Experiment 7

Determination of overall volumetric oxygen mass transfer coefficient

Objective:

To determine the overall volumetric mass transfer coefficient of oxygen (K_La) from gas phase to liquid phase in cell free media using simple dynamic method

Introduction:

Dissolved oxygen is an important substrate in aerobic fermentations. Since oxygen is sparingly soluble in water, it may be the growth-limiting substrate in these fermentations. For bacteria and yeast cultures, the *critical oxygen concentration* is about 10% to 50% of the saturated DO (dissolved oxygen concentration). Above this critical concentration, the oxygen concentration no longer limits growth. For optimum growth it is therefore important to maintain the DO above this critical level by *sparging* (bubbling gas through) the fermentor with air or pure oxygen. Of course, to be effective, the mass transfer rate from the gas bubbles to the liquid broth must equal or exceed the rate at which growing cells take up the oxygen.

Oxygen transfer is usually limited by the liquid film surrounding the gas bubbles. The rate of transport is given by:

$$\text{Rate of oxygen transport, } \frac{dC}{dt} = k_L a\left(C^* - C_t\right) \qquad (1)$$

where k_L is the oxygen transport coefficient (cm/h), a is the gas-liquid interfacial area (cm^2/cm^3), k_La the volumetric oxygen transfer coefficient (h^{-1}), C^* is saturated DO concentration, C_t is the actual DO concentration at time t.

In the model system used for the experiment to determine K_La in water i.e., in the case where no reaction is taking place (without microorganism), the following simplifications are valid:

- Oxygen uptake rate ($OUR = q_{O2}X$) = 0 because there is no O_2 sink in the system
- Only data for oxygen transfer rate [$OTR = K_La(C^* - C_L)$] will be considered in the following equation:

$$dCL/dt = OTR - OUR = K_La\,(C_L{}^* - C_L) - q_{O2}X = K_La(C_L{}^* - C_L) \qquad \textbf{(2)}$$

Where, q_{O2} is the specific oxygen uptake rate, X is biomass cocentration, $C_L{}^*$ is the saturation dissolved oxygen concentration and C_L is the dissolved oxygen concentration at any time t. Solving the above differential equation with an initial concentation C_{Lo} (at t_0) results in equation:

$$\ln\,(\,C_L{}^* - C_{Lo}\,/C_L{}^* - C_L\,) = K_La\,(t - t_0) \qquad \textbf{(3)}$$

The concentration C_{Lo} can be achieved by flushing nitrogen in the system. At time t_0 the degassing with nitrogen is stopped (Fig.1) and from time t_0 there is constant aeration. To determine the K_La value by the dynamic method, short bursts of measurement with an electrode are necessary so that measurement time with the electrode has no influence on the value of K_La.

We will perform the "gassing-in" method to measure k_La. The fermenter should be filled with required amount of water/media. The dissolved oxygen would be first removed by sparging with nitrogen, and the air will be purged. The rate of gas transfer to the liquid is determined by using a DO probe that is mounted in the fermenter. This probe is connected to a DO meter, which in turn is connected to a data acquisition (DAQ) system on the PC. Copy the collected data and export it to MS Excel sheet to do the further analysis.

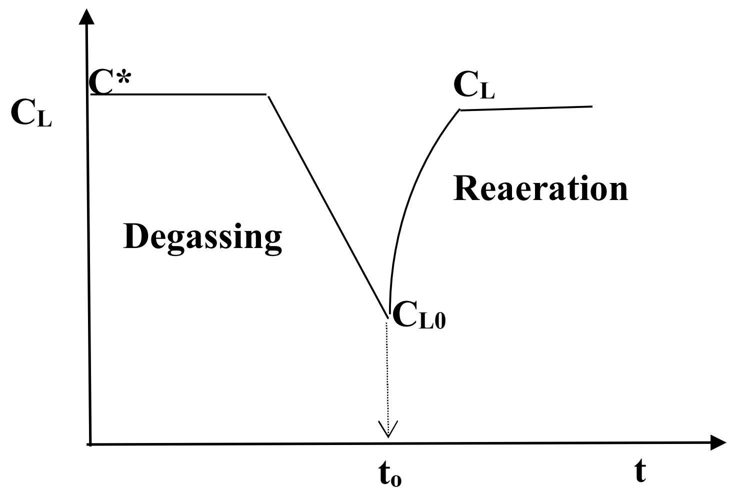

Fig.1 Schematic representation of Dynamic method

Here C* = Saturation DO, C_{L0} = DO at time t_0, C_L = steady state DO at time t

<u>Calculation:</u>
In a MS Excel sheet, prepare this **table**

Time (Sec)	C (DO)

Plot C vs Time plot. And identify the C*.

To the **existing table add new columns** to create the following:

Time (Sec)	C (DO)	$\left(\frac{C^* - C_{L0}}{C^* - C_L}\right)$	$\ln\left(\frac{C^* - C_{L0}}{C^* - C_L}\right)$
0		1	0

..			
..			

Plot $\ln\left(\frac{C^* - C_{L0}}{C^* - C_L}\right)$ **vs time plot.** Use the data only from the linear region of the first plot (C vs Time) to create this plot. Do linear regression to fit the data to a straight line (y= mx). Calculate k_La from this graph.

We will do the same experiment with different rate of stirring. For each case you have to calculate the k_La, as we have mentioned above.

Prepare the following **table**:

Stirring speed (rpm)	k_La

Plot k_La vs Stirring speed plot to show the effect of agitation on oxygen transfer. Usually, there exists a linear relation between these two. If possible, fit your data to a straight line.