Materials and Energy Balance in Metallurgical Processes

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Module No. # 01

Lecture No. # 19

Exercises on Roasting

In the previous lecture, on material and heat balance in roasting, I have shown all the problems that we are going to take up. In that lecture, I could solve problem 1, 2 and 7, though all the problems and the data I have given in an earlier lecture. Here, just for the sake, of so that you know I am just repeating those problems which are already there in my previous lecture.

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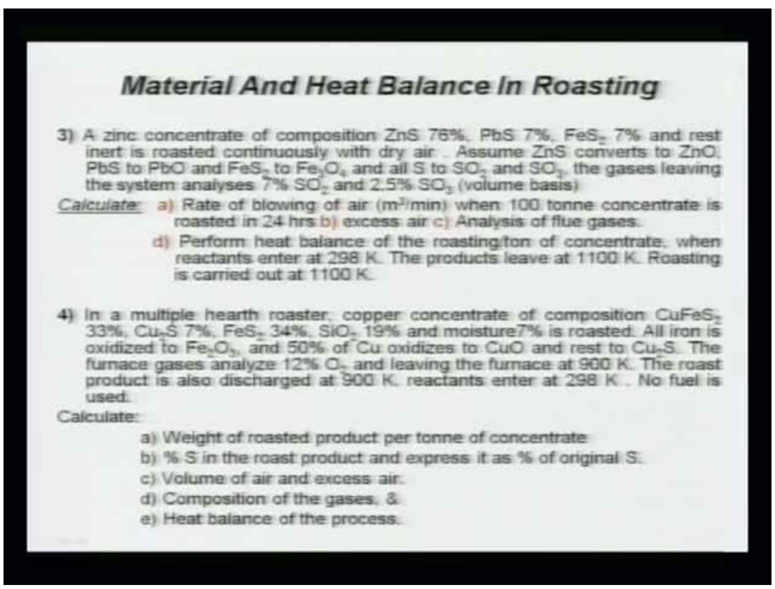

So, the problem 3 refers to the roasting of zinc concentrate. The compositions are given, the conditions are given and the roast product which came for under the given conditions of roasting is given. You have to find out rate of blowing air, excess air and analysis of flue gases. I have written here, perform heat balance of the roasting per ton of concentrate; that means you have to calculate for 1 ton of concentrate, what are the roast products and so on.

Problem fourth is for the roasting of copper concentrate. Here also the same thing, compositions are given. The roast product formation, what can form, how? What is the Cu 2 S composition? What is the Cu and so on? A problem illustrates everything over there.

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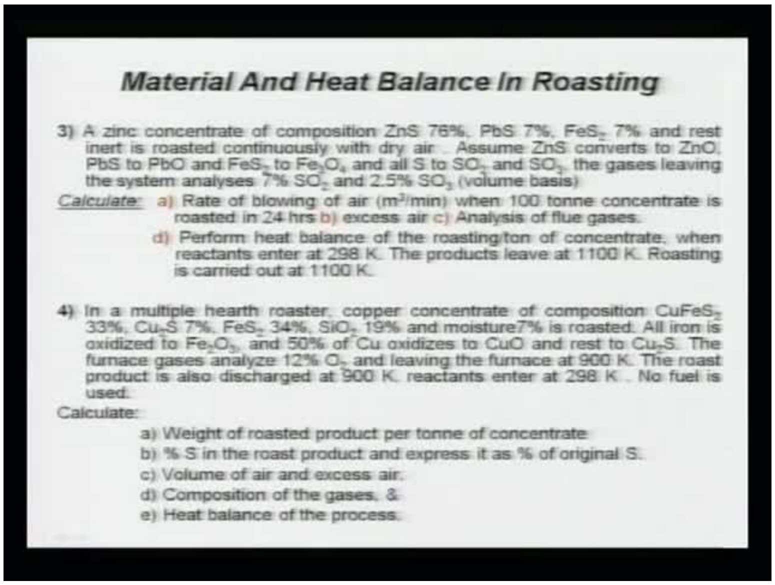

Again, you have to calculate here the percentage of sulphur in the roast product, weight of roast product, volume of air and also I have given you, you required to calculate heat balance process.

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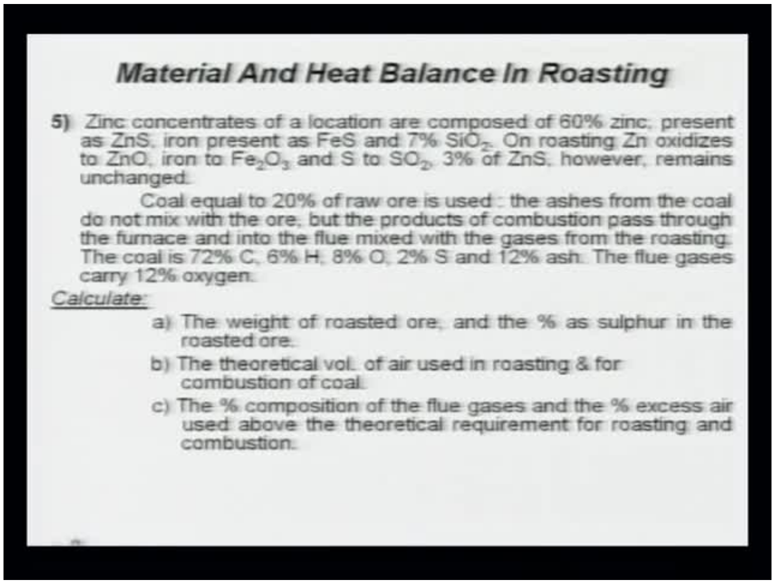

Now, problem fifth; again, it is roasting of zinc concentrate, but here you are using coal; coal composition is given. Here, both the products of combustion as well as the roasting gases which are evolved, both are mixed and they are going to be together. There are little bit different in the statement of the problem, the solution may not be similar to the earlier, but there is a little bit difference and you have to catch that particular point to solve that problem.

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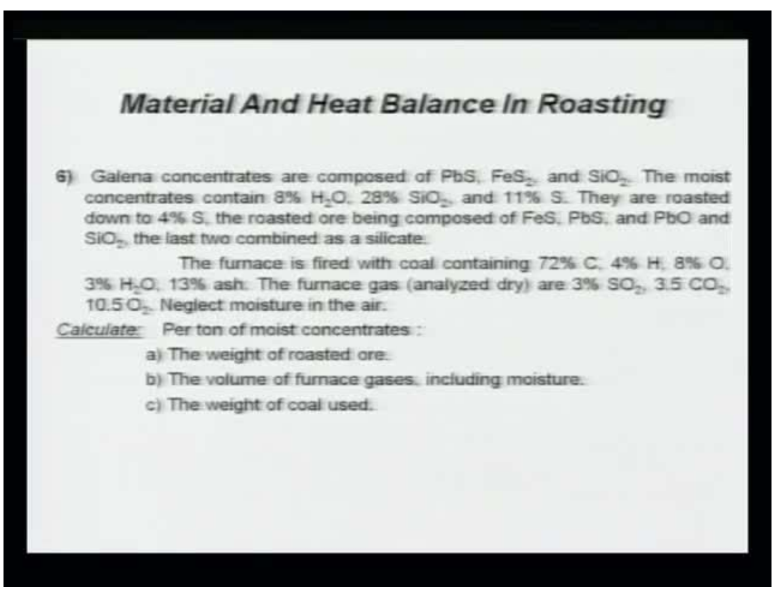

Problem 6 is about the Galena concentrates and that should be not very difficult. Again here, the roasting of Galena, furnace is fired with coal, you have to calculate weight of roasted ore, volume of furnace cases and weight of volume.

Now, you must have noted that in all the problems on roasting what you require. Say, roasted product, volume of gases, volume of air, excess air and heat balance if it is required to be done, I mean, though the objective of heat balance is to know what is the excess heat or deficit heat or whatever.

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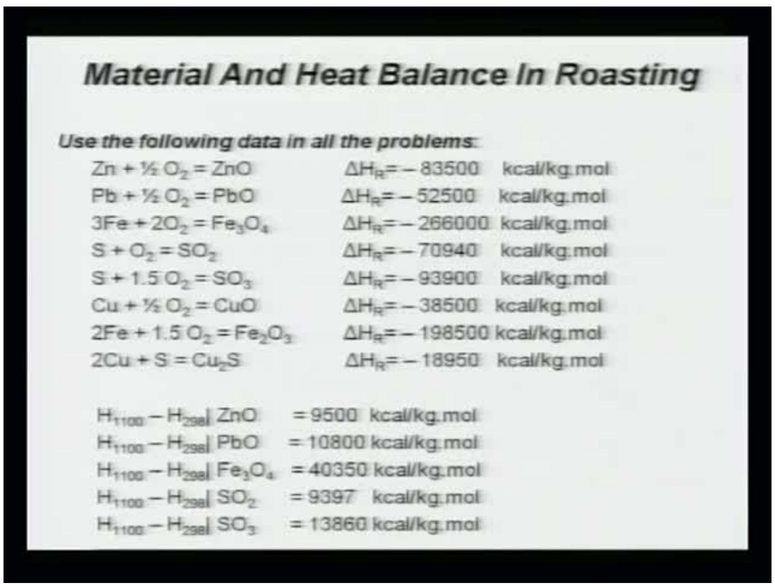

Seventh problem, I have already done. So, just I am going over here. So here, I am just projecting once again the data which are there in my previous lecture slide.

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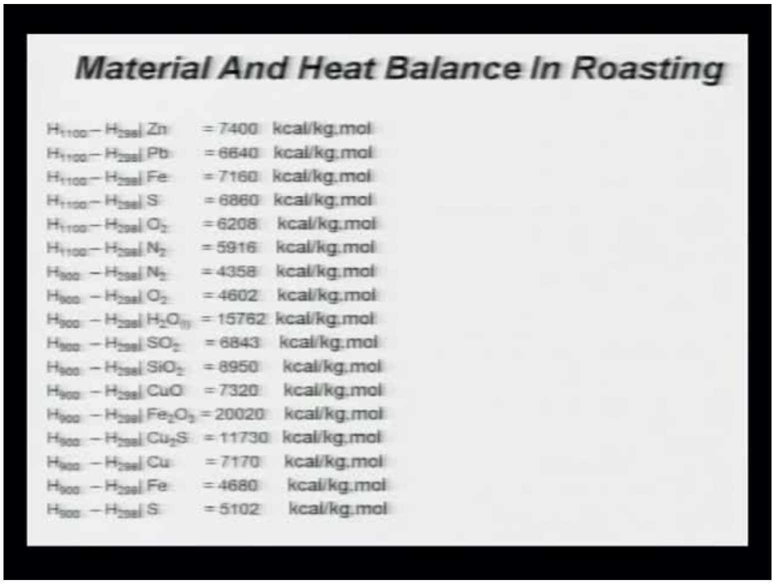

I have illustrated the data, you can note down from there. These are the further data for the problems on materials and heat balance in roasting.

