CHAPTER 3

RESULTS AND DISCUSSION

3.1 The viscosity and paint adhesion

3.1.1 Viscosity and the characteristic of adhesion when the solvent mixtures of toluene, 2-propanol and ethyl acetate is used

The results of the viscosity measurement and the characteristic of adhesion when the solvent mixtures of toluene, 2-propanol and ethyl acetate, which is the currently-used mixture, is experimented by varying the ratios as shown in Table 3.1.

Table 3.1 Viscosity and the characteristic of adhesion of the currently-used solvent mixtures with various ratios at room temperature.

Entry	Ratios of solvent mixtures (v/v) (Toluene : 2-Propanol : Ethyl acetate)[a]	Viscosity, s[c] (%RSD)	Coating Remark[b]
1	1 : 8 : 1	7.00 (1.21)	5
2	1 : 7 : 2	6.55 (2.86)	5
3	1 : 6 : 3	6.58 (1.15)	3
4	1 : 5 : 4	6.77 (0.92)	4
5	1 : 4 : 5	6.50 (0.46)	3
6	1 : 3 : 6	6.34 (0.47)	0
7	1 : 2 : 7	6.19 (0.25)	5

Table 3.1 (Continued)

Entry	Ratios of solvent mixtures (v/v) (Toluene : 2-Propanol : Ethyl acetate)[a]	Viscosity, s[c] (%RSD)	Coating Remarks[b]
8	1 : 1 : 8	6.20 (1.22)	1
9	2 : 7 : 1	6.71 (1.69)	3
10	2 : 6 : 2	6.54 (0.70)	3
11	2 : 5 : 3	6.39 (0.63)	5
12	2 : 4 : 4	6.41 (0.86)	5
13	2 : 3 : 5	6.20 (0.74)	2
14	2 : 2 : 6	6.10 (0.58)	5
15	2 : 1 : 7	6.08 (0.75)	0
16	3 : 6 : 1	6.63 (1.54)	5
17	3 : 5 : 2	6.49 (0.58)	1
18	3 : 4 : 3	6.40 (0.24)	0
19	3 : 3 : 4	6.22 (0.84)	5
20	3 : 2 : 5	6.25 (0.48)	4
21	3 : 1 : 6	6.21 (0.25)	5
22	4 : 5 : 1	6.84 (2.88)	3
23	4 : 4 : 2	6.48 (1.63)	5
24	4 : 3 : 3	6.38 (1.02)	0
25	4 : 2 : 4	6.28 (0.48)	1
26	4 : 1 : 5	6.15 (0.09)	1
27	5 : 4 : 1	6.39 (0.50)	3
28	5 : 3 : 2	6.38 (0.45)	5
29	5 : 2 : 3	6.18 (1.08)	0
30	5 : 1 : 4	6.14 (0.34)	2
31	6 : 3 : 1[a]	6.49 (0.70)	5
32	6 : 2 : 2	6.38 (1.24)	5

Table 3.1 (Continued)

Entry	Ratios of solvent mixtures (v/v) (Toluene : 2-Propanol : Ethyl acetate)[c]	Viscosity, s[c] (%RSD)	Coating Remarks[b]
33	6 : 1 : 3	6.20 (1.96)	2
34	7 : 2 : 1	6.24 (1.07)	5
35	7 : 1 : 2	6.06 (0.58)	2
36	8 : 1 : 1	6.59 (0.46)	0

[a]The thinners currently used in Siam Sindee Co., Ltd.

[b]Classification of Adhesion Test Result following:

5 None of the squares of the lattice is detached.

4 Less than 5% of the area of the squarely intersections of film coating on substrate is detached.

3 5 to 15% of the area of the squarely intersections of film coating on substrate is detached.

2 15 to 35% of the area of the squarely intersections of film coating on substrate is detached.

1 35 to 65% of the area of the squarely intersections of film coating on substrate is detached.

0 More than 65% of the area of the squarely intersections of film coating on substrate is detached.

[c]Practical unit of measurement for viscosity.

