Ch. 3 - Matter and Energy Resources: Types and Concepts

Matter: Forms, Structure, and Quality

Matter- anything that has mass and takes up space

2 chemical forms:

1. elements - distinctive building blocks of matter that make up every substance

2. compounds - two or more different elements held together in fixed proportions by attractive forces (chemical bonds)

mixtures - various elements, compounds, or both

atoms - smallest unit of matter that's unique to a particular element
"ultimate building blocks for matter"

ions - electrically charged atoms or combinations of atoms [monatomic (Na^{+}, Mg^{+2}) or polyatomic (CO_3^{-2}, PO_4^{-3})]

molecules - combinations of two or more atoms of the same of different elements held together by <u>covalent</u> bonds (O_2, CO_2, CH_4). Neutral charge.

Three physical states of matter:

solid
liquid
gas

Atoms are made of subatomic particles:

protons - positively charged; located in the nucleus

neutrons - neutral/no charge; located in the nucleus

electrons - negatively charged, found in electron clouds

atomic number - number of protons in the nucleus (tells the number of electrons as well)

mass number - total number of neutrons and protons in the nucleus

isotopes - various forms of an element with the same atomic number but different mass numbers

periodic table - classification of elements according to chemical behavior

period - horizontal row

group/family - vertical column

metals - usually conduct heat and electricity, strong

nonmetals - don't conduct heat and electricity very well, and usually aren't shiny

metalloids - mixture of metallic and nonmetallic properties

nutrients - required for all or some forms of life chemical formula- shorthand way to show the number of atoms (or ions) in the basic structural unit of a compound. e.g., H_2O, NaCl, $C_6H_{12}O_6$

ionic compounds- compounds made of oppositely charged ions (ionic bonds-strong forces of attraction between opposite charges)

covalent (molecular) compounds- compounds of molecules of uncharged atoms

> e.g., H_2O (covalent bonds-atoms share 1 or more pairs of electrons) usually gases or liquids

hydrogen bonds - forces of attraction between molecules

organic compounds - contain carbon atoms combined with each other and with atoms of 1 or more other elements, such as: H, O, N, S, P, Cl, F

-molecular compounds held together by covalent bonds (almost all)

-polymers - larger and more complex organic compounds, consist of a number of basic structural or molecular units (monomers), linked by chemical bonds

1. **complex carbs** - made by linking a number of simple carb. Molecules

e.g., Complex starches in rice and potatoes

2. **proteins** - produced in living cells by linking different sequences of about 20 different monomers (amino-acids) whose number and sequence in each protein are specified by genetic code found in DNA molecules in an organism's cells.

essential amino acids - the 10 amino acids that must be obtained from food can act as enzymes to control the rate at which chemical reactions take place in a cell.

3. nucleic acids made by linking hundreds to thousands of five different types of monomers (nucleotides- have 1 phosphate group, 1 sugar molecule, 5 carbon atoms [deoxyribose in DNA and ribose in RNA], and 1 of 4 nucleotide bases [A, G, C, T])

DNA -instructions for new cells and proteins for each cell

RNA - instructions for proteins within cells

Genes - specific sequences of nucleotides in DNA molecules; approx. 75,000 in each cell -carries codes required to make various proteins

-gene mutations - changes of the nucleotide bases in a gene sequence

-chromosomes - combinations of genes that make up a single DNA molecule together with a number of proteins; human cell- 46 chromosomes

lipids - biologically important molecules, not polymers, include molecules of fat, oils, waxes phospholipids, and various substances

-serve as energy storage molecules, regulators of certain cellular functions, nutrients, and water proof coverings around cells

inorganic compounds - all other compounds; ex. ionic and covalent

Earth's crust - outermost layer, made of inorganic materials and rocks

-mineral - element or inorganic compound that occurs naturally, is solid; usually has crystalline internal structure made of 3-d arrangement of atoms or ions.

