

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

Group

IA IIA IIIA IVA VA VIA VIIA VIIIA

1 2
H He
hydrogen helium

3 4
Li Be
lithium beryllium

11 12
Na Mg
sodium magnesium

19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
potassium calcium scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium arsenic selenium bromine krypton

37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
rubidium strontium yttrium zirconium niobium molybdenum technetium ruthenium rhodium palladium silver cadmium indium tin antimony tellurium iodine xenon

55 56 57 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
cesium barium lanthanum hafnium tantalum tungsten rhenium osmium iridium platinum gold mercury thallium lead bismuth polonium astatine radon

— Atomic number
— Symbol
— Name

Metals
Nonmetals
Metalloids

— Required for all or some life-forms
— Moderately to highly toxic

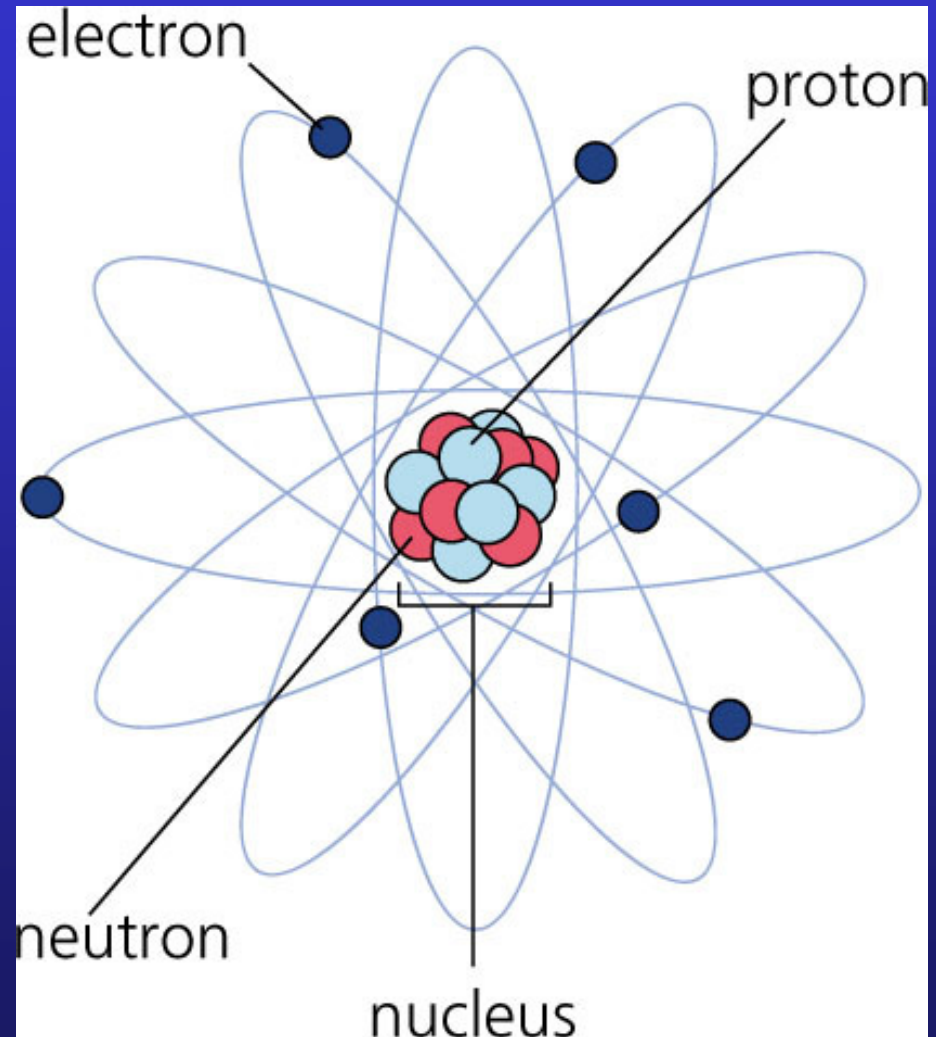
112 known elements
(92 natural, 20 synthesized)

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

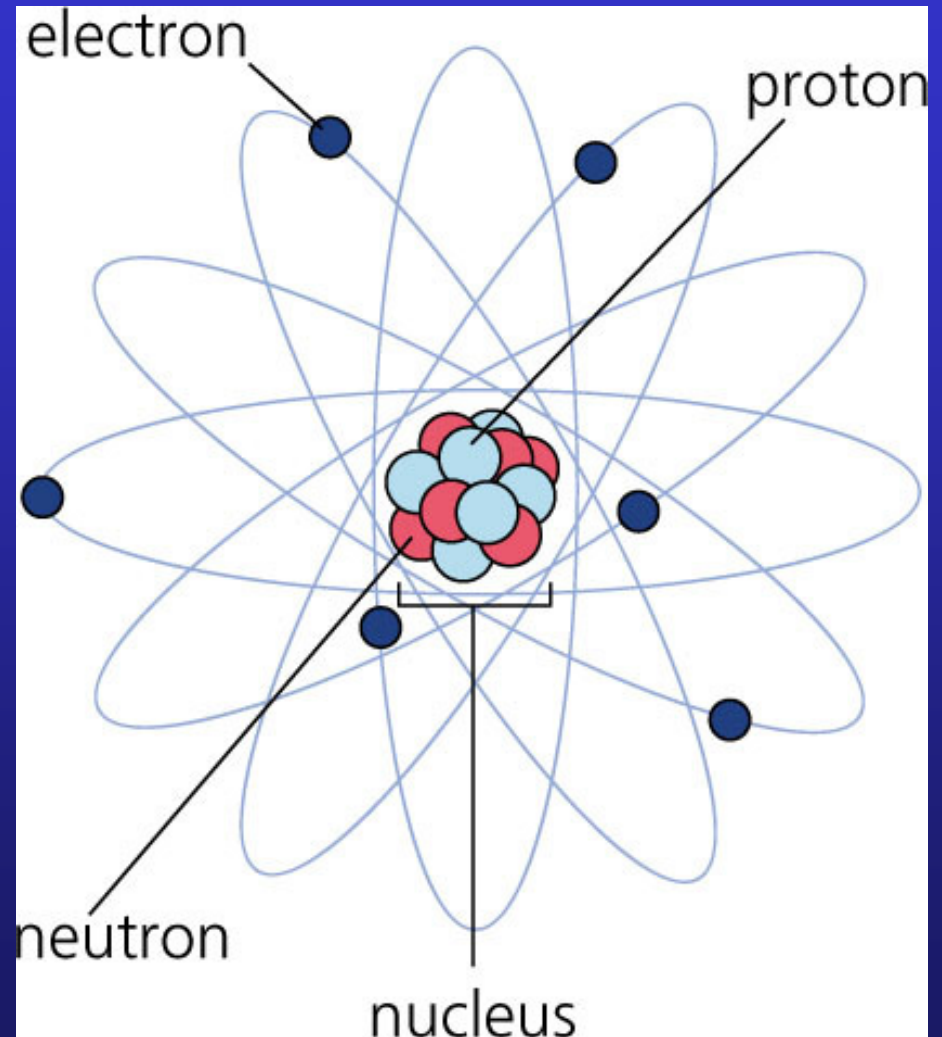
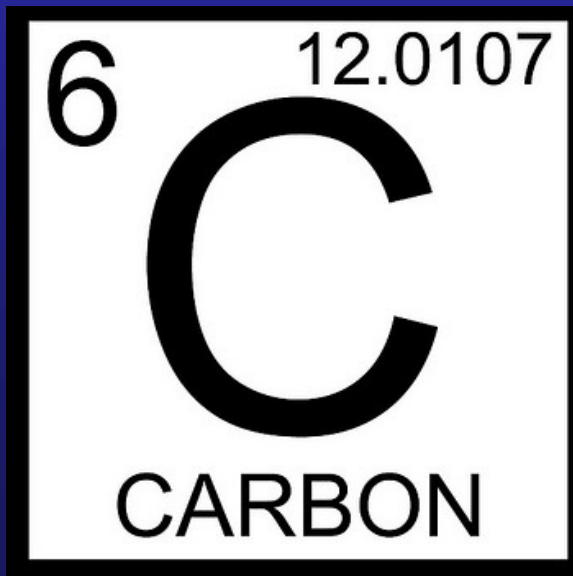


•<http://www.pfscience.com/wp-content/uploads/2010/11/atom.jpg>

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.

