Introduction to Atmospheric Science
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Lecture-08
The Earth system – Carbon cycle contd..., and Carbon in the oceans Earth's crust

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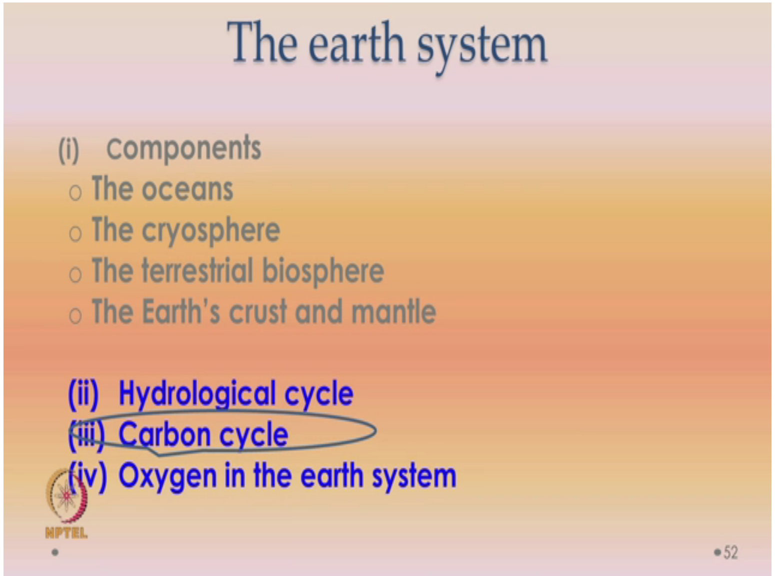

So, we were looking at the various components of the earth system first, the oceans, cryosphere, terrestrial biosphere and the Earth's crust and mantle. We completed that and then we looked at the hydrological cycle where in the last class we looked at the residence time of a reservoir, okay. And then, we looked at the draining of the lake, okay precipitation is falling on a catchment area or a basin.

And then, this rain this collected water is going to the lake; the lake and the basin are having different areas and then, we are looking at the height Z. Then, we got an ordinary differential equation and then we try to get the steady state what is the relationship between the precipitations the evaporation and the two areas. And then we solved the unsteady part of the problem where we found that finally the height of the lake varies linearly with the forcing, ok varies linearly with time, okay.

So, I also discuss some cases briefly. I also briefly mentioned some cases, where the shape of the lake can be non-uniform. Then its response, okay as it starts raining this Z, may go lawn non-linearly with T okay. So, I told you that the model can get very complicated, you can have n incoming streams n outgoing streams, okay. You can have a spatially varying rainfall, spatially varying evaporation, temporally varying rainfall, evaporation all that.

You will get a complicated model. This is essentially, this is done in the area called hydrology, okay. Next coming to the carbon cycle, so we went through these slides. So, for the sake of completeness we will quickly go through so that there is continuity.

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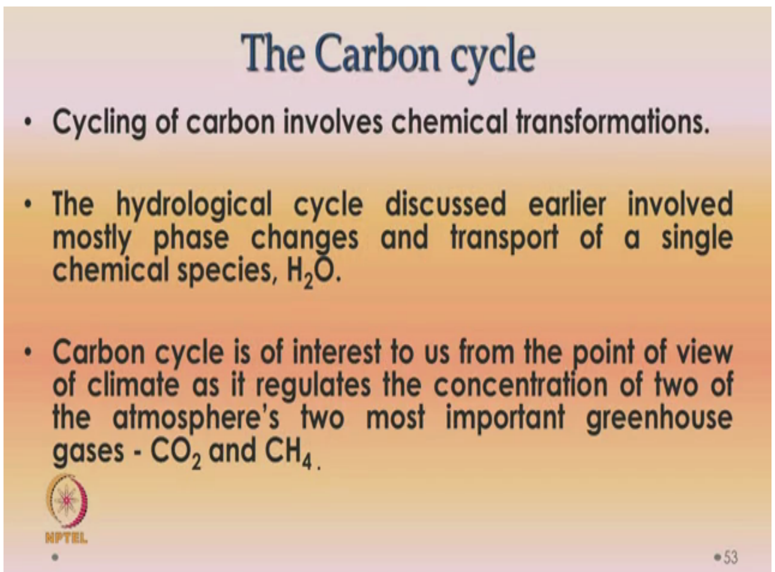

So, the basic difference between the hydrological cycle and the carbon cycle is chemical transformations are involved, okay. Chemical reactions take place in the carbon cycle whereas there is only phase change which is taking place in the hydrological cycle water to water vapour, water vapour to ice and back and so on, okay. Carbon cycle is of interest to us because it is very it is a major player in the regulation of the Earth's climate and it also regulates two very important gases namely carbon dioxide and methane, both of which are greenhouse gases.

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Major carbon reservoirs of the Earth system

Reservoir	Capacity in kg/m^2 of Earth's area	Residence time
Atmospheric CO_2	1.6	10 years
Atmospheric CH_4	0.02	9 years
Green part of Biosphere	0.2	Days to seasons
Tree trunks and roots	1.2	Up to centuries
Soils and sediments	3	Decades to millennia
Fossil fuels	10	-
Organic carbon in sedimentary rocks	20,000	2×10^8 years
Ocean dissolved CO_2	1.5	12 years

So, we saw this viewgraph in the last class where there are major carbon reservoirs of the earth system. So, we listed atmospheric carbon dioxide, methane, biosphere, trees then Earth's crust fossil fuels and so on. Look at this fossil fuel, carbon in fossil fuel is about 10 grams per meter square, 10 kilo gram per meter square of its area, okay. So, its area is 4Pi RE square, R is 6000, 6.37 into 10 to the power of 6. So, 10 into 4 into PI into 6.37 into 10 to the power of 6 it is good.

But whether it is, how long it will last and other things we are just in 5 minutes we are going to work out a problem and see and check for ourselves, all right. There is a lot of organic carbon in sedimentary rocks. So, in our lingo is ajar, okay. Organic carbon in sedimentary rocks maybe some technology will come to pull out that we don't know, later on if everything is there. So, there is a lot of reserve there.

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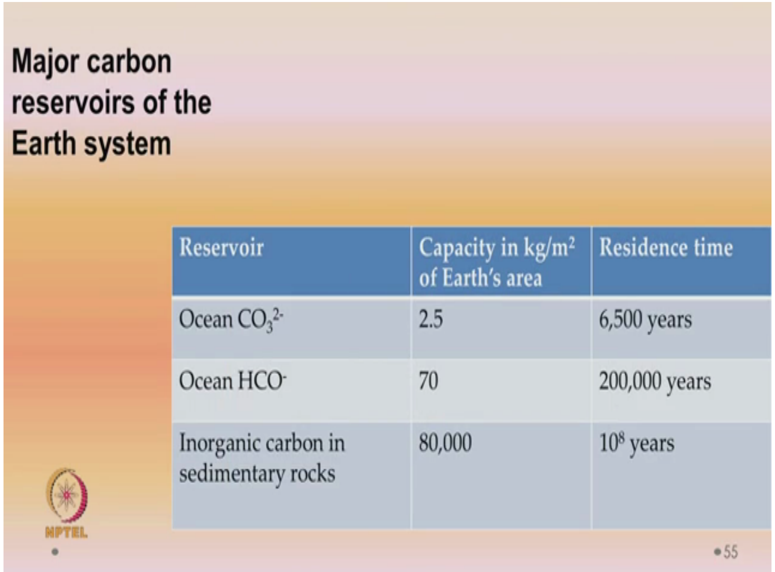

Of course, ocean dissolve carbon dioxide then, we also talked about the carbonate and the bicarbonate which are decent numbers. Inorganic carbon in sedimentary rocks is basically 80,000 kilogram per meter square, okay. So, this residence time 10 years and this thing and so on some people ask a question, sir, how will you measure and this thing in all that, right. So, what I will do now is, I will quit this presentation, is there something called carbon cycle research paper, okay how do we make this big? Control, good works okay.

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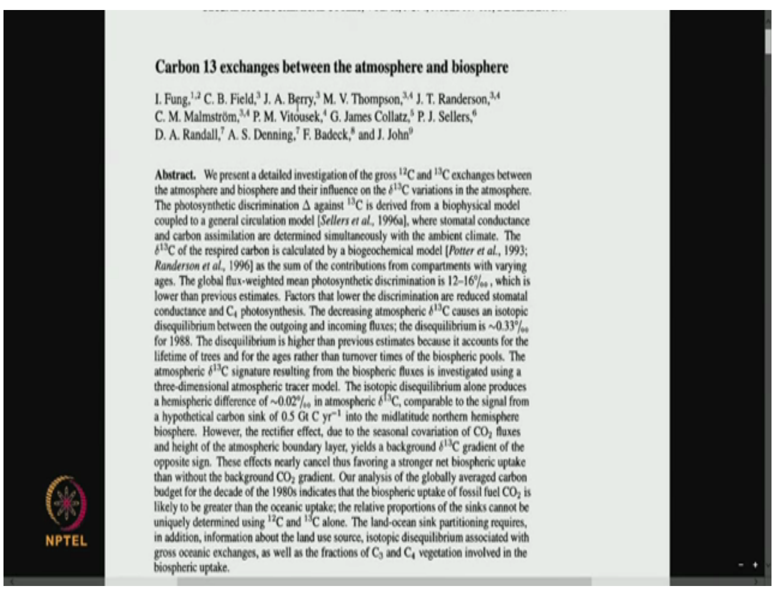

