CHAPTER IV
RESULTS AND DISCUSSION

Adsorption of *p*-xylene and *m*-xylene in the presence of toluene was studied. The experiments were analyzed by headspace gas chromatography. NaY KY, BaX, and BaY zeolites were used as the adsorbents. The effects of operating temperature and zeolites were studied. Furthermore, the applicability of headspace chromatography for C_8 aromatics adsorption measurement was investigated.

4.1 Adsorption Data from the Headspace Gas Chromatography

The binary adsorption of *p*-xylene and *m*-xylene on NaY, KY, BaX and BaY zeolites was studied in the range of 40 °C - 120 °C and *p*-xylene initial concentration of 1.25 wt% - 20 wt%. Figures 4.1 - 4.4 show the adsorption of xylenes on NaY, KY, BaX, and BaY zeolites at 40 °C from the headspace gas chromatography, respectively. The amount of the C_8 aromatics adsorbed is indicated by loading, which is mol of the adsorbed species per mol of that species in the feed From Figure 4.1, the adsorbed amounts or loadings of *p*-xylene and *m*-xylene on NaY zeolite is lowest at the *p*-xylene initial concentration of 1.25 wt%. The loading increases from 1.25 wt% to 2.5 wt% initial concentration, and then slightly decreases at 5 wt% initial concentration. The xylene loadings on NaY zeolite appears to increase from 5 wt% to 10 wt% initial concentration, and slightly decrease when it reaches the maximum adsorption. For all initial concentration, the *p*-xylene and *m*-xylene loadings on NaY zeolite are about the same. For KY zeolite, the trend of the loading is similar to that on NaY zeolite, which increases from 1.25 wt% initial concentration and drops at 5 wt% initial concentration. Then, it increases again at 10 wt% initial concentration and seems to be constant from this concentration. However, the lowest *p*-xylene and *m*-xylene loadings are at 5 wt% initial concentration, which is different from NaY zeolite. Moreover, the *p*-xylene loading on KY zeolite is higher than that of *m*-xylene for all initial concentrations, which means KY zeolite adsorbs *p*-xylene more than *m*-xylene. The adsorption of xylenes on BaX and BaY zeolites at 40 °C, Figures 4.3 - 4.4, shows that the trend of xylene

loadings on both zeolites are the same as NaY zeolite. Furthermore, the *p*-xylene and *m*-xylene loadings are about the same as that on the low initial concentration (1.25 wt% - 2.5 wt%) but the *p*-xylene loading is higher than that of *m*-xylene at 5 wt% to 20 wt% initial concentrations.

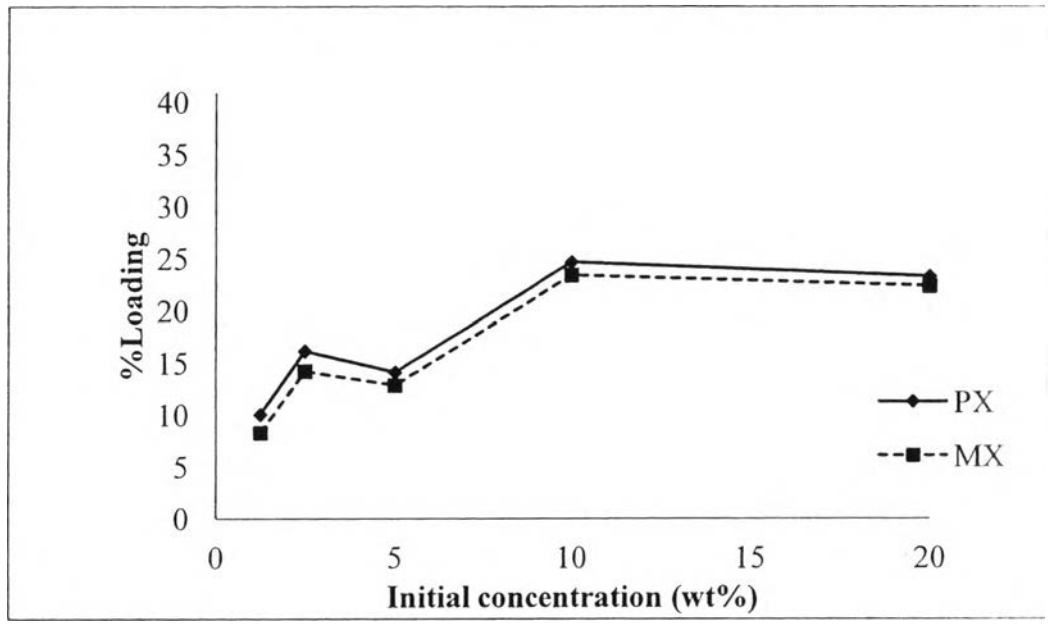


Figure 4.1 Adsorption of the C_8 aromatics on NaY zeolite at 40 °C.

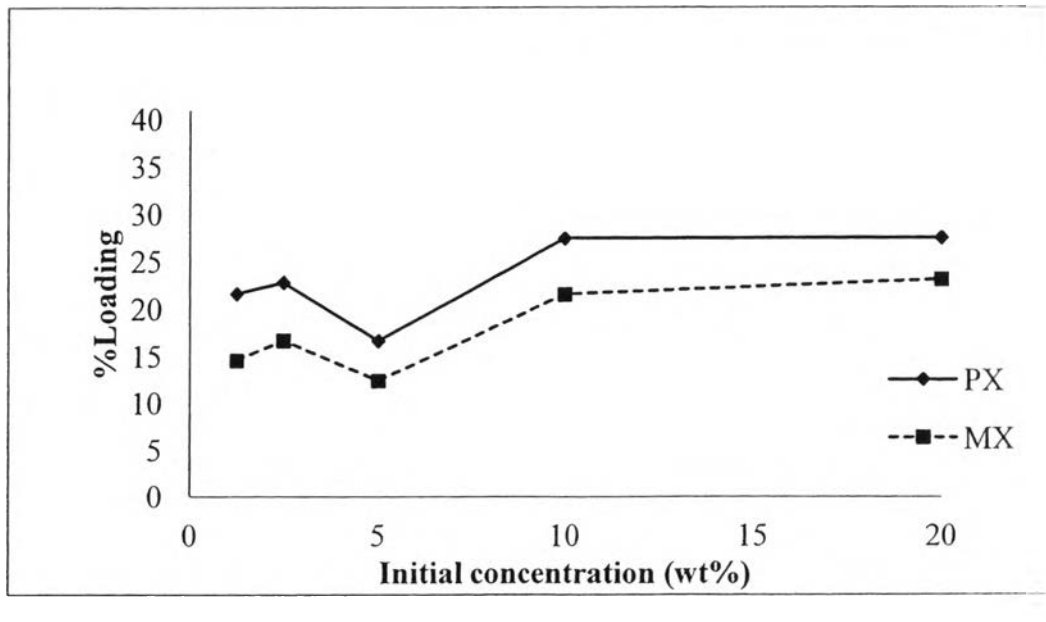


Figure 4.2 Adsorption of the C_8 aromatics on KY zeolite at 40 °C.

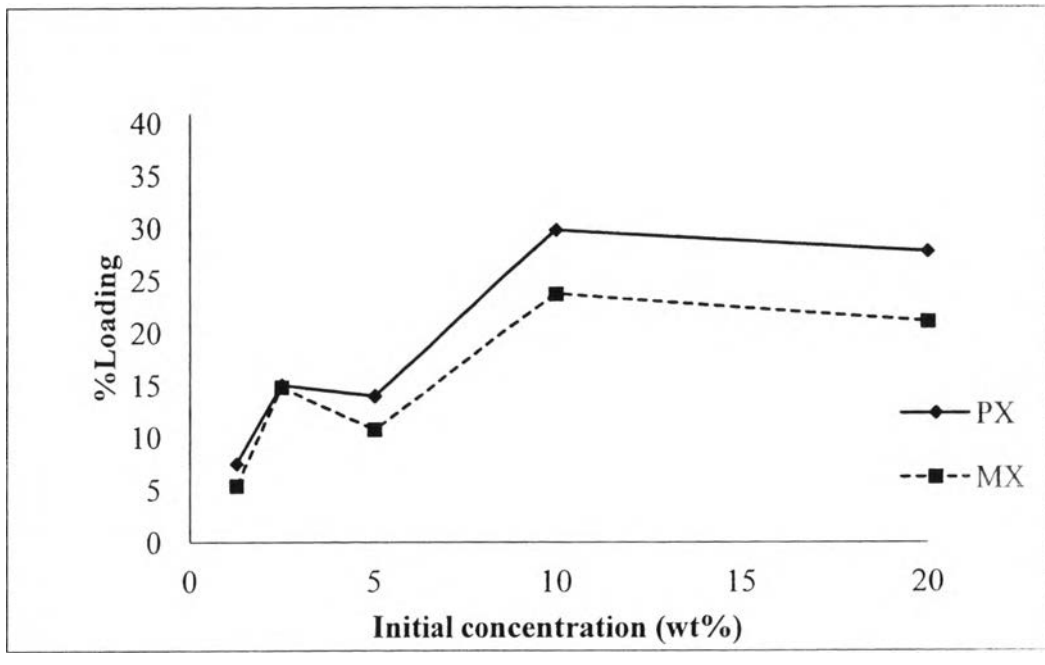


Figure 4.3 Adsorption of the C_8 aromatics on BaX zeolite at 40 °C.

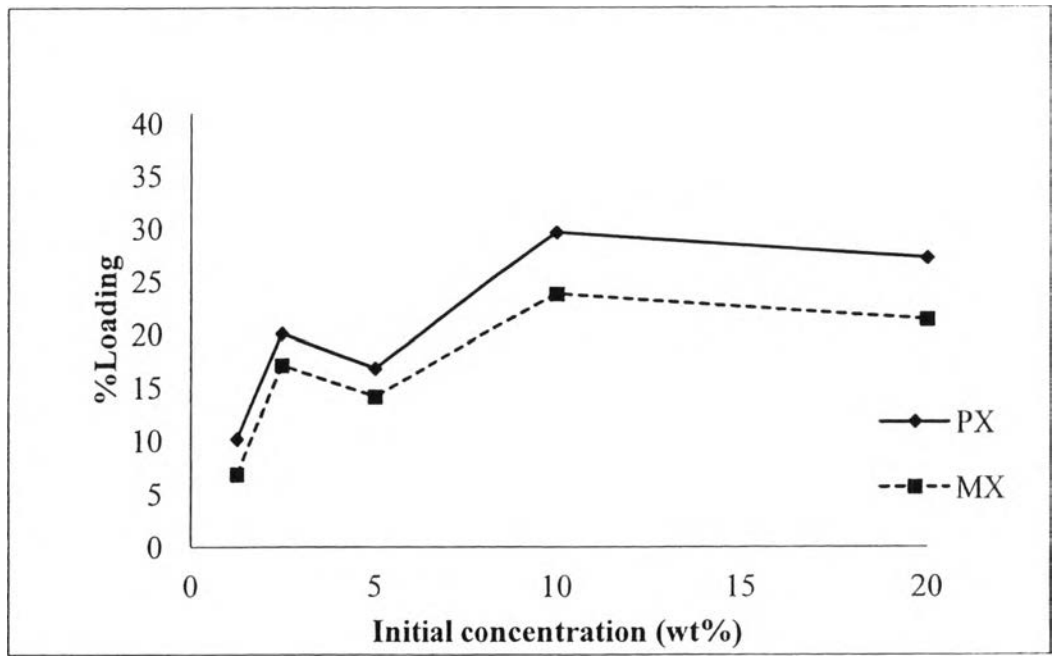


Figure 4.4 Adsorption of the C_8 aromatics on BaY zeolite at 40 °C.

The adsorption of *p*-xylene and *m*-xylene on NaY, KY, BaX, and BaY zeolites from the headspace gas chromatography at 60 °C is shown in Figures 4.5 – 4.8. For NaY zeolite, the *p*-xylene and *m*-xylene loadings are about the same for all initial concentrations. In addition, the initial concentration independence seems to the case for all zeolites at this temperature. However, KY, BaX, and BaY zeolites have the *p*-xylene loading higher than that of *m*-xylene for all initial concentrations, which means they adsorb *p*-xylene more than *m*-xylene. The zeolite selectivity towards *p*-xylene is the same as that at 40 °C.

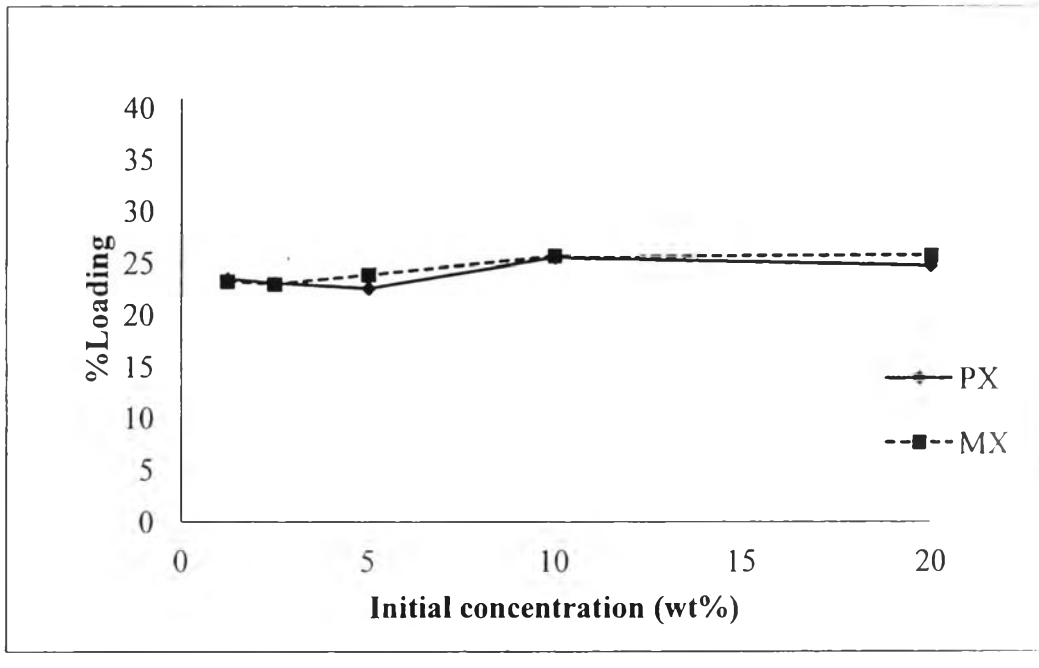


Figure 4.5 Adsorption of the C_8 aromatics on NaY zeolite at 60 °C.

