

Problem 9.8.12**KNOWN:**

Relation between moisture content of air and moisture content of wood at equilibrium, when the air is in contact with wood.

FIND:

Amount of moisture gained by wood when moisture in the air increases.

SCHEMATIC AND GIVEN DATA:**STRATEGY:**

The equilibrium relationship between moisture in wood and air, given in Figure 9.8, can be used to find moisture in wood at two moisture levels in air (two relative humidity values).

ASSUMPTIONS:

Sufficient contact time is present between wood and air so the entire wood is in equilibrium with air.

SOLUTION: Change in Moisture Content of Wood

From Figure 9.8 in text on equilibrium moisture for wood

At 20% RH, moisture content is $\frac{.04 \text{ kg water}}{\text{kg wet wood}}$

At 80% RH, moisture content is $\frac{0.17 \text{ kg water}}{\text{kg wet wood}}$

Since the wet wood (water + dry wood) is different in the two situations, the two moistures cannot be subtracted directly from each other.

Consider

$$\begin{aligned} \frac{\text{kg water}}{\text{kg dry wood}} &= \frac{\text{kg water}}{\text{kg wet wood} - \text{kg water}} \\ &= \frac{1}{\frac{\text{kg of wet wood}}{\text{kg of water}} - 1} \end{aligned}$$

$$\text{For } \frac{\text{kg of water}}{\text{kg of wet wood}} = 0.17,$$

$$\begin{aligned} \frac{\text{kg of water}}{\text{kg of dry wood}} &= \frac{1}{\frac{1}{0.17} - 1} \\ &= \frac{0.17}{0.83} \\ &= 0.205 \end{aligned}$$

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Likewise, .04 kg water/kg wet wood = .042 kg water/kg dry wood

Moisture gained

$$= .205 \frac{\text{kg water}}{\text{kg dry wood}} - .042 \frac{\text{kg water}}{\text{kg dry wood}} = .163 \frac{\text{kg water}}{\text{kg dry wood}}$$

COMMENTS:

Problem 9.8.16

KNOWN:

Desired final bacterial concentration can be reached by heating at 121°C for 6 minutes.

FIND:

How many minutes to heat to reach the same final bacterial concentration at a lower temperature of 111°C

SCHEMATIC AND GIVEN DATA**STRATEGY:**

We have the equation for concentration as function of time for a first order reaction, at a given temperature. If the final concentration is kept constant, temperature and time are related. Thus, for a different temperature, we can find the time.

ASSUMPTIONS:

First order kinetics for destruction is valid over the temperature range of interest.

SOLUTION:

$$c/c_0 = e^{-k_0 e^{-E/RT_2} t}$$

c/c_0 needs to stay the same at temperatures T_1 & T_2

$$\begin{aligned} e^{-k_0 e^{-E/RT_1} t_1} &= e^{-k_0 e^{-E/RT_2} t_2} \\ e^{\frac{E}{RT_1} t_1} &= e^{\frac{E}{RT_2} t_2} \\ t_2 &= e^{-E/R \left[\frac{1}{T_1} - \frac{1}{T_2} \right]} t_1 \\ &= e^{-35751 \left[\frac{1}{394} - \frac{1}{384} \right]} 6 \text{ min} \\ &= (10.62)(6) \text{ min} \\ &= 63.74 \text{ min} \end{aligned}$$

COMMENTS:

Problem 9.8.25

KNOWN:

Henry's law constant H at two different temperatures for oxygen-water system

FIND: Relative oxygen solubility at the two temperatures

SCHEMATIC AND GIVEN DATA**STRATEGY:**

This problem relates to equilibrium in gas (oxygen)-liquid (water with dissolved oxygen) system. Dissolved oxygen in water will be related using Henry's law constant.

