Material Balances without Chemical Reactions.

A process design starts with the development of a process flow sheet or process flow diagram. For the development of such a diagram material and energy balance calculations are necessary. These balances follow the law of conservation of mass and energy. According to the law of conservation of mass, the total mass of various compounds remains unchanged during an unit operation or a chemical reaction.

In general material balance problems are classified as follows.

Material balance problems.

- Processes involving no chemical reactions
  - Steady-state operations
  - Unsteady-state operations
- Processes involving chemical reactions
  - Steady-state operations
  - Unsteady-state operations.

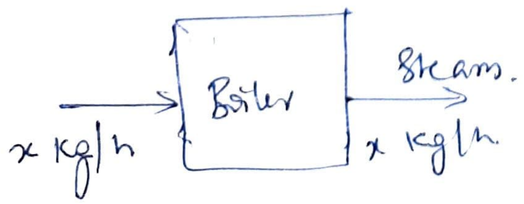
From the law of conservation of mass, it follows that for any process

Input − accumulation = output

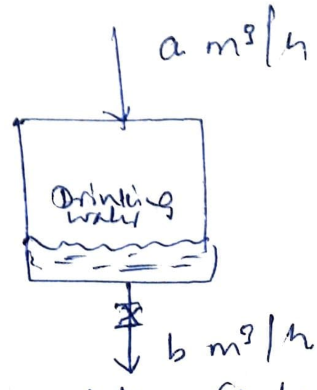
When the accumulation of the material is constant or nil

$$\boxed{\text{Input} = \text{Output}}$$

This is usually the case with steady state processes.



Steady state process.



Accumulation = (a−b) m³/h

Unsteady state process

Material balances without chemical reactions.

There are three general methods of solving material balance problems for system involving no chemical reactions

(i) Make balance of the material, the quantity of which does not change during the particular operation.

eg. ① Concentration of solution in evaporator

② drying

In the above operations dissolved solids and bone dry material quantity remain unchanged during the process

(ii) Very often one or several inert chemical species which do not take part in the operation are involved in the system. By making balance of this inert portion, the material balance calculations can be simplified

eg. ① Leaching of solids

② ash present in coal

During leaching copper from ore, the gangue is unaffected and acts as inert material. During the combustion of coal, ash is left out on the grate and it does not take part in the combustion process

(iii) When two or more compounds are present in the system and if all the compounds are affected simultaneously, it is required that the material balance equations be solved by satisfying simultaneous equations.

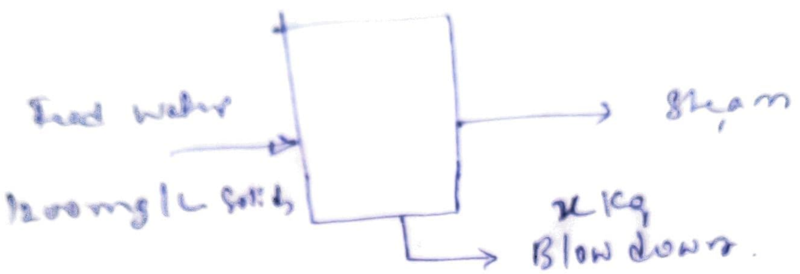
Eg. (1) Mixing of acids

(2) distillation

(3) extraction.

① A boiler is fed with softwater containing 1200 mg/L dissolved solids. IS : 10392-1982 specifies that the maximum dissolved solids in the boiler water should not exceed 3500 mg/l for boilers operating up to 2 MPa g. In order to maintain the specified level, a continuous blow-down system is adopted. Find the % of feed water which will be blown down assuming no carryover is observed.

Basis : 1 kg feed water



During evaporation of water in the boiler, the dissolved solids (a tie material) in the feed water and boiler water will provide the clue to the problem.

This a typical problem.

Let x be the amount of feed water that will be blown down. This blow-down will contain dissolved solids to the extent of 3500 mg (same as boiler water)

Solids in feed = Solids in blowdown

$1200 \times 1 = 3500 \times x$

$1200 = 3500x$

$x = \dfrac{1200}{3500}$

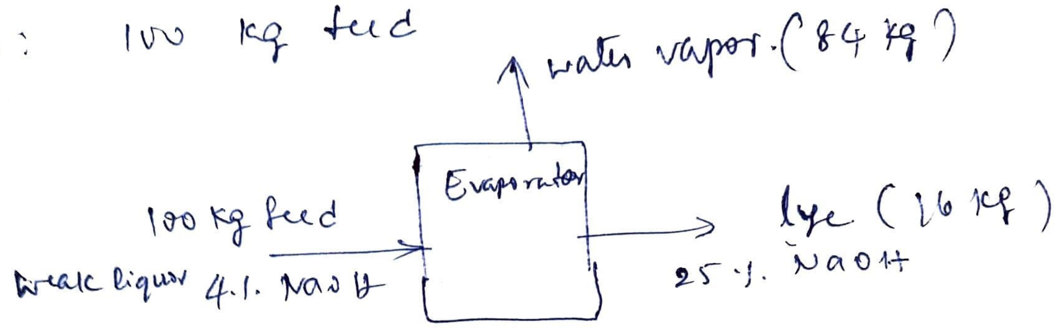
$$\boxed{x = 0.3428 \text{ kg}}$$

$\therefore$ Blow down $= \dfrac{0.343}{1} \times 100 = 34.3\,\%$

Note : Density of feed water and boiler water is assumed to be 1.0 kg/l.