Group

IA IIA — Atomic number

Li Be — Symbol

lithium beryllium — Name

11 12

Na Mg

sodium magnesium

Metals

Nonmetals

Metalloids

1 — Required for all or some life-forms

H hydrogen

8 — Moderately to highly toxic

O oxygen

Hg mercury

VIII A VIII B VIII C VIII D VIII E VIII F VIII G VIII H VIII I VIII J VIII K VIII L VIII M VIII N VIII O VIII P VIII Q VIII R VIII S VIII T VIII U VIII V VIII W VIII X VIII Y VIII Z VIII AA VIII AB VIII AC VIII AD VIII AE VIII AF VIII AG VIII AH VIII AI VIII AJ VIII AK VIII AL VIII AM VIII AN VIII AO VIII AP VIII AQ VIII AR VIII AS VIII AT VIII AU VIII AV VIII AW VIII AX VIII AY VIII AZ VIII BA VIII BB VIII BC VIII BD VIII BE VIII BF VIII BG VIII BH VIII BI VIII BJ VIII BK VIII BL VIII BM VIII BN VIII BO VIII BP VIII BQ VIII BR VIII BS VIII BT VIII BU VIII BV VIII BW VIII BX VIII BY VIII BZ VIII CA VIII CB VIII CC VIII CD VIII CE VIII CF VIII CG VIII CH VIII CI VIII CJ VIII CK VIII CL VIII CM VIII CN VIII CO VIII CP VIII CQ VIII CR VIII CS VIII CT VIII CU VIII CV VIII CW VIII CX VIII CY VIII CZ VIII DA VIII DB VIII DC VIII DD VIII DE VIII DF VIII DG VIII DH VIII DI VIII DJ VIII DK VIII DL VIII DM VIII DN VIII DO VIII DP VIII DQ VIII DR VIII DS VIII DT VIII DU VIII DV VIII DW VIII DX VIII DY VIII DZ VIII EA VIII EB VIII EC VIII ED VIII EE VIII EF VIII EG VIII EH VIII EI VIII EJ VIII EK VIII EL VIII EM VIII EN VIII EO VIII EP VIII EQ VIII ER VIII ES VIII ET VIII EU VIII EV VIII EW VIII EX VIII EY VIII EZ VIII FA VIII FB VIII FC VIII FD VIII FE VIII FF VIII FG VIII FH VIII FI VIII FJ VIII FK VIII FL VIII FM VIII FN VIII FO VIII FP VIII FQ VIII FR VIII FS VIII FT VIII FU VIII FV VIII FW VIII FX VIII FY VIII FZ VIII GA VIII GB VIII GC VIII GD VIII GE VIII GF VIII GG VIII GH VIII GI VIII GJ VIII GK VIII GL VIII GM VIII GN VIII GO VIII GP VIII GQ VIII GR VIII GS VIII GT VIII GU VIII GV VIII GW VIII GX VIII GY VIII GZ VIII HA VIII HB VIII HC VIII HD VIII HE VIII HF VIII HG VIII HH VIII HI VIII HJ VIII HK VIII HL VIII HM VIII HN VIII HO VIII HP VIII HQ VIII HR VIII HS VIII HT VIII HU VIII HV VIII HW VIII HX VIII HY VIII HZ VIII IA VIII IB VIII IC VIII ID VIII IE VIII IF VIII IG VIII IH VIII II VIII IJ VIII IK VIII IL VIII IM VIII IN VIII IO VIII IP VIII IQ VIII IR VIII IS VIII IT VIII IU VIII IV VIII IY VIII IZ VIII JA VIII JB VIII JC VIII JD VIII JE VIII JF VIII JG VIII JH VIII JI VIII JJ VIII JK VIII JL VIII JM VIII JN VIII JO VIII JP VIII JQ VIII JR VIII JS VIII JT VIII JU VIII JV VIII JY VIII JZ VIII KA VIII KB VIII KC VIII KD VIII KE VIII KF VIII KG VIII KH VIII KI VIII KJ VIII KK VIII KL VIII KM VIII KN VIII KO VIII KP VIII KQ VIII KR VIII KS VIII KT VIII KU VIII KV VIII KY VIII KZ VIII LA VIII LB VIII LC VIII LD VIII LE VIII LF VIII LG VIII LH VIII LI VIII LJ VIII LK VIII LL VIII LM VIII LN VIII LO VIII LP VIII LQ VIII LR VIII LS VIII LT VIII LU VIII LV VIII LY VIII LZ VIII MA VIII MB VIII MC VIII MD VIII ME VIII MF VIII MG VIII MH VIII MI VIII MJ VIII MK VIII ML VIII MM VIII MN VIII MO VIII MP VIII MQ VIII MR VIII MS VIII MT VIII MU VIII MV VIII MW VIII MX VIII MY VIII MZ VIII NA VIII NB VIII NC VIII ND VIII NE VIII NF VIII NG VIII NH VIII NI VIII NJ VIII NK VIII NL VIII NM VIII NN VIII NO VIII NP VIII NQ VIII NR VIII NS VIII NT VIII NU VIII NV VIII NY VIII NZ VIII OA VIII OB VIII OC VIII OD VIII OE VIII OF VIII OG VIII OH VIII OI VIII OJ VIII OK VIII OL VIII OM VIII ON VIII OO VIII OP VIII OQ VIII OR VIII OS VIII OT VIII OU VIII OV VIII OW VIII OX VIII OY VIII OZ VIII PA VIII PB VIII PC VIII PD VIII PE VIII PF VIII PG VIII PH VIII PI VIII PJ VIII PK VIII PL VIII PM VIII PN VIII PO VIII PP VIII PQ VIII PR VIII PS VIII PT VIII PU VIII PV VIII PW VIII PX VIII PY VIII PZ VIII QA VIII QB VIII QC VIII QD VIII QE VIII QF VIII QG VIII QH VIII QI VIII QJ VIII QK VIII QL VIII QM VIII QN VIII QO VIII QP VIII QQ VIII QR VIII QS VIII QT VIII QU VIII QV VIII QW VIII QX VIII QY VIII QZ VIII RA VIII RB VIII RC VIII RD VIII RE VIII RF VIII RG VIII RH VIII RI VIII RJ VIII RK VIII RL VIII RM VIII RN VIII RO VIII RP VIII RQ VIII RR VIII RS VIII RT VIII RU VIII RV VIII RW VIII RX VIII RY VIII RZ VIII SA VIII SB VIII SC VIII SD VIII SE VIII SF VIII SG VIII SH VIII SI VIII SJ VIII SK VIII SL VIII SM VIII SN VIII SO VIII SP VIII SQ VIII SR VIII SS VIII ST VIII SU VIII SV VIII SW VIII SX VIII SY VIII SZ VIII TA VIII TB VIII TC VIII TD VIII TE VIII TF VIII TG VIII TH VIII TI VIII TJ VIII TK VIII TL VIII TM VIII TN VIII TO VIII TP VIII TQ VIII TR VIII TS VIII TU VIII TV VIII TW VIII TX VIII TY VIII TZ VIII UA VIII UB VIII UC VIII UD VIII UE VIII UF VIII UG VIII UH VIII UI VIII UJ VIII UK VIII UL VIII UM VIII UN VIII UO VIII UP VIII UQ VIII UR VIII US VIII UT VIII UY VIII UZ VIII VA VIII VB VIII VC VIII VD VIII VE VIII VF VIII VG VIII VH VIII VI VIII VJ VIII VK VIII VL VIII VM VIII VN VIII VO VIII VP VIII VQ VIII VR VIII VS VIII VT VIII VU VIII VV VIII VY VIII VZ VIII WA VIII WB VIII WC VIII WD VIII WE VIII WF VIII WG VIII WH VIII WI VIII WJ VIII WK VIII WL VIII WM VIII WN VIII WO VIII WP VIII WQ VIII WR VIII WS VIII WT VIII WY VIII WZ VIII XA VIII XB VIII XC VIII XD VIII XE VIII XF VIII XG VIII XH VIII XI VIII XJ VIII XK VIII XL VIII XM VIII XN VIII XO VIII XP VIII XQ VIII XR VIII XS VIII XT VIII XU VIII XV VIII XY VIII XZ VIII YA VIII YB VIII YC VIII YD VIII YE VIII YF VIII YG VIII YH VIII YI VIII YJ VIII YK VIII YL VIII YM VIII YN VIII YO VIII YP VIII YQ VIII YR VIII YS VIII YT VIII YU VIII YV VIII YW VIII YX VIII YY VIII YZ VIII ZA VIII ZB VIII ZC VIII ZD VIII ZE VIII ZF VIII ZG VIII ZH VIII ZI VIII ZJ VIII ZK VIII ZL VIII ZM VIII ZN VIII ZO VIII ZP VIII ZQ VIII ZR VIII ZS VIII ZT VIII ZU VIII ZV VIII ZW VIII ZX VIII ZY VIII ZZ

Fig. 3-4

Some Important Elements

Symbols

C carbon

H hydrogen

N nitrogen

O oxygen

P phosphorus

Ca calcium

Fe iron

K potassium

Na sodium

S sulfur

Br bromine

Cl chlorine

Fl fluorine

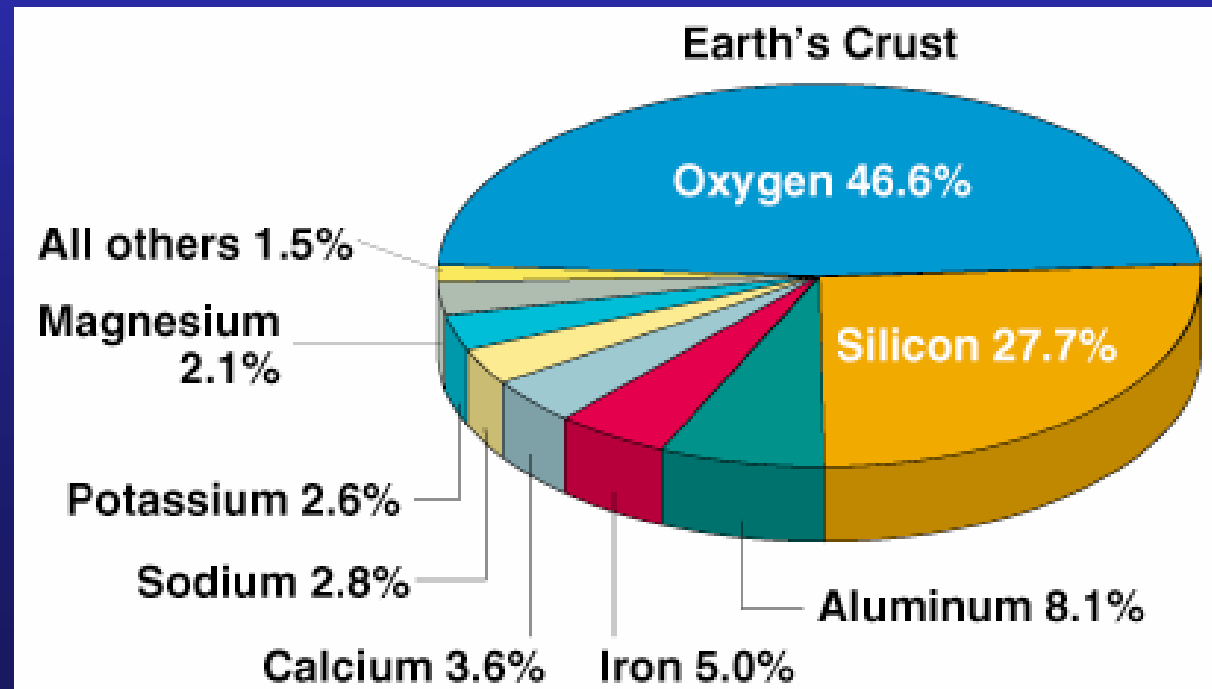
Al aluminum

Hg mercury

Pb lead

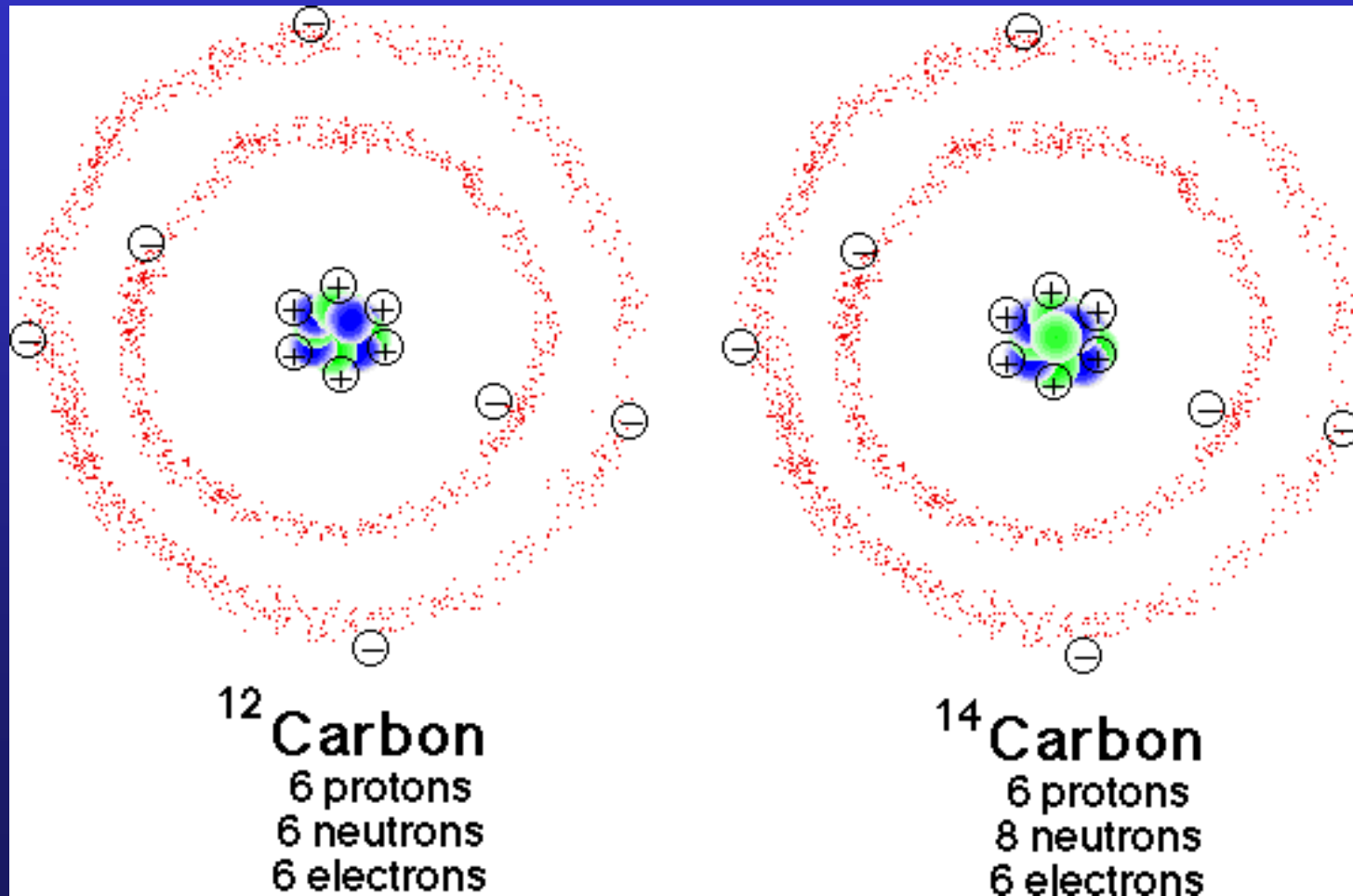
Si silicon

*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.



Isotopes

Hydrogen (H)



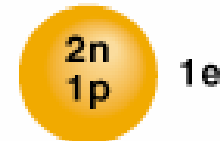
1e

Mass number = $0 + 1 = 1$
Hydrogen-1
(99.98%)



1e

Mass number = $1 + 1 = 2$
Hydrogen-2
or deuterium (D)
(0.015%)



1e

Mass number = $2 + 1 = 3$
Hydrogen-3
or tritium (T)
(trace)

Uranium (U)



92e

Mass number = $143 + 92 = 235$
Uranium-235
(0.7%)



92e

Mass number = $146 + 92 = 238$
Uranium-238
(99.3%)

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):

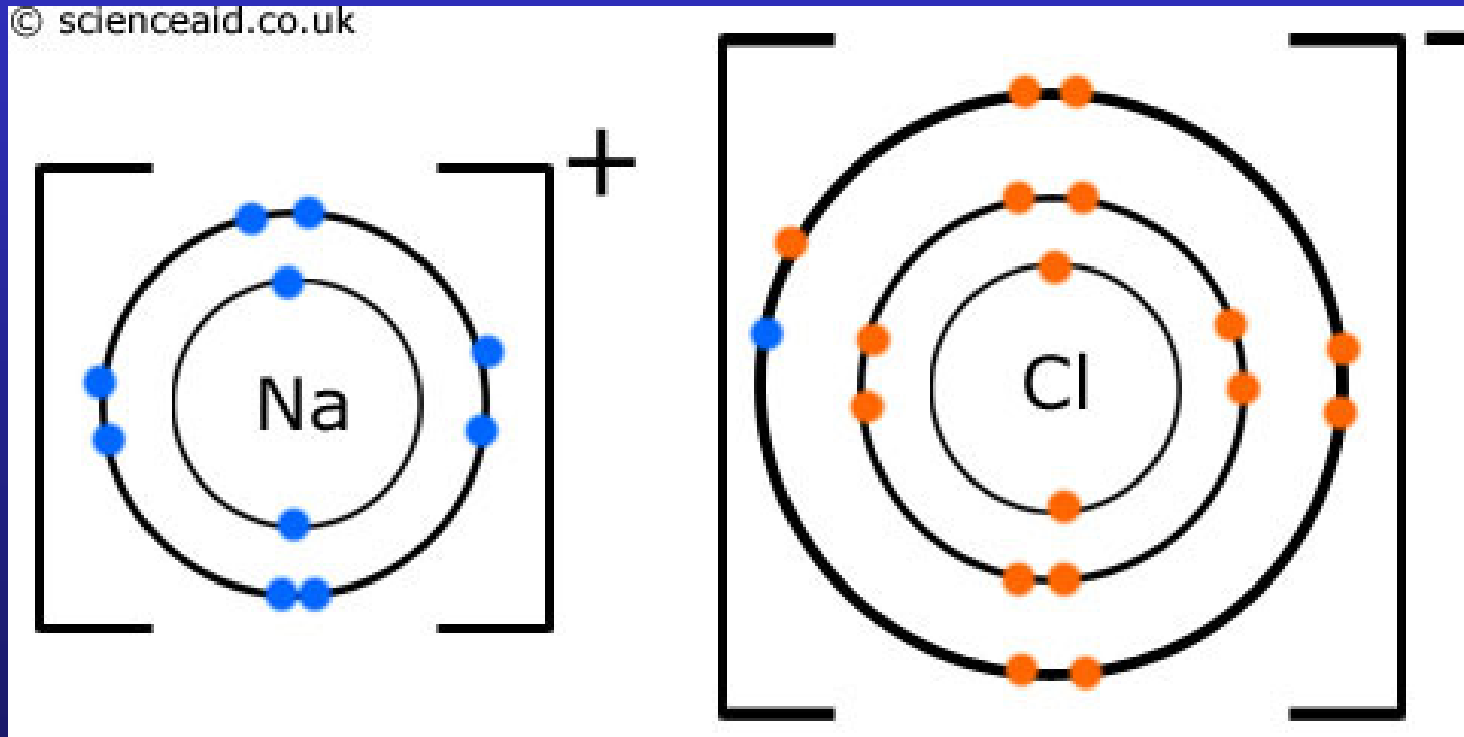
Na⁺ sodium, Ca²⁺ calcium, Fe⁺ iron, Al³⁺ aluminum

examples of negative ions (anions):

Cl⁻ chloride, PO₄³⁻ phosphate, SO₃⁻ sulfate

Matter

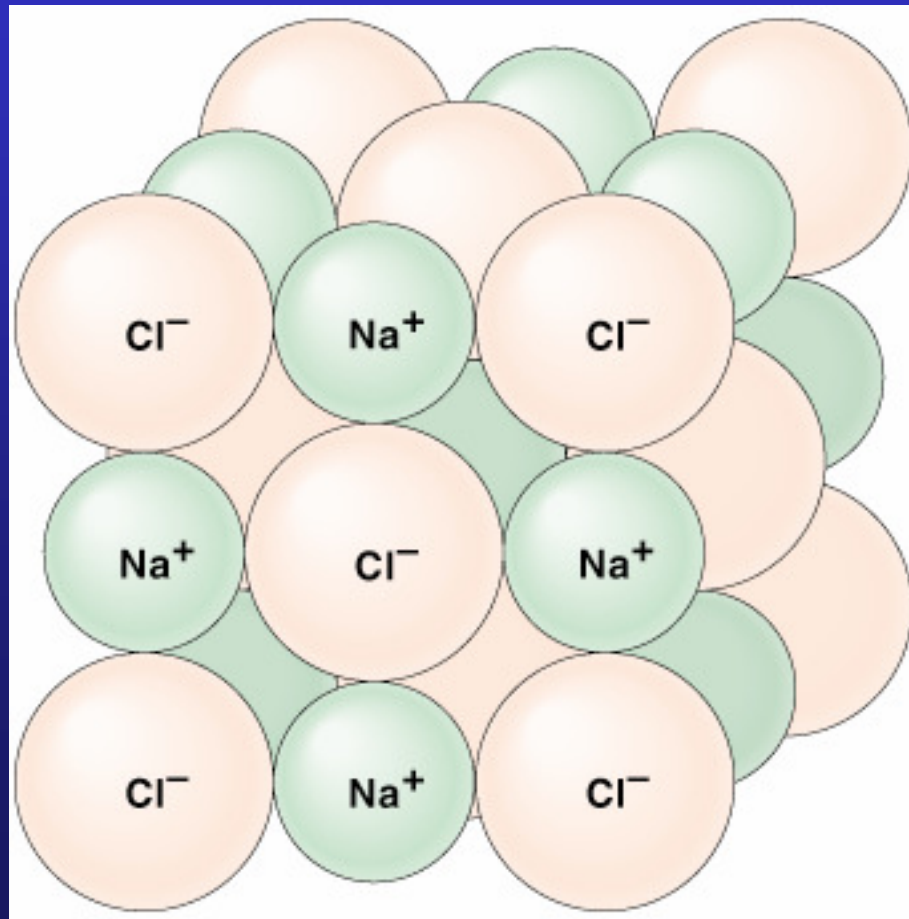
2) **compounds**: two or more different elements held together in fixed proportions by chemical bonds.



