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STUDIES ON POLYVINYL CHLORIDE COMPATIBILITY WITH OTHER POLYMERS—II

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Abstract—The authors have studied viscometrically the compatibility of PVC in cyclohexanone with the following elastomers: ABS, polyurethane rubber, chlorosulphonated polyethylene, *cis* 1,4-poly*iso*prene and polychloroprene.

The dynamic viscosity data show that PVC is not compatible with polyurethane rubber, chlorosulphonated polyethylene, *cis* 1,4-poly*iso*prene and polychloroprene. To some extent under certain conditions, ABS shows some compatibility with PVC.

IN A PREVIOUS paper[1] we studied viscometrically, the compatibility of polyvinyl chloride (PVC) with the following elastomers: butadiene–methylstyrene copolymer, butadiene–acrylonitrile copolymer, ethylene–vinyl acetate copolymer.

The criterion of compatibility used is that proposed by Zelinger and Heidingsfeld[2] expressed by the following relation:

$$\frac{\Delta_t}{\Delta_{\eta t}} = \frac{\eta_{\text{additive}} - \eta_{\text{experimental}}}{\eta_{\text{polymer}} - \eta_{\text{PVC}}}$$

Here Δ_t is the difference between additive viscosity and the experimental viscosity while $\Delta_{\eta t}$ is the difference between the viscosity of the PVC solution and another polymer solution.

The smaller the absolute value of this ratio, the less is the deviation of experimental data from the additive values and consequently the better is the compatibility of PVC with other polymers. Always linearity of the plot of viscosity against composition indicates good compatibility.

In this note, we extend the study to other elastomers, viz.

ABS (acrylonitrile–butadiene–styrene terpolymer),
polyurethane rubber,
chlorosulphonated polyethylene,
cis 1,4-polyisoprene,
polychloroprene.

The polymers used were:

(1) Polyvinyl chloride (PVC) made in the Chemical aggregate works Borzesti in Rumania; type dry blend; $Kw = 67$; $[\eta] = 0{\cdot}91$ (in cyclohexanone at 20°).

(2) ABS—made in the Synthetic rubber aggregate works in Gheorghe Gheorghiu Dej in Rumania, by grafting acrylonitrile and styrene on the butadiene–styrene copolymers; its composition is: butadiene 33 per cent, styrene 43 per cent and acrylonitrile 24 per cent; $[\eta] = 0{\cdot}611$ (in cyclohexanone at 20°).

(3) Polyurethane rubber (Urepan 640) made by Bayer AG, Leverkusen, West Germany, $[\eta] = 1{\cdot}00$ (in cyclohexanone at 20°).

(4) Chlorosulphonated polyethylene (Hypalon 20) made by DuPont, Wilmington, Del.; it contains chlorine (29 per cent) and sulphur (1·25 per cent); $[\eta] = 0{\cdot}71$ (in cyclohexanone at 20°).

(5) *cis* 1,4-Poly*iso*prene (Cariflex 1500) made by Shell (Great Britain), $[\eta] = 0{\cdot}615$ (in cyclohexanone at 20°).

(6) Polychloroprene (Perbunan C 211) made by Bayer AG, Leverkusen, West Germany. Medium tendency to crystallize; $[\eta] = 0{\cdot}76$ (in cyclohexanone at 20°).

EXPERIMENTAL

To study the compatibility of PVC with the above polymers, solutions (2, 5 and 10 per cent) in cyclohexanone were prepared. The experiments were carried out with a rotational viscometer (Rheotest Rotations Viskometer, Type R.V. Medingen). Viscosity measurements were carried out on solutions of each polymer, and also on solutions of the polymer blends in various proportion. The variations of the dynamic viscosity with the concentration, the polymer proportion in the blends, the temperature and the rate of shear (D, s^{-1}) were studied.

In the case of PVC–polyurethane rubber blends only, the influence of the nature of the solvent on the dynamic viscosity was also studied.

