1. **Combustion Reaction**

   Natural gas containing 95.8 mol% methane (CH_4), 3.4 mol% ethane (C_2H_6) and the balance inerts is burned with 20% excess air. Assume complete combustion occurs.

   a. Draw and label the flowchart.
   b. Determine the required air feed rate in <u>kg/h</u> for 20% excess.

1. **Dew-Point and Bubble-Point Calculations**

   A mixture of pentane, hexane and heptane has the following composition

	Mole (%)	Vapor Pressure (mm Hg)				
		70°C	60°C	50°C	40°C	30°C
Pentane	80	2112	1600	1188	863	612
Hexane	10	794	576	407	281	188
Heptane	10	302	209	141	92	58

   The pure component vapor pressure at different temperatures are also given in the table above. With this data answer the following questions

   a. If the mixture in the table is a vapor at 1 atm pressure (absolute) and 70°C. What is the dew point temperature of this gas? (You may linearly interpolate between the nearest two temperatures in the table)

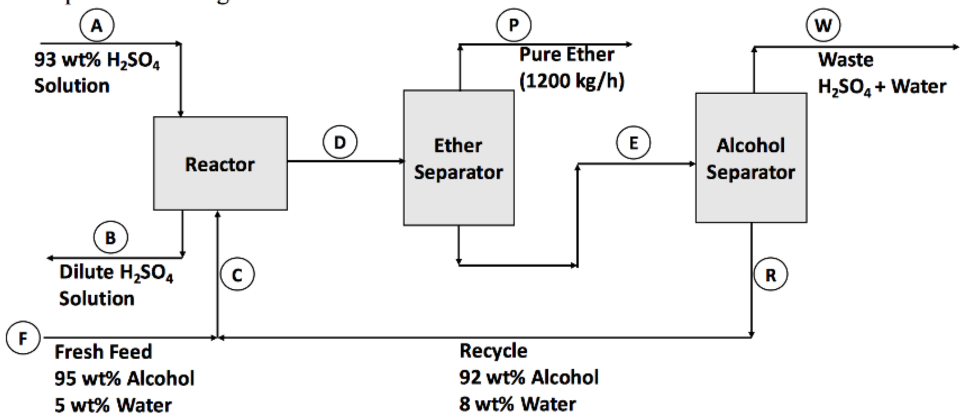
   b. If the mixture in the table is a liquid at 1 atm pressure (absolute) and 30°C. What is the bubble point temperature of this liquid? (You may linearly interpolate between the nearest two temperatures in the table)

2. **Chemical Reaction**

Ether is made by the dehydration of ethyl alcohol in the presence of sulfuric acid at 130°C to 140°C. According to the reaction

$$2\,C_2H_5OH \rightarrow C_2H_5OC_2H_5 + H_2O$$

A simplified flow diagram is shown below



Assume 87% conversion of alcohol on a single-pass basis, calculate

a. kg/h of fresh feed?

b. kg/h of recycle?

4. **Combustion reaction**

Gasoline (C_8H_{18}) is burnt in an internal combustion engine with 5% excess air to produce a gas with a ratio of CO to CO_2 of 0.05. The gasoline is only partially burnt (98% conversion).

a. What is the composition of the exhaust (product) gas on a dry basis?
b. What is the yield of CO_2?

1. **Chemical Equilibrium**
   Methanol is produced by the continuous vapor phase hydrogenation of carbon monoxide according to the reaction:

$$CO + 2H_2 \rightarrow CH_3OH$$

   This reaction occurs at 400 K and 1 atm pressure and can be considered to be at equilibrium. The equilibrium constant (K_e) at these conditions is given by

$$K_e = \frac{y_{CH_3OH}}{(y_{CO})(y_{H_2})^2} = 1.5$$

   One hundred (100) moles per hour of the product gas containing 40 mole % hydrogen are produced with a feed stream of only hydrogen and carbon monoxide fed to the reactor. What is the flow rate and composition of the feed stream?

