ES105 Fuels

I. Energy sources and uses
  A. Humans first organism to systematically exploit energy reserves
    1. First used chemical energy stored in wood—prevalent until 1850
    2. Kinetic energy of water harnessed about 2000 years ago—grind grain in Egypt
    3. Wind energy used to grind grain, pump water to grind grain perhaps as long ago as 1000 years
  B. 'Fossil fuels' include coal, petroleum and natural gas
    1. 'Fuel' burns readily to release energy—
      a. what type is released? Chemical
      b. what is it converted to? Mechanical (usually)
    2. fuels are 'reduced' forms of matter
      a. burning oxidizes the material—
      b. maximum number of atoms bonded to oxygen
  C. Recall first law of thermodynamics—conservation of energy
    1. We convert energy from high-grade to lower-grade forms
      a. 'Production' of fuel means 'make available for exploitation'
        1) Oil isn't available until it has been pumped
        2) Coal needs to be mined
        3) Turbines in dams 'produce' electricity from the kinetic energy of falling water
      b. 'Consumption' of energy is our utilization of the energy source, where we convert it from one form to another, and reap the rewards of the conversion
        1) We put gasoline in our car, and convert chemical energy to forward motion
        2) We turn on the light switches, and convert electrical energy to light
  D. Fossil fuel reserves and consumption
    1. Fossil fuels are still being created today…at a very slow rate
    2. For our purposes, the supply of fossil fuels is limited
      a. 'non-renewable'
      b. We are depleting our reserves rapidly—perhaps half of petroleum has already been burned, in about 100 years
      c. Will become prohibitively expensive in the next 100 years

E. Coal

1. High grade coal is more than 90% carbon—anthracite

$C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$

2. Lower grade coal may have less than 70% carbon
    a. Bitumin—nearly 90% carbon
    b. Sub-bitumin—70-88%
    c. Lignite—almost 70%
    d. Peat (precursor of coal)—about 60%
3. Coal formed from incompletely decayed plants
    a. Plants usually revert to CO_2 upon death
    b. Swamp conditions, with standing water, reduce decay potential
    c. Plants become buried, compressed
        1) Cellulose breaks down, releasing small molecules containing most of the hydrogen and oxygen
        2) Carbon remained as concentrated deposit
    d. Wide expanses of land surface were swamps in late Paleozoic
        1) Climate was generally warmer
        2) Great land areas existed in tropical regions
    e. Large reserves of coal are present in the United States
        1) Must be mined, either open pit or underground
        2) commonly hauled to coal-fired electrical generators to be burned to make steam, to turn turbines, to generate electricity
    f. the part of coal that is NOT carbon is source of pollutants
        1) much coal is high in sulfur—from pyrite
            a) creates aerosol sulfuric acid—chief component of acid rain
            b) pyrite can be removed by ‘floatation’
            c) sulfur bonded to carbon-rich molecules can be removed from stack fumes instead of being released
        2) other components include nitrates, arsenic, mercury
    g. coal is a source of other materials
        1) heated to make ‘coke’, a high carbon fuel used in steelmaking
        2) byproducts of coke condensed to coal oil and coal tar, that are refined into various organic chemicals

F. Natural Gas—mostly methane

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ + heat

1. Natural gas is excellent, clean-burning fuel
2. Also raw material for plastics and other chemicals
3. Natural gas also contains sulfur and nitrogen, which can be released to become acid rain.
4. from heat and pressure acting on buried organic matter
5. within geologic traps, beneath impermeable rock layers

G. Petroleum

1. replaced coal as primary fuel by about 1950
2. Complex molecules of hydrocarbon probably not derived from plants
3. Fats of planktonic animals in shallow seas
   a. Rain of dead plankton became layers of incompletely decayed organic matter
   b. Heat and pressure of burial changed animal fat into petroleum
4. combustion products are carbon dioxide and water

   This is the balanced equation for octane, a component of gasoline

   $2C_8H_{18} + 18\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

   a. Air contains nitrogen, so some is converted in combustion to nitrogen oxides
   b. Petroleum also contains some sulfur compounds also
   c. Burning gasoline leads to smog
5. Origin of petroleum
   a. Zooplankton residue in marine deposits
   b. Burial pressure and proper temperature yields petroleum
   c. Suitable rock with pore space and permeability—sedimentary
   d. Presence of trap—cap that prevents petroleum from escaping
      1) Structural traps: folds and faults
      2) Stratigraphic traps: porous rock contained in impermeable rock
         a) Sand pinches
         b) Lenses
         c) unconformities
6. Petroleum will probably last for another 100 years
   a. Concentration of location of reserves leads to political and economic vulnerability of industrialized nations that do not have vast reserves
   b. US Petroleum Reservoirs
      1) Titusville, PA, 1860s
      2) Lucas Dome, Spindletop Dome, TX, 1900s
      3) Signal Hill, CA 1930s
      4) North Slope, AK, 1980s

II. Ultimately, Earth energy comes from two sources: the sun, and heat released internally by radioactive decay
   A. Our power ultimately is nuclear:
      1. Sun's energy is from a fusion reaction.
         a. Hydrogen atoms are converted to helium by nuclear fusion. 600 million tons/s
         b. Heat of fusion of atoms is the radiant energy passed through space that we receive.
      2. We receive about 1.73×10^{17} watts of energy from Sun—99+%
         a. Internal heat is about 3.2×10^{13} watts—0.02%
         b. Tides (generated by gravitational pull of Sun and Moon) are about 3×10^{12} watts—0.002%
         c. Nearly 30% of Sun's energy is reflected back to space
         d. Energy of fuels, such as petroleum or coal, is the energy Sun converted to chemical energy by photosynthesis in plants
III. Photosynthesis
   A. Solar energy absorbed by green plants
   B. Chlorophyll is a catalyst that allows the conversion of radiant energy to glucose, a sugar $C_6H_{12}O_6$:

      $6\ CO_2 + 6\ H_2O + \text{Sun energy} \rightarrow C_6H_{12}O_6 + O_2$

   C. This reaction actually has produced the levels of oxygen we have in the atmosphere today. Ancient algae in the seas created it by photosynthesis.
   D. Rare deep sea vent communities not supported by sunlight
      1. energy source from the hot water
      2. radioactive decay, and gravity.
      3. heating converts seawater sulfates to hydrogen sulfide.
         a. Bacteria thrive on the hydrogen sulfide in the hot water,
         b. which are consumed by larger organisms,
         c. giving rise to an ecosystem (*National Geographic*, October 1977, pp.441-453).
   E. Nuclear Energy
      1. uranium created by supernova that was source of the solar system nebula
      2. fission of uranium
         a. releases energy and byproducts
            1) byproducts can be dangerous for millions of years
            2) some byproducts can be weapons fuel
         b. heats steam to turn turbines
      3. fusion remains elusive