

# Absorption Behavior of the Polyester Type Polyols Containing Benzene Rings Toward Poly(ethylene terephthalate) Fiber

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**ABSTRACT:** Polyester-type polyols with a single benzene ring and a double benzene ring attached to a polyethylene glycol (PEG) moiety on only one end (PT series and PTET series), or both ends (PTP series and PTETP series), or attached to a PEG and an ethylene glycol (EG) moiety each on the separate ends (PTE series and PTETE series), were synthesized, and absorption behavior of the polyester-type polyols toward polyethylene terephthalate fibers (PET) was investigated. The results showed that all the synthesized and tested polyols structurally belonging to the single benzene ring series (whether PT, PTE, or PTP series) and a double benzene ring system with PEG attached on both ends (i.e., the PTETP series) fit nicely to the dual sorption mode of

a combination of Henry type and Langmuir type. However, the other double benzene ring series, either with only PEG on one end (PTET series) or with a PEG and an EG moiety each separately attached on the two ends (PTETE series), displays a Freundlich-type sorption. Furthermore, it was found that the HLB value of polyols, and the disposition of the PEG moiety in the structure of polyols, are also quite important in effecting the absorption parameters. © 2002 Wiley Periodicals, Inc. *J Appl Polym Sci* 86: 2967–2976, 2002

**Key words:** polyols of the polyester type; complex dual sorption; mode of Henry and Langmuir

## INTRODUCTION

Polyethylene terephthalate (PET) fibers are valuable because of their great mechanical strength, stable dimension, and reasonable cost. In recent years, micro-PET fiber has been developed, which is a superb new product made from the same materials by means of improved spinning processes and has greatly increased the consumption of PET. However, PET fibers have some shortcomings, especially of being hydrophobic and rather inert chemically, lacking hydrophilic groups. To improve the applicability of PET fabrics and to endow the products with more added-on value, it is very important to improve its hydrophilicity. The most frequently used hydrophilic finishing process for increasing the hydrophilicity of fabrics is either by absorption or by coating the fibers with hydrophilic agents. However, most of the literature regarding the PET absorption properties deal with hydrophobic materials such as disperse dyestuffs, organic solvents, and carrier agent,<sup>1–7</sup> and there is very little written about the use of hydrophilic agents.

Among the articles concerning absorption, Patton et al.<sup>1</sup> studied the absorption of benzene toward PET

thin films and found that this process matched a dual-mode model of both Henry and Langmuir type. Shibusawa et al.<sup>2</sup> used various dyestuffs with different functional groups to study the absorption toward PET, nylon 6, and secondary cellulose acetate fibers, respectively. They discovered that the absorption of those disperse dyestuffs tested mostly belonged to a complex dual mode model of the Henry partition-type and Langmuir-type absorption. As for the relative absorption speeds, dyestuffs with two hydroxyethyl ( $-\text{CH}_2\text{CH}_2\text{OH}$ )-substituted groups in their molecules were found to be faster than those with only one such substituted group. In addition, a higher number of hydroxyethyl groups caused Langmuir-type absorption to become more apparent.

More recently, Nir et al.<sup>3</sup> employed organic liquids such as toluene, benzyl alcohol, heptane, and 1,2-propanediol in their research on the absorption kinetics of unoriented amorphous PET film (APET) as well as biaxial-oriented PET film (BPET) at 34°C. They found that heptane and 1,2-propanediol showed no absorption or swelling. Both the absorption diffusion coefficient and the absorption-swelling rate of toluene toward PET are less than that of benzyl alcohol. The molecular structure of benzyl alcohol contains a hydroxymethyl ( $-\text{CH}_2\text{OH}$ ) group which may enhance the absorbing capacity toward PET molecular chain.

Furthermore, there have been many studies related to the absorption of *o*-phenyl phenol, benzoic acid,

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TABLE I  
Structure and Analysis of Different Types of Polyester Polyol

Symbol	Structure of polyols	OH value (mg KOH/g)		C (%)		H (%)	
		Calculated	Measured	Calculated	Measured	Calculated	Measured
PT400		100	98	57.6	56.2	7.1	7.4
PT600		73	70	58.2	55.3	7.7	7.9
PT1000		48	48	54.7	53.7	7.9	7.9
PTE400		194	190	58.1	54.4	7.2	7.2
PTE600		144	142	55.5	53.7	7.4	7.9
PTE1000		95	91	55.0	52.8	7.5	7.9
PTP400		120	116	56.7	54.0	7.9	8.4
PTP600		84	84	54.1	53.6	7.9	8.0
PTP1000		52	47	54.0	52.5	7.8	7.9
PTEI400		75	74	59.9	55.9	5.9	6.6
PTEI600		60	59	57.4	55.0	6.3	6.9
PTEI1000		41	40	56.4	54.4	7.1	7.3
PTEE400		143	141	58.1	55.4	5.8	6.6
PTEE600		114	98	56.0	55.9	6.3	6.9
PTEE1000		81	79	55.4	54.0	7.0	7.2
PTEIP400		100	96	57.7	54.1	5.3	6.8
PTEIP600		74	75	55.1	54.9	7.8	7.2
PTEIP1000		48	44	54.7	53.0	7.8	8.8

P, PEG; T, terephthalate ring; E, EG. Molecular weight of PEG, 400, 600, 1000.

**TABLE II**  
**GPC Results of Different Type Polyols**

Sample	$M_n \times 10^3$		$M_w \times 10^3$	$M_w/M_n$
	Calculated	Measured		
PEG600	—	0.60	0.67	1.13
PT600	0.76	0.79	0.96	1.21
PTE600	0.79	0.81	0.98	1.20
PTP600	1.33	1.41	1.68	1.19
PTET600	0.95	1.02	1.23	1.21
PTETE600	0.98	1.02	1.23	1.21
PTETP600	1.52	1.53	1.83	1.19

salicylic acid, *p*-hydroxyl benzoic acid, and silicone-modified polyester on PET related to the dyeing behavior of PET fibers. The major interests of these studies were mostly limited to the promoting effect of their addition to the sorption amount of the dyestuff.<sup>8-11</sup> From the abovementioned studies, we get the impression that functional groups in the molecular structure of absorbents, especially the hydrophilic ones, have a significant influence on the absorption behavior toward PET fibers. Lately, there have been quite a few patents regarding enhancement of the hydrophilicity of PET fibers<sup>12-15</sup> with hydrophilic agents condensed from polyethylene glycol (PEG) and aromatic dicarboxylic acids. However, all these target the final hydrophilicity of the processed fabrics, with hardly any discussion of the effects of those hydrophilizing agents on PET fiber absorption behavior.

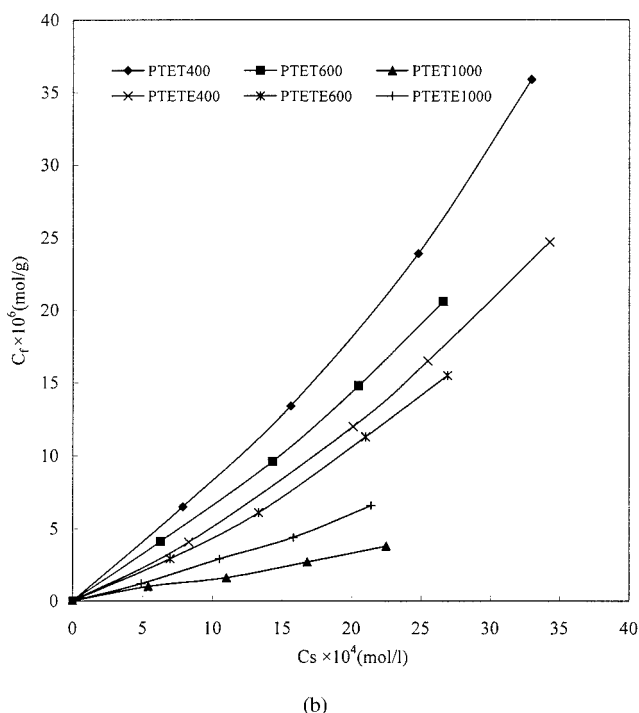
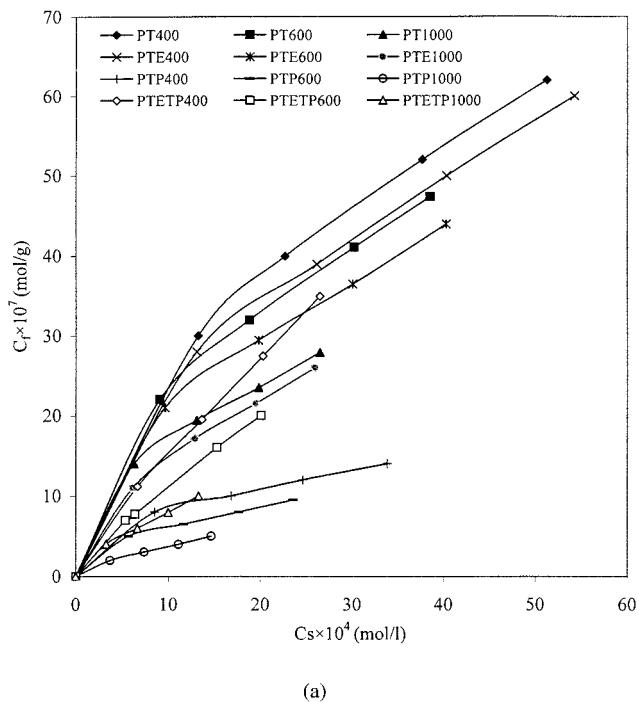
In this study, 18 different polyols of polyester type were polymerized with dimethyl terephthalate (DMT), ethylene glycol (EG), and PEG by varying the mole ratio between DMT and EG and the molecular weight of PEG. Among these 18 products, some have a single benzene ring or double benzene ring in their molecular structures as the basic structure, and with the benzene rings attached to a PEG moiety on only one end or both ends, or attached to a PEG and an EG moiety on each end. The basic physical and chemical properties of these polymers were examined; the absorptivity between polyol and PET were determined and compared at various temperatures.

