GS104 Basics Review of General Science

I. Scientific Method
   A. Process
      1. Basic Observation (Data Collection = "Sensing the Environment")

      2. Hypothesis / Working Model = a preliminary attempt at understanding a system
         a. Processes - Interactions - Mechanisms

      3. Hypothesis / Model Testing
         a. Methodical Data Collection

      4. Adjusting the Hypothesis / Reformulating the Model
         a. Data Supports or Rejects the Hypothesis
         b. Data does NOT Prove a Hypothesis

      5. More Data Collection... goal = consistent results

      6. Hypotheses lead to Theories; Theories lead to Scientific Facts or Beliefs

      7. Review of Science Terms

         a. fact - agreed-upon observations, subject to change and modification with additional data collection.

         b. hypothesis - educated guess or prediction, subject to testing.
            (1) e.g. "students will enjoy this class by the end of the semester"

         c. law or principle - a hypothesis is elevated to a law once it has been repeatably tested and supported, with no contradictions.
            (1) e.g. Newton's law of gravity

         d. Theory - a comprehensive concept representing a synthesis of a large body of knowledge that encompasses verified hypotheses.
            (1) e.g. theory of atom, theory of plate tectonics

   B. Observational vs. Experimental Science

      1. Observation - passive data collection
      2. Experimental - active data collection
         a. Experimental Design... with a purpose

C. Good Scientific Techniques

1. Unbiased Observation
   a. Organized / Thorough Note Taking

2. Understanding the Purpose of the Investigation

3. Hypothesis Formulation / Prediction

4. Hypothesis Testing through Experimental / Observational Design
   a. Controls = "known quantities of comparison"

5. Reporting Results
   a. Introduction
   b. Purpose
   c. Methods
   d. Data / Results
   e. Interpretation / Conclusion
   f. Recommendation for Further Research

II. Chemistry Basics

A. Definitions

0. Matter- any material that occupies space and has mass.

1. Elements - all matter are made of elements, over 100 elements are known. Elements include O, Au, Ag, N, H, C and have a unique, and identifiable atomic structure.

   a. Refer to periodic table/handout
      (1) 92 naturally occurring elements
      (2) 11 man-made elements (103 total)

2. Compounds - combination of two or more elements joined together at the atomic level.

3. Atom - the smallest recognized particle of matter that retains the properties of a given element. Atoms of elements are combined together to form compounds.

B. Atomic Structure - Theory of atoms and atomic structure are based on experimental evidence and mathematical models. Atoms are generally too small to observe directly even with the most powerful microscope, but they can be observed indirectly by modeling.

1. Nucleus - central portion of an atom which contains even smaller sub-atomic particles called protons and neutrons.

   a. Protons - very dense, positively charged subatomic particles in the nucleus of an atom.

b. Neutrons - dense, neutrally charged subatomic particles in the nucleus of an atom.

2. Electrons - negatively charged particles that orbit very rapidly about the nucleus of an atom. Generally considered that electrons are moving so fast, that it is difficult to locate their position at any given moment....view electrons as a cloud of charged particles hovering about the nucleus.

a. Electron clouds are organized at certain distances from the nucleus in regions called energy level shells. Each energy level shell at a given distance from the nucleus can only hold a certain number of electrons at any given time.

3. Atomic number - is the number of protons located in the nucleus, each element has its own unique atomic number making it distinct from other elements (e.g. C a.n. = 6, O a.n. = 8)

b. Isotope: same number of protons, variable no. of neutrons
(1) e.g. O^{18}/O^{16}: 8 protons but 10 and 8 neutrons respectively

4. Atomic charge balance - all atoms contain the same number of negative electrons as positive protons, thus as neutrons have no charge, then net positive charges = net negative charges (protons = electrons)

Elements can be considered to be large collection of electrically neutral atoms, having the same atomic number or no. of protons.

