National Exams December 2002

98-Chem-A1 Process Balances and Chemical Thermodynamics

Three Hours Duration

**NOTES:**

1. If doubt exists as to the interpretation of any question, you are urged to submit with the answer paper, a clear statement of any assumptions made.
2. Property data required to solve a given problem are provided in the problem statement or are available in the recommended texts. If you are unable to locate the required data, do not let this prevent you from solving the rest of the problem. Even in the absence of property data, you still have the opportunity to provide a solution methodology.
3. This is an open-book exam.
4. Any non-communicating calculator is permitted.
5. Any **FIVE** questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
6. All questions are of equal value.

1. Moist air at a total pressure of 720 mm Hg and a temperature of 35 °C, containing water vapour at a partial pressure of 30 mm Hg, is passed through a dehumidifier at an entering flow rate of 100 $ft^3$/hr. The air comes out of the dehumidifier at 30 °C and a total pressure of 720 mm Hg, containing water vapour at a partial pressure of 20 mm Hg. How many kilograms of water are removed from the air per hour?

2. One hundred kilograms of a limestone containing 80 wt % $CaCO_3$ and 20 wt % inerts are burned with 100 kilograms of pure carbon using 20 % excess air. All the $CaCO_3$ decomposes to CaO and $CO_2$, and the residue from the burner contains 40 wt % unburned carbon and 60 wt % inerts. All the carbon that undergoes combustion is burned to $CO_2$. Calculate the volume percent composition of $CO_2$ in the gaseous mixture produced by this process.

3. Methanol at 675 °C and 1 bar is fed to an adiabatic reactor where 25 % of it is dehydrogenated to formaldehyde according to the reaction:

$$CH_3OH\ (g) \rightarrow HCHO\ (g) + H_2\ (g)$$

Calculate the temperature of the gases leaving the reactor, assuming that constant average heat capacities of 17, 12 and 7 cal/mol·°C for $CH_3OH$, HCHO and $H_2$, respectively, are acceptable over the range.

4. Benzene has a Permissible Exposure Limit (or PEL) for an 8-hr exposure of 1.0 ppm. If liquid benzene is evaporating into the air at a rate of 2.5 mL/min, what must the ventilation rate be to keep the concentration below the PEL? The ambient temperature is 68 °F and the pressure is 740 mm Hg.

5. Air is compressed from 100 kPa to 500 kPa in a reversible isothermal process. Determine the change in the specific entropy of the air and comment on the physical significance of the sign (positive or negative) of the entropy change.

6. Calculate the equilibrium molar composition and extent of decomposition of nitrogen tetroxide due to the following chemical reaction at 25 °C and 1 atm:

$$N_2O_4\ (g) \rightleftharpoons 2\ NO_2\ (g)$$

7. A colleague is trying to persuade you to invest in his new heat engine. He claims that for a heat input of $10^4$ Btu, the engine rejects only 1.7568 kW·hr and is 46 % efficient. Is this claim accurate?

8. Estimate the bubble point and dew point of a 25 mole % *n*-pentane, 45 mole % *n*-hexane, and 30 mole % *n*-heptane mixture at 1 atm.