Strip 'Teas' - Solubility Data for the Removal (and Application) of Low Molecular Weight Synthetic Resins Used as Inpainting Media and Picture Varnishes

by Gregory Dale Smith & Ronald Johnson

ABSTRACT

Polymer solubility data in the form of Teas Charts are provided for low molecular weight (LMW) synthetic resins (Laropal A-81, Regalrez 1094, and MS2A) commonly used as in-painting media and picture varnishes. Laboratory case studies involving the brush application of LMW synthetic varnishes over LMW restoration colors are presented to highlight the value of comprehensive, concise, and easily understandable solubility data on these resins. Importantly, the chemical nature of the resin varnish is found to influence the solubilizing strength of the varnish solution in relation to underlying paint layers.

INTRODUCTION

The ability to predict and manipulate polymer solubility is perhaps the most valuable scientific skill of the conservator. This skill is utilized when applying or removing a varnish, eliminating overpaint, introducing adhesives, and cleaning grime. Therefore the physical, chemical, and practical aspects of polymer dissolution comprise an important component of the first year science training for art conservation graduate students at Buffalo State College (BSC). Students are taught the thermodynamic and kinetic principles of polymer solubility as well as the solubility systems of Hildebrand, Hansen, Teas, and even the more recent innovations of Snyder..[1-3]

Recently, the accompanying science lab exercises were largely revamped to augment the lectures by focusing on more practical experiments, especially those with the potential to generate new information that would be useful to the conservation field. One such experiment involves small groups of students who cooperatively generate Teas charts for artists' or restoration materials for which little or only dispersed data exists in the conservation literature.

C. V. Horie's book, *Materials in Conservation*,[4] which is an important resource of solubility data for conservation materials, was compiled over twenty years ago, and many new resins – or changes in resin formulations – have appeared since. Aside from the need for reliable and comprehensive solubility data on new and reformulated resins, much of the data in Horie's appendix of Teas charts comes from manufacturers' product literature or from industrial studies on freshly prepared resins. There is obviously a need to update and review these data.

The introduction of numerous low molecular weight (LMW, $M_n < 1000$) resins to the field of conservation since 1990 presented an ideal starting point for our student experiments on polymer solubility. Those results are presented here in the form of Teas charts for three such materials: the synthetic urea-aldehyde in-painting resin Laropal A-81,[5] the hydrocarbon resin varnish Regalrez 1094,[6] and the reduced cyclohexanone varnish MS2A (Figure 1a-c, respectively).[6]

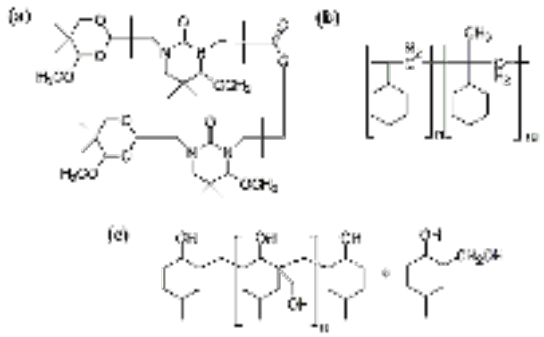

Figure 1. Proposed molecular structures of (a) Laropal A-81, (b) Regalrez 1094, and (c) MS2A.

TEAS CHARTS

Teas fractional solubility parameters and the corresponding Teas chart were developed from the earlier work on polymer solubility by first Hildebrand and later Hansen. Descriptions of this progression of polymer solubility theory and prediction have appeared in the conservation literature,[1-3] and so only a brief summary need be repeated here. In general, Hansen improved on Hildebrand's solubility parameter, δ, by further dividing Hildebrand's cohesive energy density (CED) value into component parts based on intermolecular forces. His innovation was in recognizing that it wasn't just the strength of overall interactions, that is the CED, that must be satisfied for solubility to occur, but that the forces involved must be alike in kind as well as magnitude. As a result, Hansen parameters consist of three values that indicate the tendency of a material to participate in dipolar interactions (polarity), hydrogen bonding interactions, and dispersion (London) forces. These values sum to give the Hildebrand parameter. Tea's innovation was to present this triumvirate of interactions as fractional parameters based on their respective contribution to the whole cohesive energy density. Therefore, Teas' parameters sum to give unity. Although Teas lost the overall magnitude of interactions by representing the data as fractions – i.e. his parameters assume a constant cohesive energy density that is merely divided up differently – Teas did achieve a more easily represented data set that could be visualized as the now widely recognizable triangular Teas chart.

Teas charts have come under fire for a number of simplifications, shortcomings, and "fudge factors." Two of the most cogent attacks have been printed in the *WAAC Newsletter* by Stavroudis and Blank[7] and by McGlinchey.[8] In short, Teas' system can rightly be criticized for overemphasizing dispersion forces (most of the data is in the lower right corner), neglecting ionic and acid-base interactions, rejecting the overall differences in the magnitude of cohesive energy densities, assuming solvent and solute randomness, and other transgressions. Arguments have been made elsewhere for more sophisticated solubility theories that can perhaps

predict polymer solubility more accurately.[3] However, those suggestions for more complete (and complicated) solvent theories have not caught on in conservation because they lack the simplicity of Teas charts and, importantly, the ability to calculate the effect of solvent mixtures on the fly. Furthermore, in the case of pure resins that are not prone to oxidative aging, like those studied here, Teas charts can prove an incredibly accurate and useful record – as well as predictor – of polymer solubility in pure solvents and in solvent mixtures. Therefore, with full knowledge of the insufficiencies of the Teas system, we have continued to teach and produce Teas charts for materials of use in conservation.