III. Physics
A. Physics - Study of the Physical Universe
1. Basic nature of things
a. matter / atoms, motion, forces, energy, heat, sound, light, electricity

2. Physics forms basis of other sciences
a. chemistry, geology, meteorology, astronomy

B. Linear Motion

1. Motion = displacement or change in position in space
a. Linear Motion = straight line or curvilinear displacement

2. Terms
a. Displacement = change in position = "distance" between two points = "HOW FAR"
b. Time = the amount of time to move from pt. A to pt. B
c. Speed = rate of displacement per unit time = "HOW FAST"

(1) speed = distance/time
(a) Instantaneous Speed vs. Average Speed

(2) speed = magnitude only = "scalar" quantity
(a) "magnitude" = amount or how much

d. Velocity = magnitude + direction = "vector" quantity = "HOW FAST and WHAT DIRECTION"
(1) V=d/t

e. Acceleration = rate of change in velocity per unit time = "ARE WE SPEEDING UP OR SLOWING DOWN?" - "HOW QUICKLY ARE WE SPEEDING UP OR SLOWING DOWN" - better yet ... "HOW LONG DOES IT TAKE TO SPEED UP OR SLOW DOWN"

(1) Acceleration = change in Velocity/time
(2) e.g. Acceleration = 2 m/sec/sec = 2 m /sec^2

C. Force

1. Inertia - resistance to motion
2. Mass - how much matter is contained in an object
   a. > matter, > inertia
   b. mass is a measure of the degree of inertia
   c. does not change with respect to force of gravity
3. Weight - force exerted upon an object due to gravity
   a. changes with respect to force of gravity
4. Force - "push or pull" on an object, anything that can cause an object to accelerate or move
   a. the greater the force, the greater the potential for acceleration

** It is possible to be "weightless" in space, but not "massless" ... the relative inertia of an object is constant regardless of gravitational force of attraction. **

5. Units of Measure
   a. Weight in U.S. = pounds = a force
   b. Mass = grams / kilograms
      (1) 1 kg = 2.2 lb
   c. Weight force in metric = Newtons
      (1) 1 kg mass = 9.8 Nt
   d. volume - 3-D size of object = length x width x height
   e. Density = mass / volume

6. Friction as a Force

   a. Friction = force that occurs when two objects slide over or in contact with one another
      (1) Frictional force = applied in direction opposite to motion

   Applied Force < Friction Force ==== No Acceleration / No Motion

Applied Force > Friction Force ==== Acceleration / Motion

(2) Static Friction = friction of bodies at Rest
(3) Sliding Friction = friction of bodies in motion
(a) static friction > sliding friction
(b) once in motion, sliding friction < initial friction

b. Gravity - a force that permeates the universe, the pulling action between any two bodies in space

"bodies" in space = atoms, molecules, people, planets, solar systems, galaxies, etc.

Newton's Law of Attraction:

$$F = G\,[(m_1 m_2)/r^2]$$

where F = force of gravity, G = gravitational constant, m = mass of 2 objects in space, r = distance separating the two objects in space. Given all other variables constant, F > with < r, and F < with >r. Each body exerts an equal force of attraction.

(1) Earth Gravitation Force

$$F = mg = \text{"weight"}$$

F = force of Earth gravity (i.e. "weight"), m = mass (kg), and g = acceleration of a falling object (e.g. sediment) due to gravitational force F, assumed to be constant at 980 cm/sec^2 (9.8 m/sec^2)

D. Energy

1. Energy = that which enables work to be done

a. Work = force applied to matter with motion resulting

2. Mechanical Energy = energy due to position or motion of objects in the system

a. Potential Energy = energy of position = "stored energy"
(1) position of 1 object relative to another

b. Kinetic Energy = energy of motion = "released energy"

3. Other forms of kinetic and potential energy
a. heat (thermal) energy
(1) Temperature = measure of kinetic molecular energy in a system

b. sound energy
(1) defined by kinetic and potential energy of vibrating air molecules

c. light energy

(1) emitted via kinetic energy of electrons within atoms

d. electrical energy
(1) controlled by kinetic energy associated with electrons in motion