From Table 3.1, it is found that when the mixture was coated on the plastic with the film applicator, and then the adhesion was measured according to ASTM, there are 16 types of appropriate solvent mixtures to be used in plastic printing industry, with level 4 and 5 of adhesion and the viscosity in the range of 6-7 seconds.

In addition, it is found that the viscosity is slightly reduced when the quantity of 2-propanol is decreased. This is due to the fact that the viscosity is the function of 3 types of solubility parameter including solubility parameter of nonpolar molecules, solubility parameter of polar molecules and solubility parameter of molecules that can form hydrogen bond well (Van

Dyk *et al*., 1985). In other words, when the quantity of the substances that are able form hydrogen bond is less, the viscosity is also reduced.

3.1.2 Viscosity and the characteristic of the paint on plastic when the solvent mixtures of toluene, xylene, o-xylene, p-xylene, m-xylene, ethanol, 1-butanol, 1-propanol, n-butyl acetate, ethyl acetate and propyl acetate is used

The results from the determination of viscosity and the characteristic of the paint on plastic in the case of the solvent mixture in the ratio 6:3:1 by volume which is the currently-used ratio but with various solvents are shown in Table 3.2.

Table 3.2 Viscosity and the characteristic of the paint on plastic for various solvents with the ratio of 6:3:1 by volume at room temperature.

Entry	Solvent			Viscosity, s[c] (%RSD)	Coating Remarks[b]
	a (6)	b (3)	c (1)		
1	o-Xylene	EtOH[a]	BuOAc[a]	6.46 (0.27)	5
2	o-Xylene	EtOH	PrOAc[a]	6.44 (0.47)	0
3	o-Xylene	EtOH	EtOAc[a]	6.35 (0.24)	1
4	o-Xylene	1-BuOH[a]	BuOAc	6.54 (0.26)	1
5	o-Xylene	1-BuOH	PrOAc	6.66 (0.31)	5
6	o-Xylene	1-BuOH	EtOAc	6.45 (0.27)	5
7	o-Xylene	1-PrOH[a]	BuOAc	6.58 (0.32)	5
8	o-Xylene	1-PrOH	PrOAc	6.54 (0.26)	2
9	o-Xylene	1-PrOH	EtOAc	6.50 (0.46)	5
10	p-Xylene	EtOH	BuOAc	6.20 (0.34)	5
11	p-Xylene	EtOH	PrOAc	6.22 (0.09)	1
12	p-Xylene	EtOH	EtOAc	6.28 (0.09)	3

Table 3.2 (Continued)

Entry	Solvent			Viscosity, s[c]	Coating
	a (6)	b (3)	c (1)	(%RSD)	Remarks[b]
13	p-Xylene	1-BuOH	BuOAc	6.46 (0.36)	5
14	p-Xylene	1-BuOH	PrOAc	6.31 (0.48)	3
15	p-Xylene	1-BuOH	EtOAc	7.00 (0.43)	5
16	p-Xylene	1-PrOH	BuOAc	6.53 (0.46)	1
17	p-Xylene	1-PrOH	PrOAc	6.29 (0.28)	5
18	p-Xylene	1-PrOH	EtOAc	6.46 (0.27)	2
19	m-Xylene	EtOH	BuOAc	6.41 (0.09)	5
20	m-Xylene	EtOH	PrOAc	6.27 (0.28)	0
21	m-Xylene	EtOH	EtOAc	6.61 (0.32)	5
22	m-Xylene	1-BuOH	BuOAc	6.67 (0.26)	5
23	m-Xylene	1-BuOH	PrOAc	6.52 (0.27)	1
24	m-Xylene	1-BuOH	EtOAc	6.45 (0.32)	5
25	m-Xylene	1-PrOH	BuOAc	6.42 (0.32)	1
26	m-Xylene	1-PrOH	PrOAc	6.37 (0.00)	5
27	m-Xylene	1-PrOH	EtOAc	6.56 (0.46)	0
28	Toluene	EtOH	BuOAc	6.56 (0.30)	0
29	Toluene	EtOH	PrOAc	6.26 (0.28)	5
30	Toluene	EtOH	EtOAc	6.28 (0.48)	5
31	Toluene	1-BuOH	BuOAc	6.64 (0.61)	5
32	Toluene	1-BuOH	PrOAc	6.62 (0.30)	5
33	Toluene	1-BuOH	EtOAc	6.50 (0.39)	0
34	Toluene	1-PrOH	BuOAc	6.42 (0.27)	5
35	Toluene	1-PrOH	PrOAc	6.30 (0.18)	5
36	Toluene	1-PrOH	EtOAc	6.47 (0.09)	4
37	Xylene	EtOH	BuOAc	6.67 (0.65)	5
38	Xylene	EtOH	PrOAc	6.33 (0.27)	5