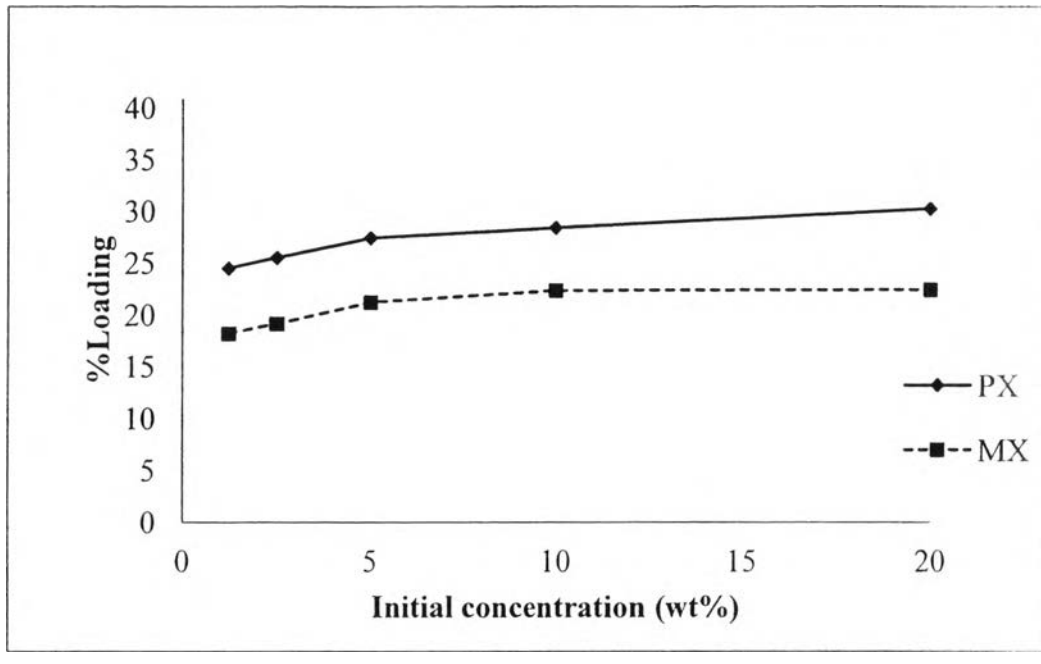


Figure 4.6 Adsorption of the C_8 aromatics on KY zeolite at 60 °C.

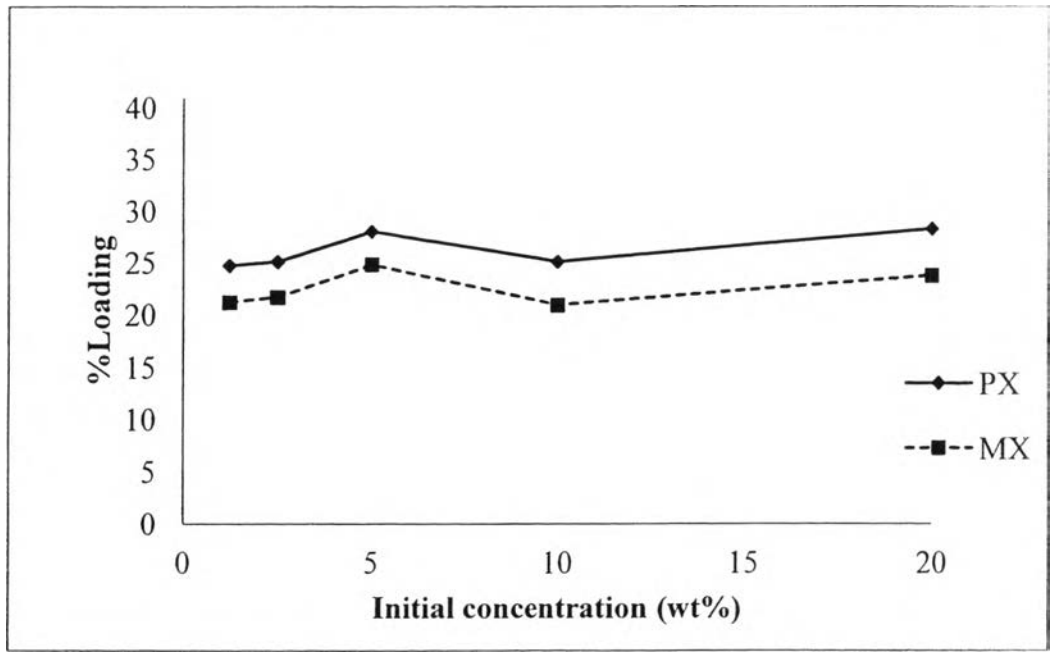


Figure 4.7 Adsorption of the C_8 aromatics on BaX zeolite at 60 °C.

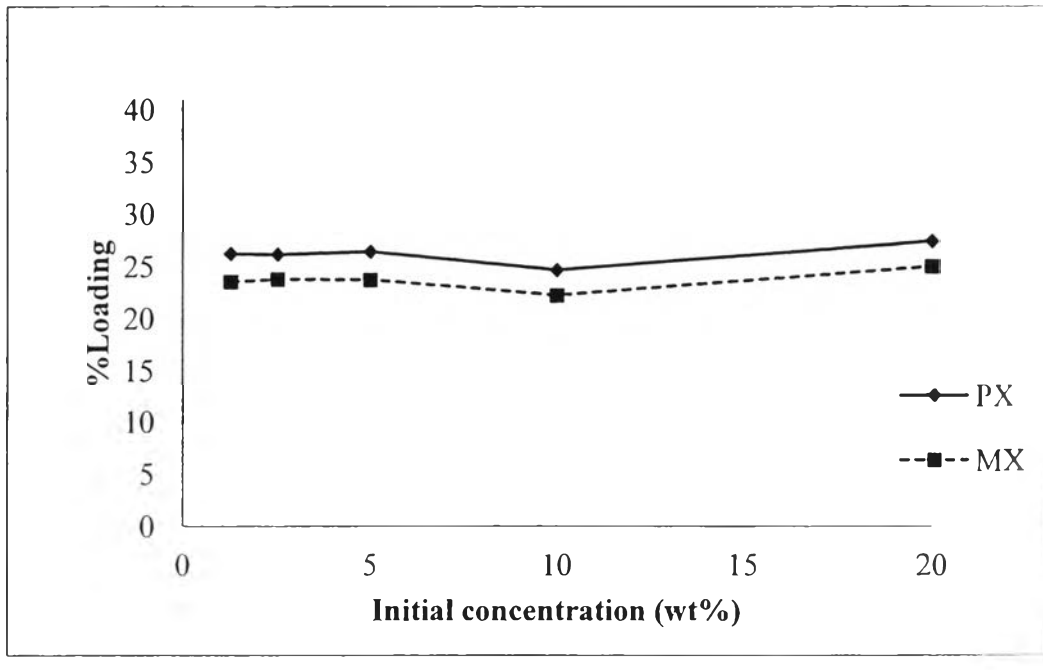


Figure 4.8 Adsorption of the C_8 aromatics on BaY zeolite at 60 °C.

At 80 °C, NaY and KY zeolites have the same trend of xylene loading. According to Figures 4.9 - 4.10, the *p*-xylene and *m*-xylene loadings seem to be constant from the initial concentration of 1.25 wt% to 2.5 wt%, and they increase from 2.5 wt% to 10 wt% initial concentration. Then, the loadings decrease at 20 wt% initial concentration. At this temperature, the loadings on NaY and KY zeolites are highest at 10 wt% initial concentration. Nonetheless, there are some differences between NaY and KY zeolites. NaY zeolite adsorbs *p*-xylene and *m*-xylene about the same amount, while KY zeolite strongly adsorbes *p*-xylene more than *m*-xylene. Moreover, the difference between *p*-xylene and *m*-xylene loadings on KY zeolite at this temperature is higher than that at 40 °C and 60 °C. Figure 4.11 shows the adsorption of xylenes on BaX zeolite at 80 °C. From the figure, BaX zeolite adsorbs *p*-xylene more than *m*-xylene for all xylenes initial concentrations. The loadings fluctuate with the xylene initial concentration. They increase from 1.25 wt% to 2.5 wt% initial concentration and drop at 5 wt% initial concentration. Then, they increase again at 10 wt% initial concentration and decrease after that. For BaY zeolite, the trend of the xylene loadings is similar to that of NaY and KY zeolites as seen in Figure 4.12. Furthermore, BaY zeolite adsorbs *p*-xylene more than *m*-xylene

as same as KY and BaX zeolites. However, the xylene initial concentration that has highest xylenes loading at 80 °C is 10 wt% xylenes initial concentration for all adsorbents.

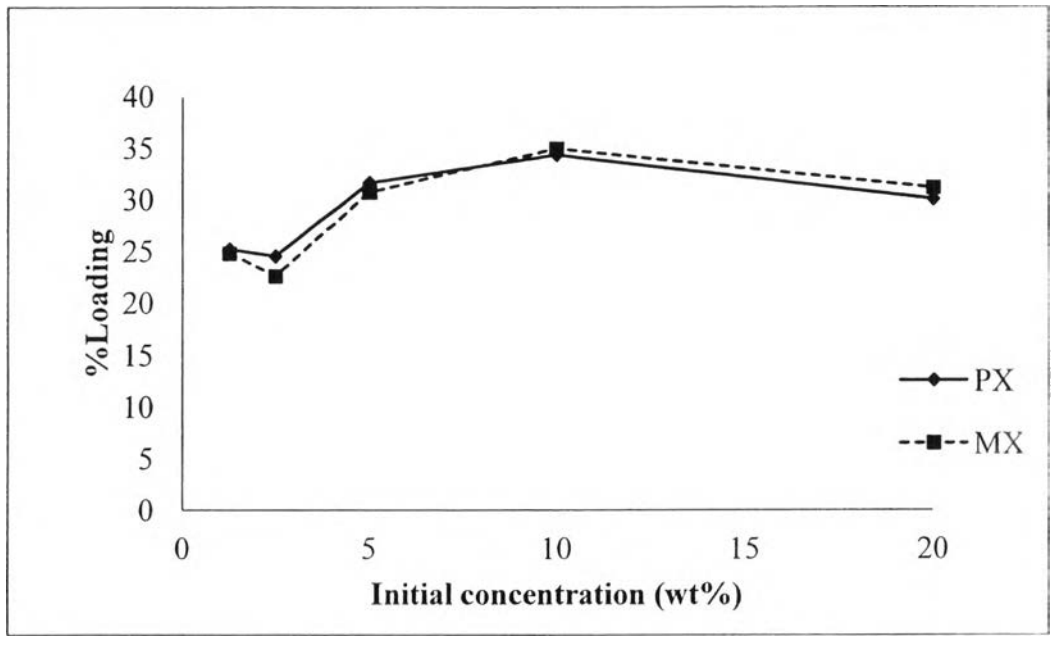


Figure 4.9 Adsorption of the C_8 aromatics on NaY zeolite at 80 °C.

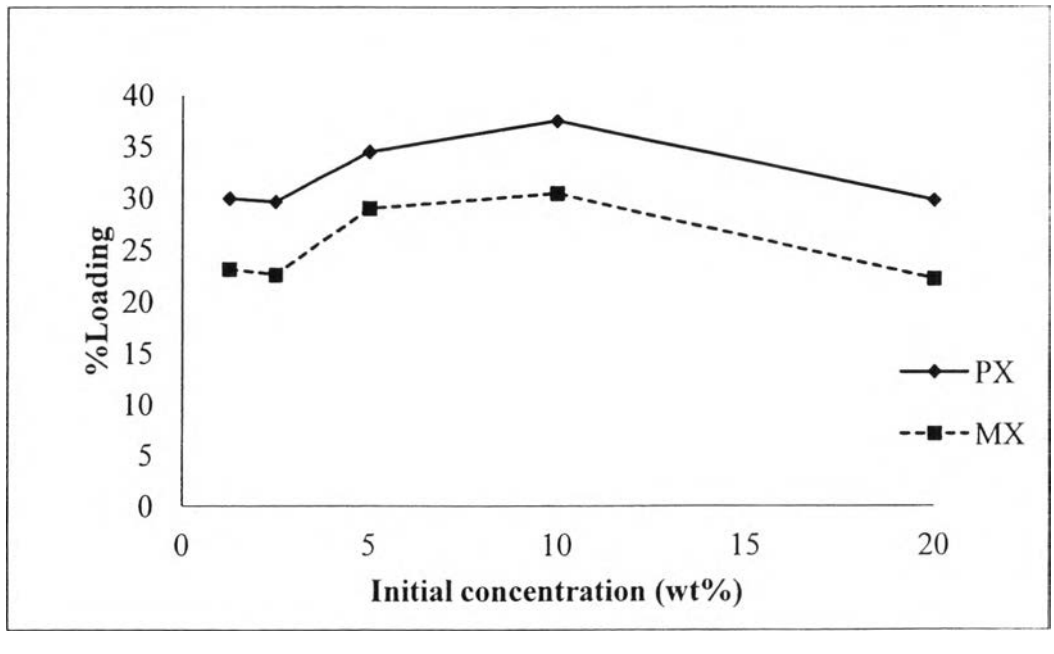


Figure 4.10 Adsorption of the C_8 aromatics on KY zeolite at 80 °C.