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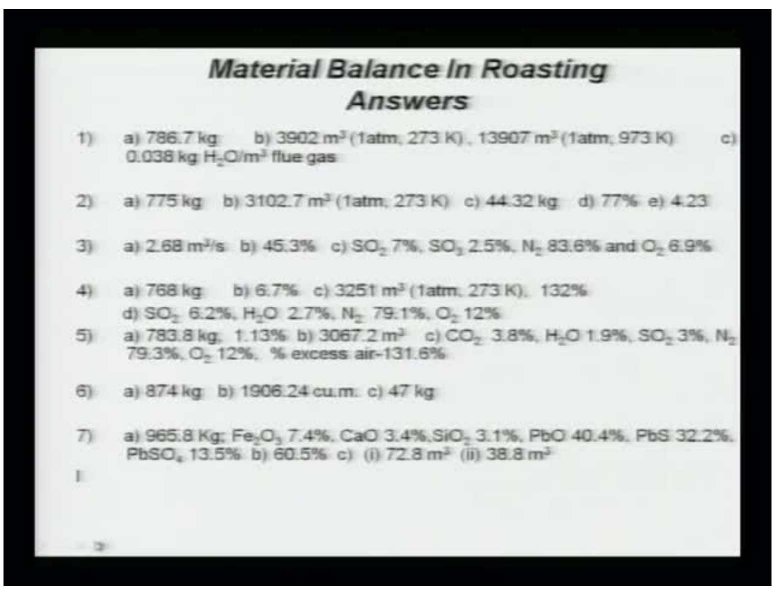

About the answers, well, I had already given in my earlier lecture, but here, once again, I will like to give you the answer. But, my appeal is as usual; please do not see the answer before you solve the problem completely, only see the answer after you have solved the problem.

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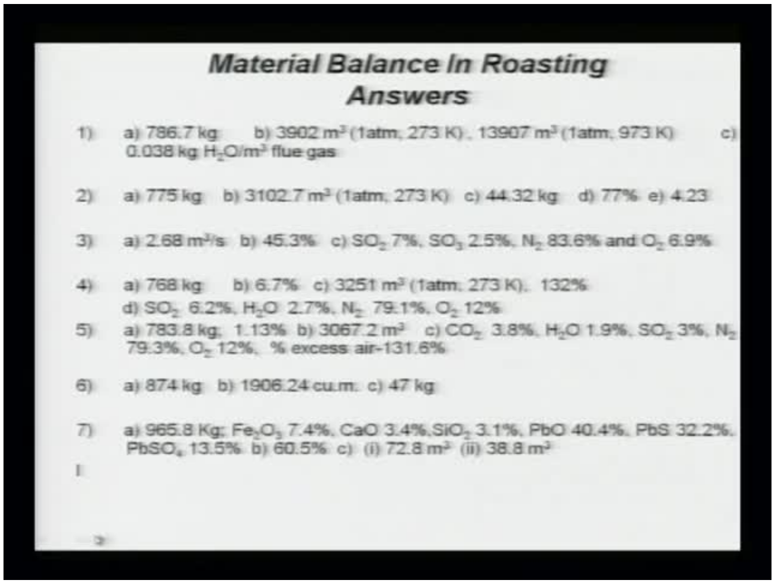

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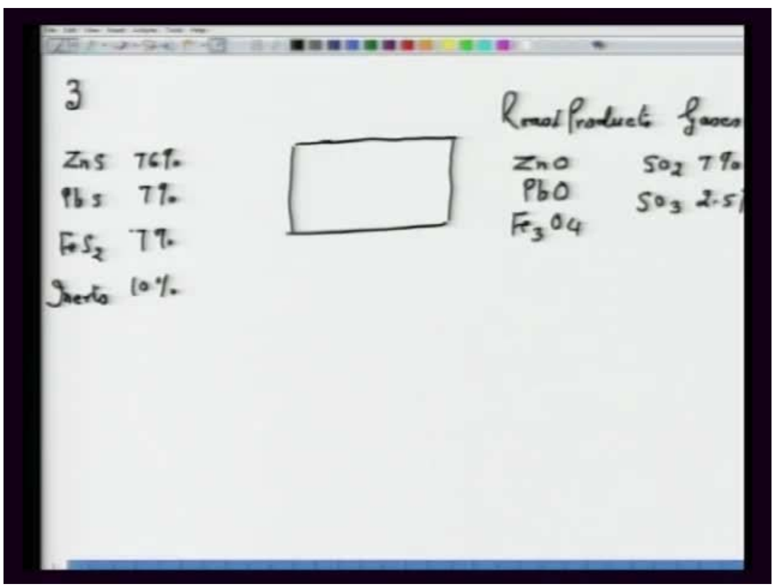

Now, I proceed to solve the problem number three. Let us take problem number three; I will just draw a block diagram because I am habitual. Whenever I solve the problems on material balance I try to write what is given and what is required in the form of a block diagram, so that I know what is given, what is being formed, how it is formed and so on. This is the way I do it. However, you can do your own way; you do not need to do the way I do it.

So, this is what the material balance box. It is the roasting unit, so here I have zinc sulfite, lead sulfite, Fe S 2 and Inerts. Zinc sulfite is given 76 percent, lead sulfite is 7 percent, Fe S 2 is 7 percent and Inerts are 10 percent. You do not bother about Inerts; Inerts that means, they are not taking part in the reaction as such, so you do not need to bother.

About the roast product, the problem says the roast product consist of Zn O, Pb O and Fe 3 O 4. The roast product will also be accompanied by gases and it is said that there is S O 2 which is 7 percent and S O 3 is 2.5 percent; that is what is given in the problem.

Additionally, it is given that zinc sulfite converts to Zn O, Pb S to Pb O, Fe S 2 to Fe 3 O 4 and sulphur is converting into S O 2 and S O 3; Mind you, not only in S O 2. So here, the problem is slightly different. If you attempt to calculate volume of air by writing down the stoichiometric equations Zn S plus 1.5 O 2 is equal to Zn O plus S O2 or S O 3, you will not able to write that equation. Because here, S O 2 and S O 3 both are forming on roasting of zinc sulfite, so in that way there is a new type of problem.

You have to think it over, how you will calculate volume of air? Earlier, we calculated by assuming the stoichiometric amount of reaction, because all sulphur was transferring to SO 2. But, here you cannot do it, because sulphur is transferring to S O 2 and S O 3. Unless you know the mole proportions, you cannot write any balance chemical equation and you cannot calculate oxygen. So, a different approach has to evolved, has to be thought and has to be innovated in order to solve this particular problem.

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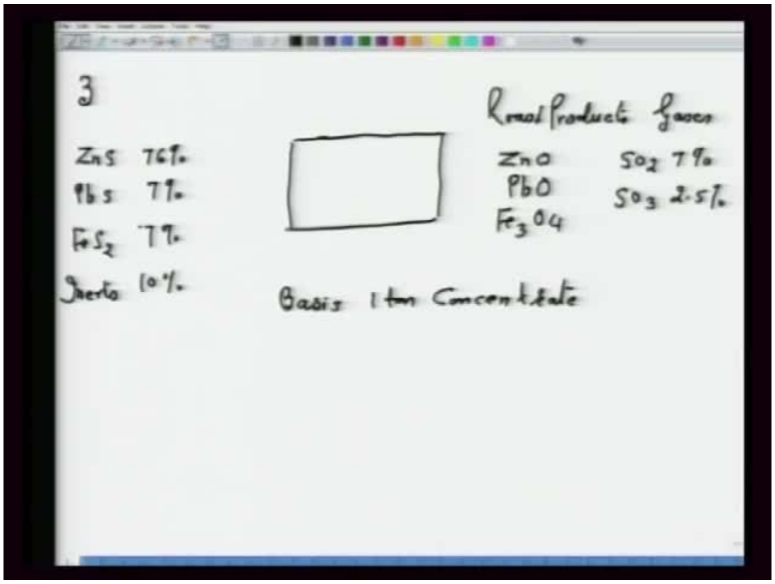

Let us see, first of all bases, as usual 1 ton concentrate or 1000 kg concentrate. First of all, you have to calculate for example, rate of blowing of air. Well, rate of blowing of air is not that easy that straight away you cannot calculate. You have to know how much amount of air you are blowing; you cannot write down the balance chemical equation. You do not know what the amount of oxygen is, so you have to catch up how much amount of flue gas is forming? How will you do it? You have to perform sulphur balance, because all these sulphur, which is there, it is now transferring into the flue gas, so that is that clue now.

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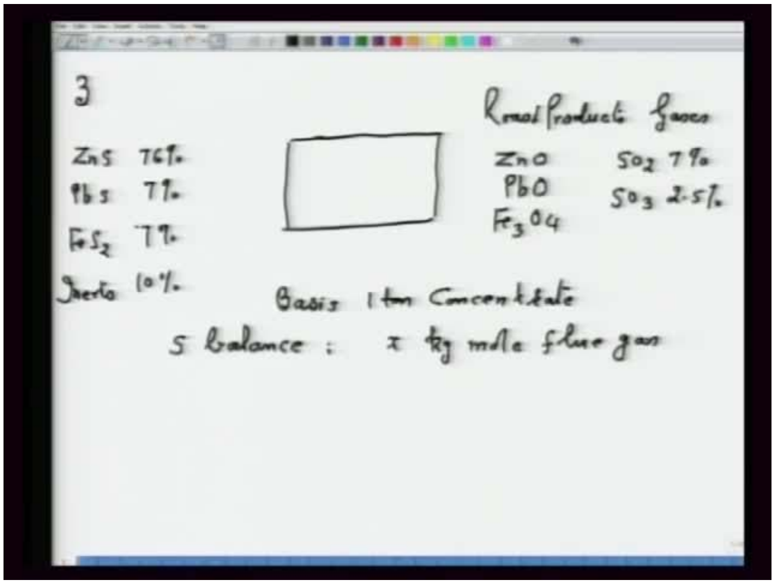

So, by doing that sulphur balances you can calculate the amount of flue gas. So, as such I am performing sulphur balance - I am performing sulphur balance.

Now, let us take x kg mole as the flue gas. Having said this thing, now I have to find out a sulphur input should be equal to sulphur output. Now, the key to this problem straight away I am doing the balance, because I am noting that in the roast product there is no sulphur. Straight away, I can do sulphur in the feed and sulphur in the gases. So, sulphur in the feed, I can convert these percentage into kg and kg to kg mole.