For some systems, the activation energy of viscous flow was obtained and its variation with the ratio of components was studied (at 20°, concentration 10 per cent, $D = 1312\ s^{-1}$).

RESULTS AND DISCUSSION

Table 1 gives the dynamic viscosity values for PVC and the studied elastomers as a function of solution concentration and the rate of shear.

TABLE 1. DYNAMIC VISCOSITY OF THE POLYMERS AT 20° IN CYCLOHEXANONE

No.	Polymer	Solution concentration (g/100 cm³)	Dynamic viscosity (cP)	D (s^{-1})
1	Polyvinyl chloride	2	11·00	1312
		5	52·48	1312
		10	372·45	1312
2	Butadiene–acrylonitrile–styrene copolymer (ABS)	2	7·25	1312
		5	18·67	1312
		10	229·22	1312
3	Polyurethane rubber	2	10·97	1312
		5	50·21	1312
		10	383·22	1312
4	Chlorosulphonated polyethylene	2	8·88	1312
		5	31·10	1312
		10	171·96	1312
5	*cis* 1,4-poly*iso*prene	2	11·51	1312
		5	175·59	1312
		10	1483·89	1312
6	Polychloroprene	2	10·42	1312
		5	49·59	1312
		10	336·17	1312

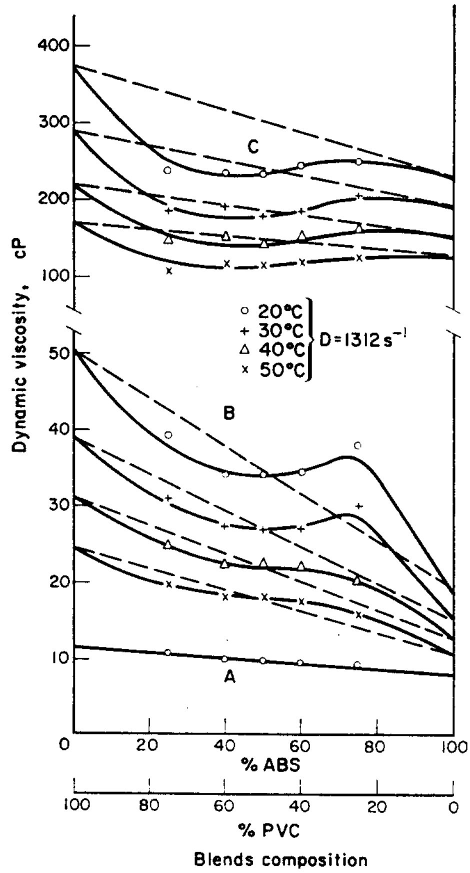

FIG. 1. The variation of the dynamic viscosity of PVC–ABS blend solutions as a function of the composition, for various concentrations and temperatures. The concentrations of the solutions were: A—2%, B—5% and C—10%.

(a) *PVC–ABS system*

Figure 1 illustrates the variations of the dynamic viscosity of the solutions of PVC–ABS blends at various concentrations (2, 5 and 10 per cent) at 20, 30, 40 and 50° by using a rate of shear $D = 1312\ s^{-1}$.

According to what was demonstrated in the previous paper,[1] the data (Fig. 1) obtained at 5 per cent concentration show that PVC is generally incompatible with ABS, except for the case when the ratio of the polymers in the blend is 1:1; the superposition of the additive values on the experimental values in the case of the 10 per cent solutions reflects the compatibility of the system when ABS is more than 80 per cent and PVC is less than 20 per cent. Similar observations were made by Friese[3] for other systems.

(b) *PVC–Polyurethane rubber*

The experimental data obtained for this system show according to the Zelinger–Heidingsfeld method[2] and that of Friese[3] that these two polymers are incompatible at all concentrations in cyclohexanone.

