A polymer blend or polymer mixture is a member of a class of materials analogous to metal alloys, in which at least two polymers are blended together to create a new material with different physical properties.

During the 1940s, '50s and '60s, the commercial development of the new monomers for production of the new polymers seemed endless. In this period, it was discovered that the development of the new techniques for the modification of the already existing polymers, would be economically viable.

The first technique of modification developed was the polymerization, in other words, the joint polymerization of more than one kind of polymer.

A new polymers modification process, based on a simple mechanical mixture of two polymers first appeared when Thomas Hancock got one mixture of natural rubber with Gutta-percha. This process generated a new polymer class called Polymer Blends.

Basic concepts

Polymer blends can be broadly divided into three categories:

- Immiscible polymer blends (heterogeneous polymer blends): This is by far the most populous group. If the blend is made of two polymers, two glass transition temperatures will be observed.
- Compatible polymer blends: Immiscible polymer blend that exhibits macroscopically uniform physical properties. The macroscopically uniform properties are usually caused by sufficiently strong interactions between the component polymers.
- Miscible polymer blends (homogeneous polymer blend): Polymer blend that is a single-phase structure. In this case, one glass transition temperature will be observed.

The use of the term polymer alloy for a polymer blend is discouraged, as the former term includes multiphase copolymers but excludes incompatible polymer blends.

Examples of miscible polymer blends:

- Homopolymer - Homopolymer:
  - Polyphenylene oxide (PPO) - polystyrene (PS): Noryl developed by General Electric Plastics in 1966. The miscibility of the two polymers in Noryl is caused by the presence of an aromatic ring in the repeat units of both chains;
  - Polyethylene terephthalate (PET) - Polybutylene terephthalate (PBT);
  - Poly(methyl methacrylate) (PMMA) - Polyvinylidene fluoride (PVDF);
- Homopolymer - Copolymer:
  - Polypropylene (PP) - EPDM;
  - Polycarbonate (PC) - Acrylonitrile butadiene styrene (ABS):

   Polymer blends can be used as thermoplastic elastomer.

What Is an Immiscible Blend?

Long ago someone came up with the idea of taking two polymers and mixing them together in order to get a material with properties somewhere between those of the two polymers mixed. Materials made from two polymers mixed together are called blends. But if you read the blends page, you'll know that it's not very often that two polymers will mix with each other. Most of the time, if you try to mix two kinds of polymers, you'll end up with something that looks like chicken soup. Take a look at a bowl of good chicken soup, and you'll see that it has two phases: a water phase and a chicken fat phase. The chicken fat is insoluble in water, so it forms little blobs in the soup separate form the water phase. So we say mixtures like chicken soup are phase-separated.

Phase-separated mixtures are just what you get when you try to mix most polymers. But strangely enough, the phase-separated materials often turn out to be rather nifty and useful. We even have a name for them. We call them immiscible blends. Ok, I have to admit, that name is an oxymoron. These materials aren't really blends; they can't be if they're immiscible, but that's the name people use.


polystyrene
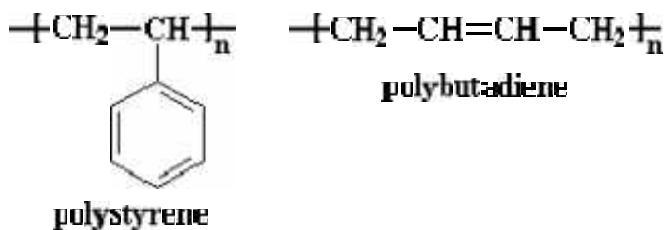
polybutadiene

Anyway...Immiscible blends turn out to be useful, as I was saying. Would you like an example? Alright, then consider polystyrene and polybutadiene. These two polymers are immiscible. When you mix polystyrene with a small amount of polybutadiene, the two polymers won't blend, of course. Instead, the polybutadiene will separate from the polystyrene into little spherical blobs, just like the chicken fat in your soup separates from the water into little blobs. If you looked at the mixture under an electron microscope you'd see something that looks like the picture below.

polystyrene phase

polybutadiene phase
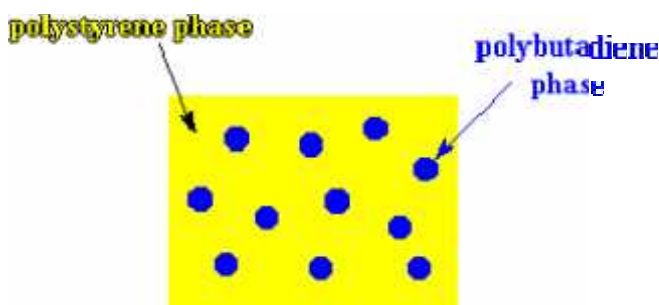
The phase morphology of HIPS.

