Department of Chemical Engineering
Thapar Institute of Engineering & Technology, Patiala

Course: Material and Energy Balances
UCH301

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Material balance over a Distillation Column

Exercise

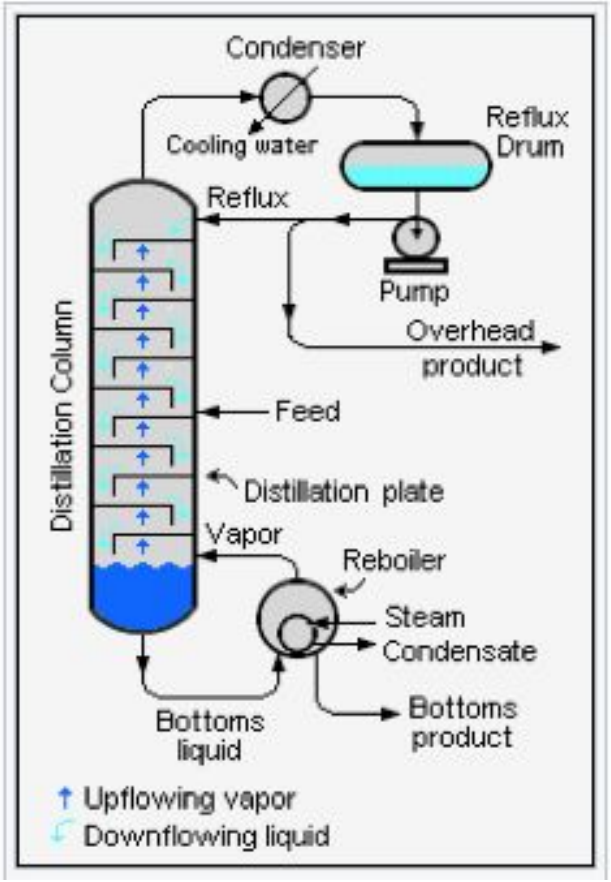
- A liquid mixture of Benzene (C_6H_6) and Toluene (C_7H_8) (having composition: C_6H_6 = 45%, C_7H_8=55%) is fed to a distillation column. A product stream leaving the top of the column contains 95 **mol%** Benzene, and a bottom product stream contains 8% of the Benzene fed to the column. The volumetric flow rate of the feed stream is 2000 L/h and density is 0.872 g/cc. Determine the mass flow rate and compositions of the top and bottoms products, and composition of bottoms product.

DISTILLATION?

Distillation

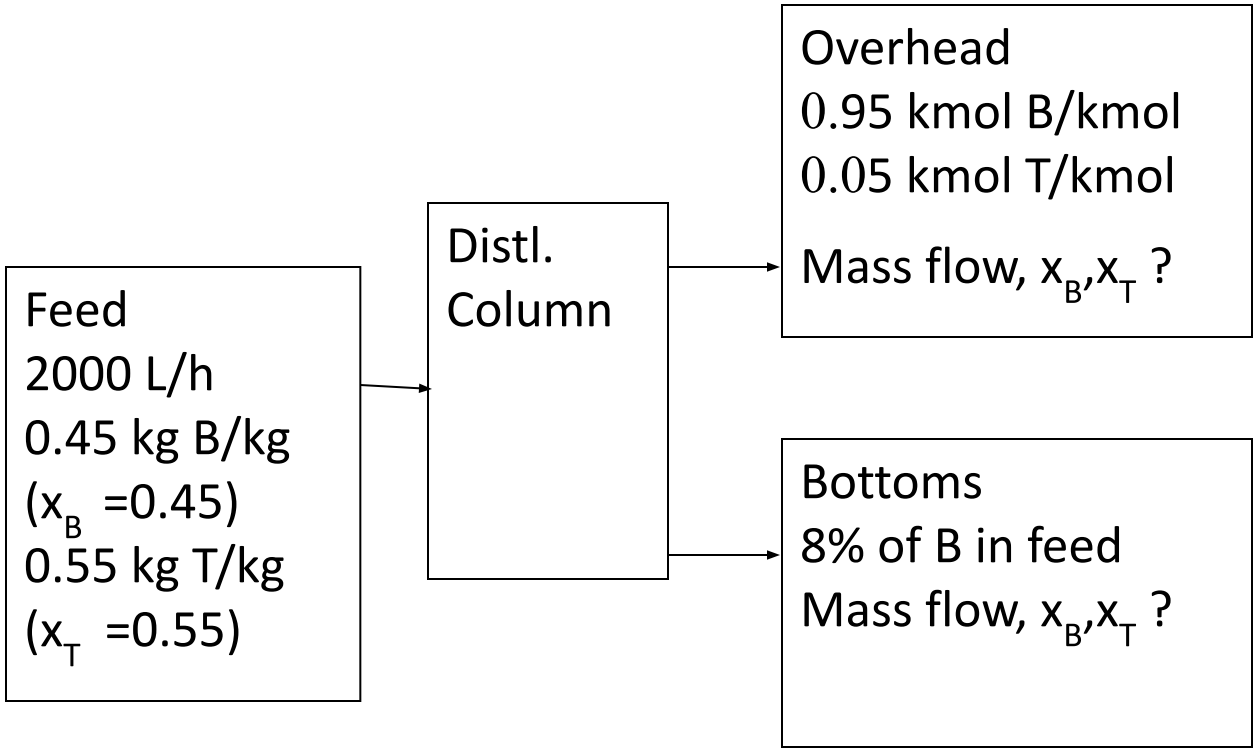
- Distillation is used for separation of a liquid mixture into its components based on the difference in their boiling points.
- One Feed stream enters the column
- Two streams leave from the column: Overhead & Bottoms

