Problem Set 7

Problem 4.22

What is the standard heat of combustion of n-pentane gas at 25 °C if the combustion products are H_2O(l) and CO_2(g)?

Problem 4.28

Natural gas (assume pure methane) is delivered to a city via pipeline at a volumetric rate of 150 million standard cubic feet per day. If the selling price of the gas is $5.00 per GJ of higher heating value, what is the expected revenue in dollars per day? Standard conditions are 60 °F and 1 atm.

Problem 4.53

Saturated water vapor, i.e., *steam*, is commonly used as a heat source in heat exchanger applications. Why *saturated* water vapor? Why saturated *water* vapor?

In a plant of any reasonable size, several varieties of saturated steam are commonly available. For example, saturated steam may be available at 4.5, 9, 17, and 33 bar. But the higher the pressure, the lower the useful energy content and the greater the cost. Why is the energy content lower at higher pressure? Why then is higher-pressure steam used?

Problem 4.54

The oxidation of glucose provides the principal source of energy for animal cells. Assuming the reactants are glucose [$C_6H_{12}O_6(s)$] and oxygen [$O_2(g)$] and the products are $CO_2(g)$ and $H_2O(l)$, answer the following:

(a) Write a balanced equation for glucose oxidation, and determine the standard heat of reaction at 298 K.

(b) During a day, an average person consumes about 150 kJ of energy per kg of body mass. Assuming glucose is the only source of energy, estimate the mass (grams) of glucose required daily to sustain a person of 57 kg.

(c) For a population of 275 million people, what mass of CO_2 (a greenhouse gas) is produced daily by mere respiration? Data: for glucose, $\Delta H^o_{f,298}$ = -1,274.4 kJ/mol. Ignore the effect of temperature on the heat of reaction.

Problem 4.45

A process for the production of 1,3-butadiene results from the catalytic dehydrogenation at atmospheric pressure of 1-butene according to the reaction:

$$C_4H_8\,(g) \rightarrow C_4H_6\,(g) + H_2\,(g)$$

To suppress side reactions, the 1-butene feed is diluted with steam in the ratio of 10 moles of steam per mole of 1-butene. The reaction is carried out *isothermally* at 525 °C, and at this temperature 33% of the 1-butene is converted to 1,3-butadiene. How much heat is transferred to the reactor per mole of entering 1-butene?

Problem 4.55

A natural-gas fuel contains 85mol-% methane, 10 mol-% ethane, and 5 mol-% nitrogen.

(a) What is the standard heat of combustion (kJ/mol) of the fuel at 25 °C with H_2O is a product?

(b) The fuel is supplied to a furnace with 50% excess air, both entering at 25 °C. The products leave at 600 °C. If combustion is complete and if no side reactions occur, how much heat (kJ per mole of fuel) is transferred in the furnace?

Problem 4.6

If the heat capacity of a substance is correctly represented by an equation of the form

$$C_P = A + BT + CT^2,$$

show that the error resulting when $\langle C_P \rangle_H$ is assumed equal to C_P evaluated at the arithmetic mean of the initial and final temperatures is

$$C(T_2 - T_1)^2 \,/\, 12.$$