Solvents for the Wood Workshop

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You may recall Viv Martin's presentation at the WWA clubhouse last year, where he showed off some products such as the White Spirit that Hardware Centre sell. This prompted me to write this article on solvents. As anybody who has study organic chemistry will know, there is a very large number out there, but only a few that woodworkers will commonly use. There are important differences between them which are useful to understand.

Wikipedia defines a **solvent** as a liquid that dissolves a solid, liquid, or gaseous solute, resulting in a solution. The most common solvent in everyday life is water. Most other commonly-used solvents are organic (carbon-containing) chemicals. These are called organic solvents.

To understand the ability of solvents to dissolve substances, it is useful to understand a little about them. Broadly speaking there are **polar** and **non-polar** solvents. This is useful to know because polar solvents dissolve polar substances better, and non-polar solvents dissolve non-polar substances better. Polar solvents are liquids whose molecules have an unbalanced dielectric charge so that one side is more negative than the other. Examples of polar solvents are water, ethanol, acetic acid and acetone. Polar substances such as salt and sugar dissolve only in very polar substances like water.

Non-polar solvents such as turpentine and hexane dissolve oils and waxes which are also non-polar. Oils and waxes are immune to water, because it is a polar solvent. You can see an example of this in salad dressing, where the oil and water quickly separate.

Solvents have varying properties and dissolve substances to varying degrees, and it is important to be aware of this. A good example of this the sticky label problem. When you buy something and wish to remove the sticky label, you have to be careful not to damage the item. Using an aggressive solvent is a quick way to ruin many items. Obviously one should try the least aggressive solvent first, which is water, but most glues are immune to this. You could try alcohol, white spirit, citrus oil or turpentine, failing which perhaps lacquer thinners or benzene can be tried. Lastly something like acetone which is a very aggressive, volatile solvent, can be tried, all the while being careful not harm the item or yourself.

If you are unsure of the properties of a solvent, it is wise to do a little research. The key documents are the Material Safety Datasheets. The manufacturers are obliged, by law, to make these available. Some try claim that the formulations are trade secrets, but this is spurious, as it is very easy for a competent chemist to discover the exact composition using modern analytical techniques. The MSDs contain information on the chemical properties and the hazards such as toxicity and flammability, which you should heed. It is a good practise that MSDs are made available in the workplace.

Other than water, all the solvents discussed below are organic, meaning that they contain carbon, together with other elements such as hydrogen, oxygen, and sometimes chlorine. It is remarkable that all these compounds contain carbon, hydrogen, sometimes oxygen and chlorine, and they have such different properties. The size and arrangement of the atoms in the molecules determine the properties. Even compounds with the same chemical formula can have different properties because the atoms are arranged differently. These are called isomers. Isomers are compounds that have same chemical formula, but different spatial structures – molecular arrangements. There is a very wide variety of organic molecules, with widely varying properties, so I am just touching the surface here.

Safety – The only solvent that I can think of that is completely safe in the workshop situation is water. All the others have risks associated with them, such as toxicity, which I have tried to document below. Some are relatively safe, but almost all are flammable, so fire is a risk, particularly with storage. It is hard to think of a more flammable mixture than wood shavings and some of the solvents below. If these should catch fire, you probably have no chance of putting out the fire. Some of the containers that solvents are sold in are not safe. If you look at some of these on the shelf in the shop, you will see that some are no longer full, and you can only wonder what happened to the missing part. It is a wonder that more shops don't burn down! A welcome exception to this is Plascon who sell their products in robust, reusable bottles with child-proof tops. Well done Plascon!

Here is a list of some the solvents you are likely to encounter in your workshop and their properties:

Water
This is a well-known chemical compound that is harmless in its pure form, which is just as well as we consist mostly of water. It freezes at 0°C and boils 100°C at sea-level. It expands when it freezes, which is a good thing, otherwise the oceans would all be filled with ice. It has some interesting chemical and physical properties, which are not yet fully understood. However, here we need only record that it is a strong polar solvent, capable of dissolving most salts and numerous other substances to varying degrees. All wood contains water some degree, as do most natural substances. In the workshop water can be used to raise the grain of wood, prior to finishing, as well as solvent for some types of dyes and water-based finishes. PVA paints use water as a carrier.

Methylated spirits

Methylated spirits (Meths) is is also called denatured alcohol. It is sold as such, to prevent human consumption. Meths is a combination of methyl (CH_3OH) and ethyl (C_2H_5OH) alcohols, with at least 10% methanol. Purple dye may be added to make the mixture unpalatable, to discourage consumption. These are weakly polar solvents that have the interesting property of being able to dissolve both polar and non-polar compounds to some degree. Water and alcohol mix uniformly (they are miscible) because they are both polar. Meths dissolves and mixes with a large number of liquids, which makes it a versatile solvent for both polar (salts) and non-polar substances, such as oils.
Ethanol freezes at -114°C and boils at 78°C. It is highly flammable (flash point 13°C) and moderately toxic, so when absorbed in small quantities, it is not harmful.
Methanol freezes around -97°C and boils at 65°C. The flash point is 11°C, so it is highly flammable, but relatively easy to extinguish. However it burns with a dim blue flame, that may not be immediately apparent in bright light. It is has similar intoxicating properties to ethanol, however, it is much more dangerous when metabolized by the body, leading to liver damage and blindness. It is absorbed through the skin, so should be used with caution, particular for exposure at occupational levels. Do not use in confined spaces to avoid inhaling the vapor.

Meths is commonly used as a solvent for shellac for finishing. Sometimes the purple aniline dye can be apparent, but this colour can removed by the addition of a small amount of caustic soda. However this should be done with caution, as the solution becomes strongly basic and can attack some types of plastics, such as the cheap bottles that meths is sold in, leading to a leak and a potential fire hazard (don't ask me how I know this). I don't know what effect it may have on shellac.

Isopropyl alcohol
Also called rubbing alcohol, it is commonly used for cleaning, as a solvent and disinfectant. (C_3H_7OH) Applications are in sterilizing pads, windscreen de-icing mixtures and cleaners such for vinyl records and printed circuit boards, which is why you may find it in your workshop. It freezes at -89°C and boils at 82°C. It is highly flammable, but only moderately toxic – about twice the toxicity of ethyl alcohol, so it is relatively safe. It is not an aggressive solvent so it is widely used for cleaning.

Turpentine
Genuine turpentine is obtained from the distillation of resin from trees, mainly pine. It was originally used as a solvent for thinning oil based paints, but now is replaced by mineral turpentine. It is expensive and only used in specialist applications, such as for oil paints for fine art. It freezes at about -50°C and boils around 150°C to 170°C. Flash point is 35°C, so it is highly flammable. It is poisonous, so should be treated with care. It was once used as a treatment for lice, but it can burn the skin, as well as damage the lungs and central nervous system, so fortunately there are better remedies available these days.

Mineral turpentine

Mineral turpentine is used as an inexpensive petroleum-based replacement for the vegetable-based turpentine described above. It is commonly used as a paint thinner for thinning oil-based paint and cleaning brushes. It consists of a mixture of highly refined hydrocarbon distillates mainly in the C_9-C_{16} range, the composition of which will vary according to the manufacturer. To closely control the properties, the composition is more closely controlled, to remove objectionable smells for example. The volatility varies with the composition, but in my experience, it evaporates only slowly. It is a mild solvent and will safely remove some sticky labels without damaging most plastics. Due to the variability in composition, it is wise to treat the fumes as potentially dangerous. The vapours are

flammable. You can see an example of the better quality bottle used by Plascon for their products on the right.

White spirit, also known as Stoddard solvent or mineral spirits, is a paraffin-derived clear, transparent liquid which is a common organic solvent used in painting and decorating. In 1924, an Atlanta dry cleaner named W. J. Stoddard worked with Lloyd E. Jackson of the Mellon Research Institute to develop specifications for a less volatile dry cleaning solvent as an alternative to more volatile petroleum solvents. Dry cleaners began using it in 1928 and it was the predominant dry cleaning solvent in the United States from the late 1920s until the late 1950s.

It is a mixture of saturated aliphatic and alicyclic C_7 to C_{12} hydrocarbons with a maximum content of 25% of C_7 to C_{12} alkyl aromatic hydrocarbons.

White spirit is used as an extraction solvent, as a cleaning solvent, as a degreasing solvent and as a solvent in aerosols, paints, wood preservatives, lacquers, varnishes, and asphalt products. White spirit is the most widely used solvent in the paint industry. In households, white spirit is commonly used to clean paint brushes used for oil paints and varnishes. Its paint thinning properties enable brushes to be properly cleaned (by preventing the paint from hardening and ruining the bristles) and therefore enabling them to be re-used. It is available from Hardware Centre.

In industry, three different types and three different grades of white spirit exist. The type refers to whether the solvent has been subjected to hydro-desulphurization (removal of sulphur) alone (type 1), solvent extraction (type 2) or hydrogenation (type 3). Each type comprises three different grades: low flash grade, regular grade, and high flash grade. The grade is determined by the crude oil used as the starting material and the conditions of distillation. More expensive varieties are sulphur-free to eliminate chemical interactions that can cause colour changes in pigments, which are not desirable.