For establishing the influence of the nature of the solvent on the compatibility of these two polymers, we chose some solvents with solubility parameters near those of the two polymers in blend. They are listed in the Table 2, which contains also their

TABLE 2

No.	Polymer	δ cal$^{1/2}$. cc$^{-1/2}$	Dynamic viscosity, cP (at 20°, 5% conc. and D = 1312 s^{-1}) PVC	Polyurethane rubber	
1	Polyvinyl chloride	9·48	—	—	(4)
2	Polyurethane rubber	10·0	—	—	(5)
3	1,2-Dichloroethylene	9·1	81·79	24·12	(6)
4	Tetrahydrofuran	9·1	13·14	14·70	(6)
5	Methyl ethyl ketone	9·3	39·79	9·07	(6)
6	Cyclohexanone	9·9	52·48	50·21	(6)
7	Dioxane	10·0	107·29	41·26	(6)
8	N,N-Dimethylformamide	12·1	21·58	20·83	(6)

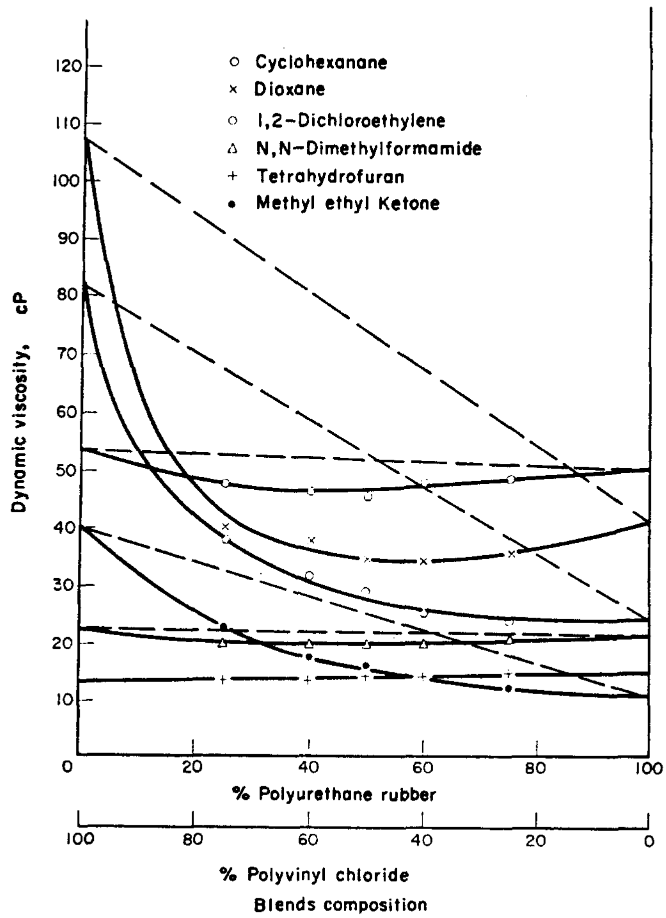

FIG. 2. The variation of the dynamic viscosity of PVC–polyurethane rubber blend solutions as a function of the composition, at 20° in various solvents. The concentrations of the solutions were 5 per cent and the rate of shear (D) was 1312 s^{-1}.

solubility parameters and the dynamic viscosities of their solutions at 5 per cent concentration (at 20° and $D = 1312\ s^{-1}$).

Figure 2 shows variation of the dynamic viscosities of 5 per cent solutions of the blends of the two polymers at 20°, and also their additive viscosities.

The examination of these data shows that PVC is incompatible with polyurethane rubber independent of the nature and solubility parameter of the solvent. From the discrepancy between the additive viscosities and the experimental curves, it appears that the incompatibility of these two polymers decreases in the following order: dioxane > 1,2-dichloroethylene > methyl ethyl ketone > cyclohexanone > N,N-dimethylformamide; the solutions in tetrahydrofuran give a reasonable compatibility.

(c) *PVC-Chlorosulphonated polyethylene system*

Study of the experimental results in Fig. 3 shows that, at 5 or 10 per cent concentration in cyclohexanone, PVC is incompatible with chlorosulphonated polyethylene.

