PHYSICAL CHEMISTRY LABORATORY II

EXPERIMENT NUMBER: 7

NAME OF THE EXPERIMENT: Adsorption

DATE OF THE EXPERIMENT:4/5/2023

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GROUP NUMBER: 5

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SECTION: Thursday Afternoon

DATA SHEET

Table 1. Datas from the Experiment

[Hac],M	NaOH used for titraton (mL)	Weight of Charcoal (g)
0,02 M	2,8 mL	1,51 g
0,04M	5,9 mL	1,51 g
0,1M	18,5 mL	1,52 g
0,2 M	19,7 mL	1,52 g
0,3 M	26,1 mL	1,51 g
0,4 M	34,3 Ml	1,50 g

CALCULATIONS

1) Calculate the number of moles of acetic acid in the solution before adsorption. Calculate the number of moles of acetic acid in the solution after adsorption.

$M = \frac{n}{V}$ thus n=(MxV)

→ **Before the adsorption**

For the first solution which is 0,4M ,

$$n = (0{,}4\ M) \times (100\ mL) \times \frac{1\ L}{1000\ mL} = 40\ mmol\ or\ 0{,}040\ mol$$

Some calculation process for other solutions then,

Table 2. [Hac],M V_{HAc} and $n_{before,HAc}$

[Hac],M	Volume of Acetic Acid (mL)	n before,HAc (mmol)
0,4	100	40
0,3	100	30
0,2	100	20
0,1	100	10
0,04	100	4
0,02	100	2

→ **After the Adsorption**

NaOH which used moles = Moles of Hac in 10 mL aliquat

Because of the using 100 mL n_{NaOH} multiplied by 10.

V_{NaOH} x M_{NaOH} = n_{NaOH} (mmol)

For 0,4 M which is first solution,

V_{NaOH} = 34,3 mL M_{NaOH}= 0,1 M n_{NaOH} = (34,3 mL)x(0,1M) = 3,43 mmol (in 10 mL aliquat)

$n_{NaOH,after\ HAc}$ = (3,43 mmol)x(10) = 34,3 mmol

Same calculation process for 0.3M and 0.2 M solutions

NaOH which used moles = Moles of Hac in 25 mL aliquat
Because of the using 100 mL n_{NaOH} multiplied by 4,
For 0,1M
V_{NaOH} = 18,5 mL M_{NaOH}= 0,1 M n_{NaOH} = (18,5mL)x(0,1M) = 1,85 mmol (in 25 mL aliquat)

$n_{NaOH,after\ HAc}$ = (1,85 mmol)x(4) = 7,4 mmol

Same calculation process for 0,04 M and 0,02 M solutions then,

Table 3. Hac],M $V_{Aliquat}$ and $n_{after,HAc}$

[Hac],M	Aliquat for analysis (mL)	n after,HAc (mmol)
0,4	10	34,3
0,3	10	26,1
0,2	10	19,7
0,1	25	7,4
0,04	25	2,36
0,02	25	1,12

→ $n_{adsorbed,HAc} = n_{before,HAc} - n_{after,Hac}$

For 0,4 M which is first solution,
$n_{adsorbed,HAc}$ = (40 mmol -34,3 mmol) = 5,7 mmol
For other steps same calculations process then,

Table 4. [HAc] and $n_{adsorbed,HAc}$

[Hac],M	n adsorbed,HAc (mmol)
0,4	5,7
0,3	3,9
0,2	0,3
0,1	2,6
0,04	1,64
0,02	0,88

2)Determine x (mmoles of adsorbed Acetic Acid /1.5 grams of Charcoal) for each sample.

$$x = \frac{mmoles\ of\ adsorbed\ Acetic\ Acid}{1{,}5\ grams\ of\ Charcoal}$$

For 0,4 M which is first solution,
$x = \frac{5{,}7\ mmol}{1{,}50\ grams\ of\ Charcoal}$ = 3,8 mmol/g

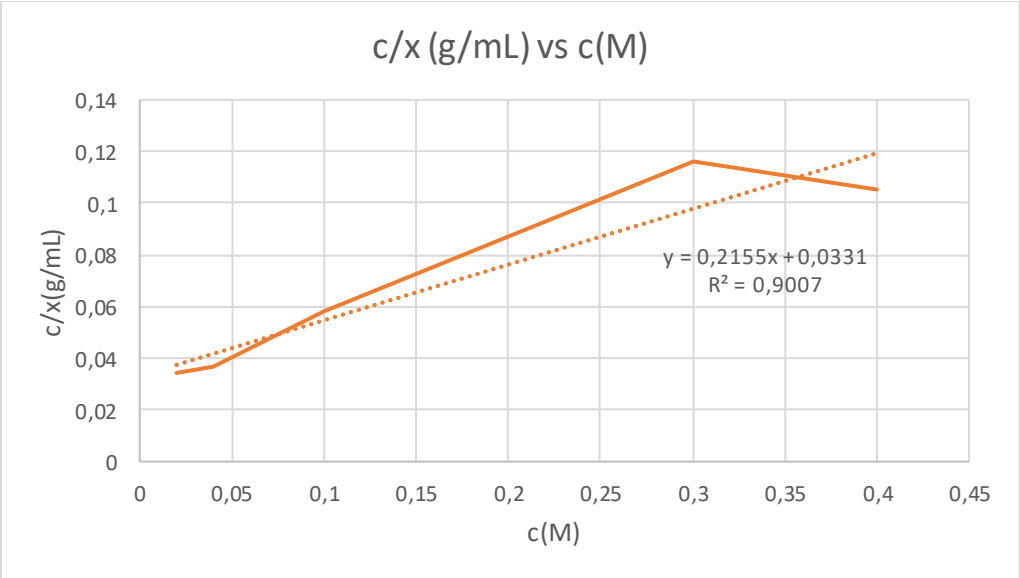
Same calculation process for other steps then,