The little spheres of polybutadiene do a lot for the material. You see, polystyrene is a rather brittle material. It's stiff, but you can break it easily if you try to bend it. But those little polybutadiene spheres are rubbery, remember, and they can absorb energy under stress. This keeps the polystyrene from breaking. This immiscible blend has more ability to bend instead of breaking than regular polystyrene. That is, it's tougher and more ductile. Immiscible blends of polystyrene and polybutadiene are sold commercially under the name high-impact polystyrene, or HIPS for short.

poly(ethylene terephthalate)
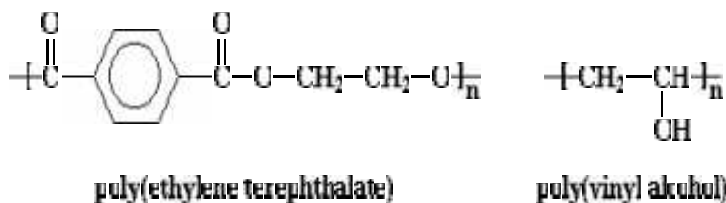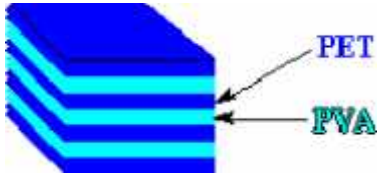
poly(vinyl alcohol)

Another immiscible blend you may be familiar with is one made from a polyester called poly(ethylene terephthalate) and poly(vinyl alcohol). We call them PET and PVA, respectively, for short. If you put just the right amounts of the two polymers together under the right conditions you'll get something that looks like the picture on the left, when you look at it under an electron microscope.

In this material, PET and PVA separate into sheetlike layers called lamellae. We call the resulting arrangement lamellar morphology. This particular immiscible blend is used to make plastic bottles for carbonated beverages. The PET makes the bottle strong, while the layers of PVA do something very important if you want your sodas to stay fizzy. Carbon dioxide can't pass through PVA. If the carbon dioxide in your soda leaked out (it can pass easily through plain PET), your soda would go flat.

Morphology

I hope you folks are asking a question right now. Did you notice a difference between the two immiscible blends we just talked about? Did you notice that in HIPS, one polymer forms into little spheres dispersed in the polystyrene? Did you also notice that in the PET-PVA system, the two polymers separated into layers? Why are the two different? Why do they separate in different fashions?

We call the shape made by the two phases, and the arrangement of the two phases morphology. The biggest thing one can do to affect the morphology of an immiscible blend is to control the relative amounts of the two polymers one is using. Let's say you're trying to make an immiscible blend from two polymers, polymer A and polymer B. If you have a lot more of polymer A than polymer B, polymer B separate into little spherical globs. The spheres of polymer B will be separated from each other by a sea of polymer A, like you see in the picture below. In such a case we call polymer A the major component and polymer B the minor component.

relative amount of polymer B in the immiscible blend
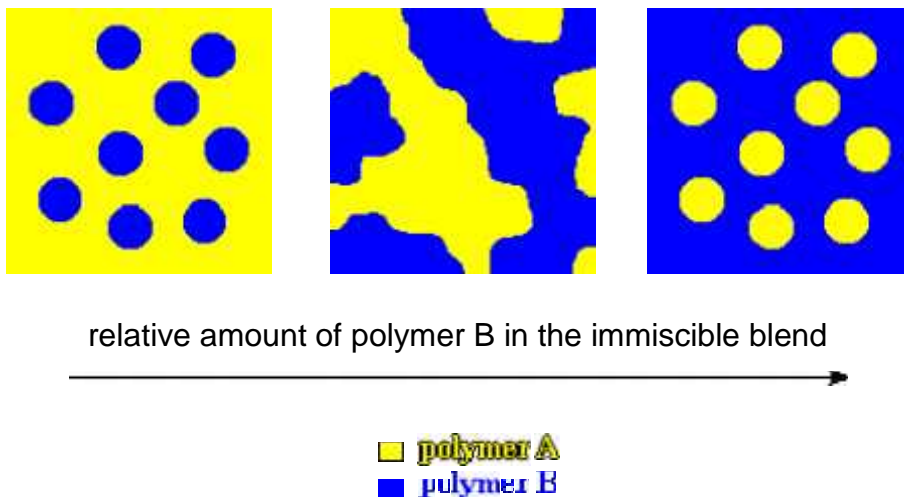
But if you put more polymer B into the immiscible blend, the spheres will get bigger and bigger, until they get so big that they become joined together. Now they aren't isolated spheres anymore, but a continuous phase. The immiscible blend now looks like the middle picture above. It might help to think of a block of colby-jack cheese. The domains of polymer B are now joined together, but so are the domains of polymer A. When this happens we say that the polymer A phase and the polymer B phase are co-continuous.

But if we keep adding more polymer B, eventually there will be so much more polymer B in the immiscible blend that polymer A will become nothing but isolated spheres surrounded by a continuous phase of polymer just like you see in the picture above on the right. Polymer B is now the major component and polymer A is the minor component, and the situation is reversed from what we had at first.

Spheres, co-continuity, then more spheres...so how do we get the neat layers that you get in the PET-PVA immiscible blend? Sometimes the way in which a product is processed affects the morphology of the material. soft drink bottles are made by a technique called blow molding. To make a bottle we take a small piece of plastic that looks like a test tube, about 1 inch (2.5 cm) in diameter and maybe 6 inches (15 cm) long. We heat the tube up, then inflate it like a balloon until it is the size we want it. This whole procedure puts the material under stress. Think about a section of the skin of the bottle. When it is being inflated, it is put under stress in two directions, like you see in this picture on the right.
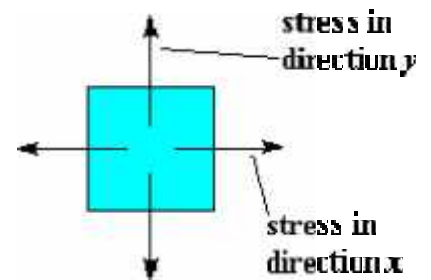
This is called biaxial stress, and it causes the domains of PET and the domains of PVA to flatten out, just like pizza dough does when you roll it. This is how we get flat layers instead of spheres in our immiscible blend.