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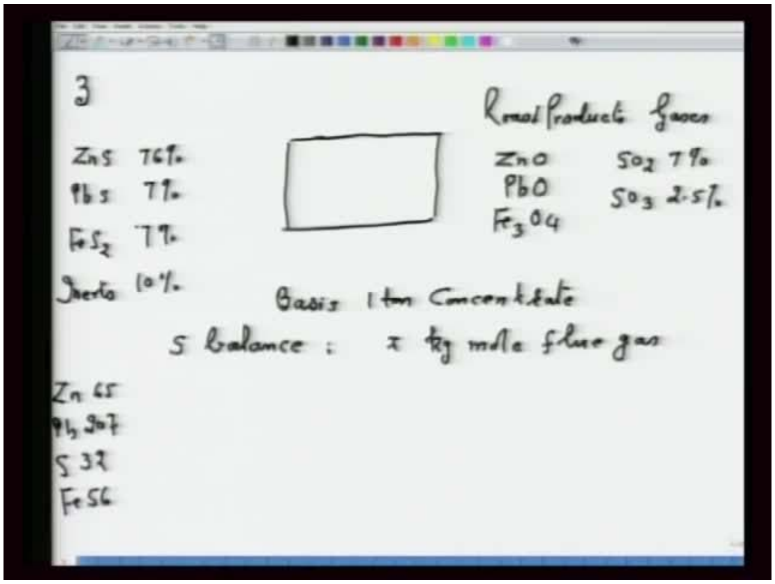

Now, for zinc I have used the atomic weight 65, for lead 207, for sulphur 32 and for iron it is 56. So, straight away what I can do, 760 is the weight of Zn S, so 760 divide by 97 that will be the kg moles of Zn S and hence the same kg mole of sulphur also.

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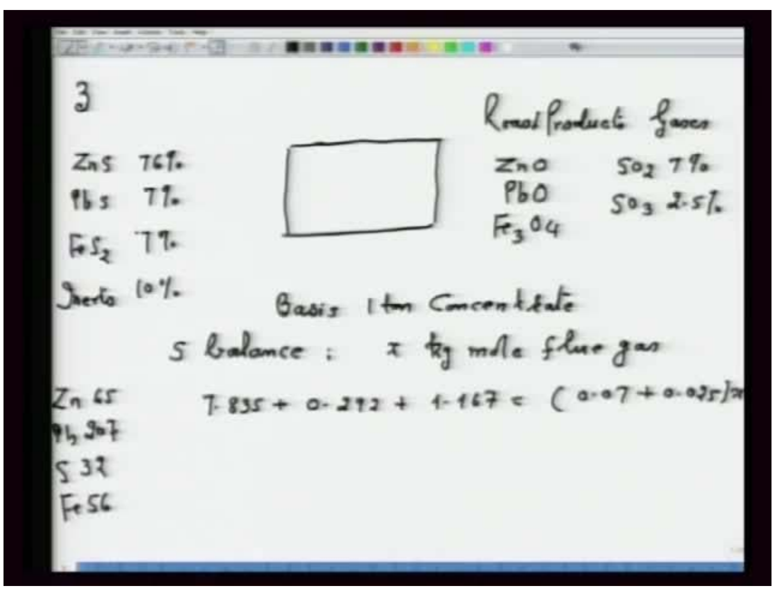

So, that way you can do that sulphur balance. So, what I am writing straight away? 7.835 plus 0.292 plus 1.167 that is equal to 0.07 plus 0.025 into x. Now, mind you here, in the zinc concentrate, the given is Fe S 2 not Fe S, so that point is to be noted. It is not Fe S, it is Fe S 2. So, accordingly this is the sulphur balance.

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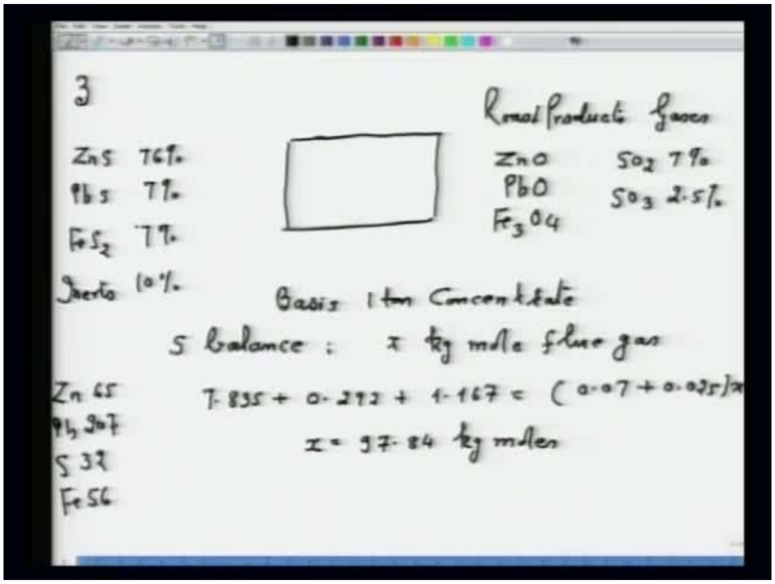

Now, I can straight away solve this equation. So, the flue gas that will be coming is 97.84 kg moles. Now, I know the amount of flue gas. However, you can also like to do it; you can also take sulphur balance x kg or x meter cube flue gas. Accordingly, you can also calculate, the choice is yours, the way you want to proceed.

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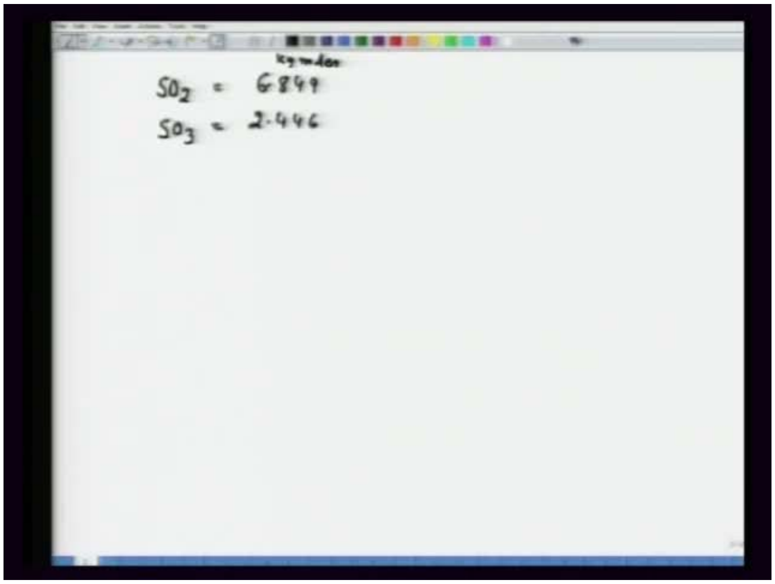

Now, let us go a step further, we know that SO 2 will be equal to 6.849 kg moles. Now, we can find out the amount of flue gases, SO 3 that is equal to 2.446. Now here, a little conceptual thinking is also required to solve this problem.

Now, if you see this particular problem, you can note that the roasting gasses or the gasses evolved during roasting will comprise of SO 2, SO 3, nitrogen and oxygen. So, I mean that thing you have to evolve after reading my conceptual lectures on roasting. That once you know which type which gasses will be present, then you can proceed to solve this problem.

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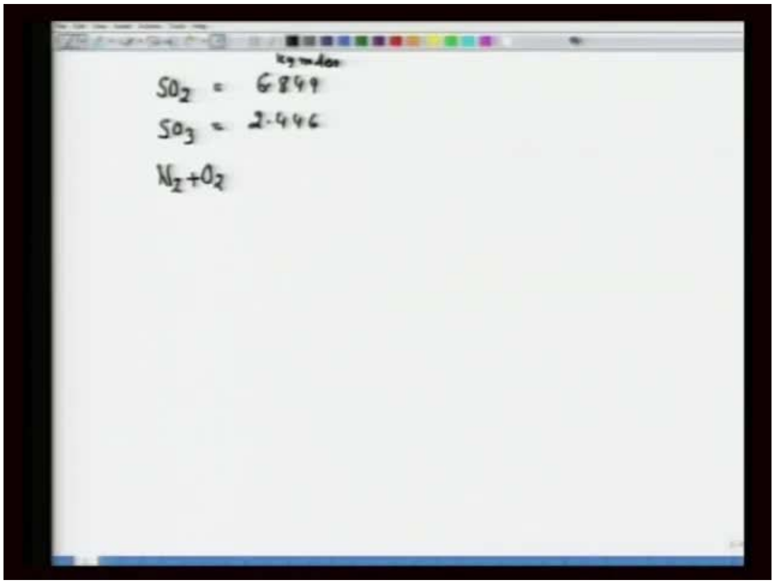

In this case you have nitrogen; nitrogen plus oxygen. Now, why I am writing oxygen also here, because I do not know whether the roasting is carried out at stoichiometric amount or some excess air is used. This problem does not say anywhere; there is not mentioned that these stoichiometric amounts of air are used.

So, keeping that thing in mind, I have to be cautious and I have to see that the roasting gases will comprise of nitrogen as well as oxygen. This N 2 plus O 2 that will be equal to; there is nothing, there is no other gas is there, no fuel is used, no CO 2, no CO and no other gas except these four gases, they constitute the flue gas.

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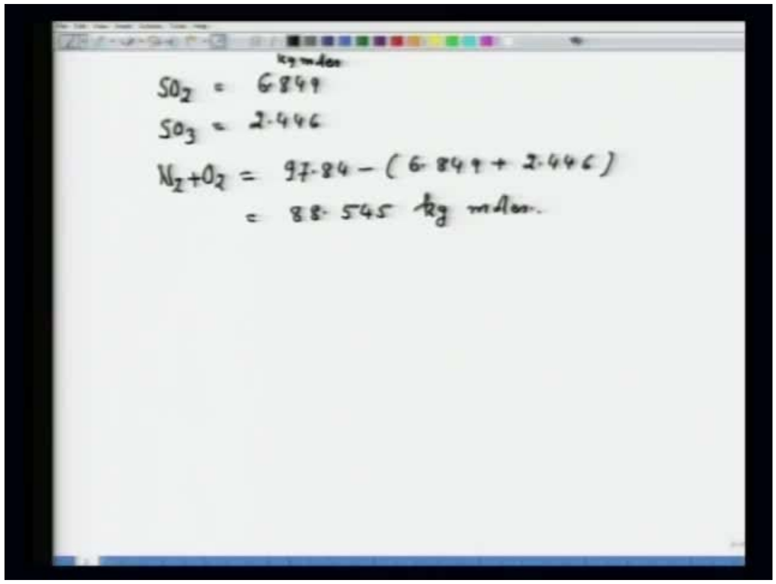

So, N 2 plus O 2 that will be equal to 97.84 that is amount of flue gas minus 6.849 plus 2.446, so that makes 88.545; mind you all in kg moles. What to do now? We have to know nitrogen and oxygen. Now here, you have to make use of that the kg mole of air, 1 kg mole oxygen, 3.76 mole of nitrogen.

