CHEMISTRY 253
Spring, 2015 - Dixon
Homework Set 3.2 Solutions

Set 3.2
Ch. 6:
Review Questions: 2, 5-8, 15

2. What is the equation relating exponential growth to the annual increase in a quantity?
$E = E_o e^{-kt}$ where k is related to the annual increase

5. What are the five main global sources of primary commercial energy?
Coal, oil, natural gas, renewable, and nuclear energy are the five main sources of energy.

6. What are the ultimate origins of coal, oil, and natural gas?
These are fossil fuels from ancient degraded biota.

7. What is the main component of natural gas? Write out the balanced chemical equation illustrating its combustion.
The main component of natural gas is methane.

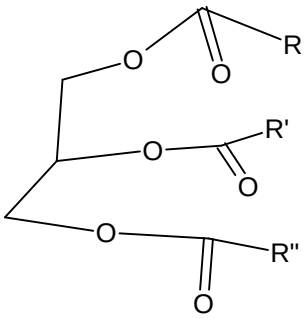
$$CH_4 + 2O_2 \leftrightarrow CO_2 + 2H_2O$$

8. Why is natural gas considered to be an environmentally superior fuel to oil or coal? What phenomenon involved in its transmission by pipeline might offset this advantage?
Natural gas is considered to be an environmentally superior fuel because it gives off more energy per mole of CO_2 formed. This can be seen by looking at heats of oxidation.
Coal = C(s) where $C(s) + O_2 \leftrightarrow CO_2$ $\Delta H = \Delta H_f(CO_2) = -413.8$ kJ/mol
Methane, $CH_4 + 2O_2 \leftrightarrow CO_2 + 2H_2O$ $\Delta H = -413.8$ kJ/mol + 2(-242 kJ/mol) – (-74.9 kJ/mol)
$\Delta H = -822.9$ kJ/mol
Oil (estimate as sum of butane and benzene) $C_4H_{10} + 13/2O_2 \leftrightarrow 4CO_2 + 5H_2O$
$\Delta H = 4(-413.8) + 5(-242) – (-126) = -2739$ kJ/mol or -685 kJ/mol CO_2
$C_6H_6 + 15/2O_2 \leftrightarrow 6CO_2 + 3H_2O$ $\Delta H = 6(-413.8) + 3(-242) – (49) = -3257.8$ kJ/mol = -543 kJ/mol CO_2 or an average of -614 kJ/mol CO_2
So, we can see the yield of energy per mol of CO_2 is about twice that of gasoline and about 33% more than oil.
The advantage, however, can be offset by leaks in pipelines (as well in operations such as fracking).

15. What is meant by the term *carbon sequestration*?
This means to take carbon dioxide out of processes where it would otherwise be released to the atmosphere and store it in a form where it will only very slowly be released back into the atmosphere.

Ch. 7
Problems: 3

3. Given the fatty acids RCOOH, R'COOH, and R"COOH, draw the molecular structure of a triglyceride that would be produced by them. The formula for glycerin is given above.



Review Questions: 2, 3, 5, 8, 9, 11

2. List three incentives supporting the development and use of biofuels.

1. These use renewable carbon so don't contribute to the greenhouse effect (assuming generated carbon dioxide is consumed to make replacement plant material).

2. These are liquid fuels which can replace current liquid petroleum based fuels (gasoline and diesel)

3. These contain higher quantities of oxygen, which is generally beneficial in cleaner burning.

4. These are naturally low in undesirable elements such as sulfur.

3. Describe what is meant by the term *carbon debt* for biofuels.

Carbon debt refers to the cost in terms of carbon dioxide emissions needed to prepare land for growth of plants used for biofuels. Removal of native vegetation and loss of organics in soil result in carbon dioxide for which production of a renewable carbon source must "pay" in the future to account for short term increases in carbon dioxide.

5. What role does vapor pressure play in the composition of ethanol-gasoline mixtures?

It plays a large role since at low ethanol percentages, ethanol, due to its polarity, is quite volatile, while at high percentages is not very volatile.

8. What are the highly energy-intensive steps involved in the production of corn ethanol? What is meant by co-product? Why isn't ethanol a fully "renewable" fuel?

The most energy-intensive step is distillation to remove water from fermented corn sugars. Other steps, such as production of fertilizer, harvesting, fermentation, and delivery of ethanol also take energy.

Co-product refers to other products produced in the process such as corn gluten or corn oil that have value.

Ethanol is not a fully "renewable" fuel, because its production requires energy that typically is produced by fossil fuels.

9. What is meant by the term cellulosic ethanol? Describe one likely source of biomass for its production. How does a second-generation biofuel differ in nature from a first-generation one?

In cellulosic ethanol production, ethanol is produced from cellulose (a structural, non-food component of plants), rather than from sugar or starch. Switchgrass is thought to be a good source of biomass. It is a second-generation fuel in which the source is from non-food components.