Bioreactors
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Lecture - 16
Solution to pp 4.1

Welcome to lecture 16 NPTEL online certification course on bioreactors. In the previous lecture, we had assigned a problem. In this lecture let us go ahead and solve that problem. This is the practice problem 4.1.

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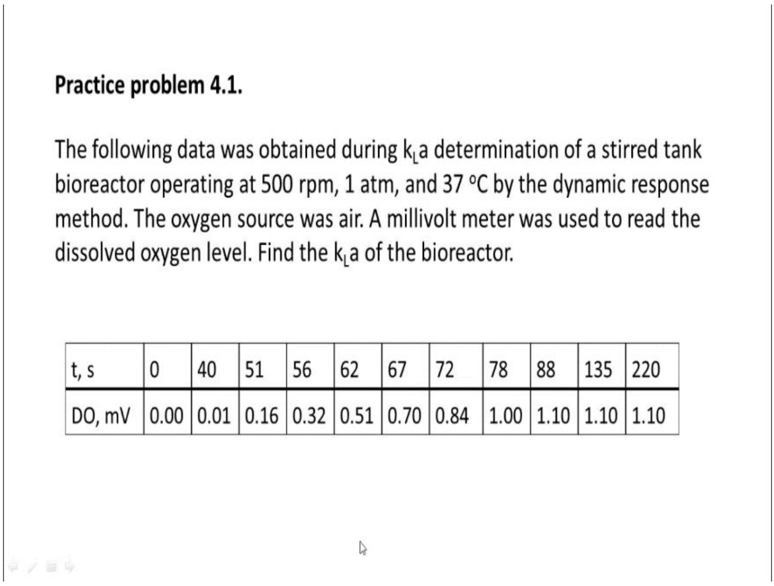

Practice problem 4.1.

The following data was obtained during k_La determination of a stirred tank bioreactor operating at 500 rpm, 1 atm, and 37 °C by the dynamic response method. The oxygen source was air. A millivolt meter was used to read the dissolved oxygen level. Find the k_La of the bioreactor.

t, s	0	40	51	56	62	67	72	78	88	135	220
DO, mV	0.00	0.01	0.16	0.32	0.51	0.70	0.84	1.00	1.10	1.10	1.10

The problem reads, the following data was obtained during $k_L a$ determination of a stirred tank bioreactor operating at 500 rpm, 1 atm and 37-degree C by the dynamic response method. The oxygen source was air. A millivolt meter was used to read the dissolved oxygen level. Find the $k_L a$ of the bioreactor. What is given here is time and dissolved oxygen in millivolts.

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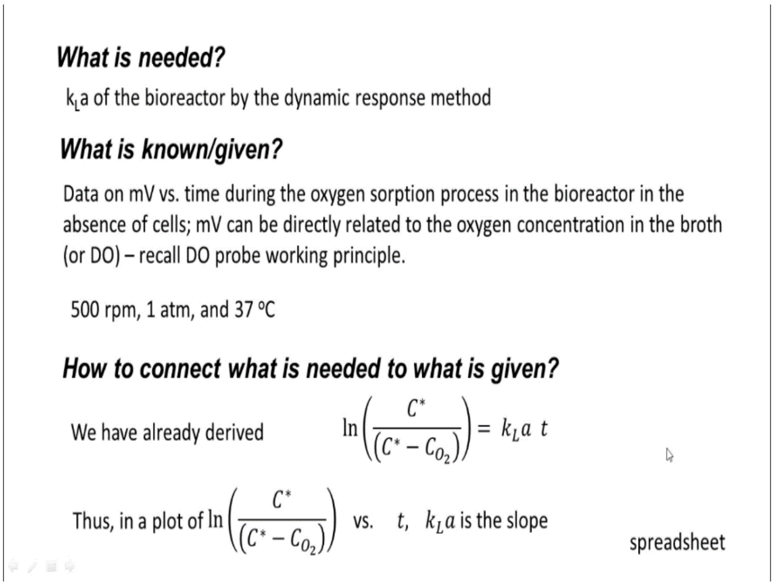

What is needed?