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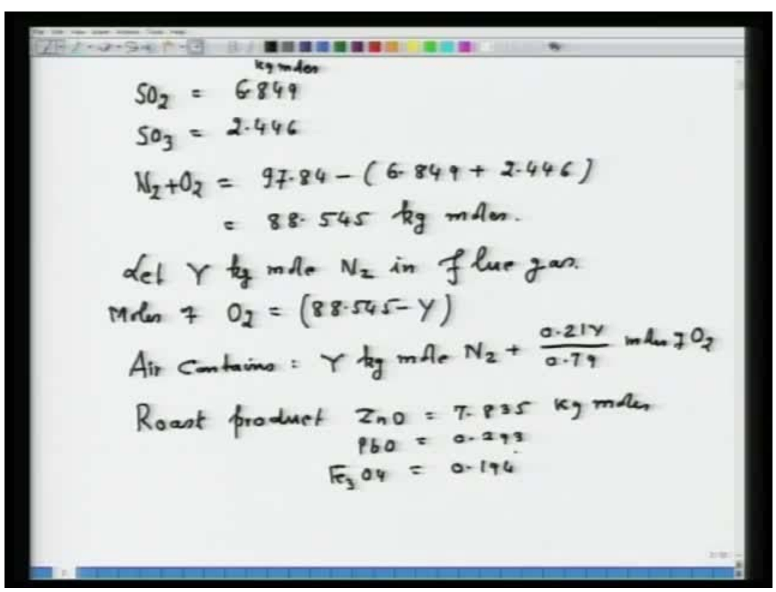

Now, let us consider Y kg mole is nitrogen in flue gas. Then, how much will be oxygen? Oxygen will be equal to 88.545 minus Y that will be moles of oxygen. What air contains? Air will contain Y kg mole nitrogen plus 0.21 Y upon 0.79 moles of oxygen. After this, we have to also we have to find out the analysis of roast product. So, the roast product as per the statement of the problem it consist of Zn O that will be equal to 7.835 all in kg moles, Pb O 0.293 and Fe 3 O 4 that is equal to 0.194.

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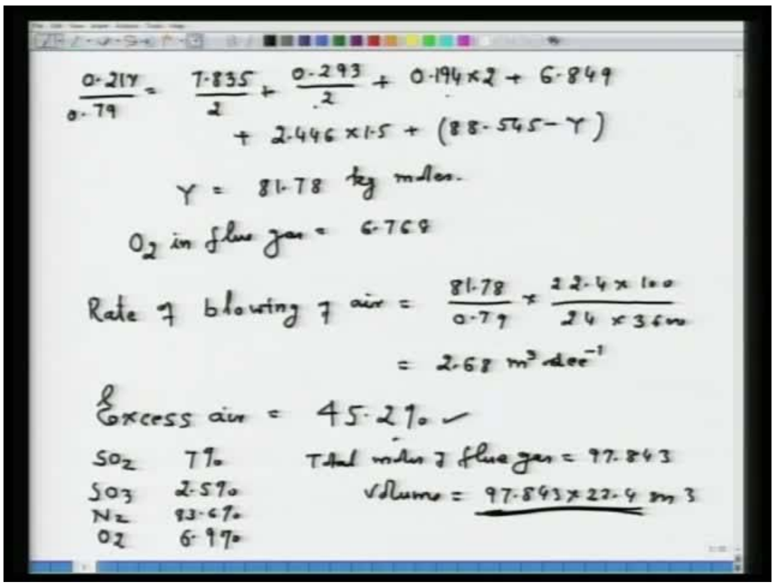

Now, I can do the oxygen balance that is the oxygen from air and oxygen that is utilized in the system. So, if I do that oxygen balance I am writing down 0.21 Y upon 0.79 that will be equal to 0.79 that will be equal to 7.835 upon 2 plus 0.293 upon 2 plus 0.194 into 2 plus 6.849 plus 2.446 into 1.5 plus 88.545 minus Y. Now, this is for Zn S to Zn O, this is for Pb S to Pb O, this is for Fe 3 O 4, this is for SO 2, this is for SO 3 and this is the excess oxygen (Refer Slide Time: 15:00). So, if I solve, then the value of Y that will be equal to 81.78 kg moles.

Now, I know O 2 in flue gas that will be equal to 6.768, so that is the O 2. Once, I know the O 2 in flue gas, now can I calculate rate of blowing of air that is what it is asked; rate of blowing of air that will be 81.78 upon 0.79 into 22.4 into 100 upon 24 into 3600, assuming that 24 hours the operation continues. So that will be equal to 2.68 meter cube per second that is the answer.

The next thing said is excess air. Excess air, you know how to calculate. That is, the excess oxygen divide by the stoichiometric amount that already I have calculated. You can calculate and that comes to 45.2 percent; that is the excess air.

You have to calculate the analysis of flue gases. Now, it is straight forward, so this flue gas will have SO 2, it will have SO 3, it will have N 2 and it will have O 2. So about the moles you can write down and all the percentage are given. So, I am straight away writing SO 2 is 7 percent as it is given, SO 3 will be 2.5 percent, N 2 will be 83.6 percent and O 2 will be 6.9 percent. So, the total moles of flue gas will be equal to 97.843 kg moles.

Now, if you want to know in volume a little bit excises you have to do it. You have to multiply 97.843 into 22.4 that will be in meter cube; this is the volume for the flue gas.

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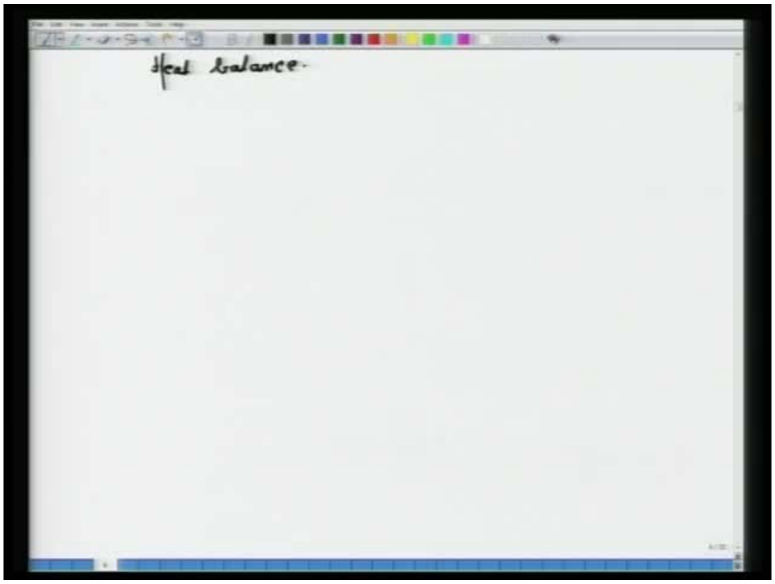

Now, the problem further says you have to perform the heat balance. In performing the heat balance, you have to know heat input and heat output. Now, heat input, because the reactants, say ore and ore concentrate plus air, they all enter at 298 kelvin, so there will be no sensible heat which is entering along with the reactant, because they are all at 298 kelvin.

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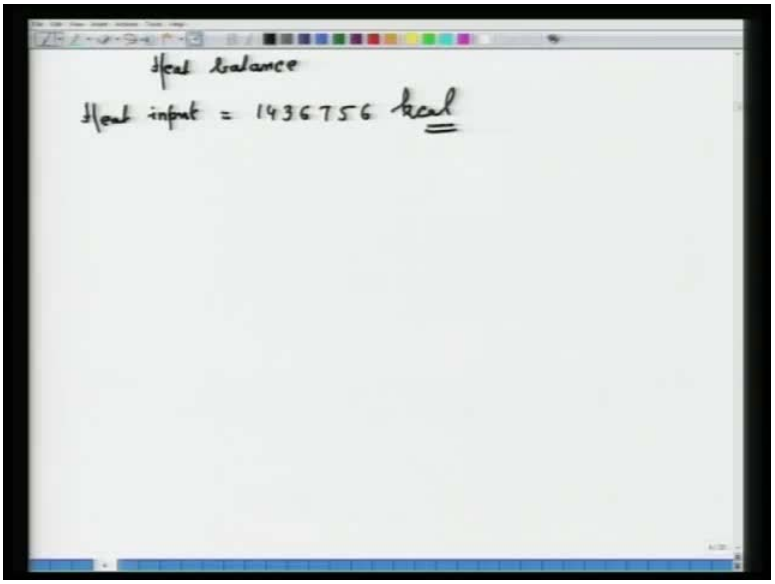

The heat input will be the heat of reaction, yet 98 Kelvin; that is the only heat input. Heat output so heat input will be the data are given, heat input will be say heat of reaction all these data's are given, so I will omit all this calculation. So, heat input will be equal to 1436756 kilo calorie. You can calculate all that is you have to multiply from the data which are given; for example, Zn plus half O to Zn O heat of formation Zn O is given. 7.835 Zn O, which is produced, so Zn O that is 7.835 into 83500. If you see those data sheet, you will find all that you have to multiply in a simple manner and you will get this particular figure.

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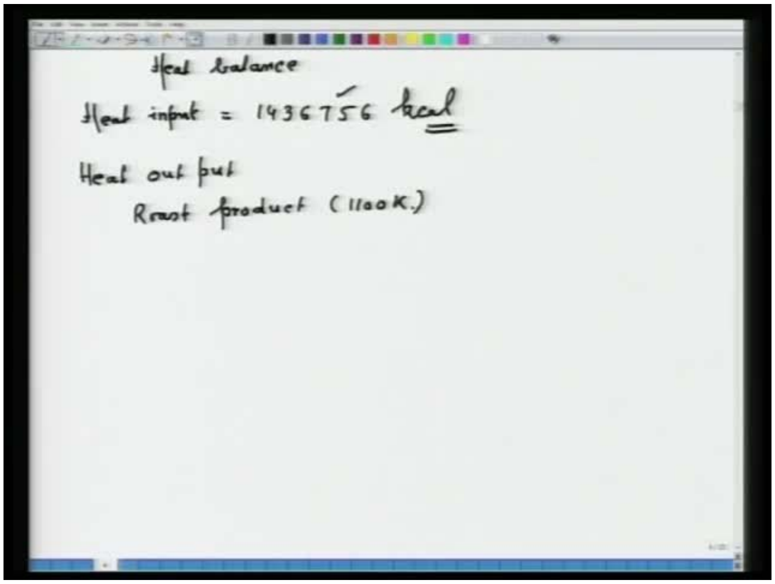

Now, the heat output one will be for roast product. The roast product leaving at 1100 degree Kelvin as the problem says. The roast product they leave at 1100 Kelvin and gases also leave at 1100 Kelvin. For the simplicity, I have given the heat content of the roast product at 1100; that is, I have already given h 1100 minus h 298 for Zn O, for Pb O and for Fe 3 O 4. So, all that what you have to do, you have to multiply the h 1100 minus h 298 value with the respective moles, you sum total it, you will get the heat take away by the roast products. I am leaving this exercise to be done by you.

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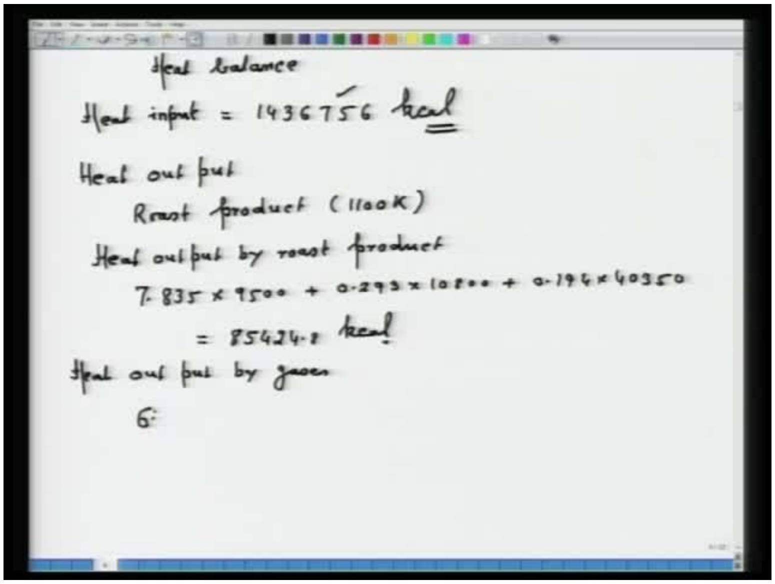

Heat output by roast product - or if you wish, I can just write down some of the value, so that will be 7.835 into 9500 plus 0.293 into 10800 plus 0.194 into 40350. Now, you have to sum total, so heat output will be equal to 85424.8 kilo calorie. Similarly, you have to calculate heat output by gases or heat carried away by gases, whichever way you want to understand. You know all the gases SO 2, SO 3, N 2 and oxygen.

Again, I will write down for your quick calculation. The heat content say h 1100 minus h 298 for SO 2, SO 3, N 2, NO 2 are given kilocalorie per kg mole, so straight away you have to multiply, But, my sincere advice at this stage of your learning would be you take the appropriate value of cp, I have already gave you the reference from which you can have the value. You develop the skill of integration and then use this particular value that will be good for your future building.

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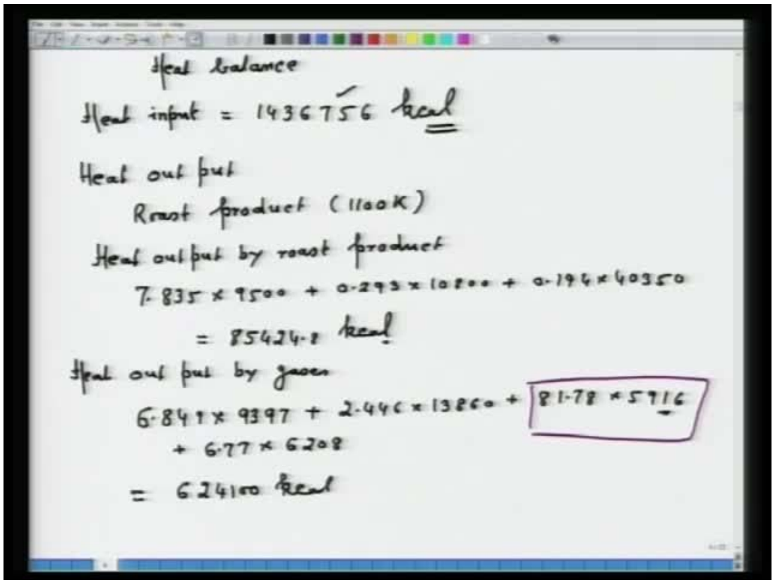

So, for the quick estimation I am writing here 6.849 into 9397 plus 2.446 into 13860; that is h 1100 minus h 298 for SO 3 plus 81.78 into 5916; 5916 is the h 1100 minus h 298 for nitrogen and plus 6.77 into 6208. So, total heat carried away by the gases that will be 624100.

Here, you will be noticing that is, very important thing in case of roasting that alone nitrogen is carrying away a large junk of heat. If you just want to see the percentage, it will come around 60 to 70 percent of the heat carried away by the gases, it is carried away by the nitrogen. There is a scope of heat recovery from the gases. Remember, these gases are leaving at 1100 Kelvin, so higher is the temperature according to second law of thermodynamics, higher is the quality of heat, because the quality of heat is directly proportional to the temperature at which the gasses are discharged.

When the temperature is very high, the quality of heat is very good that is very high, accordingly one should think also in the direction of energy or heat recovery from these gasses you see that around 70 to 80 percent of the heat is taken by the roasting. Remember, this particular aspect is the key feature of development in roasting technologies; for example, use of oxygen enriched air; that is what I thought I will illustrate.

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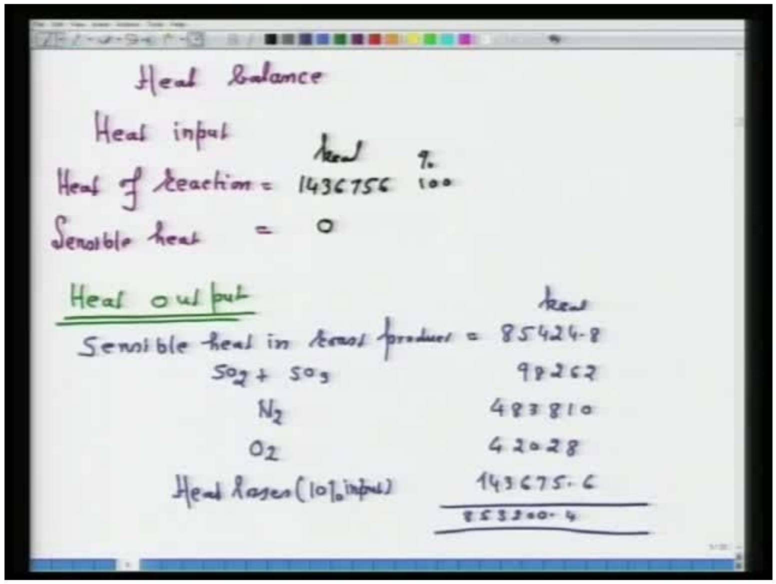

Now, if you do the heat balance, just to illustrate what I have written or said, so heat input that will be the heat of reaction and nothing else. That is equal to 1436756 in kilocalorie; that means, 100 percent of the heat which is required for the roasting is supplied by the heat of reaction that is what the 100 percent means.

Now, the sensible heat of reactant that is equal to 0, because they are all at 298 Kelvin. In the heat output, so let me put the green thing; heat output, first is the sensible heat in roast product that is equal to 85424.8 kilo calorie. In gasses, I am combining both SO 2 plus S O 3, they both takes only 98262 kilocalorie of heat. Alone nitrogen you can see, nitrogen is taking 483810 kilocalorie of heat, very large chunk.

Similarly, oxygen is say 420 not 420, I mean 42028 kilocalorie of the heat. So now, because there will be some heat losses, so I have to add heat losses. Normally, what we do? In the offence of anything we take 10 percent of heat input.

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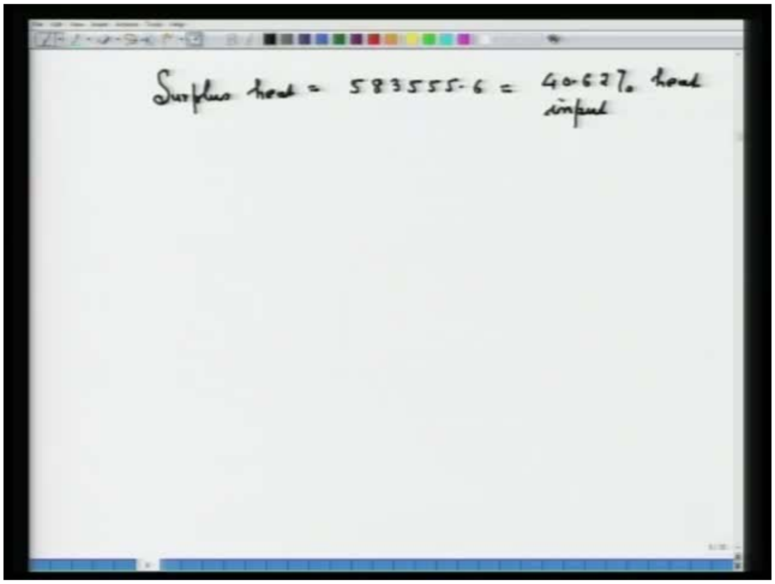

If we do that then the losses will be 143675.6, so total heats out that will be 853200.4. So, roasting of zinc concentrate in this particular problem, it is unaccompanied by a surplus heat and this surplus heat is 583555.6 that constitute around 40.62 percent of heat input.

I mean this calculation is based on only the heat output terms, gasses and roast product. Losses could be other losses also, but it still what can be said that roasting process could be an autogenious process. A large amount of heat is being generated, if precaution is not taken then temperature may rise in the reactor, so one has to be careful about the temperature, which can be raised by the excess amount of heat; it was just an illustration. So, this is all about problem number three.

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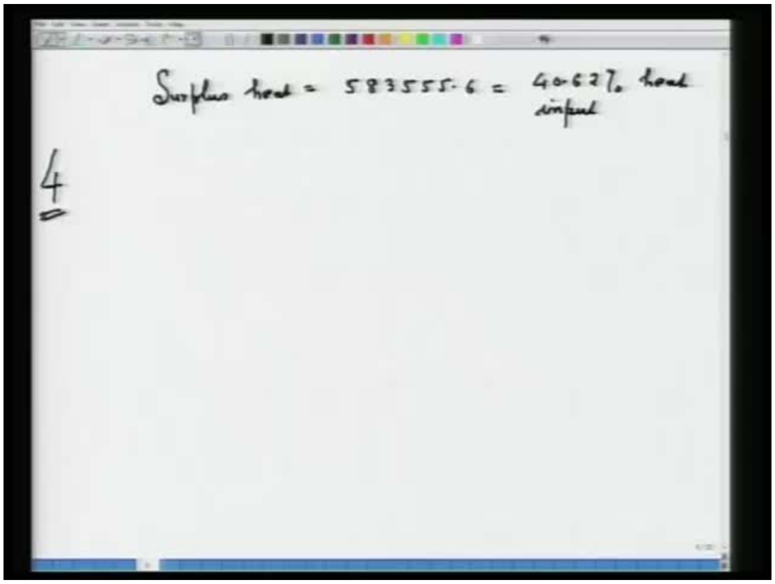

Let me take quickly problem number four. Now, problem number four is very similar to problem number three. Here also you have to do heat balance, said it is easy, but, what is first required is material balance, because you cannot get rid of the material balance. Unless you do material balance you cannot do heat balance. First, you have to do material balance and you have to find out what is weight of roasted product, volume of gasses, then composition of gasses, then and then you can perform the heat balance of the process.

So, in this particular problem, this is again a little different problem. In order to the material balance, you have to use first of all your intelligence to do the entire material balance. Now, this particular problem says that furnace gasses analyze 12 percent oxygen and nothing else is given.

Of course, some other conditions of roasting are given. So here, you have to think intuitively, how to calculate the volume of gasses in the amount of air. But again, you cannot write down the stoichiometric reaction, because it is having 12 percent oxygen anyway.

