**Problem 10.1**

Given C\* = 7.3 mg/L and dissolved oxygen (DO) v time data… estimate KLa.

|  |  |
| --- | --- |
| **Time (min)** | **DO (mg/L)** |
| -1 | 3.3 |
| 0 | 3.3 |
| 1 | 2.4 |
| 2 | 1.3 |
| . | . |
| . | . |
| . | . |

At unsteady-state we know that the accumulation of oxygen in the system is a function of the oxygen transfer rate and the oxygen uptake rate.

We can estimate oxygen uptake rate with data as seen in Fig. 1:

**The slope of the red line represents the decay of O2 in the system, or the oxygen uptake rate.**

Then, is our new equation. We can plot the slope of the curve plus the OUR against the C\* minus CL value to get a linear plot. The slope of the subsequent linear plot is our estimated kLa.

can be estimated by: . The subsequent

**Figure 1.** The plot of DO v time. The red dotted line estimates the oxygen uptake rate (OUR).

Linear regression in excel was used to compute the slope of the OUR data points. It was also used to compute the slope of subsequent linearized equation to estimate the kLa. (See excel sheets). Figure 2 shows the linearized data plot:

**KLa ≈ 3.01 min-1**

**Figure 2.** Estimating the kLa of our system requires the linearization of our equation and plotting of the proper data transformations. Linear regression allows us to estimate the specific kLa.

**Problem 10.2**

**where X is the # of cells in g dry wt per L**

**a.)**

Our process is assumed to be at steady state, that is, We can rearrange this equation to obtain an equation for number of cells as a function of the critical oxygen level, the oxygen solubility, the kLa, and the OUR, q. We then obtain…

We know that C\* = 7.3 mg/L, kLa = 30 hr-1, and CL = 0.2 mg/L. We need to do some conversion to get the OUR into units we can use. It is currently in mMol, while we need it in mg:

Now, we can plug in these values into our derived equation above for X to get a final answer for maximum number of cells per L in our system.

**b.)**

If we are using pure oxygen… the partial pressure of the oxygen now becomes 1 atm, and thus the solubility is now **40 mg/L.** We just need to replace the C\* in our equation and recalculate…

This answer intuitively makes sense as we can now supply a larger mass of cells in our processes than before. This makes sense because we are using pure oxygen in our system and we have less problems delivering a sufficient quantity to our organisms in the fermenter.

**Problem 10.3**

**a.)**

Thermal transport phenomena are a bit different than mass transport, but the general principle still applies. Accumulation = In – Out.

We are given:

*For this problem, we can assume that the specific heat capacities of the broth and the water are identical… cp,w = cp,b = 1 kcal/kg-K*

* OUR = 10 mmol/L-h
* Top = 35 C
* Tw,in = 15 C
* ΔT > 5

At steady state, the rate of energy transfer to the water is equal to the rate of energy transfer out of the fermenter. This can also be looked at in discrete quantities over the course of the entire process as well.

Mathematically, the total change of energy in the fermenter is equal to the total change in energy of the water, or…

We can estimate the energy generation of the fermenter with the following equation:

Thus,

We know that the energy change in the water can be quantified using the following equation:

Thus,

Thus,

**b.)**

We can quantify the energy transfer rate to the water using the following equation:

Lets convert the heat transfer rate to J/s:

We can substitute in the surface area of a cylinder for A and rearrange to obtain an equation for the length of pipe required. Note that the temperature change is also the log-mean temperature difference:

Thus,

**Problem 10.10**

We can assume that the concentration of oxygen in our system doesn’t change much with time and that the system in our fermenter is at steady-state. Thus,

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In this case, the oxygen uptake per weight of bacteria can be mathematically characterized as the following equation:

Substitute into our original equation and we obtain,

Check units… RHS = 1/hr(mg/L) = mg/L-h, LHS = (mg/g-h)(g/L) = mg/L-h. These match so our equation is valid. We know X must be in units of g/L. For this problem we are trying to find the critical oxygen level, CL. It is impossible (or at least very difficult) to isolate CL in this case, so we must use excel and its integrated excel to find the CL value when X is at 20 g/L.

A reasonable initial guess for CL would be around 1 mg/L. When we input this and have excel solve for CL, we get the value of 0.44 mg/L. (See attached spreadsheet for exact details of the solver).

**Problem 10.14**

Scale down reactor from 10 m3 to 0.1 m3. Since the tank scale-down is geometrically similar, we can calculate the scale down factor as such.

10 m3

0.1 m3

Thus, our scale down factor, α, 4.64.

The large tank has dimensions: Dt = 2m, Di = 0.5m, N = 100 RPM. Because of the geometric similarity, we know that the following relationship must apply:

**a.)**

Thus,

What is ho ? We can obtain this from the volume of the original tank:

Thus,

So,

**b.)**

(i) For constant tip speed, the equation N∙D must be equal to each other:

(ii) For constant Re, the equation N∙Dt2 must be the same for each tank:



