**Solvents & Sensibility**

*by Chris Stavroudis and Sharon Blank*

**Part I: No Teas-ing**

At no time in modern conservation have developments in practical, bench-top techniques been more exciting than now. The recent re-evaluation of what it is we are doing when we "clean" a work of art with solvents is revolutionary. The work pioneered by Richard Wolbers at the Winterthur Museum/University of Delaware Art Conservation Training Program has engendered a new interest and awareness in the basic processes of working with solvents.

Here we will examine the **concept of solvent strength and present a simplified, but accurate, conceptual model to help understand the interactions of solvents with materials of interest to conservators.** We will also discuss how this information can be used as a tool to help solve some of the vexing problems facing conservators. A few recipes follow at the end to illustrate the application of theory to practice, but please do not skip ahead to the end--rest assured, the butler did it.

We all have certain notions about solvent strength. Acetone is a "strong" but rapidly evaporating solvent. Water is "weak" and not really a solvent at all. Petroleum benzine, VM&P naphtha, etc. are "weak" or "very mild" solvents. All of these statements miss the point.

**A solvent is strong or weak relative to the material being dissolved (and relative to the material we do not want to dissolve).** This concept is crucial to the safe exploitation of solvents in conservation. It pertains to formulating solvent carriers for adhesives and varnishes, to the safe removal of old varnish layers from the surface of paintings, to the removal of aged masking tape adhesive residues from anywhere they shouldn't be.

**The interaction of a solvent with something we want to dissolve or, alternately, something we do not want to dissolve, is governed by a number of molecular interactions. Attempts to characterize these interactions include Hansen's Solubility parameters, the Teas diagram**, and others, too numerous to count. We modestly propose that these schema should henceforth be banned. See [figure 2](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-2b.gif) in Part II--no Teas-ing. &lt;graphic status=omitted&gt; (For those of you, gentle readers, who cannot live without those technical details, please see ["Part II, Teas-Busters"](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#part2), immediately following.)

All we ever needed to know about solubility, we learned in kindergarten: "like dissolves like". Solubility parameters, in all their guises, are merely attempts to quantify this simple notion.

**REVOLUTION**

One of the tenets of revolution is that the old order must be destroyed. Old, insufficiently accurate ideas about solvents and solutes must be dispatched. In fact, the very nomenclature that we use to discuss solvents must be re-examined; the terms are meaningless. Welcome to the revolution.

With the exception of ionic interactions, salts and acid-base reactions, the concept that is not only common-sense but rigorously and scientifically valid is: like dissolves like.

**POLARITY**

**Polarity, as we will be using the term, is a way to compare the "like-ness" of materials.** The term is used as an empirical estimate, a mental construct, which is probably how you think about solvents anyway. Polarity is an aspect of all materials and the concept allows us to fit a material's behavior into the range from non-polar to highly polar.

**Polarity can be thought of as a line which extends from polar materials like water all the way to non-polar aliphatic hydrocarbons.** Every material can be placed somewhere along that line. Some interesting effects are observed when the world is broken down and placed along the polarity line. Most of the materials which occur naturally are polar. Proteins and minerals are all polar in nature. Animal and plant derived oils, fats, and waxes are intermediate in polarity. Natural rubber and petroleum products tend to be even less polar. When rubber and petroleum are refined, the non-polar fractions are isolated.

**Consider a polymer molecule in solution: it is there because being in solution is easier (requires less energy) than not being in solution. This is because the molecules are similar; i.e., like dissolves like--their polarities are similar.**

We all have been using the imprecise term "polarity" for years. Unfortunately, the term "polarity" can be used in two ways. In the solubility parameters and Teas diagrams, dipole interactions are often called polarity--this is confusing and not accurate. Polarity indeed does include dipole interactions; but as polarity increases, so does hydrogen bonding. For more along these lines, see [Part II>](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#part2).

**The concept of polarity can be used to avoid harm to objects too. Cellulosic materials and many other materials of biological origin, such as wood, paper, and leather, are very sensitive to water, which swells and disrupts their structure.** In some cases this swelling is inappropriate. To avoid damage to an already degraded object, the conservator will wish to avoid aqueous solutions. As might be expected, the very polar solvents, such as alcohols, may also prove deleterious. In formulating a conservation treatment, the conservator will deliberately use the least polar system that works. (In other cases, as in the washing of degraded paper objects, the swelling and probable structural changes are used to advantage.)

