BITS, PILANI-DUBAI

Dubai International Academic City, Dubai, U.A.E.

III Year Chemical Engineering, I Semester 2009-10

Comprehensive Exam

CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 80 Weightage: 40%

Duration: 3 hr (Closed Book) 24.12.09

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

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1 (a) An automobile having a mass of 1250 kg is traveling at $40ms^{-1}$. What is kinetic energy in kJ? How much work must be done to bring it to a stop? (3 m)

(b) For a steady state flow process, show that the energy balance would be $\Delta H = Q + W_s$. (5 m)

(c) Liquid water at 453.15 K (180 °C) and 1002.7 kPa has an internal energy (on an arbitrary scale) of 762.0 kJ kg^{-1} and a specific volume of 1.128 cm^3 g^{-1}. **(i)** What is its enthalpy? **(ii)** The water brought to the vapor state 573.15 K (300 °C) and 1500kPa, where its internal energy is 2784.4 kJ kg^{-1} and its specific volume is 169.7cm^3 g^{-1}. Calculate ΔU and ΔH for the process. (3+5m)

2. (a) Write a short note on heat effects of industrial reactions. (3 m)

(b) A system undergoes a process 1-2 in which it absorbs 100 kJ as heat and does 40 kJ work. Then it follows another process 2-3 in which 50 kJ work is done on it while it rejects 30 kJ as heat. If it is desired to restore the system to the initial state by an adiabatic path, calculate the work and heat interactions during the process. Also determine the net work and heat interactions. (5 m)

(c) Five kilograms of liquid carbon tetrachloride undergo a mechanically reversible, isobaric change of state at 1 bar during which the temperature changes from 273.15 K(0 °C) to 293.15 k (20 °C). Determine ΔV^t, W, Q, ΔH^t and ΔU^t. The properties of liquid carbon tetrachloride at 1 bar and 273.15 K (0 °C) may be assumed independent of temperature: $\beta = 1.2 \times 10^{-3}$ K^{-1}, $C_p = 0.84$ kJ kg^{-1} K^{-1} and $\rho = 1590$ kg m^{-3}. (8 m)

3. (a) Derive an expression for the entropy change of an ideal gas from the equation $dU = dQ_{rev} - PdV$. (3 m)

(b) One mole of an ideal gas is compressed isothermally but irreversibly at 403.15 K (130 °C) from 2.5 bar to 6.5 bar in a piston cylinder device. The work required is 30 % greater than the work of reversible isothermal compression. The heat transferred from the gas during compression flows to a heat reservoir at 298.15 k (25 °C). Calculate the entropy changes of the gas, heat reservoir and ΔS_{total}. (5 m)

(c) Steam at 2100 kPa and 533.15 K (260 °C) expands at constant enthalpy (as in a throttling process) to 125 kPa. What is the temperature of the steam in its final state and what is its entropy change? What would be the final temperature and entropy change for an ideal gas? (8 m)

4. (a) Write a note on compression and give the equation for their efficiency. (3 m)

(b) Steam enters a nozzle at 800 kPa and 553.15 K (280 °C) at negligible velocity and discharges at a pressure of 525 kPa. Assuming the isentropic expansion of the steam in the nozzle, what is the exit velocity and what is the cross section al area at the nozzle exit for a flow rate of 0.75 kgs^{-1} (5 m)

(c) A Carnot engine is coupled to a Carnot refrigerator so that all of the work produced by the engine is used by the refrigerator in extraction of heat from a heat reservoir at 273.15 k (0 °C) at the rate of 35 kW. The source of energy for the Carnot engine is a heat reservoir at 523.15 k. (250 °C). If both devices discard heat to the surroundings at 298.15 K (25 °C), how much heat does the engine absorb from its heat source reservoir? If the actual coefficient of performance of the refrigerator is $\omega = 0.6\ \omega_{carnot}$ and if the thermal efficiency of the engine is $\eta = 0.6\ \eta_{carnot}$, how much heat does the engine absorb from its heat source reservoir? (8m)

5. (a) State and explain the reduced phase rule. (3m)

(b) Discuss chemical potential and phase equilibria. (5m)

(c) Explain (i) the heat effects of mixing processes with relevant equations
(ii) the working of a fuel cell with a neat sketch. (4m + 4m)

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2009-2010
III YEAR CHEMICAL ENGINEERING
CHE C311 CHEMICAL ENGINEERING THERMODYNAMICS

TEST -2 06.12.2009
(OPEN BOOK)