EXPERIMENTAL

Since the withdrawal of ASTM D3132, no standard method for polymer solubility exists. The solubility of each LMW resin in this study was tested in 50 different solvents using a modified version of the method utilized by Whitten in the *AIC Paintings Catalog*.[6] Three grams of the resin were weighed into a small jar with a tightly sealing fluoropolymer lined lid. Ten milliliters of solvent were then added to the jar, the lid sealed, and the sample agitated to ensure good mixing. The solvents were of technical or reagent grade and were used without further purification or drying. After several hours to one day later, the samples' solubility behavior was observed. Unlike Whitten's method,[6] but similar to that of Horie,[4] the action of each liquid on the polymer was described simply as being a solvent, a borderline solvent, or a non-solvent. A solvent produced a clear solution or a slightly turbid one that could not be separated by centrifugation. Borderline solvents dissolved the majority of the resin and left only a small amount of gelled residue. Non-solvents had either no effect on the resin, or else swelled or gelled the bulk of the resin with little indication of significant solubility.

Table 1 lists the standard reagent grade solvents used in the experiments, as well as their Teas fractional solubility parameters. These parameters were taken from Horie[4] when available or otherwise calculated directly from Hansen's solubility parameters.[9] In some instances, commodity solvent blends were used. Fractional parameters for mineral spirits (#6) and odorless mineral spirits (#3) have been published elsewhere,[4] however those for ShellSol 340HT (#4) were calculated proportionally from the parameters for hexane (#1) and cyclohexane (#5) based on the percent aliphatic (straight chain alkanes) to alicyclic (cyclic alkanes) composition as given in the manufacturer's literature Importantly, ShellSol 340HT is now no longer available with the closest alternative commodity solvent being ShellSol D38.[10] The values for all of these blends must therefore be taken as approximate (vide infra). The numerical assignments from Table 1 were used to identify the solvents' positions in the triangular Teas space (Appendices I-III).

In addition to recording the solubility of LMW resins in pure solvents, titration experiments were also performed to define better the solubility windows for some resins. A solution of the resin (3g in 10mL) was titrated with a mis-

Table 1. Solvents used for resin solubility testing and their Teas fractional solubility parameters.

#	Solvent	fd	fp	fh
1	Hexanes	100	0	0
2	n-Heptane	100	0	0
3	Odorless mineral spirits	98	1	1
4	ShellSol 340HT	96	2	2
5	Cyclohexane	94	2	4
6	Mineral spirits	90	4	6
7	Ethylbenzene	87	3	10
8	Turpentine	77	18	5
9	Benzene	78	8	14
10	Toluene	80	7	13
11	Xylenes	83	5	12
12	Dichloromethane	59	21	20
13	Chloroform	67	12	21
14	Carbon tetrachloride	85	2	13
15	1,2-Dichloroethane	67	19	14
16	Trichloroethylene	68	12	20
17	Tetrachloroethylene	67	23	10
18	Tetrahydrofuran (THF)	55	19	26
19	1,4-Dioxane	67	7	26
20	2-Ethoxyethanol (Cellosolve)	42	20	38
21	2-Methoxyethanol (Methyl cellosolve)	39	22	39
22	2-Butoxyethanol (Butyl cellosolve)	46	18	36
23	1-Methoxy-2-propanol (methyl proxitol)	47	19	34
24	2-Ethoxyethyl acetate	51	15	34
25	Methyl acetate	45	36	19
26	Ethyl acetate	51	18	31
27	i-Propyl acetate	54	16	30
28	n-Butyl acetate	60	13	27
29	i-Amyl acetate (i-Pentyl acetate)	60	12	28
30	Propylene carbonate	48	38	14
31	Acetone	47	32	21
32	Methyl ethyl ketone (MEK)	53	30	17
33	Methyl isobutyl ketone (MIK)	58	22	20
34	Ethylene glycol	30	18	52
35	Propylene glycol	34	16	50
36	Methanol	30	22	48
37	Ethanol	36	18	46
38	i-Propanol	38	17	45
39	n-Butanol	43	15	42
40	Diacetone alcohol	45	24	31
41	Nitromethane	40	47	13
42	Acetonitrile	39	45	16
43	N-Methyl-2-pyrrolidone (M-Pyrol)	48	32	20
44	N,N-Dimethylformamide (DMF)	41	32	27
45	Pyridine	56	26	18
46	Carbon disulfide	88	8	4
47	Dimethyl sulfoxide (DMSO)	41	36	23
48	Ethanolamine (MEA)	32	29	39
49	Triethanolamine (TEA)	27	36	37
50	Water	18	28	54

cible non-solvent until the resin just precipitated as a cloudy suspension. Because of the dearth of data on azeotrope formation among solvents commonly used in conservation, no attempt was made to avoid specifically azeotropic solvent combinations. The tendency of azeotropes to behave differently than either of the component solvents has been noted as a potential weakness of predicting solubility characteristics of solvent mixtures using Teas parameters, although to date no data has been provided to substantiate this concern.[11]

The volume composition of the two liquids at the titration endpoint was used to calculate the Teas parameters for the solvent mixture at which the resin is just insoluble. To increase the accuracy of the Teas parameters for the mixture, the freeware program *Solvent Solver* was used to assist in this calculation.[12] This program uses specific gravity data and molecular weights to determine molar volumes, which are then used to calculate more accurately the fractional parameters of the mixture. When titrations were performed, the resulting Teas chart bears an 'X' on a dashed line connecting the solvent with the non-solvent to mark the solubility border position.