Distillation column



SOLUTION

- Basis = 2000 L/h of feed mixture
- Draw a flow chart/block diagram and label the streams with the information provided in the problem statement, also identify the quantities that are unknown/to be calculated


Feed
2000 L/h
0.45 kg B/kg
(x_B =0.45)
0.55 kg T/kg
(x_T =0.55)
Distl.
Column
Overhead
0.95 kmol B/kmol
0.05 kmol T/kmol
Mass flow, x_B,x_T ?
Bottoms
8% of B in feed
Mass flow, x_B,x_T ?

- Basis: Feed = 2000 L/h

We need to convert the feed amount to mass units

Feed =2000 L/h*0.872 kg/L=1744 kg/h

Now, we need to convert the mol% composition of overhead product to mass% composition

Overhead:

- 1 Kmol/h of overhead contains 0.95 kmol/h of B, which in mass units this is equal to

B in Overhead= 0.95kmol/h*78 kg/kmol =74.1 kg/h

1 Kmol/h of overhead contains 0.05 kmol/h of T, which in mass units this is equal to

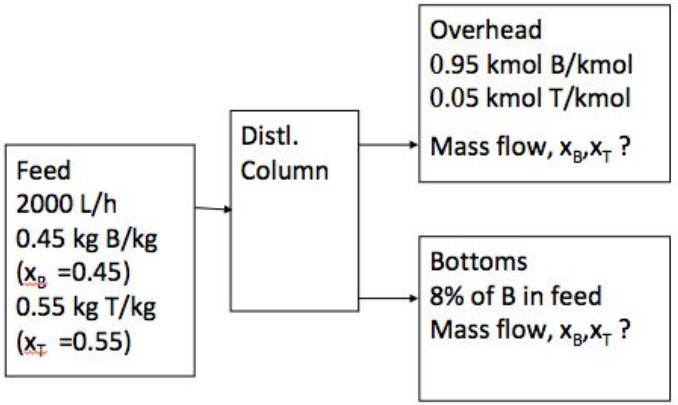
T in overhead = 0.05*92 = 4.6 kg/h

Therefore, mass fraction of B in overhead

= 74.1/(74.1+4.6) = 0.942

And, mass fraction of T in overhead

= 4.6/(74.1+4.6) = 0.058



Now,

Benzene in Bottoms product

= 0.08*(0.45*1744) = 62.8 kg/h

- Writing M. balance for B

B in feed = B in overhead + B in bottoms

B in overhead = B in feed- B in bottoms

=(1744*0.45) – 62.8

= 722.3 kg/h

This amount is 94.2 % of the overhead product

Therefore, total overhead product

= 722.3/0.924 = 766.8 kg/h

- Therefore bottoms product rate

  = feed rate – overhead product rate

  = 1744 -766.8 = 977.2 kg/h

mass fraction of B in bottoms = 62.8/977.2 = 0.064

And

mass fraction of T in bottoms = 1 -0.064 = 0.936

Composition of Bottoms product

6.4% B, 93.6% T

Overhead product = 766.8 kg/h

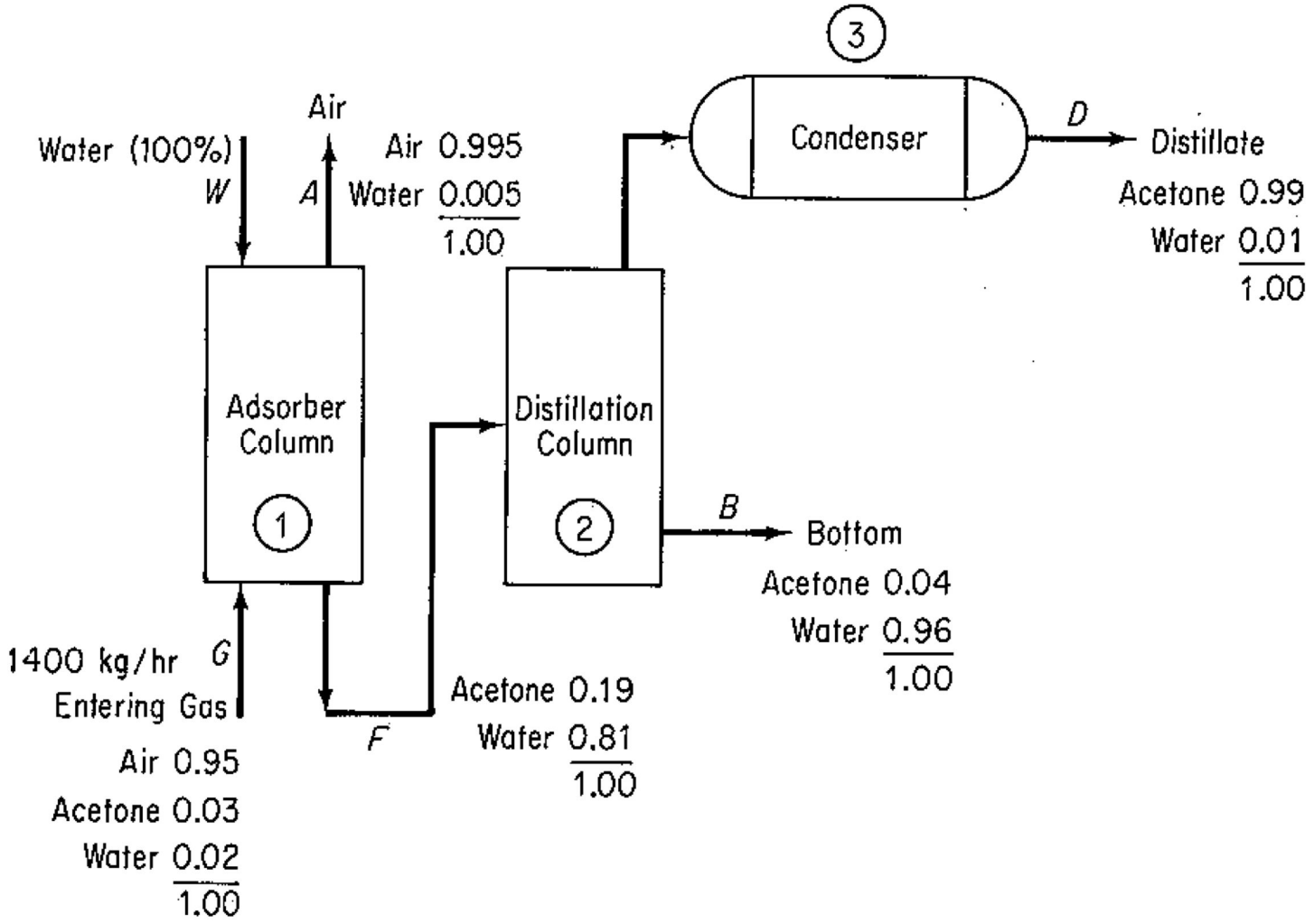
Bottoms product = 977.2 kg/h

Material balances on processes involving multiple units

Exercise

- Acetone is used as solvent in the following absorption process and recovered for reuse, as shown in fig (next slide). All the compositions for liquids and gases are given in mass%. Calculate the values of W, A, F, B, and D.