Table 3.2 (Continued)

Entry	Solvent			Viscosity, s[c]	Coating
	a (6)	b (3)	c (1)	(%RSD)	Remarks[b]
39	Xylene	EtOH	EtOAc	6.13 (0.25)	5
40	Xylene	1-BuOH	BuOAc	6.60 (0.15)	0
41	Xylene	1-BuOH	PrOAc	6.37 (0.57)	5
42	Xylene	1-BuOH	EtOAc	6.59 (0.30)	3
43	Xylene	1-PrOH	BuOAc	6.71 (1.13)	0
44	Xylene	1-PrOH	PrOAc	6.35 (0.55)	1
45	Xylene	1-PrOH	EtOAc	6.91 (0.80)	3

[a]EtOH = Ethanol, 1-BuOH = 1-Butanol, 1-PrOH = 1-Propanol, EtOAc = Ethyl acetate, PrOAc = Propyl acetate, BuOAc = n-Buyl acetate

[b]Classification of Adhesion Test Result following:

5 None of the squares of the lattice is detached.

4 Less than 5% of the area of the squarely intersections of film coating on substrate is detached.

3 5 to 15% of the area of the squarely intersections of film coating on substrate is detached.

2 15 to 35% of the area of the squarely intersections of film coating on substrate is detached.

1 35 to 65% of the area of the squarely intersections of film coating on substrate is detached.

0 More than 65% of the area of the squarely intersections of film coating on substrate is detached.

[c]Practical unit of measurement for viscosity.

From Table 3.2 it is found that of the samples that is coated on plastic with the film applicator and the adhesion is measured according to ASTM, there are 25 appropriate solvents to be the thinners for printing industry which has the adhesion in the level 4 and 5 and viscosity in the range of 6-7 seconds.

In addition it is found that when there is a change of substances in the group of polar molecules while keeping constant the nonpolar molecules or those that can form hydrogen bond well, the viscosities are essentially the same.

Therefore there are 16 appropriate solvent mixtures to be the thinners when the original solvents (toluene, 2-propanol and ethyl acetate) with changing ratios were experimented. In the case of changing the solvent under the condition of similar molecular structure with the original ratio (6:3:1 by volume), there are 25 appropriate solvents. These appropriate solvents are concluded in Table 3.3 and 3.4. The example for the adhesion of the film is shown in Figure 3.1.

Table 3.3 The ratio of the solvent mixtures with the viscosity and adhesion appropriate to be the thinners.

Entry	Ratios of solvent mixtures (v/v) (Toluene : 2-Propanol : Ethyl acetate)[a]	Viscosity, s[c] (%RSD)	Coating Remark[b]
1	1 : 8 : 1	7.00 (1.21)	5
2	1 : 7 : 2	6.55 (2.86)	5
3	1 : 5 : 4	6.77 (0.92)	4
4	1 : 2 : 7	6.19 (0.25)	5
5	2 : 5 : 3	6.39 (0.63)	5
6	2 : 4 : 4	6.41 (0.86)	5
7	2 : 2 : 6	6.10 (0.58)	5
8	3 : 6 : 1	6.63 (1.54)	5
9	3 : 3 : 4	6.22 (0.84)	5
10	3 : 2 : 5	6.25 (0.48)	4
11	3 : 1 : 6	6.21 (0.25)	5
12	4 : 4 : 2	6.48 (1.63)	5
13	5 : 3 : 2	6.38 (0.45)	5