**EXPERIMENTAL**

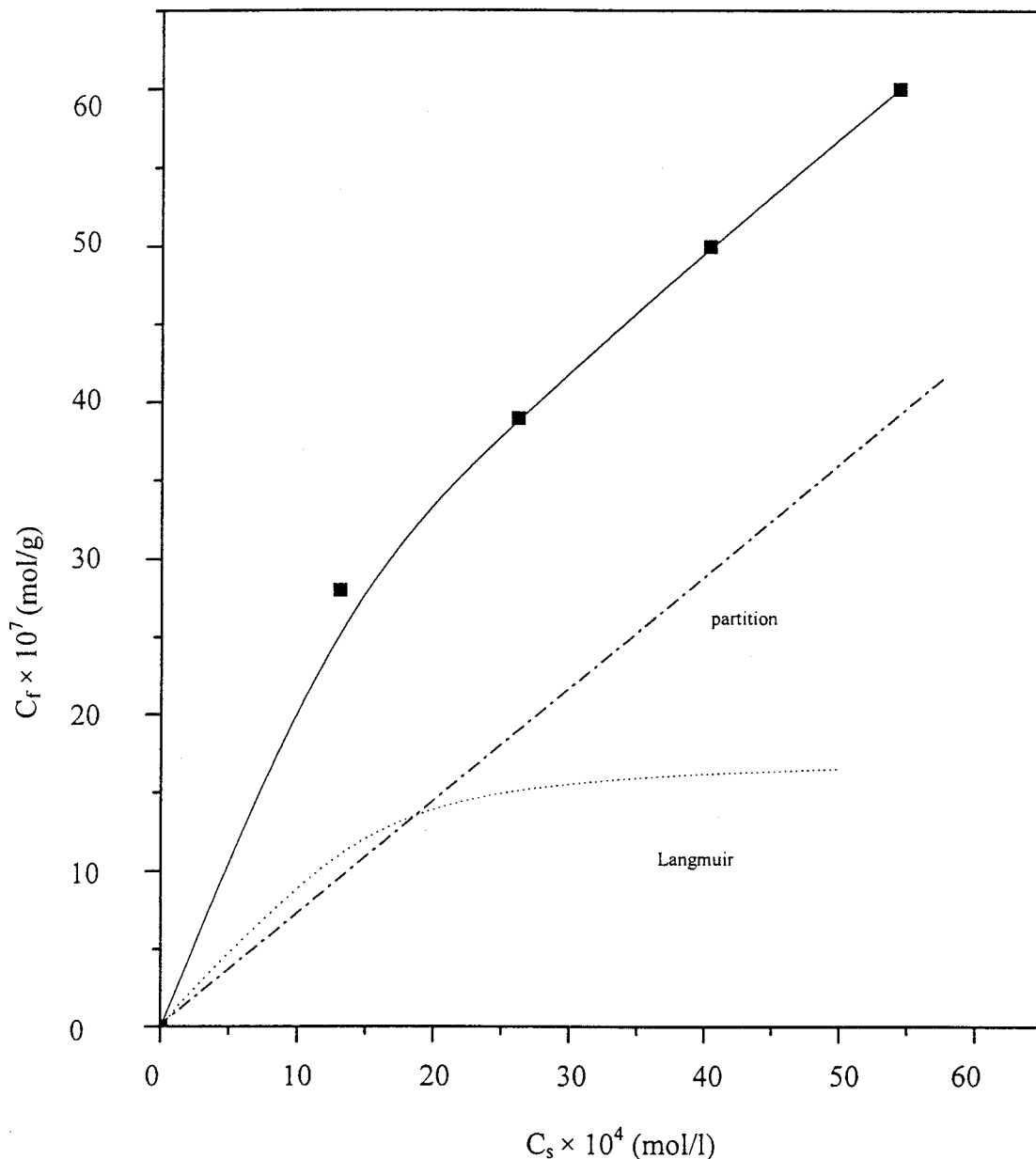
**Synthesis of polyester-type polyols**

The synthesis of the polyester-type polyols in the single benzene ring series was carried out by the transesterification reaction by using 1 mol each of DMT, EG, and PEG (MW 400, 600, or 1000) to form the PTE series, whereas, by using 2 or 1 mol of PEG with 1 mol of DMT, polyols of the PTP or PT series, were obtained, respectively. To avoid the occurrence of polycondensation at higher temperatures such as 280°C,<sup>16</sup> the abovementioned synthesis of transesterification

was carried out at 180°C for 5 h with reflux, using 0.05% of manganese acetate tetrahydrate as the catalyst, getting rid of the methanol generated through a cooling coil refrigeration facility. During this period, the hydroxyl end-group value was monitored by a titration method.<sup>17</sup> At the end of the reaction, the



**Figure 1** (a) The absorption isotherms of different types of polyester polyol at 130°C. (b) The absorption isotherms of different types of polyester polyol at 130°C.

