THE UNIVERSITY OF JORDAN

The University of Jordan
Faculty of Engineering & Technology
Chemical Engineering Department

Chemical Engineering Principles
(0905211)

Material Balance
Part 2: Balance on Multiple processes

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Content

Balance on Multiple processes

Balance with Recycle stream and Bypass Processes

Balance on Multiple processes

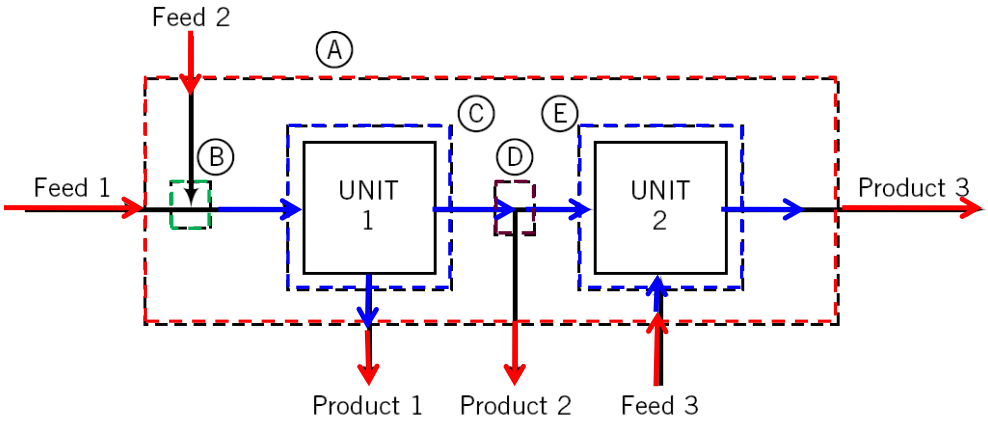
Industrial process rarely involve only one process

- Chemical rectors are often present
- Unit for mixing reactant
- Lending products
- Heating and cooling streams
- Unit for product separation and hazards disposal

We need a multiple unit process

System: is any portion of a process that can be enclosed within a boundary

The inputs and outputs to a system are the process streams that intersect the system boundary



The system can be:

The entire process: (Boundary A)

Single process : (Boundary C, Boundary E)

Point where two or more process streams come together: (Boundary B)

One steam splits into branches : (Boundary D)

Combination of process

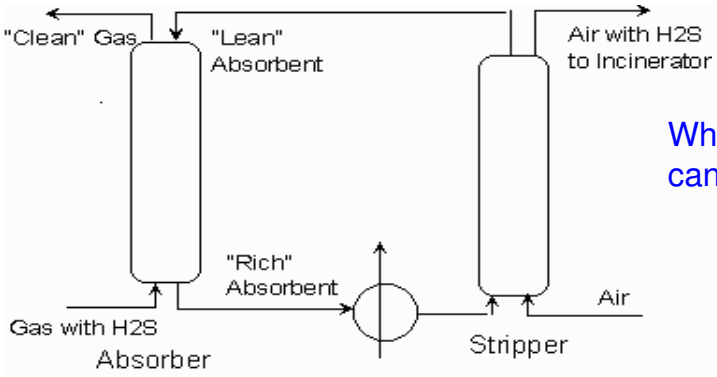
You can write material, component, and atom balances

- Around the entire system,
- Around any subsystem of the plant.

A subsystem doesn't have to be a piece of equipment; it might be a mixing point (pipe junction) or splitter

Example

The figure shows an absorber-stripper system for gas cleanup. If we consider the process to have 4 components (gas, H_2S, oil, air),

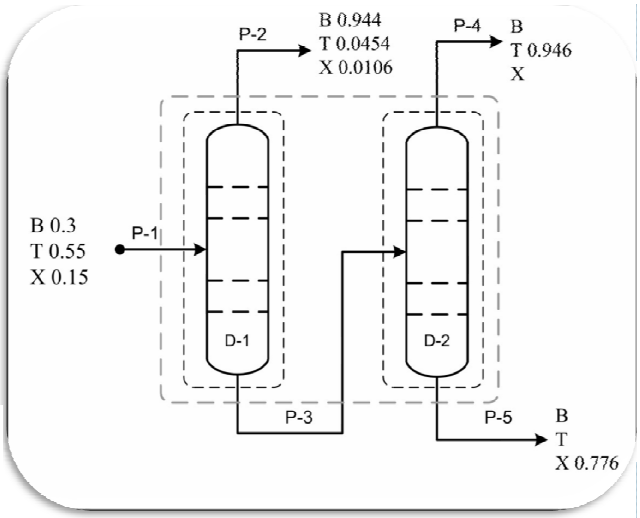


What different balances can be written?

