BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

FIRST SEMESTER 2008-2009

CHE C311 Chemical Engineering Thermodynamics

Third Year Chemical Engineering

Test - 1

(Closed Book)

DURATION: 50 MINUTES **21.09.08**

MAXIMUM MARKS: 50

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. A man whose weight is 600 N takes 2 min for climbing up a staircase. What is the power (watts) developed by him, if the staircase is made up of 20 stairs each 0.18 m in height? (5 M)

2. Nitrogen gas is confined in a cylinder and the pressure of the gas is maintained by a weight placed on the piston. The mass of the piston and weight together is 50 kg. The acceleration due to gravity is 9.81 m/s^2 and the atmospheric pressure is 1.01325 bar. Assume friction less piston. Determine
   a) The force exerted by the atmosphere, AND the piston, and the weight on the gas of the piston is 100 mm in diameter.(4 M)
   b) The pressure of the gas. (4 M)
   c) What is the change in the potential energy of the piston and the weight after the expansion by 400 mm? (4 M)

3. A spherical balloon of diameter 0.5 m contains a gas at 1 bar and 300 K. The gas is heated and the balloon is allowed to expand. The pressure inside the balloon is found to vary linearly with the diameter (P/D = constant). What would be the work done by the gas when the pressure inside reaches 5 bar? (8 M)

4. In an experimental determination of thermal conductivity of copper, one end of a copper rod is maintained at 100°C while the other end is kept at 0°C. After some time it was found that the temperature at any given location of the copper rod is constant with time. Is the copper rod in a state of equilibrium? Explain. (1 + 2 M)

5. A particular gas obeys the relation

$$\left(P+\frac{a}{v^2}\right)(v-b)=RT$$

Where a, b and R are constants. Suppose the gas is allowed to expand reversibly and at constant temperature from v_1 to v_2, calculate the work done by the gas. (6 M)

6. Heat transferred to 10 kg of air which is initially at 100kPa and 300 K until its temperature reaches 600 K. Determine the change in internal energy, the change in enthalpy, the heat supplied, and the work done in the following processes:
   a) constant volume process (8 M)
   b) constant pressure process (8 M)

Assume that air is an ideal gas. Take C_p = 29.099 KJ/Kmol, C_v = 20.785 KJ/Kmol.

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

III Year Chemical Engineering, I Semester 2008-09

Test - 2

CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 40 Weightage:20%

Duration: 50 min (Open Book) **2.11.08**

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.

Note: only pescribed txt book and hand written notes are allowed

1. Suppose a pressure cooker initially contains a mixture of saturated liquid and saturated water vapor at 101.325 kPa. If enough ice is added to the pressure cooker and the lid is closed, does the mixture in the cooker attain the triple point? Explain why or why not. (5 m)

2. Estimate the approximate pressure (in MPa) at which a boiler is to be operated if it is desired to boil water at 150°C. Assume that no other data is available except that water boils at 100C at 0.10133 MPa with the enthalpy of vaporization being 2256.94 KJ/Kg. (5 m)

3. The heat of reaction at 300K and at 1atm for the gas phase reaction A + 3B gives C is -50,000 cal/ml of A converted. Data on the molar heat capacity at constant pressure (cal/mol K) for the various components are:

   C_p for A = $-0.4 + 80 \times 10^{-3} T$, where T is in K, C_p for B = 7 and C_p = 26

   Calculate the heat of reaction at 500K and at 1atm. (10 m)

4. Superheated steam at 600 kPa and 573 K enters a nozzle at a rate of 10 kg/s and discharges it at 100kPa and 473 K, Heat loss to the surroundings is estimated to be 100KW. Assuming that the inlet velocity of steam is negligible, determine the discharge velocity. (5 m)

5. Superheated steam at 55 bar and 325C expands to 10 bar. Determine the final state of the steam if the expansion is a) at constant entropy b) at constant enthalpy. (15 m)

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III Year Chemical Engineering, I Semester 2008-09

Quiz No 1

CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 10 Weightage: 5%

Duration: 15 min (Closed Book)

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1. One kilo mol CO_2 occupies a volume of 0.381 m^3 at 313 K. Determine the pressure (in bar) by ideal gas equation. (2 marks)

3. The major limitation of the first law of thermodynamics is that it does not consider
a) heat as a form of energy b) rate of change of a process c) direction of change d) spontaneous process (1 mark)

3. At triple point of water, the number of degree of freedom is
a) zero b) one c) two d) three (1 mark)

4. _____ properties of a system do not depend on the quality of matter contained in it. (1 mark)

5. Mention the principles of thermodynamics which are summarized in the form of a set of axioms. (2 marks)

6 Reduced temperature is defined as (1 mark)
a) the ratio of density of fluid to the density at critical point
b) the ratio of volume at critical point to the volume of fluid
c) all of the above
d) none of the above