Table 3.3 (Continued)

Entry	Ratios of solvent mixtures (v/v) (Toluene : 2-Propanol : Ethyl acetate)[a]	Viscosity, s[c] (%RSD)	Coating Remark[b]
14	6 : 3 : 1[a]	6.49 (0.70)	5
15	6 : 2 : 2	6.38 (1.24)	5
16	7 : 2 : 1	6.24 (1.07)	5

[a]The thinners currently used in Siam Sindee Co., Ltd.

[b]Adhesion Test Result for none of the squares of the lattice is detached (# 5).

[c]Practical unit of measurement for viscosity.

Table 3.4 Various kinds of solvent, ratio 6:3:1 by volume, with the viscosity and adhesion appropriate to be the thinners.

Entry	Solvent			Viscosity, s[c] (%RSD)	Coating Remark[b]
	a (6)	b (3)	c (1)		
1	o-Xylene	EtOH[a]	BuOAc[a]	6.46 (0.27)	5
2	o-Xylene	1-BuOH[a]	PrOAc[a]	6.66 (0.31)	5
3	o-Xylene	1-BuOH	EtOAc[a]	6.45 (0.27)	5
4	o-Xylene	1-PrOH[a]	BuOAc	6.58 (0.32)	5
5	o-Xylene	1-PrOH	EtOAc	6.50 (0.46)	5
6	p-Xylene	EtOH	BuOAc	6.20 (0.34)	5
7	p-Xylene	1-BuOH	BuOAc	6.46 (0.36)	5
8	p-Xylene	1-BuOH	EtOAc	7.00 (0.43)	5
9	p-Xylene	1-PrOH	PrOAc	6.29 (0.28)	5
10	m-Xylene	EtOH	BuOAc	6.41 (0.09)	5
11	m-Xylene	EtOH	EtOAc	6.61 (0.32)	5
12	m-Xylene	1-BuOH	BuOAc	6.67 (0.26)	5
13	m-Xylene	1-BuOH	EtOAc	6.45 (0.32)	5

Table 3.4 (Continued)

Entry	Solvent			Viscosity, s[c]	Coating
	a (6)	b (3)	c (1)	(%RSD)	Remark[b]
14	m-Xylene	1-PrOH	PrOAc	6.37 (0.00)	5
15	Toluene	EtOH	PrOAc	6.26 (0.28)	5
16	Toluene	EtOH	EtOAc	6.28 (0.48)	5
17	Toluene	1-BuOH	BuOAc	6.64 (0.61)	5
18	Toluene	1-BuOH	PrOAc	6.62 (0.30)	5
19	Toluene	1-PrOH	BuOAc	6.42 (0.27)	5
20	Toluene	1-PrOH	PrOAc	6.30 (0.18)	5
21	Toluene	1-PrOH	EtOAc	6.47 (0.09)	4
22	Xylene	EtOH	BuOAc	6.67 (0.65)	5
23	Xylene	EtOH	PrOAc	6.33 (0.27)	5
24	Xylene	EtOH	EtOAc	6.13 (0.25)	5
25	Xylene	1-BuOH	PrOAc	6.36 (0.57)	5

[a]EtOH = Ethanol, 1-BuOH = 1-Butanol, 1-PrOH = 1-Propanol, EtOAc = Ethyl acetate, PrOAc = Propyl acetate, BuOAc = n-Buyl acetate

[b]Adhesion Test Result for none of the squares of the lattice is detached (# 5).

[c]Practical unit of measurement for viscosity.

(a)

(b)

Figure 3.1 The example of the test results for the adhesion study in the case of solvent mixtures; (a) The characteristic that the film on the plastic is removed more than 65% (# 0) in the case of the paint with the solvent mixture of toluene, 2-propanol and ethyl acetate with the ratio of 1:3:6 by volume. (b) The characteristic that the film does not scratch from the substrate (# 5) for the paint with the solvent mixture of toluene, 2-propanol and ethyl acetate with the ratio of 6:2:2 by volume.

