Materials Compatibility

http://www.coleparmer.com/techinfo/ChemComp.asp
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Where do I get this stuff?
http://www.mcmaster.com/#

Principle #1: Nothing is inert to everything. Choose Materials Appropriate to the task at hand.

General types of materials found in a lab:

Glass

Soda-lime glass

Most storage and container bottles, including vials, are made of soda-lime glass. These are readily attacked by concentrated hydroxide solutions. Due to the high coefficient of thermal expansion, molded glass objects of soda-lime glass shatter easily on heating.

Borosilicate (Pyrex, Kimax, etc)

The addition of borax to soda-lime glass makes it much more chemical resistant and relatively insensitive to thermal shattering. Most lab glassware is made of it. Popular trade names are Pyrex, Kimax, QVF, among others. Hot concentrated hydroxide solutions attack it, but it is resistant to all known acids, except hydrofluoric acid. Avoid acidic fluoride solutions in glass, as it will etch or completely dissolve away the glass. A fluoride reaction in a roundbottom flask will leave it thin as paper. *Always use teflon sleeves with standard taper glassware when working with hydroxide solutions; it will permanently glue together all the wetted joints if not separated by teflon.* Never heat crystallizing dishes, even of borosilicate glass, as the right angle of the wall with the bottom cannot tolerate even the small amount of differential expansion.

Specialty (Uranium glass, cobalt glass, ruby glass (gold))

Special glasses are typically used for their light –filtering properties. Red-glass volumetric flasks are used for light-sensitive solutions. Cobalt glass is used for flametests for potassium. Uranium glass is used as a restrictive filter for UV lights to provide a narrow range in wavelengths. It is also used in graded seals to transition from one glass type to another. The last known batches of uranium glass were made over forty years ago, and the tubing made of it is all hand-made. It is rare and valuable, and easily identified by its distinctive opalescent yellow color. All the specialty glasses should be treated like soda-lime glass, except that objects of colored glass are of substantially higher value. Gold chloride is used to make ruby-glass (sometimes known as cranberry glass.)

Vycor/Fused Quartz

Fused quartz is pure silica. It has a zero coefficient of thermal expansion and a very high softening temperature. It is also transparent to UV light, unlike all the other glasses. This makes it ideal for UV cuvettes and photolysis apparatus, and high temperature work. Just like the other glasses, it is attacked by HF and strong alkali. Items of fused quartz can only be fabricated with a hydrogen/oxygen torch by specialist glassblowers, thus it is very expensive.

Metals and alloys

Various steels

There are thousands of types of steel, each designed for particular purposes, mostly mechanical. They vary in alloying metals and their ratio, as well as types of heat treatment. They all are corroded by acidic solutions, or even water, which catalyze the oxidation process. Objects such as ring stands can be protected by applying a layer of hot beeswax or motor oil wiped on with a rag. Most steels must be protected either by a layer of paint (outside) or constant coating with oil (inside).

304/316 Stainless Steel

Of the hundreds of types of stainless steels, the two most common to be found in a lab are alloys 304 and 316. These are actually nearly identical, except 316 has a small amount of molybdenum, which imparts substantially better chemical resistance. They can't be told apart by looking at them. *Stainless only means that the passivated metal does not rust, not that it is otherwise chemically inert*. Stainless steels are attacked by acids, especially mineral acids such as hydrochloric acid, hydrobromic acid, hydriotic acid, sulfuric acid, and nitric acid. Stainless steels are resistant to most organic compounds and bases, and can be heated without harm. Beakers of stainless steel are useful for recrystallizations where the resultant crystals must be chipped out. Use stainless steel dishes for oil baths rather than glass.

Hastalloy B/Hastalloy C

Hastalloy is a trademarked name for a family of twenty-two highly corrosion resistant alloys based upon Nickel. The two most common in the lab are Hastalloy B and

Hastalloy C. These are most frequently encountered as materials of construction of pressure autoclaves and valve fittings, to be used instead of the stainless steels where mineral acids are encountered. Hastelloy B-2 is a nickel-based alloy with excellent corrosion resistance to hydrochloric, sulfuric, acetic and phosphoric acids. It also withstands attack by hydrogen chloride and has excellent resistance to pitting, stress corrosion cracking, knife-line and heat affecting zone attacks. *It is not recommended for use in the presence of ferric or cupric salts as they may cause rapid corrosion failure of components.*

An alloy composed of nickel, molybdenum, chromium and iron, Hastelloy™ Alloy-C maintains its outstanding properties in extreme heat, holding its strength and resisting oxidation. The alloy also resists chlorine and compounds with chlorine, as well as strong oxidizing acids, acid mixes and salts. One of the most corrosion-resistant alloys, it's exceptional in high-stress applications and in environments prone to repeated thermal shock.

