CH365 Chemical Engineering Thermodynamics

Lesson 8
Review

Professor Andrew Biaglow
1 September 2022

CADET ____________________ SECTION ______TIME OF DEPARTURE ________

DEPARTMENT OF CHEMISTRY & LIFE SCIENCE

CH365 2022-2023
WRITTEN PARTIAL REVIEW I
7 September 2022, A-Hour

TEXT: Smith, Van Ness, & Abbott
SCOPE: Lessons 1-8

References Permitted: Open note, book, and computer. You may not share files or communicate with other cadets in any way during the exam.

INSTRUCTIONS

1. You will have 55 minutes to complete the exam.
2. Do not mark the exam or open it until "begin work" is given.
3. There are 3 problems on 3 pages (not including the cover page). Write your name on the top of each sheet. Answer all questions.
4. Solve the problems in the space provided. Show work to receive for partial credit.

(TOTAL WEIGHT: 200 POINTS)

DO NOT WRITE IN THIS SPACE

PROBLEM	VALUE	CUT
A	50	
B	70	
C	80	
TOTAL CUT		
TOTAL GRADE	200	

WPR1

7 September 2022

(no laptops)

L4-7 Objectives

Lesson 4: Internal Energy, Energy Balances, & State Functions
1. Describe Joule's experiments.
2. Describe the relationship between internal energy and heat and work.
3. State the first law of thermodynamics in word and equation form.
4. Use concepts of thermodynamic state and state functions to calculate heat, work, and internal energy associated with changes of state (see Examples 2.3, and 2.4).

Lesson 5: Equilibrium, Reversible Processes & Enthalpy
1. Describe equilibrium in thermodynamic systems.
2. Be able to describe and discuss reversible processes (see Example 2.5).
3. Write energy balances for constant-volume and constant-pressure systems.

Lesson 6: Enthalpy, Heat Capacity, and Open Systems 1
1. Calculate enthalpy change when the amount of heat added to the system is known (see Example 2.6).
2. Calculate changes in internal energy, heat, and work in a cyclic process (Problem 2.6).
3. Calculate changes in state using heat capacity.
4. Perform calculations in both English and SI units.

Lesson 7: Enthalpy, Heat Capacity, and Open Systems 2
1. Write mass and energy balances for open systems.
2. Calculate flow rate in a conduit from velocity, cross-sectional area, and density.

Problem Set 3

Problem 2.38

Carbon dioxide gas enters a water-cooled compressor at conditions P_1 = 15 (psia) and T_1 = 50 (degF), and is discharged at conditions P_2 = 520 (psia) and T_2 = 200 (degF). The entering CO_2 flows through a 4-inch-diameter pipe with a velocity of 20 (ft) $(s)^{-1}$, and is discharged through a 1-inch-diameter pipe. The shaft work supplied to the compressor is 5,360 (Btu) $(\text{lb mol})^{-1}$. What is the heat-transfer rate from the compressor in (Btu) $(\text{hr})^{-1}$?

Additional Information:

$H_1 = 307\,(\text{Btu})\,(\text{lb}_m)^{-1}$ and $V_1 = 9.25\,(\text{ft})^3\,(\text{lb}_m)^{-1}$

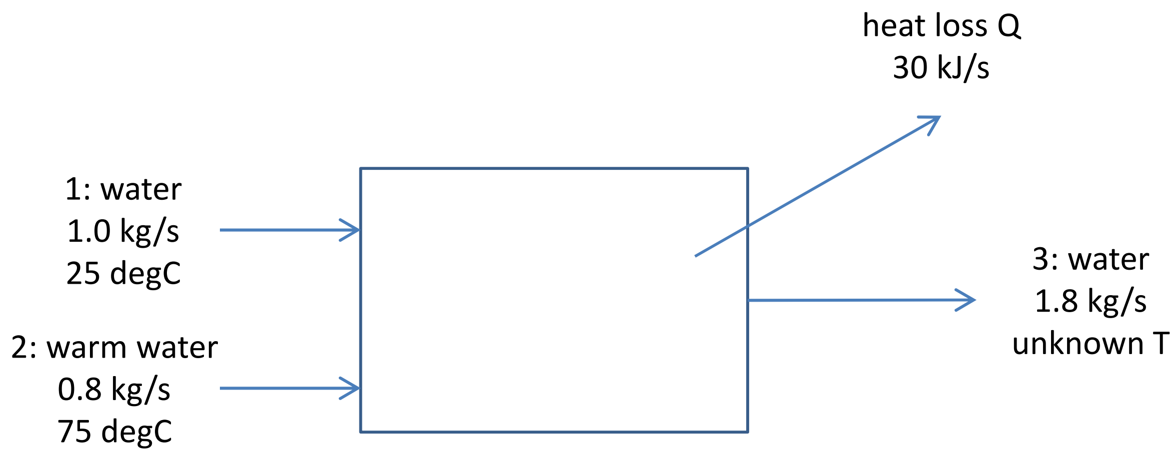
$H_2 = 330\,(\text{Btu})\,(\text{lb}_m)^{-1}$ and $V_2 = 0.28\,(\text{ft})^3\,(\text{lb}_m)^{-1}$