(2) A double effect evaporator system concentrates weak liquor containing 4% (by weight) caustic soda to produce a lye containing 25% solids (by weight). Calculate the evaporation of water per 100 kg feed in the evaporator.

Basis : 100 kg feed



Let the quantity of lye be x kg

Solids in feed = solids in lye.

$100 \times 0.04 = x \times 0.25$

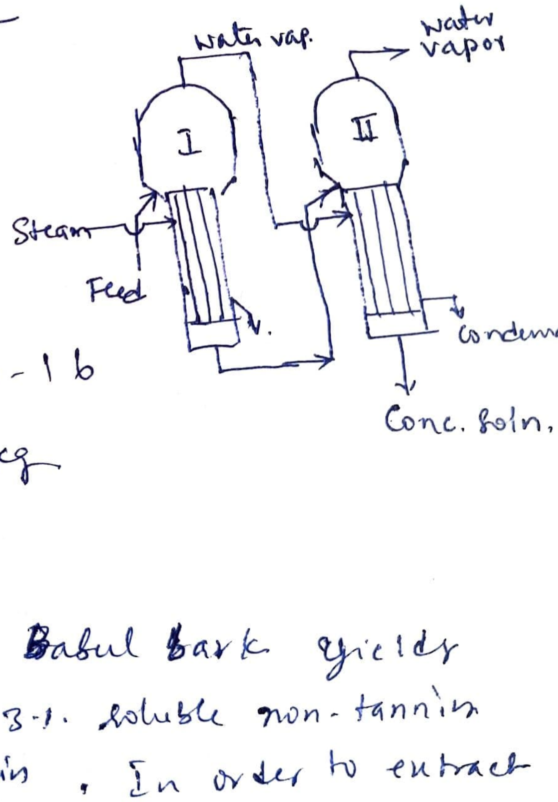
$4 = 0.25x$

$x = \frac{4}{0.25}$

$x = 16$ kg

Water evaporated $= 100 - 16$

$= 84$ kg



(3) The analysis of a sample of Babul bark yields 5.8% moisture, 12.6% tannin, 8.3% soluble non-tannin organic matter and the rest lignin. In order to extract tannin out of the bark, a counter-current extraction process is employed. The residue from extraction process is analysed and found to contain 0.92% tannin and 0.65% soluble non-tannin organic matter on a dry basis. Find the percentage of tannin recovered on the basis of the original tannin present in the bark. All the analyses are given on a weight basis.

Soln : Basis : 100 Kg Babul bark

100 kg Babul bark contains, 5.8 kg moisture, 12.6 kg ~~lignin~~ tannin, 8.3 kg Organic matter

Lignin in the bark = 100 − 5.8 − 12.6 − 8.3

= 73.3 kg

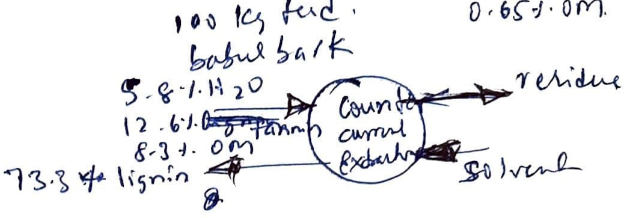
In the leaching process it is evident that the lignin is unaffected. Therefore, it will be considered inert. This is example of type (ii).

lignin = 100 − 0.92 − 0.65 = 98.43 −

0.92 % tannin

0.65 % O.M.

Lignin in the residue



Let x be the final weight of dry residue in kg

lignin in feed = lignin in residue

$100 \times 0.733 = x \times 0.9843$

$73.3 = 0.9843\,x$

$x = 74.469$ kg

Tannin present in the residue = 74.469×0.0092

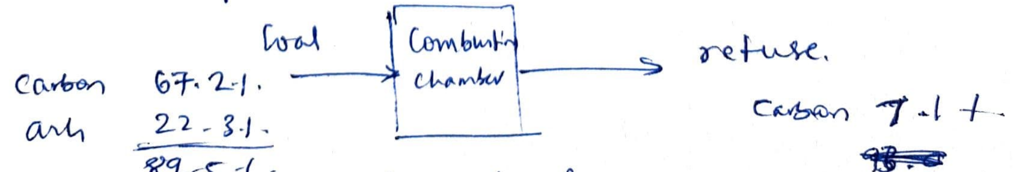
= 0.685 kg.

Tannin recovered = $\dfrac{12.6 - 0.685}{12.6} \times 100$

= 94.56 %

(3) A sample of coal ~~from~~ is found to contains 67.2 % Carbon and 22.3 % ash (wt. basis). The refuse obtained at the end of combustion is analysed to contain 7.1 % carbon and the rest ash. Compute the % of original carbon remaining unburnt in the ~~refuse~~ refuge.

Soln Basis: 100 kg coal sample



100 − 89.5 = 10.5 % moisture?

Type (ii) Inert material (ash)

Let 'x' be the quantity of refuse obtained.

ash in ~~feed~~ coal = ash in refuse

$100 \times 0.223 = x \times 0.929$ $x = 24.00$ kg

Original carbon = 67.2 kg.

Carbon in refuse = 24×0.071

= 1.7043 kg.

67.2 kg original carbon — 1.7 kg left unbu

100 kg — ?

$$\frac{100 \times 1.7}{67.2} = 2.53\,\%$$