Table 5. [Hac],M and x values

[Hac],M	c/x (g/mL)
0,4	0,10526
0,3	0,11616
0,2	1,01338
0,1	0,058463
0,04	0,036829
0,02	0,034318

3)Plot the Langmuir isotherm and determine the Langmuir parameters x_{max} and K .

Graph 1. c/x (g/mL) vs c(M) Graph



→ **The relation of Langmuir Isotherm:** $\frac{c}{x} = \frac{1}{K \times x_{max}} + \frac{c}{x_{max}}$

The slope of Graph 1 equal to ($1/x_{max}$) and intercept equal to ($1/K.x_{max}$)
Equation from the graph,
y = 0,2155x + 0,0331 and R^2 = 0,9007

$$\frac{1}{x_{max}} = 0,2155 \; thus \; x_{max} = \frac{1}{slope} = \frac{1}{0,2155} = 4,64037 \sim 4,6404$$

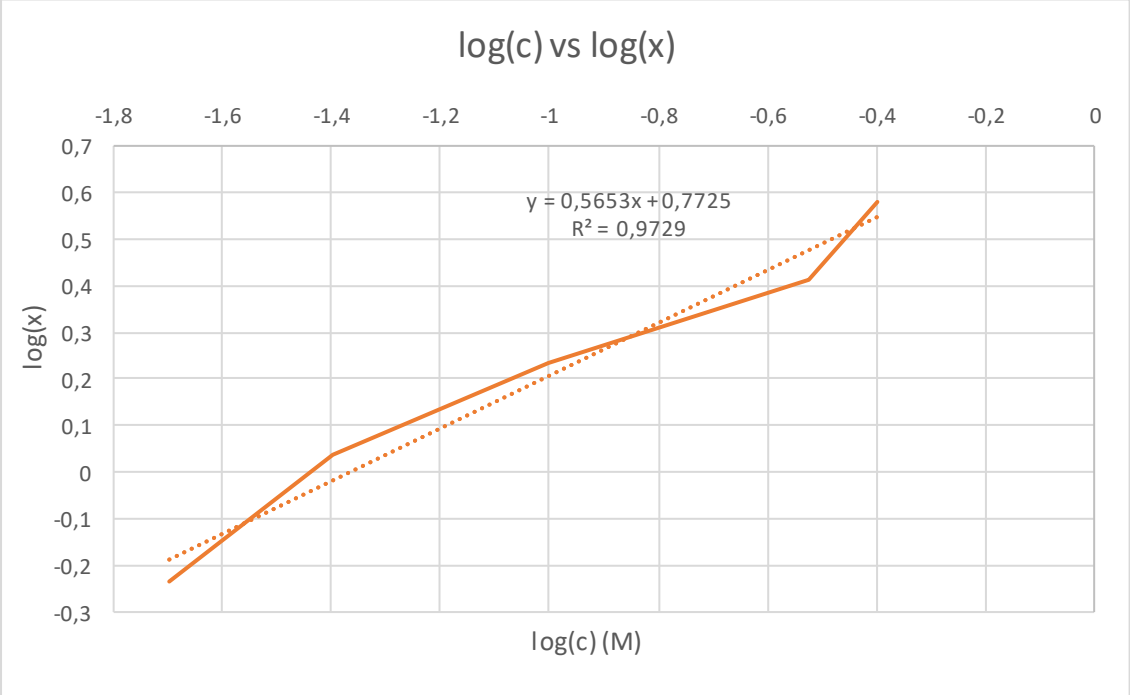
$$\frac{1}{K \times x_{max}} = 0,0331 \; thus \; \frac{1}{intercept} = K \times x_{max} \; then \; \frac{1}{0,0331} = K \times (4,64037)$$
$$= 6,51057 = 6,51$$

4)Make the suggested plot to determine the Freundlich parameters k and n.