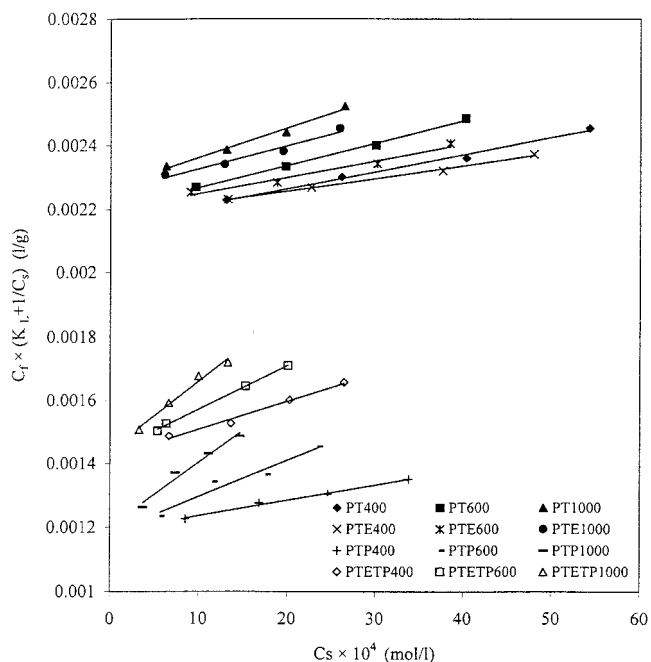


**Figure 2** Sorption isotherm of PT400 polyols on PET fabric at 130°C. ■, experimental points; ---, calculated on the basis of simple Langmuir sorption; - - -, calculated by eq. (1) using relevant values of the dual-mode sorption parameters.

hydroxyl end group value should be about half of the original value. After vacuum pumping the final procedure, we got the single benzene ring series of polyester polyols.

To synthesize the double benzene ring series of polyester-type polyols, the first step was to mix together 2 mol of DMT with 1 mol of EG and catalyst manganese acetate tetrahydrate 0.05% at 180°C for 3 h and then to increase the temperature to 220°C to form the double-benzene ring intermediates. During the reaction period, hydroxyl end-group titration was conducted to track the progress of the reaction. When the hydroxyl end-group value approached 0, the formation of intermediates was completed. The interme-

diates were then allowed to undergo transesterification reaction with 1 or 2 mol of various PEG (MW 400, 600, or 1000) to form the PTET or PTETP series of polyols, respectively. The same intermediates were also reacted with 1 mol each of EG and PEG to form the PTETE series. The reaction conditions were identical to those for the syntheses of the single benzene ring products. All synthesized polyols were dissolved in ethanol and filtered and depressurized for further purification. After vacuum drying at 40–50°C, they were ready for use. Data of hydroxyl end group titration, elemental analysis, and molecular weight distributions by GPC are listed in Tables I and II. The measured hydroxyl end-group content is close to the



**Figure 3** Dual-model sorption isotherms of the polyester type polyols at 130°C.

calculated value from the structures shown in Table I for all the synthetic polyols; the elemental analysis results of both C% and H% also appeared to be close to the theoretical values. In addition, the molecular weight distributions by GPC are considered satisfactory, although a little mix of oligomers is evident.

**Identification and analysis of the synthetic products**

The hydroxyl end-group titration was carried out according to the potassium hydroxide assay method.<sup>17</sup> Elemental analysis was conducted with a Perkin-Elmer 240 C type apparatus. The GPC measurements were obtained by using a Water Associates 6000A liquid chromatograph equipped with a refractive index detector, operated at 40°C with Plgel column of 3 μm MIXED-E in THF. The flow rate was 0.8 mL/min. Surface-tension analysis was carried out by following the protocol of the Rose-Miles method with equipment made by Kyowa Kaimenagaku Co. Ltd., Type CBVP-A3.<sup>8</sup>

**Absorption and contact-angle determination of the synthetic polyols toward PET fabrics**

The PET fabric (Dacron; the warp and woof specifications are 100<sup>D</sup>/36<sup>F</sup>; the warp and woof density are 110 ends/in. × 76 picks/in., nonalkaline weight reduction of PET fabrics) was immersed in a solution containing the polyol of certain concentrations (2, 4, 6, 8%) at a specified temperature (70, 90, 110, 130°C) for 120 min.

After the absorption process, the treated fabrics first went through a 5-min soaping in a 0.5 g/L sodium carbonate solution at 60°C, followed by rinsing with water, and drying. The absorption amount of the processed unit weight of fabric was calculated by the following equation:

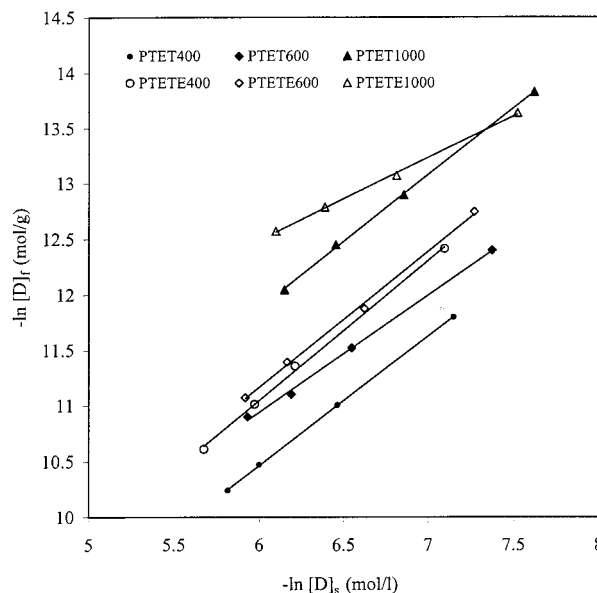
$$C_f \text{ (mol/g)} = (W_2 - W_1)/MW_1$$

where  $W_1$  is the weight of the fabric before the process,  $W_2$  is the weight of the fabric after the process, and  $M$  is the molecular weight of the polyol. The contact angle of the polyols solution to the processed PET fabric was determined according to the AATCC D724 method (Face CA-5 150C meter).<sup>18</sup>

