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Biochemical Engineering

Exercise Session 3

1) Inactivation of *B. subtilis* spores

For the inactivation of *B. subtilis* spores is $A = 9.5 \times 10^{37} \text{ min}^{-1}$ and $E = 287.4 \text{ kJ/mol}$. Calculate the holding time for a liquid enriched with spores at 115°C , so that a death ratio of 10^6 will be reached.

2) Thermal death kinetics

The number of viable spores of a new strain of *Bacillus subtilis* is measured as a function of time at various temperatures (see also Excel file).

Time [min]	Number of spores at			
	T=85 °C	T=90 °C	T=110 °C	T=120 °C
0.0	2.40×10^9	2.40×10^9	2.40×10^9	2.40×10^9
0.5	2.39×10^9	2.38×10^9	1.08×10^9	2.05×10^7
1.0	2.37×10^9	2.30×10^9	4.80×10^8	1.75×10^5
1.5	-	2.29×10^9	2.20×10^8	1.30×10^3
2.0	2.33×10^9	2.21×10^9	9.85×10^7	-
3.0	2.32×10^9	2.17×10^9	2.01×10^7	-
4.0	2.28×10^9	2.12×10^9	4.41×10^6	-
6.0	2.20×10^9	1.95×10^9	1.62×10^5	-
8.0	2.19×10^9	1.87×10^9	6.88×10^3	-
9.0	2.16×10^9	1.79×10^9	-	-

a) Determine the activation energy for thermal death of *B. subtilis* spores.

b) What is the specific death constant at 100°C ?

c) Estimate the time required to kill 99% of spores in a sample at 100°C ?

3) Sterilization of bioreactor

In a bioreactor $10'000 \text{ L}$ of medium was sterilized at 120°C . The time / temperature profile for this process is summarized in the following table:

- Heating time ($100\text{-}120^\circ\text{C}$) : 37 min
- Cooling time ($120\text{-}100^\circ\text{C}$) : 13 min
- Holding time (120°C) : 10 min

a) Calculate the total sterilization criteria!

Temperature	Time (min)	k
100	54	0.0143
105	61	0.0477
110	69	0.154
115	79	0.483
120	91	1.47
120	101	1.47
115	104	0.483
110	107	0.154
100	114	0.0143

4) Scaling-up sterilization

For a 10 L laboratory bioreactor a sterilization criteria of $\nabla = 50$ is sufficient. Which is the minimum sterilization criteria, if the process is scaled-up to a 1000 L reactor? ($N = \text{const}$).

5) Bioreactor Scheme

Please explain the temperature control of the bioreactor system shown below.

- What water cycles are installed?
- How is the temperature in the bioreactor increased?
- How is the temperature in the bioreactor decreased?

