Problem 16-10 Adsorption from solution on solids – Langmuir isotherm

The specific area of the charcoal sample was determined by means of the adsorption from the methylene blue solution. Only methylene blue is adsorbed from the solution and the adsorption data are well expressed by Langmuir isotherm. One molecule of the methylene blue occupies in the monolayer an area of 0.62 nm^2. Calculate the specific area of the adsorbent from the results of these two experiments:

(A) the equilibrium concentration of the bulk solution found after shaking 1 g of charcoal with 100 cm^3 of the solution of concentration $1{\cdot}10^{-4}$ mol dm^{-3} was $6{\cdot}10^{-5}$ mol dm^{-3},

(B) the shaking of 2 g of charcoal with the same volume of the solution of the same concentration resulted in equilibrium concentration of the bulk solution $4{\cdot}10^{-5}$ mol dm^{-3}.

[$\mathcal{A}_{sp}$ = 4.48 m^2 g^{-1}]

Solution:

c_2^{o} = 0.0001 mol dm^{-3}

V^{o} = 100 cm^3 = 0.1 dm^3

σ = 0.62 nm^2 = $6.2{\cdot}10^{-19}$ m^2

$$\Omega = \frac{V^{o}}{m_s}\cdot(c_2^{o}-c_2) \qquad \left[\frac{\mathrm{dm}^3}{\mathrm{g}}\cdot \mathrm{mol\ dm}^{-3} = \mathrm{mol\ g}^{-1}\right]$$

(A) $(m_s)_A$ = 1 g

$(c_2)_A = 6{\cdot}10^{-5}$ mol dm^{-3}

$$\Omega_A = \frac{V^{o}}{(m_s)_A}\cdot\left(c_2^{o}-(c_2)_A\right) = \frac{0.1}{1}\cdot(1\cdot10^{-4}-6\cdot10^{-4}) = 4\cdot10^{-6}\ \mathrm{mol\ g_{charcoal}^{-1}}$$

(B) $(m_s)_B$ = 2 g

$(c_2)_B = 4{\cdot}10^{-5}$ mol dm^{-3}

$$\Omega_B = \frac{V^{o}}{(m_s)_B}\cdot\left(c_2^{o}-(c_2)_B\right) = \frac{0.1}{2}\cdot(1\cdot10^{-4}-4\cdot10^{-4}) = 3\cdot10^{-6}\ \mathrm{mol\ g_{charcoal}^{-1}}$$

Langmuir isotherm:

$$\Omega = \Omega_m\cdot\frac{b\cdot c_2}{1+b\cdot c_2}$$

$$\frac{c_2}{\Omega} = \frac{1}{b\cdot\Omega_m}+\frac{c_2}{\Omega_m}$$

$$\left.\begin{aligned} &(A)\quad \frac{6\cdot10^{-5}}{4\cdot10^{-6}} = \frac{1}{b\cdot\Omega_m}+\frac{6\cdot10^{-5}}{\Omega_m}\\ &(B)\quad \frac{4\cdot10^{-5}}{3\cdot10^{-6}} = \frac{1}{b\cdot\Omega_m}+\frac{4\cdot10^{-5}}{\Omega_m}\end{aligned}\right\} \qquad \Omega_m = \frac{6\cdot10^{-5}-4\cdot10^{-5}}{\frac{6}{0.4}-\frac{4}{0.3}} = 1.2\cdot10^{-5}\ \ \mathrm{mol\ g_{charcoal}^{-1}}$$

$\mathcal{A}_{sp} = \Omega_m \cdot \boldsymbol{N_A} \cdot \sigma = 1.2{\cdot}10^{-5}{\cdot}6.022{\cdot}10^{23}{\cdot}6.2{\cdot}10^{-19}$ = 4.48 m^2 $(\mathrm{g_{charcoal}})^{-1}$