**RESULTS AND DISCUSSION**

**Study of the absorption behavior and adsorptivity kind of polyester-type polyols toward PET fabrics**

When the absorption reaches saturation, absorption and desorption arrive at a state which is called absorption equilibrium. At equilibrium, the adsorbates are distributed between two phases, the fiber  $F$  and the solution  $S$ . There are several basic constant temperature absorption models, such as the Henry type, where  $C_f = K_p \times C_s$ , the Langmuir type where  $C_f = (S \times K_C \times C_s)/(1 + K_C \times C_s)$ , and Freundlich type, where  $C_f = K_f \times C_s^n$ , where  $C_f$  and  $C_s$  are the equilibrium concentrations of the polyols in the respective phases of the PET fiber and the solution;  $S$  is the absorption saturation value in Langmuir type; and  $K_p$ ,  $K_C$ , and  $K_f$  are the absorption constants in the Henry type, the Langmuir type, and the Freundlich type, respectively.



**Figure 4** The Freundlich type absorption isotherms of the polyester type polyols at 130°C.

TABLE III  
Absorption Types and Properties of Different Types of Polyester Polyol

Symbol	Contact angle (°)	HLB value	Surface tension (dyn/cm)	Absorption types
PET fabric	140	—	—	—
PEG400	138	20	61	—
PEG600	140	20	62	—
PEG1000	144	20	64	—
PT400	80	14	38	H + L
PT600	86	16	40	H + L
PT1000	92	17	42	H + L
PTE400	92	15	40	H + L
PTE600	97	17	41	H + L
PTE1000	106	18	45	H + L
PTP400	106	17	55	H + L
PTP600	114	18	56	H + L
PTP1000	123	19	57	H + L
PTETP400	94	15	55	H + L
PTETP600	107	17	56	H + L
PTETP1000	114	18	56	H + L
PTET400	63	11	35	F
PTET600	67	13	39	F
PTET1000	68	15	41	F
PTETE400	67	11	36	F
PTETE600	72	13	40	F
PTETE1000	76	15	42	F

H, Henry Partition type; L, Langmuir type; F, Freundlich type. HLB value, (Hydrophilic groups  $M_w$ /polyols  $M_w$ )  $\times$  20.

Figure 1(a,b) shows the absorption isotherms of the synthetic polyester-type polyols at 130°C, plotted with  $C_f$  versus  $C_s$ . Those curves in the figures indicate that there are two kinds of absorption type present and none of the polyols show simple Henry-type absorption. In accordance with previous studies, part of the dyestuffs and organic solvents appear to have an absorption character of dual-mode sorption, a complex

between Henry and Langmuir types.<sup>1-3</sup> This study adopted the least-squares fitting method previously used by Shibusawa and Chigira<sup>19</sup> and others. The method separates the curves of experimental data shown in Figure 1(a) into Henry type and Langmuir type, as depicted in Figure 2, and from the resulting partial curves estimates the values of  $K_p$ ,  $K_C$ , and  $S$ . On the other hand, the combined absorption eq. (1) of Henry type and Langmuir type could be rearranged and  $C_f \times (K_C + 1/C_s)$  versus  $C_s$  could be plotted as in Figure 3 as:

$$C_f(K_C + 1/C_s) = K_p K_i C_s + K_p + K_i S \quad (1)$$

Figure 3 clearly shows that the absorption of those polyols belonging to the PT, PTE, PTP, and PTETP series form straight lines, which means that these polyols can fit the dual-mode sorption of Henry type and Langmuir type to obtain the values of  $K_p$ ,  $K_C$ , and  $S$ . This result agrees with those from previous studies on the adsorptivity of dyestuffs and benzene toward PET fibers.<sup>1-3</sup>

However, it is apparent the PTET and PTETE series polyols shown in Figure 1(b) give nonlinear curves in the above plot. To determine the absorptivity mode of these two series, they were fitted to the Freundlich model by plotting  $\ln C_f$  versus  $\ln C_s$ , and the results are shown in Figure 4.

From this figure, it can be seen that these two series of polyols match the power-law correlation that the Freundlich model predicted.