Aluminum & alloys

Although things are described as being of aluminum, it is almost never used in an unalloyed state. There are hundreds of alloys of aluminum depending upon the hardness, machinability, or corrosion resistance required. The most common alloy of aluminum found in the lab (in the form of monkeybars) is 6061, which contains small amounts of magnesium and silicon. Although alloy 6061 is among the most chemically resistant of the aluminum alloys, it is still readily attacked by acid or acid vapors, as well as hydroxide. So to protect your monkeybars (not to mention the ducting!) make sure you scrub any HCl evolved from your reactions. Aluminum monkey bars are best cleaned with a brillopad and soapy water, and best protected by a coat of hot beeswax. The same is true for other aluminum fittings in the lab.

Spin-cast zinc-aluminum alloy

Nearly all of the modern clamps found in the lab are now fabricated with zinc-aluminum spin-casting alloy. This is because the low-melting alloy can be cast into re-usable silicone molds, a substantial cost savings over sand-casting. There is a price to pay for this. The alloy loses half its strength every seven years. So if you have a clamp bought in 1996, it has one quarter of the strength of when it was made. Remember that when you reach for an old clamp to support your precious work. The alloy also loses most of its strength immediately if heated to half its melting point, then cooled. So any clamps that were involved with a fire should be discarded. Brass clamps are the best you can get but are hard to find, while cast iron ones are brittle and will break at extremely inconvenient moments. Do not use old cast-iron clamps. Use them as curios and paperweights or throw them at cats howling in the night.

Brass

Besides the rare use as the Cadillac of clamps, brass is used for the myriad of fittings and valves found in a lab. It is attacked by mineral acids. The best use for brass is for water/aqueous fittings with tubing, as well as for non-corrosive gasses. Do not use with HCl gas, chlorine gas, or ammonia.

Copper

Copper is most frequently found in the lab as electrical contacts (such as in electrical plugs) and in water pipe. Both are readily attacked by HCl released into the air, even passively from dilute HCl squirt bottles. Corroded terminals do not make proper electrical contact, and may overheat due to increased resistance. Copper is generally too reactive to be used in most wetted surface chemistry. For instance, it will displace silver from silver nitrate solutions, dissolving in the process.

Mercury

Once common in the laboratory, mercury has been systematically reduced in its use due to its toxicity if improperly handled. Electronic thermocoupled thermometers now replace mercury thermometers. Mercury diffusion vacuum pumps have been replaced by turbopumps. The one remaining use for metallic mercury is in the McLeod vacuum gauge. The McLeod gauge should be protected by an independent dry-ice cooled trap which served the second purpose of trapping any released mercury vapors. Mcleod vacuum gauges are more reliable than electronic vacuum gauges, as the latter are severely compromised by any kind of contamination, as is frequently found in distillations. Mercury is very reactive with all the mineral acids, especially nitric. It will off-gas toxic nitric oxide as it dissolves. While the metal is only marginally a health threat (except by breathing!), the salts are remarkably toxic. No salt of mercury or any mercury waste should ever be disposed of down a drain. Mercury will dissolve other metals, and will completely destroy a gold ring. It should never, ever be heated in the open. Store it only in glass or plastic containers, well sealed.

Mercury still has an indispensible use for catalysis in photo/radical reactions. It is also present in every fluorescent tube, including the new high-intensity replacements for incandescent bulbs.

Plastics (Thermosetting and thermoplastic)

Bakelite

One of the oldest plastics (Look it up!), and it is still around in the form of black bottle caps and molded components. It is somewhat brittle, but resistant to most solvents. It is attacked by strong acids. Aggressive reagents such as thionyl chloride and phosphorous oxychloride will diffuse through liners and destroy bakelite caps.

