

National Exams May 2002

98-Chem-A1 Process Balances and Chemical Thermodynamics

Three Hours Duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an open-book exam.
3. Any non-communicating calculator is permitted.
4. Any **FIVE** questions constitute a complete paper.
5. All questions are of equal value. The components (e.g. part (a), part (b), etc.) of a given multi-part question are of equal value.

- (a) Give an example from everyday life (i.e. a non-technical example) which illustrates the law of conservation of mass in its most general form.
- (b) A colleague informs you that the law of conservation of mass is always "in equals out". What is your response?
- (c) Demonstrate how the first law of thermodynamics can be reduced to a "heat balance" for an open system under certain conditions.
2. A synthesis gas analyzing 6.4 % CO₂, 0.2 % O₂, 40.0 % CO, and 50.8% H₂ (balance N₂), is burned with 40 % excess air. (All compositions are mole %'s.) What is the composition of the flue gas?
3. Formaldehyde can be made by the oxidation of methanol. If stoichiometric amounts of CH₃OH(g) and O₂(g) enter a reactor at 100 °C, the reaction is complete, and the products leave the reactor at 200 °C, calculate the heat that is added to or removed from the reactor per mol of CH₃OH(g) fed to the reactor. The reaction is:
- $$\text{CH}_3\text{OH}(\text{g}) + 1/2 \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g})$$
4. Determine the density of chlorine gas, Cl₂, at 155 bar and 248 °C using:
- (a) the compressibility factor equation of state, and
- (b) an appropriate cubic equation of state.
5. Two well-insulated tanks, each having a volume of 1 m³, are connected by means of a small pipeline containing a valve. Initially, one tank contains a gas at 2 bar and 290 K, and the other is completely evacuated. The valve is opened, and the pressures and the temperatures are allowed to equalize.
- (a) What is the final temperature and pressure in the tanks?
- (b) What is the entropy change of the gas?

6. The catalytic dehydrogenation of 1-butene to 1,3 butadiene



is carried out at 900 K and 1 atm and with a ratio of 10 mol of steam per mol of butene.

Determine:

- (a) the extent of reaction at equilibrium, and
 (b) the extent of reaction in the absence of steam.

The following thermochemical data are available:

Species	$(G^\circ_{900} - H^\circ_{298})/T$ [kcal/K]	ΔH°_{298} [kcal]
C_4H_6	- 80.35	26.33
C_4H_8	-88.03	- 0.03
H_2	- 34.762	-----

7. The most common refrigeration cycle is the vapour-compression cycle.

- (a) Draw a schematic of this cycle incorporating the following process components:
 compressor, evaporator, condenser, and throttle valve.
 (b) Draw a representative T - s diagram for this cycle.

8. Calculate the activity coefficients of isopropanol (2-propanol) and water in a liquid of composition:

- (a) 10 mole % isopropanol at 760 mm Hg, and
 (b) 13.05 mole % isopropanol at 380 mm Hg.

The following vapour-liquid equilibrium data are available:

P [mm Hg]	Mole % Isopropanol		T [°C]
	x (liquid)	y (vapour)	
760	0	0	100
760	10	50.15	82.70
760	100	100	82.25
380	0	0	81.68
380	13.05	52.55	65.59
380	100	100	66.02