Matching the polarity of materials allows a material, say Bocour Magna paints (n-butyl methacrylate), to be put into solution. n- butyl methacrylate has an intermediate polarity; it dissolves well in toluene and xylene. Water and alcohol are too polar and cannot mix with the more "oily" polymer molecules. A conservator wishing to avoid the use of the more toxic xylene or toluene can inpaint with Magna colors using a mixture of naphtha and acetone. While naphtha is not sufficiently polar to dissolve the resin, the addition of relatively polar acetone makes the solution energetically favorable.

Acryloid B-48N includes an adhesion promoter that assists the less polar acrylic molecules to adhere to a polar metal surface.

Consider the problem of formulating an adhesive to mend a stone artifact. The surface of stone is surprisingly polar. (If you think about it, it makes sense. Stone is a very insoluble ionic salt and although it doesn't dissolve, it has a great affinity for water.) To get the greatest adhesion between the glue and the stone, we want to select a material that is highly compatible with that polar surface. While the notion of the stone actually being soluble in the adhesive, or vice versa, is clearly ridiculous, the greater the interaction between the adhesive polymer and the stone substrate the greater the adhesive strength will be. Does this begin to sound like surface contact angle; well, it is. Welcome to the revolution.

Whether or not we want to make the bond as strong as possible is another matter; that's conservation. Indeed, we could formulate our adhesive in such a way that the solvent does not allow the polymer chains to unfurl properly and form a glue with less cohesive strength, but that is another story.

**One of the neat things about viewing the world through polar- colored glasses is understanding the way organic materials age. With exposure to oxygen, organic molecules will oxidize, forming polar functional groups. Precept two: as organic materials age, they become more polar. What this means to our intrepid conservator is that more polar solvents are required to remove aged, degraded materials.**

Natural resin varnishes, originally applied in "mild" solvents like turpentine, oxidize and become yellow and "insoluble". These are symptoms of aging, increasing polarity. In the bad old days, we would have to have used "strong" solvents like ethanol or acetone to remove the discolored layer. Using our new knowledge about polarity, we can now reason thus: A combination of a good solvent for fresh dammar, like xylene, and a highly polar solvent, water, should dissolve aged dammar. Sadly, oil and water don't mix; but read on--emulsifiers exist.

In other words, there are two ways to approach dissolving our aged, more polar varnish: to use progressively more polar solvents like ethyl alcohol or acetone (which are not only more polar but are very aggressive "strong" solvents); or to blend a customized mixture of solvents tailored to dissolve just that varnish layer. An example of that tailoring is a mixture of xylene and water with a nonionic detergent.

**SOAPS, DETERGENTS, SURFACTANTS, EMULSIFIERS**

**All of the above terms refer to a molecule that can insinuate itself between polar and non-polar molecules. The detergent has a polar end that dissolves in water, and a non-polar end that dissolves in greases, fats, oils, and other icky things.**

Like dissolves like and your hands are greasy; what can you do? You know the grease on your hands can be dissolved in tallow, but that really doesn't help. If you react tallow with a strong alkali like lye, you saponify the acid sites on the stearic acid portion of the tallow. The resulting soap can be used to clean your hands. The non-polar tallow-like parts of the soap molecules can interact (form Van der Waals bonds) with the grease on your hands, and the potassium salt end will dissolve in water thanks to ionic interactions. The best part is your hands will be clean.

Now for the Richard Wolbers revolution. You have a painting with a layer of aged dammar varnish on the surface. The varnish no longer dissolves in the "mild" non-polar solvent in which it was applied; the dammar has oxidized, become more polar (precept two). You want to remove the varnish layer. An old-fashioned conservator would use "strong" solvents (because "strong" solvents are more polar than "mild") to remove the varnish. You are an enlightened conservator. Richard reasoned that it should be possible to dissolve aged (oxidized) dammar into a mixture of xylene and water stabilized by a non-ionic detergent, say Triton X-100, thus allowing oil and water to mix, varnish to be removed, and the world to be a kinder, gentler place.