LOW MOLECULAR WEIGHT RESINS

LMW resins have become important in conservation for their solubility in "weak" solvents – i.e. those of low polarity – and their tendency to resist yellowing and to remain soluble in these solvents even after extensive aging.[6] In addition, being LMW these polymers – more accurately described as oligomers – exhibit low viscosity at high concentration and have good optical properties. As such, these resins can be used safely and effectively over traditional paint media and can be left in service for much longer periods of time. Appendices I-III present the solubility data for Laropal A-81, Regalrez 1094, and MS2A, respectively, in a two dimensional Teas coordinate system.

It is immediately manifest that these resins show good solubility in nonpolar and/or aromatic solvents that are safely outside the maximum swelling range of oil paints. The extent of the solubility windows for these resins also makes sense in light of the "like dissolves like" rule. Laropal A-81, the urea-aldehyde inpainting medium, which has both acetal and carbonyl functional groups, is insoluble in purely aliphatic solvents like hexane (#1), but becomes soluble in slightly more penetrating, polar, or polarizable solvents like cyclohexane (#5) or ethylbenzene (#7). In addition, its solubility window extends further along the polarity (f_p) and H-bonding (f_h) axes, encompassing the halogenated solvents, acetates, and simple alcohols (Appendix I). MS2A, with only its hydroxyl functional groups to lend polar character, has a solubility window that is slightly less extensive along the polarity axis (Appendix III). At its furthest reaches, the solubility window from our data shows a slight deviation from the limited solubility data given elsewhere,[6] namely in that ethanol (#37) and i-propanol (#38) produced only a thick gel in our experiments. This may be due to the use of drier alcohol solvents in the other experiments or to the fact that MS2A production has undergone a slight change in its monomer feedstock, from mixed isomer methyl cyclohexanone to pure p-methyl cyclohexanone, since 2005.[13] The authors are aware of at least one conservator who has commented on differences in the two resin batches' odors and kinetics of dissolution.[14] The purely hydrocarbon resin Regalrez 1094 shows even more limited solubility, restricted almost exclusively to aromatic, halogenated, alicyclic, and aliphatic solvents (Appendix II).

One can also observe several of the shortcomings of the Teas solubility system in these data. For instance, the solubility of Laropal A-81 in hexane (#1) and heptane (#2) is markedly different, although this is difficult to observe in Appendix I because of the overlying solubility parameters for these aliphatic solvents (f_d=100, f_p=0, f_h=0). Although hexane showed no solubility and produced a thick gelled residue, heptane appeared after nearly a day of stirring to be a borderline solvent, eventually producing a clear solution with only a modicum of swollen gel residue. Although dispersion forces comprise the entirety of both solvents' interaction potential, the absolute magnitude of that interaction, which is larger for heptane but is neglected by Teas, must be important. Kinetics of dissolution are also important; both xylenes (#11) and cyclohexane (#5) produced crystal clear Laropal A-81 solutions, but on vastly different timescales. The xylenes solution formed in minutes whereas it took many hours for cyclohexane to have a similar effect. These kinetic data are not represented in a typical Teas chart.

Teas parameters are also problematic when using solvent blends, themselves mixtures of solvents. In the same diagram, one notices an anomaly for Laropal A-81 when combined with mineral spirits (#6). Although it would appear that mineral spirits should be just within the solubility window, it clearly behaved like a non-solvent. In this instance, the issue surrounds the ill-defined composition of "mineral spirits." In fact, when consulting with our local supplier of commodity solvents, the authors were astonished to hear that any tanker shipment between 14% and 22% aromatics is marketed as the same product without any further disclosure to the buyer. The ASTM guidelines for "mineral spirits" are even more liberal. A range of 0-22%, divided into three classes, can all be labeled "mineral spirits."[10]

The widely reported Teas fractional parameters for generic mineral spirits were intentionally used in Figure 2 to highlight this issue with commodity solvent blends. The actual mineral spirit product used in this experiment was ShellSol 7EC, formerly ShellSol 145EC, which reportedly contains 7.1% aromatics. If one uses *Solvent Solver* to simulate a 7.1% toluene (#10) solution in hexanes (#1), the Teas parameters for this particular "mineral spirit" would be closer to those widely reported for odorless mineral spirits (#3, i.e. f_d=98, f_p=1, f_h=1). With this in mind, the fact that Laropal A-81 is insoluble in ShellSol 7EC mineral spirits is understandable and is in fact predicted by the Teas chart for that resin. In a related situation, Fisher Scientific brand petroleum benzine, which before 1995 was ~12.5% aromatics, was changed without notice to a composition of approximately 0.1% aromatics, thereby reducing its efficacy in established

cleaning and varnishing formulas. The data reported by Horie[4] and Whitten[6] would have included the earlier formulation for petroleum benzine. Clearly it is "buyer beware" when using commodity solvent blends or relying on older solubility data related to these products, and if not for their ready availability and relative economy, conservators would be advised not to rely on proprietary solvent blends.

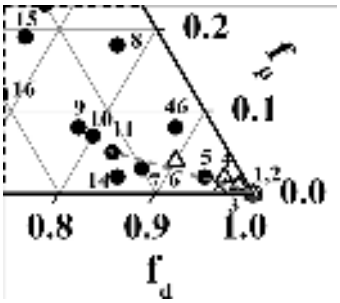

Figure 2. Detail of Teas chart for Laropal A-81 highlighting xylene (#11) – hexane (#1) titration experiment.