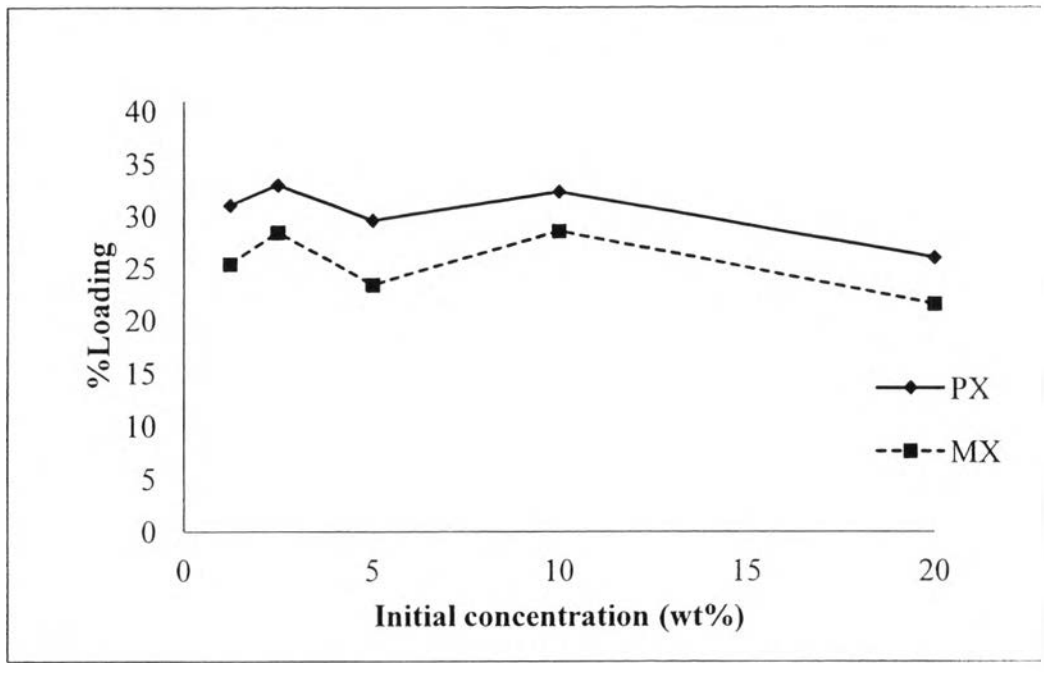


Figure 4.11 Adsorption of the C_8 aromatics on BaX zeolite at 80 °C.

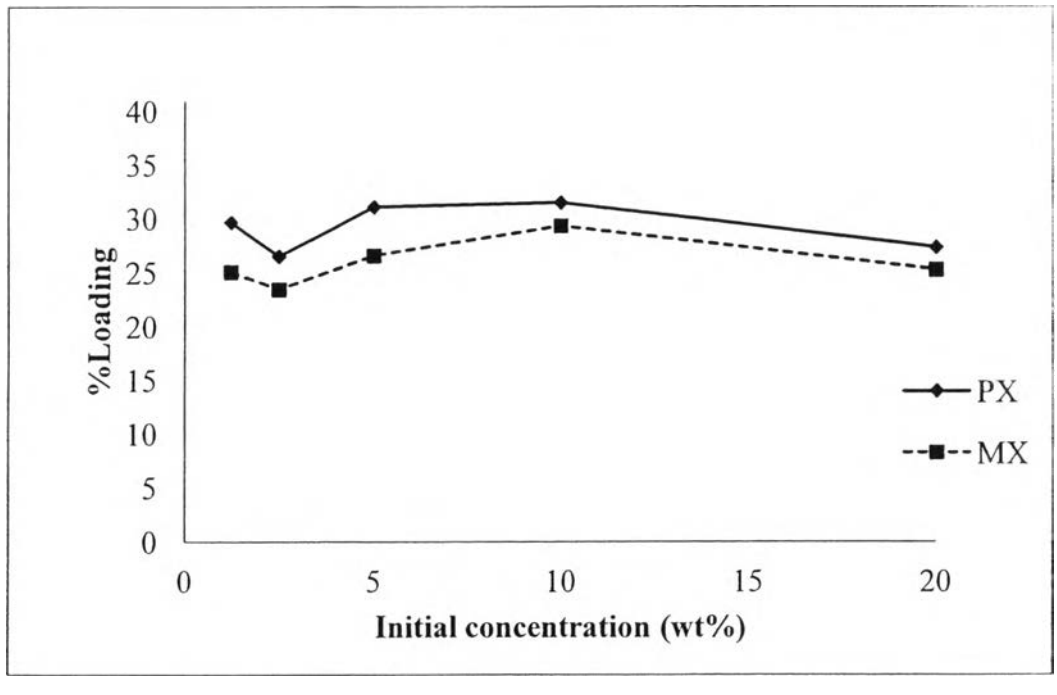


Figure 4.12 Adsorption of the C_8 aromatics on BaY zeolite at 80 °C.

Figures 4.13 – 4.16 show the adsorption of xylenes on NaY, KaY, BaX, and BaY zeolites at 100 °C, respectively. The figures indicate that NaY, KY, and BaY zeolites have the xylenes loadings increase from 1.25 wt% to 2.5 wt% initial concentration and slightly increase from 1.25 wt% to 5 wt% initial concentration. Then, they increase again at 10 wt% initial concentration and decrease at 20 wt% initial concentration. In the case of BaX zeolite, the loadings are similar at the initial concentration of 1.25 wt% - 10 wt% and then they slightly decrease at 20 wt% initial concentration. At 100 °C, all zeolites have *p*-xylene loading higher than *m*-xylene, which means all zeolites selectively adsorbe *p*-xylene. Moreover, the difference between the *p*-xylene and *m*-xylene loadings is higher than that at the lower temperature and the xylene loadings are highest at 10 wt% initial concentration for all zeolites.

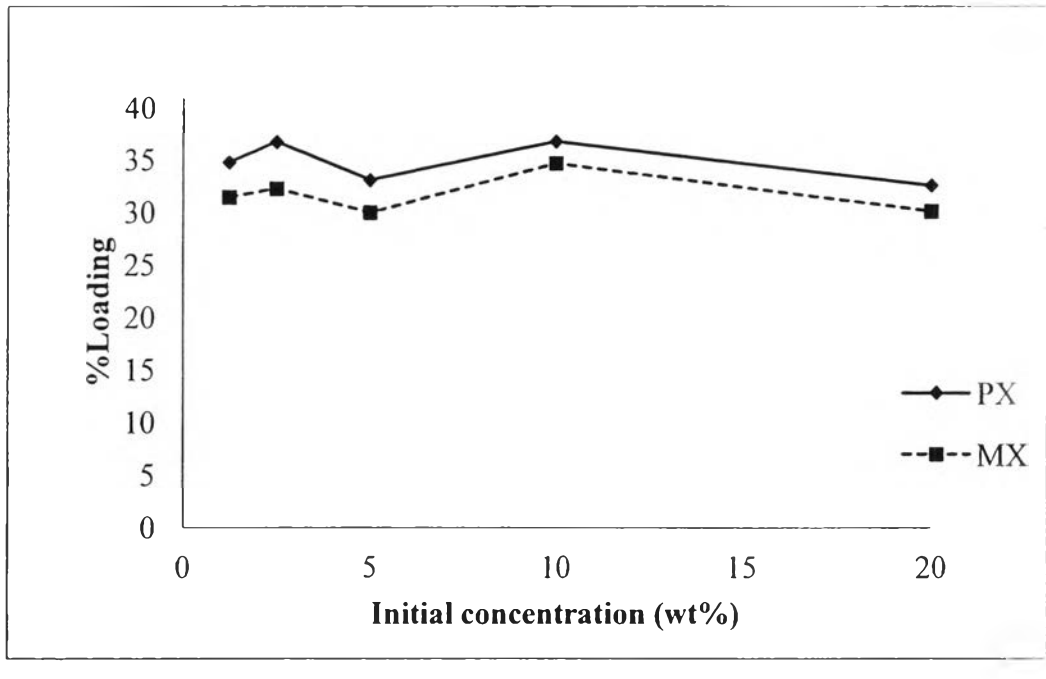


Figure 4.13 Adsorption of the C_8 aromatics on NaY zeolite at 100 °C.

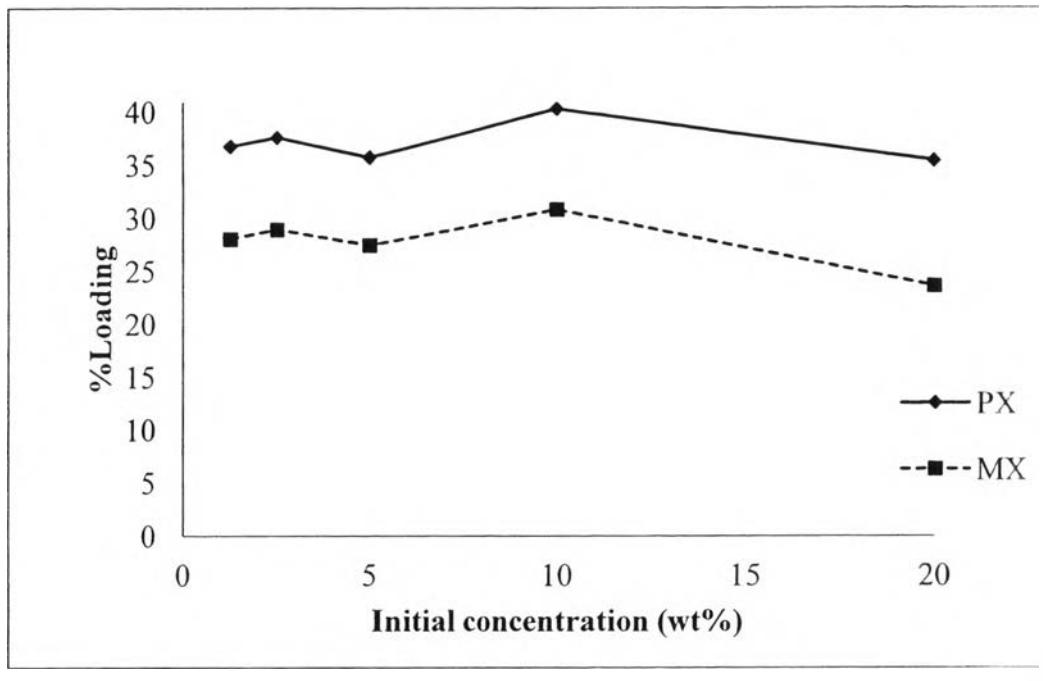


Figure 4.14 Adsorption of the C_8 aromatics on KY zeolite at 100 °C.

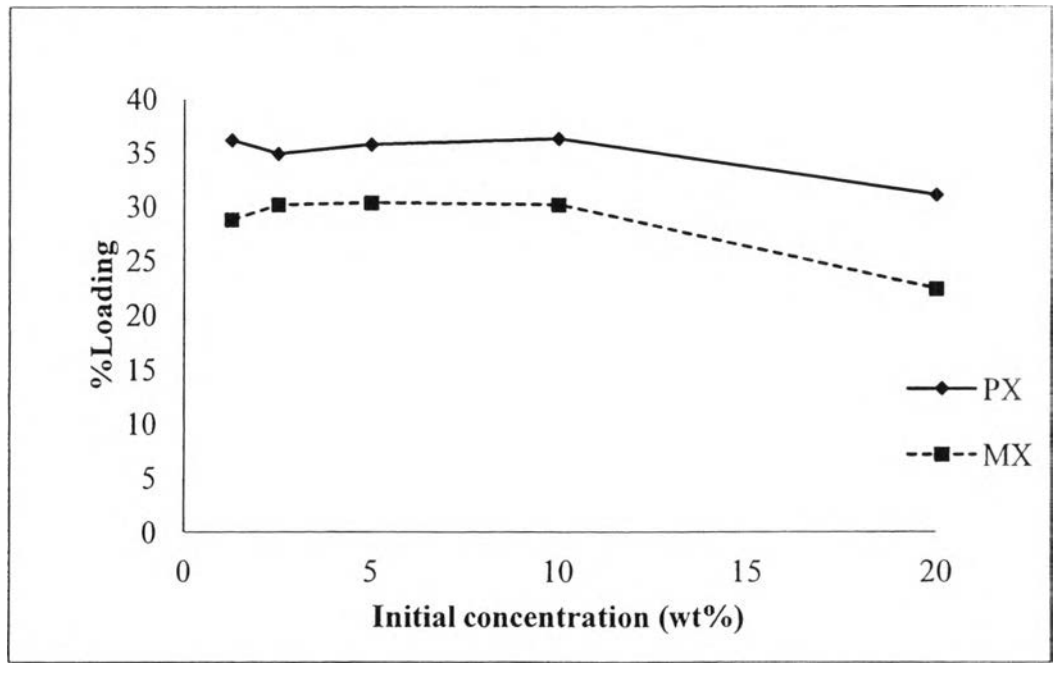


Figure 4.15 Adsorption of the C_8 aromatics on BaX zeolite at 100 °C.

