

ENGR 4510/6510

Test #3

Partial solutions

- 5) Your company has available a 1000 L bioreactor with fixed heating/cooling coils (i.e., with a given surface area). You wish to design an aerobic fed-batch process using *E. coli*, and plan to feed a concentrated carbon/energy source into the vessel. List (brainstorm) **four** ways that the process can be designed to minimize the amount of heat which needs to be removed. Which is probably the most effective way and why?

Note: This problem does not ask for methods to *remove* heat more effectively. It asks how to make the process *generate* less heat.

- 1) Lower the growth rate to the cells by feeding the carbon/energy source or another nutrient at growth limiting rate. (Note that the problem explicitly stated the process was a 'fed-batch process', but did not indicate what the growth rate would needed to be.)
- 2) Use a more oxygenated carbon/energy source, for example a short chain acid rather than an alkane. (Note that the carbon source was not specified as a constraint. We do not know what constraint on carbon sources exists.)
- 3) Lower the temperature of the feed. (Note that the problem explicitly stated the process was a 'fed-batch process'.)
- 4) Lower the relative humidity of the inflowing air. (Note that the problem explicitly stated the process was 'aerobic'.)
- 5) ...Using pure oxygen instead of air would reduce the agitation required for a given cell density and growth rate (Q_{AGIT}).

The most effective method is likely lowering the growth rate of cells (answer #1 above) because using this approach would significantly lower Q_{MET} (which is close to proportional to growth rate), while it would also reduce the agitation Q_{AGIT} at a given cell density.

*Note that "increasing the temperature of the culture" is not a viable option because 1) this approach is incompatible with *E. coli* cells, a stated constraint, and which have a maximum temperature tolerance and 2) strictly speaking, increasing the temperature does not reduce the amount of heat the system generates, but rather it makes the heat removal easier because of the greater temperature difference with cooling water and/or the ambient temperature.*

Similarly, "increase the number of coils" is not a viable option because 1) the problem stated the reactor was a given and 2) increasing the number of coils does not reduce the amount of heat the systems generates, but rather it makes the heat removal easier.

- 6) Mark each sentence as TRUE or FALSE. If False, then write a corrected sentence.
Read carefully!
- a) A structured model with only a few compartments can readily account for the lag phase observed during cell growth.
TRUE – The Williams Model is a structured model with only three compartments, and it is able to account for a lag phase.
- b) A real-time method of detecting the depletion of the carbon/energy substrate during a microbial culture is the sudden increase in oxygen uptake rate.
FALSE –
The following two sentences are each an example of a true sentence:
- “A real-time method of detecting the depletion of the carbon/energy substrate during a microbial culture is the sudden decrease in oxygen uptake rate.”
 - “A real-time method of detecting the depletion of the carbon/energy substrate during a microbial culture is the sudden increase in dissolved oxygen concentration.”
- c) The reduced cofactor NADH, generated principally in glycolysis and the TCA cycle, is required for the synthesis of building block molecules such as amino acids.
FALSE –
The following two sentences are each an example of a true sentence:
- “The reduced cofactor NADPH is required for the synthesis of building block molecules such as amino acids.”
 - “The reduced cofactor NADH is involved in maintaining the electromotive force across the cell membrane and is involved in energy generation.”
- d) At a given rate of turbulent agitation, twice as much power or more is typically required to mix a solution with a radial-flow impeller than with an axial-flow propeller of the same diameter.
TRUE

- 7) During a “static gassing out” experiment, a solution of O₂-free media was sparged with air, and the following data were obtained for the concentration of dissolved O₂ as a function of time.

Time (s)	O ₂ Conc. (mg/L)
12	1.96
24	3.97
36	5.11
48	5.88
60	6.24
∞	6.75

Find the k_{La} (in h^{-1}).

At infinite time, $C_{O_2} = 6.75$ mg/L, indicating that $C_{O_2}^* = 6.75$ mg/L under the conditions of the experiment. Calculate $\ln(C_{O_2}^* - C_{O_2})$ for every given time, and plot $\ln(C_{O_2}^* - C_{O_2})$ vs. time:

Time (s)	$\ln(C_{O_2}^* - C_{O_2})$
12	1.567
24	1.022
36	0.495
48	-0.139
60	-0.673

From the plot (next page), we find the slope is $-0.047 s^{-1}$. In the static gassing out method, the slope is equal to $-k_{La}$. Converting to h^{-1} as requested (multiply by 3600 s/h), results in $k_{La} = 168 h^{-1}$.

PLOT FOR # ⑦