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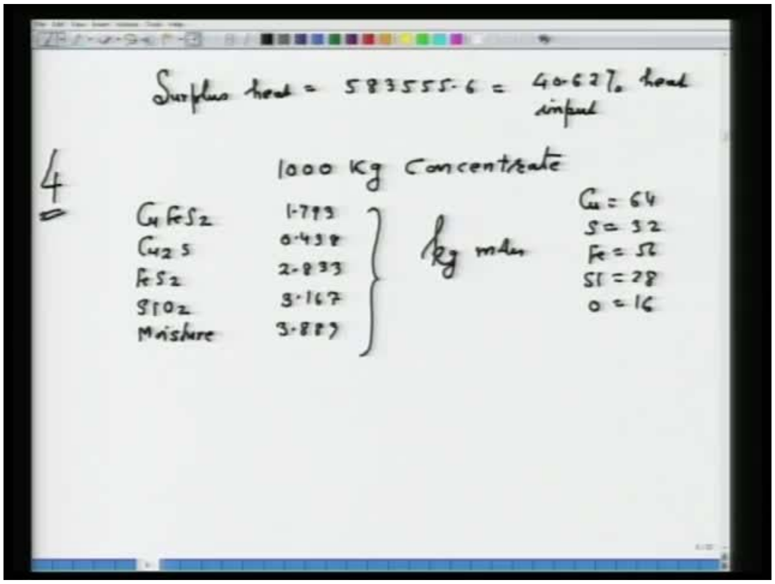

So, if we do that for example, I will go quickly, because similar problem I have solved. Let us now take 1000 kg concentrate; if we take 1000 kg concentrate, then we can calculate the amount of Cu Fe S 2 which is their, Cu 2 S, Fe S 2, Si O 2 and moisture.

Now, one can calculate the moles 1.793, 0.438, 2.833, 3.167 and moisture is 3.889; they are all in kg moles. I think I have repeatedly given, but it is my duty to give you again, copper I am using 64, sulphur I am using 32, iron is 56, silicon is 28, O is 16, so H 2 O becomes 18. Now, waste of roasted product we have to calculate. The condition is all iron is oxidize to Fe 2 O 3, 50 percent copper oxidize is to Cu O and raise to Cu 2 S, so you have to first of all do all this calculation.

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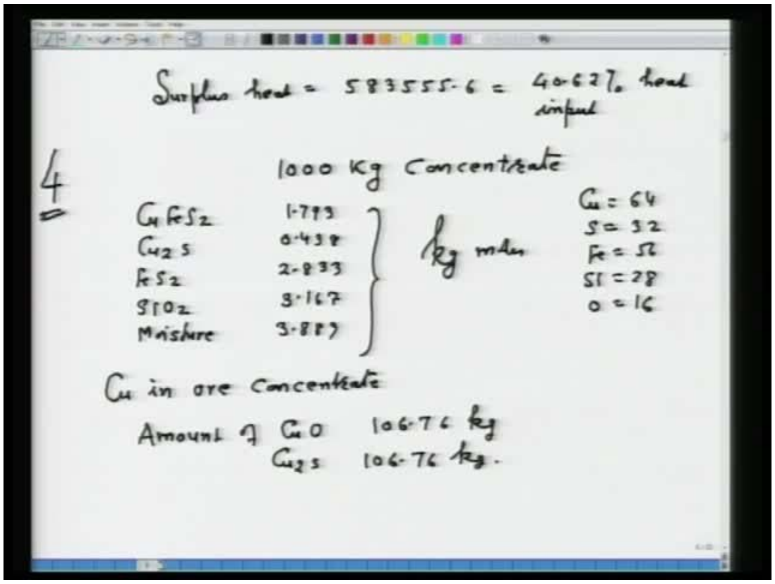

First, let us find out the copper in ore concentrate that you can find out, divide into 50 percent. So then, you can calculate amount of Cu O and amount of Cu 2 S, now both these amounts are coming 106.76 kg and this amount is also 106.76 kg.

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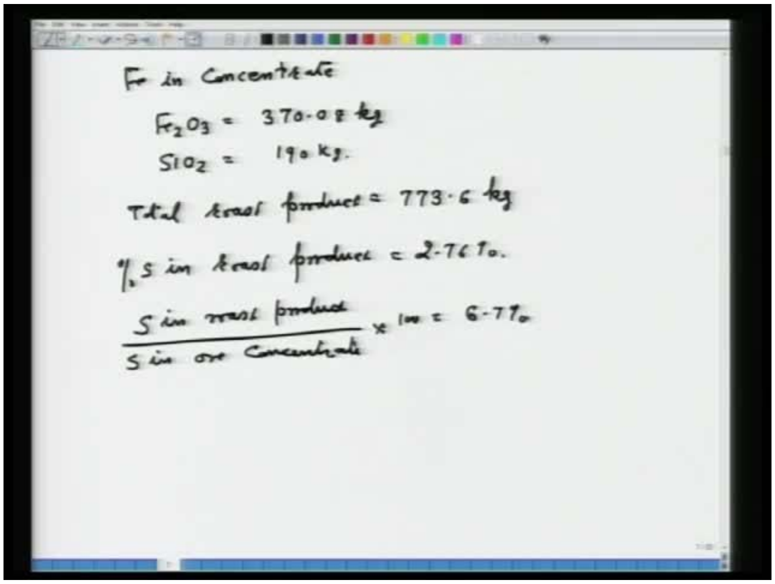

You have to calculate the Fe 2 O 3, so you calculate iron in the concentrate and then you calculate Fe 2 O 3 from that. So, Fe 2 O 3 would be 370.08 kg; this you can calculate. Of course, all Si O 2 will enter into the roast product, so Si O 2 will be 190 kg. You can now calculate the total roast product that will be equal to 773.6 kg; it is the total roast product.

So, you can find out now percentage of sulphur in the roast product and percentage of sulphur in the ore concentrate; that will be percentage of sulphur in the roast product that will be equal to 2.76 percent. If you express sulphur in roast product upon sulphur in ore concentrate into 100, so this will be around 6.7 percent. Now, we have to calculate volume of air and excess air.

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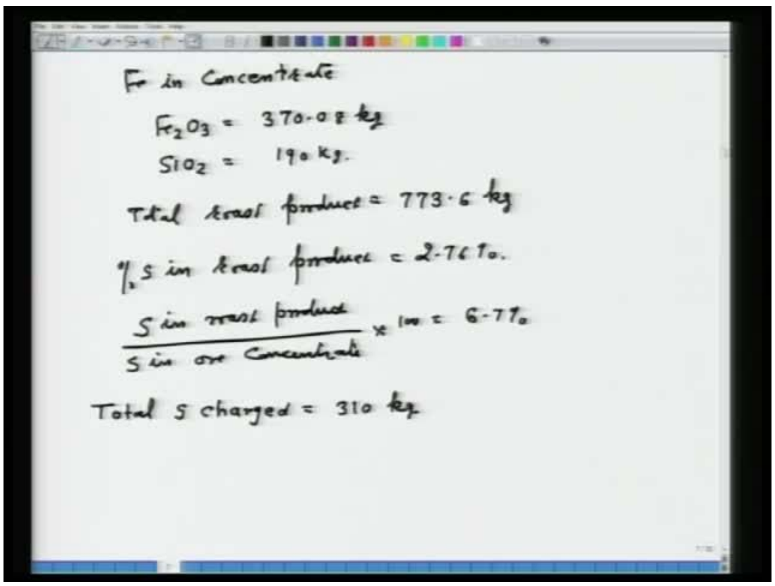

Now, let us see how we will calculate? The total sulphur charged is equal to 310 kg. Now, mind you, this is the way I am doing it. What I thought that this way I could do it, I am 100 percent confident that you might have thought some other way of doing this particular problem. I will suggest or request that please follow your way and let it be innovative solution. Do not follow what is said. So, total sulphur charged is 310 kg.

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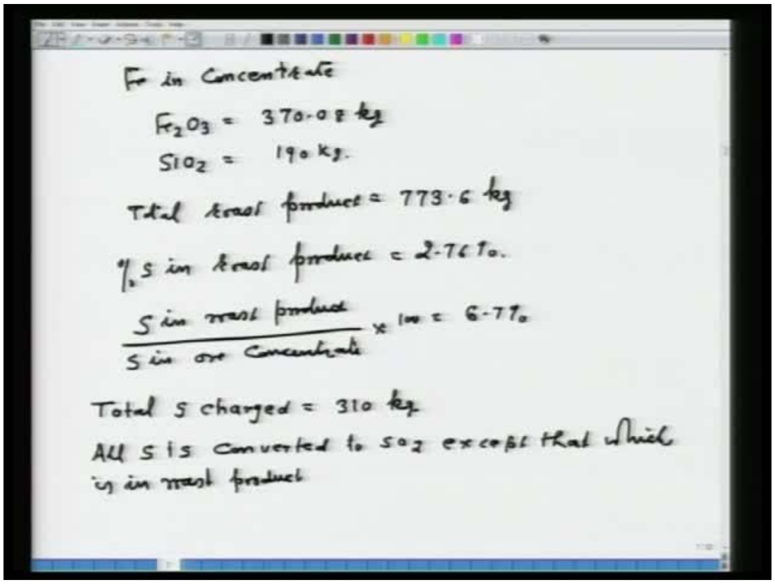

Now, all sulphur is converted to SO 2 except that which is in roast product, am I right? Because, you have calculated a roast product, it has certain amount of sulphur that will not be going into gases.

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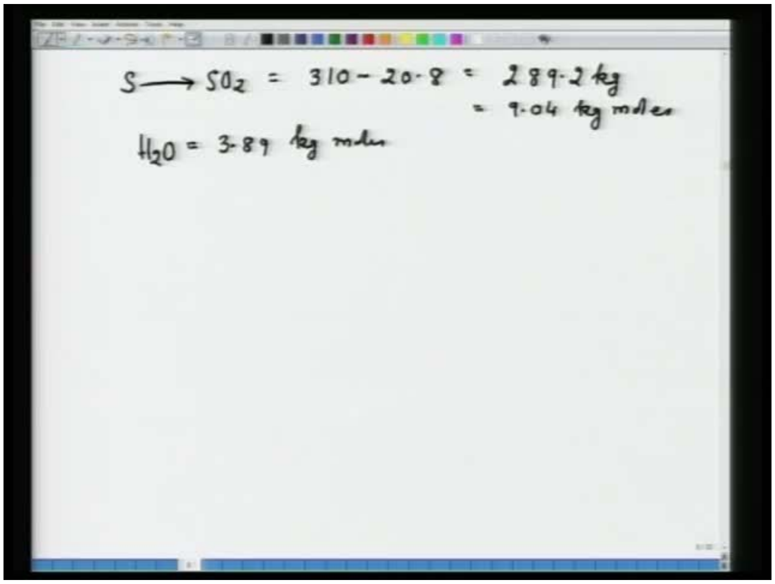

So that means, since we know this sulphur which is in the roast product, so I can calculate sulphur which is going to SO 2 that will be equal to 310 minus 20.8 that will be equal to 289.2

kg and this will be equal to 9.04 kg moles. Now, H 2 O, we know it is 3.89 kg moles that straight away you can write down very easily; straight away it goes down.

Here, you can calculate theoretical amount of oxygen, because the problem does not say that sulphur is converted to SO 2 and SO 3. Unlikely, in the problem 3, it was said that SO 2 and SO 3, so it was difficult for you to write down this stoichiometric reaction, but since the problem is silent on this.