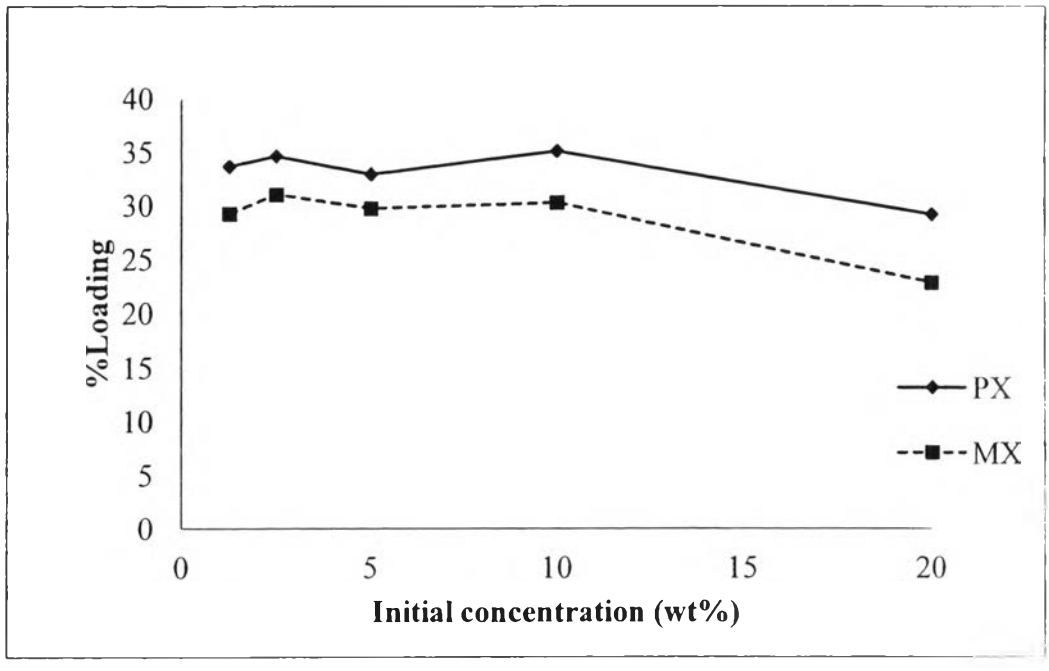


Figure 4.16 Adsorption of the C_8 aromatics on BaY zeolite at 100 °C.

The adsorption of xylenes on zeolites at 120 °C is shown in Figures 4.17 – 4.20. According to the figures, *p*-xylene and *m*-xylene loadings are about the same regardless of initial concentrations for all adsorbents or the effect of initial concentration cannot be seen at this temperature. This may be the effect of toluene, because 120 °C is higher than the boiling point of toluene, which is around 111 °C, so the vapor phase contains a high amount of toluene. Nevertheless, all zeolites also have *p*-xylene loading higher than *m*-xylene.

From Figures 4.1 – 4.20, the *p*-xylene and *m*-xylene loadings are highest at 10 wt% initial concentration for almost all studied temperatures. KaY, BaX, and BaY zeolites adsorb *p*-xylene more than *m*-xylene, while NaY zeolite adsorbs *p*-xylene and *m*-xylene about the same amount.

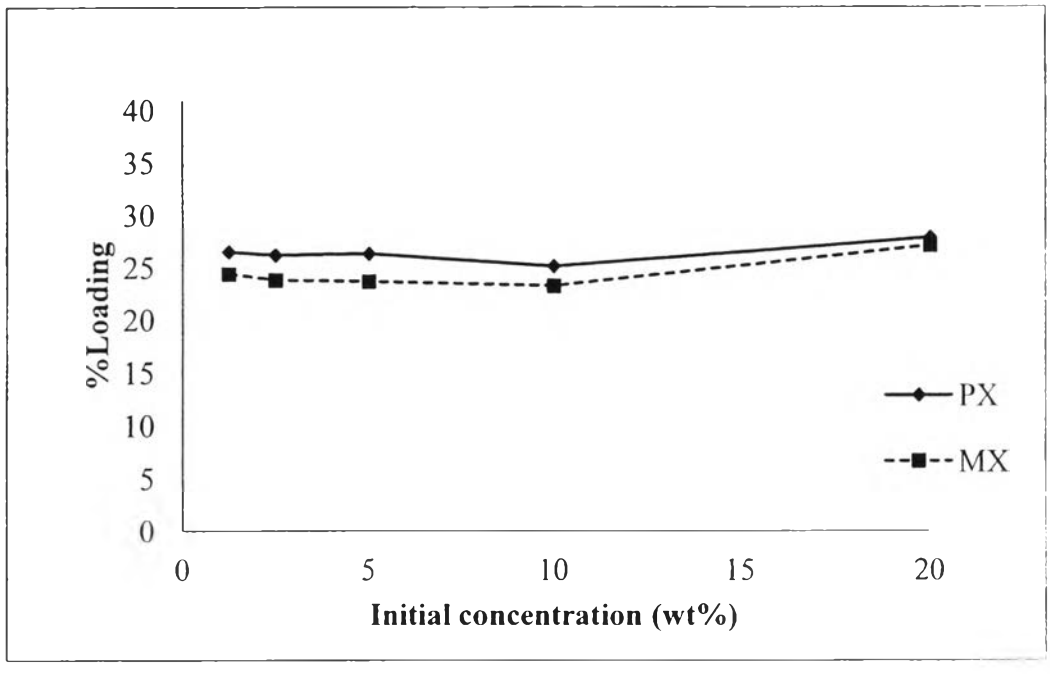


Figure 4.17 Adsorption of the C_8 aromatics on NaY zeolite at 120 °C.

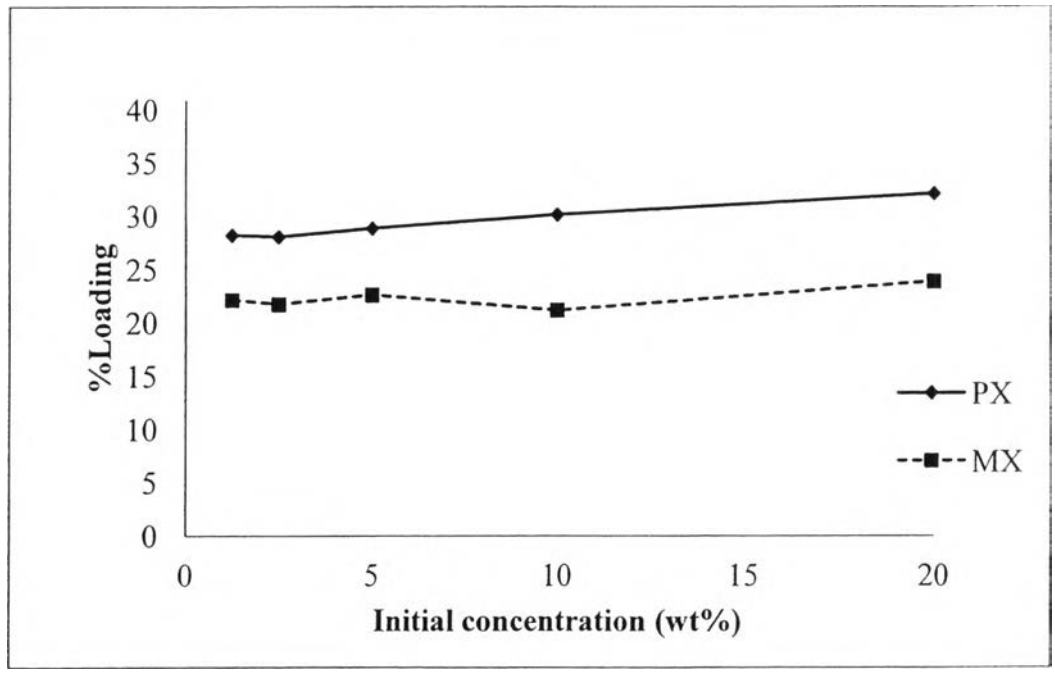


Figure 4.18 Adsorption of the C_8 aromatics on KY zeolite at 120 °C.

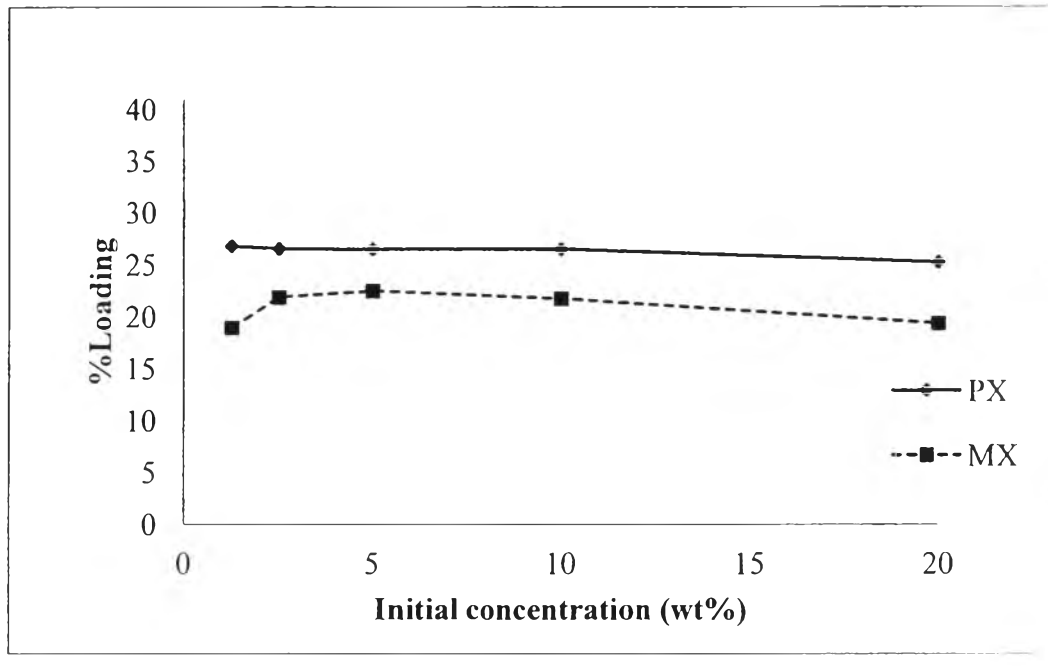


Figure 4.19 Adsorption of the C_8 aromatics on BaX zeolite at 120 °C.

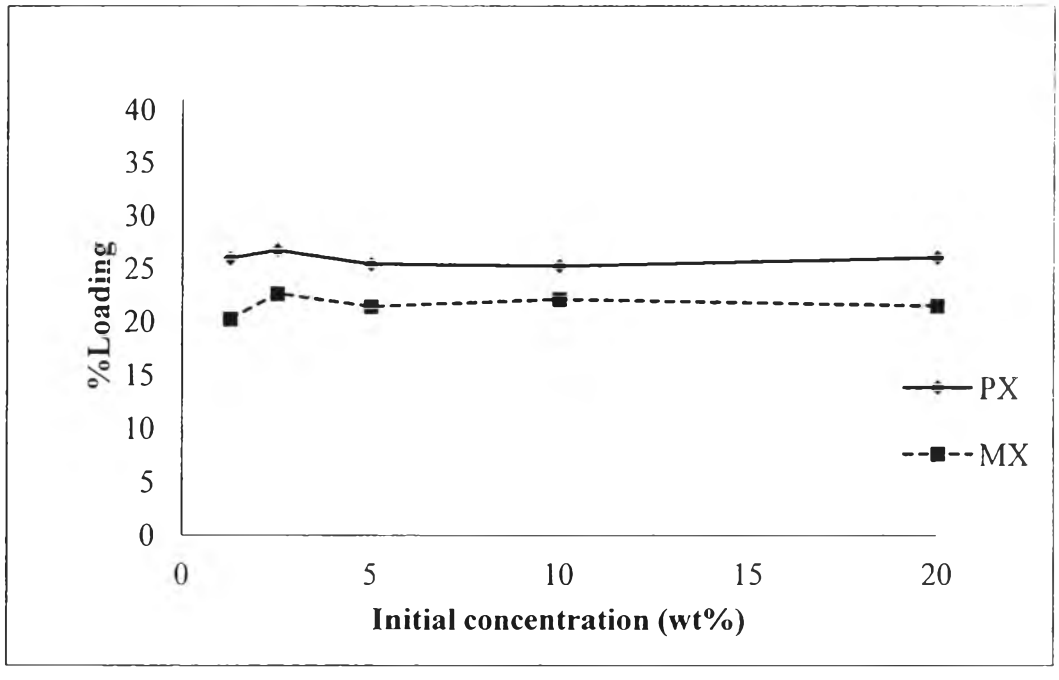


Figure 4.20 Adsorption of the C_8 aromatics on BaY zeolite at 120 °C.

p-Xylene selectivity can be calculated from the ratio of *p*-xylene and *m*-xylene in the adsorbed phase per ratio of *p*-xylene and *m*-xylene in the liquid phase as shown in equation 4.1 (Luna *et al.*, 2010).

$$\alpha_{PX/MX} = \frac{z_{PX}/z_{MX}}{x_{PX}/x_{MX}}, \tag{4.1}$$

where $\alpha_{PX/MX}$ is selectivity of *p*-xylene with respect to *m*-xylene, z is mole fraction in the adsorbed phase and x is mole fraction in the liquid phase. PX and MX represent *p*-xylene and *m*-xylene, respectively. Furthermore, *p*-xylene selectivity on NaY, KY, BaX, and BaY zeolites at the studied conditions is shown in Tables 4.1 - 4.5.