Polystyrene

Polystyrene is the plastic found in those models of ships and airplanes. Although often gray, it can be any color, including clear and colorless. It is the most common plastic of injection molding, and unfortunately it is ubiquitous throughout the lab. The airplane model parts were fused together with glue made of thickened toluene. In the lab, polystyrene is melted and damaged by nearly every solvent. The displays of electronic balances and computers are made of polystyrene, so they are seriously damaged by splashes of solvent. (What were they thinking?) Protect them with sheets of clear polyester taped on with acrylic packing tape. Polystyrene is also easily melted. Keep any parts made of it away from heat.

Acrylic

Treat this the same as for polystyrene. It is a very vulnerable plastic in the lab. Some fittings, tubing, and other parts in common use are of acrylic. Unless they are for aqueous use, avoid them

Polyethylene

Polyethylene is poor man's teflon. It is fairly flexible and is extensively used in tubing and the fabrication of other laboratory ware. Nalgene is a brand name of a line of polyethylene products. Polyethylene is tough, fairly shock resistant, and generally quite chemically resistant. It softens around 70 °C, so it should not be used for heating or hot solutions. Specially molded forms such as solvent cans are resistant to most solvents. However, some equipment such as large Büchner funnels are made up of shaped and welded thick polyethylene sheets. These are very vulnerable to differential expansion as they absorb certain kinds of solvents. A large crack will result, ruining the equipment. Particularly bad are hexanes, heptanes, cyclohexane, and to some extant, toluene and xylene and methylene chloride. The welded plastic is resistant to water, the alcohols, the lower ketones, and even ethyl acetate.

Polyethylene tubing can be used for transfer of gasses, even corrosive ones. It works well as vacuum tubing, providing there is adequate wall thickness. One hundred feet of ¼" id tubing can be bought for $21, while only 8 feet of gum rubber vacuum tubing of the same id costs nearly $90. Polyethylene tubing holds modest pressure well, and it is used extensively to transfer chemicals and solutions, even drain reactors in industry. It is easily identified by its waxy feel and easy flexibility. It can be warmed with a heat gun to put on hose nipples, or it can be connected with a compression fitting.

Polypropylene

Polypropylene has much of the same chemical resistance properties as polyethylene. It softens at 80-85° C, giving it an ability to operate at warmer temperatures. It is much stiffer than polyethylene, so tubing made of it can stand greater pressure than polyethylene. Its stiffness makes it inconvenient to use it like a hose, so it is better used for more permanent installations, like gas lines. Warming with a heat gun temporariy softens the tubing, allowing it to be formed, straightened, or bent as needed. It also aids in putting it on a hose nipple. Just like for polyethylene, items made of welded polyethylene must not be exposed to hydrocarbons, or it will crack. Hose connections are best with a compression fitting or a short length of transitional rubber vacuum hose, where permissible.

Polyvinyl chloride

PVC is another ubiquitous plastic that comes in both soft forms (usually tubing) and hard forms (frequently pipe). The soft form is popularly known as "Tygon®" tubing. It is resistant to aqueous solutions and various gasses, even corrosive ones like HCl and chlorine. However, it should never be exposed to organic solvent, as that will extract the plasticizer. The result will be hard tubing and plasticizer in your solution. Many beginning chemists who put a piece of Tygon tubing on the end of a chromatography column find this out the hard way. Heavier-walled pvc tubing may be used for vacuum.

There are some simple tricks to putting tygon tubing on glass hose barbs. First, wet the glass with soapy water. Then warm the tubing gently on the end to soften it. It will remain soft just long enough to push it on deeply. Overheating is bad. When it cools and hardens, you may not even need a hose clamp. To eventually remove it, cut it lengthwise with a razor or knife. Remove the tubing, then cut off the flayed end. Where connections are often made, then unmade, it is best to use quick-disconnects. The best choices are the ones that contain a shut-off valve so that the condenser doesn't spill out its load when disconnecting.

Hard PVC is used for water drains, and it is fairly resistant to acids and bases, but is attacked by continual exposure to solvents or solvent vapors. The result is wiggly tubing that will collapse on itself. It is frequently a material of construction for scrubbers.