CASE STUDIES

Two case studies were devised to highlight the utility of the solubility data reported here. Both examples involve the brush application of LMW synthetic resin varnishes over Laropal A-81 restoration paints, viz. Gamblin Conservation Colors. Brush application of varnishes can be desirable for rendering specific surface aesthetics as well as to provide a more protective, cohesive varnish coating.[6] The simultaneous use of these resins for inpainting as well as varnishing can be complicated due to overlapping solubility windows, mechanical agitation from the brushing, the fluidity of the resulting solutions, and the easy re-solubilization of underlying layers due to the LMW of the resins involved.

The product literature provided in the initial release of the Gamblin restoration paints specifically notes that brush application of Regalrez 1094 or MS2A over the paints is possible, although no specifics are given. And yet, conservators often report difficulties in applying these two products over Laropal A-81 paints. These difficulties often lead to either the spray application of these varnishes or to the use of the urea-aldehyde paints over another varnish with adjustment of the inpainting medium formulation or physical manipulation of the paint surface to achieve the right gloss level. However, the case studies presented here suggest that successful brush application of the varnish might be possible if one studies carefully the solubility data for both the varnish and the inpainting resin.

Brush Application of Regalrez Varnishes over Laropal A-81 Paints

Regalrez 1094 has become a popular synthetic resin varnish for oil paintings because of its solubility in non-polar solvents, deeply saturating finish, and resistance to yellowing, oxidation, and insolubility with age.[6] However, when inpainting has been performed with other LMW resins, for instance those based on Laropal A-81, the overlapping solubility windows can be problematic for brush application of the varnish.

Fortunately, when the Teas charts for Regalrez 1094 and Laropal A-81 are inspected closely, one notes that the solubility windows do not perfectly overlap, leaving an opportunity for selective solvent application of the varnish. Regalrez 1094 is soluble in all aliphatic, alicyclic, and aromatic solvents (Appendix II), whereas Laropal A-81 (Appendix I) is soluble along the dispersion axis, f_d, only to a point just past that of cyclohexane (#5), keeping in mind the issues mentioned above regarding mineral spirits (#6). Figure 2 shows a detail from Appendix I of this part of the Teas chart for Laropal A-81.

Based on these data, one should be able to apply Regalrez 1094 over Laropal A-81 using ShellSol 340HT (#4), odorless thinners (#3), heptane (#2), or hexane (#1). However, a wider range of solvent mixtures may be possible and in fact desirable to increase drying time, leveling, etc. To chart more exactly the border of the solubility window for Laropal A-81, a solution of the resin in xylenes (#11) was titrated with hexanes (#1) and the point of precipitation of the resin noted.[†]

The Teas parameters for the titration endpoint are shown with an 'X' along the dotted line connecting the two solvents in Figure 2. This mixture amounted to 28% xylene. In an effort to test this calculation, a mock-up of the Gamblin Conservation Colors was brush varnished using Regalrez 1094 solutions (3g in 10mL) in hexanes with variable amounts of xylenes. The varnish was applied by brushing five times in the same direction. Figure 3 shows the test panel.

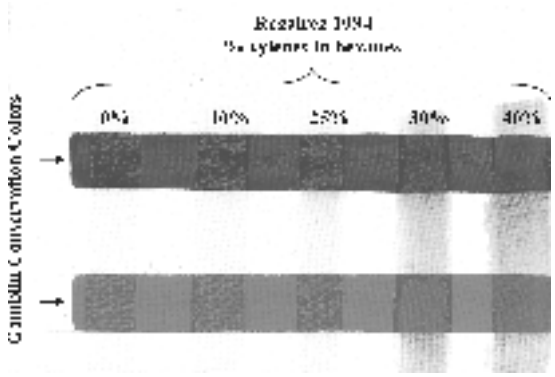

Figure 3. Mock-up showing Gamblin Conservation Colors brush varnished in 5 rapid passes using a Regalrez 1094 solution (3g in 10mL) in hexanes with increasing percentages of xylenes.

[†] Because of the controlled laboratory conditions available during the course of these experiments, hexanes could be used as the aliphatic solvent. However, the toxicity of hexanes is much worse than n-heptane, and so the use of the former by conservators should be practiced with extreme caution, if at all.

One can see that disruption of the Laropal A-81 medium is just apparent when the varnish solution contains 25% xylenes and is unacceptably smeared at 30%, just as suggested by the titration experiment. The slight bleeding at the lower value of 25% xylenes rather than the predicted 28% may be due to the effect of the resin on the polarity/polarizability of the varnish solution (vide infra). It is worth noting that the Gamblin product literature recommends rewetting of dried Laropal A-81 paints on the palette using a solvent of at least 25% aromatic character.

In summary, any primarily aliphatic solvent blend could be used to apply Regalrez 1094 by brush over Laropal A-81 paints so long as the aromatic content was kept below 25%, with 20% perhaps being a safer margin. One must keep in mind that if the aliphatic solvent evaporates faster than the aromatic solvent, or if the aromatic solvent is preferentially absorbed into the underlying Laropal A-81 layer, successive coats or vigorous brush application of an initially safe solution may eventually cause bleeding of the restoration colors. It is also important to note the makeup of the solvent blend being utilized. If a petroleum distillate containing higher amounts of cycloparaffinic hydrocarbons (e.g. ShellSol 340HT) is used in combination with aromatic solvents, the 'safety zone' is likely to be different due to the higher solubility of the resin in alicyclic hydrocarbons (e.g. cyclohexane, decalin, etc.) compared to aliphatic ones.