At 40 °C, the *p*-xylene selectivity on NaY and KY zeolites decreases with the increase in the *p*-xylene initial concentration as shown in Table 4.1. In the case of BaX and BaY zeolites, the *p*-xylene selectivity fluctuates with the *p*-xylene initial concentration. Moreover, at this temperature, the *p*-xylene selectivity is highest at 1.25 wt% *p*-xylene initial concentration for all zeolites. Table 4.2 shows the *p*-xylene selectivity on zeolites at 60 °C. From this table, the *p*-xylene selectivity on NaY, KY, BaX, and BaY zeolites seems to be constant at different *p*-xylene initial concentration. At 80 °C, the *p*-xylene selectivity on NaY is relatively constant at different *p*-xylene initial concentration as same as that at 60 °C. For KY, BaX, and BaY zeolites, the *p*-xylene selectivity varies with the *p*-xylene initial concentration as same as that at 40 °C. The *p*-xylene selectivity on KY and BaY zeolites at 100 °C is constant from 1.25 wt% to 10 wt% *p*-xylene initial concentration, and it slightly increases at this initial concentration as can be seen in Table 4.4. The *p*-xylene selectivity on BaX zeolite at this temperature varies with the *p*-xylene initial concentration. From Table 4.5, the *p*-xylene selectivity on KY zeolite at 120 °C remains constant from 1.25 wt% to 5 wt% *p*-xylene initial concentration. Then, it slightly increases at 10 wt% initial concentration. For BaX and BaY zeolites, the *p*-xylene selectivity is nearly constant for all initial concentration except at 1.25 wt% initial concentration. In addition, the *p*-xylene selectivity on NaY at 100 °C and 120 °C is the same at different *p*-xylene initial concentration. Hence, it may be

deduced that the xylene initial concentration does not affect the *p*-xylene selectivity from the headspace gas chromatography.

Table 4.1 *p*-Xylene selectivity on zeolites at 40 °C

***p*-xylene initial concentration (wt%)**	***p*-Xylene selectivity**			
	NaY	**KY**	**BaX**	**BaY**
1.25	1.271	1.615	1.577	1.538
2.5	1.162	1.478	1.017	1.217
5	1.114	1.447	1.379	1.226
10	1.072	1.377	1.364	1.349
20	1.053	1.276	1.437	1.377

Table 4.2 *p*-Xylene selectivity on zeolites at 60 °C

***p*-xylene initial concentration (wt%)**	***p*-Xylene selectivity**			
	NaY	**KY**	**BaX**	**BaY**
1.25	1.012	1.460	1.221	1.156
2.5	1.005	1.445	1.211	1.136
5	0.929	1.404	1.179	1.155
10	0.992	1.378	1.264	1.144
20	0.947	1.498	1.261	1.133

Table 4.3 *p*-Xylene selectivity on zeolites at 80 °C

***p*-xylene initial concentration (wt%)**	***p*-Xylene selectivity**			
	NaY	**KY**	**BaX**	**BaY**
1.25	1.022	1.421	1.326	1.261
2.5	1.114	1.447	1.238	1.177
5	1.043	1.288	1.380	1.247
10	0.973	1.371	1.195	1.108
20	0.949	1.487	1.279	1.115

Table 4.4 *p*-Xylene selectivity on zeolites at 100 °C

***p*-xylene initial concentration (wt%)**	***p*-Xylene selectivity**			
	NaY	**KY**	**BaX**	**BaY**
1.25	1.165	1.491	1.403	1.229
2.5	1.219	1.479	1.242	1.178
5	1.154	1.469	1.278	1.160
10	1.096	1.515	1.320	1.244
20	1.122	1.776	1.560	1.389

Table 4.5 *p*-Xylene selectivity on zeolites at 120 °C

***p*-xylene initial concentration (wt%)**	***p*-Xylene selectivity**			
	NaY	**KY**	**BaX**	**BaY**
1.25	1.118	1.380	1.572	1.384
2.5	1.136	1.403	1.290	1.249
5	1.152	1.389	1.243	1.251
10	1.108	1.603	1.299	1.190
20	1.039	1.505	1.408	1.288

4.1.1 Effects of Zeolite

According to Tables 4.1 – 4.5, KY, BaX, and BaY zeolites have *p*-xylene selectivity higher than one over the whole range of studied condition, while NaY zeolite has *p*-xylene selectivity around one. In other words, KY, BaX, and BaY zeolites selectively adsorb *p*-xylene more than *m*-xylene, while NaY zeolite equally adsorbs *p*-xylene and *m*-xylene. On average, KY zeolite has highest *p*-xylene selectivity with respect to *m*-xylene followed by BaX, BaY, and NaY zeolites, respectively. The high *p*-xylene selectivity of KY zeolite can be described by the zeolite acidity. The lower the zeolite acidity, the higher the *p*-xylene selectivity. This is a result from a strong acid-base interaction between low acidic zeolite and the least basic xylene isomer, *p*-xylene, which has the weakest electron-donating characteristic among other isomers. The main specific physical properties of zeolites

that can influence the zeolite acidity are the ratio of SiO_2/Al_2O_3 and choice of exchanged metal cations (Kulprathipanja, 2010).

Normally, zeolite acidity increases as the molar ratio of SiO_2/Al_2O_3 decreases due to the increase in AlO_4^- sites, which strengthens the electro-static field in the zeolite and increases the number of acid sites. Generally, a X zeolite refers to zeolites with between 96 and 77 Al atoms per cell or Si/Al ratios between 1 and 1 and a Y zeolite refers to zeolites with less than 76 Al atoms per cell or Si/Al ratios higher than 1.5. Therefore, a X zeolite is more acidic than a Y zeolite, and this results in the lower *p*-xylene selectivity. In other words, a X zeolite is less selective to *p*-xylene than a Y zeolite.

As mentioned before, exchanged metal cations is one factor that affects the zeolite acidity. There is a strong correlation between zeolite acidity and ionic radius or exchanged cation. The exchange cations with lower ionic radius have higher zeolite acidity (Suntornpun, 2002). Zeolite acidity increases from K to Na for monovalent exchanged cations, and divalent cations have higher zeolite acidity than monovalent cations at the similar ionic radius (Kulprathipanja, 2010). Therefore, when the acidity of a zeolite is compared, KY zeolite is the lowest acid adsorbent compared to BaX, BaY, and NaY zeolites. KY zeolite has highest *p*-xylene selectivity with respect to *m*-xylene compared to NaY, BaX, and BaY zeolites due to the acid-base interaction.

4.1.2 Effects of Temperature

Considering the effects of temperature on the adsorption of xylenes on zeolites from headspace gas chromatography, the adsorption of *p*-xylene and *m*-xylene at different temperatures is shown in Figures 4.21 – 4.24. From Figure 4.21, the *p*-xylene loading on NaY zeolite increases when the temperature increases from 40 °C to 100 °C for all initial concentrations except at 10 wt% and 20 wt% initial concentration, where *p*-xylene loadings at 40 °C and 60 °C are about the same. In the case of *m*-xylene loading, it shows the same trend as *p*-xylene, which increases when the temperature increases but it is about the same at 80 °C and 100 °C. For KY zeolite, the *p*-xylene and *m*-xylene loadings show the same trend as that on NaY zeolite; that is when the temperature increases, the loadings increase at low initial

concentrations. At 10 wt% and 20 wt% initial concentration, the *m*-xylene loadings on KY zeolite at different temperatures are about the same. According to Figures 4.23 – 4.24, BaX and BaY zeolites show that the *p*-xylene and *m*-xylene loadings increase when the temperature increases for initial concentration of 1.25 wt% - 5 wt%. At 10 wt% initial concentration, the loadings at 40 °C are higher than that at 60 °C. Moreover, the xylene loadings from different temperatures are similar at 20 wt% initial concentration. From Figures 4.21 – 4.24, the *p*-xylene and *m*-xylene loadings on zeolites from different temperatures are similar at 20 wt% initial concentration. Hence, the temperature does not affect the xylene adsorption at the initial concentration of 20 wt%. However, the *p*-xylene and *m*-xylene loadings of all zeolites tend to increase when the temperature increases and the effect of temperature can be seen clearly at low initial concentration. These results are not expected because they opposes to the adsorption theory. Theoretically, adsorption is an exothermic process so the adsorbent should adsorb xylenes in a lower amount at a higher temperature or xylene loading at the same initial concentration should decrease when the temperature increases.

From Tables 4.1 – 4.5, the *p*-xylene selectivity on NaY, BaX, and BaY zeolites at 1.25 wt% *p*-xylene initial concentration varies with the temperature, whereas the selectivity is constant in this temperature range for KY zeolite except at 40 °C. At 2.5 wt% *p*-xylene initial concentration, the *p*-xylene selectivity on KY and BaY zeolites is constant regardless of temperature, while that on NaY zeolite varies with temperature as same as that at 1.25 wt% *p*-xylene initial concentration. For BaX zeolite, the *p*-xylene selectivity seems to be constant as that on BaY zeolite except at 1.25 wt% *p*-xylene initial concentration. Moreover, all adsorbents show that the *p*-xylene selectivity at 5 wt% *p*-xylene initial concentration varies with temperature. At 10 wt% *p*-xylene initial concentration, the *p*-xylene selectivity on NaY zeolite seems to be independent on temperature, while BaX and BaY zeolites show otherwise. In the case of KY zeolite, the *p*-xylene selectivity is constant between 40 °C and 80 °C before increasing. In addition, the *p*-xylene selectivity on NaY zeolite at 20 wt% *p*-xylene initial concentration is constant over the studied temperatures, while that on KY, BaX, and BaY zeolites varies with temperature.

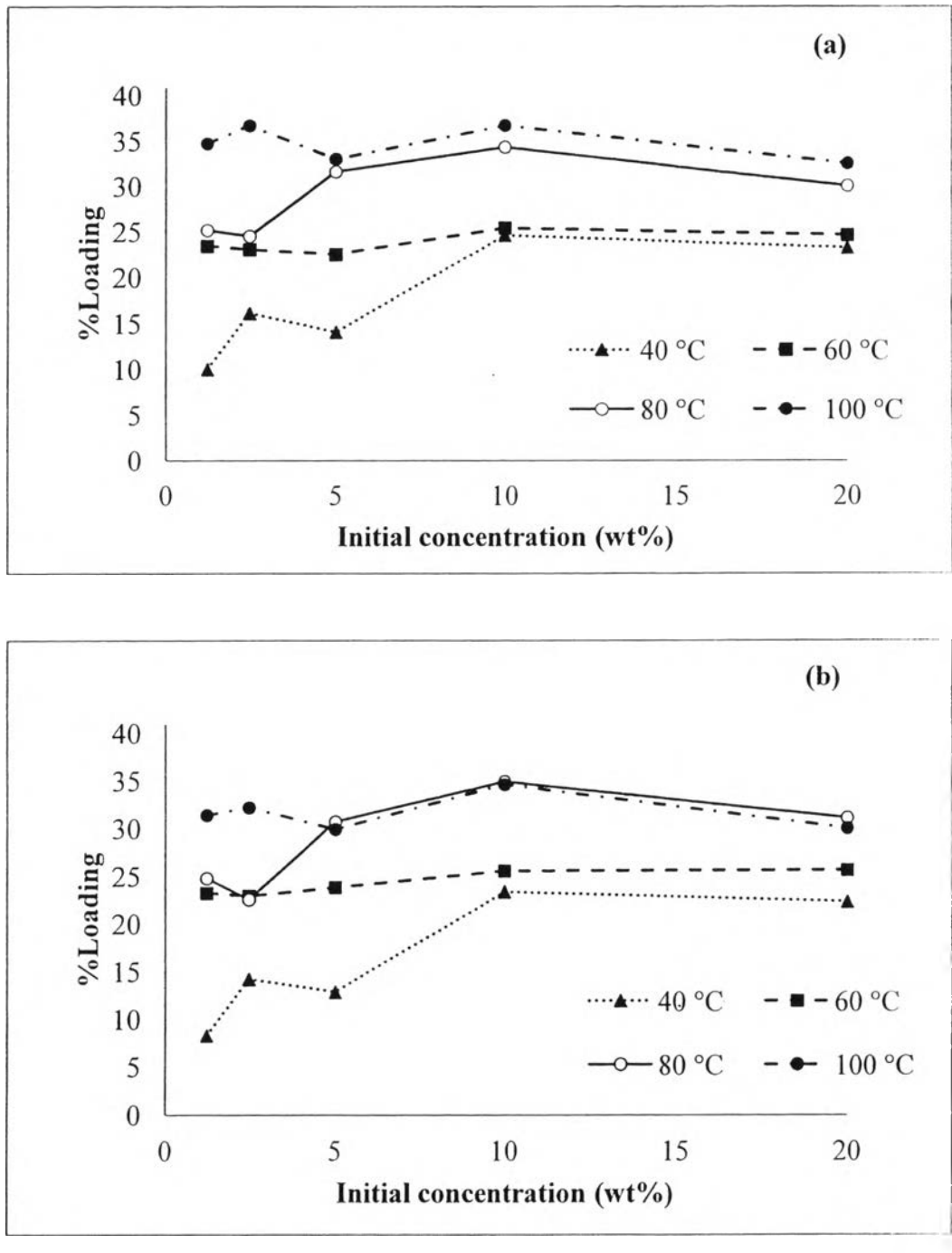
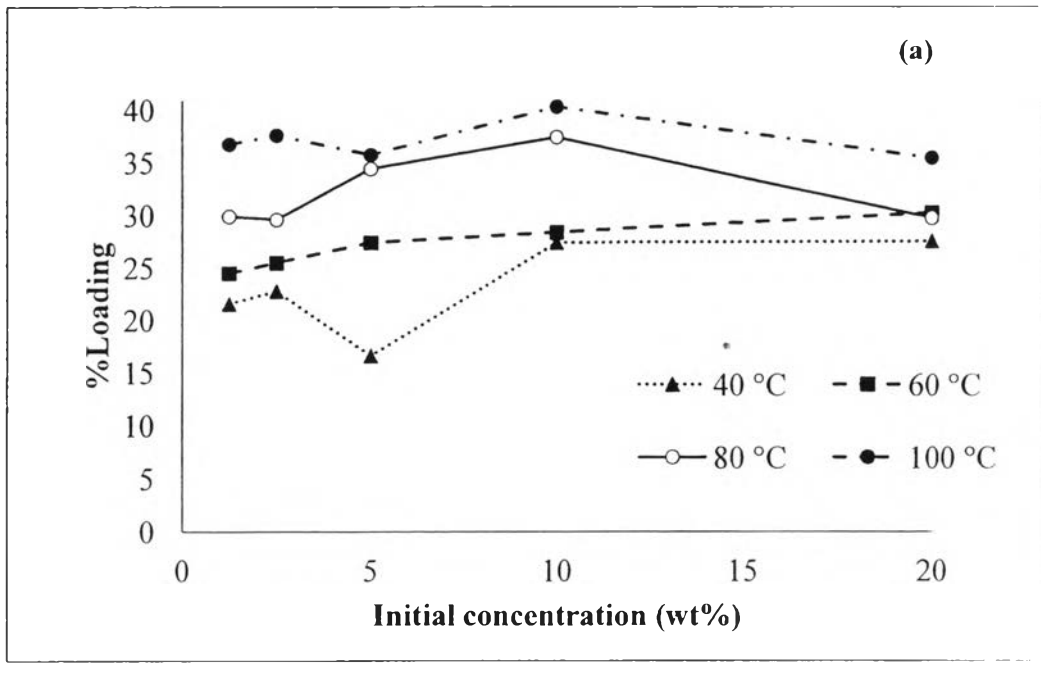