Processing under flow in one direction turns the spheres into rods.

Another interesting morphology you can get is one of rod-like domains of one polymer surrounded by a continuous phase of the other. This happens when the immiscible blend is put under stress in only one direction, such as during extrusion.

Ok, we have to talk about one last thing when we're talking about morphology, and that is size. Let's go back to that simple case we talked about earlier, where we had spheres of polymer B surrounded by continuous phase of polymer A. How big are the spheres? How far apart are they? Could you see them if you looked at a sample of an immiscible blend?

I hate to disappoint everyone, but in most cases you're not going to be able to see the two separate phases with your own eyes. In fact, it usually takes an electron microscope. So the phase domains, spherical or otherwise, are very small.

But the domains do try to be as big as they can. Take our spheres for example. The bigger the spheres are, the less surface area they will have. A few bigger spheres have less surface area than a bunch of little ones. The less surface area, the better. Remember, the two polymers in an immiscible blend don't like each other, and the smaller the surface area of the spheres, the less the two polymers have to touch each other.

I figure you're going to want some numbers, so I'll tell you some specifics on an 80:20 immiscible blend of high density polyethylene and polystyrene. Polystyrene is the minor component here, so it will form the separated spherical domains, and they tend to be in the range of 5-10 mm in diameter.[1]

Properties of Immiscible Blends

How do these immiscible blends behave? They have to behave in some interesting manner, or else nobody would make them, and people like me wouldn't write about them.

One unusual property of immiscible blends is that one made from two amorphous polymers has two glass transition temperatures or Tgs for short. Since the two components are phase separated, the retain their separate Tgs. In fact, scientists often measure the Tg of a blend to find out if it is miscible or immiscible. If two Tgs are found, then the blend is immiscible. If only one Tg is observed, then the blend is likely to be miscible.

But what about mechanical properties? Let's consider an immiscible blend of a major component polymer A and a minor component polymer B, whose morphology is that of spheres of polymer B dispersed in a matrix of polymer A. The mechanical properties of this immiscible blend are going to depend on those of polymer A, because the polymer A phase is absorbing all the stress and energy when the material is under load. In addition, the immiscible blend is going to be weaker than a sample of pure polymer A.

So why make immiscible blends then, if separate materials are stronger? It turn out there are some tricks one can do to make immiscible blends strong. One is to process them under flow. If we process them under flow in one direction, the minor component will form rods instead of spheres, Like you see in the picture on your right. These rods act like the fibers of a reinforced composite material. They make the material stronger in the direction of the rods.

Another way to make a strong immiscible blend is to use more equal amounts of the two polymers. Remember, when the relative amounts of the two polymers are equal, we get a different morphology than when one is in large excess. When polymer A and polymer B are present in roughly equal amounts, they form two co-continuous phases. This means both phases will be bearing the load of any stress on the material, so it will be stronger.

But one of the most interesting ways to make immiscible blends stronger is to use a compatibilizer. So what is a compatibilizer? A compatibilizer is anything that helps bond the two phases to each other more tightly. You see, in an immiscible blend, the two phases are not bonded very strongly to each other. Remember, they don't like each other, and that is why they are immiscible in the first place. But if stress and energy are going to be transferred between the components, they have to be bound to each other in some fashion.

That's where compatibilizers come in. Often times a compatibilizer is a block copolymerof the two components of the immiscible blend. Let's take our example of an immiscible blend of polymer A and polymer B again. Let's make polymer A the major component and polymer B the minor component, and then let's throw in a block copolymer of A and B. For those of you who may not no, a block copolymer of A and B is a polymer with one long segment of polymer A joined to another long segment of polymer B, like you can see on your right.

Of course, the A block is going to want to be in the polymer A phase, and the B block is going to want to be in the polymer B phase. So the copolymer molecule has to sit right on the phase boundary between the
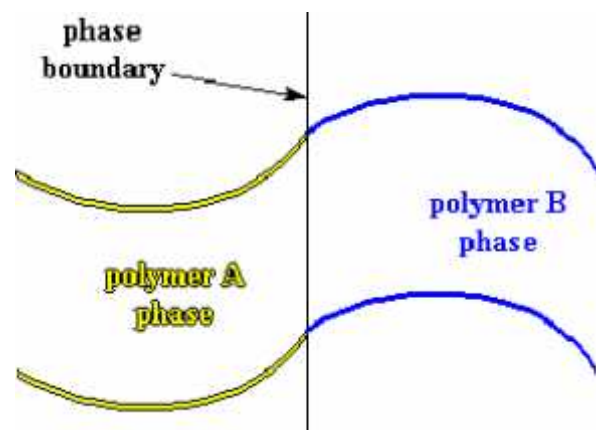
polymer A and the polymer B phases. The A block can then be happy sitting in the polymer A phase, and the B block is happy because it can stay in the polymer B phase, as you can see in the picture on your left.