Strong Chemical Bonds

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

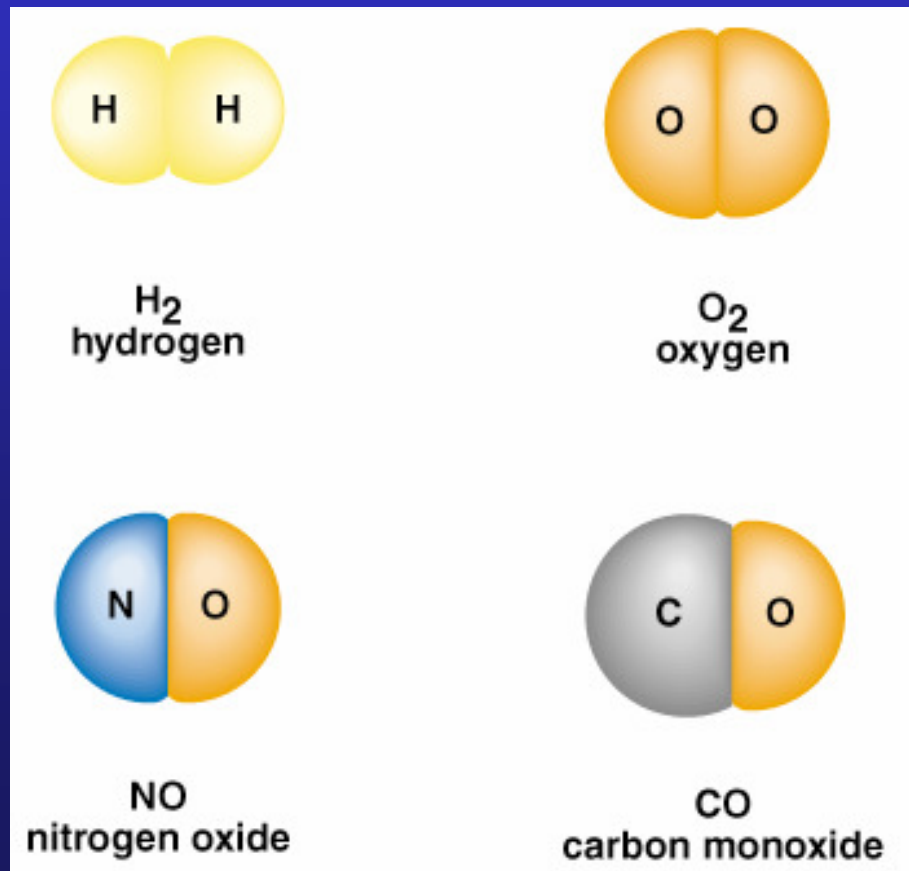
Solid crystals of ionic compounds, such as NaCl, consist of a three-dimensional array of oppositely charged ions held together by ionic bonds.



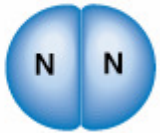
Strong Chemical Bonds

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

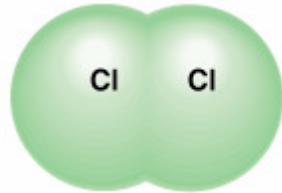
Some important molecules formed by covalent bonds.



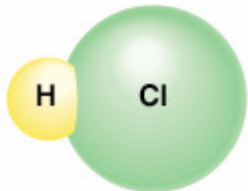
More Important Molecules



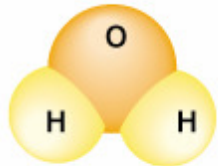
N_2
nitrogen



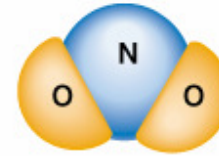
Cl_2
chlorine



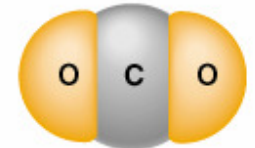
HCl
hydrogen chloride



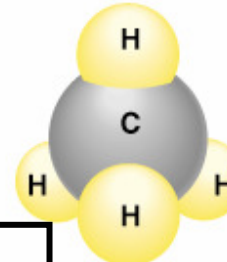
H_2O
water



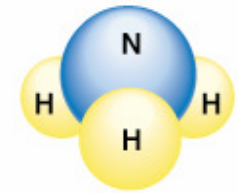
NO_2
nitrogen dioxide



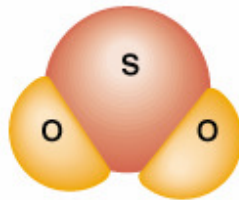
CO_2
carbon dioxide



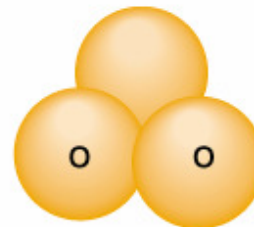
CH_4
methane



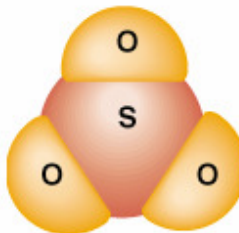
NH_3
ammonia



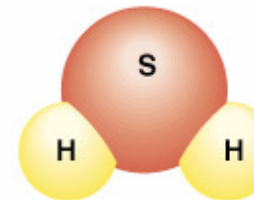
SO_2
sulfur dioxide



O_3
ozone



SO_3
sulfur trioxide



H_2S
hydrogen sulfide

Inorganic vs. Organic Molecules

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

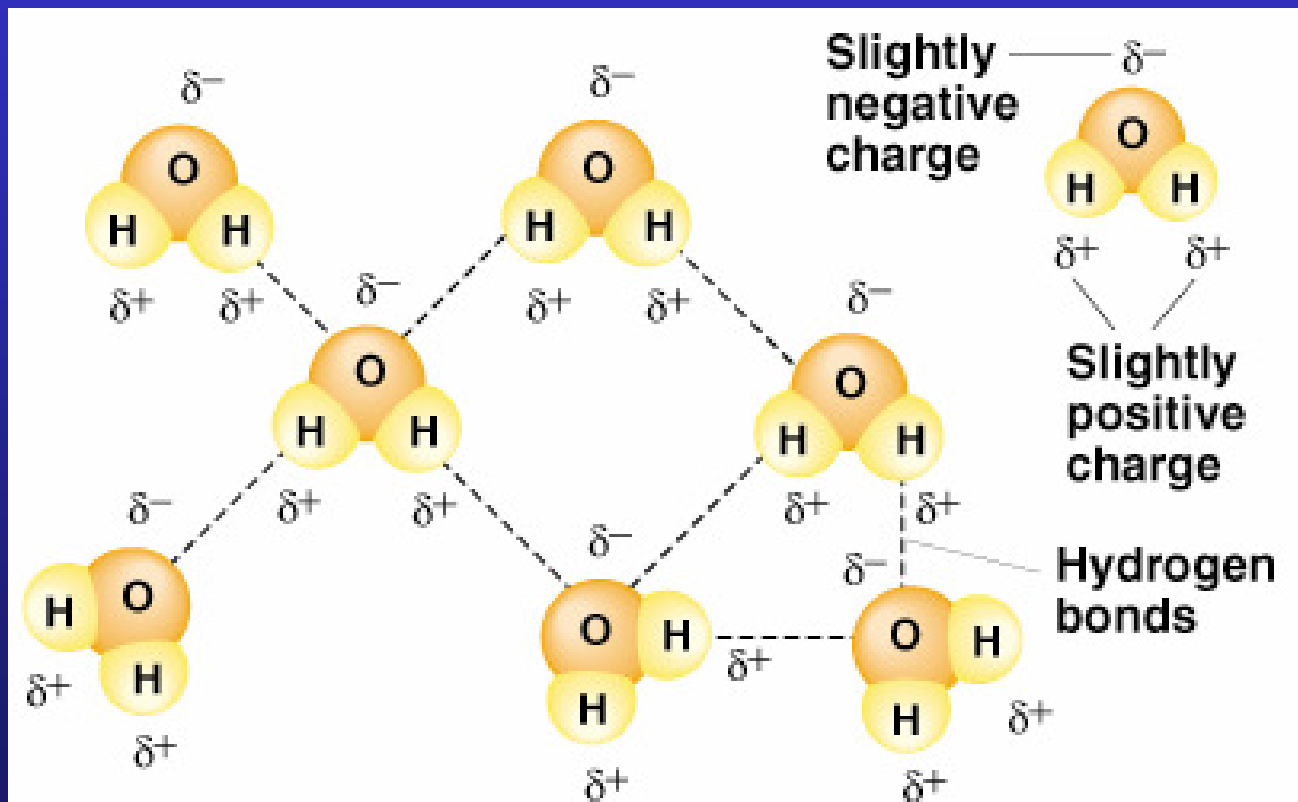
e.g., water H_2O , carbon dioxide (CO_2),
nitrogen gas (N_2), oxygen gas (O_2), ozone (O_3).