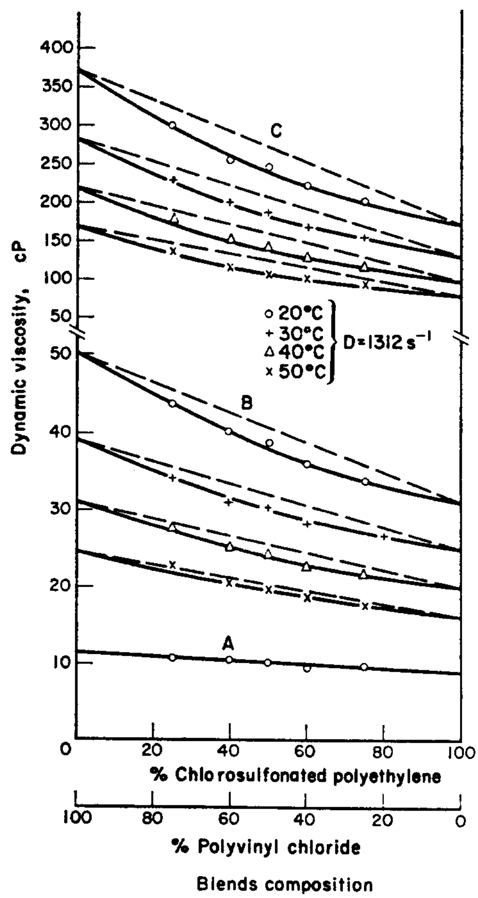

FIG. 3. The variation of the dynamic viscosity of PVC-chlorosulphonated polyethylene blend solutions as a function of the composition, for various concentrations and temperatures. The concentrations of the solutions were: A—2%, B—5% and C—10%.

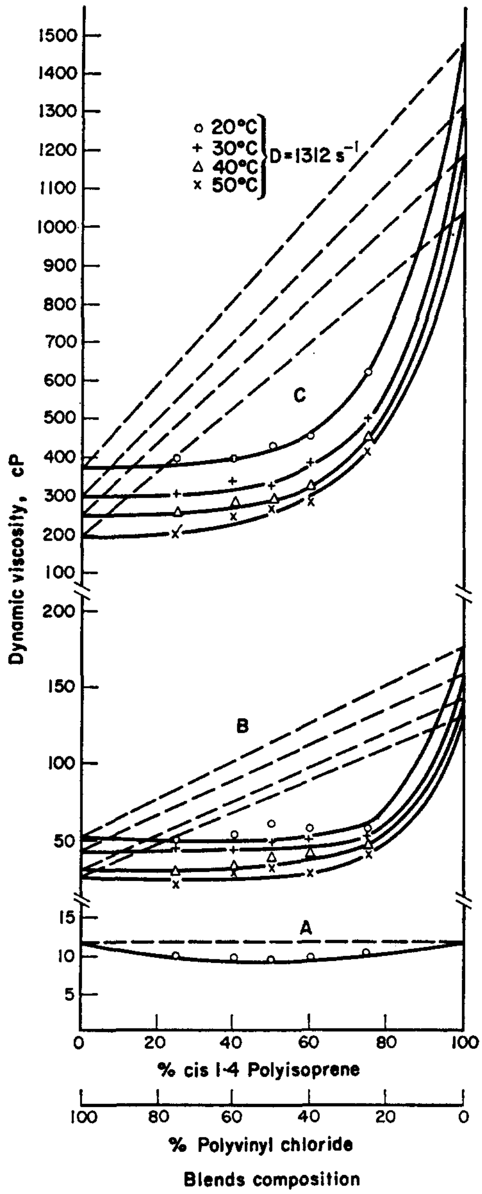

FIG. 4. Results as in Fig. 3 but for blends of PVC and *cis* 1,4-poly*iso*prene.

At lower temperatures, there was increased incompatibility judged from the departure from linearity of the viscosity-composition curves.

(d) *PVC*–cis *1,4-poly*iso*prene system*

For this system (Fig. 4) it can be seen that the incompatibility is more accentuated than in the preceding systems.

