



A novel hypercrosslinked polymeric adsorbent modified by phenolic hydroxyl group of 2-naphthol with bromoethane as crosslinking reagent

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ABSTRACT

A novel hypercrosslinked polymeric adsorbent of LM-6 was prepared by post-crosslinking reaction with 2-naphthol. Bromoethane was used as crosslinking reagent to substitute poisonous organic compound of chloromethyl methylether. Selective adsorption on LM-6 in mixture solution which consisting of 2-naphthol and naphthalene shows that the adsorption of 2-naphthol and naphthalene in aqueous solution are mainly pushed by physical interaction. The adsorption of 2-naphthol is also partly pushed by chemical interaction. The adsorptive enthalpy illuminates that there exists hydrogen-bonding between 2-naphthol and LM-6. Owing to hydrogen-bonding, the adsorption capacity of 2-naphthol on LM-6 is markedly higher than that of naphthalene. In aqueous solution, the adsorption process contains two steps: desorption of water first and then adsorption of solute. Dynamic analysis shows that adsorption capacity of 2-naphthol is higher than that of naphthalene. The adsorption rate is mainly affected by the diffusion of liquid membrane, the diffusion inside particulate or coordinated effect.

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1. Introduction

Wastewater which contains poisonous organic compounds causes a serious environmental problem due to the rapid development of chemical industry. Consequently, there has been a growing interest in developing and implementing various adsorbents to remove specific organic substances from wastewater (Azanova & Hradil, 1999). Due to their wide variations in functionality, surface area, and porosity, polymeric adsorbents have been increasingly viewed as an alternative to activated carbon or zeolite for selective removal of specific organic substances from contaminated water (Gusler, Browne, & Yoram, 1993; Juang, Shiau, & Shao, 1999; Jung et al., 2001). Amberlite XAD-4 resin is one of the polystyrene-based adsorbents with a high surface area. It has been referred as the best polymeric adsorbent for the removal of phenol from phenol-contaminated streams. However, its extreme hydrophobic surface results in poor application for aqueous solutions. Thus, some activation solvents (methanol, acetone or acetonitrile) have been used to enhance its surface contact with aqueous solutions in pre-treatment process. Moreover, its adsorption capacity to most organic substances is lower than that of the activated carbon.

In 1990, Davankov and Tsyurupa (Davankov & Tsyurupa, 1990) developed a 'hypercrosslinking technique' to improve the performance of polymeric adsorbents, that is, post-crosslinking of low-crosslinked macroporous polystyrene in accordance with the

Friedel-Crafts in solution or in a highly swollen state, by using large amount of bi-functional crosslinking reagents, yields a new type of copolymers. These products own an exceptional 'hypercrosslinked' structure and a much higher adsorption capacity than the conventional gel-type and macro-reticular copolymers. In most post-crosslinking reaction, chloromethyl methylether was used as bi-functional crosslinking reagent (Davankov & Tsyurupa, 1990; Li et al., 2002; Pan et al., 2002; Tsyurupa & Davankov, 2006). However, the chloromethyl methylether is a poisonous organic compound.

In the present research, we prepared a novel hypercrosslinked polymeric adsorbent of LM-6 (name of the novel adsorbent) for the removal of naphthalene and 2-naphthol from their aqueous solutions. To enhance the phenolic hydroxyl group content, 2-naphthol was used in the post-crosslinking reaction because the reaction activity of 2-naphthol is higher than that of phenol. To avoid using poisonous organic compound of chloromethyl methylether, bromoethane was used as crosslinking reagent. The dynamic analysis of 2-naphthol and naphthalene adsorption on LM-6 was conducted in nonaqueous solution.

2. Materials and methods

2.1. Chemicals

Styrene, divinylbenzene (purity: 55.4%) and bromoethane were purchased from Shanghai Chemical Reagent Company (Shanghai, China). Acetone, ethanol, *n*-heptane, zinc chloride, and dibenzoyl

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peroxide were purchased from Shanghai Chemical Reagent Company (Shanghai, China) and were used without further purification. Naphthalene and 2-naphthol were purchased from Shanghai Chemical Reagent Co., Ltd. (Shanghai, China). Photographic-grade gelatin and liquid paraffin were obtained from Shanghai Runjie Chemical Reagent Plant (Shanghai, China).

2.2. Synthesis LM-6 adsorbent

1. The synthesis of low-crosslinked macroporous styrene-divinylbenzene copolymers (PS-DVB) was carried out as follows: 44.0 g of styrene, 6.0 g of divinylbenzene, 0.5 g of dibenzoyl peroxide, and 25.0 g of liquid paraffin were mixed at room temperature in a 500 ml round-bottomed flask. 300 ml of 1 wt% gelatin aqueous solution was then added to the flask. Suitable stirring rate was adjusted, and the polymerization process was performed at 353 K for 12 h. At the end of the reaction, the mixture was cooled to room temperature, and the filtered polymer was rinsed more than three times with hot water. Finally, the copolymer was extracted with acetone for 8 h and then dried for 2 h under vacuum (<10 mm Hg) at 333 K.
2. Bromomethylation of PS-DVB: 28.0 g of low-crosslinked macroporous poly(styrene-divinylbenzene) beads were swollen with 300 ml bromoethane in a 500 ml round-bottomed flask. Under mechanical stirring, 11.2 g of zinc chloride was gradually added into the flask. The mixture was continuously stirred at 301 K for 12 h. The polymer beads were filtered and then extracted with acetone for 8 h in a Soxhlet apparatus and dried under vacuum (<10 mm Hg) at 333 K for 8 h.
3. The synthesis of hypercrosslinked polymeric adsorbent modified by phenolic hydroxyl group: in a 500 ml round-bottomed flask, 15 g of bromomethylated poly(styrene-divinylbenzene) beads (bromine content is 6.36%) were swollen in 200 ml of 1,2-dichloroethane. Under mechanical stirring, 2.6 g 2-naphthol was added, and then 2 g of zinc chloride was added after 1 h of stirring. The mixture was further stirred at 343 K for 4 h and at 368 K for another 10 h. Finally, the mixture was poured into an acetone bath containing 1% hydrochloric acid. The polymer bead was filtered and extracted with acetone in a Soxhlet apparatus for 8 h, and then dried under vacuum (<10 mm Hg) at 333 K for 2 h. The dried sample of hypercrosslinked polymeric adsorbent modified by phenolic hydroxyl group which comes from 2-naphthol was named as LM-6.

2.3. Characterization of polymer beads

The specific surface area and pore distribution of resin were measured with a Micromeritics ASAP-2010 surface area measurement instrument (Micromeritics Instrument, Norcross, USA) following the BET method. The bromine content was obtained by determining the mol of bromine.

The content of phenolic hydroxyl group was determined as follows: the standard sodium hydroxide solution passed through the column of polymeric adsorbent at a flow rate of 6 ml/min. Distilled water (10 ml) was used to swill out residual sodium hydroxide for three times. Standard hydrochloric acid solution (0.1 mol/L) was used to titrate the collected liquid with the indicator of methyl orange. The exchange quantity of acid (Q_w , mmol/g) was calculated by following equation (He & Huang, 1995):

$$Q_w = \frac{N_1 V_1 - N_2 V_2}{W} \quad (1)$$

where N_1 is the concentration of standard sodium hydroxide solution (mol/L), V_1 is the volume of solution (ml), N_2 is the concentra-

tion of standard hydrochloric acid solution (mol/L), V_2 is the volume of solution (ml), and W is the weight of dry sample (g).

The skeleton density (ρ_s , g/cm³) of resin was measured as follows: a special solvent was used to soak resin. The solvent can infiltrate into the interstices or pores of resin but do not swell resin. In the determination, the solvent of *n*-heptane was used. The weighed resin sample (g_1 , g) was introduced into a pycnometer, and then *n*-heptane was added to soak the resin for 5 h. *n*-Heptane was added again to reach a certain graduation of pycnometer, and then the total weight (g_3 , g, contain the weight of resin, *n*-heptane and pycnometer) was accurately weighed. A blank assay was conducted to obtain the weight g_2 (g, contain the weight of *n*-heptane and pycnometer). The skeleton density of resin was calculated according to the following equation (He & Huang, 1995):

$$\rho_s = \frac{\rho_h g_1}{g_2 - (g_3 - g_1)} \quad (2)$$

where ρ_h (g/cm³) is the density of *n*-heptane. The apparent density (g/cm³) of resin was determined by volume mensuration.

2.4. Adsorption experiment

The adsorption experiment of resin was carried out as follows: 0.100 g of home-made resin was introduced into a 250 ml conical flask, and then 40 ml aqueous solution ($V_{\text{water}}:V_{\text{ethanol}} = 5:7$) was added into flask. The initial concentration of naphthalene and 2-naphthol were both 500 mg/L. The flasks were completely sealed and placed in a G 25 model incubator shaker (THZ312, Shanghai Jinghong Laboratory Instrument Co., Ltd.) at a pre-settled temperature and shaken under 100 rpm. The batch equilibrium test run continued for over 24 h to ensure reaching adsorption equilibrium, and then the concentrations of naphthalene or 2-naphthol compounds (C_e) were determined by UV-visible spectrophotometer (UV2550, Shimadzu Corporation, Japan). Thus, Q_e (mg/g), the adsorption capacity, was calculated according to

$$Q_e = \frac{(C_0 - C_e)V}{m} \quad (3)$$

where V is the volume of solution (L), m is the weight of dry resin (g). Then the adsorption selectivity (K) of 2-naphthol was calculated by Eq. (4):

$$K = \frac{Q_A \times C_B \times M_B}{Q_B \times C_A \times M_A} \quad (4)$$

where Q_B (mg/g) and Q_A (mg/g) are the adsorption capacity of naphthalene and 2-naphthol, C_B (mg/L) and C_A (mg/L) are the concentration of naphthalene and 2-naphthol in aqueous solution, M_B (g/mol) and M_A (g/mol) are molecular weight of naphthalene and 2-naphthol.

The experiment of selective adsorption was conducted like above experiment. However, the concentrations of naphthalene and 2-naphthol were varied of 500, 400, 300 and 200 mg/L. The adsorption capacity was also calculated according to Eq. (3). The concentration of solution after reaching adsorption equilibrium was also measured by UV2550.

2.5. Dynamic experiment

In a 250 ml conical flask, 0.50 g of LM-6 and 100 ml mixed solution (the concentration of naphthalene or 2-naphthol were both 600 mg/L in non-aqueous system, $V_{\text{n-heptane}}:V_{\text{ethanol}} = 5:7$) were added. The flask was completely sealed and placed in a G 25 model incubator shaker THZ312 at 298 K and shaken under 100 rpm. The concentrations of naphthalene or 2-naphthol at a certain time (C_t) were determined by UV2550-visible spectrophotometer. Thus, Q_t (mg/g), the adsorption capacity at a certain time, was calculated according to Eq. (3). Q_e (mg/g) was also determined and calculated

after the incubator shaker continuously running over 24 h. The adsorption percent at a certain time was calculated by Q_t dividing equilibrium adsorption capacity Q_e .

3. Results and discussion

3.1. Characterizations of polymeric adsorbent

The physical characteristics of LM-6 adsorbent were listed in Table 1. The hypercrosslinked polymeric adsorbent, modified by phenolic hydroxyl group with crosslinking reagent of bromoethane instead of chloromethyl methylether, was successfully prepared. 2-Naphthol was successfully used in the post-crosslinking Friedel-Crafts reaction to obtain a novel adsorbent which modified by phenolic hydroxyl group. The residual bromine content of LM-6 is relative low, and this means that the home-made adsorbent has relatively high phenolic hydroxyl group content.

3.2. SEM analysis of polymeric adsorbent

The SEM spectrograms of LM-6 are shown in Fig. 1(a)–(c) (magnified 50, 5000 and 10,000 times). The diameters of the resin-ball of LM-6 are between 400 μm and 600 μm . The surface of polymeric adsorbent is covered with compact “grape ball”, and there distribute many micro-pore among “grape balls”. Because the diameters of “grape balls” are less than 100 nm, the hypercrosslinked polymeric adsorbent modified by phenolic hydroxyl group can be regarded as nanometer polymeric adsorbent. There is little disfigurement of grainy residua on the surface of LM-6.

3.3. Equilibrium adsorption of naphthalene and 2-naphthol on LM-6

3.3.1. Equilibrium adsorption of naphthalene and 2-naphthol on LM-6 in aqueous solution

The selective coefficients in aqueous solution were 11.7, 11.8, 11.5 and 10.7 with the initial concentration of 2-naphthol and

naphthalene at 298 K variety from 200, 300, 400 to 500 mg/L. The selective coefficient (about 11.00) of 2-naphthol on LM-6 is approximately invariable along with the initial concentration of naphthalene and 2-naphthol. This selective coefficient is much higher than that of aniline (only about 2.00) when the adsorption was conducted between benzene and aniline on LM-6 (Liu, 2007). The reason is likely that LM-6 has much better polar comparability to 2-naphthol since the phenolic hydroxyl group of LM-6 comes from 2-naphthol. The equilibrium adsorption isotherms in Fig. 2 indicate that adsorption capacity enhances with the concentration of naphthalene and 2-naphthol, and the adsorption capacity of 2-naphthol is distinctly higher than that of naphthalene. The phenolic hydroxyl group within hypercrosslinked polymeric adsorbent can form hydrogen-bonding with that of 2-naphthol. Hence, hypercrosslinked polymeric adsorbent modified by phenolic hydroxyl group is prone to adsorb 2-naphthol.

The data of the equilibrium adsorption isotherms of 2-naphthol and naphthalene on LM-6 resin at 298 K were analyzed by least squares method using Freundlich equation and Langmuir equation, respectively. The regression equations at 298 K along with the correlation coefficient R and the characteristic constants of K_F and n are listed in Table 2. The Freundlich equations are reliable because the correlation factors (R) were larger than 0.99. Hence, physical adsorption is dominant in the adsorption process of 2-naphthol and naphthalene on LM-6. The K_F value of 2-naphthol on LM-6, a relative indicator of adsorption capacity in the Freundlich theory, indicates that the adsorption capacity of 2-naphthol is higher than that of naphthalene. The exponent n was larger than 1 in the case of 2-naphthol, indicating that the adsorption of 2-naphthol is favorable adsorption. The relatively lower K_F value of naphthalene indicates that the adsorption capacity of naphthalene is less. The competitive adsorption between 2-naphthol and naphthalene is infirm when the initial concentrations are 200 mg/L. Hence, we used other three group data to regress the adsorption process by Langmuir equation. The adsorption of naphthalene can not fit Langmuir equation while that of 2-naphthol can fit the equation well. The unconformity of naphthalene illuminates that the adsorption of naphthalene do not have the characteristic of chemical adsorption. The correlation factors (R) of regression Langmuir equation for 2-naphthol indicates that there is chemical adsorption during the adsorbing process of 2-naphthol. The relative high values of K_b and R show that the chemical adsorption is not weak. The chemical adsorption is obviously caused by the forming of hydrogen-bonding between resin and 2-naphthol. This may be the reason that the adsorption capacity of 2-naphthol is distinctly higher than that of naphthalene. The high A_s value means that LM-6 has a high adsorption capacity to 2-naphthol in theory. This should be attributed to the high BET surface area, symmetrical and dense micro-aperture of LM-6.

Table 1
Characteristic properties of LM-6 resin

Property	LM-6
BET surface area (m^2/g)	588.1
Particle size (mm)	0.5–1.5
Initial bromine content (%)	6.36
Residual bromine content (%)	1.05
Phenolic hydroxyl group content (mmol/g)	2.16
Apparent density (g/cm^3)	0.771
Skeleton density (g/cm^3)	1.389
Porosity (ml/g)	0.577
Average pore diameter (nm)	2.0

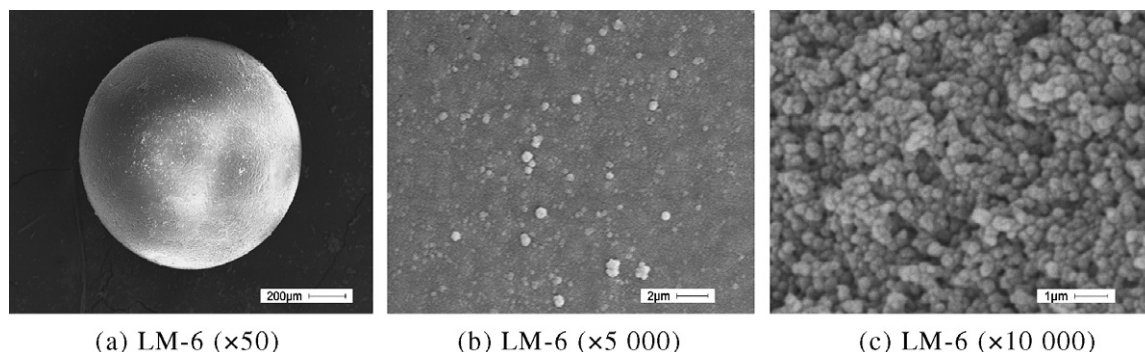


Fig. 1. (a) SEM spectrogram of LM-6 magnified by 50 times; (b) SEM spectrogram of LM-6 magnified by 5000 times; (c) SEM spectrogram of LM-6 magnified by 10,000 times. SEM spectrogram was obtained with scanning electron microscope (JXA-840A, JEOL, Tokyo, Japan).

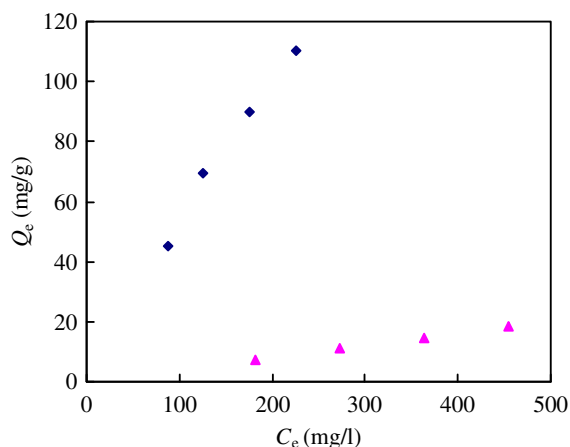


Fig. 2. Equilibrium adsorption isotherms (adsorption capacity vs. equilibrium concentration) for 2-naphthol and naphthalene on LM-6 at 298 K, the initial concentration of 2-naphthol (◆) and naphthalene (▲) are varied from 200, 300, 400 to 500 mg/L.

3.3.2. Thermodynamics for 2-naphthol adsorption on LM-6

The adsorption enthalpy was calculated according to Van't Hoff equation (Garcia-delgado, Cotoruelo-Minguez, & Rodriguez, 1992; Juang & Chou, 1996).

$$\Delta H = \frac{-R \ln(C_e^1/C_e^2)}{(1/T_2 - 1/T_1)} \quad (5)$$

where C_e^1 is the equilibrium concentration of adsorbate at T_1 temperature, and C_e^2 represents the equilibrium concentration of adsorbate at T_2 temperature.

Gibbs free energy change was obtained by Gibbs equation. Because the equilibrium adsorption isotherm of 2-naphthol can well-fit Freundlich isotherm, the Gibbs free energy change can be calculated by Eq. (6) (Bell & Tsezos, 1987):

$$\Delta G = -nRT \quad (6)$$

where n is exponent of Freundlich equation, R is the gas constant. Entropy change can be calculated according to the Gibbs–Helmholtz equation:

$$\Delta S = (\Delta H - \Delta G)/T. \quad (7)$$

The enthalpy, Gibbs free energy, entropy change of adsorption of 2-naphthol and naphthalene on LM-6 in aqueous solution at 298 K and 318 K were listed in Table 3.

Unlike other common adsorption process, the adsorption enthalpies of 2-naphthol and naphthalene are both over zero, which indicates that the adsorption is endothermic process. The phenolic hydroxyl group of hypercrosslinked polymeric adsorbent can form hydrogen-bonding with water molecule. Hence, there is a process of desorption for water molecule within the resin before adsorbing adsorbate. Desorbing water molecule is an endothermic process while adsorbing is an exothermic process. Because adsorbing 2-naphthol or naphthalene needs desorbing more water molecule, the adsorption is endothermic process. Since the regression Langmuir equation of 2-naphthol can well fit the adsorption isotherm and the adsorption enthalpy reaches 18.97 kJ/mol, there

Table 3

Thermodynamic data for the adsorption of 2-naphthol and naphthalene on LM-6

Adsorbate	Q_e (mg/g)		ΔH (kJ/mol)	ΔG (kJ/mol)		ΔS (J/mol K)	
	298 K	318 K		298 K	318 K	298 K	318 K
2-Naphthol	110.2	144.3	18.97	−2.68	−2.86	72.65	68.65
Naphthalene	18.5	27.9	2.14	−2.43	−2.60	15.34	14.91

should exist hydrogen-bonding adsorption between 2-naphthol and hypercrosslinked polymeric adsorbent of LM-6. However, the adsorption of naphthalene can only be pushed by hydrophobic interaction owing to the low adsorption enthalpy of 2.14 kJ/mol. At the same temperature, Gibbs free energy change of the adsorption of 2-naphthol on LM-6 is less than that of naphthalene. This means that there is more strong adsorbing interaction between 2-naphthol and resin. Entropy change of adsorption of 2-naphthol and naphthalene on LM-6 are both over zero, and the entropy change of 2-naphthol is much bigger than that of naphthalene. The results indicate that adsorption process contains two steps: desorption of water first and then adsorption of solute, and much more water should be desorbed before adsorbing the same quantity of 2-naphthol than that of naphthalene.

3.3.3. Dynamics for 2-naphthol and naphthalene adsorption on LM-6

Dynamic data for adsorption of 2-naphthol and naphthalene in non-aqueous system on LM-6 were listed in Table 4. The adsorption capacity of 2-naphthol at any time is much higher than that of naphthalene. The adsorption percent of 2-naphthol reaches over 80% at 30 min, while that of naphthalene only over 60%. The adsorbing rate of 2-naphthol is obviously much higher than that of naphthalene.

To illuminate the diffusion of 2-naphthol or naphthalene, the first order rate equation of Lagergren, diffusion rate equation inside particulate of Dumwald–Wagner or Kannan–Sundaram were used to calculate adsorption rate. The first order rate equation of Lagergren is shown as follows (Dutta, Baruah, & Dutta, 1997):

$$\lg(Q_e - Q_i) = \lg Q_e - \frac{K}{2.303} t \quad (8)$$

or

$$\lg(1 - F) = -\frac{K}{2.303} t \quad (9)$$

where K is diffusion rate constant, the adsorption percent F is calculated by Q_i/Q_e . Diffusion rate equation inside particulate of Dumwald–Wagner (McKay, Otterburn, & Aja, 1985) is described by Eq. (10).

$$F = \frac{Q_i}{Q_e} = 1 - \frac{6}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{n^2} \exp(-n^2 Kt) \quad (10)$$

can simplified into Eq. (11):

$$\lg(1 - F^2) = -\frac{K}{2.303} t. \quad (11)$$

According to Kannan–Sundaram (Streat & Sweetland, 1998), diffusion rate equation inside particulate can be described by Eq. (12).

Table 2

Regression equations for equilibrium adsorption of 2-naphthol and naphthalene on LM-6 at 298 K

Adsorbate/adsorbent	Regression equation	K_F	A_s (mg/g)	n	K_b (L/g)	R
2-naphthol/LM-6	$\ln Q_e = -0.2831 + 0.9249 \ln C_e$	0.7534	416.7	1.0812	1.5803	0.9946
	$C_e/Q_e = 1.5186 + C_e/416.7$					0.9923
naphthalene/LM-6	$\ln Q_e = -3.3133 + 1.0184 \ln C_e$	0.0364	/	0.9819	/	0.9986
	Unfitted Langmuir equation					/

Table 4

Dynamic data for adsorption of 2-naphthol and naphthalene on LM-6

Time (min)	5	10	20	30	50	80	120	200	300	600	Q_e
Q_t of 2-naphthol (mg/g)	35.2	52.1	84.4	95.7	103.6	105.5	108.2	110.3	111.9	113.7	116.8
Adsorption percent (%)	30.1	44.6	72.3	81.9	88.7	90.3	92.6	94.4	95.8	97.3	100
Q_t of naphthalene (mg/g)	2.7	4.8	7.3	8.5	9.7	10.4	11.1	12.4	12.6	12.9	13.2
Adsorption percent (%)	20.5	36.4	55.3	64.4	73.5	78.8	84.1	93.9	95.5	97.7	100

Table 5

Dynamic parameters at 298 K (initial adsorbate concentration, 500 mg/L)

Adsorbate	Dynamic model	Diffusion rate constant K	Intercept	R
2-Naphthol	Lagergren	0.0412 min^{-1}	-0.1193	0.9732
	Dumwald–Wagner	0.0334 min^{-1}	0.0106	0.9838
	Kannan–Sundaram	$14.791 \text{ mg min}^{-1/2} \text{ g}^{-1}$	7.8798	0.9596
Naphthalene	Lagergren	0.0216 min^{-1}	-0.1083	0.9517
	Dumwald–Wagner	0.0145 min^{-1}	-0.0090	0.9715
	Kannan–Sundaram	$1.4534 \text{ mg min}^{-1/2} \text{ g}^{-1}$	0.0833	0.9752

$$Q_t = Kt^{1/2} + c \quad (12)$$

where c is intercept for the curve of Q_t versus $t^{1/2}$. The diffusion rate constant of K , intercept and correlation factors R of adsorption rate dynamic equations were listed in Table 5.

The diffusion rate constant of Lagergren model for adsorbing 2-naphthol and naphthalene are 0.0412 and 0.0216 min^{-1} , and the correlation coefficient are 0.9732 and 0.9517 , respectively. The adsorbing for 2-naphthol and naphthalene is fast, and correlation coefficient indicates the curve can fit Lagergren model very well. The diffusion rate constant of Dumwald–Wagner model for adsorbing 2-naphthol and naphthalene are 0.0334 and 0.0145 min^{-1} , and the correlation coefficient are 0.9838 and 0.9715 , respectively. According to Lagergren and Dumwald–Wagner models, diffusion rate constant indicates that the adsorbing rate for 2-naphthol is twice over that for naphthalene. LM-6 has better selectively adsorbing capacity for 2-naphthol than that for naphthalene. Dumwald–Wagner model can illuminate the adsorption process much better because of higher correlation coefficient. When the Kannan–Sundaram model was used to describe the adsorbing process, there is a distinct difference between the diffusion rate constant of 2-naphthol and that of naphthalene. The diffusion rate constant of 2-naphthol is about 10 times to that of naphthalene. According to McKay (McKay, Otterburn, & Aja, 1985), the intercept in Table 5 represents the thickness of adsorption interface layer. More high value of intercept means much thicker adsorption interface layer. The three models all indicate that the thickness of adsorption interface layer of 2-naphthol is thicker than that of naphthalene. Hence, the adsorbing interaction of 2-naphthol on LM-6 is much stronger than that of naphthalene. All regressing curves are not through origin of coordinates, which indicates that there exists diffusion inside particulate. The adsorption rate is mainly affected by the diffusion of liquid membrane, the diffusion inside particulate or coordinated effect.

4. Conclusions

Using photographic-grade gelatin as dispersant, liquid paraffin as porogen, bromoethane as crosslinking reagent instead of poisonous organic compound of chloromethyl methylether, the novel hypercrosslinked polymeric adsorbent of LM-6 was successfully prepared by post-crosslinking reaction with 2-naphthol. The following specific conclusions can be drawn from the experimental results.

- (1) SEM spectrograms indicate that the novel home-made hypercrosslinked polymer has the typical characteristic of nanometer polymeric adsorbent.

- (2) Physical adsorption is dominant in the adsorption process of 2-naphthol and naphthalene on LM-6 in aqueous solution. There also exists chemical adsorption for the adsorbing process of 2-naphthol.
- (3) The adsorption enthalpies illuminate that there exists hydrogen-bonding adsorption between 2-naphthol and hypercrosslinked polymeric adsorbent. There is a process of desorption for water molecule within the adsorbent before adsorbing adsorbate in aqueous solution.
- (4) According to dynamic analysis, LM-6 has better selective adsorbing capacity for 2-naphthol than that for naphthalene. The adsorption rate is mainly affected by the diffusion of liquid membrane, the diffusion inside particulate or coordinated effect.

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