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

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

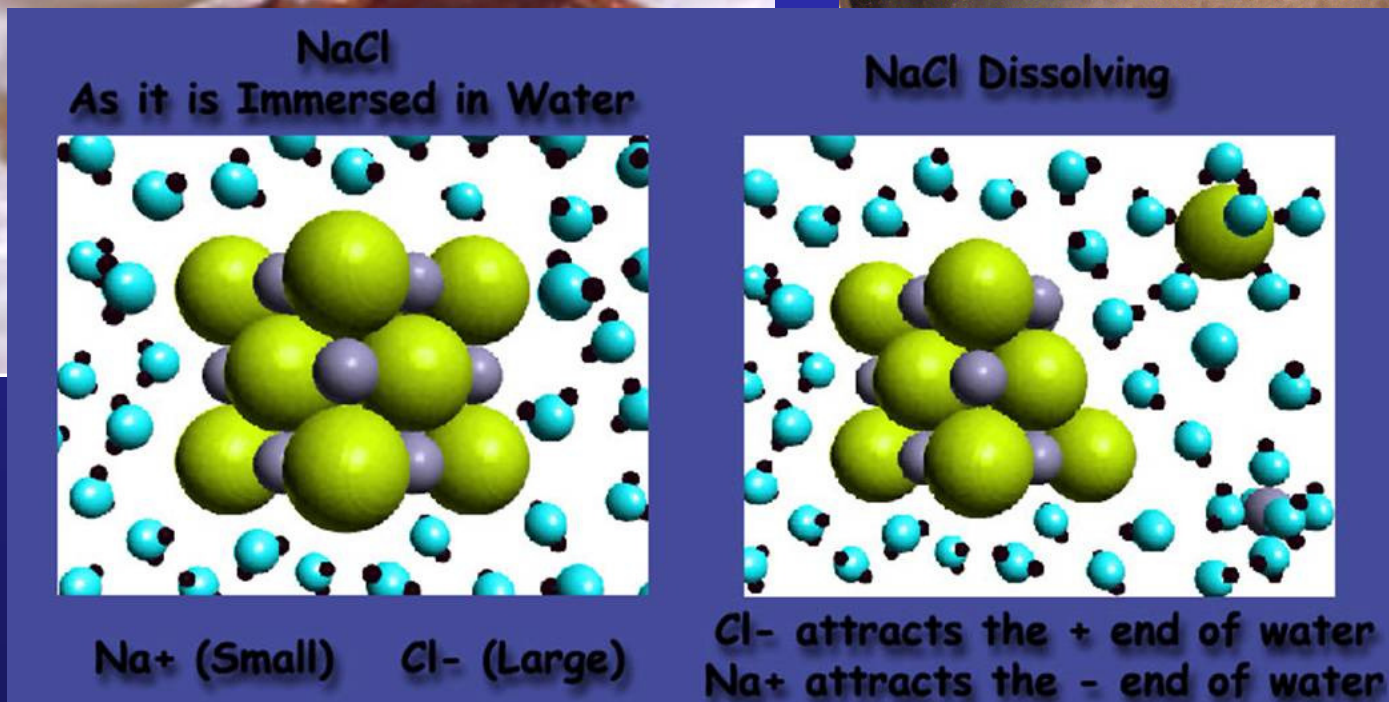
Weak Chemical Bonds

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

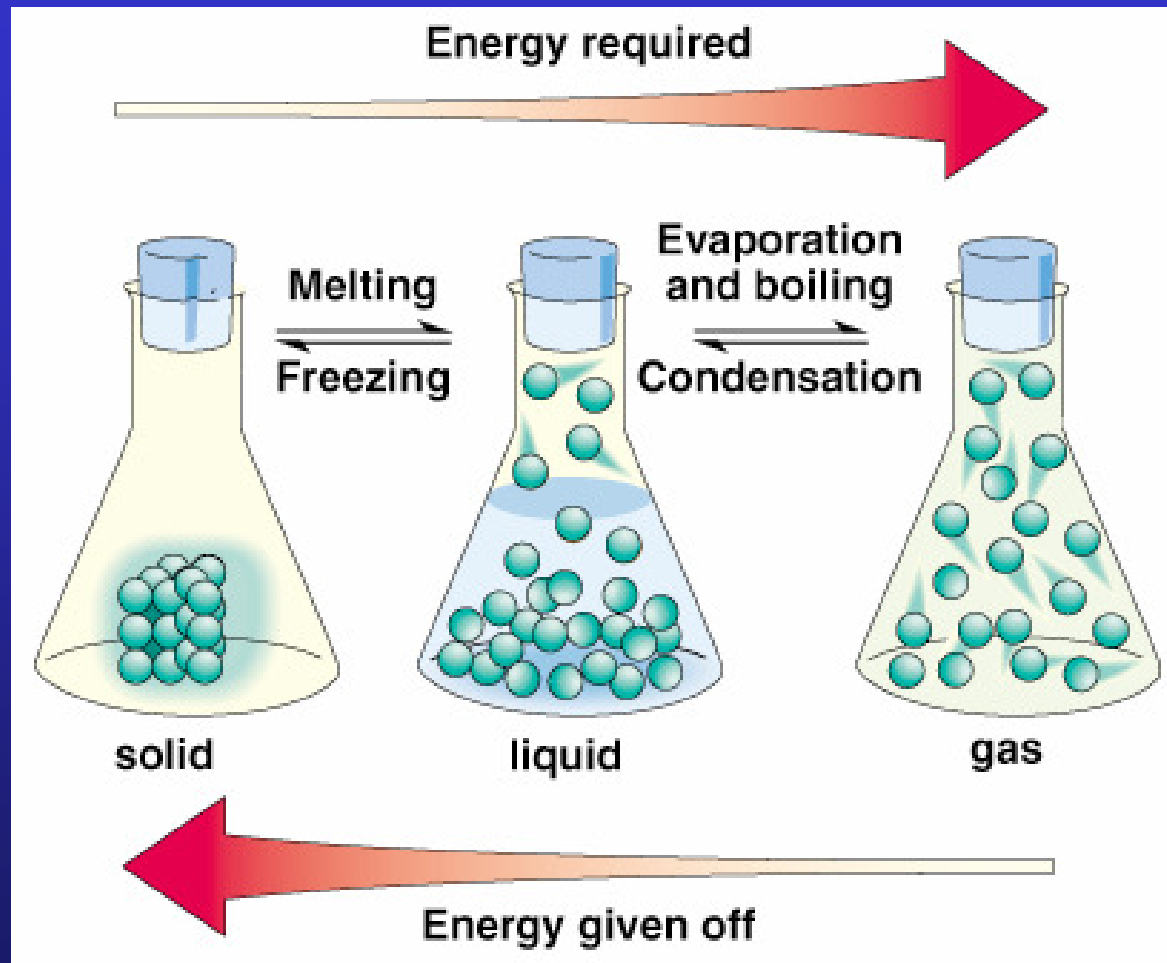


Fig. 3-2

Matter Quality

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

High Quality



Solid



Coal



Gasoline



Salt

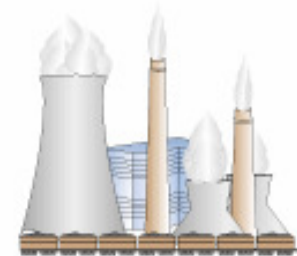


Aluminum can

Low Quality



Automobile emissions



Coal-fired power plant emissions



Gas



Solution of salt in water



Aluminum ore

2. Energy

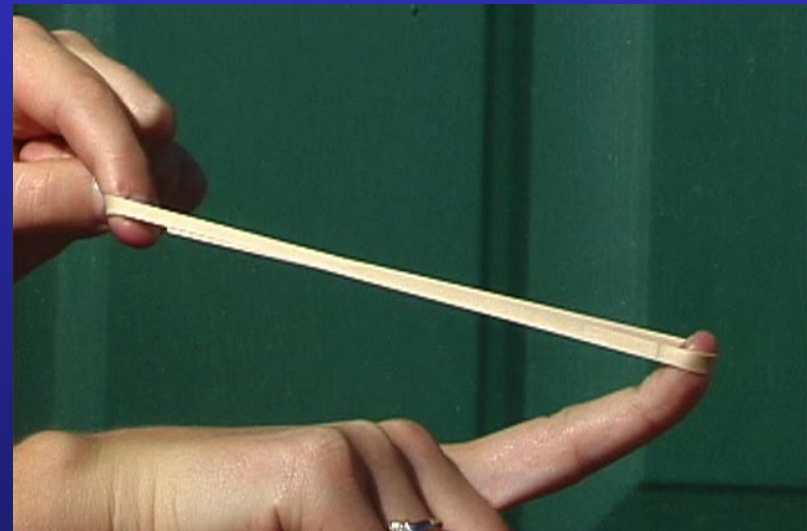
energy: the capacity to do work (by performing mechanical, physical, chemical, or electrical tasks), or to cause heat transfer between two objects at different temperatures.

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>



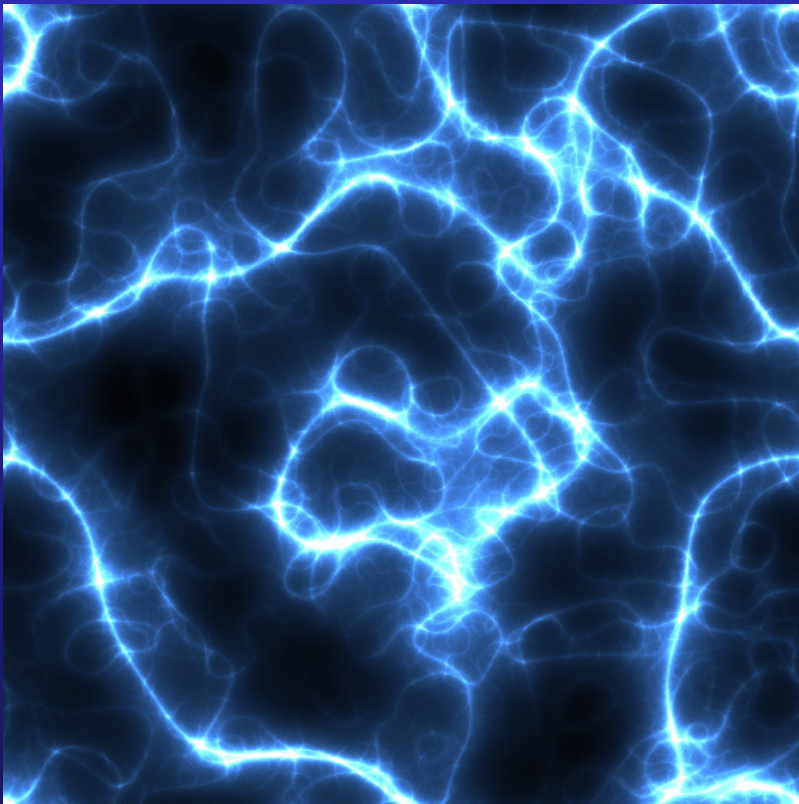
•http://video.ecb.org/badger/download/vlc/images/VLC180_Example_of_potential_energy.jpg