The appropriate solvent mixtures were then taken to study the evaporation rate by GC to choose those with the lowest rate and can be used in the industry in the future which is described in the next topic.

3.2 The evaporation of solvents

3.2.1 Effect of time to the amount evaporating of the mixture

The signals from the detection are plotted to show the relationship between temperatures and peak areas. The results are shown in Figure 3.4.

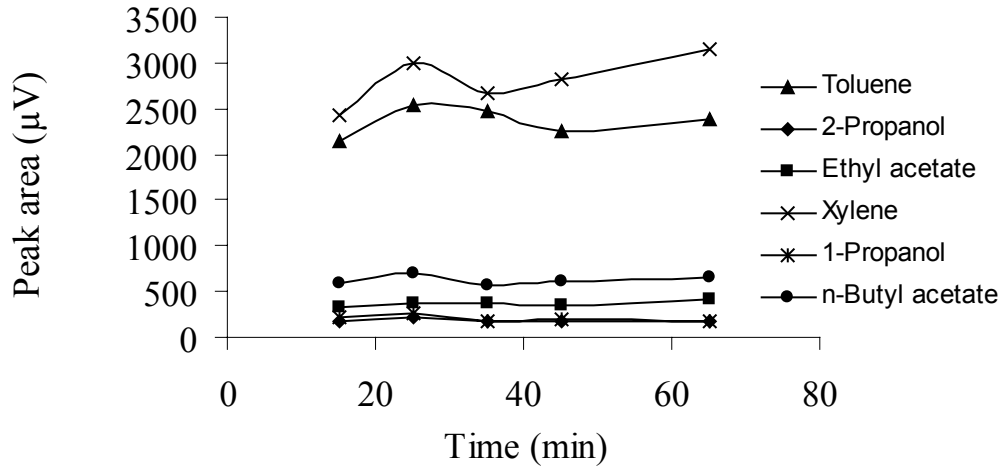

Figure 3.2 The graph showing the relationship between time and peak areas as the amount evaporating of toluene, xylene, ethyl acetate, n-butyl acetate, 1-propanol and 2-propanol at the temperature of 25±3 °C.

From the graph, it is clear that the amount of evaporating solvents remain constant with time of 65 min. Xylene has the most fluctuation. This can be due to its highest ability of evaporation, determining from its lowest relative polarity. It then get the effect from various conditions more than others. The order of the amount of solvent evaporating from the most to the least are xylene, toluene, n-butyl acetate, ethyl acetate, 1-propanol, and 2-propanol respectively

which corresponds with the polarity of the solvents. In other words, the solvent with the highest polarity, 2-propanol, has the least evaporation. The precision of the analysis in terms of RSD was less than 15 % with two replications.

3.2.2 The effect of stirring to the amount evaporating

The plot between the stirring rates and peak areas is shown in Figure 3.3.