Problem 2.28

Nitrogen flows at steady state through a horizontal, insulated pipe with inside diameter of 1.5 (in). A pressure drop results from flow through a partially opened valve. Just upstream from the valve the pressure is 100 (psia), the temperature is 120 (degF), and the average velocity is 20 (ft)$(s)^{-1}$. If the pressure just downstream from the valve is 20 (psia), what is the temperature? Assume for nitrogen that PV/T is constant, Cv=(5/2)R, and Cp=(7/2)R. (Values of R are given in App. A.)

Problem 2.24

A stream of warm water is produced in a steady-flow mixing process by combining 1.0 kg s^{-1} of cool water at 25 degC with 0.8 kg S^{-1} of hot water at 75 deg C. During mixing, heat is lost to the surroundings at the rate of 30 kJ s^{-1}. what is the temperature of the warm water stream? Assume the specific heat of water is constant at 4.18 kJ kg^{-1} K^{-1}.



assume constant P so that $Q=\Delta H$

Problem 2.40*

*Excellent review problem

One kilogram of air is heated reversibly at constant pressure from an initial state of 300 K and 1 bar until its volume triples. Calculate W, Q, ΔU, and ΔH for the process. Assume for air that $(PV/T)=83.14\ (\text{bar})(\text{cm})^3(\text{mol})^{-1}(K)^{-1}$ and $Cp=29(\text{J})(\text{mol})^{-1}(K)^{-1}$. Report your answers in kJ.

Review Problems

Problem 2.25

Fifty (50) kmol per hour of air is compressed from P_1=1.2 bar to P_2=6.0 bar in a steady-flow compressor. Delivered mechanical power is 98.9 kW. Temperatures and velocities are:

T_1=300 K T_2=520 K

u_1=10 m s^{-1} u_2=3.5 m s^{-1}

Estimate the rate of heat transfer from the compressor. Assume for air that C_P=(7/2)R and that enthalpy is independent of pressure.

Problem 2.26

Water at 28 °C flows in a straight horizontal pipe in which there is no exchange of either heat or work with the surroundings. Its velocity is 14 m s^{-1} in a section of the pipe with an internal diameter of 2.5 cm, until it flows into a section of the pipe where the internal diameter abruptly increases. What is the temperature change of the water if the downstream diameter is 3.8 cm? If it is 7.5 cm? What is the maximum temperature change for an enlargement of the pipe?

Example 2.7

Air at 1 bar and 298.15 K (25 degC) is compressed to 3 bar and 298.15 K by two different mechanically reversible processes:

(a) Cooling at constant pressure followed by heating at constant volume.

(b) Heating at constant volume followed by cooling at constant pressure.

Calculate the heat and work requirements and ΔU and ΔH of the air for each path. The following heat capacities for air may be assumed independent of temperature:

$$C_V = 20.785 \text{ and } C_P = 29.100 \text{ J mol}^{-1} \text{ K}^{-1}$$

Assume also for air that PV/T is a constant, regardless of the changes it undergoes. At 298.15 K and 1 bar, the molar volume of air is 0.02479 m^3 mol^{-1}.

1:		2:		3:
1 bar	→	1 bar	→	3 bar
298.15K		low T		298.15K
0.02479 m^3		V_2		$V_3=V_2$

system: 1 mol of air in a piston

$$V_3 = V_1 \cdot \frac{P_1}{P_3} = 0.02479 \cdot \left(\frac{1}{3}\right) = 0.008263 \text{ m}^3 = V_2$$

Example 2.7, part (a)