Brush Application of MS2A Varnishes over Laropal A-81 Paints

MS2A has achieved widespread use as a picture varnish, despite its brittle nature, due to the otherwise unachievable "silken gloss" and "lively, varied, sensitive appearance" that it produces.[6] Based on its solubility characteristics (Appendix III), the brush application of MS2A should be identical to the protocol described for Regalrez 1094. To test this supposition, a similar mock-up of Gamblin Colors was brush varnished with MS2A solutions identical to those used above for Regalrez 1094, except that the varnish concentration was lowered to 2g in 10mL to conserve what is a much more expensive resin. The results are shown in Figure 4.

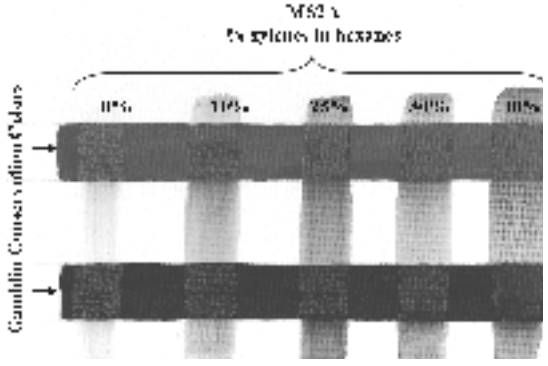

Figure 4. Mock-up showing Gamblin Conservation Colors brush varnished in 5 rapid passes using a MS2A solution (2g in 10mL) in hexane with increasing percentages of xylenes.

Clearly a more complex solvent, varnish, inpaint chemistry is at work. MS2A in pure hexanes immediately disrupted the underlying Laropal A-81 paints and became progressively worse with the addition of aromatic content. Why should a purely aliphatic solution act so aggressively on the underlying paint when the previous application of Regalrez 1094 in the same solvent on the same paint was benign?

Compared to Regalrez 1094, MS2A is a much more polar material, and the authors surmised that its incorporation into the aliphatic solvent at nearly 24% w/w was enough to raise the polarity of the resulting varnish solution to within the boundaries of the Laropal A-81 solubility window. In effect, the MS2A might be acting like a polar component in a solvent mixture. If this were so, then the bleeding effect should be reduced by lowering the amount of MS2A in the varnish solution.

A third mock-up was constructed to test this hypothesis. A series of less concentrated MS2A varnishes was prepared in hexanes. Figure 5 shows the result of the experiment after 5 unidirectional passes of the brush application.

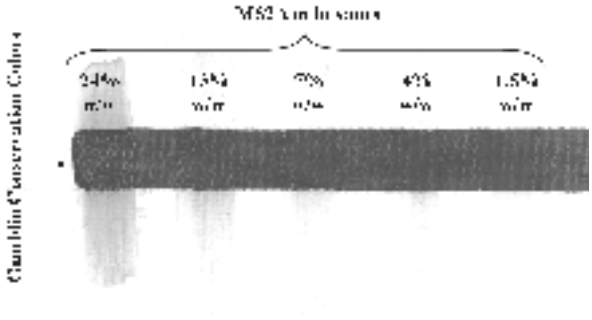

Figure 5. Mock-up showing Gamblin Conservation Colors brush varnished in 5 rapid passes using progressively less concentrated MS2A solutions in hexanes.

As hypothesized, the bleeding of the Laropal A-81 paint was reduced as the MS2A content of the varnish diminished. Although slight bleeding was still observed at concentrations of 4% and 1.5% w/w, these occurred only in the last pass of the brush. Another curious observation from this experiment relates to the appearance of the MS2A varnish solutions themselves. Those with solute concentrations equal to or higher than 13% w/w produced a yellow tinged, crystal clear solution, however lower concentrations appeared slightly milky with minor particulate residues, even after gentle heating.

Unbeknownst to the authors at the time, similar experiments performed by Sutherland on varnishes applied to oil paintings showed that a MS2A varnish solution increased the extraction of free fatty acids over that of the nonpolar solvent alone.[15] In fact, a didactic included in that paper specifically shows the ability of MS2A to increase the solubility of Laropal

A-81 in ShellSol 340HT. It was Sutherland's opinion too that the resin acts to shift the solubility parameters of the resin solution into a more polar region of the Teas chart, thus making brush application of MS2A over Laropal A-81 impossible.

Based on these observations, but without anything so restrictive as hard data, one could envision a possible working method for the brush application of MS2A varnish over Laropal A-81 inpainting that involved an initial few passes of a very low concentration varnish. After complete drying (only minutes with an aliphatic solvent), the thin dried varnish layer may provide additional protection in the event that additional passes with a more concentrated varnish solution were desirable. This suggestion is based on the relatively slow dissolution of MS2A in hexanes. Current experimentation at BSC seeks to explore these working methods more fully.

CONCLUSION

Teas charts prove a useful record and accurate predictor of solubility for LMW resins as well as a host of other conservation materials. Although the production of comprehensive Teas charts is likely to be beyond the time and material constraints of most conservators, it is an ideal exercise for conservation students. Experience has shown that students who construct a Teas chart develop an appreciation of the strengths and weaknesses of all polymer solubility theories, not just that of Teas. In addition, it presents a memorable introduction to a wide range of solvents, their properties, and their safety issues and instills in the student an intuitive sense of the "strength" of solvents to all manner of solutes, not just the oil paints that have dominated solubility thinking in conservation to date.