The block copolymers tie the two phases together, and allow energy to be transferred from one phase to the other. This means that the minor component can improve the mechanical properties of the major component rather than worsen them.

Graft copolymers are also used as compatibilizers. HIPS contains graft copolymers of polystyrene grafted onto a polybutadiene backbone chain. These graft copolymers allow stress to be transferred from the polystyrene phase to the polybutadiene phase. Since polybutadiene is rubbery, it dissipates the energy which would otherwise cause the brittle polystyrene phase to break. This is why HIPS is tougher than regular polystyrene.
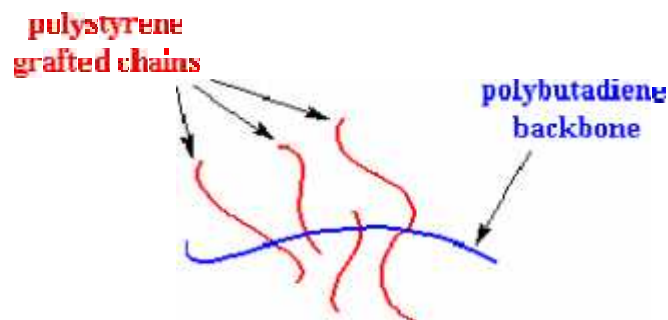
Compatibilizers also have another effect on immiscible blends. Remember, we talked earlier about the size of spheres of the minor component in an immiscible blend. The bigger the spheres, the more stable they are, because a few larger spheres will have less surface area than lots and lots of small ones. As the two polymers don't like each other, they try to minimize contact. The less surface area the spheres have, the less contact the two phases have. This means the spheres will tend to be relatively large.

But a compatibilizer lowers the energy of the phase boundary, as we say. What we mean is that the two phases can stand each other a little more when there is a compatibilizer present. So the need to minimize contact between the two phases isn't as great. So when a compatibilizer is used, our spheres don't need to be as big. Remember our 80:20 immiscible blend of high density polyethylene and polystyrene? The polystyrene spheres were about 5-10 mm in diameter. When enough of a polystyrene-polyethylene block copolymer (enough being 9%) is added to the immiscible blend, the size of the polystyrene spheres drops to about 1 mm.[1]

This is good for the mechanical properties of the immiscible blend. The smaller the spheres, the greater the area of the phase boundary between the two phases, of course. The greater the area of the phase boundary, the more efficiently energy can be transferred from one phase to the other, meaning better mechanical properties.

Sometimes we want a material that has the some of the properties of one polymer, and some of the properties of another. Instead of going back into the lab and trying to synthesize a brand new polymer with all the properties we want, we try to mix two polymers together to form a blend that will hopefully have some properties of both in the right combination.

Polymers Usually Don't Mix

Sounds easy enough, but it turns out that blending two different kinds of polymers can be really tricky business. You see, very seldom is it that two different kinds of polymers will mix together. This doesn't seem to make sense. Take a look at polyethylene and polypropylene below. Click on the model images if you want to play with the 3D model of each polymer.

polyethylene

$$-[CH_2 - CH_2]_n$$

polypropylene

$$-[CH_2 - CH]_n$$
$$\quad\quad\quad CH_3$$
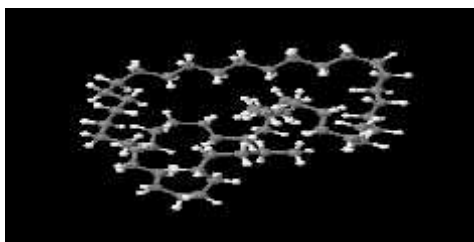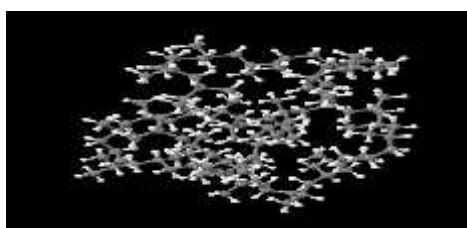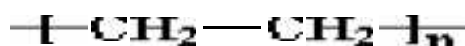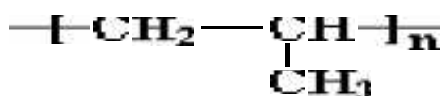
Would you believe that these two polymers don't mix? Why is that? What happened to the old "like dissolves like" rule that you learned in high school chemistry? These are both very non-polar hydrocarbon polymers. They should mix beautifully.

But they don't. And yes, there is a reason why. It has to do with that old culprit entropy. Entropy is the name we scientists call disorder. This dog is named Entropy. Just say the word "Frisbee" around her and you'll get a good demonstration of what entropy is.

This brings us to a little rule we call the second law of thermodynamics. The second law of thermodynamics says that when things change, they will change from a state of order to a state of disorder. Getting things to change in the other direction is very difficult. It's easy to mess up your room, but difficult to clean it up. It's easy to crash a car, but fixing it is much trickier. A change, in your room, in life, in polymers, is more likely to happen if that which is changing changes from a state of more order to a state of less order; that is, if it changes from a state of less entropy to more entropy.

So what does entropy have to do with polymer blends? This will take some explaining. Consider one type of polymer, in the amorphous state. When it's alone, by itself, all its chains are tangled up in each other randomly and chaotically. Entropy runs high in an amorphous polymer.