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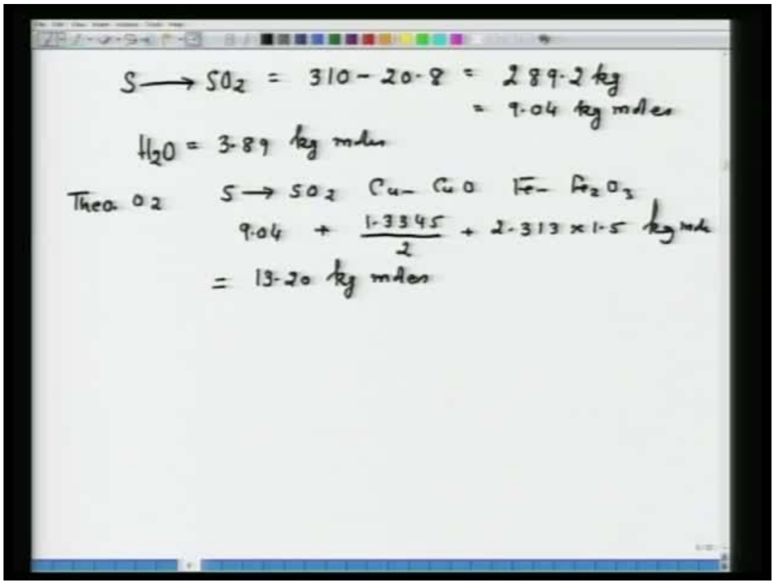

You can take it for granted that sulphur is converted according to stoichiometry of the reaction and SO 2. So that makes your life little easy. We have to now calculate theoretical oxygen and theoretical oxygen that will be S to SO 2, Cu to Cu O and Fe to Fe 2 O 3. This is where you will be requiring oxygen, so you can calculate the oxygen S to SO 2 that will be 9.04 plus Cu to C O 1.3345 upon 2 plus 2.313 into 1.5. Mind you they are all in kg moles.

So, if I sum total that becomes equal to 13.20 kg moles. What I do now? What will I do with this oxygen? This oxygen I have to calculate or I had calculated keeping in mind that at least I will be able to know that theoretical nitrogen that should have gone into flue gas. Theoretical oxygen will not go in the flue gas, because it is available in the form of roasting product or gasses, but theoretical nitrogen definitely will be available.

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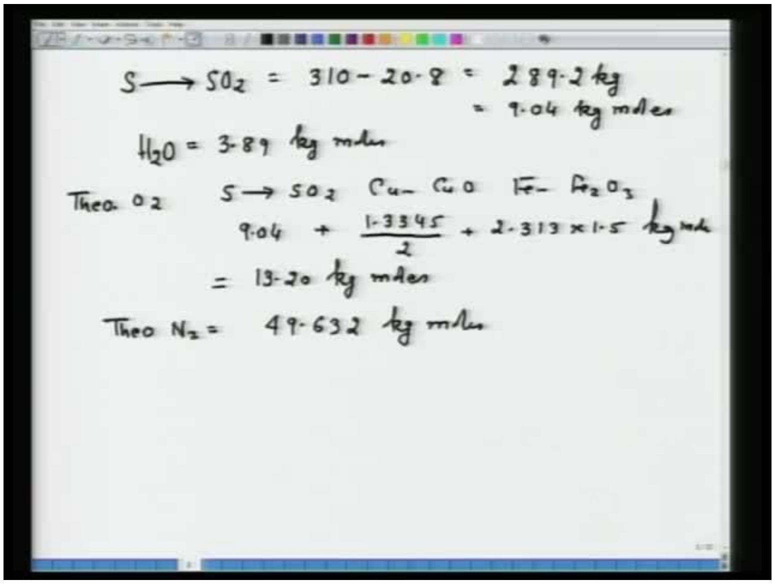

The problem says 12 percent excess oxygen, so that means there is excess oxygen, but then at least I am able to know what is the amount of oxygen that is theoretically is there and it will go to gasses, so that way I calculate, which I can calculate now. So, theoretical nitrogen will be equal to 3.76 of this, so that will be 49.632 kg moles. What should I do further now? I know now theoretical nitrogen that must have gone into the gasses, but still that is not the end of the solution, because they have to know the total amount of the nitrogen, because excess oxygen is there.

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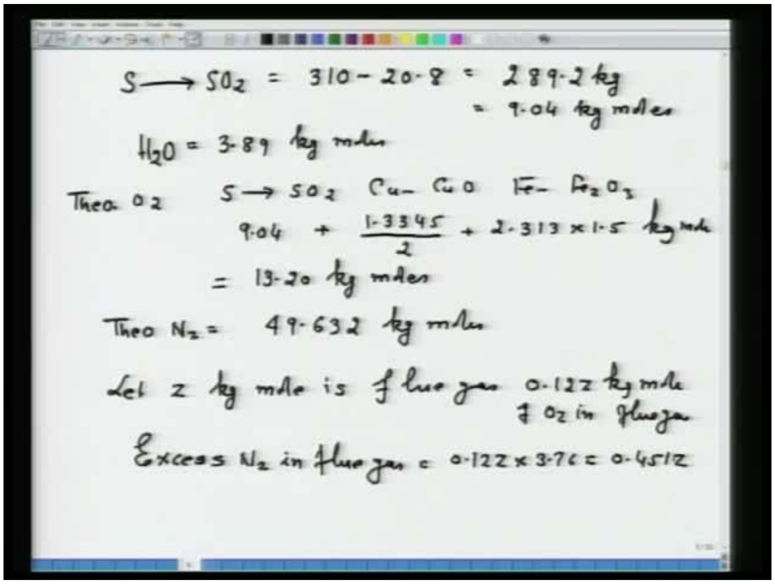

So, you have to do now, let z kg mole is the flue gas. So, 0.12 z kg mole of oxygen in flue gas, you agree with me? Now, what to do? I know now, the excess oxygen in the flue gas is 0.12 z, so accordingly excess nitrogen, how much it will be? Excess nitrogen in flue gas that will be equal to 0.12 z into 3.76 that will be equal to 0.451 z.

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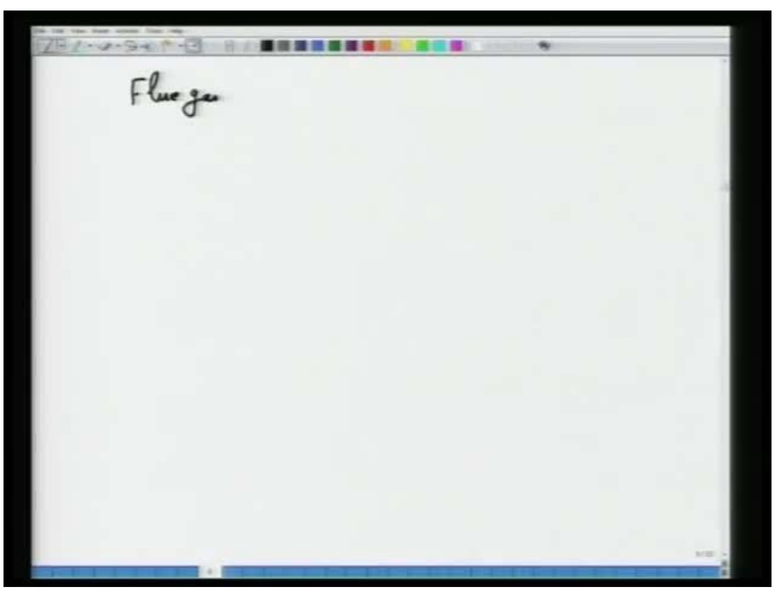

Now, I know the total amount of flue gas in terms of z plus some value are known to me. Now, I can write down the flue gas. Now, we note from here how important this is first of all to know the concept of roasting.

How important it is to understand, how the roasting is carried out? How the air is being utilized? How the excess air is being used? Where the theoretical air goes? Where the actual amount of air it is available in the flue gas that is only in the form of oxygen. Theoretical oxygen will not be available to you in the gases. So, this is where the concept of roasting is required in order to solve this particular problem.

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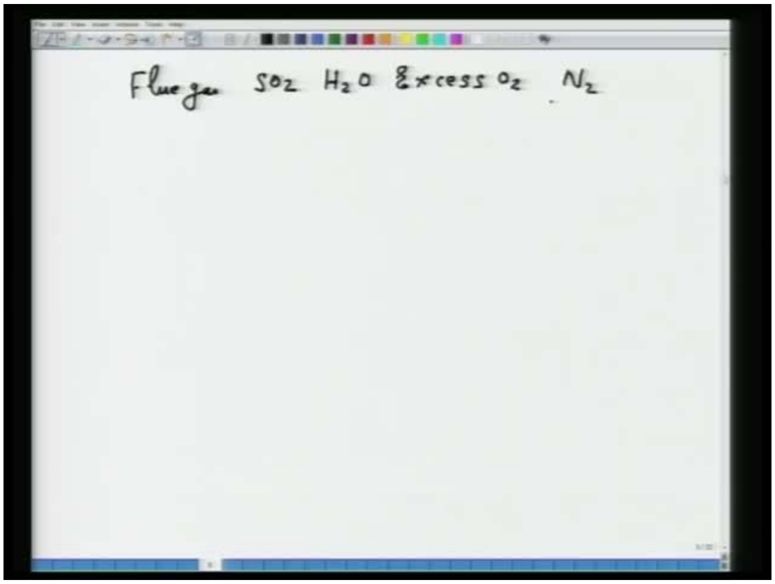

The flue gas will contain what SO 2, H 2 O, then excess oxygen and nitrogen. Now, nitrogen I can divide in two parts according to my problem one, corresponding to the theoretical and another corresponding to excess oxygen, there will be excess nitrogen also.

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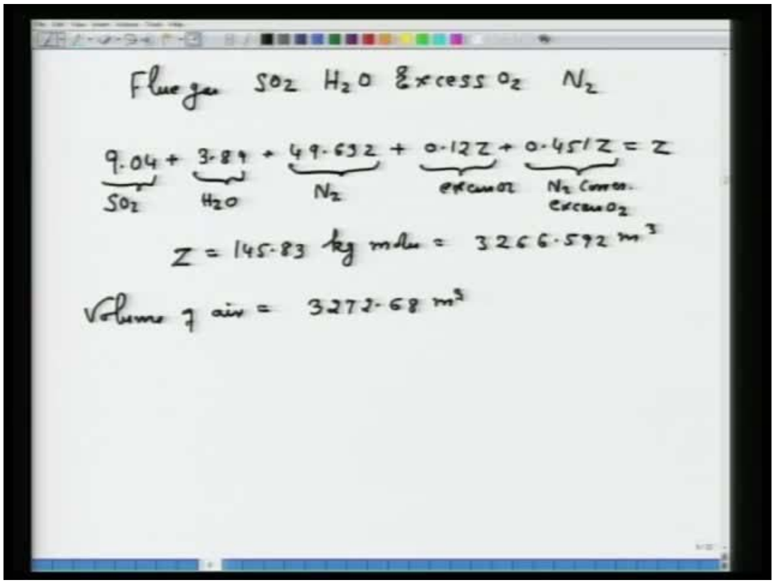

So, it is very easy now, I can write down on 9.04 plus 3.89 plus 49.632 plus 0.12 z plus 0.451 z that is equal to z. Now, this is SO 2, this is H 2 O, this is theoretical nitrogen, this is excess oxygen and this is nitrogen corresponding to excess nitrogen corresponding to excess oxygen that is all (Refer Slide Time: 40:17).