Figure 4.21 Adsorption of *p*-xylene (a) and *m*-xylene (b) on NaY zeolite at different temperatures.



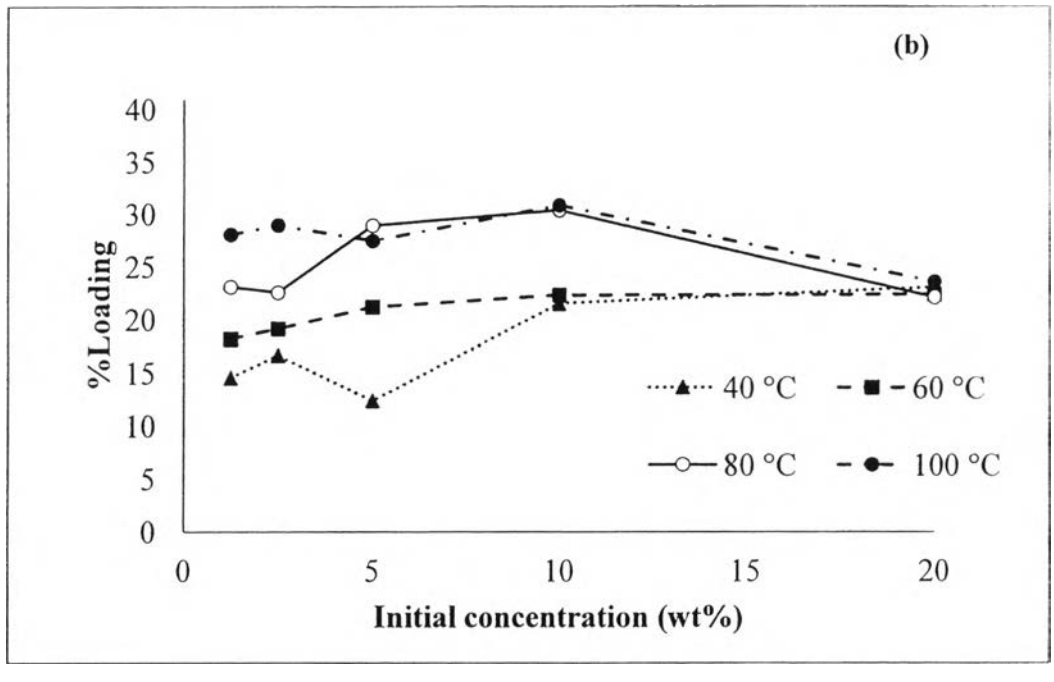


Figure 4.22 Adsorption of *p*-xylene (a) and *m*-xylene (b) on KY zeolite at different temperatures.

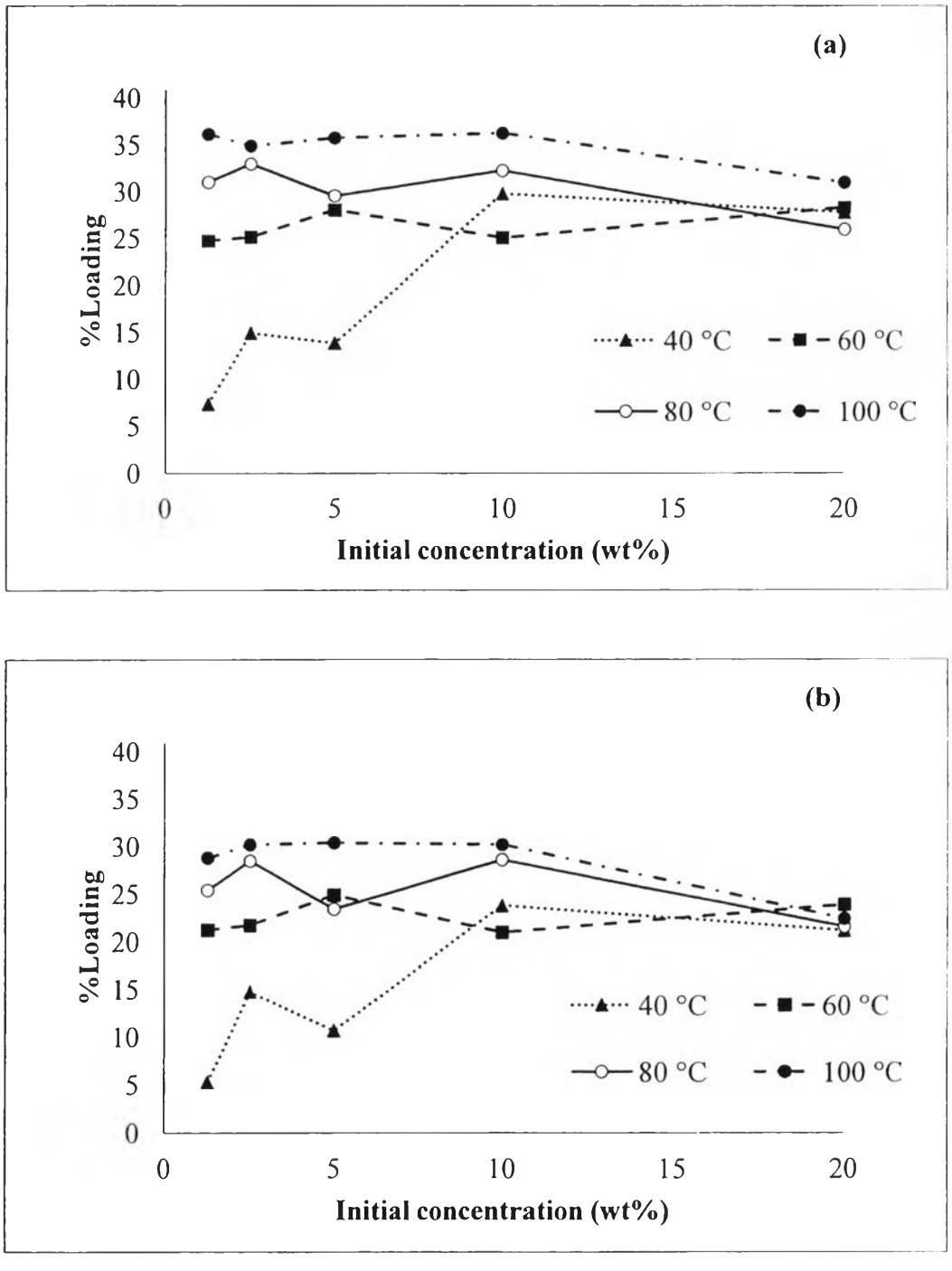


Figure 4.23 Adsorption of *p*-xylene (a) and *m*-xylene (b) on BaX zeolite at different temperatures.

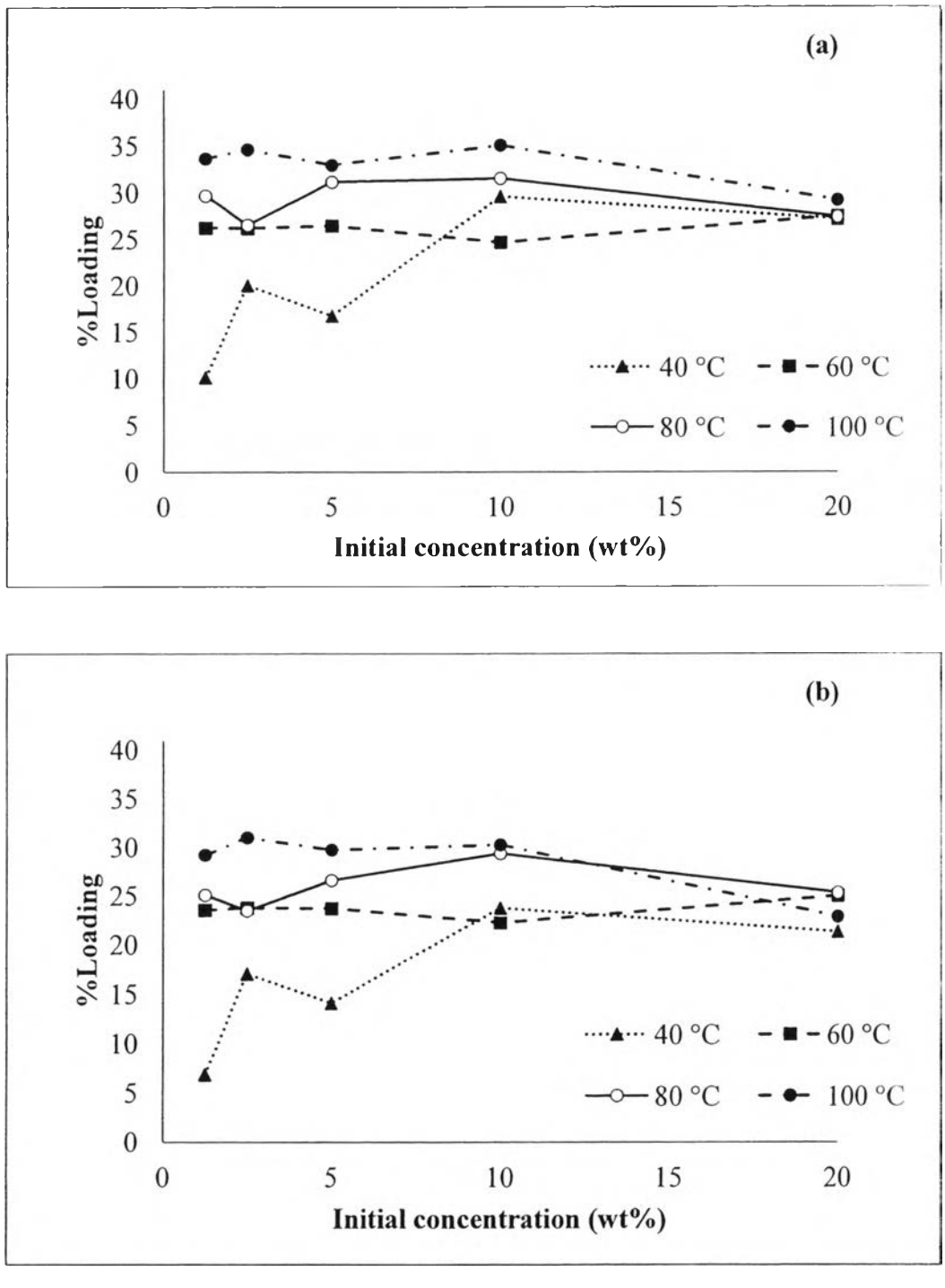


Figure 4.24 Adsorption of *p*-xylene (a) and *m*-xylene (b) on BaY zeolite at different temperatures.

In order to investigate the unexpected situation that the xylene loadings increase when temperature increases, the binary adsorption of *p*-xylene and *m*-xylene without the toluene desorbent was studied by the headspace technique at 40 °C and 60 °C, and the results are shown in Table 4.6. From the table, the adsorbed amounts or *p*-xylene and *m*-xylene loadings in the system without toluene at 40 °C are higher than that at 60 °C for all adsorbents. This result conforms the adsorption theory because the molecules of xylene have higher internal energy and tend to move around rather than being adsorbed on the zeolite at high temperature. Therefore, the conflict between the results from the system with toluene and the adsorption theory may be because the effect of toluene.