Let's take "like dissolves like" to its wildest implication, the staggering notion that we can dissolve aged varnishes into an aqueous solution. Further reflection on the nature of oxidized resins led Richard to formulate an aqueous cleaning system by making a soap customized to dissolve aged dammar. Ideally, you would like to isolate the oxidization products of dammar that are present as carboxylate groups, react them with a base (triethanolamine), and make a soap. As these groups are present at only small percentages in dammar, it is wasteful to make such a soap from dammar resin. Abietic acid, an acid component from rosin is cheap, structurally similar to dammar, and the triethanolamine salt is commercially available as a soap. A 4% solution of triethanolamine abietate in water will dissolve moderately aged (oxidized) dammar films. For more aged, highly oxidized natural resin films, a soap based on triethanolamine deoxycholate will perform miraculously.

In formulating resin soaps, there are more variables that must be considered. One is strongly advised to add Triton X-100 to improve wetting, and hydroxypropylmethyl cellulose or Carbopol to gel the solution. More importantly, pH must be controlled. Too alkaline a solution (say above pH 8- 8.5) can **saponify** or attack underlying oil layers.

The above cautions emphasize that these new approaches to cleaning require insight and thought. Merely mixing up all the new formulas and using them in testing as you do acetone will be disappointing or even destructive. You must begin to think like a detergent formulator.

**The ability to customize a solvent system to the specific nature of the substrate allows the conservator far greater control over the process of conservation.** It is like the difference between a scalpel and a machete; both are sharp, and either can do lots of damage. The amount of control possible with a scalpel, however, makes it the instrument of choice for surgery. Whether this new approach to solvency is used to unpack (Richard's term) the layers on the surface of a painting, or to remove masking tape residue from wherever it oughtn't be, it is a revolution that all practicing conservators will want to join.

**When given the choice between an aqueous system and the use of organic solvents, if both are equal in terms of effectiveness and safety of the object, then the safety of the conservator can become the deciding factor. One of Richard's more important contributions may be to dramatically extend the lives of his fellow conservators!**

While an afterthought to this article, it must be emphasized that the contributions Richard Wolbers has made to the process of cleaning artifacts has been built on the equally important analytical technique he has brought to the field, reactive fluorescent staining. A problem cannot be solved without first framing a question.

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**Part II: Teas-Busters**

In [part I](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#part1) of this suite, we offhandedly dismissed the Teas solubility diagram specifically and solubility parameters in general. This is a justification of that dismissal. Scientifically inclined readers may wish to get Kleenex, this will not be pretty; the rest of you can laugh-it-up.

The history of trying to understand solvents and why some dissolve some materials and not others is discussed elsewhere. We will also ignore the thermodynamic underpinnings of solubility theory (entropy, enthalpy, etc.) and cut to the good part. [The Hedley article, [ref. 3](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#fn3), and John Burke's work, [ref. 12](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#fn12), present much of this information in a most palatable form. Read and be enlightened.]

Based on the thermodynamics of the solution process, Hildebrand made a number of simplifying assumptions and showed that the attractive **forces holding one molecule to another in a liquid, the Cohesive Energy Density, were related to solubility.** It was reasoned that if either the solvent molecules or the solute molecules preferred sticking to themselves rather than each other, solution would not take place. For solution to occur, therefore, the attractive forces between two solvent molecules, between two solute molecules, and between a solvent molecule and solute molecule must be roughly equal--the **Cohesive Energy Density (CED)**. This force is related to the energy it takes to separate the solvent molecules from each other, the heat of vaporization, less the mechanical work done separating the molecules, all divided by the molar volume. Hildebrand defined the square root of the CED as the solubility parameter, d.