Polyurethane

In the laboratory, polyurethane has limited uses, as it may not be continually exposed to water. Polyurethane is most frequently used for fuel tubing. Even so, it is a very tough material, and well-suited for vacuum tubing. As it is considerably more expensive than PVC, it is not your first choice.

Family of perfluoropolymers "Teflon®", FEP, etc

The good news about teflon is that it is resistant to just about everything except hot molten alkaliai hydroxide. Although it is a heat-formable polymer, it can be used up to 300 °C, which makes it ideal for stirrers and stirring paddles. Aside from its cost, its downside is that it is soft as butter and easily damaged. This is particularly a problem when sep funnels with teflon stopcocks are charged with solids like bicarbonate; the gritty solids carve a groove in the teflon when they are turned, and they leak forever afterward. Therefore, never put solids in sep funnels with teflon stopcocks. That said, teflon does away with the need for greased glass stoppers, and where possible, teflon stoppered equipment should be favored. The grease invariably gets wicked into the organic phase and appears as a contaminant.

Teflon has a very high coefficient of thermal expansion, and teflon stoppers will often get stuck on flasks when used with heat. The most effective way to remove a stuck teflon stopper is to put it in a dry ice chest. No matter how stuck it was, after a few minutes it will fall out.

Teflon also sees extensive use as tubing, though often unnecessarily so, as polyethylene is nearly two magnitudes cheaper and works nearly as well. Where teflon comes into its own is where tubing must introduce a gas or liquid to where it is hot, such as a reaction flask with solvent at reflux. It is much more mechanically stable when warm than polyethylene or polypropylene. Teflon tubing can be used with virtually any gas or liquid, short of molten alkali or hot metallic sodium in liquid ammonia. With the latter merely at reflux, the teflon will only stain black.

Teflon® comes in a variety of compositions, most typically PTFE (polytetrafluoroethylene), PFA (perfluoroalkoxy), and FEP (fluorinated ethylene-propylene); these differ in transparency, hardness, permeability and bend-ability. A detailed comparison can be found on Wikipedia. The teflons have a distinctive feel and look that differentiates them from all the other plastics. Given the very high cost of these materials, they should be clearly labelled so they are not wasted on lesser uses. Use teflon where a ruptured piece of tubing would be catastrophic.

Polyester

Polyester has come a long way since the 1960's. It is now a material fairly resistant to most solvents as well as acids and alkalies. Sheets of clear polyester can be used to fabricate covers for instruments. Lab coats and clothing worn in the lab should have a high polyester content, as this will make them resistant to the many holes that are otherwise won with bluejeans and other cotton garments. Polyester is not suited for continuous exposure to solvents and reagents, as it will eventually be attacked; however, it is excellent in acute protection.

Rubber, Natural & Synthetic

There is such a large matrix of compatabilities/incompatabilities among the natural and synthetic rubbers (such as neoprene, Viton, Santoprene, etc, that one should use the charts provided at the top. In general, none of the rubbers can be used with corrosive materials, especially acids and acid-forming. They are all vulnerable to various solvents.

Nylon

Nylon is used for a wide variety of molded and machined parts. It has a characteristic feel. It is typically black or "blond" (i.e. not colored) or sometimes colored. Keck clips are made of nylon. A thermoplastic, excessive heat will melt and destroy the piece, so items made of nylon should be protected from heat. Although fairly resistant to alkali, nylon is readily attacked by acids and acid vapors, so don't use nylon fittings on gas hoses using acid gasses or expose it to other reagents like thionyl chloride. Nylon is fairly resistant to most solvents for acute exposure, but chronic exposure will eventually do damage.

Chemraz/Kalrez

Sometimes you need an O-ring that just cannot fail, like in the valve on the bottom of a chemical reactor. Such O-rings still need to be elastic to function. Enter Kal-rez, an extremely difficult-to-make perfluoropolymer. Kal-rez looks like any ordinary O-ring in that it is black, but it is resistant to just about anything you can expose it to, short of molten sodium hydroxide. A small Kal-rez O-ring that will fit on the tip of your finger can cost $45 each, whereas one can buy 100 neoprene O-rings of the same size for about five dollars. If you have a piece of equipment that has a Kal-rez O-ring, LABEL it, so some idiot doesn't replace it with a cheap O-ring with disastrous results. Available from ACE Glass is Chemraz, a white version which helps identify the nature of the O-ring.