Example

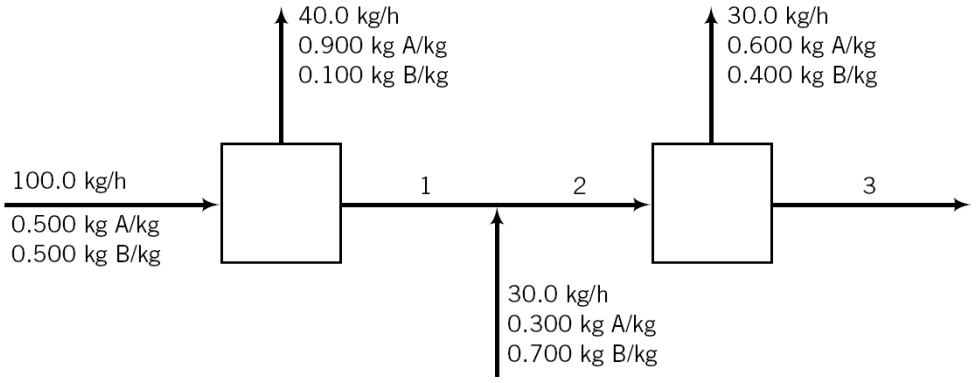
Two columns in sequence are used to separate the components of a feed consisting of 35% benzene(B),55%toloune(T),and 15% xylene (X). the analysis of the overhead stream from the first column is: 94.4%B, 4.54%T, 1.06%X. The second column is designed to recover 92% of the toluene in the original feed in the overhead stream at a composition of 0.946.The bottoms are intended to contain 92.6% of xylene at a composition of 0.776. Comput the composition of all stream.