Charles M. Hansen, in 1967, developed a set of three solubility parameters to more accurately describe a solvent, non-ionic emulsifier, pigment, or polymer ([ref. 1](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#fn1)). The three parameters were derived in part empirically and in part from thermodynamic properties. He felt that the Cohesive Energy Density, or Hildebrand's solubility parameter squared, represented the summation of three component energies, or squared solubility parameters. **Hansen isolated and attached numbers to the three component forces that hold molecules together: van der Waals forces, dipole forces, and hydrogen bonding forces.**

**Van der Waals forces, also called dispersion forces, are extremely weak forces present between all molecules. They are explained by quantum mechanics. As electrons zip about in their orbits, they can induce a distortion in the electrons in neighboring molecules. The distortion causes the molecules to be ever-so-slightly attracted to each other. While not the most convincing explanation, it's quantum mechanics, and that's our best guess at reality. Van der Waals forces are related to the surface area of molecules; they only operate between portions of different molecules that are in close contact. Van der Waals or dispersion forces are the attractive forces in aliphatic hydrocarbons.**

**Dipole forces, also called polar forces (an unfortunate use of the term as polar should include hydrogen bonding too), are the forces between molecules with permanent dipoles. A permanent dipole is the consequence of a lack of symmetry in the electron clouds surrounding the molecule. The lack of symmetry causes one area of the molecule to have a partial positive charge; another area, a corresponding negative charge. Interaction between molecules takes place as the partial negative areas of one molecule are attracted to the partial positive areas of adjacent molecules. Because dipole forces are electrostatic, they are stronger than van der Waals forces. The ketones have strong polar intermolecular forces.**

**Hydrogen bonding forces occur between molecules where a hydrogen atom is bonded to a strongly electronegative atom, O, N, or F. The oxygen or nitrogen atom attracts the hydrogen electron cloud so strongly that very powerful dipole forces result within the molecule. Hydrogen bonding explains why water is a liquid rather than a gas at room temperature. Although water is a small, light weight molecule, the hydrogen dipole is attracted to an adjacent oxygen dipole, thus increasing the CED. Hydrogen bonding is important in alcohols, in addition to water**.

Hansen assigned a partial solubility parameter to each of these forces. The calculation of the dipole partial solubility parameter was based on measurements of refractive index, dielectric constant, and the dipole moment, all of which can be measured for solvents. The hydrogen bonding partial parameter is based on a "reasonable value for the OH...O bond" of 5000 calories per mole, as indicated by infrared spectroscopy and other measurements. The value is corrected for the molar volume of the molecule and the number of hydrogen bonding sites present. Having calculated partial solubility parameters for dipole and hydrogen bonding, the van der Waals or dispersion component could be calculated as what was left over in the total, Hildebrand, solubility. Then these figures were adjusted, adding a good deal of intuition.

Hansen worked with the three parameters in three dimensions using a computer. The graphs presented in his book are very difficult to read and are projections of two of the three dimensions. Polymer solubility is represented by a central value, the point of best solubility (often the solvent or solvent combination that produces the lowest intrinsic viscosity value), and a radius that represented the size of a sphere about that point that included solvents that would dissolve the polymer.

We have all seen, or at least been shown, the infamous triangular Teas diagram ([figure 1](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-2a.gif)). **The Teas diagram** is a graphical short-cut to represent the three dimensions that Hansen's solubility parameters demand onto two dimensional paper. The diagram graphically represents the combined effects of dipole forces, hydrogen bonding forces, and dispersion forces as a visual indication of a solvent's relative "strength." The three solubility parameters are not that accurate, although they are among the best predictors we have. Compressing the parameters onto a triangular diagram makes matters worse. [Barton, [ref. 6](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#fn6), is even more disparaging. He says Teas' values have "the disadvantage that they are completely empirical, without even the limited theoretical justification of Hansen's three-component parameters."] In the Teas diagram, the range of solubilities of a polymer is distorted into an odd shape, some relations between solvents are lost (xylene and dimethylformamide have very similar dispersion solubility parameters and vastly different polarity and hydrogen bonding values, but the reduction process obliterates this information).

In the preparation of the graphics for this article, we noticed that the formula given by everyone for converting from Hansen's solubility parameters to Teas coordinates did not work for a number of solvents, notably the aromatic and aliphatic hydrocarbons. This was unsettling. The formula is very simple and to get the numbers wrong once is embarrassing; repeatedly, down-right demoralizing.

After a bit of research, we found the following confession by Teas' own hand: "The coordinates for some seven solvents were also arbitrarily adjusted to bring family grouping in more reasonable arrangement." No wonder the paper ([ref. 2](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#fn2)) only received $150, fifth prize, in the 1967 Roon Awards competition.

