Problem 16-03 Langmuir adsorption isotherm

The adsorption of methane on the solid adsorbent can be described by Langmuir adsorption isotherm. The surface area of 3.4 g of the solid adsorbent is 629 m^2. One adsorbed methane molecule occupies on the solid surface an area σ = 0.25 nm^2. One of experiments revealed that at equilibrium pressure 62.9 kPa the capacity of the solid surface for methane adsorption was saturated from 65 %. Determine the constants of Langmuir isotherm. (M_{CH4} = 16.043 g mol^{-1}).

[a_m = 0.00123 mol_{CH4} /g_s = 0.0197 g_{CH4}/g_s ; b = 0.03 kPa^{-1}]

Solution:

Langmuir isoterm: $a = a_m \cdot \frac{b \cdot p}{1 + b \cdot p}$

a_m the amount of adsorbate on 1 g of the solid adsorbent necessary to form a monolayer

Calculation of the constant a_m:

m_s = 3.4 g (index $_s$ ...solid adsorbent)

$\mathcal{A}$ = 629 m^2

specific area: $\mathcal{A}_{sp} = \mathcal{A} / m_s = 629/3.4 = 185\ m^2\ g_s^{-1}$

σ =0.25 nm^2 = $2.5 \cdot 10^{-19}$ m^2

Number of methane molecules adsorbed on the surface of 1 g of solid:

$N = \mathcal{A}_{sp} / \sigma = 185/2.5 \cdot 10^{-19}$ [$(m^2\ g^{-1})/m^2 = g^{-1}$]

$N = 7.4 \cdot 10^{20}$

a_m /($mol_{CH4}\ g_s^{-1}$):

$a_m = N/\boldsymbol{N_A} = 7.4 \cdot 10^{20}/6.022 \cdot 10^{23} = 1.2288 \cdot 10^{-3}\ mol_{CH4}\ g_s^{-1}$

or

a_m /($g_{CH4}\ g_s^{-1}$):

$a_m = M_{CH4} \cdot N/\boldsymbol{N_A} = 16.043 \cdot 7.4 \cdot 10^{20}/6.022 \cdot 10^{23} = 1.9714 \cdot 10^{-2}\ g_{CH4}\ g_s^{-1}$

Calculation of the constant b:

p = 61.9 kPa $a_1 = 0.65\ a_m$

$$\frac{p}{0,65 \cdot \cancel{a_m}} = \frac{1}{b \cdot \cancel{a_m}} + \frac{p}{\cancel{a_m}}$$

$$b = \frac{1}{\left(\frac{1}{0.65} - 1\right) \cdot 61.9} = 0.03\ kPa^{-1}$$