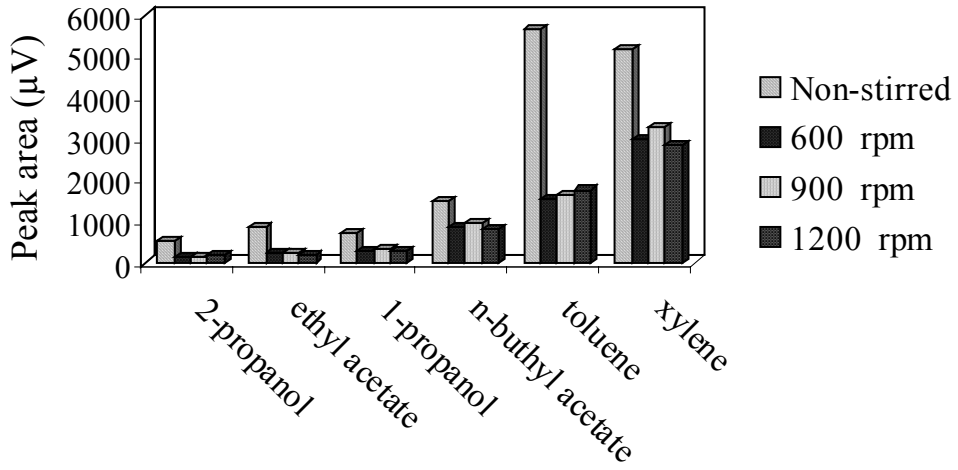

Figure 3.3 The graph to show the relationship between stirring rate and peak areas which is the amount evaporating of 2-propanol, ethyl acetate, 1-propanol, n-butyl acetate, toluene and xylene respectively at the stirring rates of 0, 600, 900 and 1200 rpm at the temperature of 25±3 ^{o}C for 25 min.

From the graph, it is clear that with no more than 1,200 rpm, the amount evaporating for each solvent has no significant difference at different stirring rates. Xylene is found to be the most volatile, followed by toluene, n-butyl acetate, 1-propanol, ethyl acetate and 2-propanol respectively. This can be attributed to the relative polarity as in 3.2.1.

Furthermore, it is found that in the case of the solvent mixtures left unstirred at 25± 3 °C for 25 min, each solvent evaporates more than the stirred ones. This can be described that the way of unstirred makes each solvent not completely contact with each other, therefore the attractive force is less or they even have repulsion, resulting in higher evaporation. With the stirring, the solvent molecules get contact and there are more chances to have an attractive force, making the evaporation less preferable. The precision of the analysis in terms of RSD was less than 6% with two replications.

3.2.3 The effect of temperature to the amount evaporating

The signal from the detection is plotted to show the relationship between temperatures and peak areas. The results are shown in Figure 3.4.

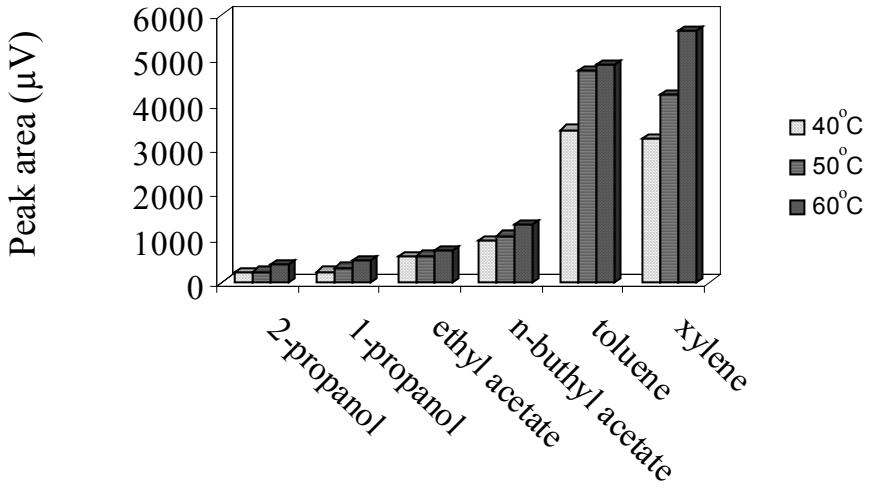

Figure 3.4 The graph showing the relationship between the temperature and peak areas as the amount evaporating of toluene, xylene, ethyl acetate, n-butyl acetate, 1-propanol and 2-propanol at the temperatures of 40, 50 and 60 °C for a period of 25 min.

From the graph, it is found the amount of solvent evaporating is higher with higher temperature from 40 to 60 ^{o}C. Xylene is found to be the most volatile, followed by toluene, n-butyl acetate, ethyl acetate 1-propanol and 2-propanol respectively. The results can be described by polarity as in 3.2.1. The precision of the analysis in terms of RSD was less than 10% with two replications.

From the studies of the effects from various factors on the amount of solvent evaporating, the optimum condition for further studies can be concluded, that is, the temperature of 40 ^{o}C without stirring. The temperature selected is lower than 60 ^{o}C which exhibits highest response intensity due to the fact it is the temperature closest to the working environment.

