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Adsorption Isotherms of Glucose on Barium Sulphate Crystallites in Aqueous Positively Charged Solution at Room Temperature

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The adsorption isotherms of glucose on barium sulphate crystallites in aqueous positively charged solution at room temperature was investigated by spectrophotometric method. The amount of glucose adsorbed (X) increases with the increasing of the equilibrium concentrations (C) which agrees well with Freundlich-Langmuir isotherms.

Key Words: Adsorption, Isotherms, Glucose, Barium Sulphate.

INTRODUCTION

The adsorption isotherms of glucose on barium sulphate crystallites in aqueous positively charged solution at room temperature was investigated by spectrophotometric method. The amount of glucose adsorbed (X) increases with the increasing of the equilibrium concentrations (C) which agrees well with Freundlich-Langmuir isotherms[1-4].

EXPERIMENTAL

All chemicals used were AnalaR grade. All solutions were prepared according to the usual analytical procedures using double distilled water.

Solid barium sulphate crystallites was prepared by the addition of 1 L 0.2 M sodium sulphate to 1 L 0.2 M barium chloride and the solution was left for 12 h after which the precipitate was filtered and washed for 4 d. The first day washed with about 100 mL NH_3/methanol and then with double distilled water. After that for 2 consecutive days wash with about 100 mL methanol and then with double distilled water. Finally, On fourth day and till seventh day washed with double distilled water. The precipitate was filtered and dried in an oven to about 50 ºC and finally stored in a desiccator.

Nelson's **A** reagent was prepared by dissolving 12.5 g of anhydrous sodium carbonate, 12.5 g of potassium sodium tartarate, 10 g of sodium bicarbonate and 100 g of anhydrous sodium sulphate in 350 mL of double distilled water and the volume was diluted with water to 500 mL. Nelson's **B** reagent was prepared by dissolving 7.5 g of copper sulphate pentahydrate in 50 mL of double distilled water and a drop of conc. sulphuric acid. Nelson's alkaline copper reagent was prepared by mixing 12.5 mL of Nelson's reagent **A** with 0.5 mL of Nelson's reagent **B**.

Arsenomolybdate reagent was prepared by dissolving 25 g of $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ in 250 mL of double distilled water and 21 mL of conc. H_2SO_4. 3 g of $Na_2HAsO_4\cdot 7H_2O$ dissolved in 25 mL of double distilled water and added to the above acid molybdate solution and stored in a brown bottle at 37 ºC to be used within 24 h.

The standard solution of glucose was prepared by dissolving 100 mg of glucose (Hopkins and Williams reagent grade) in 1 L of double distilled water to give a concentration of 100 μg/mL other concentrations were prepared by dilution.

Glucose standard calibration curve[5]: From each of the glucose concentrations 1.6×10^{-4}, 3.2×10^{-4}, 4.8×10^{-4}, 6.4×10^{-4}, 8.0×10^{-4} and 10.0×10^{-4} M known volumes were added in six optically uniform tubes in the order listed as follows:

Tube number	1	2	3	4	5	6
Volume of glucose	0.00	0.2	0.4	0.6	0.8	1.00
Volume of water added	0.00	0.8	0.6	0.4	0.2	0.00

1 mL of Nelson's alkaline copper reagent was added to each tube and shaken well. The tubes were placed simultaneously in a boiling water bath and heated for exactly 20 min. The tubes were then removed simultaneously and cooled in a beaker of cold water (25 ºC) , then 1 mL of arsenomolybdate reagent was added to each tube and then shaken well occasionally for 5 min to dissolve the Cu_2O precipitate and to reduce the arsenomolybdate. After coprous oxide has dissolved, 7 mL of distilled water were added to each tube and then mixed thoroughly. The absorbance of each tube was then measured in a spectrophotometer at 540 nm after setting the instrument to zero absorbance[6] with blank (Table-1).

Method of adsorption: 250 mL of each of the (glucose + $BaCl_2$) concentrations 1.6×10^{-4}, 3.2×10^{-4}, 4.8×10^{-4}, 6.4×10^{-4}, 8.0×10^{-4} and 10.0×10^{-4} M were prepared by diluting the required volume of the glucose standard solution and 0.001 M $BaCl_2$ (positive charges) in the appropriate amount of double distilled water. 100 mL of each of these solutions were transferred to a 250 mL conical flask, then 1 g of the dried prepared barium sulphate was added to each flask and the mixture in each flask was shaken well for 3 h and allowed to settle down at room temperature overnight.

