Homework Set 8

Due: Thursday, November 5 (sections 001, 003, and 004)/Friday, November 6 (section 002)

This assignment is to be completed in assigned homework groups. Be sure to include the group number as well as first and last names of all contributing group members in addition to the assignment number and instructor name on the submitted homework. The assignment must be in one person's handwriting. If you use an equation solving tool (calculator, APEx, Solver, MATLAB), write out the equation(s) and note the tool that you used; otherwise, show all hand calculations in equation solving. All problems are from the end of the chapters in the 4th edition of the Felder, Rousseau, and Bullard (FR&B) text unless otherwise stated.

1. (**5 pts**) Team Check Step: This is your second homework assignment completed by the group. Discuss with your team what has gone well and any opportunities for improvement. Address both your team's process for getting work done as well as each individual's contribution. Briefly summarize what you discussed.
2. (**9 pts**) Write and simplify the closed-system energy balance (Equation 7.3-4) for each of the following processes, and state whether nonzero heat and work terms are positive or negative. Begin by defining the system. The solution for part (a) is given below as an illustration.

   (a) The contents of a closed flask are heated from 25°C to 80°C.

   Solution. The system is the flask contents.

   $Q + W = \Delta U + \Delta E_k + \Delta E_p$

   $W = 0$ (no moving parts or generated currents)

   $\Delta E_k = 0$ (system is stationary)

   $\Delta E_p = 0$ (no height change)

   $Q = \Delta U$

   $Q > 0$ (heat is transferred to the system)

   (b) A tray filled with water at 20°C is put into a freezer. The water turns into ice at -5°C. (*Note:* When a substance expands, it does work on its surroundings, and when it contracts, the surroundings do work on it.)

   (c) A chemical reaction takes place in a closed adiabatic (perfectly insulated) rigid container.

   (d) Repeat Part (c), only suppose that the reactor is isothermal rather than adiabatic and that when the reaction was carried out adiabatically, the temperature in the reactor increased.

3. (**15 pts**) Values of the specific internal energy of bromine at three conditions are listed here.

State	T(K)	P(bar)	$\hat{V}$(L/mol)	$\hat{U}$(kJ/mol)
Liquid	300	0.310	0.0516	−28.24
Vapor	300	0.310	79.94	0.000
Vapor	340	1.33	20.92	1.38

   (a) What reference state was used to generate the listed specific internal energies?

(b) Calculate $\Delta \hat{U}$ in kJ/mol. for a process in which bromine vapor at 300K is condensed at constant pressure. Then calculate $\Delta \hat{H}$ in kJ/mol for the same process. (See Example 7.4-1.) Finally, calculate ΔH(kJ) for 5.00 mol of bromine undergoing the process.

(c) Bromine vapor in a 5.00-liter container at 300K and 0.205 bar is to be heated to 340 K. Calculate the heat (kJ) that must be transferred to the gas to achieve the desired temperature increase, assuming that $\hat{U}$ is independent of pressure.

(d) In reality, more heat than the amount calculated in Part (c) would have to be transferred to the container to raise the gas temperature by 40 K. State two reasons for this.

4. (**10 pts**) Saturated steam at 100°C is heated to 350°C. Use the steam tables to determine (a) the required heat input (J/s) if a continuous stream flowing at 100 kg/s undergoes the process at constant pressure and (b) the required heat input (J) if 100 kg undergoes the process in a constant-volume container. What is the physical significance of the difference between the numerical values of these two quantities?

5. **(10 pts)** Energy may be produced from solid waste in two ways: (1) generate methane from anaerobic decomposition of the waste and burn it (landfill-gas-to-energy, orLFGTE)or (2) burn the waste directly (waste-to-energy, or WTE).The heat generated by either method can be used to produce steam, which impinges on a turbine rotor connected to a generator to produce electricity. LFGTE produces about 215 kWh electricity/ton of waste, and WTE produces roughly 600kWh/ton of waste. The average output of a large power plant is 1GW, which is enough to supply the annual residential energy consumption of a city of roughly 800,000 people.

(a) The current rate of municipal solid-waste generation in the United States is approximately 413 million tons per year. If all of it were used for energy recovery, how many 1GW power plants could LFGTE supply? How many if WTE is used?

(b) A municipality trying to decide between LFGTE, WTE, and a natural gas-fired combustion turbine has called you in as a consultant. Use information in the sources cited below to summarize the pros and cons of each choice.

A useful source of information regarding LFGTE is the U.S. EPA Landfill Methane Outreach Program, http://www.epa.gov/lmop/; the Waste-to-Energy Research and Technology Council at Columbia University provides useful information on WTE, http://www.seas.columbia.edu/earth/wtert/; and information on natural gas can be obtained from the U.S. Energy Information Administration, http://www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html.

6. **(15 pts)** Superheated steam at 40 bar absolute and 500°C flows at a rate of 250 kg/min to an adiabatic turbine, where it expands to 5 bar. The turbine develops 1500 kW. From the turbine the steam flows to a heater, where it is reheated isobarically to its initial temperature. Neglect kinetic energy changes.

   (a) Write an energy balance on the turbine and use it to determine the outlet stream temperature.

   (b) Write an energy balance on the heater and use it to determine the required input (kW) to the steam.

   (c) Verify that an overall energy balance on the two-unit process is satisfied.

   (d) Suppose the turbine inlet and outlet pipes both have diameters of 0.5 meter. Show that it is reasonable to neglect the change in kinetic energy for this unit.

(**36 pts**) The remainder of the assignment (6 problems) will be completed online using WileyPLUS. You can work with your team members to solve these problems, although note that each person may have unique values for some variables. **Each person should submit their own solutions through their own WileyPLUS link.** *You do not have to turn in any paperwork with this portion of the assignment.* Use the link for your class on the Moodle site, and then you can access the Assignment within WileyPLUS. The due date for the WileyPLUS completion is the same as for the homework assignment – the beginning of your class period. Note that the WileyPLUS assignment cannot be submitted late.

Challenge Problem for Honors Contract: FR&B 7.34