In releasing this report to the conservation community, it is hoped that these solubility data will prove useful in challenging varnishing or inpainting situations or perhaps in the exploration of solvent effects on a LMW coating's physical and optical properties. A few contrived laboratory examples have been presented here, but further careful exploration under realistic situations is warranted. In addition to the experiments detailed in this report, the BSC graduate students have produced comprehensive Teas charts for other recently introduced resins (Aquazol 200), for temporary consolidants (cyclododecane), surfactants (Triton X-405), and fresh and aged natural resin varnishes (dammar). Future classes of students will continue to explore and chart polymer solubility, and the authors welcome any suggestions for new or understudied target materials.

Acknowledgements

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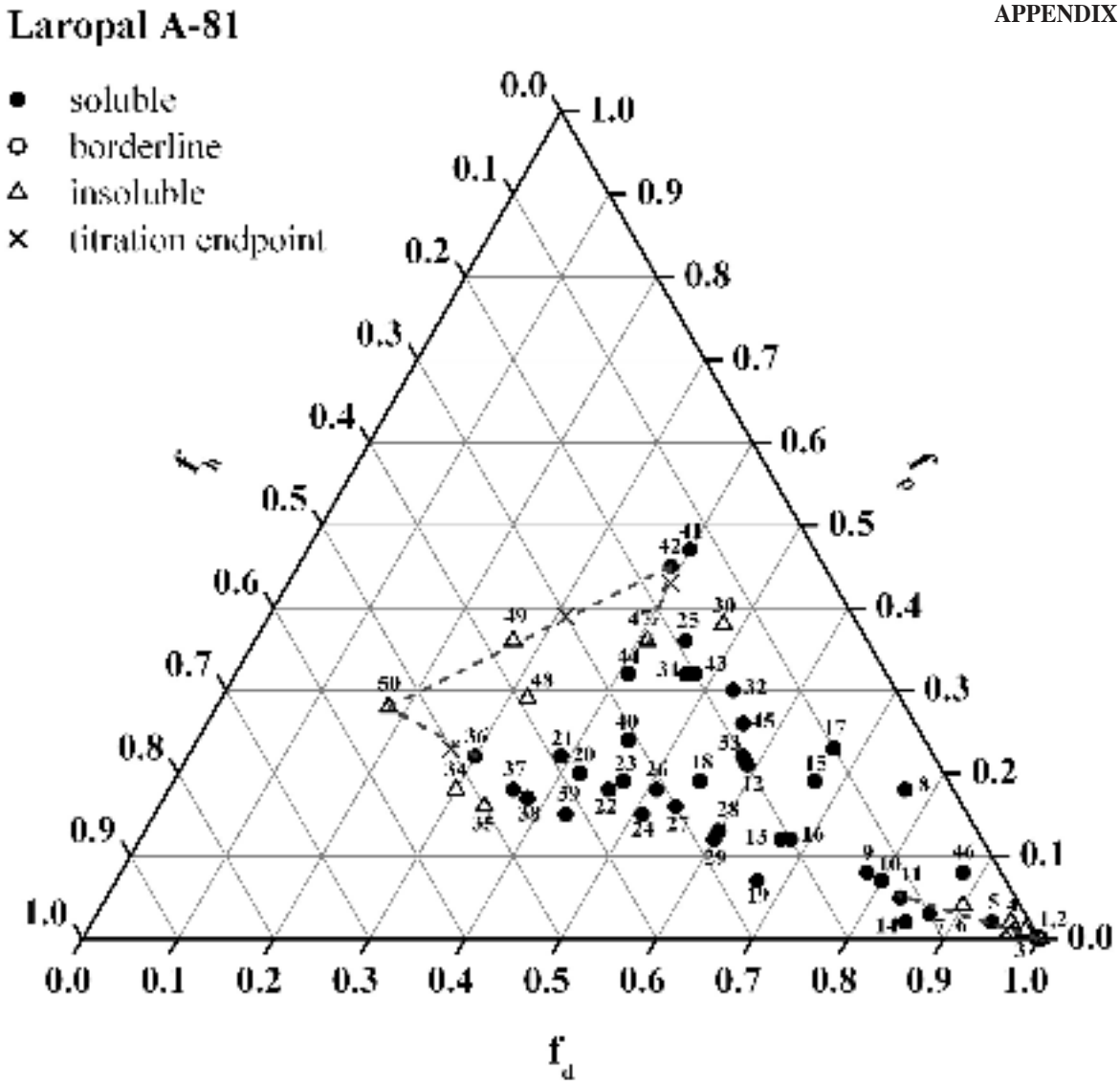
APPENDIX 1