Moreover, the *p*-xylene selectivity of zeolites in the system without toluene is shown in Table 4.7. KY, BaX, and BaY zeolites have *p*-xylene selectivity with respect to *m*-xylene higher than one same as the system with toluene. The major difference between the system with and without toluene is *p*-xylene selectivity of NaY zeolite. NaY zeolite has *p*-xylene selectivity around one, which means that it equally adsorbs *p*-xylene and *m*-xylene. For the system without toluene, NaY zeolite has the *p*-xylene selectivity lower than one, which means NaY zeolite adsorb *m*-xylene more than *p*-xylene. In addition, the *p*-xylene selectivity decreases when temperature increases for KY, BaX, and BaY zeolites. This result from the system without toluene obtained from the headspace gas chromatography conforms to other techniques (Suntornpun, 2002; Limsamutchaikul, 2003).

Table 4.6 Xylene loading of zeolites in the system without toluene

Temperature (°C)	Xylene	%Loading			
		NaY	KY	BaX	BaY
40	PX	32.96	37.51	36.19	40.00
	MX	36.75	23.79	30.91	36.38
60	PX	31.36	32.80	23.68	23.31
	MX	32.11	27.13	21.13	22.10

Table 4.7 *p*-Xylene selectivity of zeolites in the system without toluene

Temperature (°C)	*p*-Xylene selectivity			
	NaY	KY	BaX	BaY
40	0.842	1.923	1.268	1.166
60	0.966	1.312	1.158	1.071

4.1.3 Effects of Toluene

Considering the results from the headspace gas chromatography shows that the xylene initial concentration does not affect the xylene loadings for almost all studied temperatures. But, the xylene initial concentration plays an important role on the xylene loadings especially at 40 °C. At this temperature, the xylene loadings change when the xylene initial concentration is lower than 10 wt%. As shown in Table 4.8, toluene vapor pressure at 40 °C is much higher than that of xylene. Consequently, toluene may affect the adsorption data at the low xylene initial concentration in a greater extent than that at the high xylene initial concentration. As the headspace gas chromatography takes the vapor for the quantitative analysis, it is unavoidably that the presence of toluene in a significant amount undermines the collected data.

Table 4.8 Properties of each component in the sample

Property	*p*-Xylene	*m*-Xylene	Toluene	n-Nonane
Molecular weight	106	106	92	128
Boiling point, °C	138.37	139.12	110.6	151
Melting point, °C	13.263	- 47.872	-93	-53
Vapor pressure @ 40 °C, mmHg	19.977	19.062	59.157	10.656

4.2 Adsorption Data from the Batch Method

In the batch method, the binary adsorption experiments were done at operating temperatures of 40 °C and 60 °C and the *p*-xylene initial concentration was varied from 1.25 wt% to 20 wt%. The *p*-xylene selectivity with respect to *m*-xylene from batch method is shown in Table 4.9, and the binary adsorption is shown in Figures 4.25 – 4.32.

From Table 4.9, the effect of zeolite can be seen for the whole range of studied condition. KY, BaX, and BaY zeolites have the *p*-xylene selectivity higher than one but NaY zeolite has *p*-xylene selectivity lower than one. In other words, KY, BaX, and BaY zeolites selectively adsorb *p*-xylene, while NaY zeolite selectively adsorbs *m*-xylene. Moreover, KY zeolite has highest *p*-xylene selectivity followed by BaX, BaY, and NaY zeolite, respectively. These results were consistent to other research (Suntornpun, 2002; Limsamutchaikul, 2003). In addition, the effect of temperature was also observed. When the temperature is increased from 40 °C to 60 °C, all adsorbents have lower *p*-xylene selectivity except NaY zeolite.

Table 4.9 *p*-Xylene selectivity of zeolites from the batch method

p-Xylene initial concentration (wt%)	Temperature (°C)	*p*-Xylene selectivity			
		NaY	KY	BaX	BaY
1.25	40	0.752	2.027	1.142	1.081
	60	0.735	1.905	1.114	1.188
2.5	40	0.708	2.442	1.171	1.113
	60	0.747	1.890	1.138	1.111
5	40	0.702	2.092	1.191	1.226
	60	0.770	1.838	1.147	1.093
10	40	0.681	2.366	1.276	1.159
	60	0.808	1.879	1.191	1.100
20	40	0.698	2.189	1.306	1.152
	60	0.835	1.797	1.244	1.149

From Figures 4.25 – 4.28, the xylene loadings on NaY zeolite at 40 °C increase from 1.25 wt% to 2.5 wt% initial concentration, and seem to be constant from this concentration. Nevertheless, the xylene loadings on KY, BaX, and BaY zeolites fluctuate with the initial concentration. The loadings decrease from 1.25 wt% to 2.5 wt% initial concentration, and increase at 5 wt%. Then, they decrease again at 10 wt% and slightly increase at 20 wt% initial concentration. At 60 °C, the xylene loading on NaY and BaY zeolites seem to fluctuate with initial concentration as same as that on BaX zeolite at 40 °C. In the case of KY and BaX zeolites, the xylene loading at 60 °C are about the same at different initial concentrations. However, the trend of xylene loading when the initial concentration increases cannot be clearly seen. Therefore, the xylene initial concentration may not has high influence to xylene loading or it may not affect xylene loading. From all results from the batch method, the *p*-xylene loading on KY, BaX, and BaY zeolites higher than that of *m*-xylene while NaY zeolite has *m*-xylene loading higher than *p*-xylene loading. This means KY, BaX, and BaY zeolites selectively adsorb *p*-xylene, whereas NaY zeolite selectively adsorbs *m*-xylene, which correspond to *p*-xylene selectivity. Considering the effect of temperature, the *p*-xylene loading on NaY zeolite is about the same at 40 °C and 60 °C for almost all initial concentration except at 1.25 wt% and 5 wt% initial concentration, while *m*-xylene loading on NaY zeolite at 40 °C is higher than that at 60 °C at 10 wt% and 20 wt% initial concentration. For KY zeolite, the *p*-xylene loading is about the same between 40 °C and 60 °C except at 1.25 wt% and 5 wt% initial concentration, which shows that *p*-xylene loading at 40 °C is a little higher than that at 60 °C. On the other hand, the *m*-xylene loading on KY at 40 °C is lower than that at 60 °C except at 1.25 wt% and 5 wt% initial concentration. The *p*-xylene loading on BaX zeolite at 40 °C and 60 °C is about the same except at 1.25 wt% and 5 wt% initial concentration as same as that on KY zeolite. In the case of *m*-xylene loading on BaX zeolite, there is no difference between 40 °C and 60 °C for all initial concentration. For BaY zeolite, the *p*-xylene and *m*-xylene loadings between 40 °C and 60 °C are about the same as same as that on BaX zeolite.

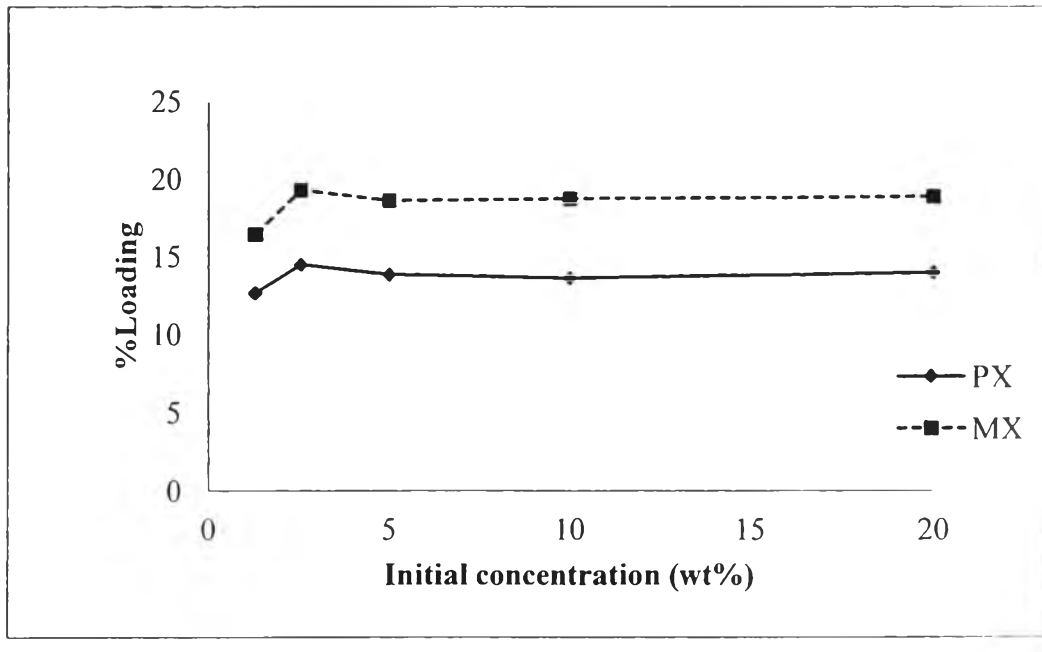


Figure 4.25 Adsorption of the C_8 aromatics on NaY zeolite at 40 °C from the batch method.

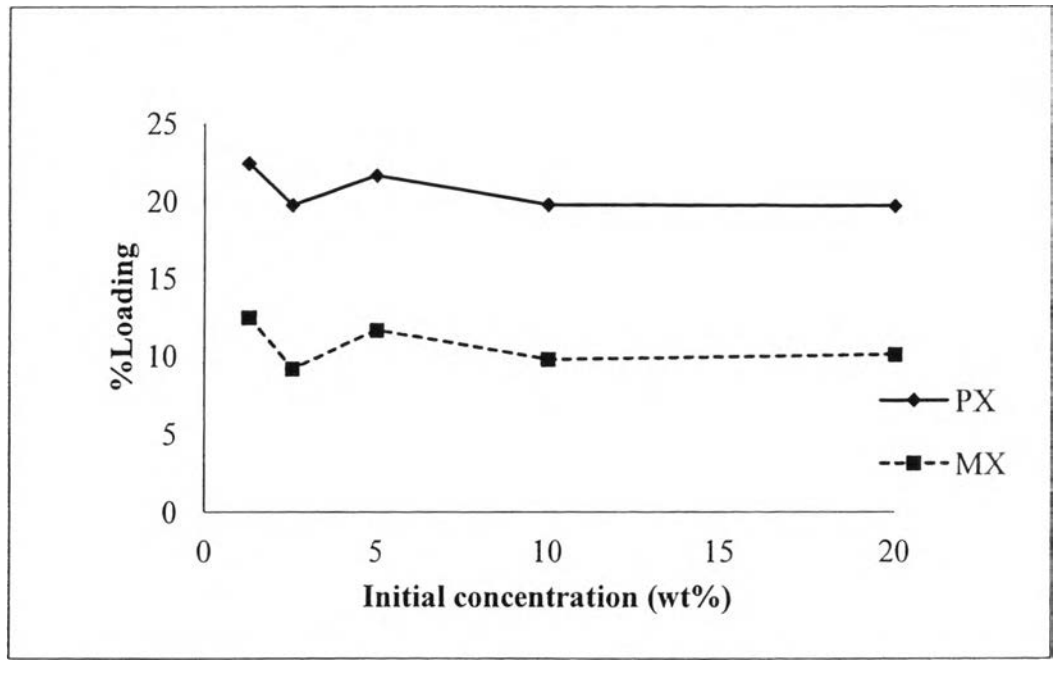


Figure 4.26 Adsorption of the C_8 aromatics on KY zeolite at 40 °C from the batch method.

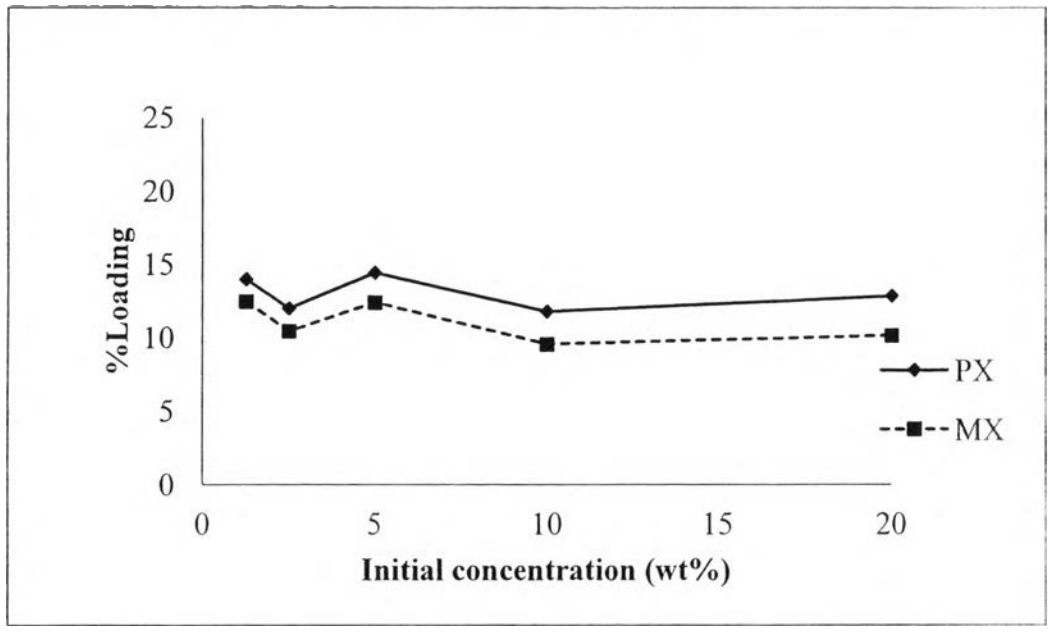


Figure 4.27 Adsorption of the C_8 aromatics on BaX zeolite at 40 °C from the batch method.

