Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Polymer 47 (2006) 1772–1773
polymer
www.elsevier.com/locate/polymer

Polymer Communication

Reply to Comments on 'Chitosan functionalized with 2[-bis-(pyridylmethyl) aminomethyl]4-methyl-6-formyl-phenol: Equilibrium and kinetics of copper(II) adsorption' by Yuh-Shan Ho: Discussion on pseudo second order kinetic expression

K. Vasanth Kumar [a,*], V.T. Fávere [b,1]

[a] *Department of Chemical Engineering, AC College of Technology, Anna University, Chennai, TN 600 025, India*
[b] *Departamento de Química, Universidade Federal de Santa catarina, Florianópolis, SC 88040-900, Brazil*

Received 10 November 2005; received in revised form 9 December 2005; accepted 17 January 2006
Available online 7 February 2006

Abstract

The present communication reports a short history on the pseudo second order kinetic models previously reported for sorption systems. This present paper presents the information citing the original presentation of pseudo second order kinetic expression.

Keywords: Pseudo second order; Sorption; Citation error

In reaction to the comments by Dr Y.S. Ho [1] on the work of Justi et al. [2], we would like to address the following topics:

Our work was mainly commented asking to cite the correct reference for pseudo second order kinetic expression. We would like to point out that in 1984, Blanchard et al. proposed [3] a second order rate equation for the exchange reaction of divalent metallic ions onto NH_4^+ ions fixed zeolite particles. The linearized form of Blanchard et al's second order kinetics was given by:

$$\frac{1}{q_e - q} - \alpha = kt \tag{1}$$

where q_e and represents the amount of dye adsorbed at equilibrium and at any time t and represented in terms of milligram/gram, k is the second order rate constant. The rate constant can be obtained from the slope of plot between $1/(q_e - q)$ versus time t. Applying boundary conditions $q=0$ for $t=0$, it follows that $\alpha = 1/q_e$. Thus this model has an advantage to predict the equilibrium uptake capacity without the support of experimental data. The non-linearized form of Eq. (1) can be given by:

$$q = \frac{ktq_e + \alpha q_e - 1}{kt + \alpha} \tag{2}$$

Applying the value of α in Eq. (1) and rearranging, the non-linearized form of pseudo second order expression can be obtained as follows:

$$q = \frac{q_e^2 kt}{1 + kq_e t} \tag{3}$$

Eq. (3) can be linearized to different types as shown in Table 1. From Table 1, it was observed that the Eq. (3) can be linearized to atleast four different types: type 1, type 2, type 3 and type 4, respectively. Table also shows the way to obtain the kinetic parameters from these linearized pseudo second order expressions. Out of the four linearized form of pseudo second order expression shown in Table 1, type 1 was reported by Ho and McKay [4] in 1998 for the sorption of dye ions onto peat particles. Thus it is evident that pseudo second order model for solid/liquid adsorption systems was originally proposed by Blanachard et al. [3]. In the adsorption field, Langmuir isotherm [5] have been the most widely used isotherm to represent the adsorption process at equilibrium conditions. In literatures four linearized types of Langmuir isotherm have been reported [6–9]. Irrespective of the linearized expressions reported, it have been widely called as the Langmuir isotherm.

* Corresponding author. Tel.: +91 9884353192; fax: +91 44 265 34748.
E-mail addresses: vasanth_vit@yahoo.com (K.V. Kumar), favere@qmc.ufsc.br (V.T. Fávere).
[1] Tel.: +55 4833316844; fax +55 4833316850.

0032-3861/$ - see front matter © 2006 Published by Elsevier Ltd.
doi:10.1016/j.polymer.2006.01.061

Table 1
Different linearized form of pseudo second order expression

Type	Linear form	Plot	Parameters
Type-1	$\frac{1}{q}=\frac{1}{kq_e^2}+\frac{1}{q_e}t$	t/q_t vs. t	$q_e=1/\text{slope}$ $K_2=\text{slope}^2/\text{intercept}$ $h=1/\text{intercept}$
Type-2	$\frac{1}{q}=\left(\frac{1}{kq_e^2}\right)\frac{1}{t}+\frac{1}{q_e}$	$1/q_t$ vs. $1/t$	$q_e=1/\text{intercept}$ $K_2=\text{intercept}^2/\text{slope}$ $R=1/\text{slope}$
Type-3	$\frac{1}{t}=\frac{K_2q_e^2}{q}-\frac{K_2q_e^2}{q_e}$	$1/t$ vs. $1/q$	$q_e=-\text{slope}/\text{intercept}$ $K_2=\text{intercept}^2/\text{slope}$ $R=\text{slope}$
Type-4	$\frac{q}{t}=K_2q_e^2-\frac{K_2q_e^2q}{q_e}$	q/t vs. q	$q_e=-\text{intercept}/\text{slope}$ $K_2=\text{slope}^2/\text{intercept}$ $R=\text{intercept}$

Irrespective of the linearized type of pseudo second order expression, it will be more appropriate to cite the original paper of Blanachard et al. [3] for pseudo second order kinetics thus the paper of Blanachard et al. [3] would be read for the pseudo second order model we had used in our paper.

References

[1] Ho YS. Comments on Chitosan functionalized with 2[-bis-(pyridylmethyl) aminomethyl]4-methyl-6-formyl-phenol: equilibrium and kinetics of copper(II) adsorption. Polymer 2005;46:1451–2.
[2] Justi KC, Laranjeira MCM, Neves A, Mangrich AS, Fávere VT. Chitosan functionalized with 2[-bis-(pyridylmethyl) aminomethyl]4-methyl-6-formyl-phenol: equilibrium and kinetics of copper(II) adsorption. Polymer 2004;45(18):6285–90.
[3] Blanachard G, Maunaye M, Martin G. Removal of heavy metals from waters by means of natural zeolites. Water Res 1984;18:1501–7.
[4] Ho YS, McKay G. The kinetics of sorption of basic dyes from aqueous solution by sphagnum moss peat. Can J Chem Eng 1998;76: 822–7.
[5] Langmuir I. The constitution and fundamental properties of solids and liquids. J Am Chem Soc 1916;38:2221–95.
[6] Longhinotti E, Pozza F, Furlan L, Sanchez MNM, Klug M, Laranjeira MCM, et al. Adsorption of anionic dyes on the biopolymer chitin. J Brazilian Chem Soc 1998;9:435–40.
[7] Ho YS. Selection of optimum sorption isotherm. Carbon 2004;42: 2115–6.
[8] Kumar KV, Sivanesan S. Prediction of optimum sorption isotherm: comparison of linear and non-linear method. J Hazard Mater 2005; 126(1-3):198–201.
[9] Kumar KV, Sivanesan S. Comparison of linear and non-linear method in estimating the sorption isotherm parameters for safranin onto activated carbon. J Hazard Mater 2005;123(1-3):288–92.