CH365 Chemical Engineering Thermodynamics

Lesson 20
Review

WPR 2

Lesson 21 – Tuesday 15 October

Coverage – Lessons 10-20 (Chapters 3 and 4) and Problem Sets 4, 5, 6, and 7

(1) Calculation of ideal ΔH, ΔU, W, and Q in a multi-step process. Sketching process path on PV axes.

(2) Real gases and cubic equations of state (RK, SRK, PR, virial)

(3) Correct enthalpy for temperature changes

a. Sensible Heat (direct integration of Cp, ICPH, MCPH)

b. Latent Heat / Heats of Reaction (IDCPH, MDCPH)

(4) Comparing CHEMCAD (to verify results of #2 and #3 above)

3 problems, (A-80, B-70, C-50 pts, 200 pts total), 55 minutes.

Make sure you have working Mathematica files for Problem 3.44 (c-e) 3.58 (c-f), 4.45, 4.55, and 4.83. Make sure you replicate approved solutions exactly or you have something wrong.

All WPR2 e-work uploaded to CANVAS (Mathematica)

Homework

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

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

Problem 4.22

What is the standard heat of combustion of n-pentane gas at 25 deg 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 deg 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 [$C_6 H_{12}O_6(s)$] 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, $\Delta H^0_{f,298} = -1{,}274{,}4$ 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 deg 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 deg C with H_2O(g) is a product?

(b) The fuel is supplied to a furnace with 50% excess air, both entering at 25 deg C. The products leave at 600 deg 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 X

Hydrocarbon fuels such as methanol are used to store energy in liquid form. Flow calorimeters are frequently used to measure standard heats of reaction for liquid fuels. An example is shown in Slide 5 from Lesson 17. Use CHEMCAD to construct a simulation of a flow calorimeter that is designed to combust methanol in a stoichiometric amount of air.

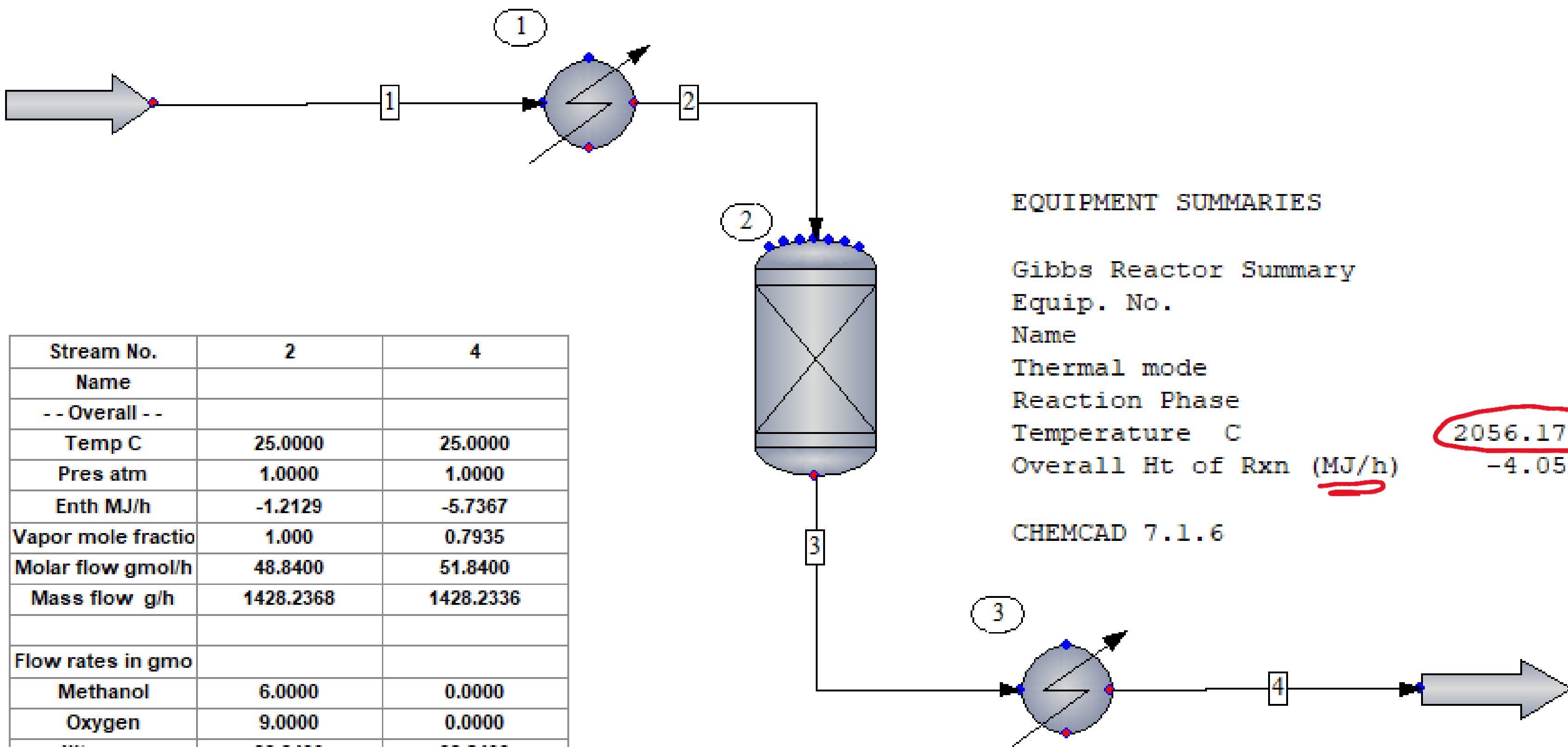
The feed mixture enters the process at 20 deg C and must be preheated to 25 deg C before entering the reactor. The reactor effluent must be cooled to 25 deg C before discharge to the atmosphere.