-rock - any material that makes up a large, natural, continuous part of the earth's crust; must contain at least 2 minerals

matter quality - measurement of how useful a matter resource is; availability and concentration

high-quality matter-organized, concentrated, and usually found near the earth's surface; has great potential for use as a matter resource

low-quality matter- disorganized, dilute, and often deep underground or dispersed in the ocean or atmosphere; has little potential as a matter resource

entropy - measurement of disorder or randomness of a system.

high disorder = high entropy

3-2 Energy: Forms and Quality

energy- capacity to do work and transfer heat

-many forms: light, heat, electricity; chemical, mechanical, nuclear energy

-**kinetic** - energy that matter has b/c of its mass and speed (velocity)

~ energy in action or motion

~ wind, flowing water, falling rocks, electricity

~ electromagnetic radiation- consists of wide band (spectrum) of electromagnetic waves that differ in wavelength and energy content

e.g., radio waves, TV waves

~ heat - total kinetic energy of all moving atoms, ions, molecules with a given substance; excluding the motion of the whole object

~ temperature - measurement of the average speed of motion of an atom, ion, molecule in a sample of matter at a given moment

-**potential energy** - stored energy that's potentially available for use

~ rock, dynamite, still water behind dam

~ can be changed to kinetic energy

energy quality - measurement of energy source's ability to do useful work:

high energy quality - organized or concentrated and can perform much useful work

e.g., electricity, coal, gas

low energy quality - disorganized, dispersed and has little ability to do useful work

e.g., heat in atoms

3-3 Physical and Chemical Changes and the Law of Conservation of Matter

physical change- involves no change in chemical composition - ex. cutting, changing states

chemical change (reaction)- chemical compositions are altered -chemical equation: reactants ------> products

$$C + O_2 \text{ ------> } CO_2 + \text{energy}$$

Law of Conservation of Matter

- we may change elements and compounds from one physical of chemical form to another, but we cannot create or destroy the atoms involved

- nothing is "consumed" or "thrown away"

3-4 Nuclear Changes

Law of Conservation of Matter and Energy- In any nuclear change, the total amount of matter and energy involved remains the same

nuclear changes- nuclei of certain isotopes spontaneously change or are made to change into one or more different isotopes; 3 types:

1. **natural radioactive decay**- nuclear change in which unstable isotopes (radioisotopes) spontaneously emit fast-moving particles, high-energy radiation, or both at a fixed rate, continues until isotopes are stable and not radioactive

-**gamma rays**- most common; form of high energy radiation

-2 types of high speed ionic particles:

1. **alpha** - fast-moving, positively charged chunks of matter with 2 protons and 2 neutrons (helium nuclei)

2. **beta** - high-speed electrons

half-life - time needed for half of the nuclei in radioisotopes to decay and emit their radiation to form different isotopes

radiocarbon dating - using carbon-14 to estimate ages of fossils, etc.

tracers - used in pollution detection, agriculture, industry

nuclear medicine - uses radioisotopes for diagnosis and treatment

2. **nuclear fission** - nuclear change in which the nuclei of certain isotopes with large mass numbers are split into lighter nuclei when struck by neutrons

-each fission releases 2 or 3 neutrons and energy

-4 multiple fissions, enough critical mass must be present

-forms chain reaction - releases huge amounts of energy

3. **nuclear fusion** - nuclear change in which 2 isotopes of light elements are forced together at extremely high temperatures until the fuse to form a heavier nucleus and release energy

- uncontrolled nuclear fusion - used to develop extremely powerful thermonuclear weapons

3-5 The Two Ironclad Laws of Energy

1st Law of Thermodynamics

In all physical and chemical changes, energy is neither created nor destroyed, but may be converted from one form to another.

Energy input = energy output

2nd Law of Thermodynamics

When energy is changed from one form to another, some of the useful energy is always degraded to low quality, more dispersed, less useful energy

-can never recycle or reuse high quality energy to perform useful work

-all forms of life are tiny pockets of order (low entropy) maintained by creating a sea of disorder (high entropy) in their environment.

3-6 Connections: Matter and Energy Laws and Environmental Problems

high-waste or high-throughput societies - attempt to sustain ever-increasing economic growth by increasing throughput of matter and energy resources in the economic system; will eventually become unsustainable

matter recycling society - allow economic growth to continues without depleting matter resources or producing excess pollution and environmental degradation; will but some time

low-waste society - recycling and reusing discarded matter, preventing pollution, conserving matter and energy resources; reducing