TABLE-1
ABSORBANCE AT ROOM TEMPERATURE OF THE DIFFERENT CONCENTRATIONS OF GLUCOSE IN POSITIVELY CHARGED SOLUTION AT 540 nm

Tube no.	1	2	3	4	5	6	AA
Volume of glucose (mL)	0.00	0.200	0.400	0.600	0.800	1.000	1.000
Volume of water added (mL)	0.00	0.800	0.600	0.400	0.200	0.000	0.000
Absorbance of 1.6×10^{-4} M	0.00	0.038	0.083	0.117	0.156	0.185	0.049
Absorbance of 3.2×10^{-4} M	0.00	0.101	0.179	0.294	0.365	0.426	0.171
Absorbance of 4.8×10^{-4} M	0.00	0.120	0.261	0.398	0.480	0.651	0.305
Absorbance of 6.4×10^{-4} M	0.00	0.188	0.349	0.523	0.697	0.822	0.444
Absorbance of 8.0×10^{-4} M	0.00	0.224	0.441	0.644	0.899	0.137	0.634
Absorbance of 10.0×10^{-4} M	0.00	0.281	0.545	0.960	1.121	1.362	0.852

AA = Unknown glucose after the establishment of the adsorption equilibrium.

After the adsorption equilibrium an aliquot of the aqueous solution (1 mL not containing any barium sulphate crystallites) of each flask was withdrawn and analysed for glucose concentration remained at equilibrium spectrophotometrically.

Spectrophotometric analysis[6]: After the establishment of the adsorption equilibrium above 1 mL not containing any barium sulphate crystallites of each of the six conical flasks was withdrawn and transferred to six optically uniform test tubes and analysed for glucose concentration remained at equilibrium spectrophotometrically by the addition of 1 mL of Nelson's alkaline copper reagent and 1 mL of arsenomolybdate reagent and treated as in the glucose standard calibration curve. The results are given in Tables 2-7.

TABLE-2
ABSORBANCE OF THE STANDARDIZATION RUNS FOR A (1.6×10^{-4} M) GLUCOSE SOLUTIONS THAT CARRY POSITIVE CHARGES

Tube number	Concentration (c) mol/L	Absorbance at 540 nm
1	0.00	0.000
2	3.2×10^{-5}	0.038
3	6.4×10^{-5}	0.083
4	9.6×10^{-5}	0.117
5	12.8×10^{-5}	0.156
6	16.0×10^{-5}	0.185
7	Equilibrium concentration	0.049

RESULTS AND DISCUSSION

Beer-Lambert's law relation is[7]

$$\log_{10} I_O/I = A = \varepsilon C\ d$$

TABLE-3
ABSORBANCE OF THE STANDARDIZATION RUNS FOR A (3.2×10^{-4} M) GLUCOSE SOLUTIONS THAT CARRY POSITIVE CHARGES

Tube number	Concentration (c) mol/L	Absorbance at 540 nm
1	0.00	0.000
2	0.60×10^{-4}	0.101
3	1.28×10^{-4}	0.179
4	1.92×10^{-4}	0.294
5	2.56×10^{-4}	0.365
6	3.20×10^{-4}	0.426
7	Equilibrium concentration	0.171

TABLE-4
ABSORBANCE OF THE STANDARDIZATION RUNS FOR A (4.8×10^{-4} M) GLUCOSE SOLUTIONS THAT CARRY POSITIVE CHARGES

Tube number	Concentration (c) mol/L	Absorbance at 540 nm
1	0.00	0.000
2	0.90×10^{-4}	0.120
3	1.92×10^{-4}	0.261
4	2.88×10^{-4}	0.398
5	3.84×10^{-4}	0.480
6	4.80×10^{-4}	0.651
7	Equilibrium concentration	0.305

TABLE-5
ABSORBANCE OF THE STANDARDIZATION RUNS FOR A (6.4×10^{-4} M) GLUCOSE SOLUTIONS THAT CARRY POSITIVE CHARGES

Tube number	Concentration (c) mol/L	Absorbance at 540 nm
1	0.00	0.000
2	1.28×10^{-4}	0.188
3	2.56×10^{-4}	0.349
4	3.84×10^{-4}	0.523
5	5.12×10^{-4}	0.697
6	6.40×10^{-4}	0.822
7	Equilibrium concentration	0.449

were A is the absorbance, ε is the molar absorptivity constant, C is the concentration and d is the thickness of the absorbing medium. The value of C is proportional to the number of moles (n), thus the above equation can be written as:

$$A = \alpha n$$

were α is the calibration constant = εd, to calculate the concentration C from the equation $A = \alpha n$

TABLE-6
ABSORBANCE OF THE STANDARDIZATION RUNS FOR A (8.0×10^{-4} M) GLUCOSE SOLUTIONS THAT CARRY POSITIVE CHARGES

Tube number	Concentration (c) mol/L	Absorbance at 540 nm
1	0.00	0.000
2	1.60×10^{-4}	0.224
3	3.20×10^{-4}	0.441
4	4.80×10^{-4}	0.644
5	6.40×10^{-4}	0.899
6	8.00×10^{-4}	1.137
7	Equilibrium concentration	0.634