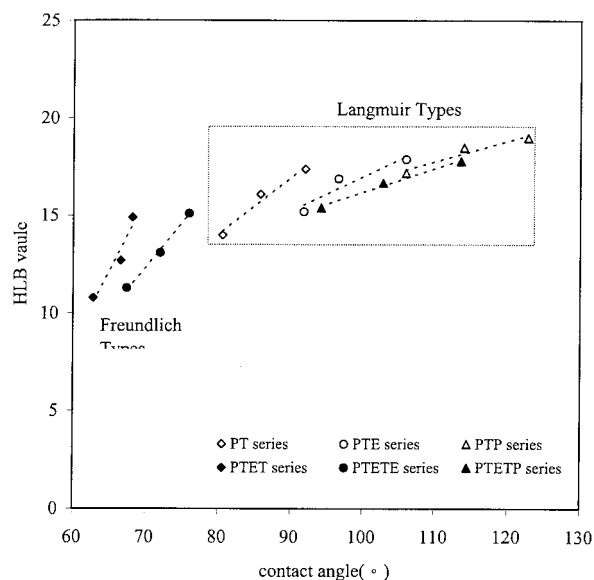


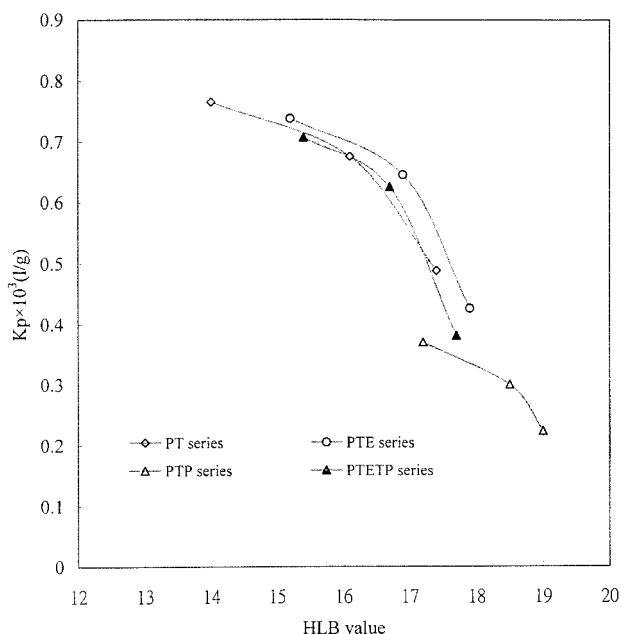
Figure 5 The influences of the contact angle and the HLB value of the polyols on the absorption behavior of PET.

**TABLE IV**  
**Dual-Mode Sorption of Henry and Langmuir Parameters**  
**for Polyols Sorption by PET Fabrics**

Symbol	Temp. (°C)	$K_p \times 10^3$ (l/g)	$K_l$ (l/mol)	$S \times 10^6$ (mol/g)
PT400	70	1.263	230.1	5.88
	90	0.895	225.8	3.74
	110	0.783	190.1	1.76
	130	0.766	156.9	1.00
	70	0.789	425.9	3.47
PT600	90	0.744	373.2	3.00
	110	0.717	313.2	1.02
	130	0.676	307.9	0.50
	70	0.742	760.2	2.57
PT1000	90	0.538	586.2	1.10
	110	0.505	457.1	0.50
	130	0.472	220.9	0.14
	70	0.992	296.3	5.50
PTE400	90	0.844	232.2	3.42
	110	0.788	216.4	2.79
	130	0.739	193.6	0.50
	70	0.986	332.9	3.09
PTE600	90	0.840	324.4	1.44
	110	0.717	324.9	0.50
	130	0.646	329.1	0.14
	70	0.889	716.9	1.54
PTE1000	90	0.747	558.1	0.50
	110	0.717	539.0	0.20
	130	0.427	492.9	0.11
	70	0.805	347.7	3.11
PTP400	90	0.673	341.1	1.97
	110	0.531	339.4	1.97
	130	0.371	318.4	0.33
	70	0.757	729.8	1.36
PTP600	90	0.616	593.7	1.00
	110	0.523	510.6	1.00
	130	0.351	684.7	1.00
	70	0.731	1120.7	1.02
PTP1000	90	0.448	1120.7	0.20
	110	0.29	1061.7	0.20
	130	0.223	1009.2	0.20
	70	0.934	520.1	2.01
PTETP400	90	0.852	516.5	1.71
	110	0.774	441.5	1.0
	130	0.708	359.2	0.50
	70	0.901	840.2	1.96
PTETP600	90	0.892	818.9	1.05
	110	0.743	681.4	0.50
	130	0.626	642.6	0.25
	70	0.594	1508.4	1.00
PTETP1000	90	0.588	1229.4	0.50
	110	0.442	1113.1	0.33
	130	0.382	1021.7	0.03

To sum up the above results, the synthesized polyols structurally belonging to the single benzene ring series (the PT, PTE, or PTP series) can fit a dual sorption mode of a combination of Henry type and Langmuir type. It does not matter whether the polyols have a single benzene ring attached to a PEG moiety on only one end or both ends, or attached to a PEG and an EG moiety each on separate ends. In addition, the series having a double benzene ring system yet with PEG each attached on both the ends (PTETP series)

also belong to the same mode of absorption. As for the other double benzene ring series, either only with PEG on one end (PTET series), or with a PEG and an EG moiety each separately attached on the two ends (PTETE series), they fit the Freundlich mode. The above results indicate that the absorption phenomenon of those polyols toward PET fibers depends on the number of benzene rings in the molecular structure and the presence of PEG moiety on the ends. However, it was found in our experiments that the molec-



**Figure 6** The influences of  $K_p$  (Henry-type partition coefficient) and the HLB value of the polyols at 130°C.

ular weight of the PEG did not affect the type of absorption mode.

To study the correlation between the absorption and the properties of the aqueous solution of the synthetic products, the solution's surface tension and its contact angle with PET fabrics were measured. In addition, the hydrophilic-lipophilic balance (HLB) values of these polyols were also calculated according to Griffin's method<sup>20</sup> and these results are listed in Table III.

All three parameters appear to fall in the same decreasing order of  $PTP > PTETP > PTE > PT > PTETE > PTET$ . This orderly phenomenon shows that the absorption of various series of polyols is very much related to the hydrophilicity of the polyols. The larger contact angle (i.e., a liquid having a smaller cosine  $\theta$ ) show the polyol aqueous liquid does not wet the PET fabric as readily.

