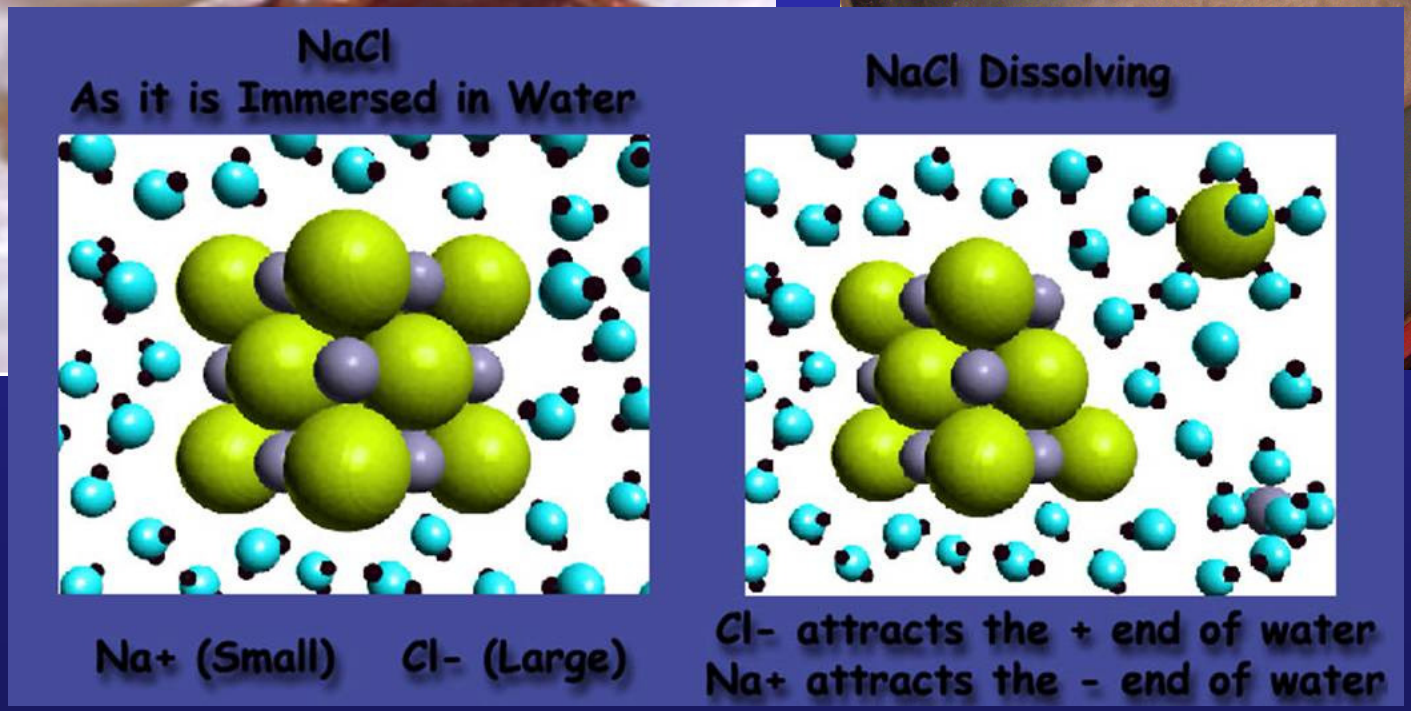
Weak Chemical Bonds

hydrogen bonds – weak bonds between molecules containing hydrogen & nonmetallic atoms, in particular between water molecules.



Accounts for various properties of water, including high surface tension, high heat content, & excellent ability to serve as solvent of ionic compounds.

Accounts for various properties of water, including high surface tension, high heat content, & excellent ability to serve as solvent of ionic compounds.



•http://www.teachmeteamwork.com/photos/uncategorized/pennychallenge_1_1.jpg
•http://www.joyfulabode.com/wp-content/uploads/HLIC/02e12ebb2dbe70016b8d6e74a1fe8343.jpg
•http://www.shorstmeyer.com/msj/geo130/water/water_files/image003.jpg