3.2.4 The determination of the evaporation rate of solvent mixtures

3.2.4.1 The evaporation rate of the mixture of toluene, 2-propanol and ethyl acetate

The evaporation rates of the currently-used solvent mixtures (toluene, 2-propanol and ethyl acetate) were studies by varying the solvent ratios. The results are shown in Table 3.5.

Table 3.5 The evaporation rate (mg/min) of each currently-used solvent with various ratio of mixing.

Entry	Ratios of solvent mixtures (v/v) (Toluene : 2-Propanol : Ethyl acetate)[a]	Evaporation rate (mg/min)		
		Toluene	2-PrOH	EtOAc
1	1 : 8 : 1	0.041	0.334	0.05
2	1 : 7 : 2	0.018	0.048	-0.048
3	1 : 5 : 4	0.004	-0.046	0.164
4	1 : 2 : 7	0.035	0.028	0.094
5	2 : 5 : 3	0.074	0.023	0.117
6	2 : 4 : 4	0.085	0.350	0.041
7	2 : 2 : 6	0.070	-0.010	0.097
8	3 : 6 : 1	0.131	-0.143	0.045
9	3 : 3 : 4	0.087	-0.020	0.082
10	3 : 2 : 5	-0.014	0.006	-0.024
11	3 : 1 : 6	0.136	-0.001	0.318
12	4 : 4 : 2	0.090	-0.160	0.004
13	5 : 3 : 2	-0.127	-0.076	-0.095
14	6 : 3 : 1[b]	0.210	-0.137	0.030
15	6 : 2 : 2	-0.085	-0.017	-0.028
16	7 : 2 : 1	0.091	0.023	0.014

. [a]The thinners currently used in Siam Sindee Co., Ltd.

From the analysis of toluene, 2-propanol and ethyl acetate which are the components in the solvent mixture used in present plastic printing by studying the evaporation rate in various ratios (Table 3.5), it is found that the solvent can evaporate when the concentrations are as follows: toluene, 5-73 ; 2-propanol, 6-40; ethyl acetate, 3-28 mg/ml. The precision of the analysis in terms of RSD was less than 18% with two replications.

From Table 3.3, two formulas were found to be appropriate to be a thinners comprising (i) toluene, 2-propanol and ethyl acetate with the ratio of 3:2:5 and the evaporation rates of 0.014, 0.006 and 0.024 mg/min respectively; and (ii) toluene, 2-propanol and ethyl acetate with the ratio of 7:2:1 and the evaporation rates of 0.091, 0.023 and 0.014 mg/min respectively. When compared with the rate of evaporation of the currently-used solvent, 6:3:1 by volume, toluene, 2-propanol and ethyl acetate with the new mixing ratio have lower evaporation rate. If overall rate of evaporation of the solvent is taken into consideration, it can be concluded that the best ratio is 7:2:1 by volume.

3.2.4.2 The evaporation rate of the solvent mixtures of toluene, xylene, o-xylene, p-xylene, m-xylene, ethanol, 1-butanol, 1-propanol, n-butyl acetate, ethyl acetate and propyl acetate.

From the study of the various kind of solvent mixture which are considered to be appropriate with the ratio of 6:3:1 by volume, the results are shown in Table 3.6.

Table 3.6 The evaporation rate (mg/min) of various solvents with the ratio of 6:3:1 by volume.

Entry	Solvent			Evaporation rate (mg/min)		
	a (6)	b (3)	c (1)	a	b	c
1	o-Xylene	EtOH[a]	BuOAc[a]	-0.087	-0.021	0.006
2	o-Xylene	1-BuOH[a]	PrOAc[a]	-0.197	-0.432	-0.044
3	o-Xylene	1-BuOH	EtOAc[a]	-0.209	-0.500	-0.038
4	o-Xylene	1-PrOH[a]	BuOAc	0.010	-0.017	-0.035
5	o-Xylene	1-PrOH	PrOAc	-0.468	-0.229	0.035
6	p-Xylene	EtOH	BuOAc	0.006	0.013	-0.125
7	p-Xylene	1-BuOH	BuOAc	-0.063	-0.307	-0.092