Since the Teas diagram is but a predictive tool (often it works much better in hindsight) fraught with problems, we propose to ban the diagram, see [figure 2](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-2b.gif). The diagonal line in the figure represents, in a practical sense, polarity. To make the diagram simpler to use and understand, we have removed the edges and all the little triangles, and tipped it on its side. Now the polarity line is horizontal, and solvent families can be represented schematically, as in [figure 3](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-2c.gif). As organic materials oxidize, they move in the direction of the polarity line, towards the left.

One of the weaknesses of the Hansen solubility parameters, and therefore also the Teas diagram, is that in assigning a hydrogen bonding parameter, an important detail in the nature of hydrogen bonding is eliminated. For hydrogen bonding to occur there must be both a proton (hydrogen) donor site (eg. an O-H group) and an acceptor site (for example, the electron pairs zipping about an oxygen atom, c=O, in a ketone). Some molecules possess a donor site and no acceptor, chloroform; others, like MEK, have an acceptor without a donor. A single number cannot represent both affinities.

For any reader further interested in what's new in solubility and dissolving power, see Huyskens et al., [ref. 5](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#fn5). In the discussion of the new system utilizing the concept of dissolving power, symbolized by $, one can appreciate the value of Hansen's original system. [The dissolving power, $, has not been shown to have any influence on the diminishing buying power of the $.]

The concepts presented here do not apply to ionic interactions, the solubility of salts, or acid-base reactions. It is also important to emphasize that solubility concerns itself only with thermodynamics, not how fast something may go into solution. Kinetic solvent effects are based only on the size of the solvent molecule; the smaller the solvent, the faster it can wiggle its way into a solute to begin thermodynamic dissolution. Large solvent molecules have more trouble diffusing and are therefore slower.

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**Part III: What the Butler Did or, Some Tips on Formulations**

Mere formulae are not enough; the revolution requires a re-thinking about how we remove one material from another. Hopefully, the No-Teas-ing diagram will help. &lt;graphic status=omitted&gt; Below are some other helpful starting points.

As mentioned in [Part I](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#part1), oxidized varnish, too polar to be soluble in xylene alone, can be dissolved in a gel, formulated by Richard Wolbers, based on xylene, water, and Triton X-100. The formulation published previously in the [*WAAC Newsletter*](http://cool.conservation-us.org/waac/wn/wn08/wn08-2/wn08-203.html) in an article by Dare Hartwell (Vol. 8, no. 2, 1986, pp 4-6), reprinted from the *WCG Newsletter*, has since been revised slightly by Richard. 20 ml of Triton X-100 is dissolved in 50 ml of xylene. When mixed, add 30 ml of water to which a small amount of triethanolamine (no more than 1%) has been added, and shake vigorously until a gel has formed. The gel is effective on fairly young resin layers that have not oxidized to the point where resin soaps can be used, but that are too polar to be dissolved in xylene alone.

**When combining a non-polar solvent, water, and a detergent there are four possible outcomes. The ingredients can: 1) not mix, leaving two or three layers in your beaker (a bad solution). They can form an emulsion, either 2) an oil in water, or 3) a water in oil emulsion; or 4) a gel can be formed. The high concentration of Triton in the above formulation stabilizes the suspension of xylene and water at a mid-point between oil/water and water/oil emulsion.**

Such solvent gels have very nice working properties. The evaporation of the solvent is reduced, the polarity of the mixture is quite high because of the water present, and the gel is transparent so its activity on the surface can be monitored.

**Carbopol Gels:**

Carbopol is an acrylic acid polymer that can be used to gel both aqueous and solvent/water cleaning systems. To be of use, the acrylic acid groups have to be neutralized, in effect unfurling the polymer chain and giving a structure to the solution. If the neutralization is achieved with an amine that also has detergent properties, like triethanolamine (TEA) or Ethomeen C-25, the large net of Carbopol provides a backbone for the solution stabilizing emulsifier, allowing the formation of very stable solvent gels.