States of Matter

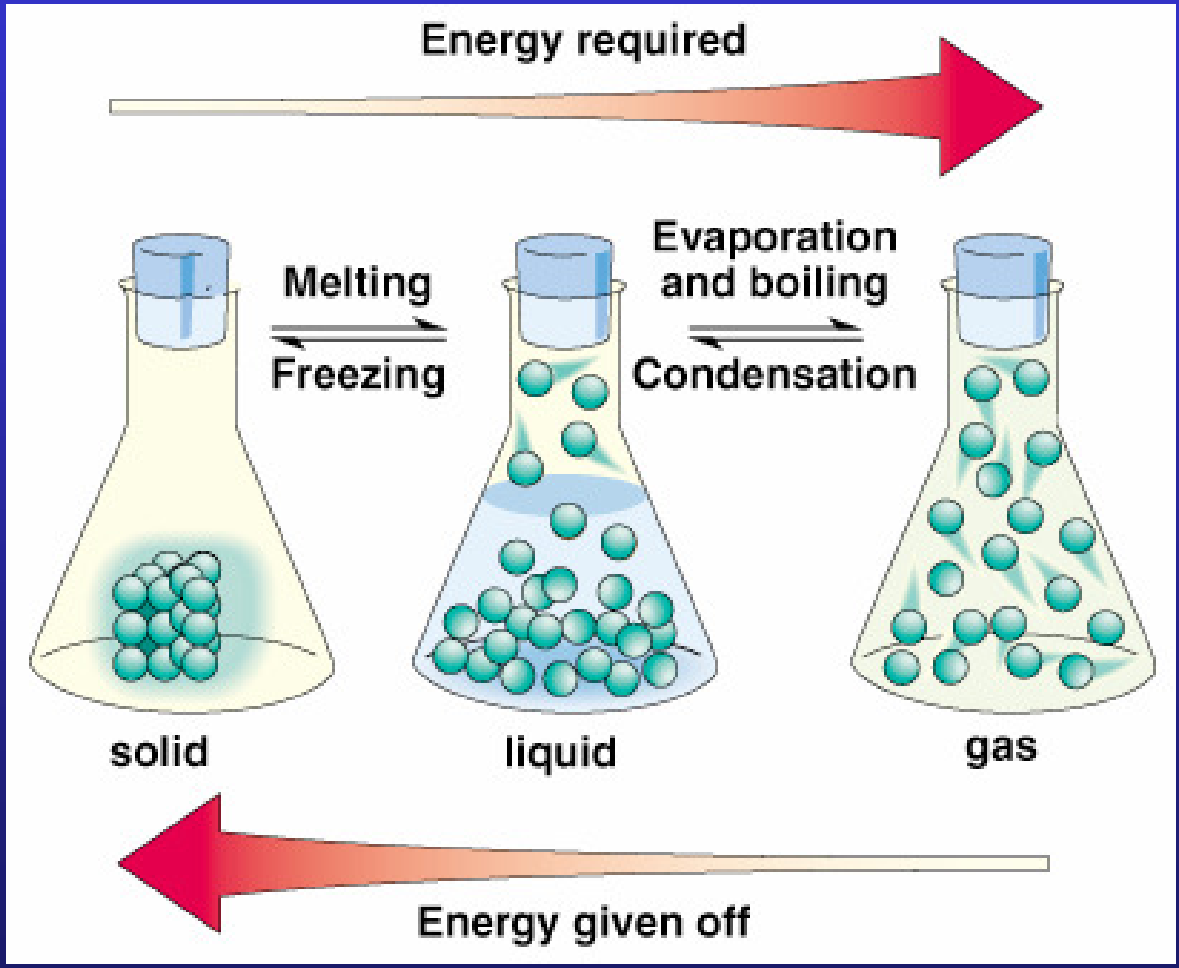
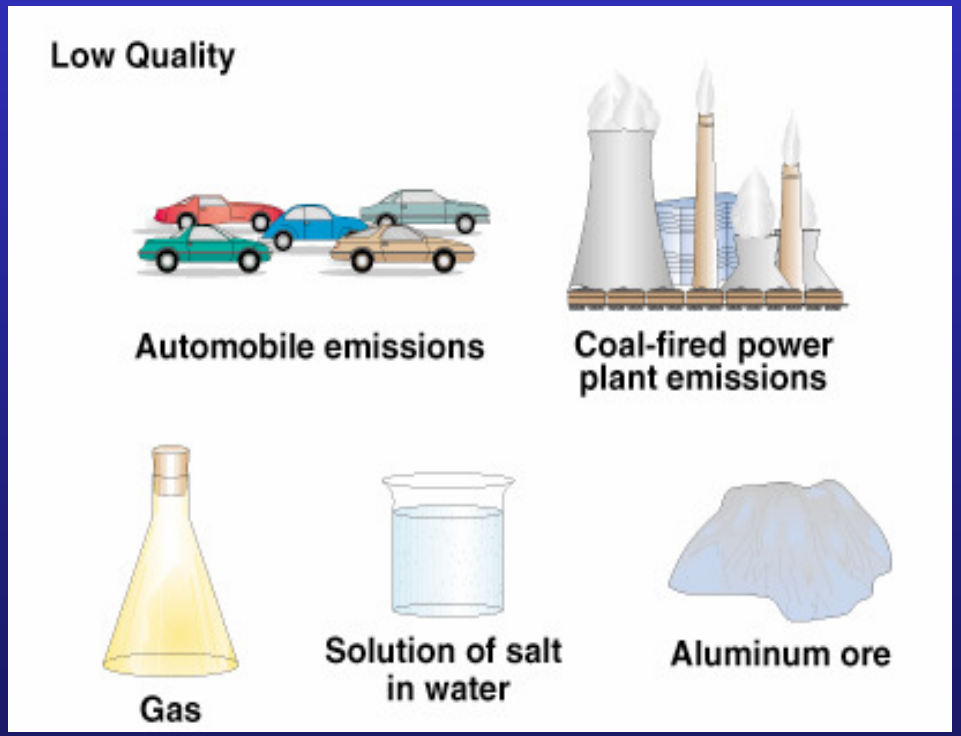


Fig. 3–2

Matter Quality

Matter quality is a measure of how useful a matter resource is for humans, based on its availability & concentration.



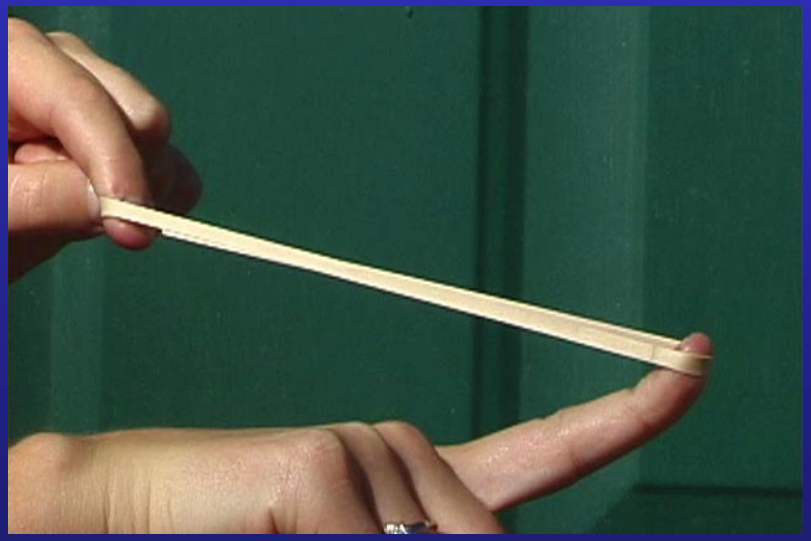
2. Energy

energy: the capacity to do work (by performing mechanical, physical, chemical, or electrical tasks), or to cause heat transfer between two objects at different temperatures.

Types:

- **kinetic energy** – energy of motion. e.g., a moving car, a rock rolling down a hill.

•http://www.comparecheapinsurance.com/car-insurance/images/car-insurance-policy.jpg



