5.1 In a standard five-day BOD test:

(a) Why is the BOD bottle stoppered?

We don't want any additional oxygen to be available from a contact with atmosphere.

(b) Why is the test run in the dark (or in a black bottle)?

If light is available, organisms in the bottle may generate oxygen through photosynthesis.

(c) Why is it usually necessary to dilute the sample?

DO in water is normally 8-15 mg/l. It is possible that during the test, the DO may be finished in the water, thereby making the BOD test result not valid. So, we dilute the sample. Then even after five days, some oxygen will be available in the solution.

(d) Why is it sometimes necessary to seed the sample?

Pure water may not be readily available. Therefore, it becomes necessary to use normal water, which means we seed the sample.

(e) Why isn't ultimate BOD measured?

To satisfy all the Biochemical oxygen demand, it may take some weeks. So it may not be practical to wait till that time to measure ultimate BOD.
Incoming wastewater, with BOD$_5$ equal to about 200 mg/L, is treated in a well-run secondary treatment plant that removes 90 percent of the BOD. You are to run a five-day BOD test with a standard 300 mL bottle, using a mixture of treated sewage and dilution water (no seed). Assume the initial DO is 9.2 mg/L.

(a) Roughly what maximum volume of treated wastewater should you put in the bottle if you want to have at least 2.0 mg/L of DO at the end of the test?

\[ \text{DO}_i = 9.2 \text{ mg/L} \]
\[ \text{DO}_f = 2.0 \text{ mg/L} \]
\[ \text{BOD}_5 \text{ of incoming wastewater} = 200 \text{ mg/L} \]
\[ \text{BOD}_5 \text{ of treated water} = 10\% \text{ of } 200 = 20 \text{ mg/L} \]

\[ \text{BOD}_5 = \frac{\text{DO}_i - \text{DO}_f}{\text{P}} \]

\[ \text{P} = \frac{9.2 - 2.0}{20} = 0.36 \]

\[ \frac{V_w}{V_m} = 0.36 \quad \Rightarrow \quad V_m \text{ (total bottle)} = 300 \text{ mL} \]

\[ V_w = 300 \times 0.36 = 108 \text{ mL} \]

Maximum vol of treated wastewater = 108 mL

(b) If you make the mixture half water, half treated wastewater, what DO would you expect after five days?

\[ \text{P} = 0.5 \]
\[ \text{BOD}_5 = 20 \text{ mg/L} \]

so
\[ 20 = \frac{9.2 - \text{DO}_f}{0.5} \]

\[ 9.2 - \text{DO}_f = 10 \]

\[ \text{DO}_f = -ve \Rightarrow \text{DO}_f = 0 \text{ mg/L} \]
5.3 A standard five-day BOD test is run using a mix consisting of four parts distilled water and one part wastewater (no seed). The initial DO of the mix is 9.0 mg/L, and the DO after five days is determined to be 1.0 mg/L. What is BOD$_5$?

\[
P = \frac{1}{1+4} = \frac{1}{5} -
\]

\[
DO_i = 9.0 \text{ mg/L} \quad \text{DO}_5 = 1.0 \text{ mg/L}
\]

\[
BOD_5 = \frac{9.0 - 1.0}{\frac{1}{5}} = 8 \times 5 = 40 \text{ mg/L}
\]

5.4 A BOD test is to be run on a sample of wastewater that has a five-day BOD of 230 mg/L. If the initial DO of a mix of distilled water and wastewater is 8.0 mg/L, and the test requires a decrease in DO of at least 2.0 mg/L with at least 2.0 mg/L of DO remaining at the end of the five days, what range of dilution factors (P) would produce acceptable results? In 300 mL bottles, what range of wastewater volumes could be used?

Ans:

\[
\begin{align*}
\text{BOD}_5 &= 230 \text{ mg/L} \\
\text{DO}_i &= 8.0 \text{ mg/L} \\
\Delta \text{DO} &= 2.0 \text{ mg/L} \\
\text{BOD}_5 &= \frac{\text{DO}_i - \text{DO}_5}{P} \\
P &= \frac{\text{DO}_i - \text{DO}_5}{\text{BOD}_5} \leq \frac{2}{230} \\
0.0087 \leq P \leq 0.026
\end{align*}
\]

if 300 mL is used, range of waste water volume = 0.0087 * 300 to 0.026 * 300

\[
P = \frac{V_o}{V_{total}} = \frac{2.61 \text{ mL}}{7.8 \text{ mL}}
\]
5.5 The following data have been obtained in a BOD test that is made to determine how well a wastewater treatment plant is operating:

<table>
<thead>
<tr>
<th></th>
<th>DOI</th>
<th>Final DO</th>
<th>Vol of Wastewater</th>
<th>Dilution ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated sewage</td>
<td>6.0</td>
<td>2.0</td>
<td>5</td>
<td>2.95</td>
</tr>
<tr>
<td>Treated sewage</td>
<td>9.0</td>
<td>4.0</td>
<td>15</td>
<td>2.85</td>
</tr>
</tbody>
</table>

What percentage of the BOD is being removed by this treatment plant? If this is a secondary treatment plant that is supposed to remove 85% of the BOD, would you say it is operating properly?

\[ \text{BOD}_{5} \text{ of untreated sewage} = \frac{6-2}{5} = \frac{4}{5} \times 300 = 240 \text{ mg/L} \]

\[ \text{BOD}_{5} \text{ of treated sewage} = \frac{9-4}{15} = \frac{5}{15} \times 300 = 100 \text{ mg/L} \]

\[ \text{efficiency of the plant} = \frac{\text{BOD}_{5} \text{ of untreated sewage} - \text{BOD}_{5} \text{ of treated sewage}}{\text{BOD}_{5} \text{ of untreated sewage}} = \frac{240-100}{240} = \frac{140}{240} = 0.58 \]

This is less than 85%. The plant is not removing 85% of the BOD, it is not operating properly.

5.6 Figure below shows a plot of BOD remaining versus time for a sample of effluent taken from a wastewater treatment plant.

(a) What is the ultimate BOD \( (L_0) \)?

40 mg/L

(b) What is the five day BOD?

40 - 20 = 20 mg/L

(c) What in \( L_5 = 20 \) mg/L.

5.7 If the \( \text{BOD}_5 \) for some wastewater is 200 mg/L, and the ultimate BOD is 300 mg/L, find the reaction rate constants \( k \) (base e) and \( K \) (base 10).

\[ \text{BOD}_5 = 200 \text{ mg/L} \]

\[ \text{BOD}_5 \text{ ult} = L_0 = 300 \text{ mg/L} \]

\[ L_5 = \text{BOD}_5 \text{ ult} - \text{BOD}_5 \implies e^{-k(5)} = \frac{100}{300} = \frac{1}{3} \]

\[ k = -\ln(\frac{1}{3}) = 1.0986 \]

\( k \) (base 10) \( = 2.303 \times 0.22 = 0.5066 \)
5.12 Some wastewater has a BOD<sub>5</sub> of 150 mg/L at 20°C. The reaction rate constant at that temperature has been determined to be 0.23/day.

(a) Find the ultimate carbonaceous BOD.

\[ -k_0 \]

\[ L_t = L_0 - BOD_5 = L_0 e^{-k_0 t} \]

\[ L_0 (1 - e^{-k_0}) = BOD_5 \]

\[ L_0 = \frac{BOD_5}{1 - e^{-k_0}} = \frac{150}{1 - 0.317} = \frac{150}{1 - 0.317} = 219.6 \text{ mg/L} \]

(b) Find the reaction rate coefficient at 15°C.

\[ k_{15} = k_{20} \theta \]

\[ k_{20} = 0.23/\text{day} \]

\[ \theta = 1.047 \]

\[ k_{15} = 0.23 \times 1.047 \]

\[ = 0.183/\text{day} \]

(c) Find BOD<sub>5</sub> at 15°C.

\[ BOD_5 = L_0 (1 - e^{-k_{15} t}) \]

\[ = 219.6 (1 - e^{-0.183}) \]

\[ = 131.6 \text{ mg/L} \]

(This should be less than BOD<sub>5</sub> at 20°C)

5.13 Some waste has a five-day BOD at 20°C equal to 210 mg/L and an ultimate BOD of 350 mg/L. Find the five-day BOD at 25°C.

\[ BOD_5 = L_0 (1 - e^{-k_0 t}) \]

\[ 1 - e^{-k_0 t} = \frac{210}{350} = 0.6 \]

\[ e^{-k_0 t} = 0.4 \Rightarrow k_0 = \frac{-\ln(0.4)}{5} = 0.183/\text{day} \]

\[ k_{25} = k_{20} \theta \]

\[ = 0.23 (1.047)^{25} = 0.226/\text{day} \]

\[ BOD_5 \text{ at 25°C} = L_0 (1 - e^{-k_{25} t}) = 350 (1 - e^{-0.183 	imes 0.226}) \]

\[ = 2.37 \text{ mg/L} \]

(This should be greater than BOD<sub>5</sub> at 20°C)