Multiple units process

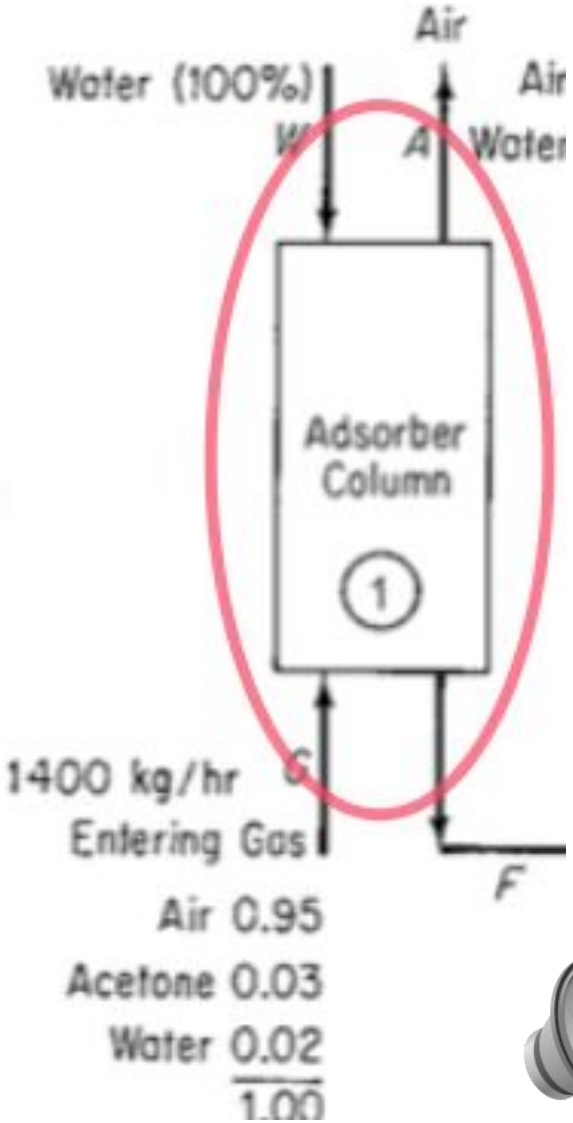


Solution

M.B. for absorption column:

See the boundary marked here, as the unit absorption column (unit 1) is selected for writing m.b., the streams crossing the boundary are shown in figure

As you can see that air is entering through one stream and leaving through one stream, so air is tie material and we may get some information by writing balance for air, as all compositions are known



Unit 1

writing m.b. for air :

G*0.95 = A* 0.995 (G = 1400)