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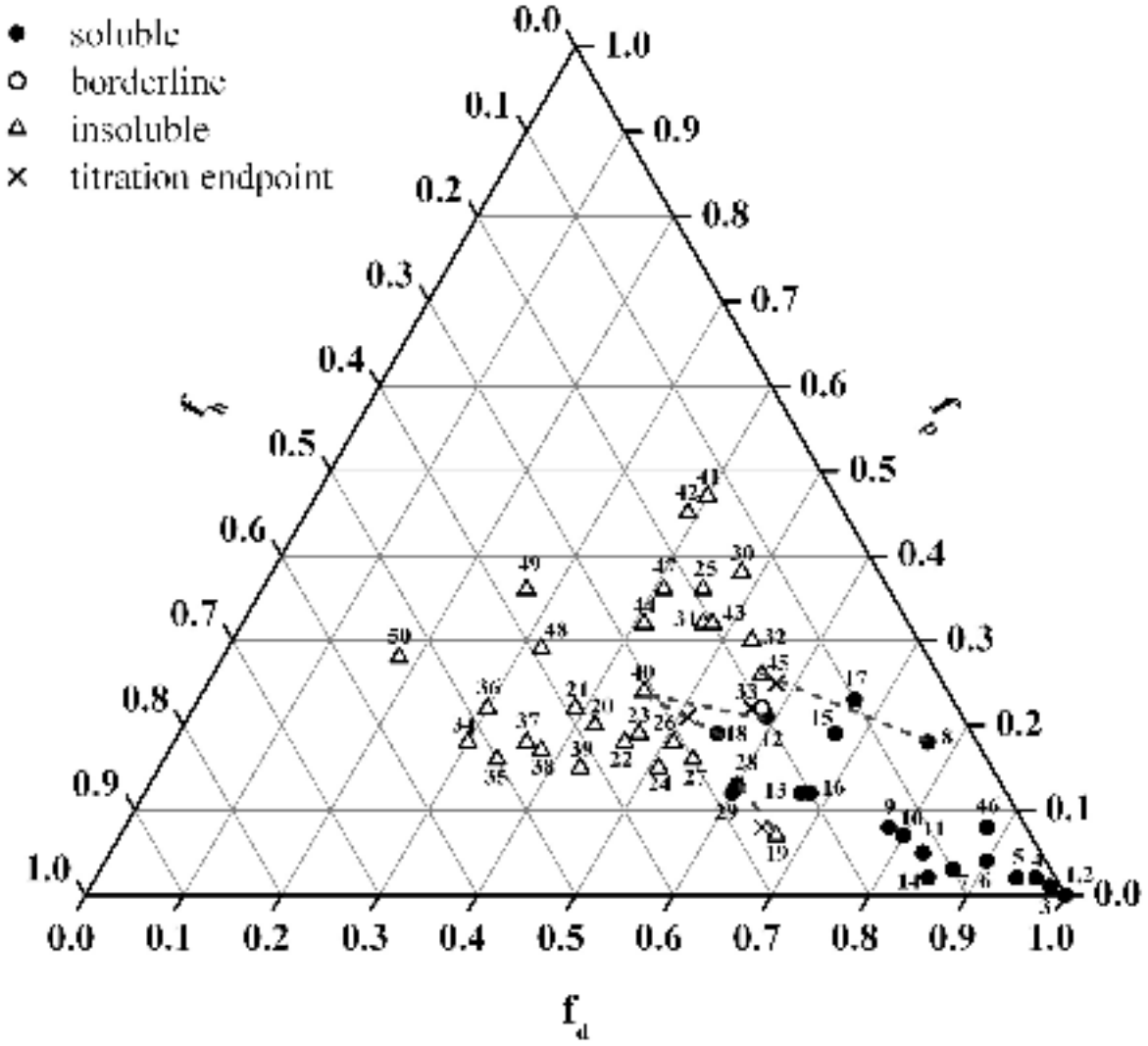
10	Toluene	80	7	13
11	Xylenes	83	5	12
12	Dichloromethane	59	21	20
13	Chloroform	67	12	21
14	Carbon tetrachloride	85	2	13
15	1,2-Dichloroethane	67	19	14
16	Trichloroethylene	68	12	20
17	Tetrachloroethylene	67	23	10
18	Tetrahydrofuran (THF)	55	19	26
19	1,4-Dioxane	67	7	26
20	2-Ethoxyethanol (Cellosolve)	42	20	38
21	2-Methoxyethanol (Methyl cellosolve)	39	22	39
22	2-Butoxyethanol (Butyl cellosolve)	46	18	36
23	1-Methoxy-2-propanol (methyl proxitol)	47	19	34
24	2-Ethoxyethyl acetate	51	15	34
25	Methyl acetate	45	36	19
26	Ethyl acetate	51	18	31
27	i-Propyl acetate	54	16	30
28	n-Butyl acetate	60	13	27
29	i-Amyl acetate (i-Pentyl acetate)	60	12	28
30	Propylene carbonate	48	38	14
31	Acetone	47	32	21
32	Methyl ethyl ketone (MEK)	53	30	17
33	Methyl isobutyl ketone (MIK)	58	22	20
34	Ethylene glycol	30	18	52
35	Propylene glycol	34	16	50
36	Methanol	30	22	48
37	Ethanol	36	18	46
38	i-Propanol	38	17	45
39	n-Butanol	43	15	42
40	Diacetone alcohol	45	24	31
41	Nitromethane	40	47	13
42	Acetonitrile	39	45	16
43	N-Methyl-2-pyrrolidone (M-Pyrol)	48	32	20
44	N,N-Dimethylformamide (DMF)	41	32	27
45	Pyridine	56	26	18
46	Carbon disulfide	88	8	4
47	Dimethyl sulfoxide (DMSO)	41	36	23
48	Ethanolamine (MEA)	32	29	39
49	Triethanolamine (TEA)	27	36	37
50	Water	18	28	54