TABLE-7
ABSORBANCE OF THE STANDARDIZATION RUNS FOR A (10.0×10^{-4} M) GLUCOSE SOLUTIONS THAT CARRY POSITIVE CHARGES

Tube number	Concentration (c) mol/L	Absorbance at 540 nm
1	0.00	0.000
2	2.00×10^{-4}	0.281
3	4.00×10^{-4}	0.545
4	6.00×10^{-4}	0.960
5	8.00×10^{-4}	1.121
6	10.00×10^{-4}	1.362
7	Equilibrium concentration	0.852

$$n = C\,V/1000$$ were V is the volume

since V = 100 in this research, thus

$$A = \alpha C/10$$

and hence

$$C = 10\,A/\alpha$$

According to Beer-Lambert's equation the plot of the absorbance A against the concentration C must be straight line passing through the origin from which the slope of the line can be calculated which equals to εd, thus the value of α was estimated since the value of the thickness of the absorbing medium d was equal to 1 cm (the width of the cell used in the spectrophotometer).

The results are evaluated graphically (graphs are not shown) from which the value of α (the calibration constant) was calculated from the slope of the straight line that fits nicely in the calibration curve, according to the equation:

$$A = \alpha C/10$$

When the equilibrium concentration of glucose (C) was plotted against the amount of glucose adsorbed (X), the results showed that the amount of glucose adsorbed (X) increases with the increase of the equilibrium concentration until a certain equilibrium concentration is reached where there is no adsorption occurs. This facts indicates that the whole available surface of barium sulphate crystallites is covered with a monolayer of glucose (Table-8). The Langmuir isotherm depends on the assumption that every site is equivalent and the ability of a particle to bind is independent on whether or not nearby sites are occupied[1]. Failure of these assumptions, results in the Freundlich isotherm and that is why Freundlich isotherm is better represented by adsorption from solutions. To support this fact log (X) was plotted against log (C), where a straight line has been obtained with slope 1/n and intercept log k as a fit for the Freundlich isotherm according to Freundlich equation[8,9]:

$$\log x/m = \log k + 1/n \log c$$

TABLE-8
ADSORPTION DATA FOR GLUCOSE IN AQUEOUS POSITIVELY CHARGED SOLUTION AT ROOM TEMPERATURE

Flask number	1	2	3	4	5	6
Initial concentration of glucose $\times 10^{-4}$ in mol/L	1.60	3.20	4.80	6.40	8.00	10.0
Absorbance at 540 nm	0.048	0.141	0.247	0.434	0.553	0.792
Equilibrium concentration (C) of glucose $\times 10^{-4}$ in mol/L	0.35	1.10	2.00	3.00	4.00	5.80
Adsorbed concentration (m) of glucose $\times 10^{-4}$ in mol/L	1.25	2.10	2.80	3.40	4.00	4.40
Adsorbed concentration (X) of glucose $\times 10^{-3}$ in g/g	2.252	3.783	5.044	6.125	7.206	7.927
log (C)	-4.456	-3.959	-3.699	-3.523	-3.398	-3.237
log (X)	-2.647	-2.422	-2.297	-2.213	-2.142	-2.101

Thus, the adsorption of glucose on barium sulphate crystallites that carry positive charges (Ba^{2+}) is enhanced to some extend compared to the adsorption of glucose on the barium sulphate crystallites with no charge on them[10]. The poor adsorption observed, generally could be explained by the fact that the barium sulphate crystallites are not finely divided and of different particle size, also the temperature is not constant as these experiments were carried out at room temperature which changes enormously during the day.

REFERENCES

1. P.W. Atkins, Physical Chemistry, Oxford University Press, Oxford, edn. 3 (1986).
2. A.E. Alexander and P. Johnson, Colloid Science, Oxford University Press, Oxford (1949).
3. I. Langmuir, *J. Am. Chem. Soc.*, **83**, 2767 (1916).
4. I. Langmuir, *J. Am. Chem. Soc.*, **40**, 1361 (1918).
5. R.M. Oliver and B. Marsden, European Spectroscopy News (1975).
6. D.P. Shoemaker, C.W. Garland and J.W. Nibler, Experiments in Physical Chemistry, edn. 5 (1989).
7. G.H. Brown and E.M. Sallee, Quantitative Chemistry, Prentice-Hall Inc., USA, edn. 1 (1963).
8. Organic Electronic Spectral Data, Wiley-Interscience, Vol. 1-13 (1960-1977).
9. G. Halsey, *J. Phys. Chem.*, **16**, 931 (1948).
10. I.A. Yassin, M.Sc. Thesis, Faculty of Science, University of Khartoum, Khartoum, Sudan (2000).

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