Material and Energy Balances
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Module No # 02
Lecture No # 07
Material Balance Calculations for Single Units Without Reactions - Part 4

Welcome everybody today we will talk about material balance calculation for single units without reaction we have already looked at many different processes today we will look at one of the most common processes seen in all chemical and bio chemical industries it is the filtration process.

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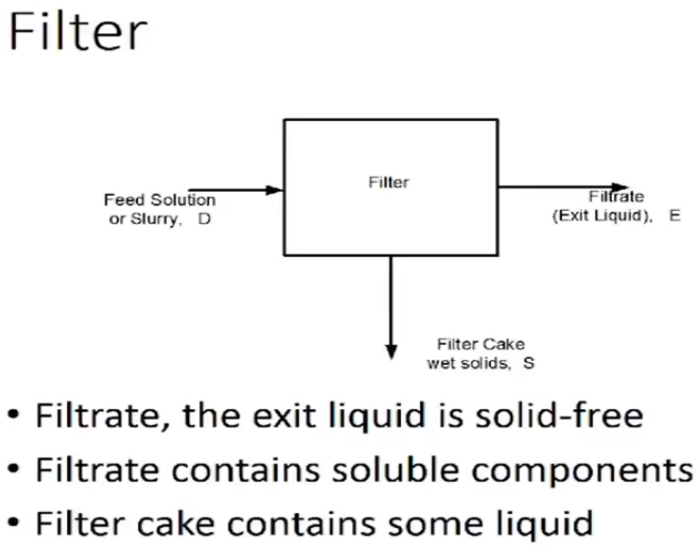

A feed solution or a slurry which enters into the system which separate into two different streams during a filtration process. The liquid stream which leaves the system is called the filtrate and you will also have a filter cake which is the wet solids which leaves the system. So the filtrate which is exit liquid is solid free and the filtrate contain all the soluble components which are accompanying the liquid which enters into the filter.

Filter cake can actually contains some of the liquids the filter cake is not always dry it will always contain some of the liquids which are coming along with the slurry entering into the filter. Imaging this process where you have water and sand mixture so this slurry when it is

filtered you will have the liquid which is water collected as the filtrate and you will have the sand which is collected on top of the filter paper. So this sand will not be dry will have the accompanying water along with it.

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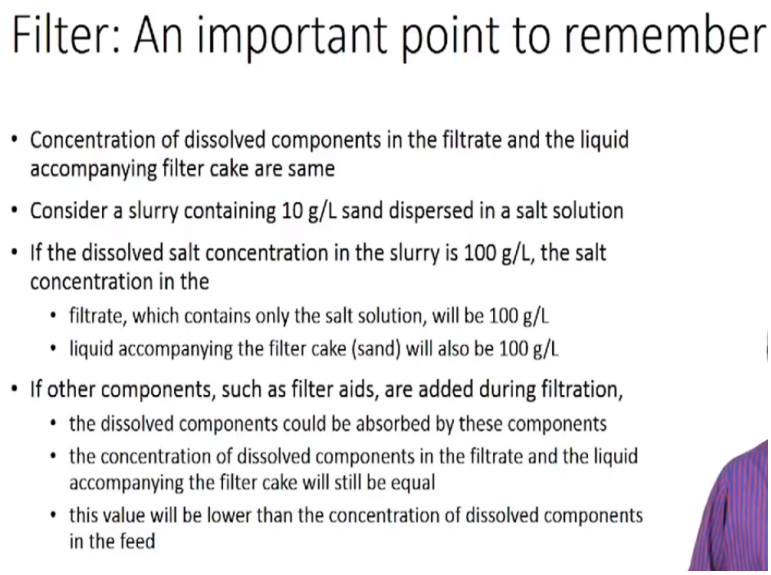

So now there is an important point that need to be remembered when we talk about a filtration process so that we can perform material balance calculation it is the concentration of dissolved concentration in the filtrate and the liquid accompanying the filter cake or the same. What do I mean by this consider this example extending the example which I gave earlier you have now the slurry which contains 10 grams per liter of sand disbursed in slat solution instead of just water now let us consider the salt solution in which the sand disbursed.

If the dissolve salt concentration in the slurry is 100 grams per liter then the salt concentration in the filtrate which contains only the solution will also be 100 grams per liter and the liquid accompanying the filter cake which is the sand which also contain 100 grams per liter so this will be true if the sand which is the component solid component present in the slurry does not absorbed the dissolved components.

If there are other components such as filter aids which are added then you can expect that the dissolve components can be observed by these filter aids or other components which are added in which case the concentration of dissolve components in the filtrate and the liquid accompanying

the filter cake will still be equal they will just be lower than the concentration of feed which is entering into the filtration systems.