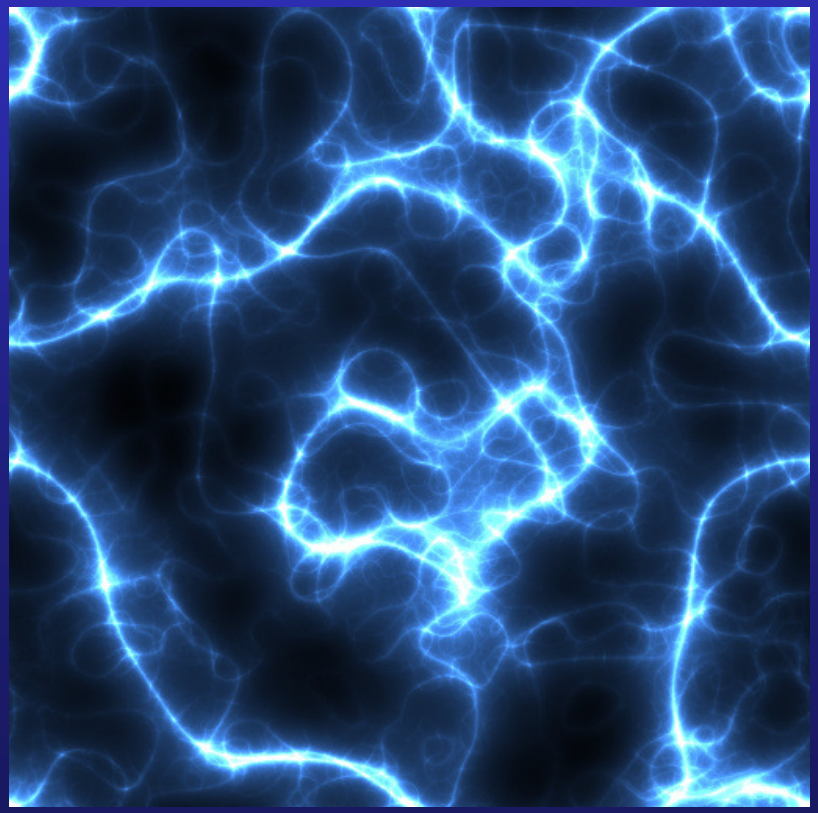
•http://video.ecb.org/badger/download/vlc/images/VLC180_Example_of_potential_energy.jpg

- **potential energy** – stored energy. e.g., a stretched rubber band, a rock on top of a hill, water stored behind a dam.

Energy

some kinds of kinetic energy:

- **electrical** – energy of moving electrons

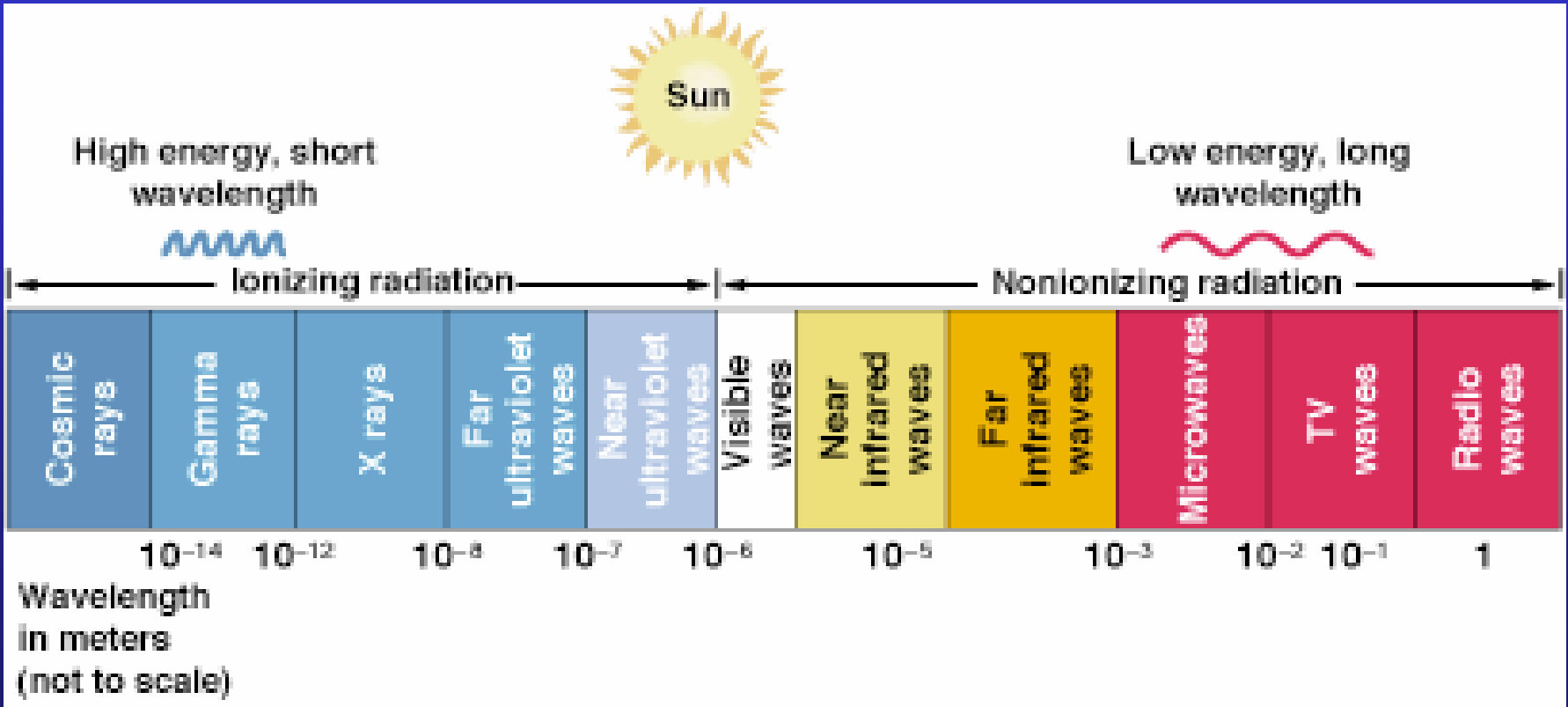


•http://www.filterforge.com/filters/237.jpg

•http://i1.trekearth.com/photos/5162/flames.jpg

- **heat** – total kinetic energy of all moving atoms, ions, or molecules; *temperature* is measure of the motion.

- **electromagnetic radiation** – form of kinetic energy that travels as electromagnetic waves, e.g., radio waves, microwaves, visible light, ultraviolet radiation, & X–rays.



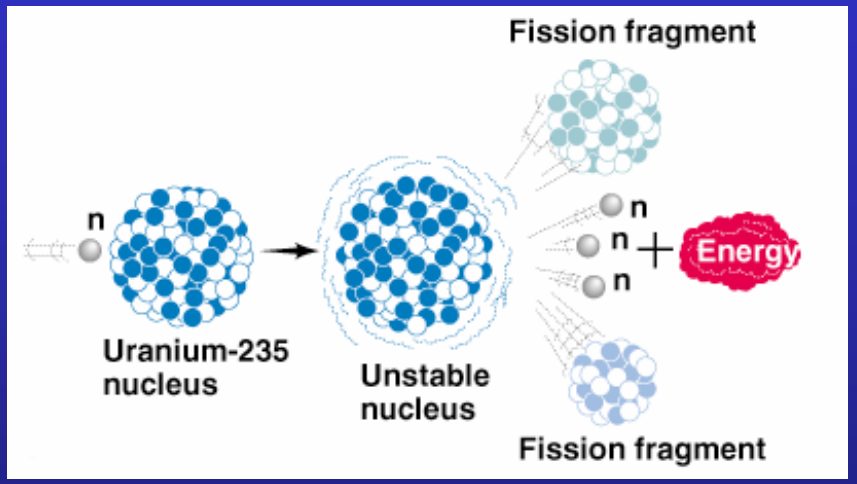
Energy content of electromagnetic radiation varies in proportion to wavelength. Shorter wavelengths have higher energy content than longer wavelengths.