Benzene
Benzene, or Benzol is an organic chemical compound with the formula C_6H_6. Benzene is a colourless and highly flammable liquid with a sweet smell. It is an important industrial solvent and used in the production of drugs, plastics, synthetic rubber, and dyes. Benzene is found naturally in crude oil, and can be synthesized from other compounds present in crude. It freezes at 5°C and boils at 80°C. It is a known carcinogen, is toxic for short term exposure, and can cause long term chronic health problems at lower exposure levels. Exposure is best avoided. Because of this, its use as an additive in petrol is now limited.

Benzine is a mixture of hydrocarbons in the range of C_7 to C_{11} and comes in a variety of grades depending on the intended uses. It contains significant amounts of paraffin, so it behaves similarly. It freezes around -73°C and boils from 20°C to 75°C depending on the composition. It is a non-polar solvent and is highly flammable. Depending on the exact composition, the toxicity will vary. It is not normally used in a workshop. It is sometimes sold as a proprietary fuel for camping stoves.

Lacquer Thinners
These are used to thin spraying lacquers, such as cellulose nitrate used in sanding sealer and some older automotive lacquers. The composition varies by manufacturer depending on the desired properties. For example:
Toluene: 40 to 70%, Methanol: 15 to 40%, Methyl Ethyl Ketone: 7 to 13%, Butyl Acetate Normal: 3 to 7%.
Sasol make one called Thinsol, with the following composition:
n-Propanol: 26%, Toluene: 19 to 26%, Acetone: 17%, Xylenes: 7 to 12 %, Glycol Ether: 6%, Ethyl Methyl benzene: 1 to 4% and Butan-2-ol: 3%.

Other ingredients may include Acetone, Naphtha, Cyclohexane, Heptane, Xylene, Propanol, and Methyl Cyclohexane. The ingredients will vary according to the exact application, depending on the lacquer composition, and the type of application – the aim is to control the speed of drying, flow characteristics, initial flash-off, etc. of the lacquer.

All of these constituents are poisonous, through skin contact, ingestion and inhalation – Material Safety Data Sheets rate toxicity as low to medium depending on the composition. Lacquer Thinners can be carcinogenic, depending on the composition. They are highly flammable and fast evaporating by design for spray applications. Typically they freeze around 0°C and boil at about 65 to 82 °C. Due to the methanol, it is a mixed polar and non-polar solvent, so it is partly soluble in water. It is a fairly aggressive solvent – it will

dissolve some rubbers and plastics. You should use it only in a well ventilated area, such as outdoors, or with an appropriately rated respirator cartridge if spaying indoors. When used for spraying, do not assume that different brands will have the same properties, as they may be formulated differently to suit the particular paint application. Cheaper brands may even vary between batches due to quality problems or availability of feed stocks.

Citrus Oil

Citrus oil is extracted from the skin of citrus fruit by pressing or steam distillation. It is composed of 95% d-limonene. D-limonene is the substance that gives citrus fruit its characteristic fragrance. It has the chemical formula $C_{10}H_{16}$, freezes at -95°C and boils at 176°C. It is flammable. Limonenes have a variety of isomers that have different properties, such as different scents. One isomer (d-limonene) has an orange-like scent, and another (l-limonene) a piney scent.

It is a relatively stable non-polar solvent. As a solvent it can be used for cleaning, and can be used on some delicate surfaces, such as removing sticky labels. However, it will dissolve some plastics, such as polystyrene, ABS and urethane. It is also reputed to remove CA glue which may be useful where damage to the underlying surface (skin?) is to be avoided. Citrus oil finds application in paint strippers, so it should be used with caution, particularly when working with antiques - always test it on a patch of finish that is not visible before taking the plunge and using it on the whole piece. Citrus oil is a mild irritant and some people may become sensitized to it, albeit over time, probably at levels of occupational exposure. It is widely used in cosmetic products, so it is relatively safe for humans. It is used an insecticide and a mosquito repellent which is probably why it is present in the skins of citrus fruit. Like most solvents, it will remove the protective oils from the skin, so the appropriate gloves should be worn.

Acetone

Acetone (CH_3COCH_3) is a colourless, mobile, flammable liquid. It is the simplest example of a ketone. Acetone is miscible with water, ethanol, ether, etc. because it is a medium polar solvent. It can dissolve most plastics including CA glue, so it should be used with caution, as it will attack nearly all finishes and synthetic fibres. It is usually stored in glass bottles. It is the active ingredient in some nail polish removers. Acetone is also used to make plastic, fibres, drugs, and other chemicals. It is also found naturally in the environment, including in small amounts in the human body. It freezes at -95°C and boils at 53°C. It evaporates very rapidly, is highly flammable, and burns with an almost invisible flame. Acetone is not highly poisonous, but can cause liver damage in large quantities. Eye contact can lead to permanent eye damage.