7 At a given temperature and pressure, a liquid mixture of benzene and toluene is in equilibrium with its vapor. The available degree(s) of freedom is (are) (1 mark)
a) zero b) one c) two d) three

8 Which of the following is true for virial equation of state? (1 mark)
a) virial coefficient are universal constants
b) virial coefficient B represents three body interactions
c) virial coefficients are functions of temperature only
d) for some gases, virial equations and ideal gas equations are the same

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III Year Chemical Engineering, I Semester 2008-09

Quiz No 2

CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 10 Weightage: 5%

Duration: 15 min (Closed Book) (Each question carries 1mark)

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1. Cp = Cv when

   a) $\left(\frac{\partial V}{\partial P}\right)_T = 0$ b) $\left(\frac{\partial V}{\partial T}\right)_P = 0$ c) $\left(\frac{\partial T}{\partial P}\right)_H = 0$ d) $\left(\frac{\partial S}{\partial V}\right)_T = 0$

2. Which one of the following is incorrect?

   a) dU = TdS – PdV b) dH = TdS – VdP c) dA = -SdT – PdV d) dG = -SdT + VdP

3. The difference between the heat supplied and the work extracted in a steady state flow process in which the kinetic and potential energy changes are negligible is equal to,

   a) the change in internal energy b) the change in enthalpy c) the change in the work function d) the change in the Gibbs free energy.

4. The coefficient of compressibility k is defined as

   a) $-\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$ b) $\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$ c) $\left(\frac{\partial T}{\partial P}\right)_H$ d) $\left(\frac{\partial Q}{\partial T}\right)_V$

5. The second law of thermodynamics states that

   a) the energy change of a system undergoing any reversible process is zero
   b) it is not possible to transfer heat from a lower temperature to a higher temperature
   c) the total energy of the system and the surroundings remain constant
   d) none of the above

6. A closed system is cooled reversibly from 373K to 323K. If no work done is done on the system

   a) its internal energy decreases and its entropy increases
   b) its internal energy and its entropy both decreases.
   c) its internal energy decreases but its entropy is constant.
   d) its internal energy is constant and its entropy decreases.

7. In the statement $(\Delta S)_{total} \geq 0$, the inequality refers to _____ process.

8. The Maxwell relation derived from the differential equation for the Helmolz free energy is

a) $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$ b) $\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$ c) $\left(\frac{\partial V}{\partial S}\right)_P = \left(\frac{\partial T}{\partial P}\right)_S$ d) $\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$

9. A system from which finite quantities of heat can be removed without affecting its temperature is called _____.

10. The second law of thermodynamics states that heat cannot be completely converted to work. (T/F)

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III Year Chemical Engineering, I Semester 2008-09

Quiz No 3

CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 10 Weightage: 5%

Duration: 15 min (Closed Book)

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1. The compressibility factor of an ideal gas is defined as (1m)

   a) 0 b) 1 c) < 1 d) > 1

2. Match the following (2 m)

a)	Gibb-deihem equation	a) $y_i P = \gamma_i x_i P_i^{sat}$
b)	Roult's law	b) $\ln P^{sat} = A - \frac{B}{T+C}$
c)	Antoine equation	c) $\hat{f}_i^{id} = x_i j_i$
d)	Lewis/Randall rule	d) $\sum_i x_i \left[\frac{d \ln r_i}{d x_i}\right]_{T,P} = 0$
		e) none
		f) $y_i P = x_i P_i^{sat}$

3. Mollier diagram is a plot of (1 m)

   a) temperature vs enthalpy b) temperature vs enthalpy

   c) entropy vs enthalpy d) temperature vs internal energy

4. The substance not used as refrigerant is (1m)

   a) SO_2 b) NH_3

   c) CCl_4F_2 d) CH_4Cl_2

5. Chemical potential (1m)
a) is an intensive property
b) is a force which derives the chemical system to equilibrium
c) of a substance is equal to its partial molar properies
d) all of the above
e) none of the above

6. For the reversible reaction (1m)

$$2A + B \leftrightarrow 3C$$

a) $\dfrac{\hat{a}_{A^2}\ \hat{a}_B}{\hat{a}_{C^3}}$ b) $\dfrac{\hat{a}_{C^3}}{\hat{a}_B\ \hat{a}_{A^2}}$ c) $\dfrac{3\hat{a}_{C^3}}{\hat{a}_B\ 2\hat{a}_{A^2}}$ d) $\dfrac{2\hat{a}_{A^2}\ \hat{a}_B}{3\hat{a}_{C^3}}$

where a is the activity coefficient in the mixture

7. In the gas phase reaction (1 m)

$$AB + CD \leftrightarrow BC + AD$$

at equilibrium 1/3 moles of each reactant and 2/3 moles of each product are present. If the equilibrium mixture behaves as an ideal solution and an ideal gas, the equilibrium constant is _____