The following tricks aid in the formulation of Carbopol based gels. Elaborate stirring procedures (air driven paddle stirrers, magnetic stir-bars) are avoided with a commensurate increase in time to let materials equilibrate. The procedures also allow preparation of small batches with considerably less bother.

**Stock Carbopol Gels:**

To make the Carbopol Gel precursor, sprinkle 5 g of dry Carbopol 934 onto the surface of 65 ml distilled water while stirring briskly. Allow the stiff gel to stand until uniform in texture and appearance. Depending on the efficiency of the dispersion, this could be from 5 minutes to a day or two (four hours is my average). With all the Carbopol gels, only distilled water should be used as the resin will react and precipitate with the calcium salts in hard water.

To make the triethanolamine based gel, dissolve 10.2 grams (9.1 ml) of triethanolamine (or 12 g, 11.5 ml, of 85% triethanolamine) into 10 ml distilled water. While stirring, add the triethanolamine solution to the precursor. The above gel should have a pH of about 8.0-8.5. You must check the pH yourself with pH papers or a meter; trust no one. After standing for a time, the pH can be raised (more alkaline) with small additions of diluted TEA solution. (The pH can be lowered by adding additional precursor, but equilibrium requires considerable waiting time.) If the solution is too stiff for measuring pH with test papers, remove a small amount and mix with distilled water, then test.

To make the Ethomeen based gel, add 10 ml of distilled water to the precursor and stir until smooth. While stirring, add 12.5 g of Ethomeen C-25. The pH may be adjusted by adding additional C- 25 (or triethanolamine solution).

To make a dual neutralization gel, dissolve 8.8 grams TEA in 10 ml water. While stirring, add the TEA solution to the precursor and then 10 grams of Ethomeen C-25. "Dual neutralization sets up a bridge between the oil phase and the water phase by forming [Carbopol] salts soluble in both phases." (Quoted from the Carbopol manual, [ref. 11](http://cool.conservation-us.org/waac/wn/wn11/wn11-2/wn11-202.html#fn11).)

**Aqueous Gels:**

Aqueous gels can be made with either of the Carbopol stock gels or with hydroxypropylmethyl cellulose (HPMC), or any of the other cellulose ethers like methyl cellulose, Ethulose, or Klucel. Richard usually uses the HPMC for gelling his cleaning mixtures. Carbopol gels have a slight detergency effect on their own and have a different feel on the swab.

**HPMC gels are neutral in solution and are a must for enzyme gels, gels containing EDTA, or gels with high ionic strengths.** HPMC forms a nicely workable gel at a concentration of 1.5 grams per 100 ml of water or aqueous solution. The HPMC can be stirred into solution on a **magnetic stirrer or it can be sprinkled on the surface of the liquid, allowed to swell overnight, and stirred in the next day.** It should also be possible to pre-make stock HPMC/water gels for use as described for the Carbopol gels.

The Carbopol gels can be prepared by cutting a small amount of any of the stock gels (triethanolamine, Ethomeen C-25, or dual neutralization) into an aqueous solution. 3-4 grams of stock will gel 25ml of water or aqueous solution. A combination of stirring and patience yields very good results. I personally prefer the feel of the Carbopol gel to the HPMC.

**Solvent Gels:**

Solvent gels are more complicated. The solubility of the solvent solution must be compatible with the gelled Carbopol. Generally the Ethomeen based gel is more compatible with higher proportions of solvent to water. If the Carbopol is not soluble in the solvent system, it will precipitate out of the solution as a sticky, white, stringy residue. To test the compatibility of the Carbopol with a solvent system, submerse a small piece of the stock gel into the solution. If the surface of the gel becomes cloudy, the Carbopol is not soluble in the solution. Try modifying the solvent/water mixture. Generally more water, additional Triton X-100, or additional polar solvents will make the Carbopol soluble in the solution.

When the solution is compatible with the Carbopol gel, cut the stock gel into the solvent solution. Generally letting the mixture stand for a few hours with occasional stirring will form a smooth gel. Check the pH of the resulting gel; it will very probably have become acidic, in which case more Ethomeen C-25 or triethanolamine should be added.

Solvent gels based on immiscible solvents, water and xylene for example, are more difficult to make. Surfactants help, but very often one ends up with a stabilized, thickened emulsion. That's ok, but we would prefer a gel.

