Problem 16-04 Gas adsorption on solids, Langmuir adsorption isotherm, specific area

Experimental data on adsorption of pentane on the charcoal at the temperature of 230 °C were well described by the Langmuir isotherm

$$\upsilon = \frac{1.953 \cdot p}{1 + 0.09 \cdot p}$$

υ denotes the volume of the gas (cm^3, corrected to standard conditions 273.15 K and 101.325 kPa), adsorbed on 1 g of charcoal, and p equilibrium pressure (kPa). Calculate the total area of 5 g of charcoal. One molecule of pentane occupies on the surface of the charcoal an area of 0.76 nm^2.

[$\mathcal{A}$ = 2215.6 m^2 (υ_m = 21.7 $cm^3\ g^{-1}$)]

Solution:

m_s = 5 g

σ = 0.76 nm^2 $molecule^{-1}$ = $7.6 \cdot 10^{-19}$ m^2 $molecule^{-1}$

[p] = kPa

[υ] = $cm^3\ g^{-1}$

T_o = 273.15 K , p_o = 101.325 kPa

$$\left.\begin{array}{l} \upsilon = \dfrac{1.953 \cdot p}{1 + 0.09 \cdot p} \\ \upsilon = \dfrac{\upsilon_m \cdot b \cdot p}{1 + b \cdot p} \end{array}\right\} \quad \begin{array}{l} b = 0.09\ kPa^{-1} \\ \upsilon_m \cdot b = 1.953\ cm^3\ kPa^{-1} \end{array} \quad \left.\begin{array}{l} \\ \\ \end{array}\right\} \quad \upsilon_m = \frac{1.953}{b} = \frac{1.953}{0.09} = 21.7\ cm^3$$

Gas amount adsorbed in a monolayer on 1 g of the solid: $n_m = N / N_A$

$$p_o\, \upsilon_m = n_m \boldsymbol{R}\, T_o = \frac{N}{N_A} \boldsymbol{R}\, T_o$$

$$N = \frac{p_o \cdot \upsilon_m}{\boldsymbol{R} T_o} \cdot N_A = \frac{1.01325 \cdot 10^5 \cdot 21.7 \cdot 10^{-6}}{8.314 \cdot 273.15} \cdot 6.022 \cdot 10^{23} = 5.8305 \cdot 10^{20}\ g^{-1}$$

$$\left[\frac{(N\ m^{-2}) \cdot (m^3\ g^{-1})}{(N\ m\ mol^{-1}\ K^{-1}) \cdot K} \cdot mol^{-1} = g^{-1}\right]$$

Specific area: $\mathcal{A}_{sp} = N \cdot \sigma = 5.8305 \cdot 10^{20} \cdot 7.6 \cdot 10^{-19} = 443.118\ m^2\ g^{-1}$

Area of 5 g of the solid:

$\mathcal{A} = m_s \cdot \mathcal{A}_{sp} = 5 \cdot 443.118 = 2215.6\ m^2$