- **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



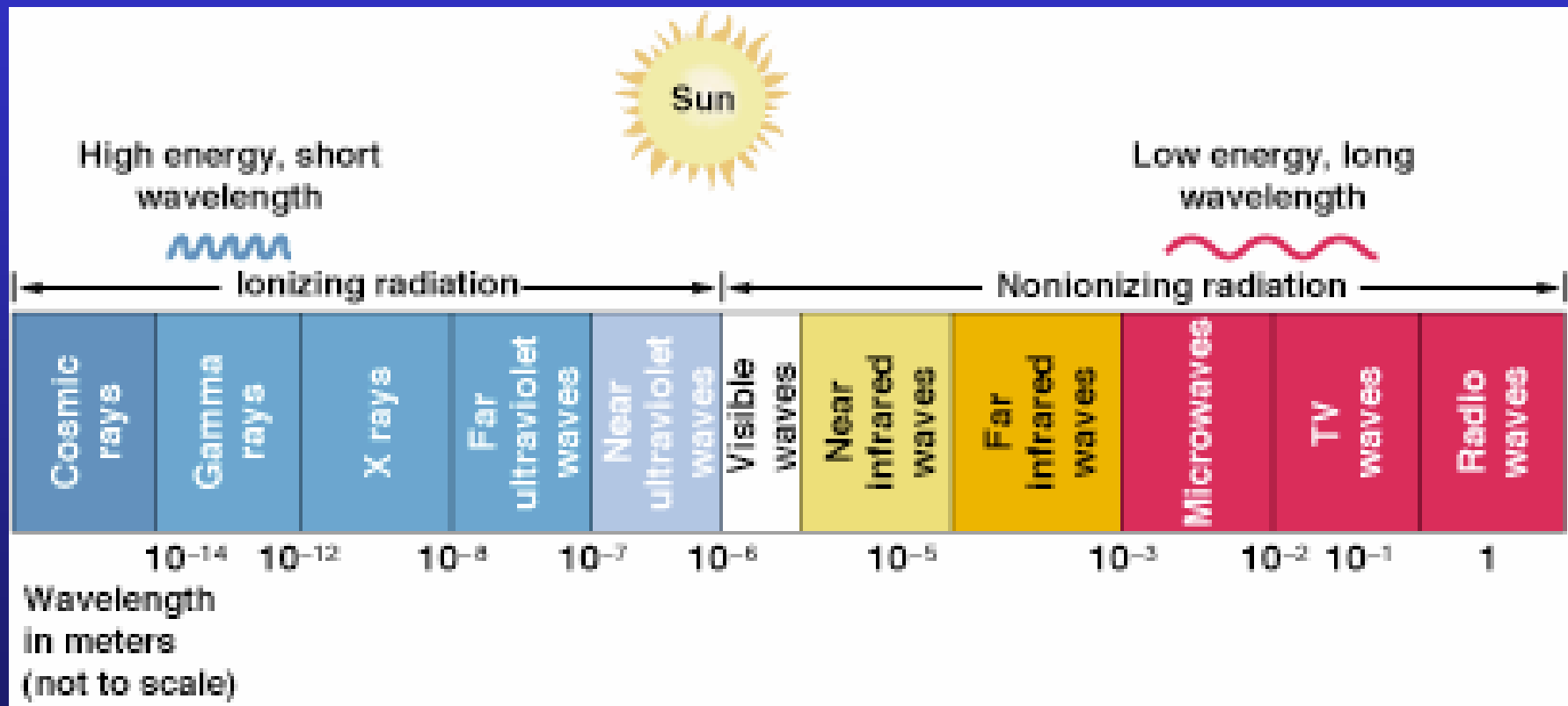
•<http://www.filterforge.com/filters/237.jpg>



•<http://i1.treearth.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.

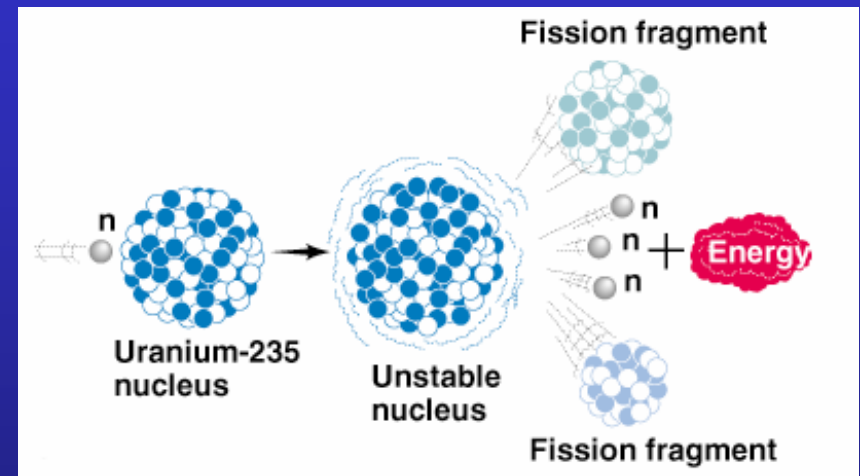


Energy content of electromagnetic radiation varies in proportion to wavelength. Shorter wavelengths have higher energy content than longer wavelengths.

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.



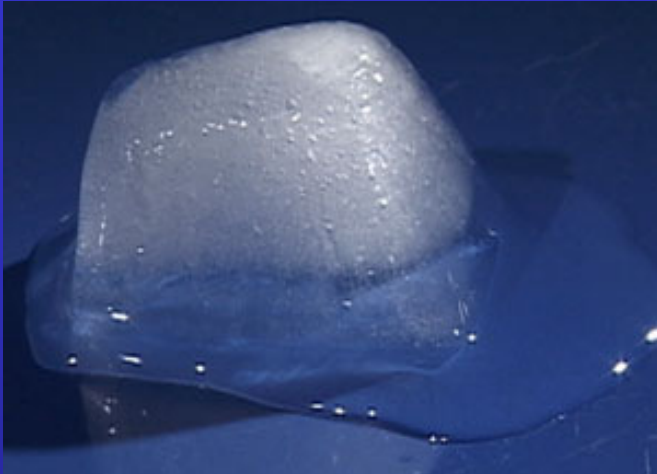
- **atomic energy** – energy associated with nuclear structure, e.g., energy released by fission of Uranium–235.

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.

Source of Energy	Relative Energy Quality (usefulness)	Energy Tasks
Electricity Very high-temperature heat (greater than 2,500°C) Nuclear fission (uranium) Nuclear fusion (deuterium) Concentrated sunlight High-velocity wind	 <p>VERY HIGH</p>	Very high-temperature heat (greater than 2,500°C) for industrial processes and producing electricity to run electrical devices (lights, motors)
High-temperature heat (1,000°C–2,500°C) Hydrogen gas Natural gas Gasoline Coal Food	 <p>HIGH</p>	Mechanical motion (to move vehicles and other things) High-temperature heat (1,000°C–2,500°C) for industrial processes and producing electricity
Normal sunlight Moderate-velocity wind High-velocity water flow Concentrated geothermal energy Moderate-temperature heat (100°C–1,000°C) Wood and crop wastes	 <p>MODERATE</p>	Moderate-temperature heat (100°C–1,000°C) for industrial processes, cooking, producing steam, electricity, and hot water
Dispersed geothermal energy Low-temperature heat (100°C or lower)	 <p>LOW</p>	Low-temperature heat (100°C or less) for space heating

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:

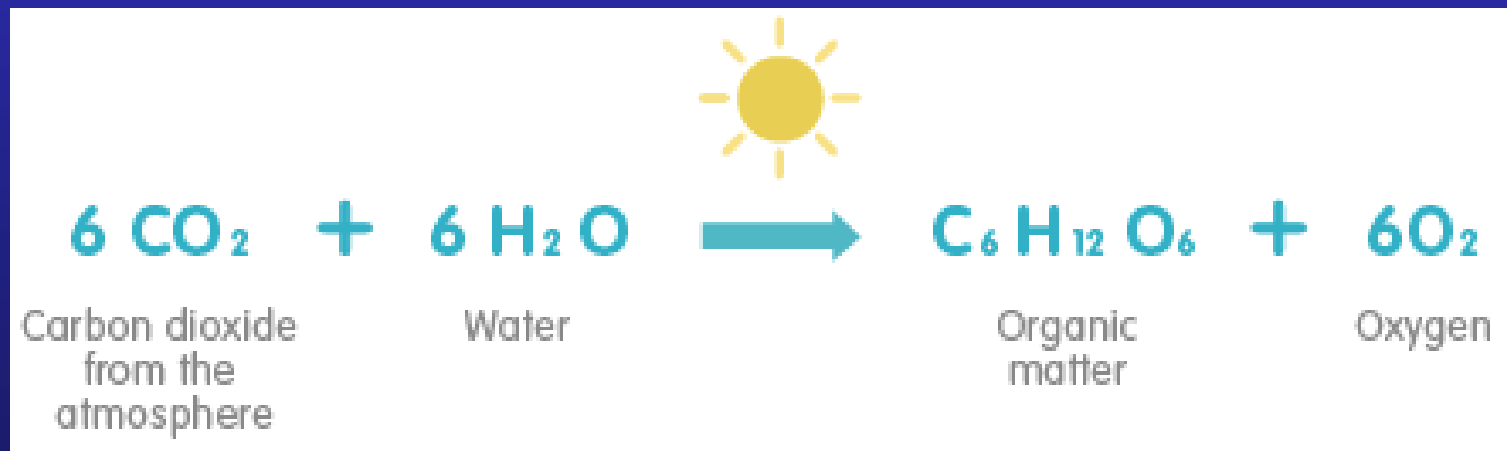


•<http://nahs2010hphysscipd9.wikispaces.com/file/view/Fire-big.jpg/176889739/Fire-big.jpg>

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.

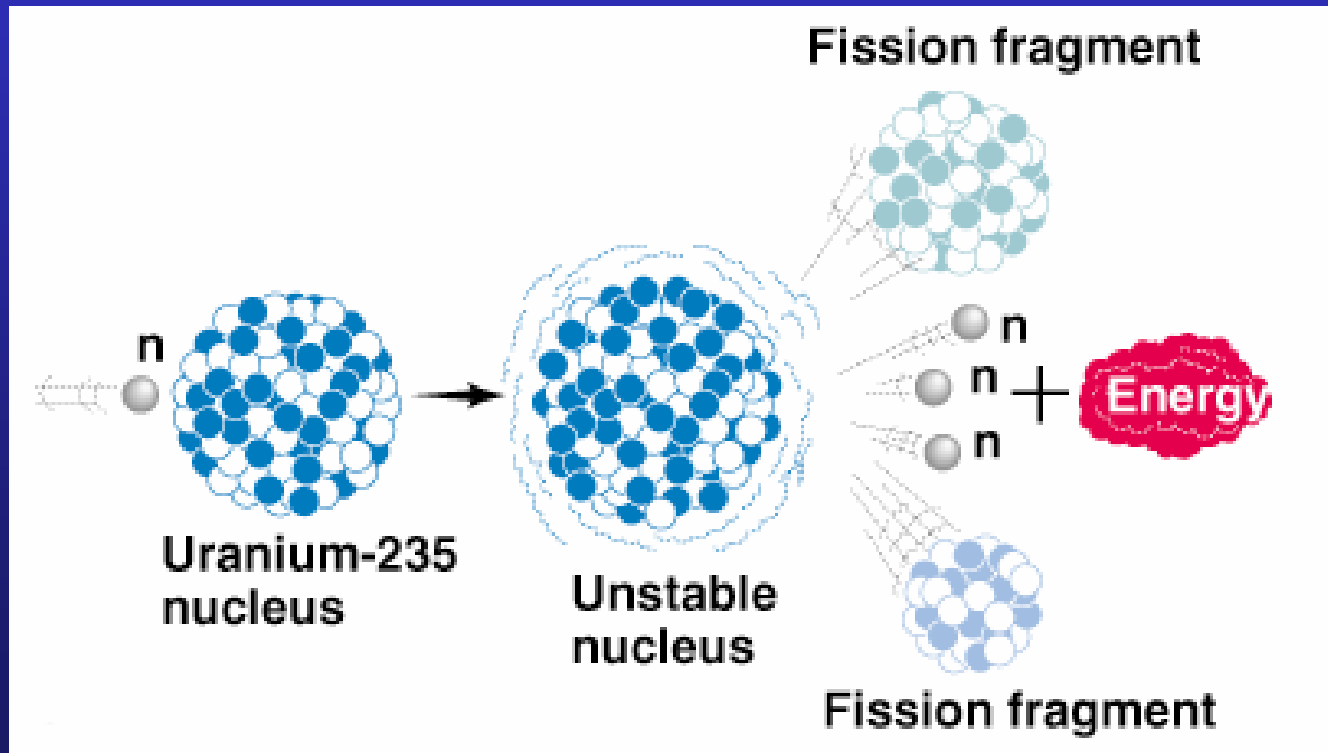


•<http://www.teacherthomas.com/wp-content/uploads/2010/01/photosynthesis-equation.gif>