So knowing this we would be able perform material balances calculating for a filtration process.

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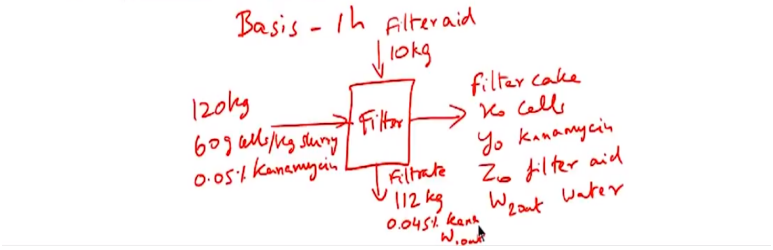
Material Balance – Filtration

- A fermentation slurry containing *Streptomyces kanamyceticus* cells is filtered using a continuous rotary vacuum filter. 120 kg/h slurry is fed to the filter; 1 kg slurry contains 60 g cell solids. To improve filtration rates, particles of diatomaceous-earth filtrate aid are added at a rate of 10 kg/h. The concentration of kanamycin in the slurry is 0.05% by weight. Liquid filtrate is collected at a rate of 112 kg/h; the concentration of kanamycin in the filtrate is 0.045%. Filter cake containing cells and filter aid is continuously removed from the filter cloth.
  - What is the percentage of liquid in the filter cake?
  - If the concentration of kanamycin in the filter-cake liquid is the same as in the filtrate, how much kanamycin is absorbed per kg filter aid?



Let us now look at an example problem for filtration a fermentation containing Streptomyces kanamyceticus cells is filtered using a continuous rotary vacuum filters 120 kilograms per hour slurry is fed to the filter 1 kilogram slurry contains 60 grams of cell solid to improve the filtration rates particle of diatomaceous earth filter aid are added at a rate of 10 kilograms per hour.

The concentration of kanamycin in the slurry is 0.05% by weight liquid filter is collected at a rate of 112 kilograms per hour the concentration of kanamycin in the filtrate is 0.05% filter cake containing cells and filter aid is continuously removed from the filter cloth. What is the percentage of liquid in the filter cake if the concentration of kanamycin in the filter cake liquid is the same as that in the filtrate how much kanamycin is absorbed as the kilogram of filter aid.

So now go through the problem one more time so that you familiarized with all the terminologies and all the information that has been given to you after you have completed this let us start with identifying the basis for this problem what would be the basis what would be the suitable basis for the problem. In this problem for the multiple flow rates which have been given which means we can either use the given flow rate as the basis or we can use per hour as the basis.

For calculation I have used one hour as the basis and perform the calculation so let us go about solving this problem. Basis is 1 hour let us draw a flow chart which would explain the problem given we have filtration system which has an input which is the slurry it is being fled to the filter at a rate of 120 kilogram per hour because I have assume as basis of one hour I would write this as 120 kilogram of slurry being fed.

This has been given that 60 grams per cells are present in 1 kilogram of slurry which is fed in addition we also know that the slurry contains 0.05 % kanamycin in the dissolve component. In addition to the slurry we are all also adding a filter aid which is diatomaceous earth this is entering as 10 kilograms per hour considering the basis as 1 hour we write this as 10 kilograms. Now we would have two exit streams one being he filter cake which contain the cells solids and the liquid which is accompanying the filter cake.

So we write that as filter cake which contains X naught cells Y naught kanamycin and Z naught filter aid and the accompany water which I am calling as W2 out so the other stream is your filtrate. The filtrate would contain only the dissolve component and water it has been given that the filtrate is collected at a rate of 112 kilograms per hour so considering the basis and writing this as 112 kilograms and this contains 0.045% kanamycin and the rest is water which I am just writing as W1 out.

So all the information that has been given to you a problem as been entered into the flow chart now if you look at the concentration of kanamycin which is the dissolve component in the filter feed and the filtrate you would see that there is a decrease which indicates that some of the kanamycin which have been fed to the system as actually been absorbed by either the diatomaceous earth filter aid or the cells solid itself.

So the second part of the question actually asked for amount of kanamycin which could have been absorbed by filter aid. Indicating that filter aid that has been used actually absorbs some of the kanamycin which has resulted in increased concentration. But we also know that in a filtration the concentration of kanamycin so the dissolve component would be same in the filtrate would be same in the filtrate accompanying the filter cake.