Carbon 13 exchanges between the atmosphere and biosphere

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Abstract. We present a detailed investigation of the gross ^{12}C and ^{13}C exchanges between the atmosphere and biosphere and their influence on the $\delta^{13}C$ variations in the atmosphere. The photosynthetic discrimination Δ against ^{13}C is derived from a biophysical model coupled to a general circulation model [*Sellers et al.*, 1996a], where stomatal conductance and carbon assimilation are determined simultaneously with the ambient climate. The $\delta^{13}C$ of the respired carbon is calculated by a biogeochemical model [*Potter et al.*, 1993; *Randerson et al.*, 1996] as the sum of the contributions from compartments with varying ages. The global flux-weighted mean photosynthetic discrimination is 12–16‰, which is lower than previous estimates. Factors that lower the discrimination are reduced stomatal conductance and C_4 photosynthesis. The decreasing atmospheric $\delta^{13}C$ causes an isotopic disequilibrium between the outgoing and incoming fluxes; the disequilibrium is ~0.33‰ for 1988. The disequilibrium is higher than previous estimates because it accounts for the lifetime of trees and for the ages rather than turnover times of the biospheric pools. The atmospheric $\delta^{13}C$ signature resulting from the biospheric fluxes is investigated using a three-dimensional atmospheric tracer model. The isotopic disequilibrium alone produces a hemispheric difference of ~0.02‰ in atmospheric $\delta^{13}C$, comparable to the signal from a hypothetical carbon sink of 0.5 Gt C yr^{-1} into the midlatitude northern hemisphere biosphere. However, the rectifier effect, due to the seasonal covariation of CO_2 fluxes and height of the atmospheric boundary layer, yields a background $\delta^{13}C$ gradient of the opposite sign. These effects nearly cancel thus favoring a stronger net biospheric uptake than without the background CO_2 gradient. Our analysis of the globally averaged carbon budget for the decade of the 1980s indicates that the biospheric uptake of fossil fuel CO_2 is likely to be greater than the oceanic uptake; the relative proportions of the sinks cannot be uniquely determined using ^{12}C and ^{13}C alone. The land-ocean sink partitioning requires, in addition, information about the land use source, isotopic disequilibrium associated with gross oceanic exchanges, as well as the fractions of C_3 and C_4 vegetation involved in the biospheric uptake.

So, for those doubting Thomases who are having doubt sir how this is measured and all that very said good she asked, he also asked how do they measure and all that, so he is looking at before coming to the class. So, for some people it is bread and butter. It is their life, research on these topics, okay. For example, this is a paper which says in a man in a journal called global by biochemical cycles, carbon-13 exchanges between the atmosphere in biosphere; so, it is all highly technical.

Basically they are using an atmosphere ocean coupled model, okay and they look at the fluxes and then you change the fluxes, okay. If you change the fluxes you solve the equations for various values of fluxes, you find it what will be the atmospheric carbon dioxide over time and all that. Now, the atmospheric carbon dioxide over time is a measured quantity. Now, you keep fudging these fluxes and solve your governing equation.

So, it is a combination of measurements and these fluxes and find out when at what value of these fluxes will the model match with the measurement then you say so, it is an inverse problem; and then you say this will be the exchange like that. They have done for each of this, okay. There are many papers you just Google it up, how to measure, how to measure the carbon exchange, put in the atmosphere some so many papers will come.

So, 2000 people cited that, this paper 100 people cited this paper and so on, okay. So, this is the way they do it for each of this. There is so there is a model and there is also a, right so we are getting back to this. Like that you can get a residence time for each of this, alright okay. So, if you want you can take down this picture otherwise I am going to send it as a presentation to you, PDF.

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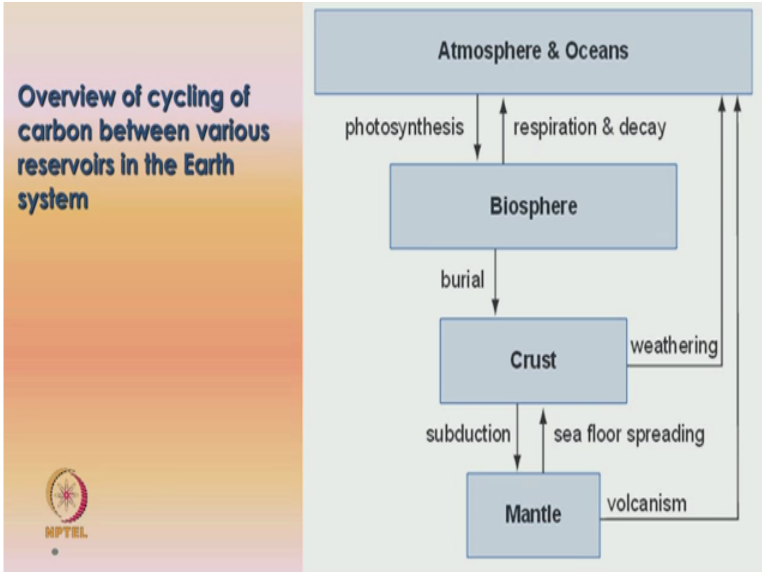

So, the atmosphere and oceans, biosphere, crust and mantle so, this gives you an overview of the cycling of carbon between various reservoirs. At the top is basically atmosphere in oceans, at the bottom you are the mantles. From the atmosphere and oceans up to the biosphere you have the photosynthesis. Photosynthesis is taking place in the terrestrial biosphere as well as in the ocean the phytoplankton, okay. Then, the respiration and decay after respiration in decay, from the biosphere you can again go into the atmosphere and the oceans, right.

I have the phytoplankton they die; then, they will sink it will go down, okay in the atmosphere. After something days, you can burn and that will also go, even that carbon will go. Now, from the biosphere if it is buried in the biosphere, it is buried it goes down further. It is possible for after many, many, many years it can go down to the crust. In the crust some weathering can take place and this weathering, okay can take back some carbon again into the atmosphere or to the oceans.

There will be some calcium carbonate, calcium silicate rocks in the oceans and which will be continuously on because of weathering it may enter into the atmosphere, into the oceans and so on. Then, from the crust to the Mantle, mantle we already saw you can have sea force as seafloor spreading as well as subduction. We saw this plate tectonic theory where they are moving with respect to each other, they are moving towards each other, they are moving, moving away from each other there is shear and so on because of all this some season logical activities taking place.

And so the there could be exchange between the crust and the mantle. And finally there is a direct route, there is a direct visa for this carbon from the mantle to the atmosphere, that is through volcanic eruption, from deep inside you can get this using when there is a volcanic eruption straight away because of this volcanism or volcanic activity, you can get carbon, can be carbon and other aerosols can be ejected directly into the atmosphere.

In fact some people say that sulphur aerosols which they rejected from the sulphur aerosols, if they rejected from the volcanic eruptions in the mantle, then, they there will be an antidote to the carbon dioxide and they will reduce the global temperatures by one or two degrees. So, whenever there has been a major volcanic eruption, the subsequent years we have, what we have had a dip in temperature.

So, one model for example what the Americans would like to do is this sulphur aerosol, you just carry it in hundred or thousand planes and put it all over the place and then you still burn carbon; if you want to do this, this is a new field called geoengineering, you engineer the weather or you engineer the climate, okay. It is a very expensive solution but it is possible, okay. For example, the Chinese have engineered the weather to delay the, to stop the rain in the Olympics, right.

They did that right or you can engineer the weather state that it drains the previous day and all the moisture is drained so it does not rain the next day and so on, okay. All right, carbon in the atmosphere:

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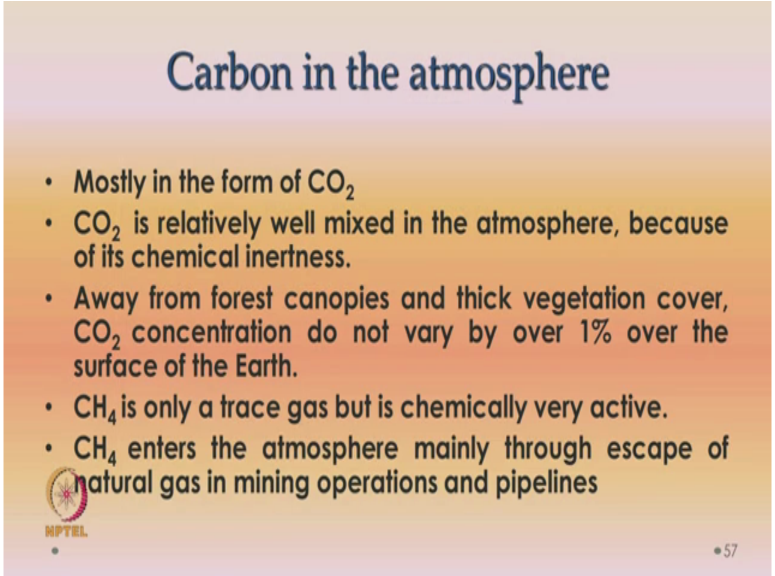

Carbon in the atmosphere is mostly in the form of carbon dioxide, right. Carbon dioxide is relatively well mixed in the atmosphere so because of its chemical inertness it does not react so easily and because of its well mixed nature which arises as a consequence of its chemical inertness heat is distributed uniformly throughout the atmosphere. So, the carbon dioxide concentration is pretty much the same whether it is in the United States or in Asia or in Australia or wherever.