Energy

some kinds of potential energy:

- **chemical energy** – potential energy stored in chemical bonds, e.g., energy in C–C & C–H bonds of fossil fuels or foods.

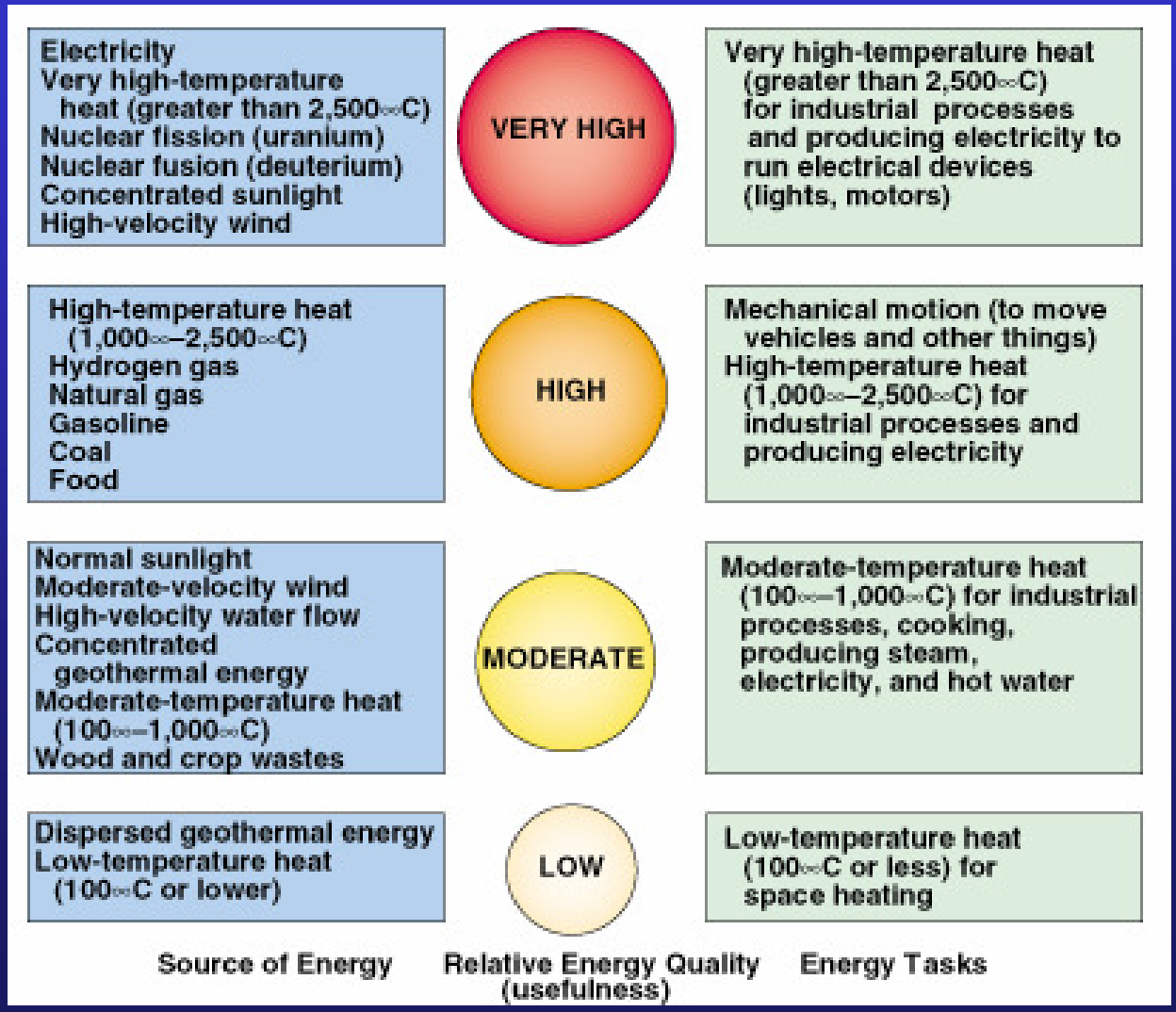
•http://ncgogreen.myncblogs.com/files/2009/02/071019_ap_oil.jpg



- **atomic energy** – energy associated with nuclear structure, e.g., energy released by fission of Uranium–235.

Energy Quality

Energy quality is a measure of how useful an energy source is for humans, in terms of its concentration & ability to perform useful work.



3. Changes of Matter

•http://www.learner.org/courses/essential/physicalsci/images/s4.ice_melt2.jpg

Physical change involves no change in chemical composition.

Chemical change or **chemical reaction** involves changes in the composition of compounds.

Example:

$$C + O_2 \rightarrow CO_2 + \text{energy}$$

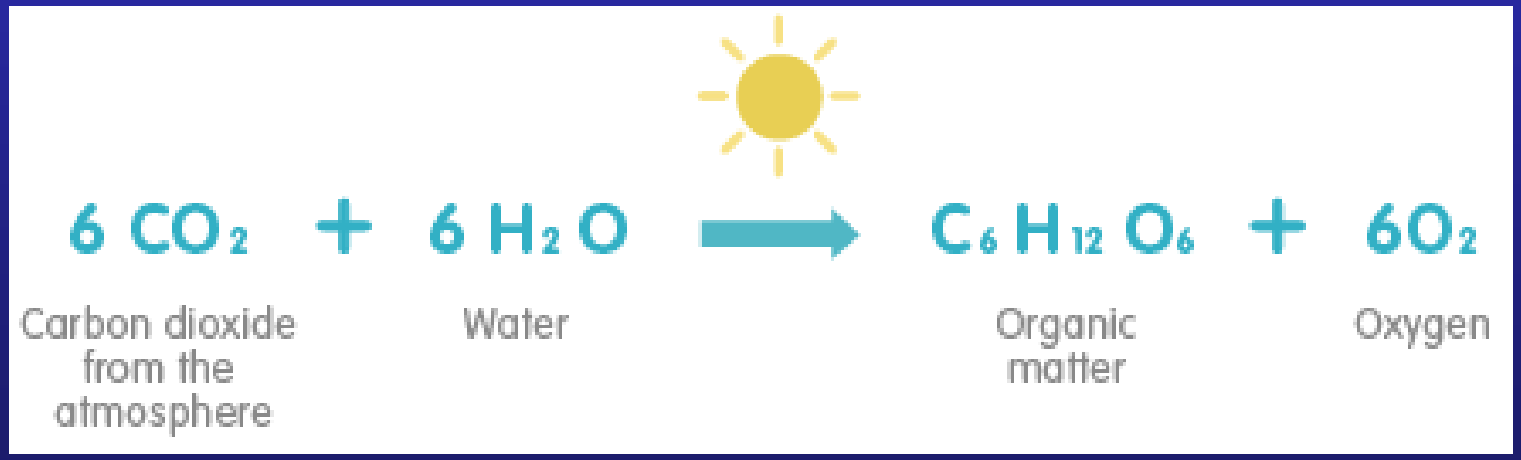
burning of fossil fuels or wood

•http://nahs2010hphysscipd9.wikispaces.com/file/view/Fire-big.jpg/176889739/Fire-big.jpg

Conservation of Matter

Law of Conservation of Matter: In chemical reaction atoms are never created, destroyed, or changed one into another; they are only rearranged to form different molecules & compounds.

- Foundation of chemistry, biology, & ecology.

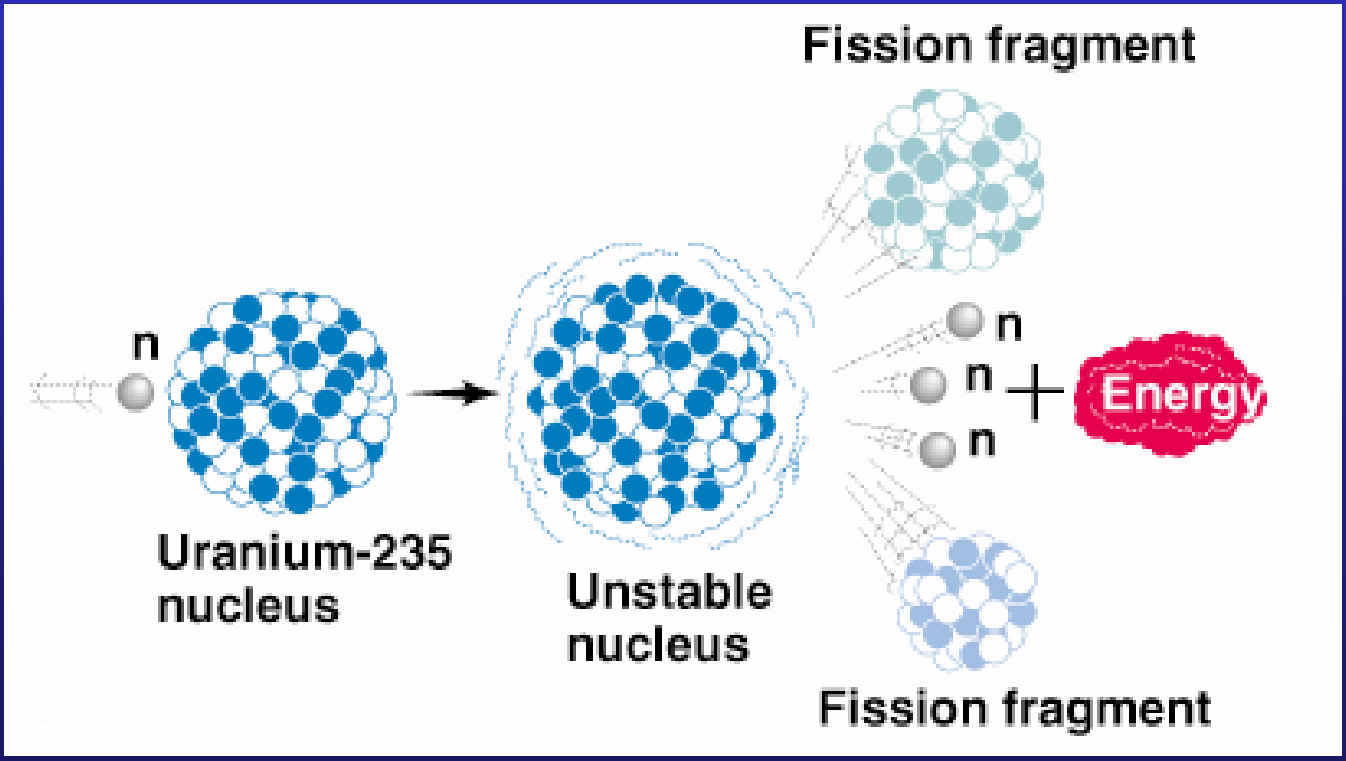


•http://www.teacherthomas.com/wp-content/uploads/2010/01/photosynthesis-equation.gif

- Implication that "there is no away" – earth has essentially all the matter it will ever have.

