Problem 16-05 Gas adsorption on solids – Langmuir adsorption isotherm

The specific area of a solid adsorbent is 230 $m^2\ g^{-1}$. Experiments revealed that 18 cm^3 of argon (corrected to standard conditions) is adsorbed on 1 g of this adsorbent at equilibrium pressure of 22 kPa. Assuming that adsorption in this system is adequately described by the Langmuir isotherm, calculate the volume of argon adsorbed on the surface of 26 g of the solid at equilibrium pressure of 90 kPa. One atom of argon occupies on adsorption on the solid surface the area of 0.2 nm^2.

[V = 832.5 cm^3 on 26 g (v_m = 42.8 $cm^3\ g^{-1}$, b = 0.033 kPa^{-1}, v_2 = 32.02 $cm^3\ g^{-1}$)]

Solution:

$\mathcal{A}_{sp}$ = 230 $m^2\ g^{-1}$
σ = 0.2 nm^2 molecule^{-1} = $2\cdot10^{-19}$ m^2 molecule^{-1}

p_1 = 22 kPa v_1 = 18 $cm^3\ g^{-1}$ at T_o = 273.15 K , p_o = 101.325 kPa
p_2 = 90 kPa v_2 = ?

Calculation of the constant v_m :

Number of molecules adsorbed in monolayer on the surface of 1 g of solid

$N = \mathcal{A}_{sp} / \sigma$
[($m^2\ g^{-1}$) / (m^2 molecule^{-1})]

$$p_o\, v_m = n\, \boldsymbol{R}\, T_o = \frac{N}{\boldsymbol{N_A}}\, \boldsymbol{R}\, T_o = \frac{\mathcal{A}_{sp}}{\sigma \cdot \boldsymbol{N_A}}\, \boldsymbol{R}\, T_o$$

$$v_m = \frac{230}{2\cdot10^{-19}\cdot6.022\cdot10^{23}}\cdot\frac{8.314\cdot273.15}{1.01325\cdot10^{5}} = 4.28\cdot10^{-5}\ m^3\ g^{-1} = 42.8\ cm^3\ g^{-1}$$ (at standard conditions)

Calculation of the constant b (from p_1, v_1 and v_m):

$$v = \frac{v_m\cdot b\cdot p}{1+b\cdot p} \quad\Rightarrow\quad \frac{v_m}{v_1} = \frac{1}{b\cdot p_1}+1 \quad\Rightarrow\quad b = \frac{1}{p_1\cdot\left(\frac{v_m}{v_1}-1\right)} = \frac{1}{22\cdot\left(\frac{42.8}{18}-1\right)} = 0.033\ kPa^{-1}$$

$$v_2 = \frac{v_m\cdot b\cdot p_2}{1+b\cdot p_2} = \frac{42.8\cdot0.033\cdot90}{1+0.033\cdot90} = 32.02\ cm^3\ g^{-1}$$

Volume of gas adsorbed on 26 g:

$V = 26\cdot v_2 = 26\cdot32.02 = 832.5\ cm^3$