But however there is a caveat there, there is a rider there. This should be away from forest canopies and peak vegetation cover because if there is forest canopies and thick vegetation cover because of heavy photosynthesis there may be an increase or decrease there may be a change in the carbon dioxide because of heavy photosynthesis in this activity. If you remove that, if you remove this from the data points then, the variation in carbon dioxide is less than one percent for the entire globe this is remarkable, right.

That is why that Keeling's measurements and Mauna Lao are highly valid because that is representative of the average carbon dioxide concentration, the whole of the Earth's surface, okay. CH4, methane is only a trace gas but it is chemically very active, okay. You do you know that CH4 is released when rice is produced; Rice, yes when rice is produced CH4 is released.

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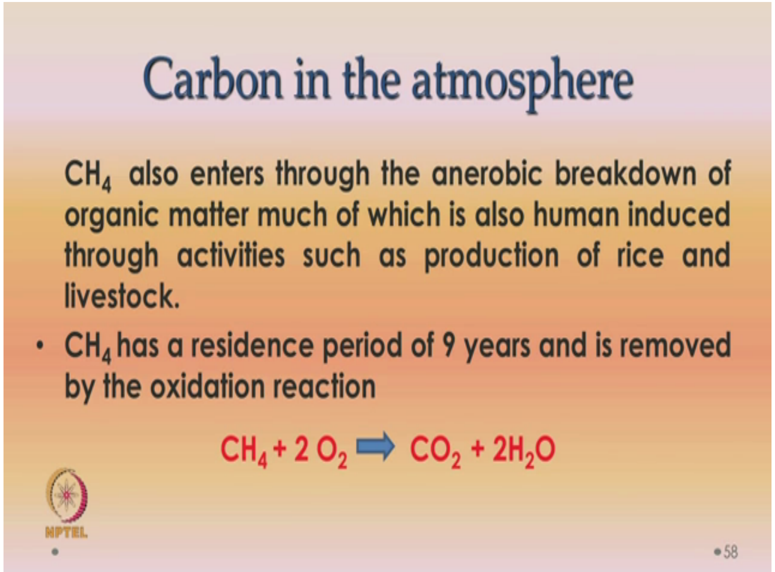

So, CH4 enters the atmosphere mainly through escape of natural gas in mining operations and pipelines. It also enters to the anaerobic breakdown of organic matter, okay much of which is human induced through activities such as production of rice and livestock. Cattle and all this through cattle also has a lot of CH4 natural gases released, okay. CH4 has a residence period of 9 years and is removed by the oxidation reaction.

Simple, CH4 + 2 O2 is CO2 + 2H2O. It is a simple single carbon; hydrocarbon is a simplest, okay which results in less pollution. The heavy G big chain hydrocarbon the heavy hydrocarbon C8G and all that will result in dumping of more carbon dioxide into the atmosphere, ok.

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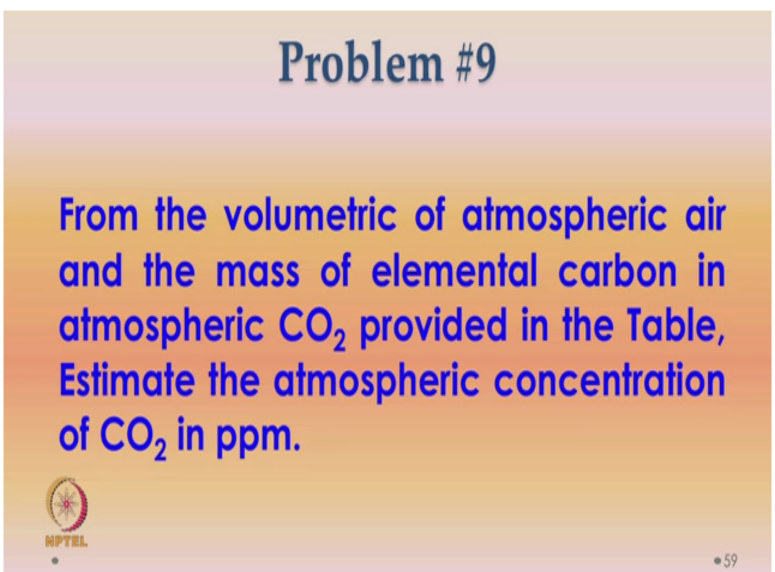

Yes, this was a problem which I already discussed in the previous class from the volume, what is it, so the volumetric analysis of atmosphere, atmospheric air and the mass of elemental carbon in atmospheric CO2, estimate the atmospheric concentration. So, problem nine we got the solution as:

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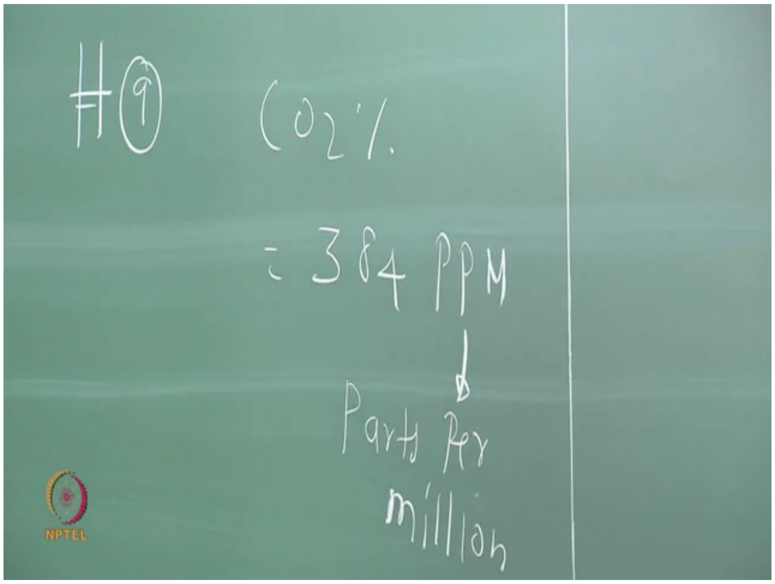

It is 384 parts per million, okay. This is continuously increasing so if you are doing radiation calculations, if you are trying to do climate study and if you are trying to get the average temperature of the earth using carbon dioxide concentration you can have future scenarios where instead of 384 you put 394, 404 and so on. And you can find out what is the change in the temperature because of this.

This is called studying of forcing, this is a radiative forcing if you study the forcing through carbon dioxide or you can also study the effect of forcing by the increase in atmospheric increase in solar radiation or insolation, you know. Not insulation you know this, incoming solar radiation if it changes, how much will it change in all this, ok. Now, please take down problem number 10.

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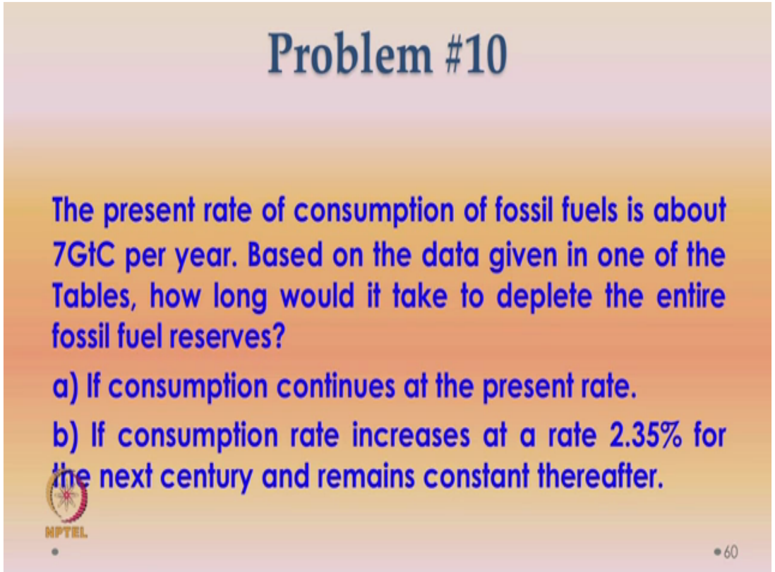

So, this is a problem wherein we get an idea of the amount of time for which we will have possibly fossil fuels for different scenarios, okay. Problem number 10: the present rate of consumption of fossil fuels is about seven Geiger ton carbons per year. Based on the data given in one of the tables how long would it take to deplete the entire fossil fuel reserves, okay.

Based on the data given in one of the tables how long would it take to deplete the entire fossil fuel reserves? I am giving you two scenarios a, if the consumption continues at the present rate what is the present rate 7 Giga tons carbon per year. Giga is how much 10 to the power 9 and it is Giga tons. So, it is 7 to 10 to the power of 12 kg, 7 into 10 to the power of 12 kg per year. So, scenario a is if the consumption continues at the present rate b, if the consumption rate increases at a rate of 2.35 percent for the next 100 years and then it remains constant thereafter.

Therefore, it is intrinsically implicit that I am expecting that it lasts for more than hundred years otherwise Part b would become irrelevant, yeah. Got it? So, a, if consumption continues at the present rate b consumption rate increases consumption rate increases at a rate of 2.35 percent for the next century and remains constant thereafter, okay. Please start solving.