Tow distillation column in series



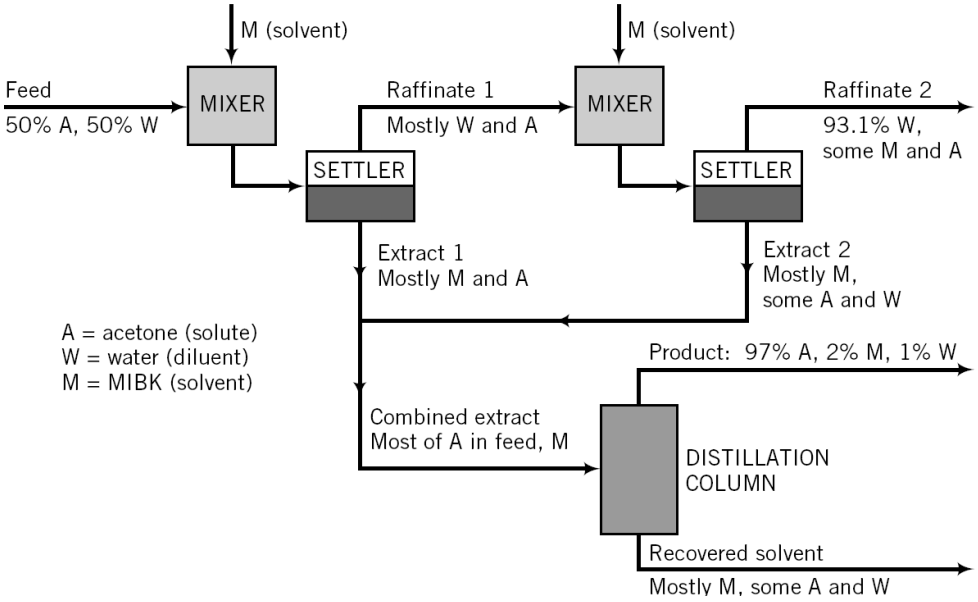
Example

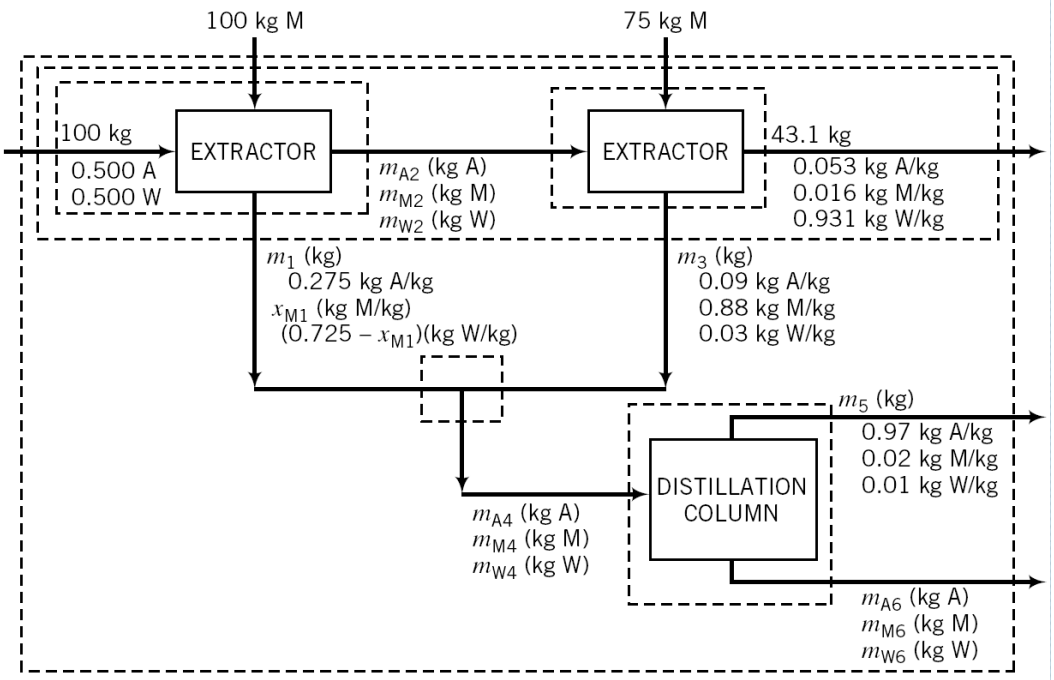
In the flow sheet, each stream contains 2 components A and B, calculate the mass flow rate and composition of streams 1, 2 and 3.



Example

A mixture containing 50.0 wt% acetone and 50.0 wt% water is to be separated into two streams—one enriched in acetone, the other in water. The separation process consists of extraction of the acetone from the water into methyl isobutyl ketone (MIBK), which dissolves acetone but is nearly immiscible with water. The description that follows introduces some of the terms commonly used in reference to liquid extraction processes. The process is shown schematically below.



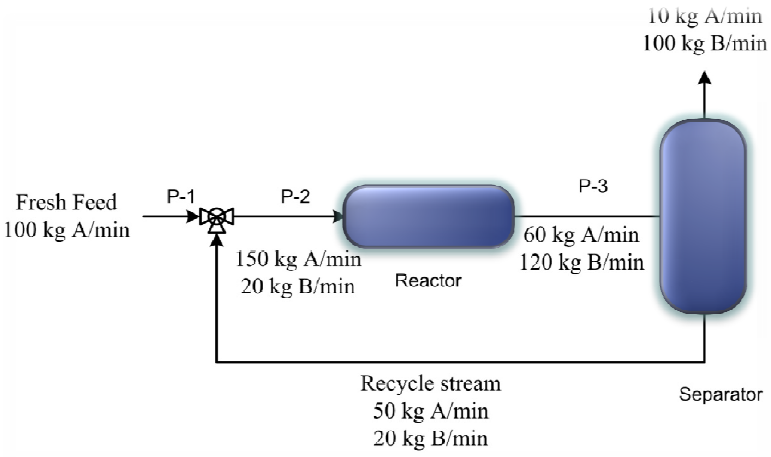


Recycle, Bypass Process Makeup and Purge

- Recycle: is a common feature of chemical process

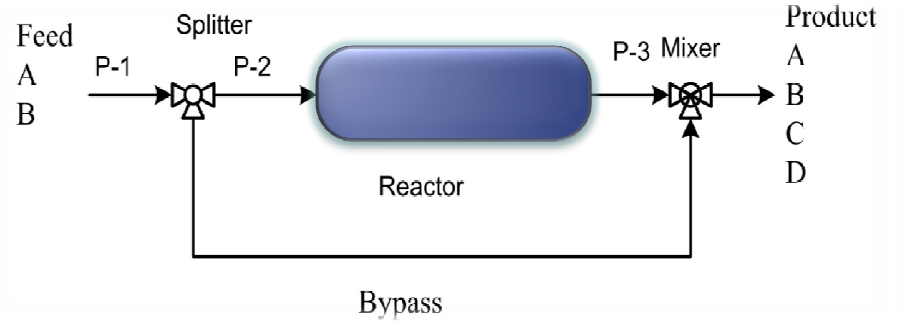
- The reasons for using the recycle are:
  1. Recovering and reusing unconsumed reactants
  2. Recovery of catalyst
  3. Dilution of a process stream
  4. Control of a process variable
  5. Circulation of a working fluid
  6. No accumulation of mass since input = output