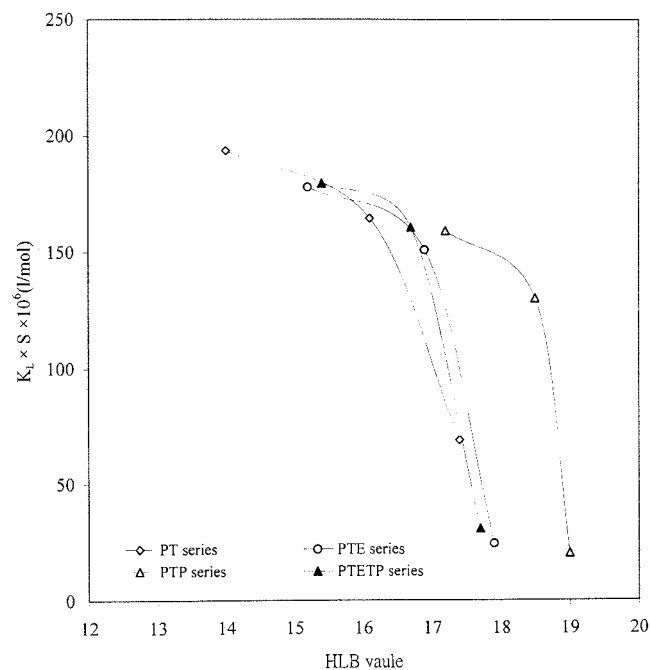
Figure 5 shows the relationship between the contact angle and the HLB value of the polyols. From this figure, it can be seen that both the HLB value and the contact angle affect the absorption behavior of the polyols. All polyols with a single benzene ring, or the ones with double rings but attached with two end PEG moieties (i.e., PT series, PTE series, PTP series, and PTETP series), display quite large contact angles (lower wettability to the treated PET fabric) and high HLB values, which is typical for a dual mode of single-layer molecular Langmuir-type and Henry-type sorption. On the contrary, polyols with double benzene rings and no more than one PEG moiety attached on the end (i.e., PTETE series and PTET series) display smaller contact angles and lower HLB values, which is characteristic for multilayer molecular Freundlich-type sorption.

Contact angles  $> 80^\circ$  seem to be associated with Langmuir-type single molecular layer absorption, while contact angles  $< 80^\circ$  seem to be associated with Freundlich-type multimolecular-layer absorption, as observed in Figure 5. It also seems that the contact angle of polyols toward PET fiber, regardless of its composition or structure, displays a roughly linear relation with its HLB value. In addition, the molecular weight of PEG, number of benzene rings, and single-end PEG group in the polyols all have some degree of influence on the HLB value. However, within the scope of this study, to lower the contact angle to  $< 80^\circ$  to change the absorption behavior, the polyol should have double benzene ring structure without PEG moiety attaching to both ends.

### Study of the absorption parameters of polyester-type polyols toward PET fibers

#### Henry and Langmuir dual mode sorption

The dual-mode absorption model was separated into Henry and Langmuir modes. Table IV lists the parameters  $K_p$ ,  $K_C$ , and  $S$  to obtain least-squares fitting of the concentration distribution of polyols. From these results, it can be seen that  $S$  increases with  $K_C$ . To investigate the correlation between these parameters and the interfacial interaction,  $K_p$  versus HLB was plotted in Figure 6 and  $K_C \times S$  versus HLB in Figure 7. In Figure 6, it can be seen that, for polyols with higher HLB, the range of the variation in  $K_p$  is less.



**Figure 7** The influences of  $K_L \times S$  (Langmuir type coefficient) and the HLB value of the polyols at 130°C.



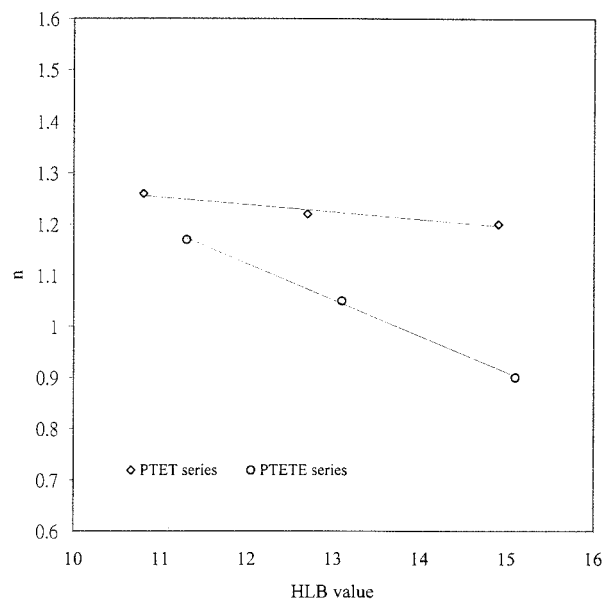
**TABLE V**  
The Freundlich Parameters of Polyols Sorption by PET Fabrics