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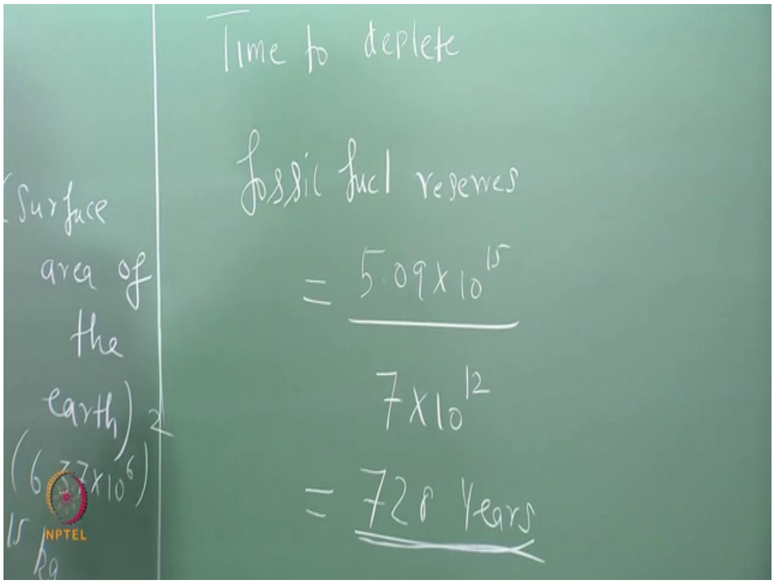

Fixed consumption rate of per year? Did you say that? Consumption rate is known so if you have to find out how long will it take to deplete, you should know the total amount of carbon. I mean to total I mean fossil fuel, okay. So, what is the fossil, total fossil fuel reserve? How much is it? Now, you tell me the steps is = 10 into 10 kg per meter, how much is it little Giga Delta n to the power kg, so the total reserves in kg and the consumption rate in kg per year kg per, kg per year will give you so many years.

That I think you get a decent number, okay. So, what how long what is it, what, what do you want to write here. Something is = 720. What is it? Time to time to deplete, okay: 7, so, if you consume petrol and diesel and kerosene and stuff at the same rate at seven Giga tons carbon per year, it will stay for 728 years. Then, why are people crying so much. The problem is it would not stay, it is not staying fixed at seven Giga ton carbon per year;

It is actually increasing because the increasing is contributed by the growing by the development and growing economic prosperity of the world. Just look at the number of cars, look at the number of cars in Bangalore. More than people living correct. The number of cars is more than people, okay. So, if that is the case then this 728 years is a very, very highly optimistic situation, okay. But if you have some inject some growth rate into it now you will see that it becomes deadly.

Let us know please work out the Part b of the problem, where you have got a variable consumption rate, okay. And I have given a modest increase of 2.35 percent which is based on some previous data. We should not go by what they are consuming in Japan, US, Germany and all that. So, average is there are some African countries were and still cars are very limited. It is a global average from 2.35 okay. Now, Part b, variable consumption rate:

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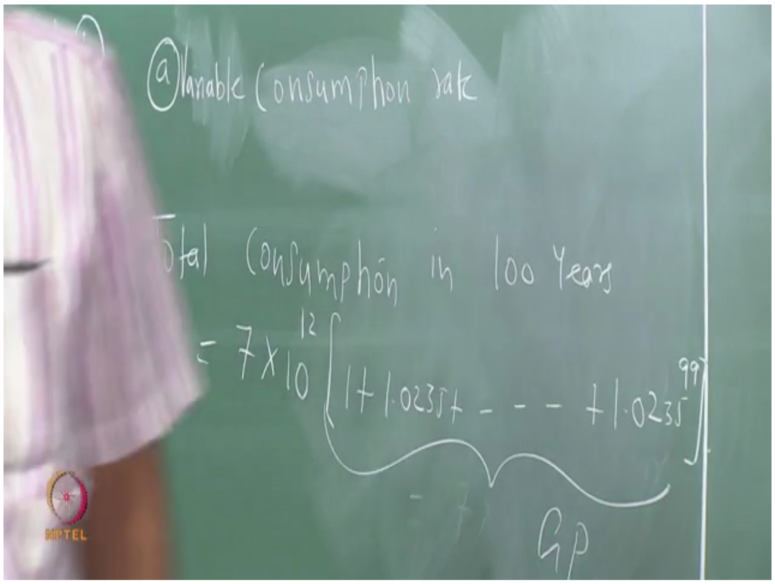

What do you get? What is the consumption rate in the first year? Ok. How do you proceed? No integrate, sum of GP. Correct so you will get a geometric progression. So, what are the numerator and denominator, what is the n? It is for the first100 years I said know. So, it is easy; otherwise the n has to be founded means it is a terrible, ok. So, total consumption in 100 years let us start like this, okay. That is a good idea, okay. 1, 1.235 into the power of 99 why 100? So, this is a GP geometric progression, okay. What is that value?

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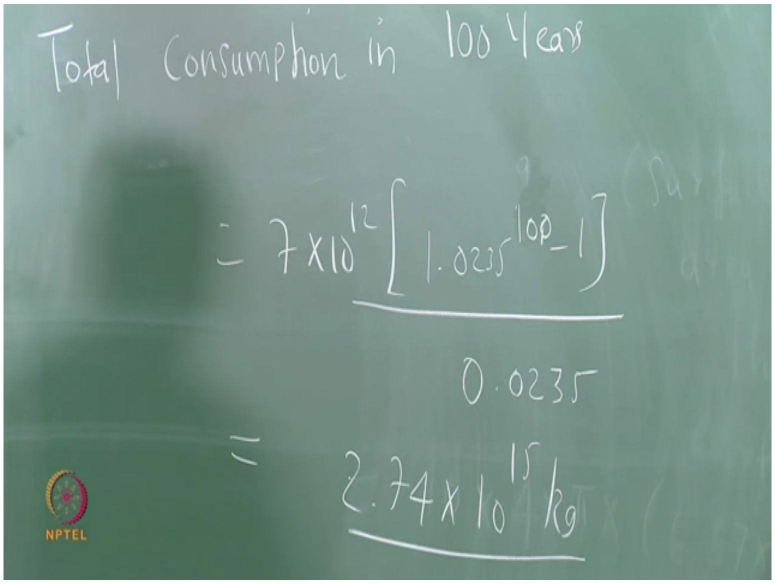

What is the expression for sum of GP, what is 199 whatever you see divided by 0.235. Yes, it is less than the total evidence 2.74 into okay; the good news is it is less than whatever is available, okay. At the end of, now at the end of 100 years, you have to find out what is available, right. That is the next part.

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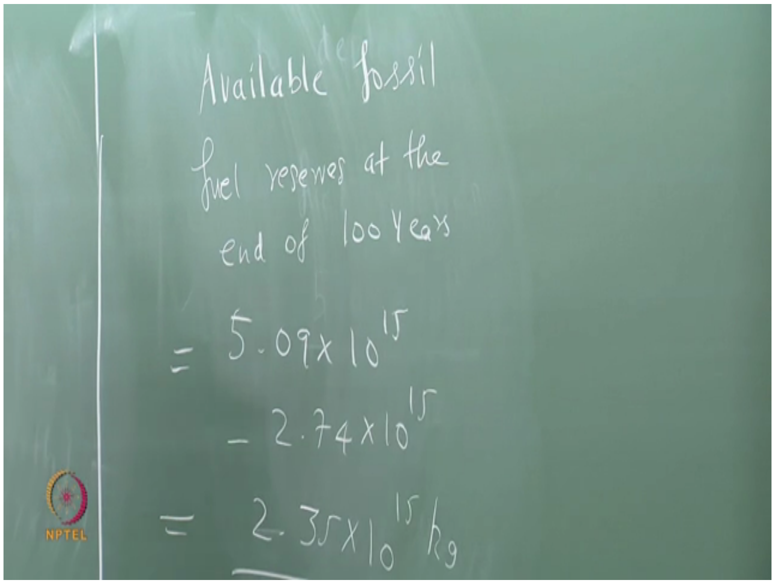

What was the total sum 2 point now you have got a uniform consumption uniform rate of consume consumption. That uniform rate of consumption is 7 into 1.0235 to the power of 99, right, correct so there is struckness in the problem, okay. You have to pay attention so you have to find out at the end of 100 years what is the consumption rate?

Then, divide this by the consumption rate at the end of 100 years, to find out how long you can sustain after hundred years. Then, you get a number add 100 to it that is the total number of years and common sense tells you that it must be less than 728 years because you have got an increasing rate of consumption. You just do it, know.

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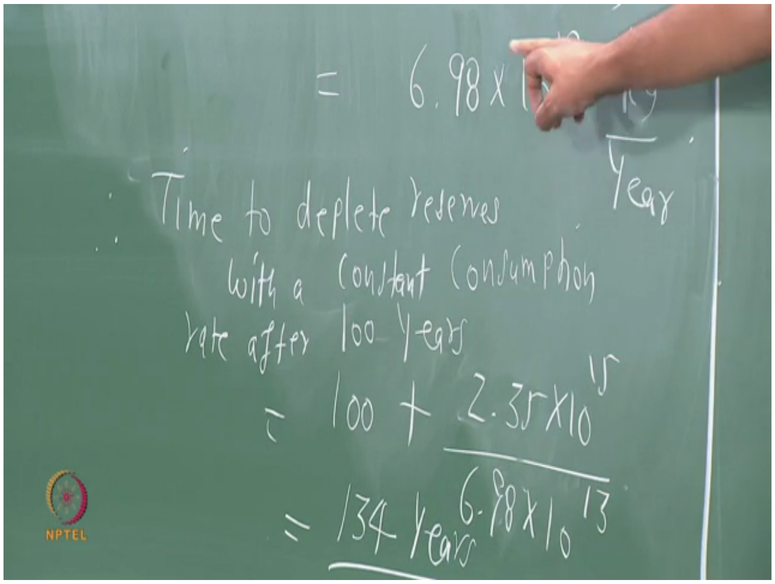

12, okay? How much is this? How much is this 6.65, what are the units? Kg per year. 100 + what is it? 13, 100 and 6.9, 6.98 why is it well please tell me one value 6.98.13, so we just a 2.35 percent increase its 728 years has come down 135 years, okay. So, this 7 into 10 to the power of 12, it has become 6.98 into 10 to the power of 13 that is 69 into 10 to the power of 12. That means it has around 10 times, okay. You know what is the doubling time?