3. **Ideal gas**

Quantities of two chemical species A and B are placed in a constant volume, isothermal vessel. The following reactions are known to take place at the temperature of the vessel:

$$A + 2B \rightarrow C$$
$$A + 2C \rightarrow D + B$$

Initially only 10 moles of A and 10 moles of B are placed in the vessel.
The pressure in the vessel is monitored throughout the experiment and is noted that the final pressure in the reactor is $0.9P_1$, where P_1 is the initial pressure before any reactions have taken place, It is also noted that the gas mixture that finally occupies the vessel has a mole fraction of B of 0.4667.
What is the final composition of the gas remaining in the vessel? (you may assume that ideal gas behavior is obeyed).

4. **Multiple Chemical Reaction**

Acetaldehyde is produced by the catalytic dehydrogenation of ethyl alcohol according to the reaction:

$$C_2H_5OH \rightarrow CH_3CHO + H_2$$

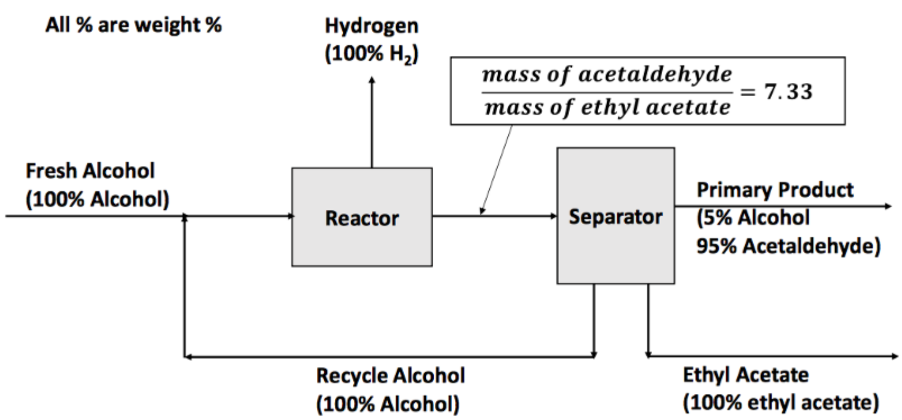
However, the following side reaction also takes place producing undesired ethyl acetate:

$$2\ C_2H_5OH \rightarrow CH_3COOC_2H_5 + 2H_2$$

With a copper nitrate catalyst at 330°C, 85% of the alcohol fed to the reactor is reacted (i.e. single-pass conversion is 85%). The stream leaving the reactor goes to separation scheme in which ethyl acetate is removed as a waste stream, pure alcohol is separated and recycled back to reactor feed and the acetaldehyde product (containing some alcohol) is removed as the primary product stream.

The process is shown in the diagram below with additional information. If the process is to produce 100 moles/h of primary product calculate

a. Ratio of moles of recycle to moles of fresh feed.
b. Mass flow rate of feed to the separator.



1. Liquid-Liquid Extraction

Benzene and hexane are being considered as solvents to extract acetic acid from aqueous mixtures.

At 30°C, distribution coefficients for the two solvents are K_B= 0.098 mass fraction acetic acid in benzene/mass fraction acetic acid in water and K_H=0.017 mass fraction acetic acid in hexane/mass fraction acetic acid in water.

a. Based on the distribution coefficients only, which of the two solvents would you use and why?
b. Demonstrate the logic of your decision by comparing the quantities of the two solvents required to reduce the acetic acid content in 100 kg of an aqueous solution from 30 wt% to 10 wt%.
c. What other factors may be important in choosing between benzene and hexane?

4. **Non-Ideal gas**
   A process stream flowing at 35 kmol/h contains 15 mole% hydrogen and the remainder 1-butene. The stream pressure is 10.0 atm absolute, the temperature is 50°C, and the velocity is 150 m/min. Determine the diameter (in cm) of the pipe transporting this stream, using Kay's rule in your calculations.