Symbol	Temp. (°C)	<i>n</i>	<i>K<sub>f</sub></i> × 10 <sup>2</sup> (l/g)
PTET400	70	1.40	2.882
	90	1.30	3.007
	110	1.29	3.029
	130	1.26	3.126
PTET600	70	1.28	1.447
	90	1.27	1.816
	110	1.26	2.066
	130	1.22	2.211
PTET1000	70	1.26	0.327
	90	1.25	0.535
	110	1.23	0.642
	130	1.20	0.930
PTETE400	70	1.39	2.025
	90	1.29	2.228
	110	1.26	2.312
	130	1.17	2.469
PTETE600	70	1.18	0.649
	90	1.14	0.777
	110	1.07	0.831
	130	1.05	1.301
PTETE1000	70	0.89	0.212
	90	0.87	0.251
	110	0.85	0.262
	130	0.81	0.272

Figure 7 reveals that  $K_C \times S$  decreases with the increase in the HLB, which indicates that polyols with higher HLB would be adsorbed less. Furthermore, from the polyols that were tested, it was found that, once the molecular weight of PEG increased, the adsorptivity decreased abruptly. The reason for the lowering of Langmuir sorption or Henry sorption with longer PEG might be hydrophilic hydration of PEG with water,<sup>21</sup> which in turn can interfere with hydrophilic sorption of the polyols toward PET fibers. On the other hand, there is bound to be less interference from surrounding water molecules in the case of the shorter PEG. It is easier for a smaller PEG moiety to distribute and absorb into the amorphous regions as well as on the surfaces of polymer crystallites of the PET fibers.<sup>22-23</sup> As to the influence of temperature on the absorption behavior, Table IV shows that lower temperature is always associated with greater adsorptivity. Because the absorption process is an exothermal reaction, the initial absorption speed becomes greater with elevated temperature but the equilibrium absorption amount decreases<sup>7</sup> (i.e., the distribution coefficient is higher at a lower temperature).

**Dual-mode sorption of Freundlich types**

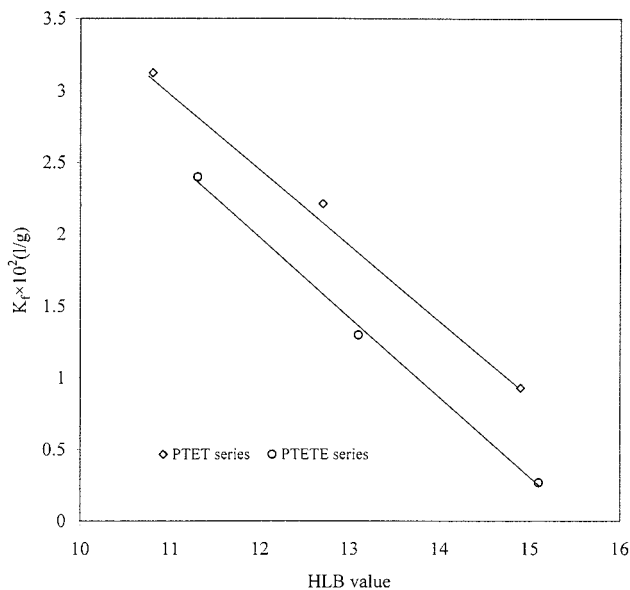
From Figure 4, we obtained the constant *n* and *K<sub>f</sub>* (Freundlich constant) for the isotherm line of Freundlich sorption at constant temperature as listed in



**Figure 8** The influences of *n* (Freundlich-type coefficient) and the HLB value of the polyols at 130°C.

Table V. Again, these parameters were plotted with respect to HLB.

Figures 8 and 9 show that the sorption parameters, *n* and *K<sub>f</sub>*, decrease linearly with increasing HLB. Lower HLB value means more hydrophobicity and is more favorable for multibenzene ring polyols to associate with each other. As to the influence of temperature on Freundlich type adsorptivity, it has an insignificant effect on *n*, but *K<sub>f</sub>* seems to increase somewhat as the temperature increases (Table V).



**Figure 9** The influences of *K<sub>f</sub>* (Freundlich-type coefficient) and the HLB value of the polyols at 130°C.

## CONCLUSION

Different types of polyester polyol with a single benzene ring and a double benzene ring attached to a PEG moiety on only one end (PT series and PTET series), or both ends (PTP series and PTETP series), or attached with a PEG and a EG moiety each on the separate ends (PTE series and PTETE series), were synthesized and their absorption toward PET fabrics was investigated. The following conclusions were obtained:

(1) The single benzene ring series (PT, PTE, and PTP series) and a double benzene ring system, also with PEG attached on both the ends (PTETP series), have absorption isotherms matching the dual sorption mode of a combination of Henry type and Langmuir type.

(2) The other double benzene ring series, either with PEG only on one end (PTET series) or with a PEG and an EG moiety each separately attached on the two ends (PTETE series), display a Freundlich type of absorption.

(3) The surface tension, the contact angles, and the HLB values are in the same decreasing order with PTP series > PTETP series > PTE series > PT series > PTETE series > PTET series. Both the HLB value and the contact angle are related to the absorption behavior of the polyols.

(4) The higher the HLB value is, the lower are Henry-type, Langmuir-type, and Freundlich-type sorption parameters ( $K_p$ ,  $K_C \times S$ ,  $n$ , and  $K_f$ ).

(5) For Langmuir type of absorption of the polyols toward PET fiber, when the molecular weight of the PEG moiety is over 1000 (HLB above 17), the adsorptivity decreased abruptly.

(6) The Freundlich-type absorption parameters ( $n$  and  $K_f$ ) increased linearly with decreasing HLB (i.e., it is more hydrophobic).

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