You can solve this equation, so z will be equal to 145.83 kg moles. Of course that you can convert now to meter cube, this will be 592 meter cube 1 into m 273 Kelvin, now everything can be calculated.

Now, you can calculate volume of air and that volume of air that will come 3272.68. In all the problems, you might have noted that amount of air or volume of air and volume of flue gas are in the ratio of 1 is to 1 that is what you must have noted. So, here lies the self-checking of the problem, while solving the problem if suppose you get the flue gas amount is 50 percent of air, you must think that you have committed a mistake somewhere. You are seeing in almost all the problems always 1 to 1 ratio around 1 to 0.98 or 1 to 1 ratio.

So, that is also a clue and that is also the thing which should be perceived while solving the problem. These are the certain things that you should develop, when you solve an unknown problem and when you committed a mistake. So, if you keep these ratios in mind and then you solve the problem, if all of a sudden you get the ratio 0.5, you must think that you did a mistake. So, this is also one of the objectives of solving the problem to see that you develop skill to solve the problem for the future that is an important thing.

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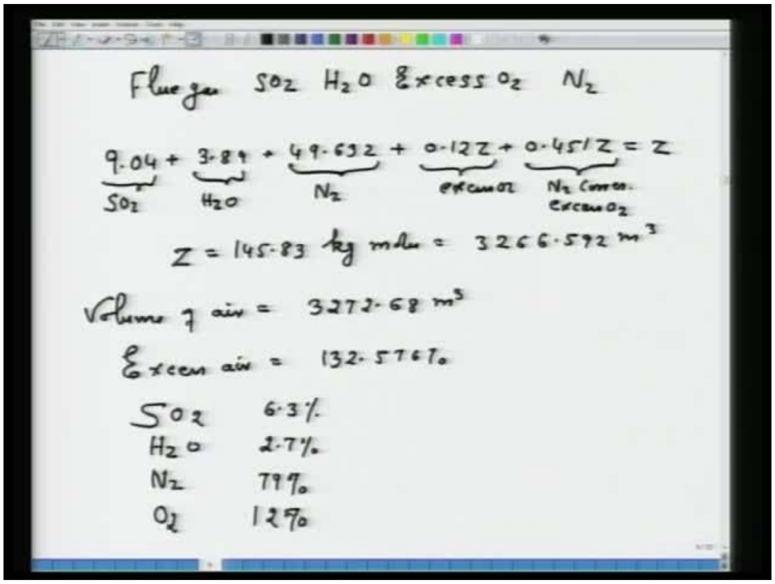

Now, I can do now excess air. I will quickly go through, because these things I have already illustrated that will be around 132.576 percent, you do not need to go 3 decimal what I have written. The composition, now I can write down SO 2, H 2 O nitrogen and oxygen. So, the percentages are 6.3, percent 2.7, percent 79, percent and 12 percent, so this is how this analysis goes.

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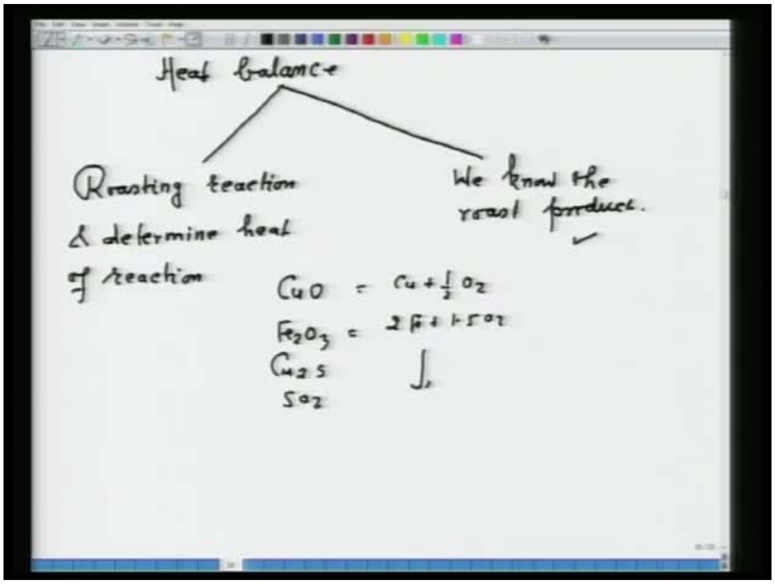

Now, quick glance at the heat balance. Now here, heat balance can be done at two approaches: say one approach is that you write all roasting reaction and determine heat of reaction, which is one way; for example, Cu 2 S to Cu O write down that equation find out the heat; that is one way. Another way is that we know the roast product, we get heat input from various heat of information of individual reactions; for example, we know the roast product Cu O, say roast product comprise of Cu O, Fe 2 O 3, Cu 2 S and S O 2. So, Cu while forming Cu plus half O 2 Fe 2 O 3 will be 2 Fe plus 1.5 O 2 and so on.

So, I can just calculate their heat of formation and multiply I will get, you can follow this way or this way, I am going on following the roast product, because the values are given, so I can calculate now heat liberated.

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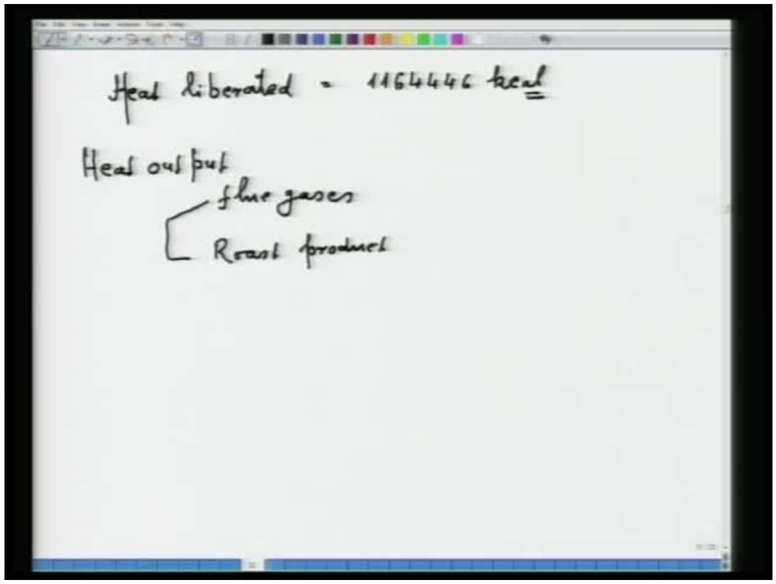

Heat liberated, I will be straight away multiplying the moles with the values of the heat of formation of the product. So, if I do that then heat liberated will become 1164446 kilo calorie that is the thing. Now, heat output; one heat output will be as usual by flue gases and another heat output will be roast product.

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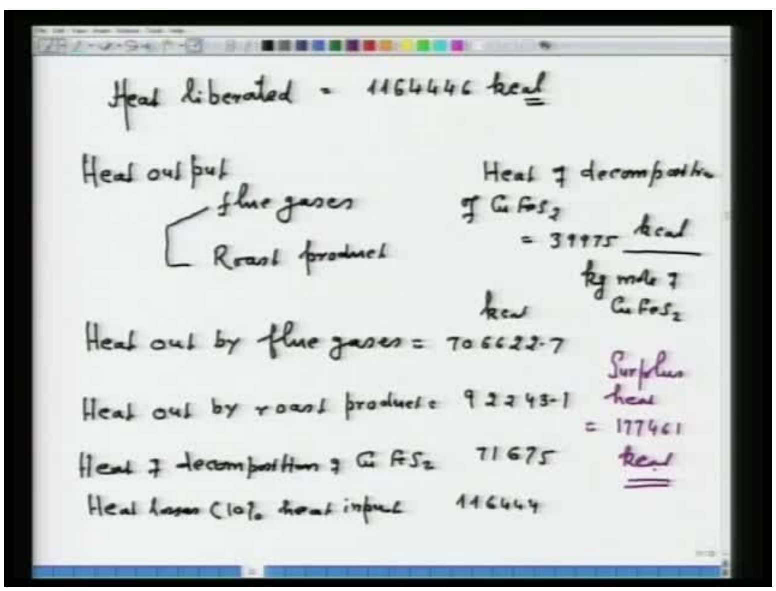

Here, the chalcopyrite concentrate consist of Cu Fe S 2. So, one is to have some heat of decomposition of Cu Fe S 2 that also we have to consider.

So, that is equal to 39975 kilo calorie per kg mole of Cu Fe S 2. Now, with this, I can now write down heat output by flue gases that will be equal to the heat out by roast product, third will be heat of decomposition of chalcopyrite, heat of decomposition of Cu Fe S 2 and then heat losses.

Heat losses I am doing with 10 percent of heat input, so all these values you can write down. Say, heat out by flue gases that will be 706622.7 in kilo calorie, by roast product it will be 92243.1, by the heat of decomposition of Cu Fe S 2 that will be 71675 and 10 percent heat losses that will be 116444. So, if you sum total and subtract it from the heat input, then you will find that surplus heat in this particular situation is 177461 that is in kilocalorie.

So, that is what the advantage or that is what the idea that you get by performing heat balance. You know, beforehand that well so much amount of excessive heat is available, what should be done? If no proper care has been taken the temperature during the roasting will raise and sufficient steps can be taken to rectify the raise in temperature vis- a-vis cooling medium or whatever you want to do it.

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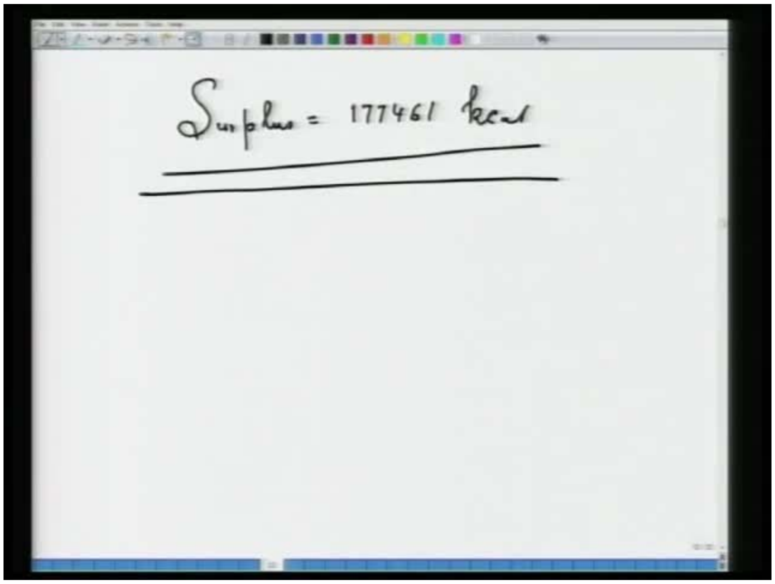

So, problem 5 and 6 please solve by yourself, the answers are given.