What is the doubling time, you have not studied? Any finance or economic, okay doubling time what is the formula for doubling time?

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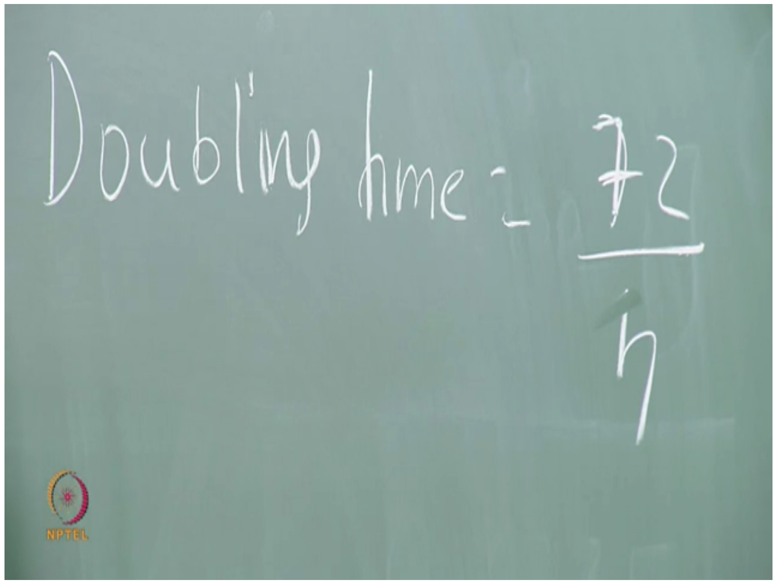

Doubling time is 72 by n where n is the simple interest. If a bank gives you a simple interest of 12% in six years that money will double it gives an interest of 6% which is compounded we do not pull out the interest it will double in 12 years. 72 by n is the formula, okay. So, this 72 by n 72 by 2.3 phase over 34, 35 years itself it is double, okay in 70 years it will quadruple, in 100 years it will become some eight times, whatever.

But it is not 2, it is 2.35. So, it may change, this is okay, fine. Now, so, this gives you an idea of the scary situation just change the 2.35 percent to 3.35 percent may fail, okay we can make a big change to the numbers, okay. So, the challenge is to, the challenge is to be able to make the systems more fuel efficient to coordinate the fuels, hybrid vehicles, electric vehicles, photovoltaic, solar thermal, solar photovoltaic, whatever, what you have, ok, right.

Now, carbon in the biosphere: The biosphere is basically trees plants and all this now on shorter time scales large quantities of carbon dioxide carbon passed back and forth between the atmosphere and biosphere.

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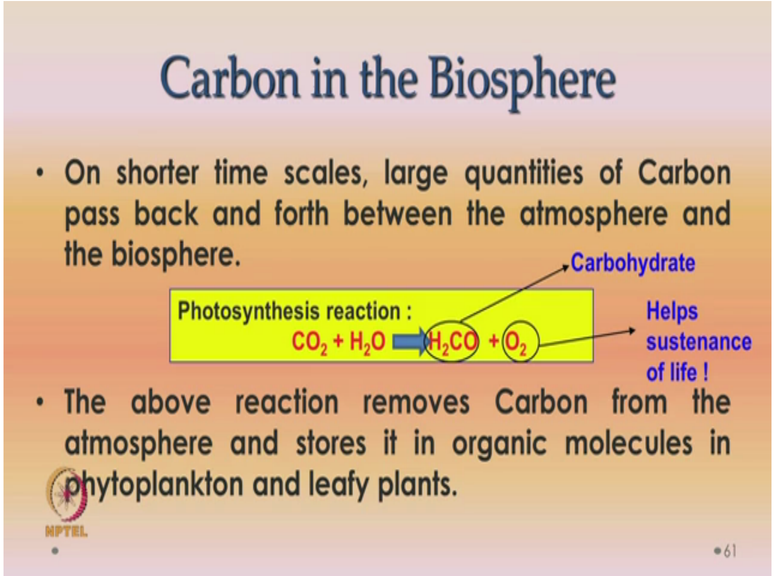

Basically, because of photosynthesis burning and all this is right. Now, photosynthesis right reaction is basically carbon dioxide + water give rise to a carbohydrate H2CO + O2. So, the photosynthesis reaction as you all, know produces oxygen which is the elixir of life, okay. So, this photosynthesis is largely responsible for the sustenance of life on Earth, okay. So, the above reaction actually removes carbon from the atmosphere and stores it and stores the carbon in an organic molecule.

This is basically the carbohydrate and in where in both phytoplankton in the marine biosphere as well as in leafy plants in the biosphere, okay. Now, the opposite reaction is basically the respiration in decay reaction where either there is decay or the food is consumed and it is burning in oxygen and then, this result in carbon dioxide and water vapor. So, this is an exothermic reaction okay.

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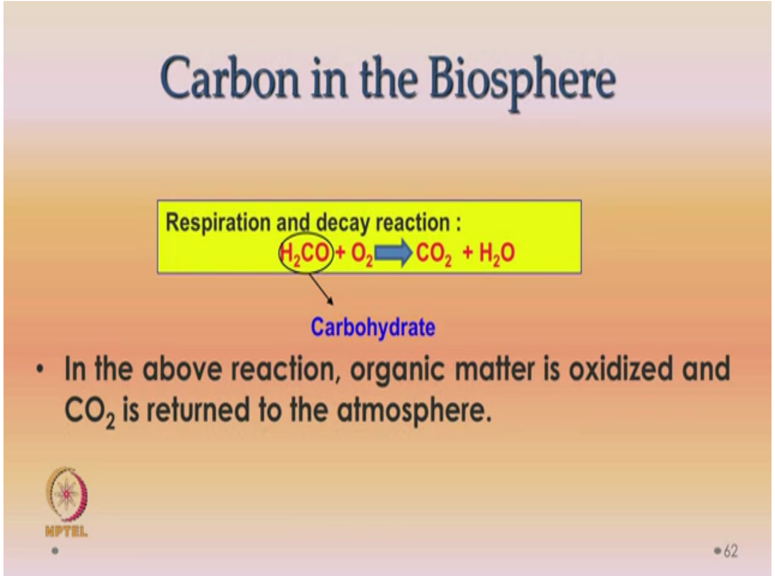

It results in the production of heat energy, okay. So, in this reaction the organic matter is oxidized and CO2 is released back to the atmosphere, okay. So, in photosynthesis CO2 is absorbed from the atmosphere in the respiration and decay reaction CO2 is released back into the atmosphere.

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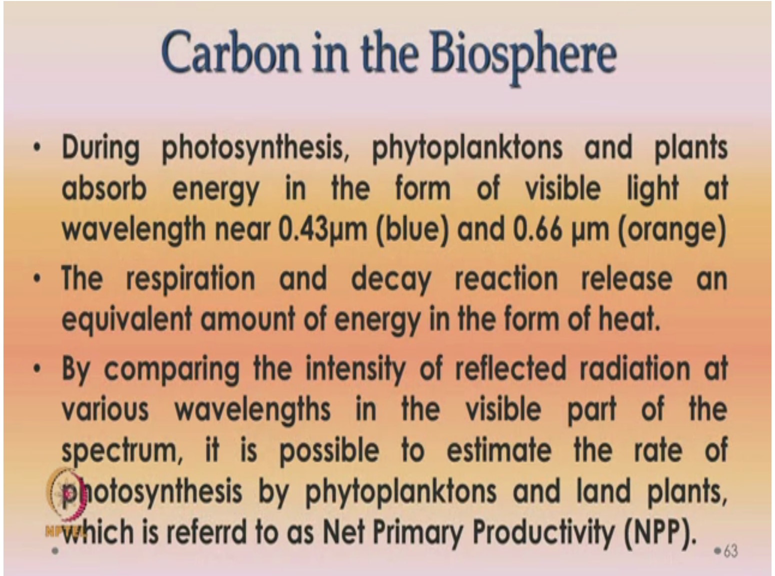

During photosynthesis, phytoplankton and clients absorb energy in the form of visible light at wavelength 0.43 micrometer and 0.66 micrometer which is orange. If you look at the electromagnetic spectrum, we will look at it in a more detailed fashion when we come to the chapter on atmospheric radiation.