This presents a problem if you're trying to make polymer blends. You see, one of the biggest reasons two compounds will ever mix together is that they are more disordered mixed together than they are separate. So, mixing is favored by the second law of thermodynamics. But an amorphous polymer is so disordered as it is, that it really doesn't gain that much entropy when it's blended with another polymer. So, mixing is disfavored.

Making Polymers Mix This presents a challenge to would-be polymer blenders. Without entropy to make polymers blend, how can we ever get two polymers to mix? To make that happen, we have to go back to go back to the first law of thermodynamics. Aha! Just like lawyers, we can use one law to get around another. The first law of thermodynamics says that when things change, they change from a state of more energy to a state of less energy. Think of it this way: it's easier to go to sleep than it is to get out of bed in the morning. Or if you'd like a physics example, a rock on top of a mountain will roll down to the bottom of the mountain more easily than a rock on the bottom will roll to the top. (I learned this the hard way when I was mountain climbing one summer and almost got killed by a falling boulder.)

What, then, does this first law of thermodynamics have to do with blending polymers? This: in order to make two polymers mix, we have to make them have less energy when mixed than they would be separate. Let me use an example to illustrate. Two polymers that do actually mix are polystyrene and poly(phenylene oxide). Again, you can view the 3D models by clicking on the model images of the two polymers, right and left.

poly(phenylene oxide)   polystyrene
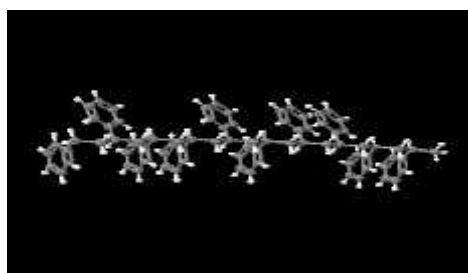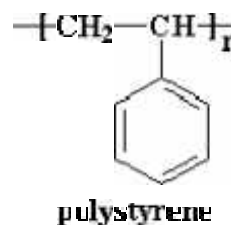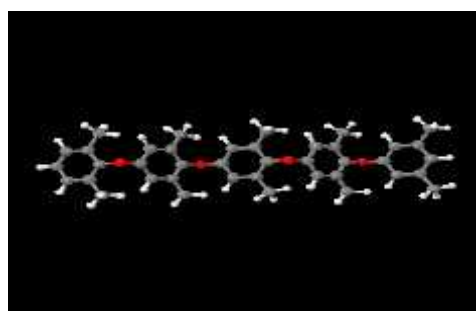
As you can see, both of these polymers have aromatic rings. As you may know, aromatic rings like to stack up like little hexagonal poker chips. For this reason, these two polymers like to associate with each other. So they blend very nicely.

There are a few other examples of polymer pairs which will blend. Here is a list of a few:

poly(ethyleneterephthalate) with poly(butyleneterephthalate)
poly(methyl methacrylate) with poly(vinylidene fluoride)

Copolymers

But most of the time, the two polymers you want to blend won't be miscible. So you have to play some tricks on them to make them mix. One is to use copolymers. Polystyrene doesn't blend with many polymers, but if we use a copolymer made from styrene and p-(hexafluoro-2-hydroxyisopropyl)styrene, blending is a lot easier.

$$-[CH_2-CH]_n-[CH_2-CH]_m-$$

$$F_3C-C-CF_3$$
$$OH$$
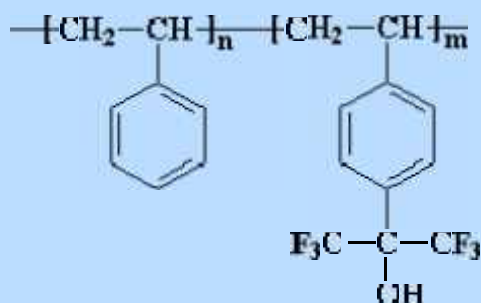
poly[styrene-*co*-(*p*-hexafluoro-2-hydroxyisopropyl)styrene]

You see, those fluorine atoms are very electronegative, and they're going to draw electrons away from all the nearby atoms. This leaves the alcohol hydrogen very lacking in electrons, which means it is left with a partial positive charge. So that hydrogen will form strong hydrogen bonds with any group with a partial negative charge. Because of this, it's easy to form blends of this copolymer with polycarbonates, poly(methyl methacrylate), and poly(vinyl acetate).[2,3]

There's another way copolymers can be used to help polymers blend. Let's consider a random copolymer of styrene and acrylonitrile. This copolymer will blend with poly(methyl methacrylate) (PMMA). This is where it gets weird. PMMA won't blend with either polystyrene or polyacrylonitrile.

$$-[CH_2-CH]_n-[CH_2-CH]_m-$$
$$C\equiv N$$
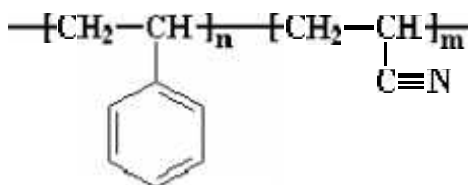
poly(styrene-*co*-acrylonitrile)

$$-[CH_2-CH]_n-$$
$$C=O$$
$$O$$
$$CH_3$$
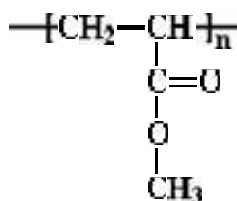
poly(methyl methacrylate)

So why does the random copolymer blend with PMMA? The explanation is something like this: the styrene segments and the acrylonitrile segments of the random copolymer may not like PMMA, but they like each other even less. The styrene segments are non-polar, while the acrylonitrile segments are very polar. So, the styrene segments and the acrylonitrile segments blend into the PMMA to avoid coming into contact with each other.