ASSUMPTIONS: Partial pressure of oxygen in air does not change

SOLUTION:

$$H_{0^\circ\text{C}} = 25000 \text{ atm/mole fraction}$$

$$H_{20^\circ\text{C}} = 40000 \text{ atm/mole fraction}$$

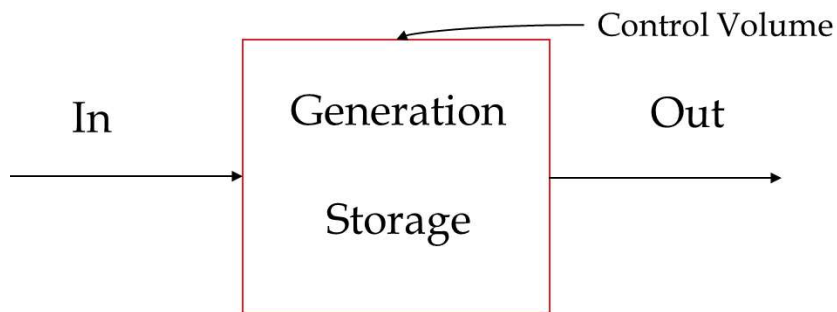
$$x_A = p_A / H$$

Thus,

$$\frac{x_{\text{O}_2, 20^\circ\text{C}}}{x_{\text{O}_2, 0^\circ\text{C}}} = \frac{H_{\text{O}_2, 0^\circ\text{C}}}{H_{\text{O}_2, 20^\circ\text{C}}} = \frac{25000}{40000} = 0.625$$

Problem 9.8.29**KNOWN:****FIND:**

Concentration of oxygen as a function of time and the steady state concentration.

SCHEMATIC AND GIVEN DATA**STRATEGY:**

Perform a mass balance on oxygen as a species, carefully tracking the units.

ASSUMPTIONS:

None

SOLUTION:

$$\begin{aligned}
 & 1) \\
 & \left(\underbrace{V \left[\text{cm}^3 \right] k_2 \left[\frac{1}{\text{s}} \right] \left(c_0 \left[\frac{\text{cm}^3 \text{O}_2}{\text{cm}^3} \right] - c \left[\frac{\text{cm}^3 \text{O}_2}{\text{cm}^3} \right] \right)}_{\text{In}} - \underbrace{0}_{\text{Out}} - \underbrace{V \left[\text{cm}^3 \right] N \left[\frac{\text{b}}{\text{cm}^3} \right] k \left[\frac{\text{cm}^3 \text{O}_2}{\text{b} \times \text{s}} \right]}_{\text{Consumption}} \right) \Delta t \\
 & = \underbrace{V \left[\text{cm}^3 \right] \Delta c \left[\frac{\text{cm}^3 \text{O}_2}{\text{cm}^3} \right]}_{\text{Change in Storage}}
 \end{aligned}$$

which simplifies to

$$-Nk + k_2(c_0 - c) = \frac{dc}{dt}$$

To solve it, we need the initial condition,

$$c = c_i \quad \text{at} \quad t = 0$$

All units are in $\text{cm}^3 \text{O}_2$ per s.

2) Solving the above governing equation

$$-Nk + k_2(c_0 - c) = \frac{dc}{dt}$$

$$\text{let } p = -Nk + k_2c_0$$

$$\frac{dc}{dt} = -k_2c + p$$

$$\int_{c_i}^c \frac{dc}{-k_2c + p} = \int_0^t dt$$

$$-\frac{1}{k_2} \ln \frac{p - k_2c}{p - k_2c_i} = t$$

$$c = \frac{-(p - k_2c_i)\exp(-k_2t)}{k_2} + \frac{p}{k_2}$$

$$c = \frac{-Nk + k_2c_0}{k_2} - \frac{(-Nk + k_2c_0 - k_2c_i)\exp(-k_2t)}{k_2}$$

3) At steady state,

$$-Nk + k_2(c_0 - c) = 0$$

$$\frac{Nk}{k_2} = c_0 - c$$

$$c = c_0 - \frac{Nk}{k_2}$$