Solvent gels can also be formulated based on modified cellulose ethers like Klucel GF and Ethulose.

**Resin Soaps:**

The resin soaps are for dissolving aged (oxidized) natural resin films into water-based systems. The triethanolamine abietate tends to work better for less oxidized films. Triethanolamine deoxycholate seems to be better for more degraded, highly oxidized films.

**Stock Solutions (20% w/v):**

5 g Triethanolamine Abietate
0.6 g Triton X-100
25 ml distilled water
Triethanolamine

3.7 g Deoxycholic Acid (Free acid)
1.4 g (1.2 ml) Triethanolamine (1.6 g, 1.4 ml, 85%)
0.6 g Triton X-100
25 ml distilled water
Triethanolamine

In both cases, the first ingredients should be mixed. The additional triethanolamine is added, drop-wise, to obtain the desired pH (8.0-8.5 as a general rule). For the deoxycholate, an additional 0.6-0.9 grams of triethanolamine may be required to neutralize and dissolve the non-water soluble free acid. Use either a magnetic stirrer, or allow sufficient time for equilibrium to be reached (overnight for the first measurement of the deoxycholate soap) before testing pH and adjusting.

To make the working solutions, dilute the stock solution to 4% (or less) w/v solution (i.e. 1 ml stock solution to 4 ml distilled water). The working solutions may be gelled with either hydroxypropylmethyl cellulose (1.5 g/ 100 ml) or Carbopol/TEA gel (adjusted to the same pH as the resin soap). More Triton X-100 may be added to improve wetting of more non-polar surfaces, but remember; the oil layer is non-polar as well. (The working solution already has 0.5% Triton in it.)

To further improve solubility of less polar natural resin films (say, with a small amount of drying oil added), 1-3% of benzyl alcohol may be included in the formulation. Before adding the benzyl alcohol, add additional Triton X-100 to bring the total Triton percentage up to 4%.

For even higher drying oil content natural resin films, the deoxycholate soap solution (4%), gelled with hydroxypropylmethyl cellulose, can be used as a buffer solution for a lipase enzyme. A pH of 8.5 is recommended. Do not use a gel laden with air bubbles as the air can denature the enzyme. Sprinkle a small amount of enzyme on the surface of the gel in a wide mouthed container. Only prepare enough of the enzyme gel for the day's work. Allow the gel to stand for 15-30 minutes, then gently stir the enzyme into the gel, avoiding air bubbles. Allow to stand for an additional 30 minutes to an hour. The solubility limit of the enzyme is 10-30 mg/ml; if the gel is slightly hazy, too much enzyme has been added.

If there is a varnish film below the oil layer that is susceptible to the deoxycholate soap solution, the Lipase can be prepared in a Tris buffer solution, i.e. Trizma pH 8.4, and gelled with HPMC. The buffer is made according to directions (0.664 g/100 ml), 0.01% Triton X-100 (or more) is added, and 1-2% hydroxypropylmethyl cellulose is used to thicken it. The same cautions about air bubbles apply.

The Lipase should be kept refrigerated in a desiccator to prolong its usable life. Before opening the vial, warm it in your hand to avoid moisture condensing on the inside surface.

**Surface Cleaning Strategies**

**Surface grime is very polar in nature. It has an enormous surface area which is exposed to oxygen and therefore tends to be oxidized. Surface dirt also tends to be weakly acidic (oxidation to carboxylic acid groups) which is why it responds so well to ammonia and triethanolamine solutions.** (Important layers beneath the surface grime may not respond so favorably to such alkaline attacks; solutions with a pH exceeding 8-8.5, advises Richard, should be avoided.)