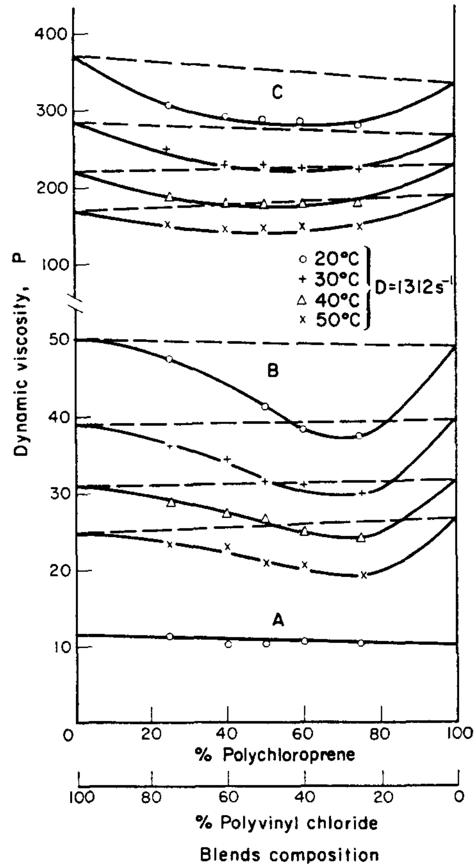

FIG. 5. Results as in Fig. 3 but for blends of PVC and polychloroprene.

(e) *PVC–Polychloroprene system*

Unexpectedly PVC and polychloroprene are incompatible although they have quite similar structures (Fig. 5).

(f) *The variation of the activation energy for viscous flow*

From the viscosity data, one can obtain the activation energy (U) from the Bartenev relationship:[7]

$$\eta \doteq A.e^{U/kT}.$$

The variation of the activation energy for viscous flow has been obtained as a function of the ratio of components for the following blends: PVC–butadiene–acrylonitrile copolymer, PVC–ABS, PVC–*cis* 1,4-poly*iso*prene and PVC–polyurethane rubber.

The data show (Figs. 6 and 7) that whether the polymers are compatible, as in the case of the PVC–butadiene–acrylonitrile copolymer system,[1] have limited compatibility (PVC–ABS) or are incompatible, the variation of the activation energy for viscous flow is linear.

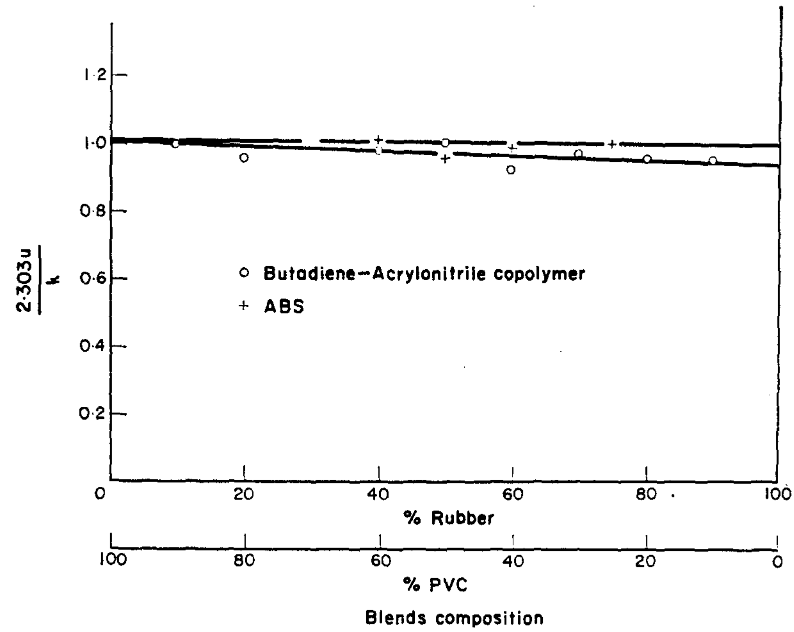

FIG. 6. The variation of the activation energy for viscous flow of solutions of blends of PVC with a synthetic rubber as a function of the blend composition, for 10 per cent concentration at 20° and at a rate of shear (D) of 1312 s^{-1}.

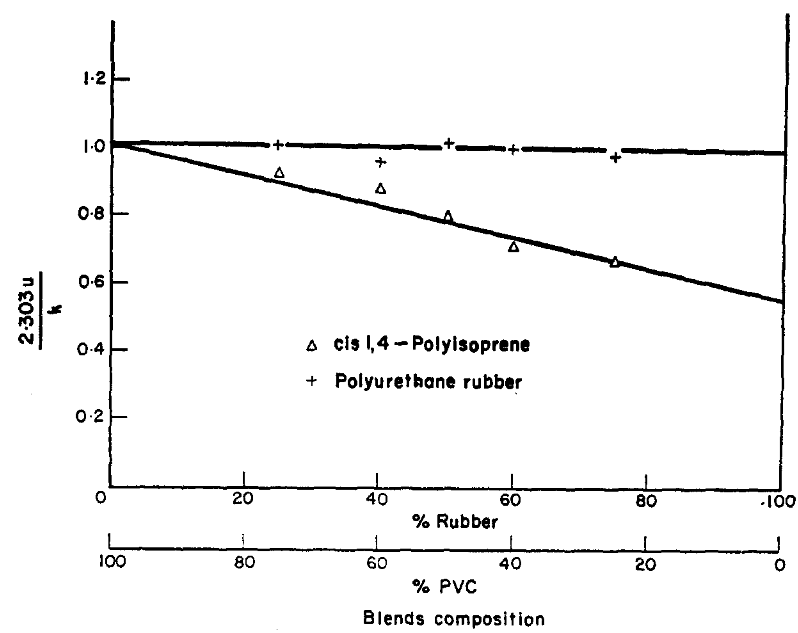

FIG. 7. Results as in Fig. 6 but using another synthetic rubber.

CONCLUSIONS

The study by viscometry of the compatibility of PVC with some elastomers leads to the following conclusions:

In cyclohexanone solutions, PVC is compatible with ABS only at a 1:1 ratio at 5 per cent concentration and at ratio smaller than 1:4 at 10 per cent concentration.

Polyurethane rubber, chlorosulphonated polyethylene, *cis* 1,4-poly*iso*prene and polychloroprene are not compatible with PVC.

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Résumé—Les auteurs ont étudié par viscosimétrie la compatibilité du PCV dans la cyclohexanone avec les élastomères suivants: ABS, caoutchouc de polyuréthane, polyéthylène chlorosulfoné, cis-polyisoprène 1,4 et polychloroprène. Les données viscosimétriques montrent que le PCV n'est pas compatible avec le caoutchouc de polyuréthane, le polyéthylène chlorosulfoné, le cis polyisoprène 1,4 et le polychloroprène. Dans certaines conditions, l'ABS présente une certaine compatibilité avec le PCV.

Sommario—Gli autori hanno studiato dal punto di vista viscometrico la compatibilità del PVC in cicloesanone con i seguenti elastomeri: ABS, gomma al poliuretano, polietilene clorosolfonato, cis 1,4-poliisoprene e policloroprene. In alcune condizioni, l'ABC mostra una certa compatibilità rispetto il PVC, in certa misura.

Zusammenfassung—Die Autoren untersuchten viskosimetrisch die Verträglichkeit von PVC in Cyclohexanon mit den folgenden Elastomeren: ABS, Polyurethan-Kautschuk, chlorsulfoniertes Polyäthylen, *cis* 1,4-Poly*iso*pren und Polychloropren. Die Werte der dynamischen Viskosität zeigen, daß PVC unverträglich ist mit Polyurethan-Kautschuk, chlorsulfoniertem Polyäthylen, *cis* 1,4-Poly*iso*pren und Polychloropren. ABS zeigt in gewissem Ausmaß und unter bestimmten Bedingungen.