Compare the heat of reaction from CHEMCAD to the value obtained in Problem 4.20.

(Submit your CHEMCAD as a pdf inclusion to your other work)

Problem X

Hydrocarbon fuels such as methanol are used to store energy in liquid form. Flow calorimeters are frequently used to measure standard heats of reaction for liquid fuels. An example is shown in page 54. Use CHEMCAD to construct a simulation of a flow calorimeter that is designed to combust methanol in a stoichiometric amount of air. The feed mixture enters the process at 20 deg C and must be preheated to 25 deg C before entering the reactor. The reactor effluent must be cooled to 25 deg C before discharge to the atmosphere. Compare the heat of reaction from CHEMCAD to the value obtained in Problem 4.20.




```
EQUIPMENT SUMMARIES

Gibbs Reactor Summary
Equip. No.                              2
Name
Thermal mode                            1
Reaction Phase                          1
Temperature  C                  2056.1731
Overall Ht of Rxn (MJ/h)          -4.0573

CHEMCAD 7.1.6
```

Stream No.	2	4
Name		
- - Overall - -		
Temp C	25.0000	25.0000
Pres atm	1.0000	1.0000
Enth MJ/h	-1.2129	-5.7367
Vapor mole fractio	1.000	0.7935
Molar flow gmol/h	48.8400	51.8400
Mass flow g/h	1428.2368	1428.2336
Flow rates in gmo		
Methanol	6.0000	0.0000
Oxygen	9.0000	0.0000
Nitrogen	33.8400	33.8400
Carbon Dioxide	0.0000	6.0000
Water	0.0000	12.0000

The CHEMCAD Gibbs Reactor gives a calculated value of -4.0573 MJ per hour. Since the flow rates are specified in mol per hour, this is equivalent to -4.0573 MJ per 6 moles of CH3OH. This is very close to the value of 4.0589 MJ per 6 moles of CH3OH obtained in Problem 4.20. The difference is probably due to slight differences in the standard state gas phase heats of formation in the CHEMCAD database. We also note here that the heat duty on exchanger 3 is -4.5238 MJ. This accounts for the sensible heat contributions from Nitrogen, which are not included in the calculation of the standard heat of reaction.