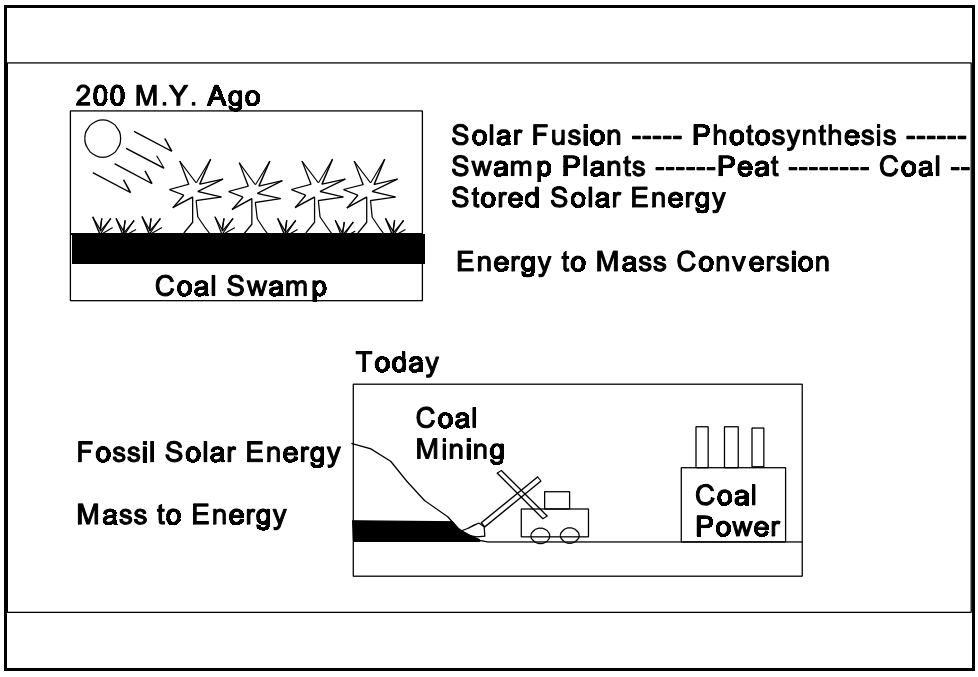
4. Conservation of Energy

a. Law of Conservation of Energy
(1) Energy cannot be created or destroyed, but may be transformed from one form to another

b. The total energy in a system is constant (i.e. closed systems)
(1) Energy In = Energy Out

c. Stored Energy vs. Transformation of Energy
(1) Energy may be stored in a system and transformed
(2) Energy may be converted from mass, and mass converted to energy

(a) matter in it's pure form is energy
(b) $E = mc^2$ Einstein's Equation relating mass to energy
i) E = total energy, m = mass, c = speed of light



E. Thermal Energy, Heat, and States of Matter
1. States or Phases of Matter

a. The state of matter is determined by the amount of vibrational energy at the atomic and molecular level

(1) atoms / molecules possess kinetic energy
(a) electron orbits
(b) bond vibration

2. Three States of Matter
   a. Solid
      (1) Fixed "hard" shape to matter
      (2) atoms / molecules are in fixed positions
      (3) kinetic or vibrational energy is relatively low
   b. Liquid
      (1) "fluid" material / changes shape easily; conforms to shape of container
      (2) atoms / molecules are mobile (not fixed / rigid)
      (3) higher kinetic / vibrational energy compared to solid
   c. Gas
      (1) Even higher state of kinetic / vibrational energy
      (2) atoms / molecule separated
      (3) "fluid" material / "invisible" matter

3. Heat Flow

   a. "Thermodynamics" = study of heat, heat flow and behavior of heat

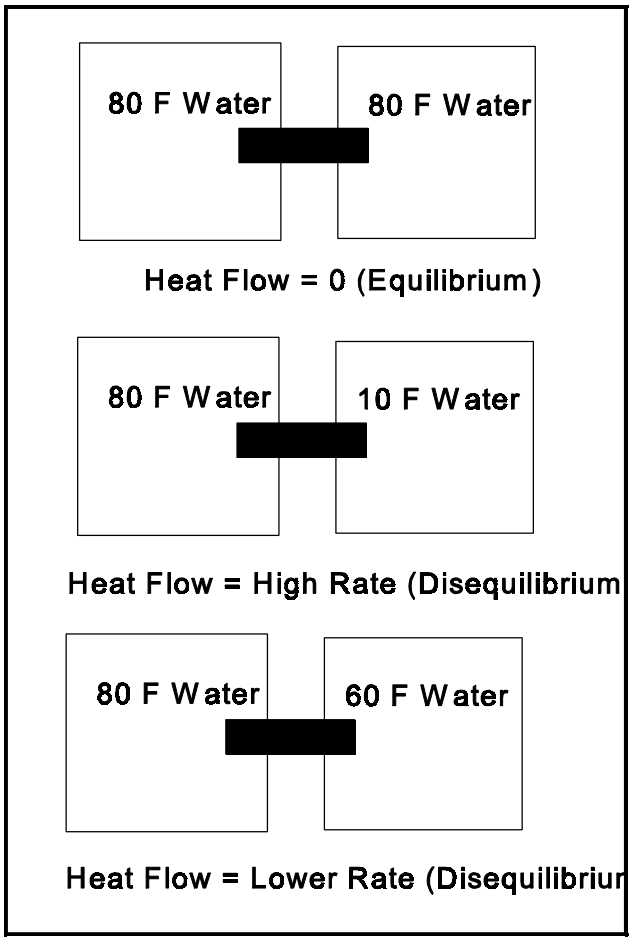
   b. Heat Flow : An Equilibrium Process