$k_L a$ of the bioreactor by the dynamic response method

What is known/given?

Data on mV vs. time during the oxygen sorption process in the bioreactor in the absence of cells; mV can be directly related to the oxygen concentration in the broth (or DO) – recall DO probe working principle.

500 rpm, 1 atm, and 37 °C

How to connect what is needed to what is given?

We have already derived $\ln\left(\frac{C^*}{(C^* - C_{O_2})}\right) = k_L a\ t$

Thus, in a plot of $\ln\left(\frac{C^*}{(C^* - C_{O_2})}\right)$ vs. t, $k_L a$ is the slope

spreadsheet

We will ask our usual questions for closed ended problems. What is needed? The $k_L a$ of the bioreactor by the dynamic response method. What is known or given? The data on millivolt verses time during the oxygen sorption process in the bioreactor in the absence of cells, the dynamic response method. If you recall the dissolved oxygen probe, its working principle, it is an electro chemical principle. Platinum is the cathode; silver is the anode.

And then these have to be in an electrolyte for an electrochemical system. The electrolyte happens to be KCl. These are placed in a housing, which is dipped into the broth in which the dissolved oxygen level needs to be measured, and this housing is covered with an oxygen permeable membrane. The rate at which oxygen permeates through the membrane and reaches the electro chemical cell is proportional to the current that is generated by these 2 electrodes in the electrolyte and therefore, the oxygen level can be directly related to the current. In this example, the current is directly given instead of percentage air saturation. The current what is actually measured and then there is conversion that takes place electronically in the meters available nowadays to give you air saturation by calculation. Here, we will deal with millivolts themselves as direct indicators of the dissolved oxygen there will which is the bare minimum. As I mentioned this happens to be my own data my doctoral studies and I had used a millivolt meter to measure DO under these circumstances. This is one of my own K L a measurement data. So, we are going to us millivolts as measure of dissolved oxygen. We also know that the bioreactor conditions are, the stirrer is rotating at 500 rpm, the pressure is 1 atm, temperature is 37-degree C

As mentioned in the lecture, all these parameters - the agitation level, rpm, aeration level, liters per minute or volume per volume per minute, temperature, pressure all have significant impact on the $k_L a$ value. Changes in these will change the $k_L a$ value. So, what is normally done while finding the $k_L a$ is to set all these conditions at the operating condition and measure the $k_L a$. That gives us an idea of the oxygen transfer capacity or oxygen supply capacity of the bioreactor.

The third question, how to connect what is needed to what is given?

We have already derived $\ln\left(\frac{C^*}{(C^* - C_{O_2})}\right) = k_L a \ t$

C_{O_2} is the dissolved oxygen level concentration and C^* is the concentration in the liquid phase that is in equilibrium with the gas phase oxygen concentration

Thus, in a plot of $\ln\left(\frac{C^*}{(C^* - C_{O_2})}\right)$ vs t, $k_L a$ is the slope.

