BITS-PILANI, DUBAI CAMPUS

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

III Year Chemical Engineering, I Semester 2011-'12

Comprehensive Exam

CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 80 Weightage: 40%

Duration: 3 hr **(Closed Book)** 07.01.2012

Note: This question paper contains 3 pages.
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) A 5 *kg* mass is suspended in a spring (A) which extends to 3.46 *cm* on the surface of Jupiter (has 2.5 times the gravity of earth). How much extension can be expected for the same mass with another spring (B) having double the value of spring constant of A on earth? (3 M)

   (b) A mechanical stirrer delivers work for two hours to 40 *kg* of water to raise its temperature from 20 to 40 ^{o}C. Determine the power in this process. How long it will take for 40 *kg* of another liquid to under go the same changes, whose $Cp = 20.81\ kJ\ kg^{-1}\ C^{-1}$. (5 M)

   (c) One *kg* of nitrogen gas is heated at constant pressure from an initial state of 50 ^{o}C and 2 *bar* until its volume is increased to 2.5 times. Assuming N_2 as ideal gas calculate *W, Q,* ΔU and ΔH for the process. [Assume $R=83.14\ bar\ cm^3\ mol^{-1}\ K^{-1}$ and $Cp\ for\ N_2 = 29.11\ J\ mol^{-1}\ K^{-1}$]. (8 M)

2. (a) A gaseous mixture contains three ideal gases A (20 %), B (30 %) and C (50 %) by moles. The molar heat capacity values are 8.81, 8.51 and 8.21 $J\ mol^{-1}\ K^{-1}$ respectively. Calculate the $Cv_{mixture}$ by treating the gaseous mixture as single gas which behaves ideally. (3 M)

   (b) An organic liquid of chemical formula $C_{10}H_{18}$ is combusted in a constant volume process in the presence of oxygen. At 25 ^{o}C the heat evolved is $43,960\ J\ g^{-1}$. Calculate the standard heat of combustion of the compound at 25 ^{o}C in the reaction giving H_2O *(g)* and CO_2 *(g)* as products. [Enthalpy of Vaporization of water is $44012\ J\ mol^{-1}$].
   (5 M)

(c) An ideal gas initially at 600 K and 10 *bar* undergoes a four step mechanically reversible cycle in a closed system.
Step 1-2 - Pressure decreases isothermally to 3 *bar*.
Step 2-3 - Pressure decreases at constant volume to 2 *bar*.
Step 3-4 - Volume decreases at constant pressure.
Step 4-1 - The gas returns adiabatically to its original state. Assuming $Cp=7/2\ R$ and $Cv=5/2\ R$ determine the unknown T and P in states *1, 2, 3 & 4* and W, Q, ΔU & ΔH for the process. (8 M)

3. (a) What is partial molar free energy? Discuss its significance with phase equilibrium. (3 M)

(b) An ideal gas with $Cv=5/2\ R$, at 500 K and 1 *bar* is confined in a rigid vessel of volume $6x10^{-2}\ m^3$. What will be the entropy change if 15 *kJ* of heat is transferred to the gas? Determine the entropy change by considering the above process as adiabatic. Comment on the irreversibility of the process. (5 M)

(c) A thermal power station generates 750 *MW* of electricity. The steam temperature is 315 ^oC. Determine the maximum possible thermal efficiency and the minimum rate at which heat must be discarded to the cooling stream. If the actual efficiency of the plant is 60 % of the Carnot's efficiency, at which rate heat must be discarded to the cooling stream and what is the temperature rise of the stream? The flow rate of water in the stream is 165 $m^3\ s^{-1}$. (8 M)

4. (a) Liquid water enters an adiabatic hydroturbine at 5 *atm* and 288 K, and exhausts at 1 *atm*. If the turbine has an efficiency of 55 %, determine the power output. What is the outlet temperature if water is assumed to be an incompressible liquid? (3 M)

(b) Determine Q, W, ΔU & ΔH for a mechanically reversible isothermal process in which one kg of water at 25 ^oC ($V_1 = 1.003x10^3\ cm^3\ kg^{-1}$) is compressed from 1 *bar* to 1500 *bar*. [Given that $\beta = 2.5x10^{-4}\ K$ and $\kappa = 4.5x10^{-5}\ bar^{-1}$]. (5 M)

(c) Saturated vapor steam ($1.4x10^{-2}\ m^3$) and $2.1x10^{-2}\ m^3$ of saturated liquid water (100 ^oC) are in equilibrium in a rigid vessel. If heat is transferred to the vessel to make one phase just to disappear (single phase exists) determine the temperature and pressure and which phase will remain? Calculate the heat transferred in this process. (8 M)

5. (a) Discuss the liquefaction of gases by Linde's process with a neat sketch. (3 M)

(b) Determine the BUBL point pressure for methane(1)/ethylene(2)/ethane(3) system at -51 ^{o}C [Given $x_1 = 0.10$ and $x_2 = 0.50$]. Also calculate the DEW point pressure for the same system at -51 ^{o}C [Given $y_1 = 0.50$ and $y_2 = 0.25$]. (5M)

(c) A 20 *mol%* of $LiCl/H_2O$ is made by the following three different processes.

i. Mixing $LiCl_{(s)}$ with $H_2O_{(l)}$

ii. Mixing $H_2O_{(l)}$ with a 25 *mol%* $LiCl/H_2O$ solution.

iii. Mixing $LiCl_{(s)}$ with 10 *mol%* $LiCl/H_2O$ solution. Assuming the mixing processes are isothermal at 25 ^{o}C, calculate the heat effect in $J\ mol^{-1}$ of final solution for each of the above processes. (8M)

BITS, PILANI – DUBAI CAMPUS, ACADEMIC CITY, DUBAI

THIRD YEAR CHEMICAL ENGG. - FIRST SEMESTER, 2011-'12

TEST- 2 (Open Book)

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

Date:04.12.2012 **Maximum Mark: 20**

Time:50 min **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.

