Chemical Engineering 140 **November 5, 2010**

Midterm Examination #2

(150) 1. Acetaldehyde (C_2H_4O) is produced by partial oxidation of ethane (C_2H_6) over a catalyst.

$$C_2H_6 + O_2 \rightarrow C_2H_4O + H_2O \quad (1)$$

A number of side reactions also occur, the most important of which are:

$$C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O \quad (2)$$

and

$$C_2H_6 + 1.5O_2 \rightarrow CH_3OH + CO + H_2O \quad (3)$$

A process flow diagram to produce acetaldehyde is shown in Figure 1 below. The fresh feed consists of a mixture of ethane at 6000 gmol/h and air at 30,952 gmol/h air. The ethane:oxygen molar ratio in the reactor feed is 6:1. The reactor outlet stream is fed to a gas-liquid separator where the off gas, consisting of N_2, CO, CO_2, and C_2H_6, is to be recycled. Part of the recycle stream is split and sent to a flare to be burned. The purge stream is analyzed for composition and found to contain 10% C_2H_6, no O_2, and a CO_2:CO molar ratio of 2:1. The bottoms stream from the separator is sent to the first distillation column, where acetaldehyde and methanol are completely separated from water. Acetaldehyde is further separated cleanly from methanol in a second distillation column. . The amount of methanol out of the bottoms stream of distillation column 2 is 1206 gmol/h.

(10) a. Draw the molecular structure of acetaldehyde.

(15) b. What is the limiting reactant?

(15) c. Why is part of the recycle stream split off and sent to a flare?

(20) d. What is the recycle ratio?

(35) e. Calculate the single-pass conversion of ethane.

(15) f. Calculate the molar flow rate of the separator gas.

(20) g. Calculate the composition of the purge gas.

(20) h. Calculate the overall conversion of ethane.

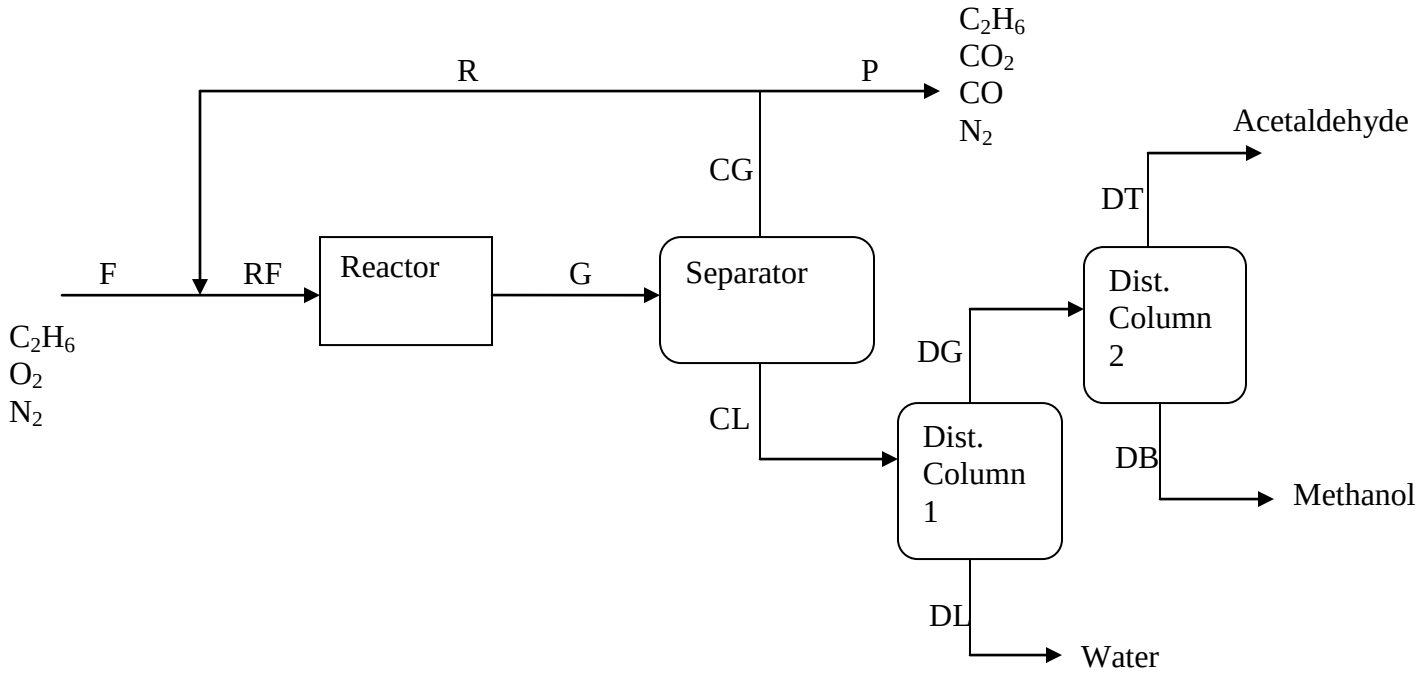

Figure 1. Process flow diagram for production of acetaldehyde from ethane oxidation

(40) 2. The gas-phase reaction 1 above is at equilibrium at 600 K and ΔH^o_{rxn} -382 kJ/mol.

(20) a. Write the equilibrium expression.

(5) b. What happens to the mole fraction of *ethane* in equilibrium when pressure is decreased?

(5) c. What happens to the mole fraction of *ethane* in equilibrium when pressure is increased?

(5) d. What happens to the mole fraction of *acetaldehyde* in equilibrium when temperature is decreased?

(5) e. What happens to the mole fraction of *acetaldehyde* in equilibrium when temperature is increased?