Recycle



Bypass

Bypass: is a fraction of the feed to a process unit that is diverted around the unit and combined with the output stream



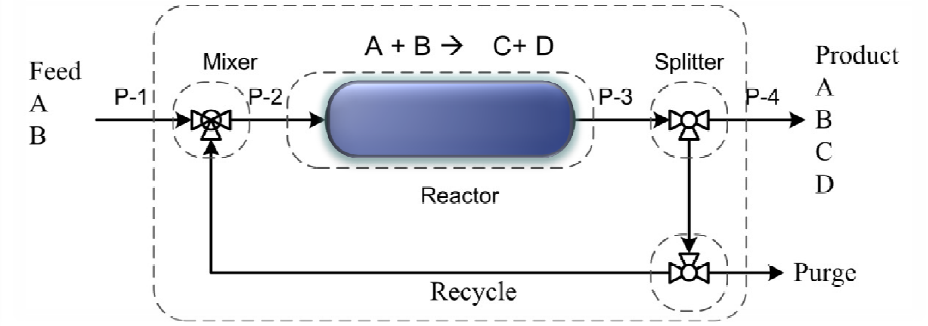
Chemical process of bypass similar to recycle

In steady state there is no buildup or depletion of material within the system or recycle stream of a properly designed and operated process

Purge

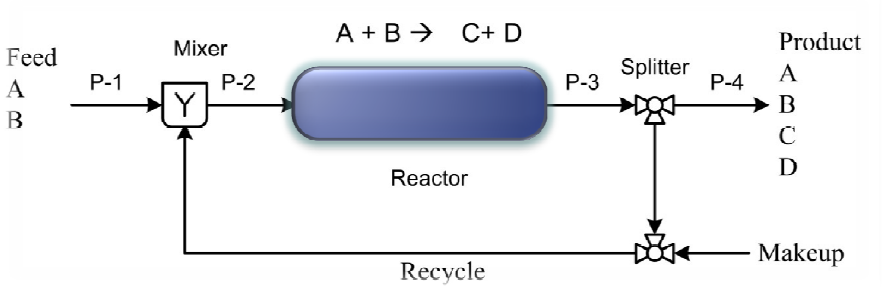
A purge stream is a small stream bled off form a recycle loop to prevent building of inerts or impurities in the system

It can be neglected because of the size



Make up

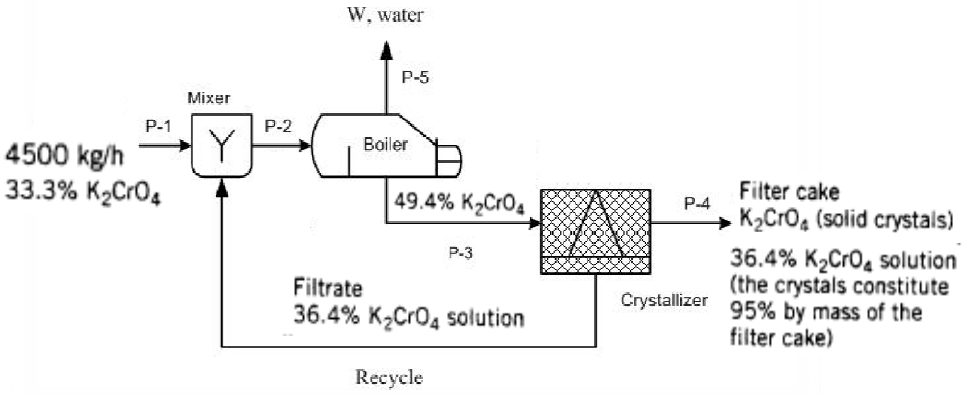
A make up stream is required to replace losses to leaks, carryover, etc. within the recycle loop

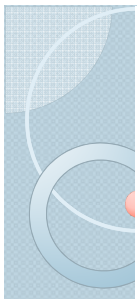


Example

Forty-five hundred kilograms per hour of a solution that is one-third K_2CrO_4 by mass is joined by a recycle stream containing 36.4% K_2CrO_4, and the combined stream is fed into an evaporator. The concentrated stream leaving the evaporator contains 49.4% K_2CrO_4; this stream is fed into a crystallizer in which it is cooled (causing crystals of K_2CrO_4 to come out of solution) and then filtered. The filter cake consists of K_2CrO_4 crystals and a solution that contains 36.4% K_2CrO_4 by mass; the crystals account for 95% of the total mass of the filter cake. The solution that passes through the filter, also 36.4% K_2CrO_4, is the recycle stream.