Only prescribed text book and own hand written notes are permitted.

1. Steam at 2550 kPa and 460 °C is fed in to a turbine with a flow rate of 0.6 kg s^{-1}, and 28 m s^{-1} to give a power out put of 145 kW. The exhaust steam exits at 40 kPa, has the quality of 0.90. Calculate the heat lost in the process. What will be the exit velocity of the steam? (6 M)

2. Determine the Dew point pressure and Bubble point pressure for a mixture of 15 mol % methane, 25 mol % ethane, 35 mol % propane and 25 mol % ethylene at 60 (°F). (Use the Figures 10.13 and 10.14). (5 M)

3. 5 kW power is utilized by a refrigeration system, produces refrigeration at a rate of 12.5 kJ s^{-1}. If it rejects heat at 35 °C calculate the quantity of heat rejected and the possible lower temperature the system can maintain. (4 M)

4. In a two stage cascade refrigeration system. T_C = 220, K T_H = 300 K. intermediate temperatures are T'_C = 250 K and T'_H = 255 K Coefficient of performance for each stage are 62 % of the corresponding values for a Carnot's refrigerator. Determine the coefficient for the real cascade and compare with that for a Carnot's refrigerator operating between T_C and T_H. (5 M)

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THIRD YEAR CHEMICAL ENGG. - FIRST SEMESTER, 2011-'12

TEST- 1 (Closed Book)

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

Date:09.10.2011 **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.

1. Calculate the number of degrees of freedom, when liquid water is in equilibrium with its vapor. **(2 M)**
2. Water enters and exits from heating coil with a velocity of 10 $m\ s^{-1}$ and 200 $m\ s^{-1}$ respectively. If the enthalpies of the inlet and exit streams are 350 $kJ\ kg^{-1}$ and 2800 $kJ\ kg^{-1}$ respectively, calculate the heat transferred to 1 kg of water by the coil. **(2 M)**
3. Heat in amount of 2250 kJ is added to 1 kg of water. The water gets vaporized at 100 ^{o}C at a constant pressure of 101 kPa. The specific volumes of liquid vapor water are $1x10^{-3}\ m^3\ kg^{-1}$ and $1.6\ m^3\ kg^{-1}$ respectively. Calculate ΔH and ΔU. **(4 M)**
4. Liquid water when brought to vapor state at 240 ^{o}C and 1200 kPa the enthalpy is 2910 kJ (on arbitrary scale) and specific volume is 188 cm^3g^{-1}. Initially the water was at 800 kPa and 175 ^{o}C where its enthalpy was 2775 kJ and Sp.volume 243 cm^3g^{-1}. Calculate the ΔH and ΔU for the process. **(4 M)**
5. In a mechanically reversible process, an ideal gas from an initial state of 70 ^{o}C and 1 bar pressure is compressed adiabatically to 150 ^{o}C and then cooled to 70 ^{o}C at constant pressure. Finally it is expanded isothermally to its initial state. Calculate ΔH, ΔU, W and Q for each process and for the entire cycle. [Given that $C_p = (7/2\ R)$ & $C_v = (5/2\ R$]. Plot the process in a PV diagram. **(13 M)**

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FIRST SEMESTER 2011 – '12 THIRD YEAR CHEMICAL ENGG.

QUIZ-2 (Closed Book)

Course Code: CHE C311
Course Title : Chemical Engineering Thermodynamics
Duration : 20 minutes

Date : 23-11-2011
Max Marks : 7
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. Steam undergoes a change from an initial state of 450 °C and 3000 kPa to a final state of 240 °C and 440 kPa. Calculate the ΔH and ΔS. (3M)

2. Superheated steam enters in to a turbine (operating in a reversible adiabatic mode) at 3000 kPa. The discharge is saturated vapor at 200 kPa. Calculate the temperature at which the steam enters in to the turbine. (2M)

3. Calculate the power out put and the quality of steam (assuming as saturated vapor) from a turbine operating in an isentropic process, utilizes steam at initial conditions 2500 kPa, 400 °C and final condition 40 kPa, 100 °C. (2M)

(Use next page)...

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FIRST SEMESTER 2011 – '12 THIRD YEAR CHEMICAL ENGG.

QUIZ-1 (Closed Book)

Course Code: CHE C311		Date	: 26-10-2011
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. Using watson's expression calculate the latent heat of water at 100 °C. Given that the latent heat at 300 °C is 1406 J/g and critical temperature of water is 647.1 K. (2M)

2. Calculate the standard heat of combustion of methane, if the standard heat of formation of CH_4, H_2O and CO_2 are -75, -286 and -394 kJ/mol respectively. (2M)

3. Assuming air as an ideal gas, calculate the heat capacity at 25 °C. (From table C1: A = 3.355, B = 0.575×10^{-3} C = 0 and D = -0.016×10^{5}). (2M)

4. Write the equation to find out the latent heat of a pure species at a given 'T'. (2M)