Carbon Tetrachloride

Carbon tetrachloride (formula CCl_4) was once used for dry cleaning, as a weak solvent with well known properties. Fast evaporation and no residues make it a good choice for cleaning clothes. It may affect some plastics and fabrics and dyes. It freezes at -23C and boils at 77C. It is a non-polar solvent, well suited to dissolving fats and oils, which is why it was used in dry cleaning and stain removal. It was also used as a refrigerant and in fire-extinguishers, but due to high toxicity levels, it has been banned in consumer products since the 1970's. It is a dangerous liver and kidney toxin and a known carcinogen. It is not flammable at low temperatures, but at high temperatures, it can react to form phosgene which was used as a poisonous gas in World War 1. It is ozone depleting and a greenhouse gas, so its use is discouraged for these reasons as well.

Toluene

Widely used as a solvent, such as in Lacquer Thinners. The chemical formula is C_7H_8. It freezes at -93°C and boils at 110°C. It is related to benzene and has a similar characteristic paint thinners smell. It occurs naturally in crude oil and some gums and resins, but is usually synthesized in the oil refining process from a variety of feed-stocks. It has been used as an octane booster in petrol and was the main constituent of fuel for Formula 1 cars during the turbo era in the 80's due to its high energy density and good anti-knock properties. Its low freezing point meant that it was cooled close to its freezing point before being poured into Formula 1 car fuel tanks, taking up less space, allowing more fuel to be carried and further improving the anti-knock properties. It is volatile and highly inflammable. It is moderately toxic, however because it is not soluble in water it must be metabolized to be eliminated from the body and some the products of metabolism are also toxic.

Methyl Ethyl Ketone

Methyl ethyl ketone (MEK) also called Butanone is a colorless liquid with a sharp, sweet butterscotch odor reminiscent of acetone. It is widely used in paints and as a carrier for various resins. The chemical formula is C_4H_8O. It is a polar solvent that will dissolve many substances and will quickly evaporate. It occurs naturally,

being produced in small quantities by trees, fruit and vegetables. It freezes at -86C and boils at 80C. It is highly flammable, but only slightly toxic. It is not considered dangerous, except in large doses.

Petrol

Petrol is commonly used as a solvent for motor car repairs, because it is readily available. However, it is not a good choice, due to health and safety issues. Petrol is a blend of many of the above hydrocarbons which varies according to the origins of the feed stocks used to produce it and the intended usage. Petrol typically contains: Benzene: up to 5%; Toluene: up to 35%; Naphthalene: up to 1%; Trimethylbenzene: up to 7%, MTBE: up to 18% and about 10 other ingredients. Many of these have been discussed previously, so you can see what the properties of these are. Petrol is highly toxic in both liquid and vapour forms. Many of the compounds are known carcinogens. It is highly volatile, and highly flammable, with low ignition temperatures, and high energy yields. These properties make it a good fuel, but not a good solvent for use in the workshop. The energy density of fuels such as petrol is very high, which is desirable for motor vehicles. The power delivered into your fuel tank while you refuel your car is equivalent to 8MW, which is very high, when compared to your household electricity supply of 60A at 230V = 14 kW at maximum.

In addition, petrol contains a dye for identification, and some blends contain anti-knock additives which are also harmful. In the past petrol contained a lead compound called Tetra-ethyl lead to improve the octane number, to make it more suitable for use in high performance engines. TEL was banned in South Africa in 2006, and an alternative called MMT was introduced for lead replacement petrol. MMT is also controversial as it contains manganese which is also poisonous, but it is not as bad as lead. In South Africa and elsewhere, ethanol is also added to petrol, which has the effect of improving the octane number and reducing some pollution due to better combustion. Ethanol can introduce additional problems due to being miscible with water, which can cause corrosion problems. The freezing and boiling points of petrol are carefully controlled depending on the target market and time of year. In cold countries and in winter, higher volatility components are used to improve combustion at low temperatures. Conversely in warm climates and in summer, low volatility components are increased to reduce evaporation and the possibility of vapour locks in fuel lines.

Paraffin

Paraffin, commonly called Kerosene outside of Britain and South Africa, is a hydrocarbon liquid with compositions of $C_{12}H_{26}$ to $C_{15}H_{32}$. It has a boiling point of between 150°C and 275°C. It is a non-polar molecule that is mostly un-reactive – for example it can be used to safely store reactive compounds such as white phosphorus, which is immersed in paraffin to prevent contact with atmospheric oxygen. It does burn and is widely used as a fuel, such as jet fuel, usually called Jet A1. It can be used as a solvent and as a lubricant, such as for thread tapping and metal cutting. It is poisonous if ingested, and is particularly dangerous if it gets into the lungs. However, in normal use, it is safe. Avoid skin contact, as you would with any mineral oil. There is a form called liquid paraffin that has medicinal uses, being swallowed to alleviate constipation. It can also be used as a finish for wooden items intended for contact with food, such as salad bowls.