Making Your Own Blends

Blends are usually made in two ways. The first way is to dissolve two polymers in the same solvent, and then wait for the solvent to evaporate. When the solvent has all gone away, you'll be left with a blend at the bottom of your beaker, presuming your two polymers are miscible.

While this method works fine in the laboratory, it could get expensive if you tried to do this industrially. Solvents aren't cheap, and if you're going to evaporate hundreds or thousands of

gallons of them, you'll be paying a lot of money. Not to mention the effects on the environment of putting so much of your toxic solvents into the air, or the extra cost of recapturing all that solvent so it could be reused.

So for making blends in large amounts, you heat the two polymers together until you're above the glass transition temperatures of both polymers. At this point they will be nice and gooey, and you can mix them together like a cake mix. This is often done in machines such as extruders. When your material cools, you'll have a nice blend, again, presuming your two polymers are miscible.

Properties of Blends

So what are these blends like? How do they behave? In general, a miscible blend of two polymers is going to have properties somewhere between those of the two unblended polymers. Take for example the glass transition temperature, or T_g for short. If we take polymer A and blend it with polymer B, the T_g will depend on the ratio of polymer A to polymer B in the blend. You can see this in the graph below.
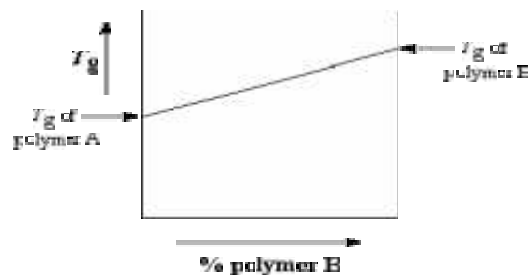
If polymer B has a higher T_g than polymer A, the T_g of the blend is going to increase as the relative amount of polymer B in the blend increases. The increase is generally linear, like you see in the graph. But the plot isn't perfectly linear. Sometimes if the two polymers bind more strongly to each other than to themselves, the T_g will be higher than expected, because the stronger binding lowers chain mobility. The plot will look like you see in the graph on the right below.
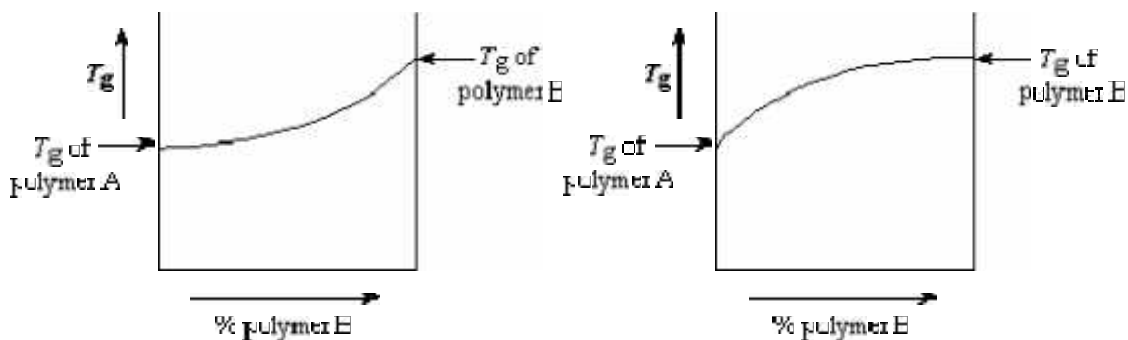
Of course, in most cases, the two polymers bind less strongly with each other than with themselves, so the T_gs of the blends are usually a little lower than expected. The T_g plot will look like the one you see above on the left.

We've been talking about T_gs up until now, but what holds for T_gs generally holds for other properties. Mechanical properties, resistance to chemicals, radiation, or heat; they all generally plot the same way as the T_g does with respect to the relative amounts of each polymer in the blend.

This makes altering the properties of your blend fairly simple. When you vary the amount of the two polymers, you vary the properties. This can be very useful. I'll use the example of poly(phenylene oxide), a.k.a. PPO, to illustrate. PPO is a very heat resistant polymer. This is

wonderful. People need heat resistant materials. But it has some drawbacks. It's very hard to process. You see, it's too heat resistant. Amorphous polymers are usually processed by heating them above their T_gs so they get soft and gooey. But with a T_g of 210 ℃, heating PPO enough to make it soft and gooey is not only difficult, but expensive.