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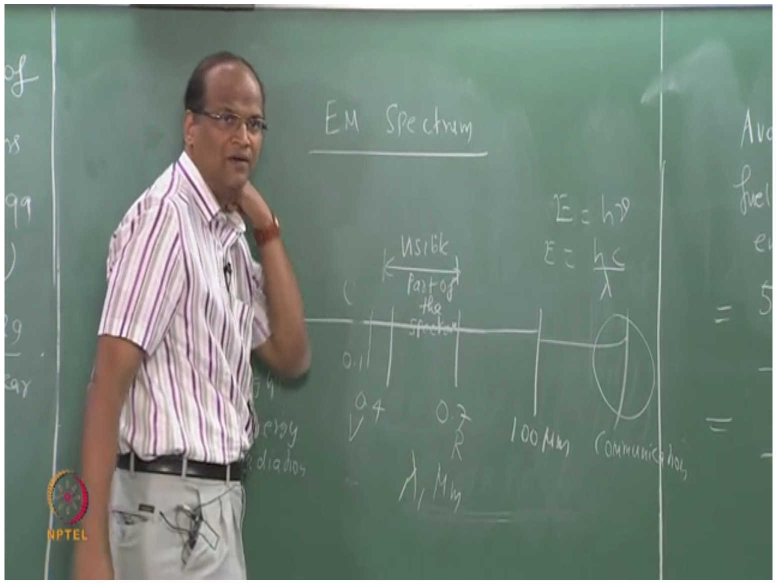

So, we normally use the term, the term or notation lamda you know to denote the wavelength in micrometer meter is too big for us 0.4 to 0.7. This is the visible part of the spectrum; so, here you have got infrared here. You have got ultraviolet, okay. The infrared will be up to 300 micrometer, okay and we know that E = H Nu. As the lambda increases the energy level decreases.

So, then you may have to but this is basically used for communication, right. If lambda is very small you have got high energy. So, this is basically high energy radiation X-rays gamma rays and all this which is of interest. So, usually 0.1, 0.1 into 100 is of interest particularly to mechanical, chemical, aerospace engineers and largely mechanical engineers so, mechanical engineers are interested in the reasonable part of the spectrum.

Physics people are interested in one asymptotic end of the spectrum. The communication engineers are interested in the other part of the spectrum. Why are we interested in .1 to 100 because from the Wiens displacement law you know that lambda max into T is 2898 micro meter Kelvin. Do not think I am reeling of formula 1 after the other. We will derive it later on.

So, for the temperatures which are encountered in mechanical engineering normally the radiation which is emitted is in the wavelength of 0.1200 micrometer. Now, this .4 VIBGR right, this is violet, this is red; blue is very close to this .4. So, here we say that the photosynthesis basically the absorption is in the 0.43 micrometer which is the blue 0.66 micrometer which is orange, which is orange which is very close to red, all right.

Now, the respiration and decay reaction release an equivalent amount of energy in the form of heat. So, what we can do is, how do we measure this, how do you measure globally, the amount of photosynthesis which is taking place and all that? So, this can be done by mapping it with the help of satellites. So, this is called remote sensing, ok. So, you can compare the intensity of the reflected radiation at various wavelengths in the visible part of the spectrum.

So, whatever is coming from Saudi Arabia will be quite different from whatever is coming from the Amazon. There is no vegetation in the Gulf, ok. So, by looking at this reflected radiation in the visible part of the spectrum, it is possible to estimate the photosynthesis. This is what is done by both phytoplankton and land plants. Phytoplanktons are the plants in the ocean and land plants and we get estimate of what is called a NPP, Net Primary Productivity of the earth, okay.
So, what we get is: So, NPP.

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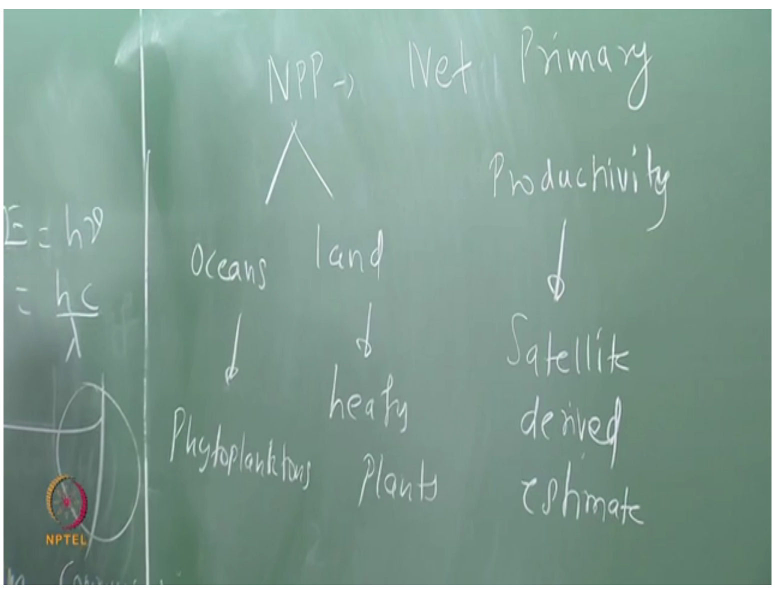

Leafy plants so, we cannot call it as a measurement. It is a satellite derived estimate, okay. I will show you a picture in the next slide. You can see enhanced Marine productivity is clearly seen in the region of the equator and the regions of coastal upwelling where nutrients are brought to the surface. But generally as you can very well guess the net primary productivity is more over the land rather than over the oceans, correct.

And then the greening of the northern hemisphere in spring and summer, after the rains, the greening of the northern hemisphere, pulls out a lot of CO2, correct because photosynthesis takes place because of which and this is stored in plant biomass, which is subject to decay at a more uniform rate, because of which, if you measure if you have a satellite derived estimate of NPP during spring and summer and autumn and winter there will be a difference.

This was and this results in the change in carbon dioxide. That is why if you see Mauna Lao people had this one is a spring and one is a summer. So, it is very clear variation within a seed seasonal variation that is because of the greening and the photosynthesis activity which is different in winter than from summer, okay. Now I will show you this picture.

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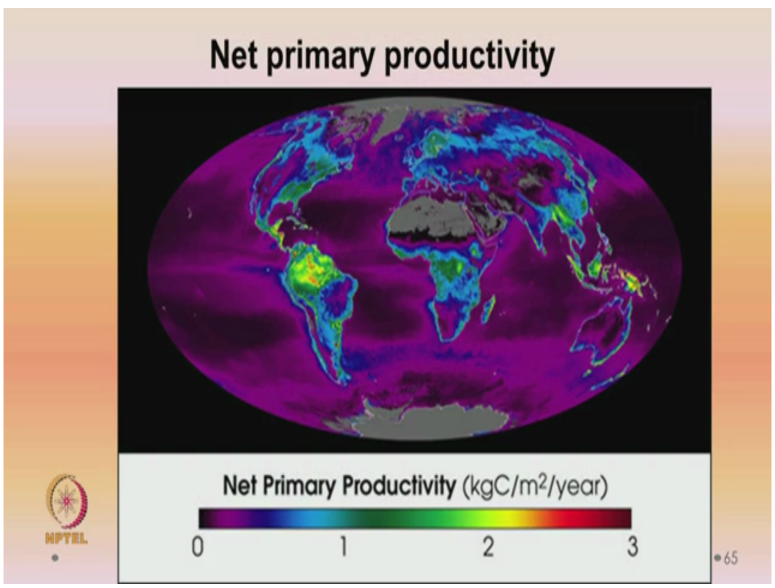

I will give it to you, do not worry. So, this is the net primary productivity kilogram of carbon per meter square per year. So, what can we see a book from this? Where is it highest in this? Amazon, okay. So, it is highest in Amazon South America. So, here also it is very high you can see all along the equator. Here, Indonesia, Singapore, what is this? Papua New Guinea, is it Papua New Guinea? All these places where it is very high so, this is Sahara obviously the productivity is very low, okay.

But sub-saharan Africa, what is this? Kalahari deserts, all these piers all this, okay rhinos and all this if you want to see. So then, there is good net primary productivity. Europe, America and Europe also you can see there is a good productivity. As I told you in earlier class, it is because of this Gulf Stream and all this thermohaline convection and all this which is bringing warm waters, okay. Therefore, this climate is, ok. This side is basically the, this is the North Atlantic Ocean, correct. I am not making mistake, right.

So, this is a North Atlantic Ocean so it results in equitable climate. So, this as you can see there are regions where dark color is there over the ocean, where there is a increase productivity but oceans largely you have got this magenta color which is very low net primary productivity land. It is wherever there is forest it is better, ok. So, these are basically satellite derived estimate, but you can see since satellites are working for the last 30 years, once in 5 years you take the data and get a time series, you can see whether there is an afforestation or deforestation taking place.

If you have a high resolution satellite in fact, you can also detect forest fires from satellites because the reflectivity will change and this thing will change and what the radiation reaching the top of the satellite will change, okay. Now, carbon in the biosphere:

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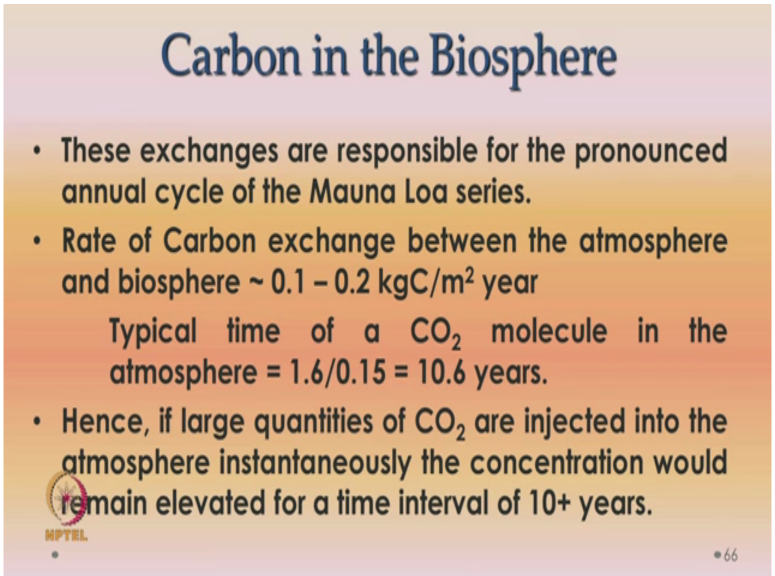

So, these exchanges which are taking place because of the greening of the northern hemisphere during summer and spring, is responsible for the pronounced annual cycle of the Mauna Loa time series which I have indicated here, okay.