8. For an ideal gas the fugacity coefficient is always (1 m)
a) zero b) one c) infinite d) uncertain

9. In steam table, different data of steam can be arranged according to (1 m)
a) saturated steam data with reference to varying temperature
b) saturated steam data with reference to varying temperature
c) superheated steam data for different states of temperatures and pressures
d) all of the above
e) none of the above

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III Year Chemical Engineering, I Semester 2008-09

Comprehensive Exam

CHE C311 Chemical Engineering Thermodynamics

Maximum Marks: 80 Weightage: 40%

Duration: 3 hr (Closed Book) 04.01.09

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) Usually the weather data is collected by releasing helium or hydrogen filled balloons carrying the required measuring instruments into the atmosphere. In one such experiment a balloon which is initially flat is slowly filled with hydrogen from a cylinder forming a sphere of 1 m radius. The atmospheric pressure is 101.325 kPa. Calculate the work done by the cylinder-balloon system. (3 m)

(b) A system consisting of some fluid is stirred in a tank. The rate of work done on the system by the stirrer is 2.25 hp. The heat generated due to stirring is dissipated to the surroundings. If the heat transferred to the surroundings is 3400 KJ/h, determine the change in internal energy. (6 m)

(c) One mole of ideal gas with $C_p = (7/2)R$ and $C_v = (5/2)R$ expands from $P_1 = 8$ bar and $T_1 = 600K$ to $P_2 = 1$ bar by each of the following paths:
(i) Constant temperature (ii) Adiabatically. Assuming mechanical reversibility, calculate W, Q, ΔU and ΔH for each process. (2 + 4 m)

2. (a) Superheated steam originally at P_1 and T_1 expands through a nozzle to an exhaust pressure P_2. Assuming the process is reversible and adiabatic and that equilibrium is attained, determine the state of the steam at the exit of the nozzle for the following conditions: $P_1 = 800kPa$, $T_1 = 260°C$ and $P_2 = 200$ kPa. (10 m)

(b) Discuss briefly about the Carnot cycle for an ideal gas. (4 m)

(c) Mention various methods to calculate latent heat. (2 m)

3. (a) Prove that

$$dH = C_P\,dT + \left[V - T\left(\frac{\partial V}{\partial T}\right)_P\right]dP$$

(6 m)

(b) Discuss in detail about the Mollier diagram. (3 m)

(c) Mention the characteristics of the flow of a nozzle. (4 m)

4. (a) Discuss in detail about absorption refrigeration unit with a neat sketch. (5 m)

(b) Asumming the validity of Raoult's law, for the benzene (1)/toluene (2) system, if the overall mole fraction of benzene is $z_1 = 0.33$ determine the molar fraction of the two phase system (x_1 and y_1). Given data T = 387.15 k (105°C) and P = 120 kPa. (5 m)

5. (a) It is known that benzene (1) and toluene (2) form an ideal liquid solution. If a liquid mixture of benzene and toluene having $x_1 = 0.6$ is heated in a closed vessel at 760Torr. Determine the temperature at which vaporization starts and the composition of the vapor that forms.

	A	B	C
Benzene (1)	6.879	1196.76	219.161
Toulene (2)	6.95	1342.31	219.187

Where P is in Torr and t is in °C. Prepare a P-x-y diagram at 95°C (10 m)

(b) At 318K and 24.4 kPa the composition of the system toluene (2) and ethanol (1) at equilibrium is $x_1 = 0.3$, $y_1 = 0.634$. the saturation pressure at the given temperature for the pure components are $P_1^s = 23.06$ kPa and $P_2^s = 10.05$ kPa respectively. Calculate the value of G^E/RT for the liquid phase system. (4 m)

6. (a) The equilibrium constant K for the reaction below at 100°C is found to be 2.92. Determine the concentration if 1 m^3 of an aqueous solution containing 5 kmol acetic acid, 10 kmol ethanol and 10 kmol water at 100°C is allowed to reach a state of equilibrium. (4 m)

$$CH_3COOH + C_2H_5OH \longrightarrow CH_3COOC_2H_5 + H_2O$$

(b) Assuming that $\Delta H°$ is constant in the temperature range 298.15 k to 800K, estimate constant at 800K for the following reaction, (4 m)

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

(c) Develop expressions for the mole fractions reacting species as functions of reaction coordinate for a system initially containing 2 mol NH_3 and 5 mol O_2 and undergoing the reaction: (4 m)

$$4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(g)}$$