Nuclear Fission

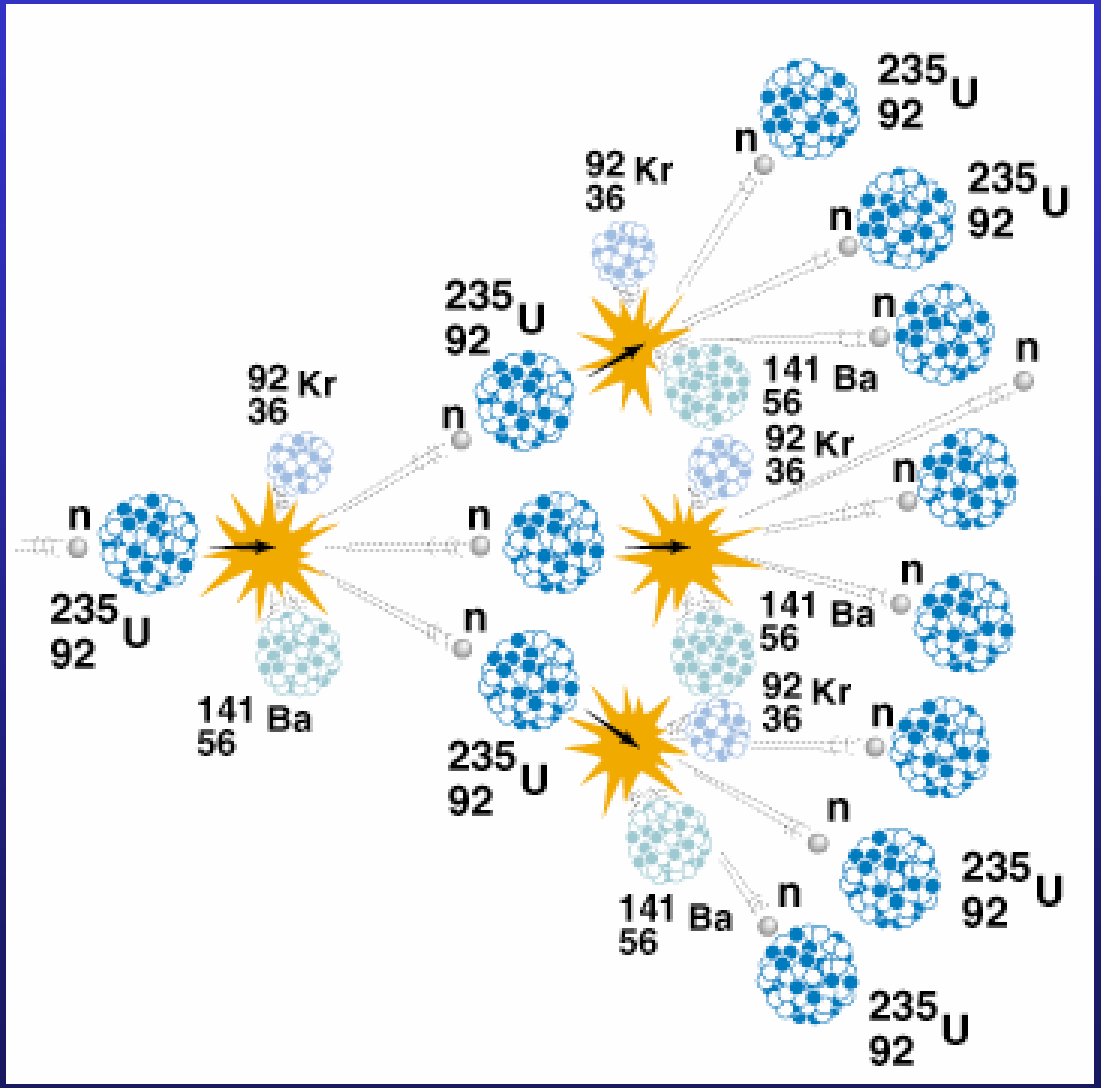
nuclear fission: a nuclear change in which certain unstable isotopes of high mass numbers split into lighter nuclei & release energy in the process.



Fission of a uranium–235 nucleus, initiated by a neutron.

Nuclear Fission

nuclear chain reaction: multiple fissions resulting from a positive feedback loop in which each fission releases neutrons that cause more fissions to occur.

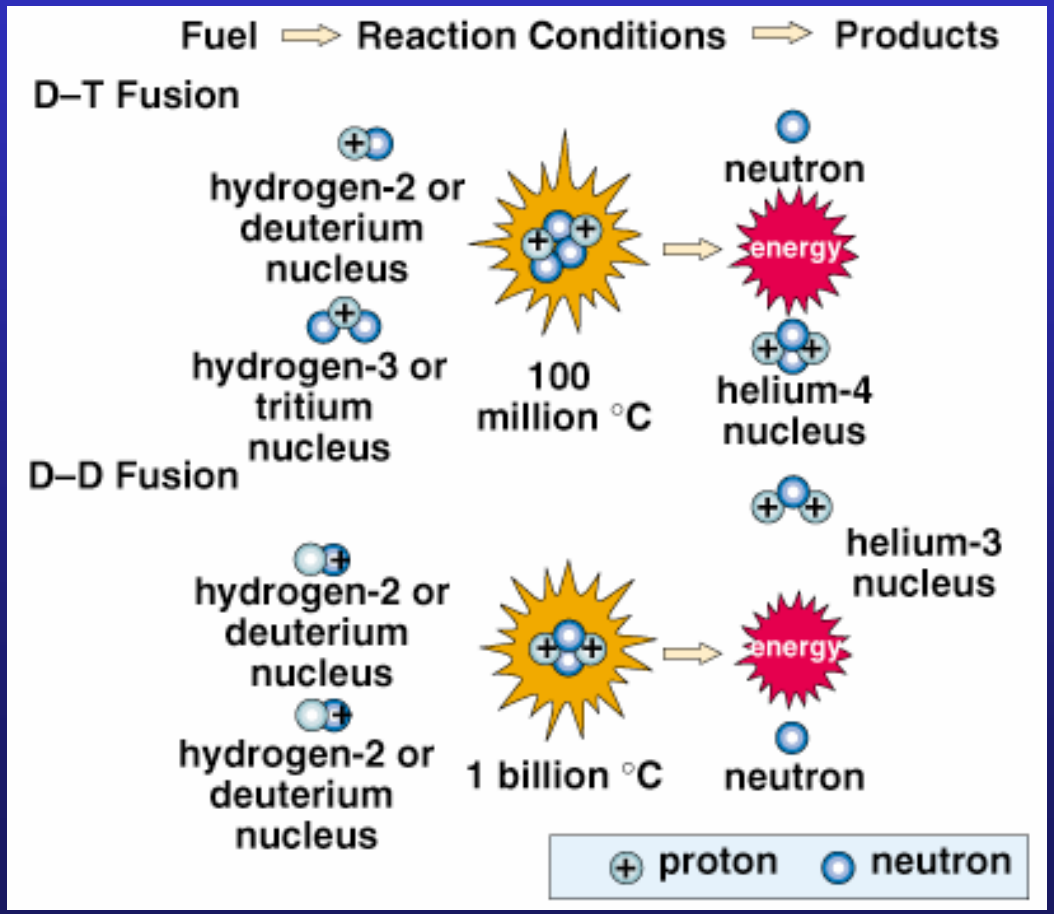


A nuclear chain reaction.

Nuclear Fusion

nuclear fusion: a nuclear change in which two isotopes of light elements are forced together to form a heavier nucleus, releasing energy in the process.

A nuclear fusion reaction in which helium (He) is formed by fusion of two hydrogen (H) nuclei; fusion in Sun is major source of energy for Earth processes.