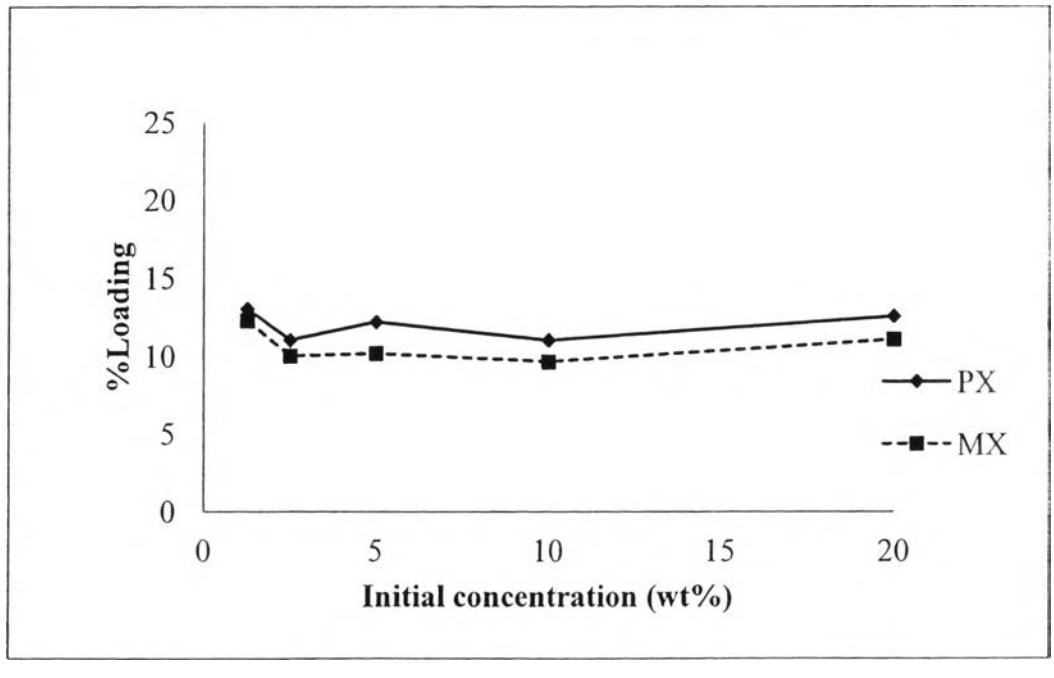


Figure 4.28 Adsorption of the C_8 aromatics on BaY zeolite at 40 °C from the batch method.

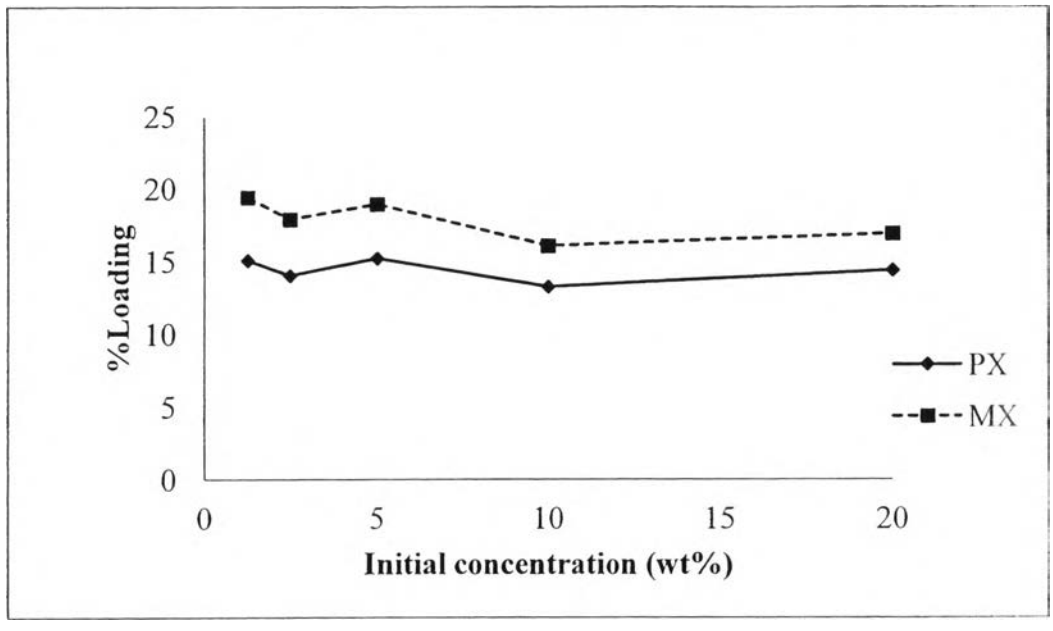


Figure 4.29 Adsorption of the C_8 aromatics on NaY zeolite at 60 °C from the batch method.

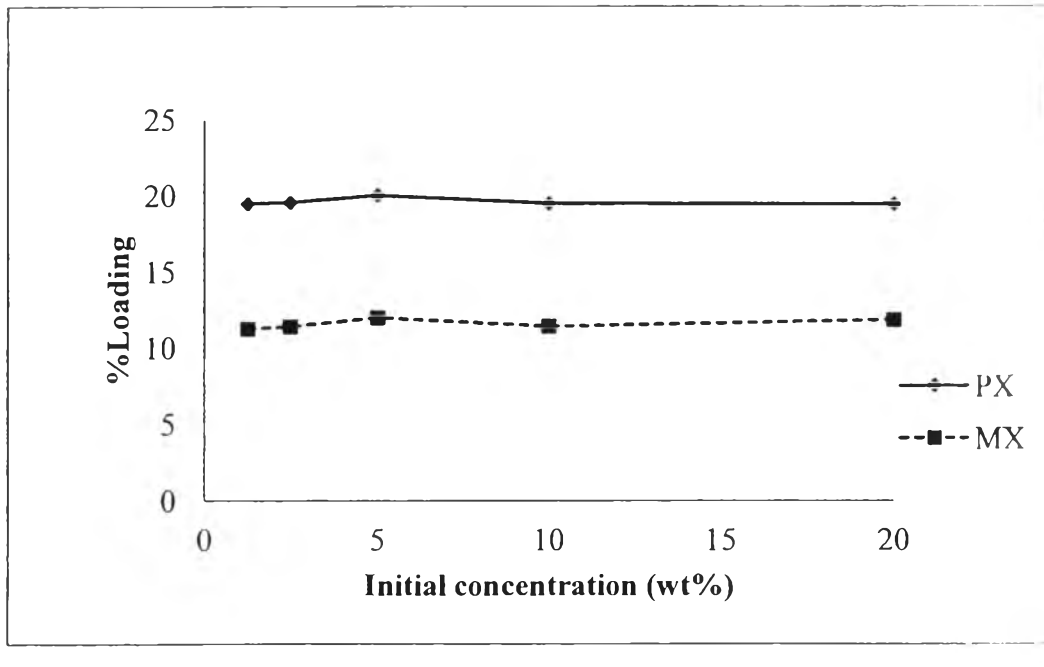


Figure 4.30 Adsorption of the C_8 aromatics on KY zeolite at 60 °C from the batch method.

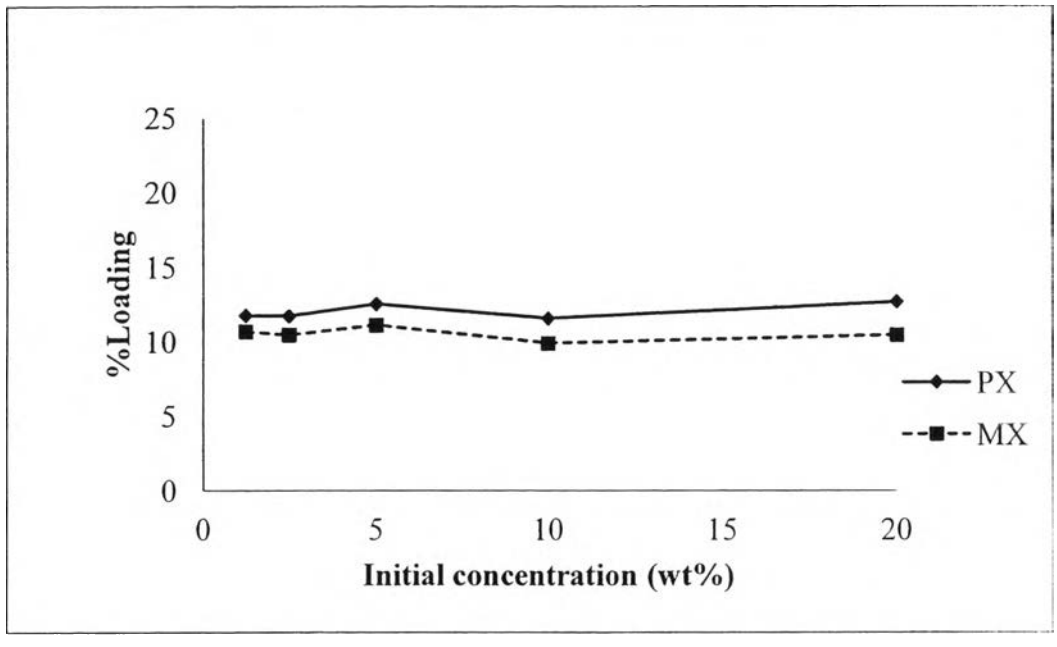


Figure 4.31 Adsorption of the C_8 aromatics on BaX zeolite at 60 °C from the batch method.

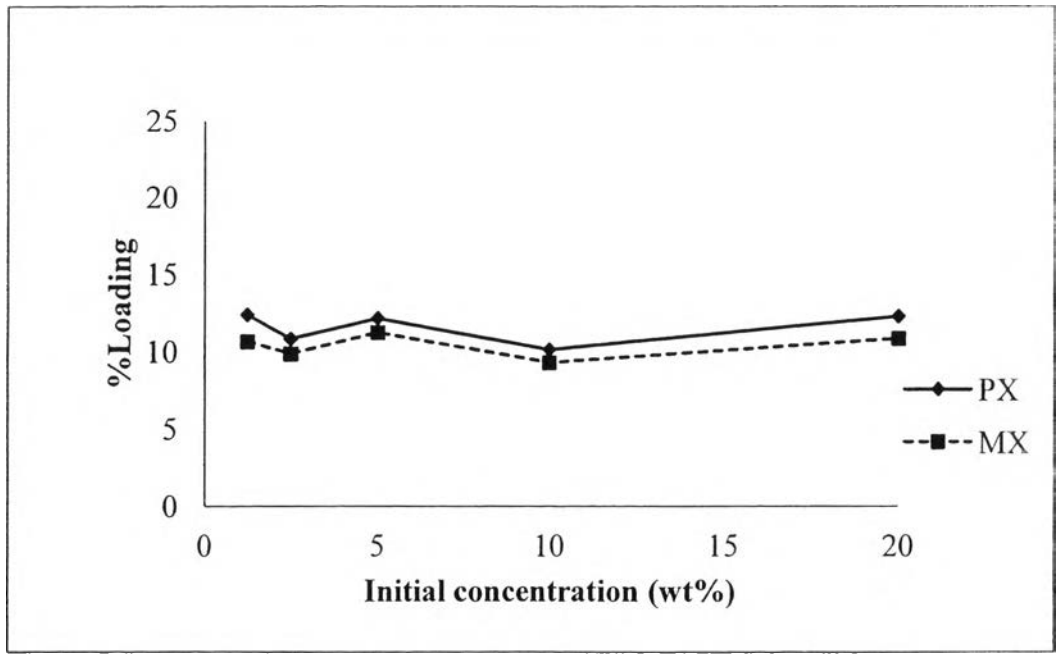


Figure 4.32 Adsorption of the C_8 aromatics on BaY zeolite at 60 °C from the batch method.

4.3 Comparison between Data from the Headspace Gas Chromatography and Batch Method

The difference between headspace technique and batch method is that the headspace technique measures composition in a gas phase then converts to the composition in the liquid phase, while the batch method directly measures the composition in the liquid phase. When the results from the headspace gas chromatography and batch method are compared at the same condition, they show the same trend for *p*-xylene selectivity, which decreases when the temperature increases from 40 °C to 60 °C for all adsorbents except KY zeolite as represented in Table 4.10. Moreover, NaY zeolite has *p*-xylene selectivity higher than one for the headspace technique, which means it selectively adsorbs *p*-xylene. On the contrary, the results from the batch method show that *p*-xylene selectivity on NaY zeolite is lower than one, which means NaY zeolite selectively adsorbs *m*-xylene. In the case of adsorbed amount or %loading, the trend of xylene loadings at different temperatures from the two methods is different. For the system with toluene from the headspace gas chromatography, the xylene loadings tend to increase when the temperature increases at the same initial concentration. On the other hand, the xylene loadings are about the same when temperature increases from 40 °C to 60 °C for the batch method. This difference may be the effect of toluene on the data collected from the headspace gas chromatography. This is substantiated when the *p*-xylene selectivity from the batch method and headspace technique in the system without toluene is compared. The values from the two methods are close and they show the same trend. Furthermore, the xylene loadings from the two methods show the trend that it decreases or about the same when temperature increases, which does not oppose adsorption theory. However, there is a similar point from the three systems that KY zeolite has the highest *p*-xylene selectivity followed by BaX, BaY, and NaY zeolites.

Table 4.10 *p*-Xylene selectivity from the batch method and headspace gas chromatography

Zeolite	Temperature (°C)	*p*-Xylene selectivity		
		Headspace gas chromatography		Batch method
		with toluene	w/o toluene	
NaY	40	1.053	0.842	0.698
	60	0.947	0.966	0.835
KY	40	1.276	1.923	2.189
	60	1.498	1.312	1.797
BaX	40	1.437	1.268	1.306
	60	1.261	1.158	1.244
BaY	40	1.377	1.166	1.152
	60	1.133	1.071	1.149