Table 3.6 (Continued)

Entry	Solvent			Evaporation rate (mg/min)		
	a (6)	b (3)	c (1)	a	b	c
8	p-Xylene	1-BuOH	EtOAc	-0.189	-0.484	0.005
9	p-Xylene	1-PrOH	PrOAc	-0.248	-0.096	-0.018
10	m-Xylene	EtOH	BuOAc	-0.044	0.007	-0.057
11	m-Xylene	EtOH	EtOAc	-0.060	-0.098	-0.002
12	m-Xylene	1-BuOH	BuOAc	-0.262	-0.646	-0.129
13	m-Xylene	1-BuOH	EtOAc	-0.288	-0.391	-0.046
14	m-Xylene	1-PrOH	PrOAc	-0.459	-0.056	-0.028
15	Toluene	EtOH	PrOAc	0.072	-0.005	0.021
16	Toluene	EtOH	EtOAc	-0.03	-0.152	0.007
17	Toluene	1-BuOH	BuOAc	-0.071	-0.227	-0.092
18	Toluene	1-BuOH	PrOAc	0.028	-0.317	-0.035
19	Toluene	1-PrOH	BuOAc	0.117	-0.205	-0.082
20	Toluene	1-PrOH	PrOAc	-0.154	-0.295	-0.080
21	Toluene	1-PrOH	EtOAc	0.114	-0.186	0.006
22	Xylene	EtOH	BuOAc	-0.218	constant†	-0.062
23	Xylene	EtOH	PrOAc	-0.454	-0.034	-0.054
24	Xylene	EtOH	EtOAc	-0.340	-0.154	-0.028
25	Xylene	1-BuOH	PrOAc	-0.386	-0.614	-0.015

*EtOH = Ethanol, 1-BuOH = 1-Butanol, 1-PrOH = 1-Propanol, EtOAc = Ethyl acetate, PrOAc = Propyl acetate, BuOAc = n-Buyl acetate

† The amount of evaporating of remains constant with experimental interval of 5-35 mins.

The results of the measuring the evaporation rate of 6:3:1 solvent mixtures (Table 3.6) are: toluene, 51.5-58.8; xylene,60-76; o-xylene, 56-70; p-xylene, 52-55; m-xylene, 61-80.5; ethanol, 9.5-14.5; 1-butanol, 12-25; 1-propanol, 9.5-15; n-butyl acetate, 4-7.5;

ethyl acetate, 4-8.5; and propyl acetate 5.5-8.4 mg/ml. The precision of the analysis in terms of RSD was less than 20% with two replications.

From the table five formulas were found to be appropriate to be a thinners comprising (i) toluene, ethanol and propyl acetate with the ratio of 6:3:1 and the evaporation rate of 0.072, 0.005 and 0.021 mg/min respectively; (ii) o-xylene, 1-propanol and n-butyl acetate with the ratio of 6:3:1 and the evaporation rate of 0.010, 0.017 and 0.035 mg/min respectively; (iii) o-xylene, ethanol and n-butyl acetate with the ratio of 6:3:1 and the evaporation rate of 0.087, 0.021 and 0.006 mg/ml respectively; (iv) m-xylene, ethanol and n-butyl acetate with the ratio of 6:3:1 and the evaporation rate of 0.044, 0.007 and 0.057 mg/min respectively; and (v) m-xylene, ethanol and ethyl acetate with the ratio of 6:3:1 and the evaporation rate of 0.060, 0.098 and 0.002 mg/min respectively.

From the results in Table 3.5 and 3.6, there are 7 formulas of appropriate thinners which can be used in the plastic printing industry. However, due to the fact that the investment cost must be as low as possible, the most appropriate mixture is toluene, 2-propanol and ethyl acetate with the ratio of 1:7:2 by volume.

In this research, headspace was prepared in laboratory with opened system iv which the temperature could not be controlled, in contrast with headspace readily equipped for gas chromatography, resulting in somewhat higher relative standard deviation than that reported in publications current.