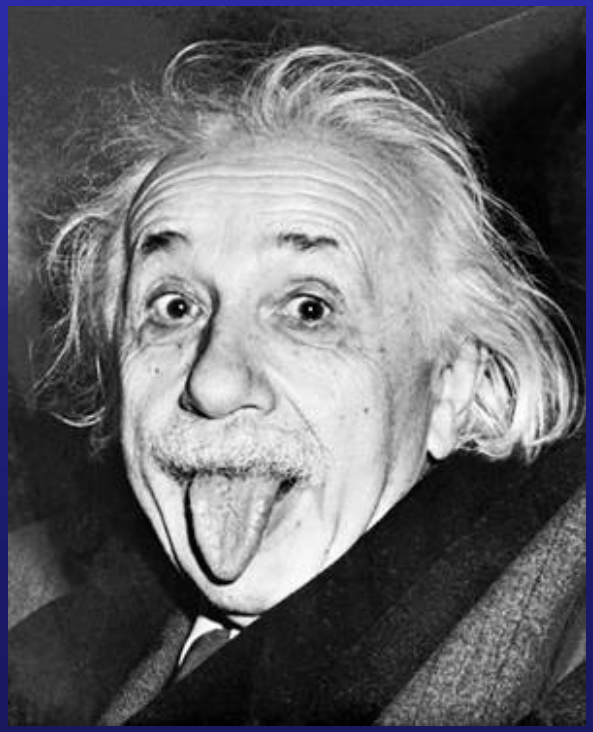


In 1993 scientists at the Tokamak Fusion Test Reactor, at Princeton University's plasma physics laboratory in New Jersey, produced a controlled fusion reaction, during which the temperature in the reactor surpassed three times that of the core of the sun. In a tokamak reactor, massive magnets confine hydrogen plasma under extremely high temperatures and pressures, forcing the hydrogen nuclei to fuse. When atomic nuclei are forced together in nuclear fusion, the reaction releases an extraordinary amount of energy.

Do Nuclear Reactions Break the Law of Conservation of Matter?

- in nuclear reactions, atoms can be changed, e.g., fusion H to He.
- energy & matter are conserved because very small amounts of matter converted to energy

$$E = mc^2$$

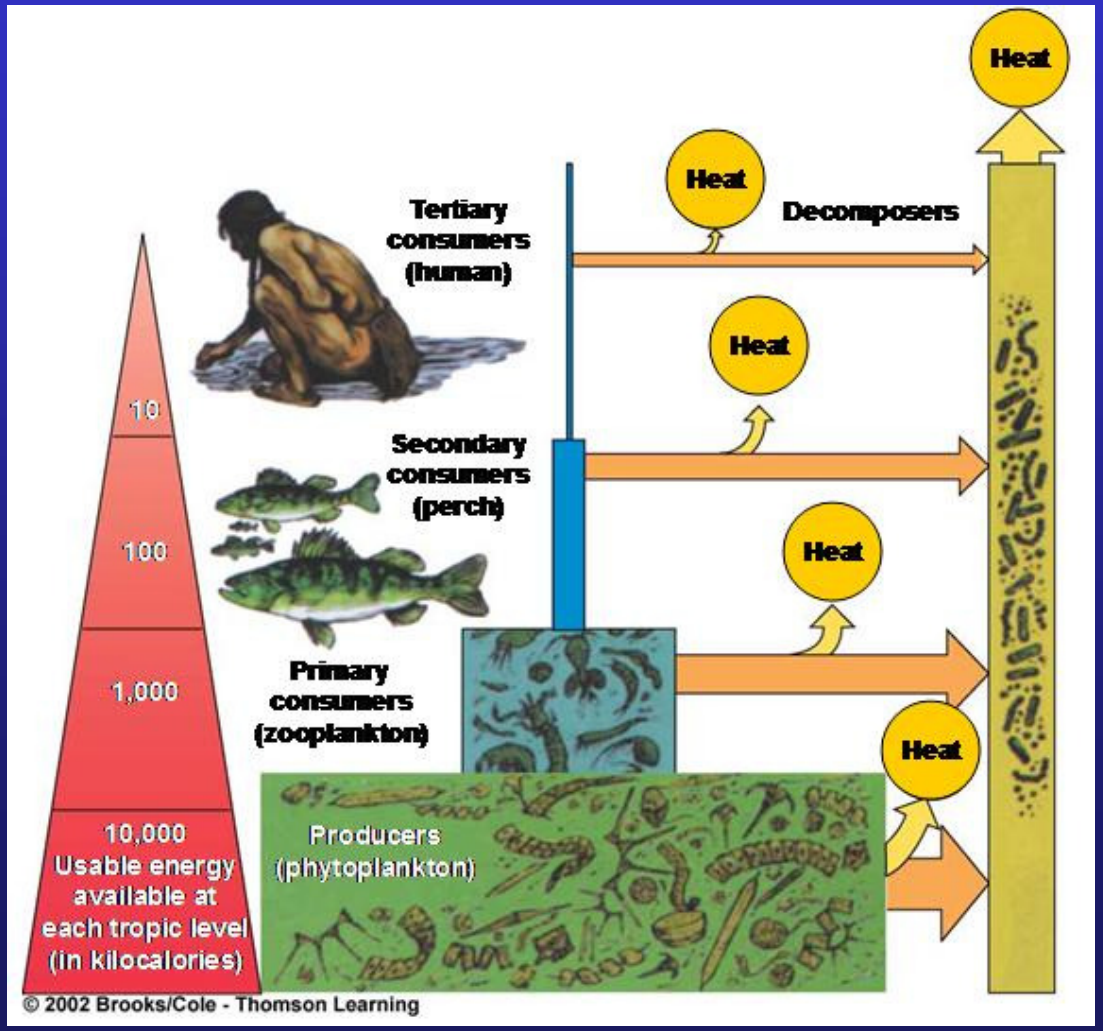


•http://0.tqn.com/d/physics/1/0/C/0/-/-/Einstein_tongue.jpg

4. Energy Laws

first law of thermodynamics: energy is neither created nor destroyed, but may be converted from one form to another;