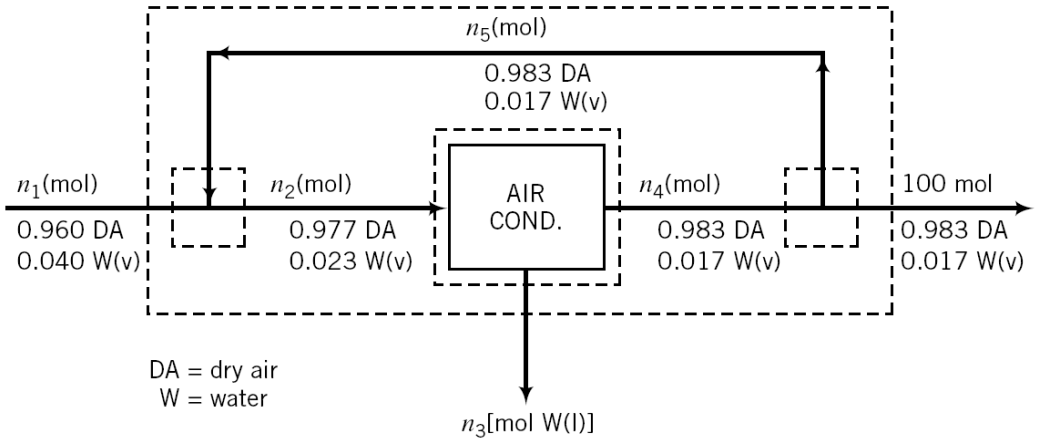
1. Calculate the rate of evaporation, the rate of production of crystalline K_2CrO_4, the feed rates that the evaporator and the crystallizer must be designed to handle, and the *recycle ratio* (mass of recycle)/(mass of fresh feed).
2. Suppose that the filtrate were discarded instead of being recycled. Calculate the production rate of crystals. What are the benefits and costs of the recycling?





Example *Material and Energy Balances on an Air Conditioner*

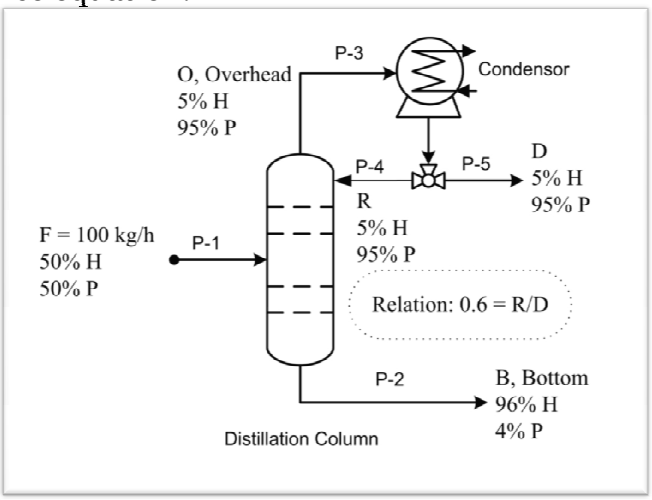
Fresh air containing 4.00 mole% water vapor is to be cooled and dehumidified to a water content of 1.70 mole% H_2O. A stream of fresh air is combined with a recycle stream of previously dehumidified air and passed through the cooler. The blended stream entering the unit contains 2.30 mole% H_2O. In the air conditioner, some of the water in the feed stream is condensed and removed as liquid. A fraction of the dehumidified air leaving the cooler is recycled and the remainder is delivered to a room. Taking 100 mol of dehumidified air delivered to the room as a basis of calculation, calculate the moles of fresh feed, moles of water condensed, and moles of dehumidified air recycled.



Example

Hexane & pentane are being continuously split in a distillation column with a reflux ratio of 0.69(Reflux ration=R/D). If the feed is 50% hexane, the distillate is 5% hexane and the bottom is 96% hexane (all by weight), determine the distillate, bottoms, and overhead flow rate for a feed of 100 kgmol/h. Hint: the composition do not change on the splitter , but the total masses are different, therefore, there is only one independent material balance equation.

This will always be true of a splitter. It just divides the flow rates, so there is only one independent balance that can be performed:



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