Table 6. logc and logx values of solutions

[Hac],M	log c	log x
0,4	-0,39794	0,57978
0,3	-0,52288	0,41207
0,2	-0,69897	-1,7047
0,1	-1	0,23312
0,04	-1,3979	0,035869
0,02	-1,6989	-0,23449

Graph 2. log(c) vs log(x) Graph



→ **The relation of Freundlich Isotherm : $x = kc^{1/n}$**
log(x) = log(k) + (1/n)log(c)

Equation from Graph 2 is
y = 0,5653x + 0,7725 and R^2 = 0,9729

Slope of Graph 2 equal to (1/n)) and the intercept of Graph 2 equal to log(k) thus

$$\frac{1}{n} = 0{,}5653 \; thus \; n = \frac{1}{0{,}5653} = 1{,}7689 \sim 1{,}8$$

$$Intercept = \log(k) \; thus \; k = 10^{intercept} \; thus \; k = 10^{0{,}7725} = 5{,}92243$$

QUESTIONS

1) Acetic acid is adsorbed on the surface of the activated Charcoal. In this process, activated Charcoal acts as an adsorbent. The activated Charcoal's large surface area and high pore structure provide suitable conditions for adsorbing acetic acid. In addition to these features, activated Charcoal does not react with many compounds and molecules because of its inert quality, which is very useful for adsorption. It is also an inexpensive and readily available adsorbent. It is a solid compound and helps molecules absorb better than ions.[1]

2) In the case of acetic acid on activated Charcoal, the Langmuir isotherm is generally considered the most appropriate model. The isotherm used for the adsorption process should be chosen according to the adsorbate and adsorbent properties. In addition, the ambient conditions where the absorption takes place are also essential and are not independent of these properties. There are three different isotherms suitable for specific systems. The first is the Langmuir isotherm, and if the adsorption is done as a single layer, The latter is the Freundlich isotherm and is more suitable for the adsorption process of gases. Finally, it suits Brauner - Emmett - Teller (B.E.T.) semi-empirical isotherm multi-molecular adsorption layers.[2] Freundlich isotherm is ideal for this experiment. The reason for this is that the adsorption in this experiment is reversible. It is homogeneous and occurs in some areas of the adsorbent surface. The fact that acetic acid is a small and polar molecule with low concentration helps the activated charcoal surface to be adsorbed in certain regions, which helps to provide the conditions that the Freundlich isotherm has. Therefore, the Freundlich isotherm is the most suitable for this experiment because Freundlich the adsorption capacity is provided, and the adsorption can be performed at the highest level.[3]

DISCUSSION

The experiment aims to search for isotherms suitable for the adsorption of acetic acid on the adsorbent-activated charcoal surface. It was investigated whether Freundlich isotherm or Langmuir isotherm was more fortunate. Different concentrations of equal amounts of activated Charcoal were prepared in the experiment. These designed solutions were mixed in a water bath at room temperature. It was kept for twenty minutes. Then, a 25 mL aliquot was filtered from 10 mL of these solutions from those with 0.4, 0.3 0.2 M concentrations and those with 0.1, 0.04, and 0.02 M concentrations. Afterward, the indicator was added to the solutions and titrated with 0.1 M NaOH, and when the color change was observed, the spent volumes were recorded. Thus, the adsorbed moles could be calculated by finding the concentrations before and after the adsorption. The adsorbed moles values found helped find the maximum and experimental value of the adsorbed molecule per gram of adsorbent.

For Langmuir's theorem, c/x (g/mL) vs. c(M) was plotted, and the x_{max} value was found based on the slope of this graph. For the Freundlich isotherm. The graph of log(c) vs log(x) is plotted to find n from its slope and the k value using the intercept. With the help of these calculations, it can be decided which isotherm is suitable for the experiment.By comparing the values obtained from the slopes and intercepts of the graphs, it is seen that the Freundlich isotherm is ideal for the adsorption of acetic acid in the activated charcoal process.

While doing the experiment calculations, I observed that the x value for 0.2 M suddenly deviated. As a result, I got this value by subtracting it from the graphics. This may be due to an error in the experiment. The main reasons for these errors can be considered as the following:

The water bath cover was not working, and the experiment could not achieve the desired temperature. In addition, the point where the color change was observed in the titration may be missed, and as a result, the volume used may be recorded incorrectly. When measuring on the scale for activated Charcoal, it is too long to calibrate the scale. It lasted and changed constantly, so the activated charcoal values added and subtracted to reach the grams of activated Charcoal required in the experiment may not have been correctly read and mismeasured.

References

[1] Dąbrowski, A., Podkościelny, P., Hubicki, Z., & Barczak, M. (2005). Adsorption of phenolic compounds by activated carbon—A critical review. *Chemosphere*, *58*(8), 1049–1070. https://doi.org/10.1016/j.chemosphere.2004.09.067

[2] Sing, K. S. (1985). Reporting physisorption data for gas/solid systems with special reference to the determination of surface area and porosity (recommendations 1984). *Pure and Applied Chemistry*, *57*(4), 603–619. https://doi.org/10.1351/pac198557040603

[3] Zhang, Y., Chen, Y., Wang, C., & Wei, Y. (2014b). Immobilization of 5-aminopyridine-2-tetrazole on cross-linked polystyrene for the preparation of a new adsorbent to remove heavy metal ions from aqueous solution. *Journal of Hazardous Materials*, *276*, 129–137. https://doi.org/10.1016/j.jhazmat.2014.05.027