APPENDIX 2



#	Solvent	fd	fp	fh
1	Hexanes	100	0	0
2	n-Heptane	100	0	0
3	Odorless mineral spirits	98	1	1
4	ShellSol 340HT	96	2	2
5	Cyclohexane	94	2	4
6	Mineral spirits	90	4	6
7	Ethylbenzene	87	3	10
8	Turpentine	77	18	5
9	Benzene	78	8	14
10	Toluene	80	7	13
11	Xylenes	83	5	12
12	Dichloromethane	59	21	20
13	Chloroform	67	12	21
14	Carbon tetrachloride	85	2	13
15	1,2-Dichloroethane	67	19	14
16	Trichloroethylene	68	12	20
17	Tetrachloroethylene	67	23	10
18	Tetrahydrofuran (THF)	55	19	26
19	1,4-Dioxane	67	7	26
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31	Acetone	47	32	21
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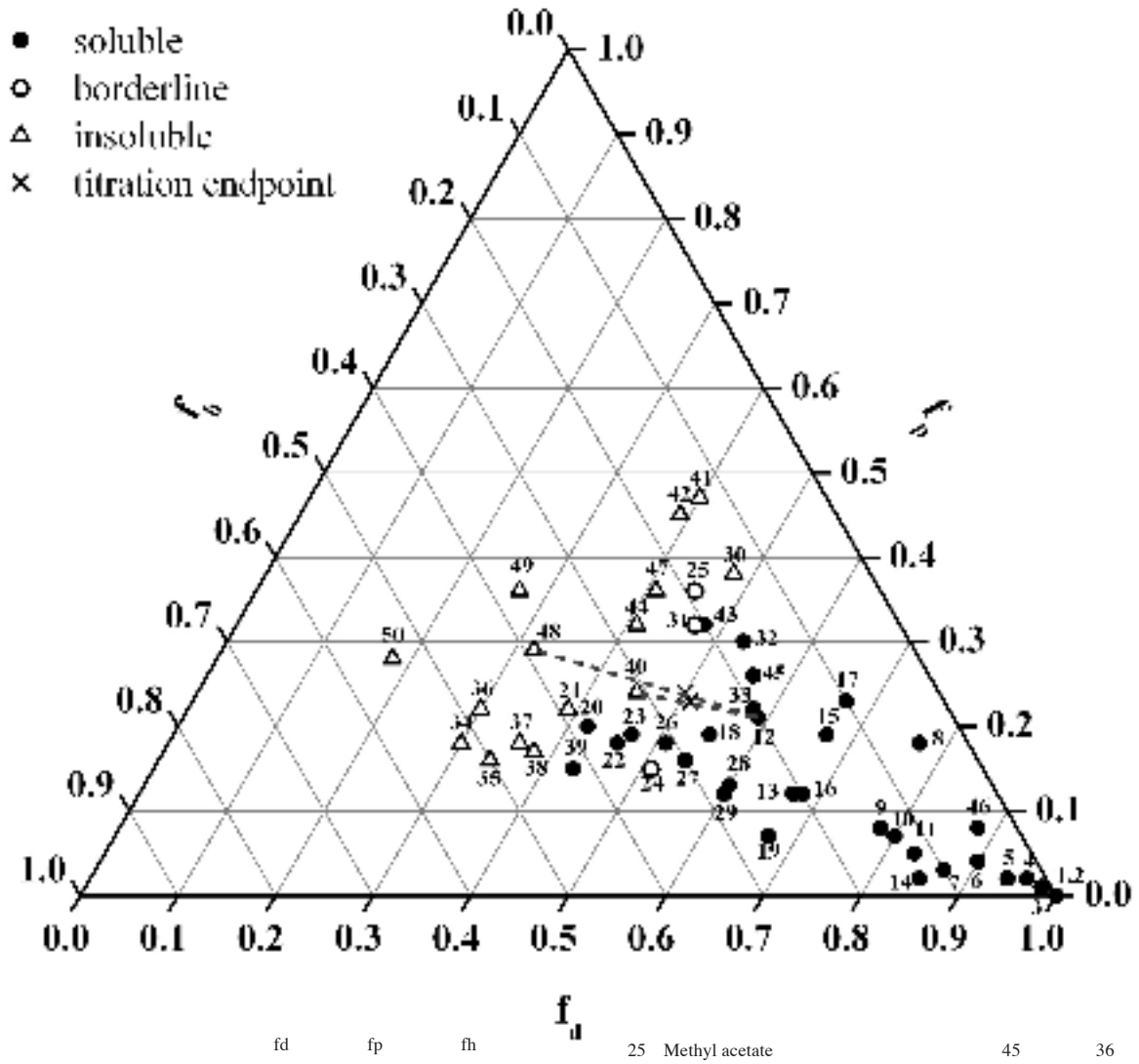
35	Propylene glycol	34	16	50
36	Methanol	30	22	48
37	Ethanol	36	18	46
38	i-Propanol	38	17	45
39	n-Butanol	43	15	42
40	Diacetone alcohol	45	24	31
41	Nitromethane	40	47	13
42	Acetonitrile	39	45	16
43	N-Methyl-2-pyrrolidone (M-Pyrol)	48	32	20
44	N,N-Dimethylformamide (DMF)	41	32	27
45	Pyridine	56	26	18
46	Carbon disulfide	88	8	4
47	Dimethyl sulfoxide (DMSO)	41	36	23
48	Ethanolamine (MEA)	32	29	39
49	Triethanolamine (TEA)	27	36	37
50	Water	18	28	54

Strip 'Teas' - Solubility Data for Low Molecular Weight Synthetic Resins, continued

APPENDIX 3



#	Solvent	fd	fp	fh
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6	Mineral spirits	90	4	6
7	Ethylbenzene	87	3	10
8	Turpentine	77	18	5
9	Benzene	78	8	14
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36	Methanol	30	22	48
37	Ethanol	36	18	46
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40	Diacetone alcohol	45	24	31
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50	Water	18	28	54