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

Nuclear Fission

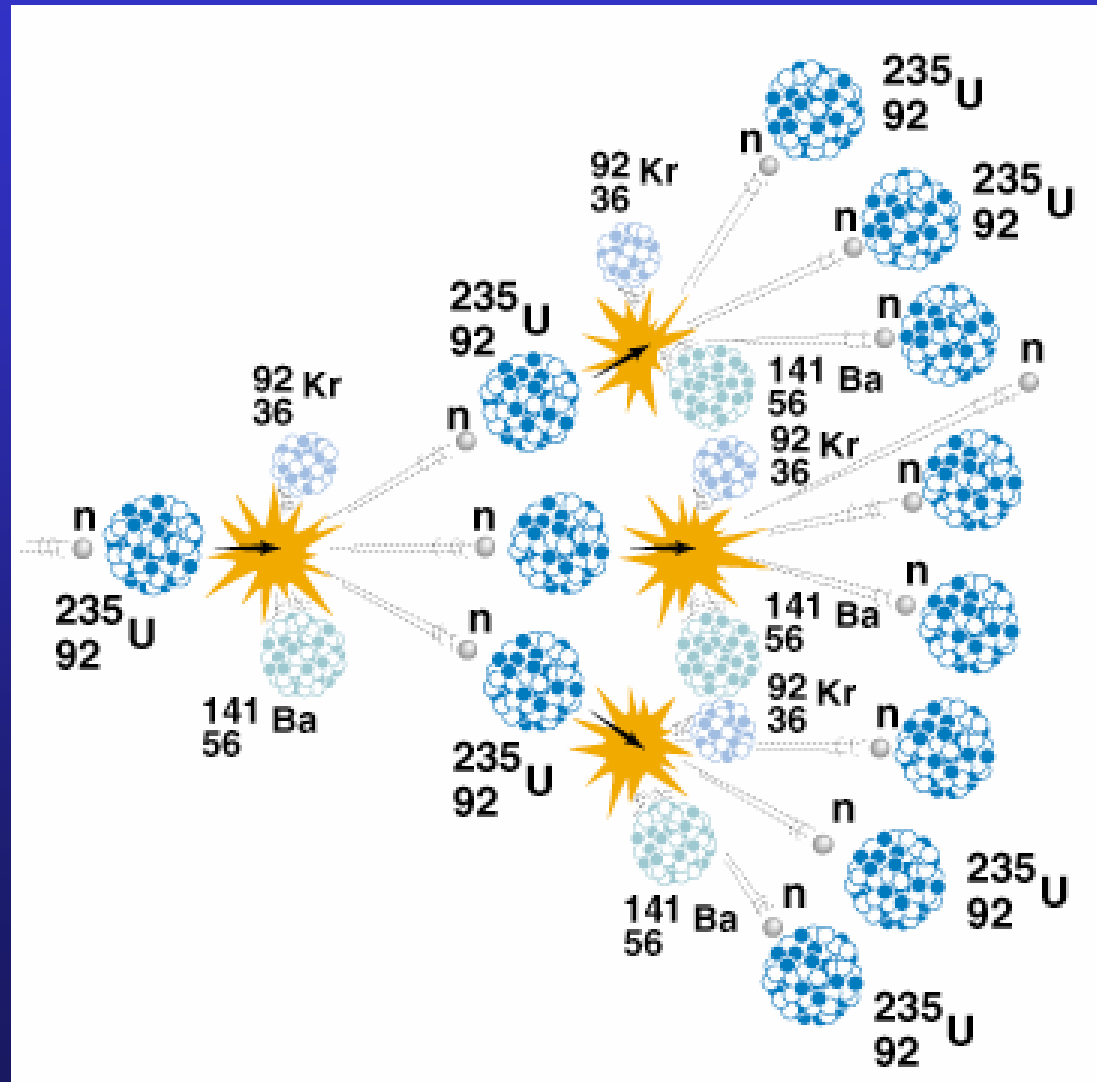
nuclear fission: a nuclear change in which certain unstable isotopes of high mass numbers split into lighter nuclei & release energy in the process.



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.

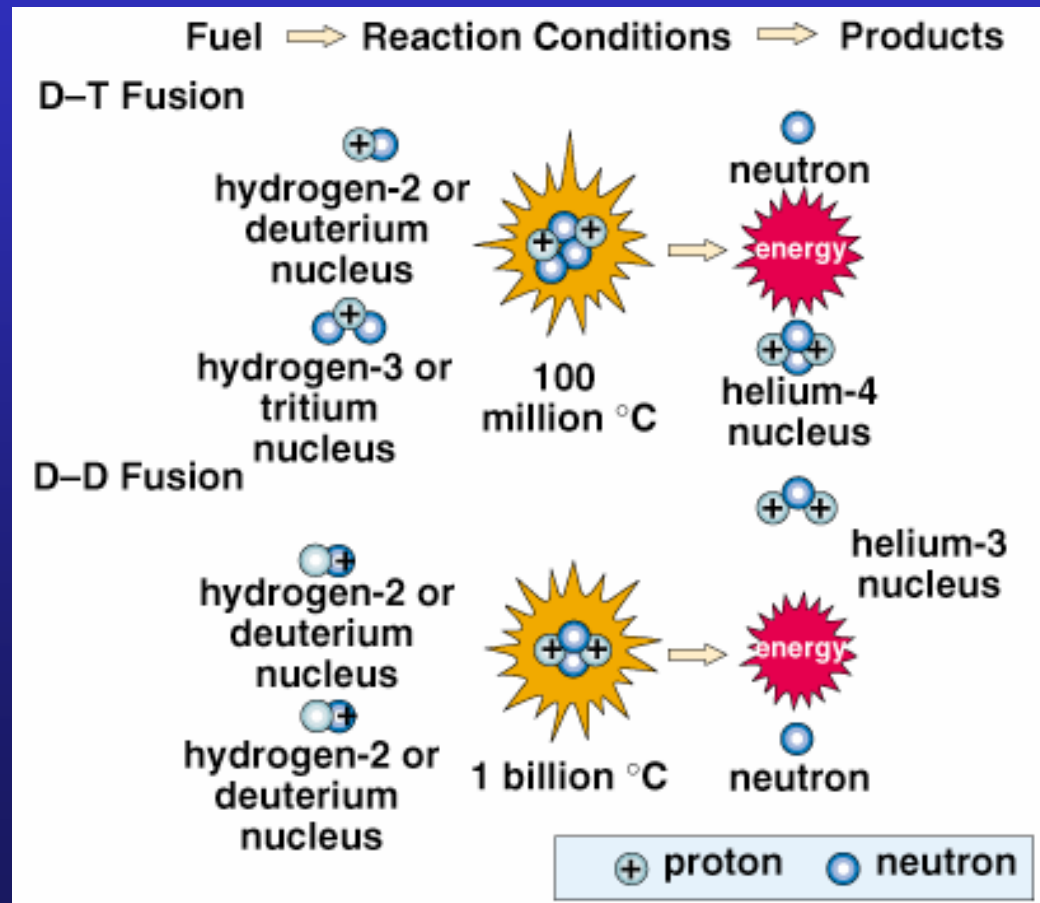


A nuclear chain reaction.

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.



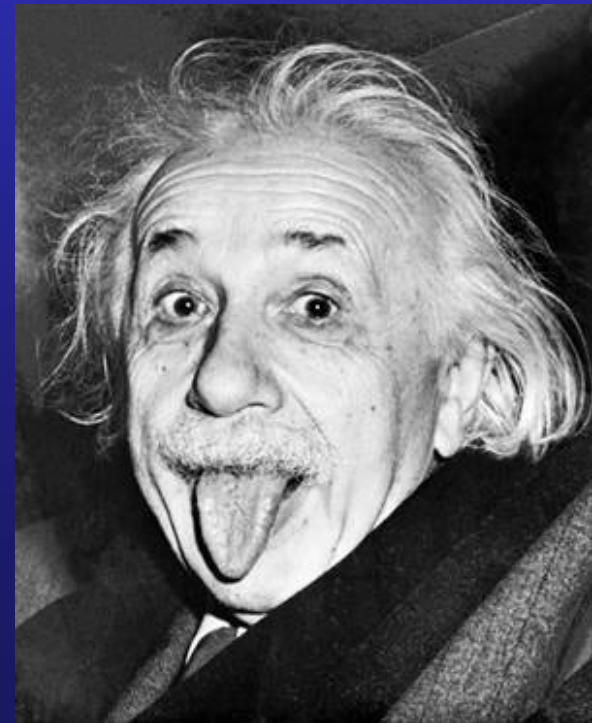


In 1993 scientists at the Tokamak Fusion Test Reactor, at Princeton University's plasma physics laboratory in New Jersey, produced a controlled fusion reaction, during which the temperature in the reactor surpassed three times that of the core of the sun. In a tokamak reactor, massive magnets confine 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