DURATION: 50 MINUTES MAXIMUM MARKS: 20
WEIGHTAGE : 20%

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

Answer all the questions

1. Liquid water at 298.15 K (25 °C) and 1 bar fills a rigid vessel. If heat is added to the water until its temperature reaches 323.15 k (50 °C), what pressure is developed? The average value of β between 298.15 to 323.15 K (25 and 50 °C) is 36.2×10^{-5} K^{-1}. The value of κ at 1 bar and 323.15 K (50 °C) is 4.42×10^{-5} bar^{-1}, and may be assumed independent of P. The specific volume of liquid water at 298.15 K (25 °C). is $1.0030\ cm^3\ g^{-1}$. (2 M)
2. A vessel contains 1 kg of water as liquid and vapor in equilibrium at 1000 kPa. If the vapor occupies 70% of the volume of the vessel, determine H and S for the 1 kg of water. (4 M)

3. Air is discharged from an adiabatic nozzle at 298.14 K (25 °C) with a velocity of 600 ms^{-1}. Assuming air to be an ideal gas with Cp = (7/2)R and the entrance velocity to be negligible, calculate the temperature of the air at the entrance of the nozzle. (4 M)

4. Steam enters the turbine of a power plant operating on Rankine cycle (Fig.8.3 in Text Book) at 873.15 K (600 °C) and exhausts at 30 kPa. To show the effect of boiler pressure on the performance of the cycle, calculate the thermal efficiency of the cycle and the quality of the exhaust steam from the turbine for boiler pressures of 5000, 7500 and 10,000 kPa. (8M)

5. Differentiate Carnot and Rankine Cycle (2 M)

BITS PILANI,INTERNATIONAL ACADEMIC CITY ,DUBAI

THIRD YEAR CHEMICAL ENGG. - FIRST SEMESTER, 2009-2010

TEST- 1 (Closed Book)

Course Title : Chem. Engg. Thermodynamics **Course No: CHE C311**

Date:11.10.09 **MAXIMUM MARKS: 25**

Time: 50 min **Weightage:25%**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

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1. Define phase rule. Explain the terms involved. (3M)

2. What are the characteristics of a reversible process? (3M)

3. Show that the mass flow rate at steady state in a single entrance and single exit system is $\dot{m} = uA / V$ (3M)

4. Explain the theory involved and working of a flow calorimeter (3M)

5. One mole of an ideal gas is expanded isothermally and reversibly at 27 °C from a volume of 4.56 m^3 to 6.84 m^3. Calculate q, w, ΔE and ΔH for this process. (8M)

6. A tank containing 20 Kg of water at 293.15 K (20 °C) is fitted with a stirrer that delivers work to the water at the rate of 0.25 kW. How long does it take for the temperature of the water to rise to 303.15 K (30 °C), if no heat is lost from the water. For water Cp = 4.18 KJ Kg^{-1} °C. (5M)

BITS, PILANI – DUBAI

FIRST SEMESTER 2009 – 2010

THIRD YEAR : CHEMICAL ENGG.

Course Code: CHE C311 **QUIZ-2 (Closed Book)** Date : 11-11-09

Course Title : Chemical Engineering Thermodynamics Max Marks : 7

Duration : 20 minutes Weightage : 7%

Name: ..... **ID No:** ..... **Sec / Prog:** .....

Instructions: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1. Give the general equation for the calculation of entropy change of an ideal gas (1M)

2. A Carnot engine receives 250 kW of heat from a reservoir at 525°C and rejects heat to another reservoir at 50°C. Calculate the power developed and the heat rejected? (2M)

3. A power plant operates with a heat source at 623 K and a sink at 303 K and has 55% efficiency of Carnot engine for the same temperature.

   (i) What is the actual thermal efficiency of the power plant? (1M)

   (ii) If the efficiency of the power plant is 35%, calculate the rise in temperature of the hot reservoir (Assume the efficiency of the power plant as 55% of that of Carnot engine). (3M)

(Use the next page for answering)

BITS, PILANI – DUBAI

FIRST SEMESTER 2009 – 2010

THIRD YEAR : CHEMICAL ENGG.

Course Code: CHE C311 **QUIZ-1 (Closed Book)** Date : 22-10-09

Course Title : Chemical Engineering Thermodynamics Max Marks : 8

Duration : 20 minutes Weightage : 8%

Name: . . . . . **ID No:** . . . . . **Sec / Prog:** . . . . . .

Instructions: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1. In a PV diagram what are the characteristics of a triple point? (1M)

2. Write the virial equation truncated to three terms. (1M)

3. For Acetone at 293 K and 1 bar pressure, $\beta = 1.487*10^{-3}\ K^{-1}$, $\kappa = 62*10^{-6} bar^{-1}$ and $V = 1.287*10^{-3}\ m^3kg^{-1}$. Find the value of $(\delta P/\delta T)_V$. Find the volume change when acetone is changed from 293 K and 1bar pressure to 273 K and 10 bar pressure. (3+3 = 6M)