Experiment No 1

Kinetic Dissolution of Benzoic Acid

Aim: To study physical dissolution of benzoic acid in water and determine the rate constant for physical dissolution.

Theory: The experiment consists of dissolving a solid in to a solution involving no reaction. The solid is moulded into a regular shape i.e. sphere or cylinder or a cube so that the surface area of the solid phase can accurately calculated. Rate of dissolution of the solid is measured and from the time dependent concentration of solid in solution data rate of mass transfer is obtained and hence the rate constant.

Rate of dissolution of benzoic acid (R^1)

$$R^1 = \frac{\{Conc\ of\ Benzoic\ acid\}_t - \{Conc\ of\ Benzoic\ acid\}_{t=0}}{Time\ (Sec)} \times Volume\ of\ water$$

$$R^1\ in\ {}^{gmole}/_{Sec}\ \ or\ \ {}^{kmole}/_{Sec}$$

Specific Rate of Dissolution (R)

$$R = {}^{R^1}/_{A_{ar}} \qquad {}^{kmole}/_{m^2 - Sec}$$

Solid liquid mass transfer plays an important role in many industrial operations. The dissolution may be accompanied by a dissolved solid-liquid or dissolved solid-gas reaction. If dissolution is accompanied with chemical reaction we expect enhancement in the rate of mass transfer due to simultaneous chemical reaction.

Procedure:

1. Measure the dimensions of the benzoic acid cylinder and couple to the main shaft.
2. Adjust the operating temperature of the water bath. Start the experiment and wait till temp of water in inner vessel is constant at the desired temperature.
3. Add about 400 ml of water in the inner tank and adjust the benzoic acid cylinder so that a water level of about 3 cm above the cylinder surface is maintained.
4. Adjust the speed of the motor at the desired level and run the experiment for about 3 hours. Take out 5 or 10 ml sample after every 10 or 15 min interval and titrate each sample with N/50 NaOH using phenolphthalein as indicator and hence estimate the time dependent concentration of benzoic acid in water. Record the concentration Vs time data.
5. Stop the motor and measure the dimensions of the cylinder (OD, length)
6. Repeat steps 1 to 5 for 4 different rotation speed and study the effect of the same on the rate constant.
7. This experiment can also be conducted at 4 different temperatures at single rotation speed and temperature dependence of rate constant can be evaluated.

If V_{NaOH} is the volume of N/50 NaOH used for titration against 10 ml of Benzoic Acid Solution the concentration of Benzoic Acid in solution is,

$$C = [Benzoic\ Acid] = \frac{V_{NaOH}}{10} \times \frac{1}{50} = \frac{V_{NaOH}}{500} \text{ gmole/l or kmole/m}^3$$

Calculations:

Record –

Initial dimensions of Benzoic Acid Cylinder, D_i (m)

Initial length of Benzoic Acid cylinder, L_i (m)
Diameter of steel rod, d_{rod} (m)
Final dimensions of Benzoic acid cylinder, Di, L_f
Average diameter of Benzoic acid cylinder $D_{ar} = \frac{D_i + D_f}{2}$
Average length of Benzoic acid cylinder $L_{ar} = \frac{L_i + L_f}{2}$
Average surface area of Benzoic acid cylinder
$A_{ar} = \pi D_{ar} L_{ar} + 2[\pi/4(D_{ar}{}^2 - D_{rod}{}^2)$

Rate of dissolution of benzoic acid (R^1)

$$R^1 = \frac{\{Benzoic\ acid\ in\ water\}_t - \{Benzoic\ acid\ in\ water\}_{t=0}}{Time\ (Sec)} \times Volume\ of\ water$$

$$R^1\ in\ {}^{gmole}/_{Sec}\quad or\quad {}^{kmole}/_{Sec}$$

Specific Rate of Dissolution (R)

$$R = {}^{R^1}/_{A_{ar}} \qquad {}^{kmole}/_{m^2 - Sec}$$

$\{Benzoic\ acid\ in\ water\}_{t=0} = 0$ Initially,
$\{Benzoic\ acid\ in\ water\}_t$ = t = bulk concentration of Benzoic Acid in water.
Solubility of Benzoic Acid in water = $C^* = 0.0276$ kmole/m^3

The rate constant, K_{SL} for physical dissolution is obtained from the integrated material balance for benzoic acid-

$$-K_{SL}\frac{A_P}{V}t = \ln\left[1 - \frac{C}{C_{A0}}\right]$$

Where V = volume of solution
C = Concentration of Benzoic Acid in solution at time t
A_p= Cylinder Surface

Plot of $ln\left[1 - \frac{C}{C_{A0}}\right]$ Vs t

Slope = $K_{SL}\frac{A_P}{V}$
Or, $K_{SL} = Slope \times \frac{V}{A_P}$ m/sec