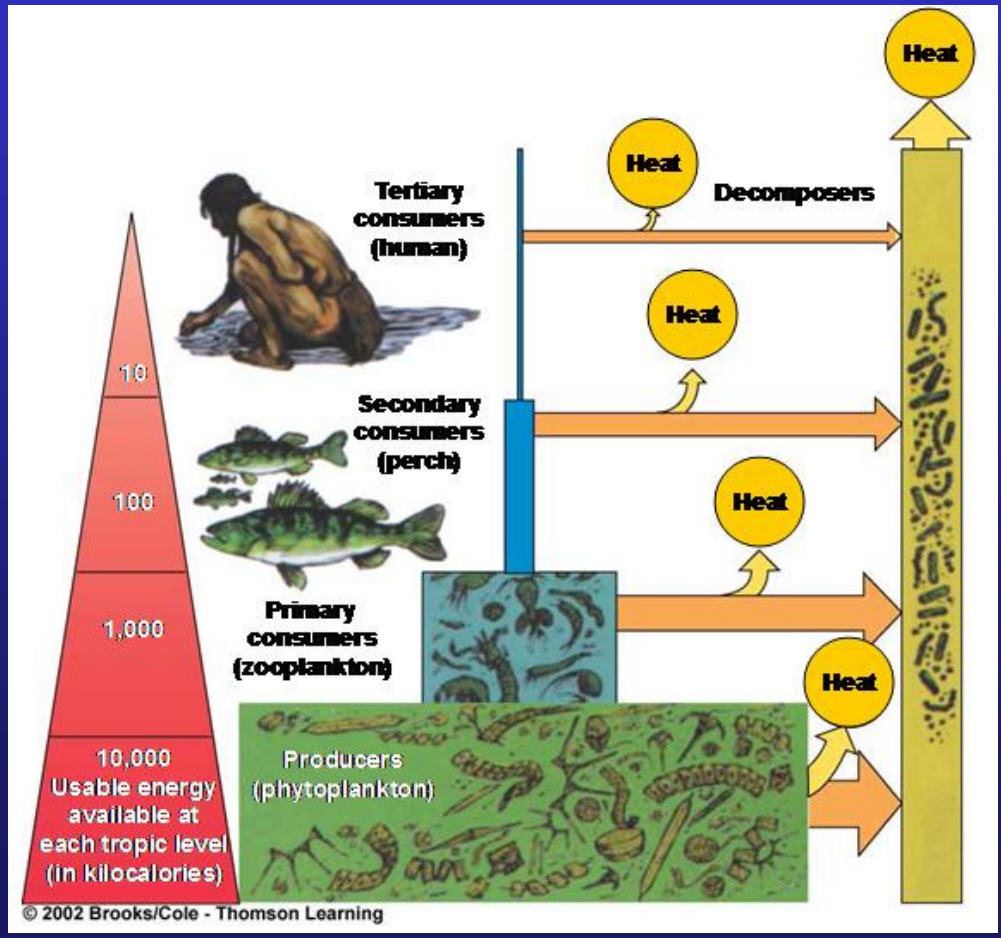
- energy is conserved
- implication that bookkeeping is possible, e.g., in ecological study, energy flow can be followed
- also stated, "you can't get something for nothing", in terms of energy quantity.



Energy Laws

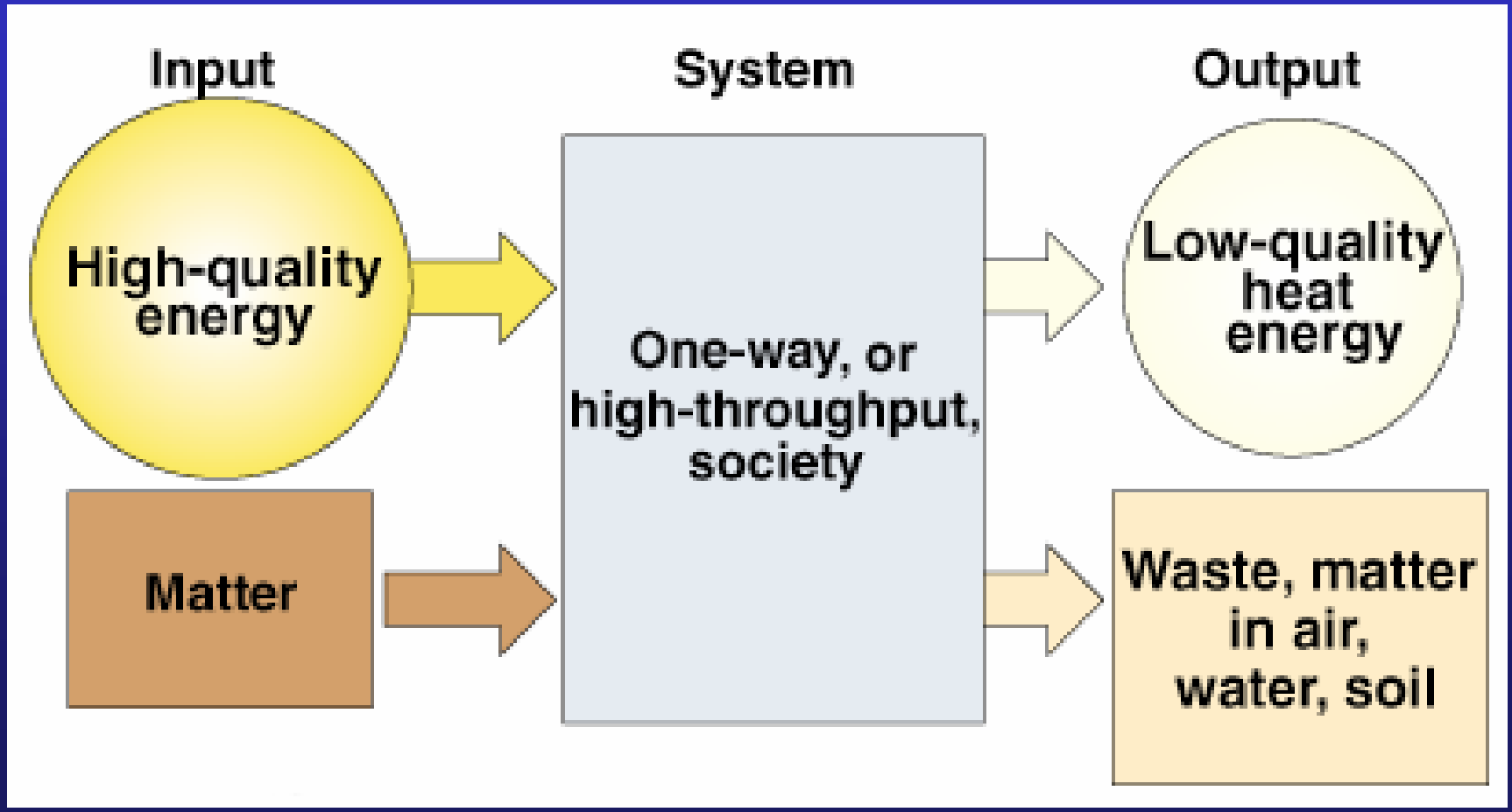
second law of thermodynamics: when energy is converted from one form to another, some of the useful energy is always degraded to lower–quality, more dispersed energy.

- also stated, **entropy** increases.
- **entropy** is a measure of disorder; increased entropy means increased randomness or dispersion;
- degraded energy generally in form of heat;
- implication that continual energy input is needed to maintain a system



Implications for Environment

Conceptual model of eventually unsustainable high–waste, high–throughput societies.



Implications for Environment

Conceptual model of sustainable low–waste, low–throughput societies.