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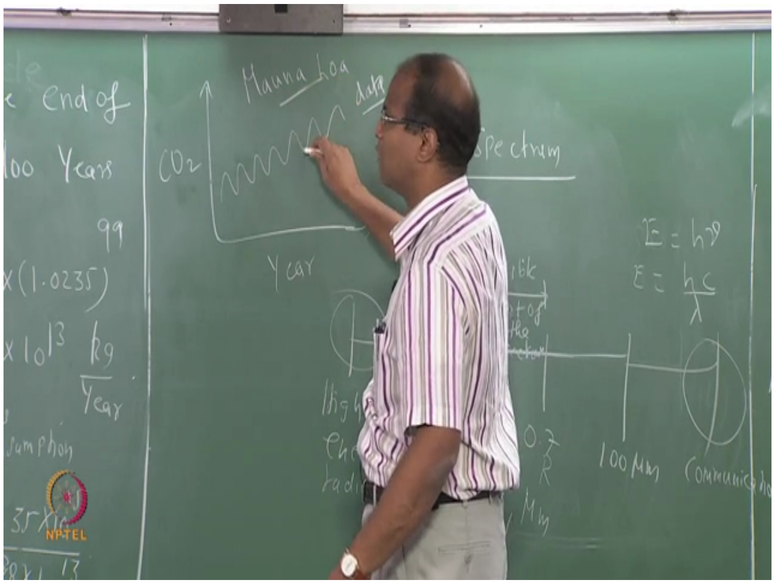

CO2, so this is what I am talking about the rate of carbon exchange is measured marrier the rate of carbon exchange using some formulae and inverse measurements and models is found out to be 0.1 to 0.2 kilograms of carbon per meter square per year. So, therefore the typical residence time of carbon dioxide will be;

So, what is the capacity of atmospheric carbon dioxide, 1.6 kilo gram per meter square. Now the exchange is between 0.1 to 0.2 kilogram carbon per meter square. Let us take an average value of 0.15. So, the residence time is 1.6 kilo gram per meter square divided by 0.15 kilograms carbon per meter square per year and so finally the answer will in years that is the time it gives approximately 10.6 years.

That is why in the table I would not have put 10.6 we would have put a much simplified 10, okay like that it is possible for you to calculate the exchange rate for various reservoirs and find out the residence time. So, if you if you burn if the jet engine exhausts, there in the stratosphere, okay today twenty 21st August on 22nd August 2014, 22nd August to the up to 2024 it will be there, okay. So, this is an important thing you have to bear in mind, okay.

So, the bad news is if large quantities of carbon dioxide are injected into the atmosphere instantaneously, the concentration would remain elevated at a time interval of nearly 10 years. So, whatever you do you have already injected so much it will be there for 10 years as you keep your consumption is increasing then; you are pumping out more CO2 into this? So then, because of this more CO2, more greenhouse effect, increase emission, then the increase absorption, then increase the temperature, increase in melting. So, decrease the reflectivity is changing so it has got a feedback. It has got a positive feedback.

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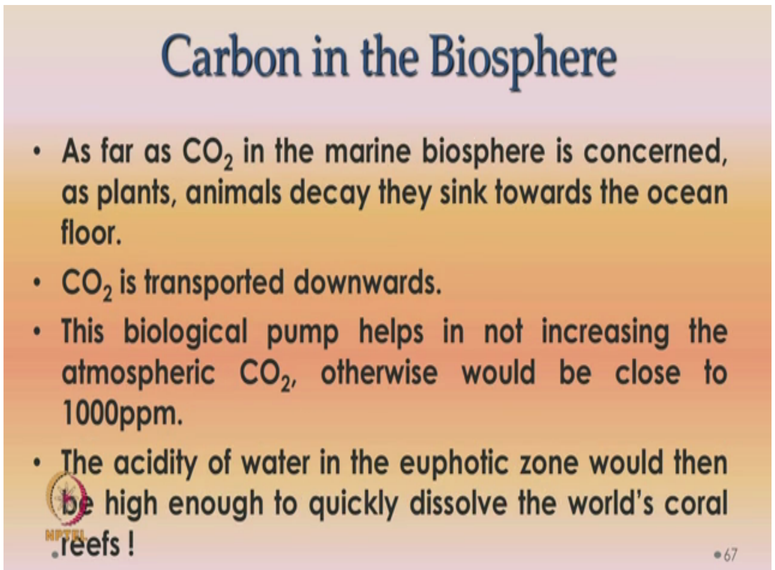

As far as CO2 in the marine biosphere is concerned as plants and animals and decay, they die, they go to the ocean floor, okay. So, the CO2 is actually transported downwards, okay. It goes along with the dead organisms. So, this is actually a biological pump. It is very important. This biological pump helps in not increasing the atmospheric CO2. It is not going up therefore this is something which they are trying to replicate and what is called sequestration, carbon capture, carbon capture technologies.

They want to bury all the carbon in the ocean, right. That is, this is one of the technologies so this biological pump helps in not increasing the atmospheric CO2, which would have been close to 1000 ppm. For example, all this dead matter where to dissolve in the surface itself the ocean ppm concentration of CO_2 would have been in 1000. What is the danger? What is the difficulty with 1000 there?

The water would become so acidic it will be carbonic acid, okay. $CO_2 + H_2O$ will give H_2CO_3 which is carbon carbonic acid. The carbonic acid will what it will do to the euphoric zone would be it will quickly dissolve all the world's coral reefs. So, it has got a lot of ramifications, alright carbon in the oceans, okay.

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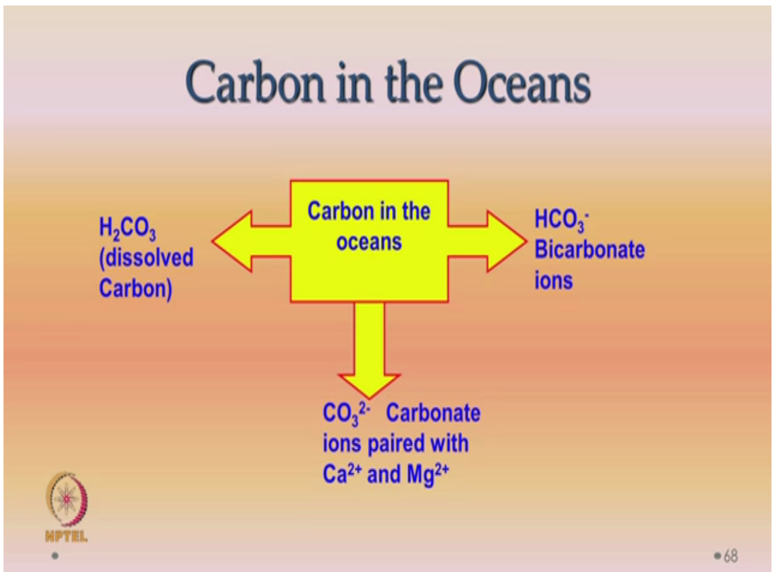

So, we have looked at carbon in the biosphere then carbon and so far and now carbon in the oceans. Carbon in the oceans basically three types: The dissolved carbon has carbonate; the dissolved carbon has first carbonic acid H_2CO_3 and bicarbonate ions and also has carbonate ions which are basically paired with calcium and magnesium which are coming from the rocks, alright. Okay please take down these reactions $CO_2 + H_2O$ gives you H_2CO_3, okay. Let, let me write it down.

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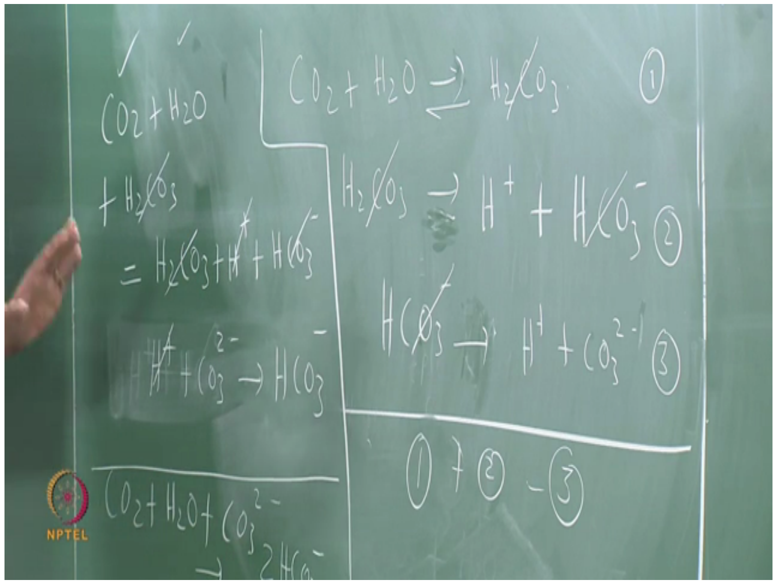

So, this is basically then H2CO3 can decompose, ionize HCO3 - let us see what remains then so these are all forward reaction HCO3 - becomes H +, now we can add carbonic acid, bicarbonate ion, carbonate ion, okay anything else? CO2, correct no CO2 okay did you put it as 1 + 2 - 3. What is in the reverse, okay? So, let us add 1 + 2 now. You are putting it in the other form, correct. Now, we add correct so which all get canceled which one here what is the last equation, is this okay.