Enter polystyrene. Remember, polystyrene and PPO blend nicely with each other. Since polystyrene has a T_g of only about 100 ℃, blending polystyrene with PPO drops the T_g of the blend down to temperatures which make the blend much more processable than straight PPO.
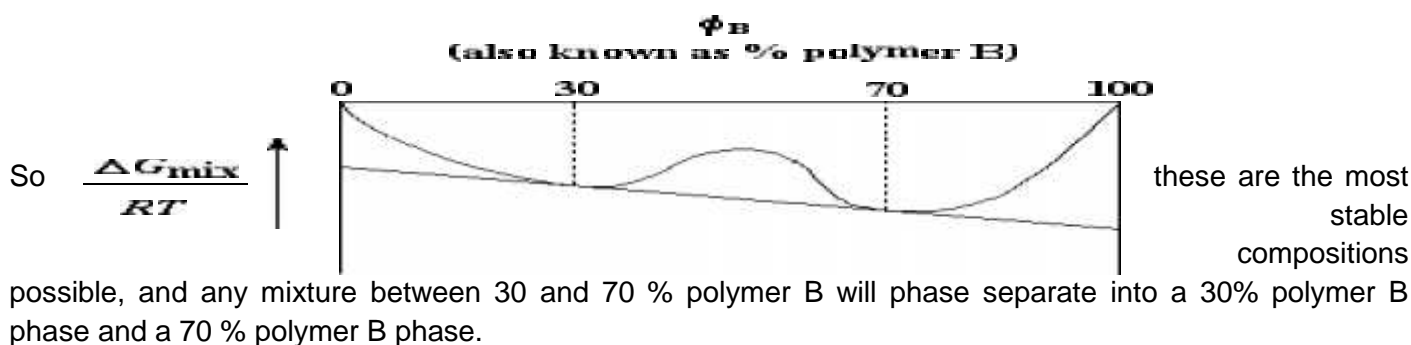
Here's a nifty piece of information: Noryl™, the PPO/polystyrene blend that GE sells, uses a special kind of polystyrene, called high-impact polystyrene, or HIPS for short. HIPS is really a mixture of polystyrene and polybutadiene. These two polymers don't blend. The rubbery polybutadiene separates from the polystyrene. But the little blobs of rubbery polybutadiene make HIPS, and Noryl™, a lot tougher. We call a mixture of two polymers like polystyrene and polybutadiene that phase separates an immiscible blend. Immiscible blends aren't really blends at all, because they phase-separate like water and chicken fat in a bowl of homemade chicken soup. But such phase-separated mixtures are also useful, mind you. If you want to read more about them go visit the Immiscible Polymer Blends Page.

To Blend or Not to Blend

A few polymer pairs mix. Most don't. But there are also polymer pairs that sometimes mix and sometimes don't. The variables that one can control to make them mix or not mix are usually temperature and composition. A lot of polymer pairs are only miscible when there is a lot more of one polymer than of the other. There will be a range of compositions for which the two polymers won't mix. For example, let's say we have two polymers, polymer A and polymer B. Let's also say they are miscible when we have less than 30% polymer B, that they are miscible when there is more than 70% polymer B. But between 30 and 70% polymer B, the blend phase-separates into two phases. Here's a graph for those who of you who like that sort of thing:
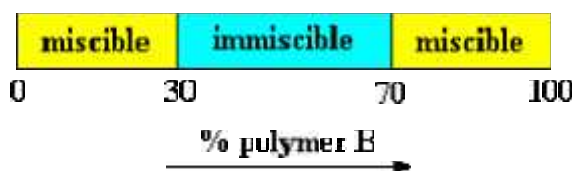
Interestingly, one phase will have 30% polymer B and the other will have 70% polymer B. There's a reason for this. If we look at a plot of free energy versus composition, we'll see that these two compositions are lower in energy than any other compositions.[4]One note first: we chemists usually use the Greek letter ϕ to represent the relative amount of one or the other component in a mixture of any kind, so we're going to use ϕ_B instead of "% B" from here on.

So $\dfrac{\Delta G_{mix}}{RT}$ these are the most stable compositions possible, and any mixture between 30 and 70 % polymer B will phase separate into a 30% polymer B phase and a 70 % polymer B phase.

But the composition range over which the two polymers phase-separate isn't constant. It can change with temperature. For some polymer pairs that range gets smaller as temperature increases. Eventually, if you heat such a pair high enough, that range of immiscibility will become so small that it will disappear. The temperature at which this happens is called the upper critical solution temperature or UCST. The graph on the right shows this. The upside-down parabola is the boundary between those temperatures and compositions at which there is one phase, and those at which there is phase separation.
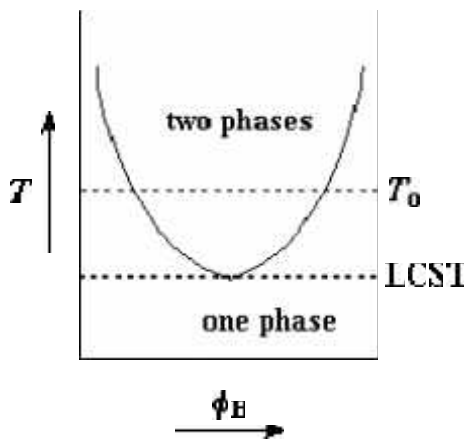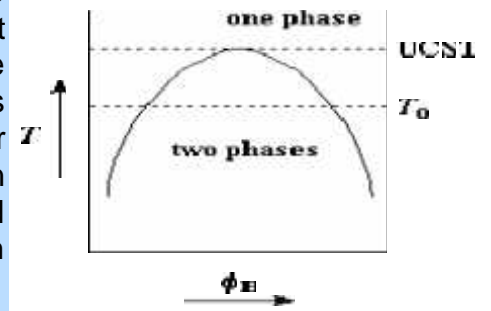
But sometimes the opposite happens. For some polymer pairs the range of immiscibility decreases with decreasing temperature. If one cools such a pair enough, eventually we'll reach a temperature at which the range gets so small that it disappears. This temperature is called the lower critical solution temperature or LCST. If one plots the range of immiscibility versus temperature, the plot looks like an inversion of the UCST plot, as you can see on the left.