→ A = (1400*0.95)/0.995

= **1336.7 kg/h**

Acetone is also in one inlet and one outlet stream, so writing m.b. for acetone

1400*0.03 = F*0.19

→ F = (1400*0.03)/0.19

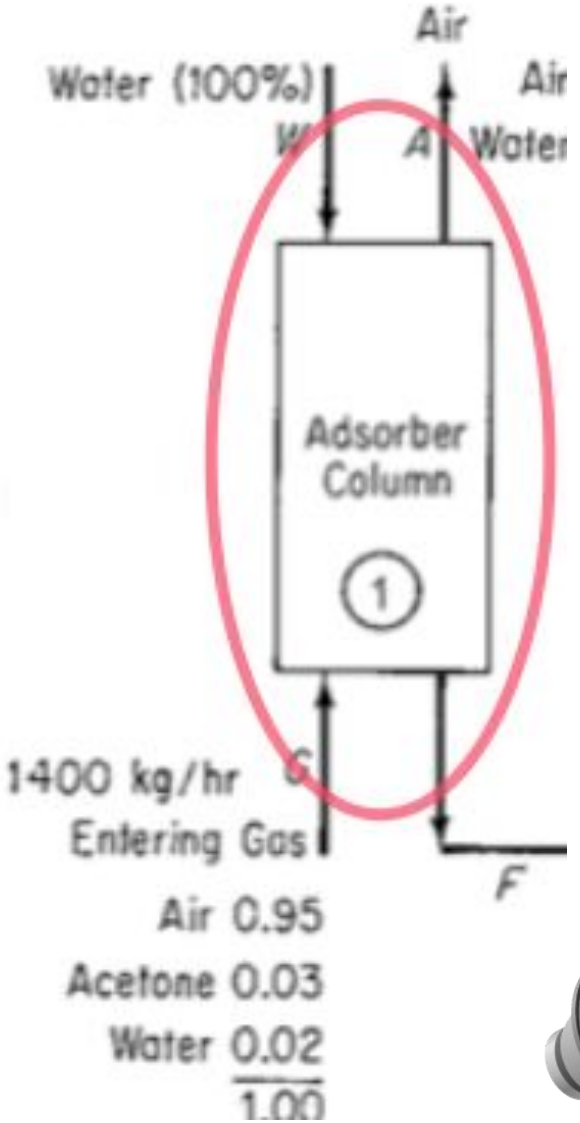
= **221.1 kg/h**

Now, from overall m. balance, W can be calculated

Overall m.b. on column:

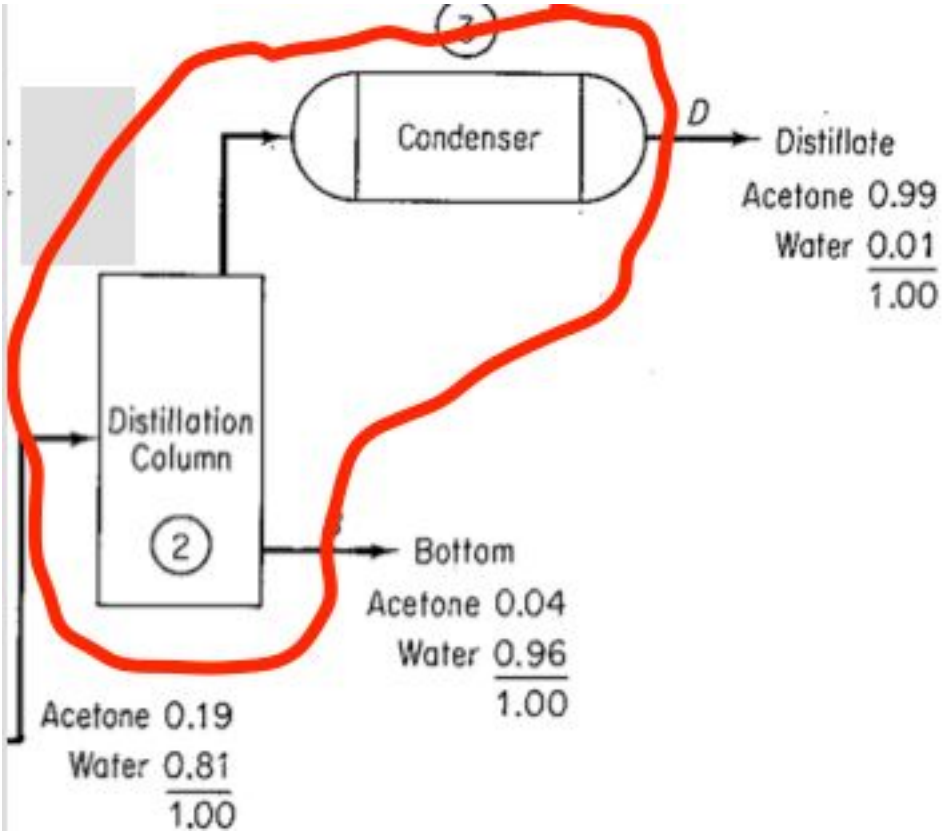
G + W = A + F or 1400 + W = 1336.7+221.1

→ **W = 157.8**



Unit 2 &3 Distillation Column & Condenser

- Here we have chosen to write m.b. for unit 2 & 3 combined (why??).
- See the boundary marked in the figure, stream F is entering, and streams B & D are leaving through this boundary.



Oveall balance:

F = B +D ; (F is known 221.1)

(two unknowns one more equation is needed,

balance for any of the two components can be used)

Balance on acetone:

F*0.19 = B*0.04+ D*0.99

Solving these two equations:

D = 34.9 kg/h; B = 186.2 kg/h