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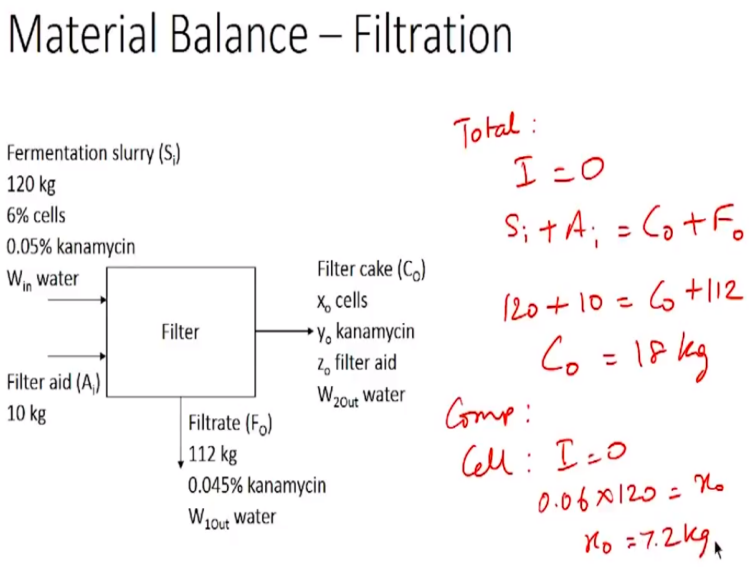

So knowing all these information let us go about solving this problem here is the flow chart which we drew so in more legible fonts. Now let us start with the balance equation so the first balance we write either total balance the total balance equation for this system the total balance equation for this system would basically be input = output because it is the system is in steady state leading to accumulation be 0 and ask the system does not have any reaction happening.

Generation and consumption terms will also be 0 so input = output so this would means SI + AI = C naught + F naught where SI is the slurry and AI is the filter aid entering C naught is the filter cake leaving the system and F naught is the filtrate leaving the system. We already know the values of SI AI and F naught. So that is 120 + 10 = C naught + 112 so this means C naught which is the filter cake is 18 kilograms.

So the mass of the filter cake which would be leaving the filter system would be 18 kilograms now we can then write component balances. So the component balances we can start with would be cell balance. Cell is entering only through the fermentation slurry and is leaving only through the filter cake we do not know the amount of cell which is leaving through the filter cake we have just written the mass to be X naught.

So this would mean input = output implying 6% of the fermentation slurry which is 0.06 times 120 = X naught. So X naught = 7.2 kilograms.

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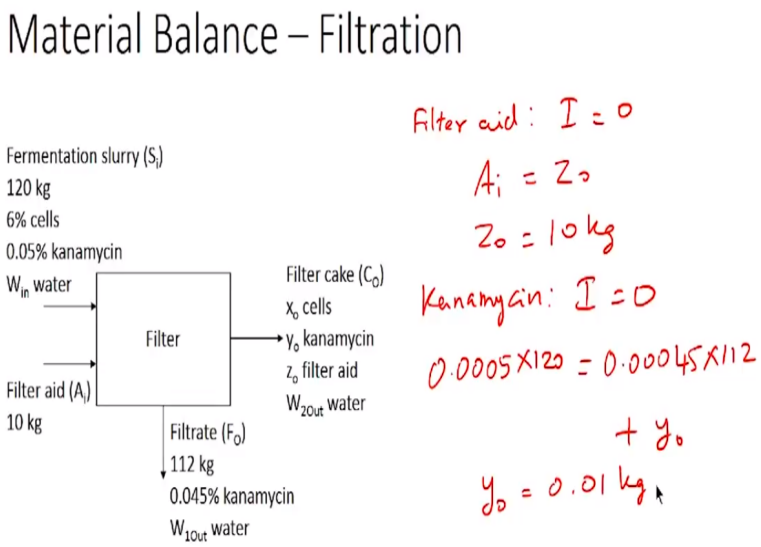

We can continue writing component balances for filter aid we can write the component balance as again input = output so the input comes only through AI and output leaves only through C naught so the amount of filtering leaving the system through the filter cake which is written as Z naught. So AI = Z naught implying Z naught would be 10 kilograms. So we can still write a balance equation for kanamycin and for water.

Let first write the kanamycin balance so again it would be input = output and input for kanamycin is 0.05 % kanamycin in the fermentation slurry so you would have 0.0005 times 120 entering the system which is equal the kanamycin which is leaving through the filtrate and the kanamycin is leaving through the filter cake. So this would be 0.00045 times 112 + Y naught so based on this equation we can calculate Y naught as 0.01 kilograms.

What you need understand here is this Y naught term contain kanamycin which is present in the solution along with the filter cake and also the kanamycin which is absorbed by the filter aid. So both the components are accounted for 1 term which is Y naught.