$$E = mc^2$$

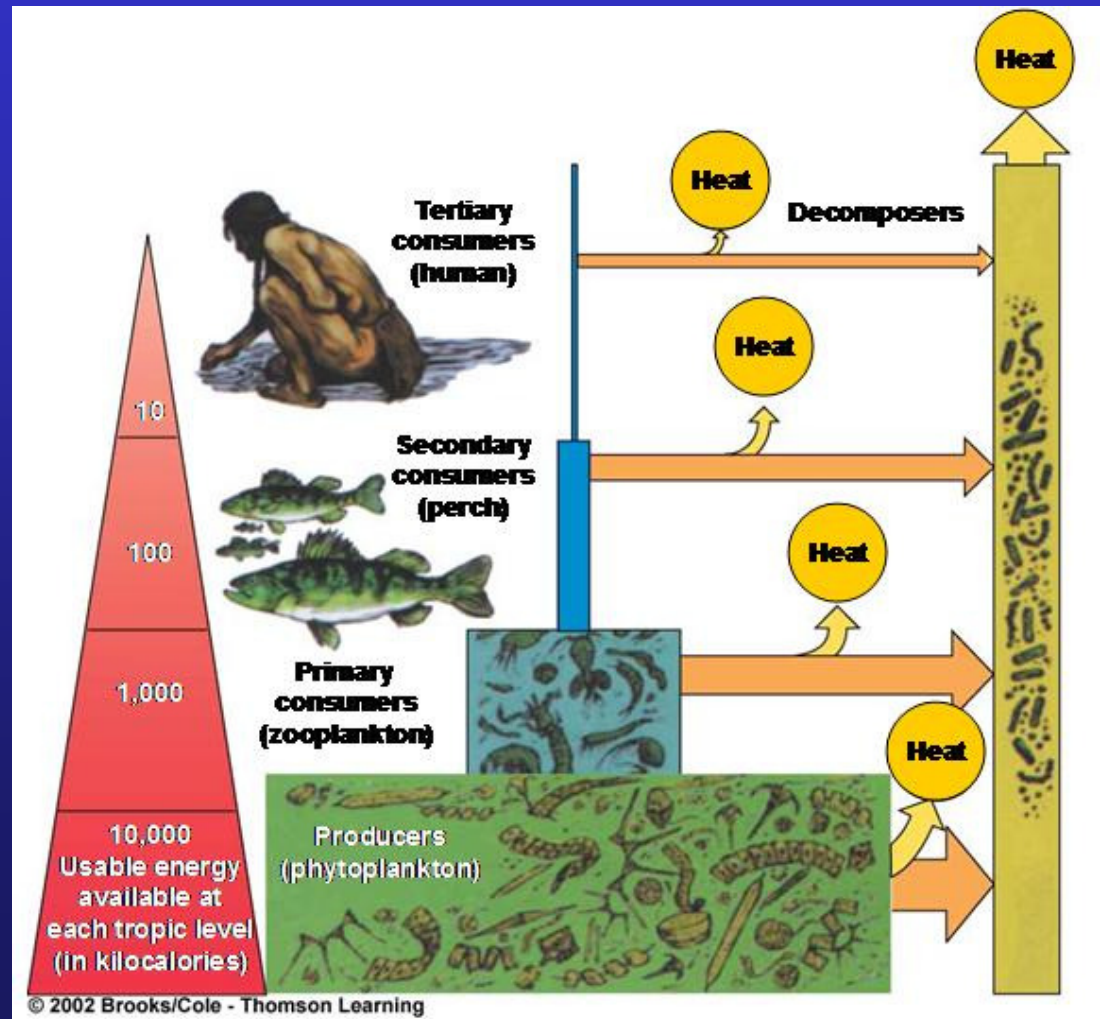


•http://0.tqn.com/d/physics/1/0/C/0/-/-/Einstein_tongue.jpg

4. Energy Laws

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

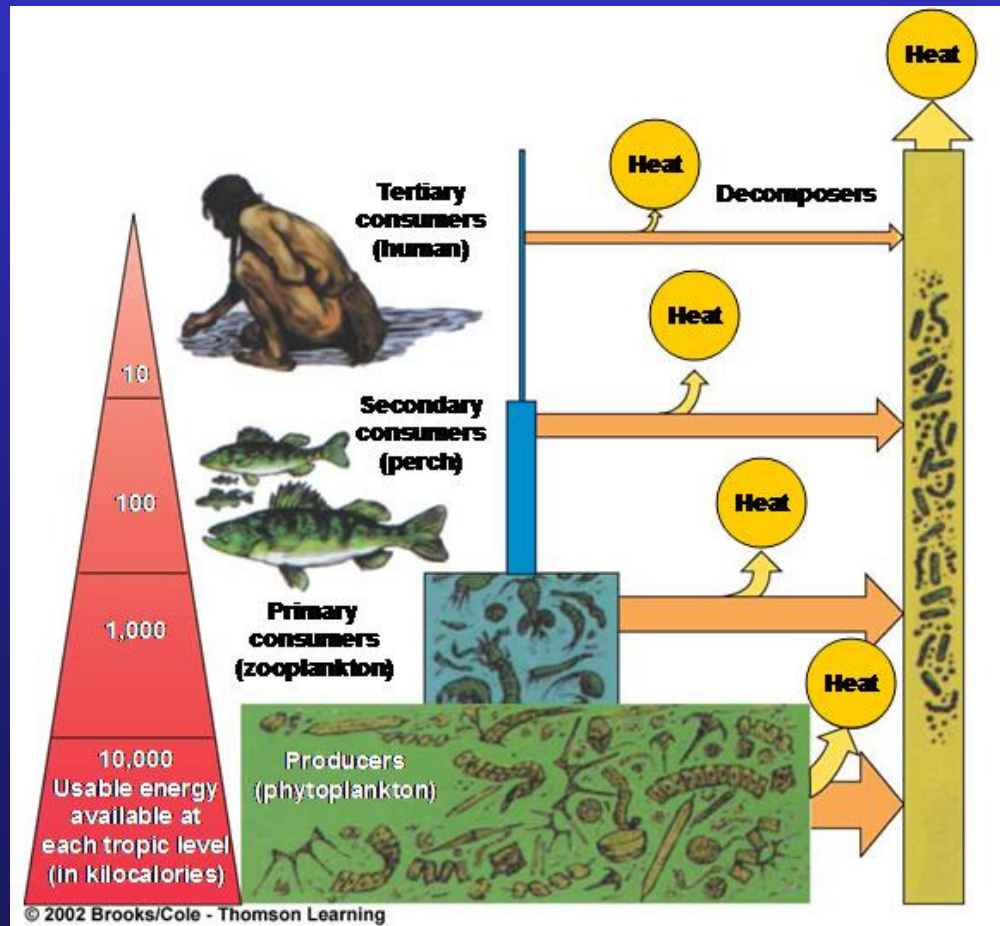
- energy is conserved
- implication that bookkeeping is possible, e.g., in ecological study, energy flow can be followed
- also stated, "you can't get something for nothing", in terms of energy quantity.



Energy Laws

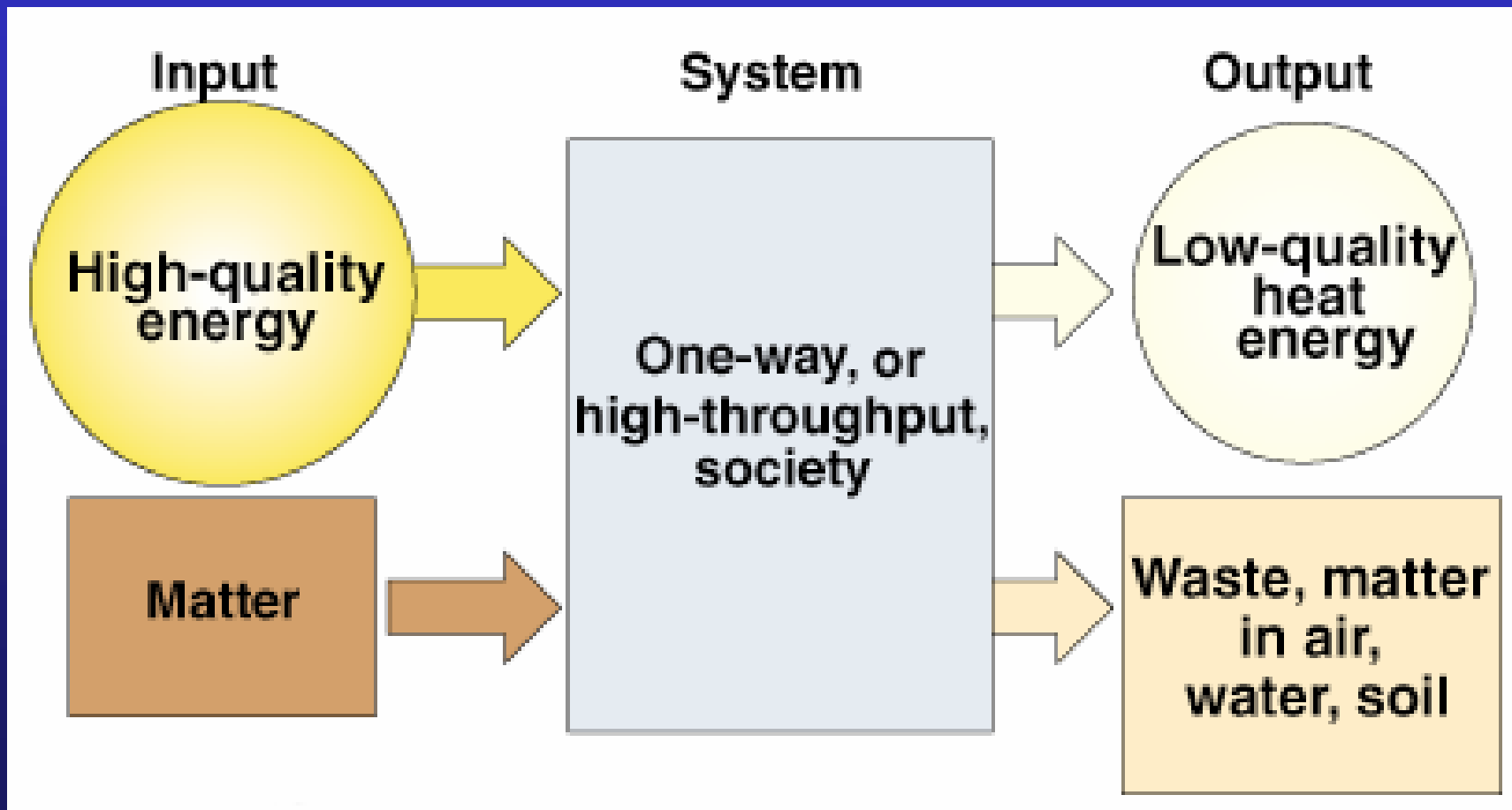
second law of thermodynamics: when energy is converted from one form to another, some of the useful energy is always degraded to lower-quality, more dispersed energy.

- 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.