      (1) Temperature Imbalance Causes Heat to Flow or Transfer
      (2) Substances at Same Temperature = Temperature Equilibrium

   c. Heat Flows from High Temperature Regions to Low Temperature Regions

      (1) At temperature equilibrium: net heat flow = 0
      (2) The higher the temperature differential, the faster the heat flow
      (3) The lower the temperature differential, the slower the heat flow

Consider an experiment with two vessels of water, with variable heat-content. They are connected by a tube that allows heat to exchange between the two vessels.



4. Mechanisms of Heat Transfer

a. Conduction: heat and vibrational kinetic energy is passed from molecule to molecule, without actual transfer of mass
   (1) heat transfer without mass transfer
   (2) e.g. heating an iron rod, the heat is transferred from one end to the other without transfer of mass

   (3) Examples
      (a) Good conductors of heat = iron / metal (rapidly transmit heat)
      (b) Poor conductors of heat = adobe / brick, fiber glass insulation
         i) Poor conductor = "good insulator"

b. Convection - heat transferred via transfer of mass

   (1) e.g. "fluid currents" transfer heat

   (2) Convection cells common in ocean, atmosphere, and earth's interior
      (a) e.g. Warm air rises, cools, sinks
      (b) e.g. Warm ocean water rises, cools, sinks

c. Radiation - heat transfer via electromagnetic radiation

   (1) infrared radiation = "thermal radiation"
      (a) remember: infrared = wavelengths longer than visible spectrum

   (2) Emitters of radiant energy
      (a) Sun (hydrogen fusion)
      (b) Earth (radioactive decay of elements)

   (3) Absorbers and Emitters of Radiation
      (a) Good Absorbers are Good Emitters
         i) e.g. black paper experiment in lab
            a) black objects cool and warm faster
            b) black is a poor reflector of energy
      (b) Poor Absorbers are Poor Emitters
         i) e.g. white paper experiments in lab
            a) white objects cool and warm slower
            b) white reflects radiant energy
      (c) All materials absorb and emit radiation at the same time

F. List of Basic Equations

Velocity = Distance / Time V = d/t m/sec
Volume = length x length x length Vol = L^3 m^3
Density = mass / volume D = m/Vol gm/cm^3 kg/m^3

Temperature Conversions

From C to F: $F = 9/5C + 32^o$
From F to C: $C = 5/9(F - 32^o)$

E.g. convert 40 C to F ... $F = 9/5(40) + 32 = 104^o$ F

Degrees K = Degrees C + 273
0 C = +273 K

IV. Biology - study of life

A. Characteristics of Living Matter
1. metabolism - biochemical reactions / energy transfer
2. growth - making larger molecules out of smaller ones
3. reproduction - making copies
4. evolutionary history - selective success of some living organisms, some more than others

B. Hierarchy of Life
1. atoms / molecules
2. cells - complex group of chemical compounds, bounded by membrane
3. tissues - arrangment of cells
4. organs - complex tissue arrangement
5. organisms - complex arrangement of organs
6. population of organisms
   a. species - interbreeding possible
      (1) genus - sharing of genetic characteristics
7. Ecological Communities - interactive associations of species
   a. biomes - classes of ecosystems

C. Autotrophic Organisms - the basis of life and food chain on Earth
1. Autotrophs - self feeding organisms, create own food from energy

   a. Photosynthetic Plants

   b. Photosynthesis: sunlight + carbon dioxid + water = carbohydrates (sugars and starches) = food

$CO_2 + H_2O$ + sunlight (energy) => $CH_2O + H_2O$