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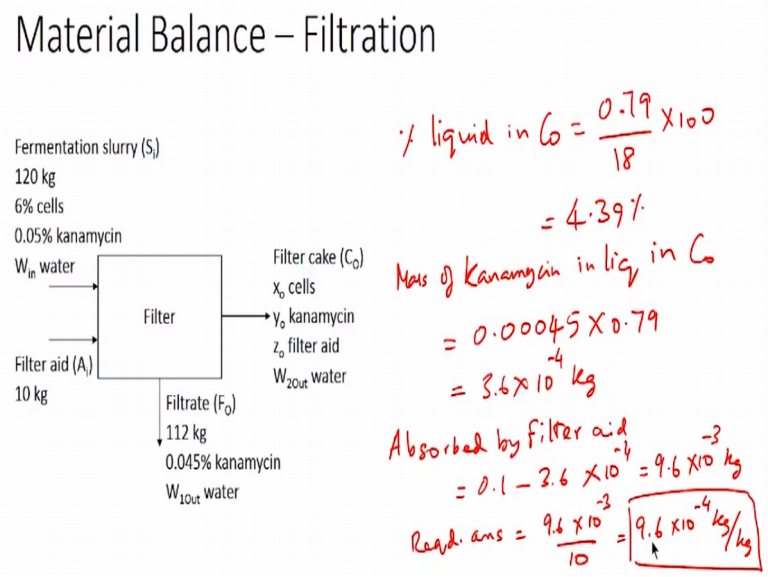

Now the next balance equation we can write would be the water balance again input = output so input is through water is coming in through the slurry so we would call that W in = W 1 out + W2 out. Water is entering into the system through the fermentation slurry it has been given that the concentration of kanamycin in fermentation slurry is 0.05% and the concentration of cells in the slurry is 6% so the rest as to be water.

Knowing that we can calculate the mass fraction of water as 1- 0.06 – 0.0005 times 120 so this is the mass of water entering the system. So water is leaving the system through two different streams in the filtrate the concentration of kanamycin is given as 0.005% which means the rest would be water. So the mass fraction of water would be 1 – 0.00045 times the mass which is 11 giving you the total mass of water leaving the system through the filtrate.

So we need to calculate the mass of water leaving the system through the filter cake which is given as W2 out. So from here we can calculate W2 out as 0.79 kilogram. So 0.79 kilograms of water leaves the system along with the filter cake the first part of the question was to calculate the percentage of liquid accompanying the filter cake we now know the total mass of filter cake and also the amount of water which is accompanying the filter cake.'

So based on this we can calculate the percentage of liquid accompanying the filter cake as percentage liquid in C naught = 0.79 divided by 18 which is the total mass C naught times 100 this gives the percentage of 4.39 % so this gets us the final answer for part. The second part of

the problem we need to calculate the mass of the kanamycin which is absorbed by the filter cake so which contains the filter aid.

So now for doing that we need to know how much the kanamycin is actually present in the liquid accompanying the filter cake and how much is actually absorbed by the filter aid in the filter we know that the concentration of kanamycin in the filtrate and the liquid accompanying the filter cake are the same with this information we can actually calculate the amount of kanamycin which is leaving the system which is water accompanying the filter cake.

So we know the mass of water is 0.79 kilogram and the concentration of kanamycin in this would be 0.045% using this information we can calculate the mass of kanamycin in the liquid present in C naught which is the filter cake would be 0.00045 times 0.79 kilograms which is the mass of water.

So the total mass of kanamycin leaving in the liquid is 3.6 times 10 power -4 kilogram so based on the material balances we which we have performed earlier we know that 0.01 kilogram kanamycin is actually present in the filter cake. So out of this 3.6 times -4 kilograms is leaving in the liquid which means the rest is actually being absorbed by the filter aid so the amount absorb by the filter aid would be 0.1 – 0.36 sorry 0.1 – 3.6 times 10 power -4 which gives you have value of 9.6 times 10 power -3 kilograms of kanamycin.

So this is the total amount of kanamycin which is absorbed by the filter aid the problem actually asked for the amount of kanamycin is absorbed by 1 kilogram of filter aid which is added. So these divided / 10 would be the required answer. Required answer which is the mass of kanamycin is absorbed per gram of filter aid would be 9.6 times 10 power -3 divided by 10 giving you 9.6 times 10 power -4 kilograms per kilogram.

So this would be kilograms of kanamycin per kilogram of filer aid so with this we would have solved for all the required parameter that has been asked hopefully you are able to follow the procedure for calculating the balances with this we will conclude today's lecture and we wil continue in this future classes where we will start looking at the system where more than 1 unit exist.

So until now we have been looking at simple processor with single unit but in most cases you would see multiple processes and we will look at how to approach material balances for system containing more than 1 operation thank you.