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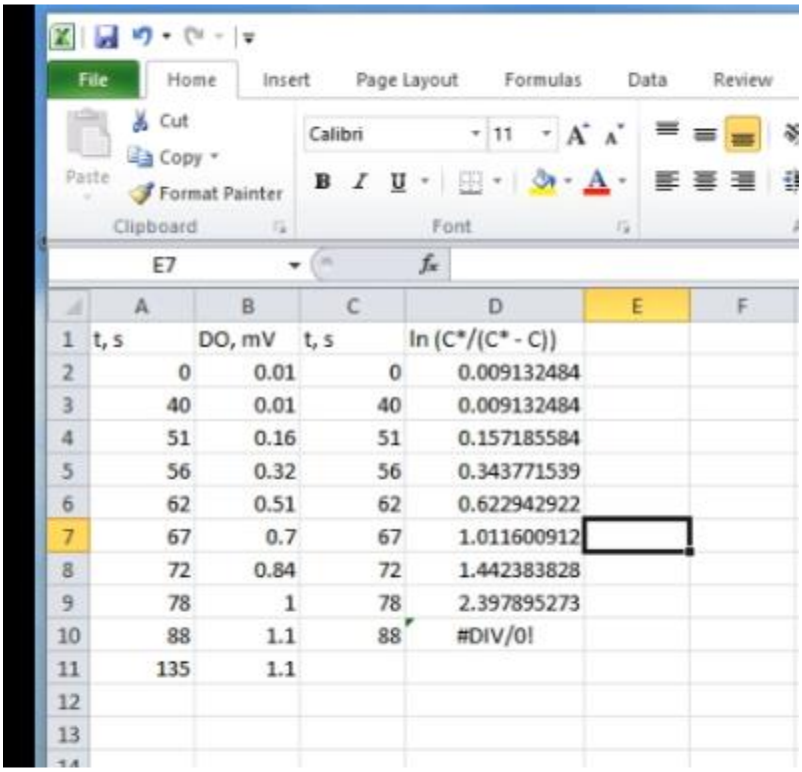

	A	B	C	D	E	F
1	t, s	DO, mV	t, s	ln (C*/(C* - C))		
2	0	0.01	0	0.009132484		
3	40	0.01	40	0.009132484		
4	51	0.16	51	0.157185584		
5	56	0.32	56	0.343771539		
6	62	0.51	62	0.622942922		
7	67	0.7	67	1.011600912		
8	72	0.84	72	1.442383828		
9	78	1	78	2.397895273		
10	88	1.1	88	#DIV/0!		
11	135	1.1				
12						
13						

The calculation for the pints in the plot is shown in the figure above. From the date we can see that the DO level increases and reaches a constant value at 1.1. This indicates that the liquid has reached saturation or equilibrium condition with the gas phase, which is air here. So, this millivolt value is directly proportional to $C^*$and therefore, let us take it as C^*. The values are then calculated for $\ln\left(\frac{C^*}{(C^*-C_{O_2})}\right)$ for the different time points.

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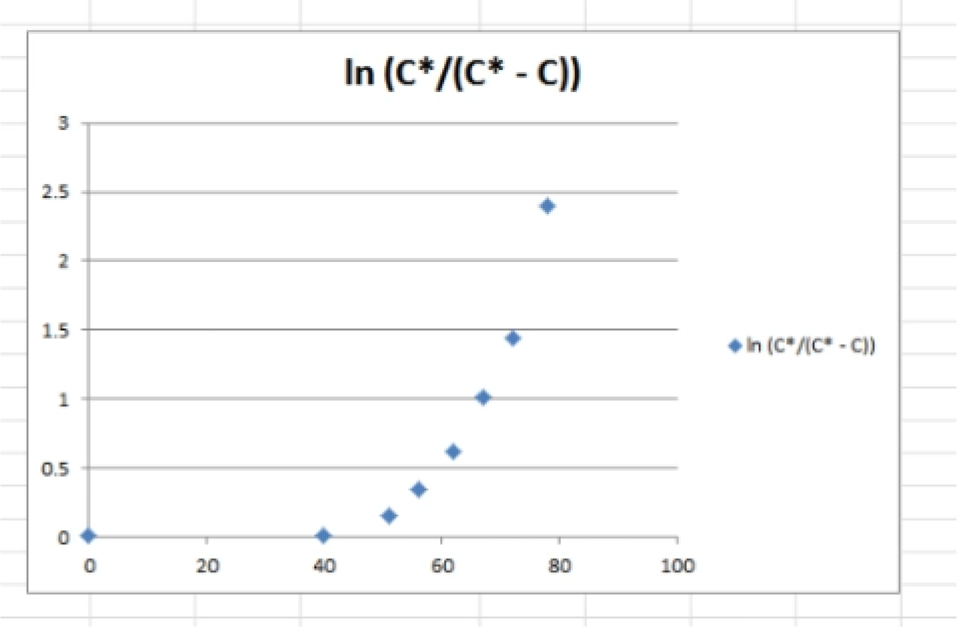

