1. a) $Al_2(SO_4)_3 \cdot 18H_2O + Ca(HCO_3)^- \rightarrow$

$2Al(OH)_3 + 6CO_2 + 18H_2O + 3SO_4^{2-}$

$200 \text{ mg/L} \times \frac{\text{mmol} \text{ Al}_2}{66.7 \text{ g}} \times \frac{\text{Ca(HCO}_3)^-}{1 \text{ mmol}} \times \frac{1 \text{ meq}}{1 \text{ mmol}}$

$\times \frac{50 \text{ mg CaCO}_3}{\text{meq}} = 90.0 \text{ mg/L as CaCO}_3$

b) Amount of alkalinity needed =

$90 - 48 \text{ mg/L as CaCO}_3 = 42 \text{ mg/L as CaCO}_3$

$42 \text{ mg/L as CaCO}_3 \times \frac{\text{meq CaCO}_3}{50 \text{ mg}} \times \frac{1 \text{ mmol HCO}_3^-}{1 \text{ meq}}$

$\times \frac{8.4 \text{ mmoles }}{\text{mg}} = 70.4 \text{ mg/L NaHCO}_3$
5.3 \( \text{BOD}_5 = \frac{9 - 1 \text{ mg/L}}{15/300} = 40 \text{ mg/L BOD}_5 \)

5.5 \( \text{BOD}_5 \) of untreated sewage:

\[
\text{BOD}_5 = \frac{\text{DO}_i - \text{DO}_{final}}{\rho} = \frac{6 - 2}{5/300} = 240 \text{ mg/L BOD}_5
\]

Treated wastewater:

\[
\text{BOD}_5 = \frac{9 - 4}{15/300} = 100 \text{ mg/L BOD}_5
\]

Percent \( \text{BOD}_5 \) remaining after treatment:

\[
= \frac{100 \times 100}{240} = 41.7\%
\]

\( \text{BOD}_5 \) removed: \( 1 - 41.7\% = 58.3\% \)
5.6 Read each value from the graph

a) $L_0 = 40 \text{ mg/L}$

b) $BOD_5 = 40 - 15 = 25 \text{ mg/L}$

c) $L_5 = 15 \text{ mg/L}$

5.8 a) $BOD_5 = \frac{9 - 4}{100/300} = 15 \text{ mg/L}$

b) $L_0 = \frac{9 - 2}{100/300} = 21 \text{ mg/L}$

c) $L_5 = 21 - 15 = 6 \text{ mg/L}$

d) $BOD_5 = L_0 \left(1 - e^{-\lambda t}\right)$

$15 = 21 \left(1 - e^{-\lambda (5)}\right)$

Solving for $\lambda$,

$\lambda = 0.25 \text{ day}^{-1}$
5.17 \: C_6H_{15}O_6N + 6 \: CO_2 \rightarrow 6 \: CO_2 + 6 \: H_2O + N_2H_3

\[ \text{NH}_3 + 2 \: O_2 \rightarrow \text{NO}_3^- + H^+ + H_2O \]

a) \[ 10 \: \text{mg/L algae} \times \frac{\text{mmol algae}}{197 \: \text{mg algae}} \times \frac{6 \: \text{CO}_2}{1 \: \text{algae}} \times \frac{32 \: \text{mgO}}{1 \: \text{mmol}} = 9.75 \: \text{mg O}_2 \text{ L}^{-1} \text{ demand} \]
(b) \[ 10 \: \text{mg L}^{-1} \text{ algae} \times \frac{1 \: \text{mmol algae}}{197 \: \text{mg algae}} \times \frac{1 \: \text{NH}_3}{1 \: \text{mmol algae}} \times \frac{2 \: O_2}{1 \: \text{NH}_3} \times \frac{32 \: \text{mg}}{1 \: \text{mmol}} = 3.25 \: \text{mg O}_2 \text{ L}^{-1} \text{ demand} \]

Total \: \text{O}_2 \text{ demand} = 9.75 + 3.25 = 13 \: \text{mg L}^{-1}
5.19  200 mg/L casein

\[
C_8H_{12}O_8 N_2 + 8O_2 \rightarrow 8CO_2 + 3H_2O + 2NO_3^-
\]

MW of Casein = 184 g/mole

a) Carbohydrate \(O_2\) Demand

\[
200 \text{ mg/L} \times \frac{\text{mmol}}{184 \text{ mg}} \times \frac{8 \text{O}_2}{1 \text{ casein}} \times \frac{32 \text{ mgO}_2}{1 \text{ mmol}} = 278 \text{ mg/L O}_2
\]

b) \(N\) demand:

\[
NH_3 + 2O_2 \rightarrow NO_3^- + H^+ + H_2O
\]

\[
200 \text{ mg/L casein} \times \frac{\text{mmol}}{184 \text{ mg}} \times \frac{2NH_3}{1 \text{ casein}} \times \frac{2O_2}{1 NH_3} \times \frac{32 \text{ mgO}_2}{1 \text{ mmol}} = 139 \text{ mg/L}
\]

c) Total \(O_2\) Demand = 278 + 139 = 417 mg/L \(O_2\) demand

d) BOD\(_5\) = 278 \((1 - e^{-0.25 \times 5})\) = 198 mg/L
\[ \text{c) Total } O_2 \text{ demand } = 1.42 \text{ g } O_2 + 0.57 \text{ g } O_2 = 1.99 \text{ g } O_2 \]