**We all know the virtues of spit cleaning. Spit is warm, when fresh, and highly polar. It is also pH and ionic strength balanced and contains amylase, the starch-"eating" enzyme. No conservator could live without spit, no matter how embarrassing it is in a report.**

One strategy for removing surface grime, also published in the [*WAAC Newsletter*, Vol. 8, no. 2, developed by the author, is to increase the polarity of naphtha by adding a small amount of water. To stabilize the mixture, the least amount of detergent possible is added (because any residue may be difficult to remove). An extremely stable emulsion is formed by the mixture of 9 parts naphtha to 1 part 5% Triton X-100 in water. The final concentration of Triton is 1/2%. If desired, after an emulsion has formed, the emulsion can be diluted in half again with naphtha, yielding a final formulation of 95% naphtha, 4.75% water, and 0.25% Triton X-100. As with the xylene/water/Triton gel, activity can be increased by adding a small amount of triethanolamine to the 5% Triton solution to make the emulsion slightly alkaline (no more than pH 8-8.5).](http://cool.conservation-us.org/waac/wn/wn08/wn08-2/wn08-204.html#emulsion)

[Other highly effective approaches to the removal of surface grime developed by Richard are soap solutions based on Maypon 4C. Maypon 4C is used in the formulation of "baby" shampoos, and is a soap based on an esterified protein molecule. The soap, at 4% dilution in distilled water and gelled with hydroxypropylmethyl cellulose (or Carbopol triethanolamine, pH 8-8.5), works rather well on surface grime. Remarkable results are obtained when 5% (or less) benzyl alcohol are added to the gel. The benzyl alcohol functions as a co-solvent, in the solubility context, discussed above, and as a low HLB detergent, increasing the detergency of the Maypon.](http://cool.conservation-us.org/waac/wn/wn08/wn08-2/wn08-204.html#emulsion)

[**For highly oxidized surface grime (very old residue from cigarette smoke, I believe) that was not entirely or evenly removed by "spit" cleaning, I found 4% triethanolamine deoxycholate soap, gelled with Carbopol-TEA, pH 8-8.5, to be remarkably effective.**](http://cool.conservation-us.org/waac/wn/wn08/wn08-2/wn08-204.html#emulsion)

[**NOTE:**](http://cool.conservation-us.org/waac/wn/wn08/wn08-2/wn08-204.html#emulsion)

[Many of the materials discussed pose safety and health hazards to the conservator! It is the responsibility of each conservator to familiarize themselves with any special handling procedures necessary with these materials. Consult](http://cool.conservation-us.org/waac/wn/wn08/wn08-2/wn08-204.html#emulsion)[Material Safety Data Sheets](http://cool.conservation-us.org/bytopic/health/index.html#msds), and read any and all cautions.

**SUPPLIES:**

Triethanolamine Abietate (S-85): Chem Service; P.O. Box 3108; West Chester, PA 19381-3108; (215) 692-3026.

Deoxycholic Acid, Free acid (D-2510); hydroxypropylmethyl cellulose, 4000 centipoise at 2% (H-7509); Lipase, type VII, from Candida Cylindracae (L-1754); Protease, type XXIII, from Aspergillus Oryzae (P-4032)[recommended by Bob Futernick, FAMSF]; Trizma buffer, at 0.05M pH 8.4 (T-5253). Sigma Chemical Company; P.O. Box 14508; St. Louis, MO 63178; (800) 325- 3010.

Carbopol 934, (Carbopol Water Soluble Resins formulating guide, 36pp): BF Goodrich Company; Specialty Polymers & Chemicals Division; 6100 Oak Tree Blvd; Cleveland, OH 44131; (800) 331- 1144. Tri Ess Sciences, Inc.; 1020 W. Chestnut St.; Burbank, CA 91506; (213) 245-7685.

Ethomeen C-25: Armak; Industrial Chemical Division; New Providence, NJ 07974; (201) 665- 2500.

Maypon 4C: Inolex Chemical Co.; Jackson & Swanson Streets; Philadelphia, PA 19148-3487; (215) 271-0800.

Triton X-100, everything else, and much much more: Conservation Materials, Ltd.; 1165 Marietta Way; P.O. Box 2884; Sparks, NV 89431; (702) 331-0582.

*Chris Stavroudis, Private Paintings Conservator*

**DISCLAIMER:**

These formulae are presented to provide an exchange of information between conservators. The authors, sources, and/or WAAC cannot be responsible for any undesirable outcome experienced by another practitioner. Further, it is not intended for any person who is not a trained conservator to use these formulae on works of art.

Authors' postscript, 1993:
Since publication, some of the formulas and techniques (particularly with regard to solvent gels) have been improved upon.

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