$\ln\left(\frac{C^*}{(C^*-C_{O_2})}\right)$ Versus time you get a curve something like this however, we can use that particular equation only in the linear regime for oxygen sorption. This is a non-linear regime here that is to be expected, the linearity probably starts here and goes up therefore, we are going to look only at this region for calculation of $k_L a$ we are going to look at only the slope of this particular region. We are going to drop the first 3 points which are in the non-linear region.

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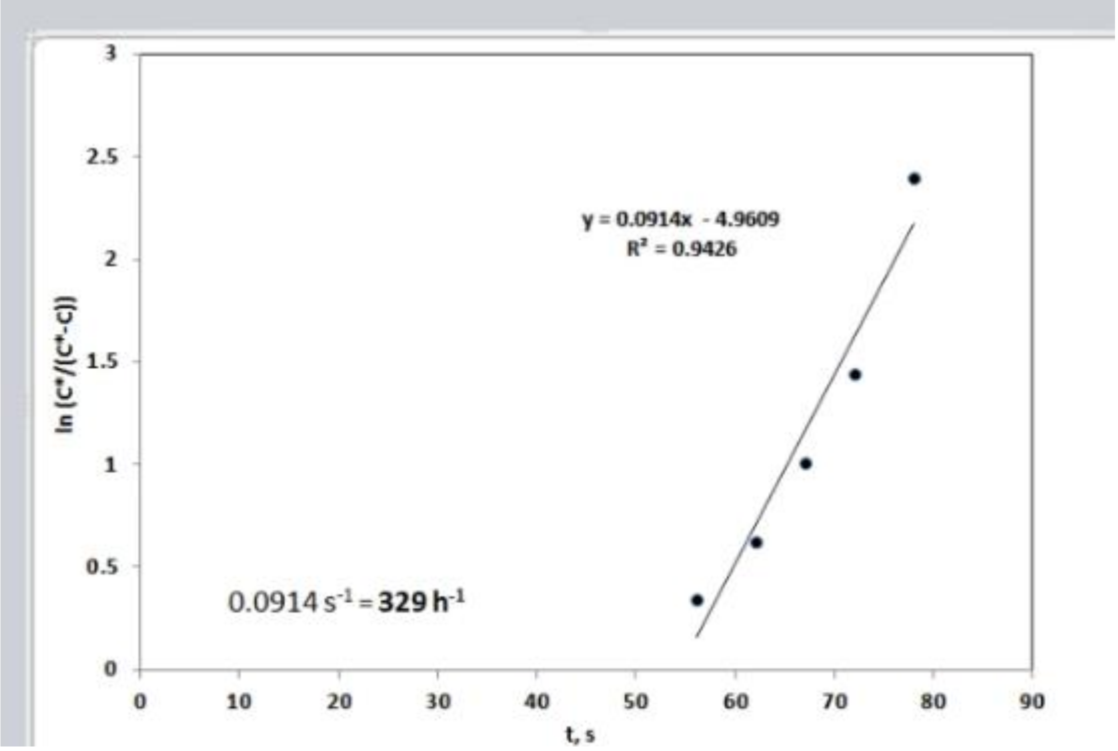

If we do that then we get a curve like this. At about 56 seconds, the linearity began. We used all the points here, of course this is the experimental data. So, you do not expect it to always fall on an exact strict line. This is good enough, the R squared value is about 0.94 that is probably the best, that is obtainable from this particular data, and this is the equation.

The fitted equation. The slope is 0.0914 s^{-1}. We typically provide K L a in per hour, that is easy to make sense because we normally look at K L a values on per hour basis. On a per hour basis this turns out to be 329 h^{-1}.