What did I write, okay? Gives now what are the things, which place is getting cancelled? Then, H2CO3, so what do you get CO2 + H2O, CO3 - gives very good. Charges are balanced, all right. 1,2,3,4 so, there is a lot of activity going on carbonate and bicarbonate and carbonic acid all this right. These are so, the funda is the dissolved CO2 equilibriates with the atmospheric CO2, the surface of the ocean. So, to a limited extent increase in co2 can be buffered by the bicarbonate reservoir.

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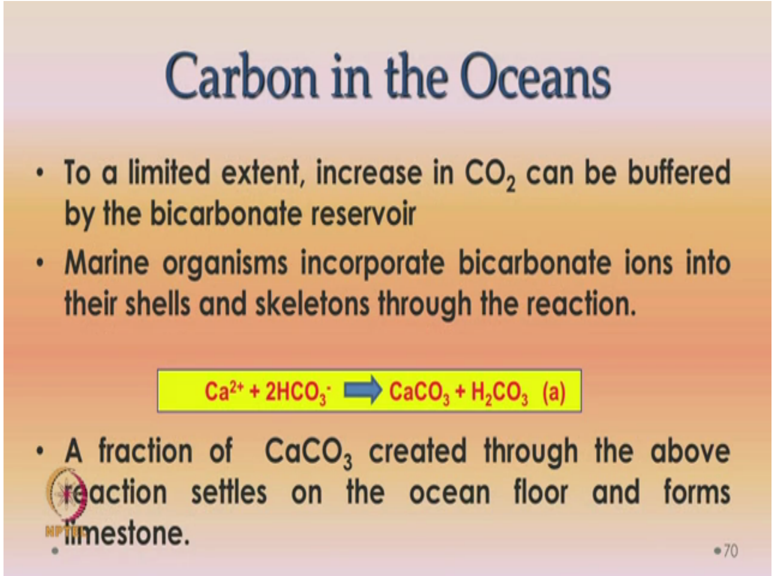

So, the bicarbonate reservoir acts as a boon to us. It captures all the CO2 and put itself back up in it and keeps it does not release it into the atmosphere, okay or into the ocean. So, marine or what this bicarbonate it would not keep quiet. What this bicarbonate does is the marine organisms incorporate bicarbonate ions into the shells and skeletons, okay which have got calcium, okay. In the shell and skeleton you have got calcium so calcium CA2 + reacts with the bicarbonate to hit CO3 - and results in the formation of limestone, CaCO3. The funda is there.

See, how carbon is getting into the system and then again it releases the bicarbonate. So, this bicarbonate will continue with this activity and sorry the carbonic acid, right CaCO3 + H2CO3. A fraction of the CaCO3 created through the above reaction it settles on the ocean floor and forms limestone, ok. So, the carbon dioxide which are producing very nicely it settles known as limestone into these. If you have a technology to convert all this and make it settle in the limestone then we can burn as much carbon dioxide as we want.

But we do not have technology now. So, limited extent it is able to manage, you are able to understand that. So, the carbon is finally going into the ocean floor as limestone. This is not the one, there are other rocks there is a calcium silicate. So, there is a silicate story which is also coming we will complete that.

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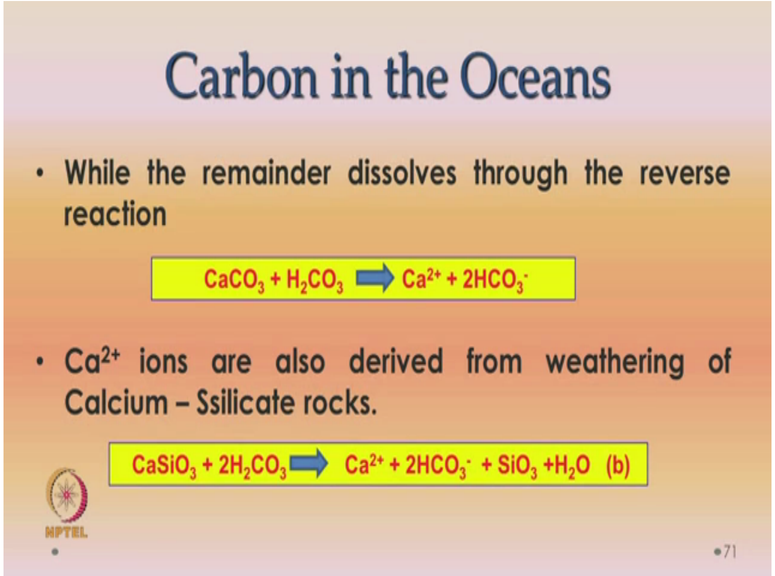

And the remainder what happens is, so a part makes results in the formation of limestone the remainder reacts, the limestone reacts with carbonic acid and again to, through the reverse reaction and through the reverse reaction again releases calcium 2 + ions. This actually the Ca 2 + ions are also derived from weathering of calcium silicate rocks. The calcium silicate rocks can also react with carbonic acid and this will again result in Ca2 +.

This Ca2 + is very important because the Ca2 + goes and captures the CO2. So, the sources of this are okay. There is an organic source for Ca2 + and an inorganic source for Ca2 2 +. The organic sources are the dead, the skeleton and this thing and bones and all that. The inorganic is what is available in as calcium silicate. So, both of these contribute in making of this limestone and all this and capturing the carbon dioxide.

So, if you want to mimic it and do it artificially, this is a carbon capture technology, okay. So, Ca2 + ions are also derived from the weathering of this thing and you again get a bicarbonate + SiO3 + H2O, okay.

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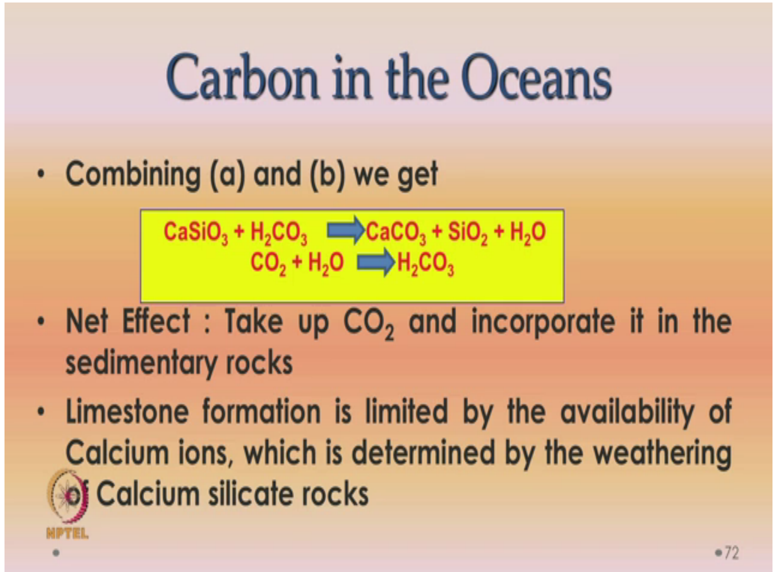

Combining a and b we get, calcium silicate + carbonic acid is K CaCO3 + SiO2 + H2O. Then CO2 + H2O gives H2CO3. Now, let us combine these two. I think this should be the last leg.

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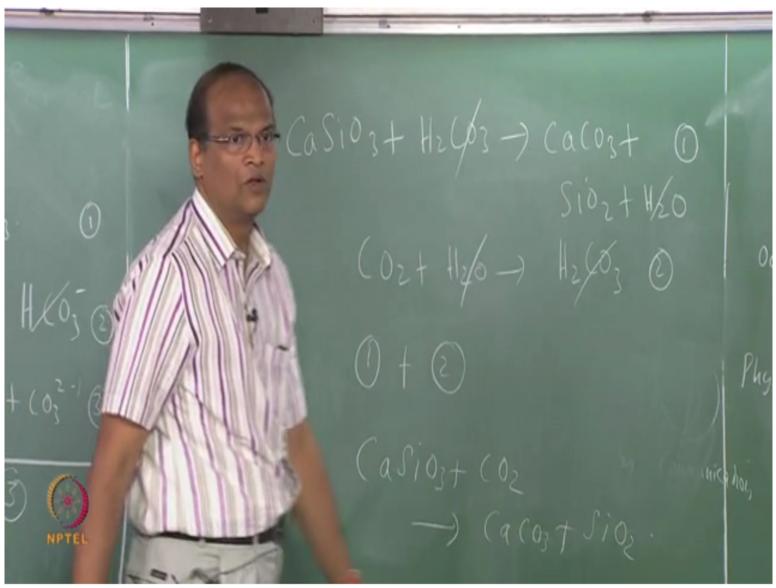

So, what is happening now that is all know. So, the calcium silicate is also capable of absorbing the carbon dioxide. And it will return it as limestone + silicon dioxide. However, the limestone formation is limited by the availability of calcium ions which is basically determined by the weathering of calcium silicate rocks and some calcium which is coming from the decay, death and decay of this organism.