Chemistry 145 – Van Bramer
Fall 2014 Problem Set – Week 9

1. Propane, butane, ethanol, and white gas are all commonly used as fuel for camping. In this problem you will compare the efficiency of these four fuels.

a. First we will compare the energy content of the fuels by mass. Use standard heat of formation values to determine the amount of heat produced by the combustion of 100 grams of each fuel given:

i. Propane is C3H8
ii. Butane is C4H10
iii. Ethanol is C2H6O
iv. White gas is primarily isooctane, C8H18

Reaction for propane: C3H8(g) + 5 O2(g) -> 3 CO2(g) + 4 H2O(g)

$kJ := 10^3 \cdot J$

$H\_propane := -2043.8 \cdot \frac{kJ}{mole}$

$MW\_propane := 44 \cdot \frac{gm}{mole}$

$Mole\_propane := \frac{100 \cdot gm}{MW\_propane}$ $\quad Mole\_propane = 2.273\,mol$

$Heat\_propane := H\_propane \cdot Mole\_propane$ $\quad Heat\_propane = -4.645 \times 10^3\,kJ$

Reaction for butane: C4H10(g) + 6.5 O2 -> 4 CO2 (g) + 5 H2O (g)

$H\_butane := -2657.3 \cdot \frac{kJ}{mole}$

$MW\_butane := 58 \cdot \frac{gm}{mole}$

$Mole\_butane := \frac{100 \cdot gm}{MW\_butane}$ $\quad Mole\_butane = 1.724\,mol$

$Heat\_butane := H\_butane \cdot Mole\_butane$ $\quad Heat\_butane = -4.582 \times 10^3\,kJ$

Reaction for ethanol: C2H6O(l) + 3.5 O2 -> 2 CO2 (g) + 3 H2O (g)

$$H\_ethanol := -1277.6 \cdot \frac{kJ}{mole}$$

$$MW\_ethanol := 46 \cdot \frac{gm}{mole}$$

$$Mole\_ethanol := \frac{100 \cdot gm}{MW\_ethanol} \qquad Mole\_ethanol = 2.174\,mol$$

$$Heat\_ethanol := H\_ethanol \cdot Mole\_ethanol \qquad Heat\_ethanol = -2.777 \times 10^{3}\,kJ$$

Reaction for white gas: C8H18(l) + 12.5 O2 -> 8 CO2 (g) + 9 H2O (g)

$$H\_gas := -5074.2 \cdot \frac{kJ}{mole}$$

$$MW\_gas := 114 \cdot \frac{gm}{mole}$$

$$Mole\_gas := \frac{100 \cdot gm}{MW\_gas} \qquad Mole\_gas = 0.877\,mol$$

$$Heat\_gas := H\_gas \cdot Mole\_gas \qquad Heat\_gas = -4.451 \times 10^{3}\,kJ$$

b. Use the NIST Webbook web site to find the heat of combustion for each of the fuels and compare these results with the calculations based on the heat of formation values.

Results are all very close. Heat of combustion values in NIST webbook are for production of liquid water.

c. Look up the physical properties of each fuel to determine which are liquids and which are gases at room temperature.

Propane and butane are a gas at room temperature and pressure. They are normally compressed to a liquid when used as a fuel. This requires a thick walled container, but the stove is less complex.

d. Determine the mass that you need to carry with you if you go on a trip for 1 week, and expect to heat 1 gallon of water to boiling each day. Assume that the stove is 30% efficient. Liquid fuels can be transported in lightweight containers similar to metal water bottles, but gas fuels need to use heavier metal containers.

$$Water\_volume := 1 \cdot \frac{gal}{day} \cdot 7 \cdot day \qquad Water\_volume = 7\,gal$$

$$Water\_volume = 26.498\,L$$

$$Water\_volume = 2.65 \times 10^{4}\,mL$$

$$Water\_mass := Water\_volume \cdot 1 \cdot \frac{gm}{mL} \qquad Water\_mass = 26.498\,kg$$

$$\Delta T := (100 - 15) \cdot C \qquad \Delta T = 85\,C$$

$$E := Water\_mass \cdot \Delta T \cdot 4.18 \cdot \frac{J}{gm \cdot C} \qquad E = 9.415 \times 10^{6}\,J$$

$$E = 9.415 \times 10^{3}\,kJ$$

If stove is 30% efficient

$$E\_total := \frac{E}{0.30} \qquad E\_total = 3.138 \times 10^{4}\,kJ$$

$$Mass\_propane := \frac{E\_total}{-H\_propane} \cdot MW\_propane \qquad Mass\_propane = 0.676\,kg$$

$$Mass\_butane := \frac{E\_total}{-H\_butane} \cdot MW\_butane \qquad Mass\_butane = 0.685\,kg$$

$$Mass\_ethanol := \frac{E\_total}{-H\_ethanol} \cdot MW\_ethanol \qquad Mass\_ethanol = 1.13\,kg$$

$$Mass\_gas := \frac{E\_total}{-H\_gas} \cdot MW\_gas \qquad Mass\_gas = 0.705\,kg$$