Now for you thermodynamicists out there who are wondering what happens to our plot of free energy versus composition once we've crossed either a UCST or LCST and out polymer pair has become miscible in all compositions, we have a graph showing just that right here:
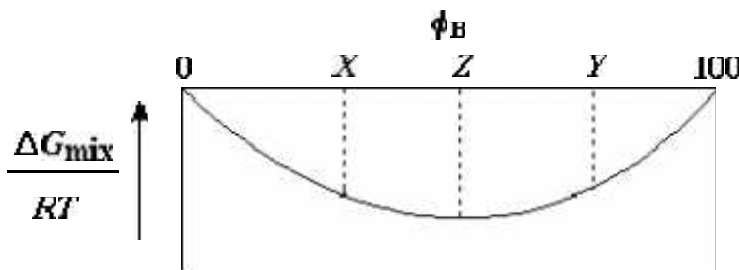
This plot takes some explaining. Imagine, if you will, a blend of polymers A and B, of composition Z. Now, imagine it phase-separating into two phases, one of composition X and the other of composition Y. As you can see, the two separate phases are both higher in free energy than the single phase at composition Z, so they are less stable than that single phase at composition Z. So, if the two separate phases were somehow generated they would spontaneously merge into one phase, whose composition is, you guessed it, Z.

Interpenetrating polymer network

An **Interpenetrating polymer network** (IPN) is a polymer comprising two or more networks which are at least partially interlaced on a polymer scale but not covalently bonded to each other. The network cannot be separated unless chemical bonds are broken.[1] The two or more networks can be envisioned to be entangled in such a way that they are concatenated and cannot be pulled apart, but not bonded to each other by any chemical bond. Simply mixing two or more polymers does not create an interpenetrating polymer network (polymer blend), nor does creating a polymer network out of more than one kind of monomers which are bonded to each other to form one network (heteropolymer or copolymer).

Compatibilizers:

Compatibilization in polymer chemistry is the addition of a substance to an immiscible blend of polymers that will increase their stability. Polymer blends are typically described by coarse, unstable phase morphologies. This results in poor mechanical properties. Compatibilizing the system will make a more stable and better blended phase morphology by creating interactions between the two previously immiscible polymers. Not only does this enhance the mechanical properties of the blend, but it often yields properties that are generally not attainable in either single pure component.

Block or graft copolymers as compatibilizing agents

Block or graft copolymers are commonly used as compatibilizing agents. The copolymer used is made of the two components in the immiscible blend. The respective portions of the copolymer are able to interact with the two phases of the blend to make the phase morphology more stable. The increased stability is caused by reducing the size of the phase-separated particles in the blend. The size reduction comes from the lower interfacial tension, due to accumulating block copolymers at the many interfaces between the two copolymers. This helps the immiscible blends break up into smaller particles in the melt phase. In turn, these phase separated particles will not be as inclined to consolidate and grow because the interfacial tension is now much lower. This stabilizes the polymer blend to a usable product. An example of this are Ethylene/propylene copolymers. They are able to act as good compatibilizing agents for blends of polypropylene and low density polyethylene. In this specific application, longer ethylene sequences are preferred in the copolymer. This is because co crystallization also factors into this case, and the longer ethylene sequences will retain some residual crystallinity.

Reactive compatibilization

Reactive compatibilization is a procedure in which immiscible polymer blends are compatibilized by creating copolymers in the solution or melt state. Copolymers are formed when the proper functional groups in each component of the immiscible blend interact in the compatibilization process. These interactions include hydrogen, ionic or covalent bonding. The functional groups that cause these interactions can be the end groups that are already present in the blend polymers (e.g., carboxylic acids or alcohols on polyesters, or amine groups on nylons). Another approach is to add functional groups to the component chains by grafting. The many possible functional groups allow for many types of commercial polymer blends, including polyamide/polyalkene blend systems. There are a number of advantages reactive compatibilization has over using the traditional block or graft copolymer as the compatibilizing agent. Unlike the latter approach, reactive compatibilization does not rely on diffusing pre-formed copolymers. Copolymers form at the interfaces of the two immiscible blends and do not need to be dispersed. In the traditional approach the system needs to be well mixed when adding the copolymers. Reactive compatibilization is also much more efficient than traditional compatibilization. This is because in reactive compatibilization, functional groups are either already present, or easily grafted on the blend components. In the traditional compatibilization, copolymers must be synthesized on a case by case basis for the components to blend.

PVC –NBR Blend

Blending of polymers for property improvement or for economic advantage has gained considerable importance in the field of polymer science in the last decade. Miscibility of the constituent polymers is often a necessity for forming successful blends. One of the commercially important and miscible polymer blends is that of NBR and PVC. 1-1 NBR acts as a permanent plasticizer for PVC in applications like wire and cable insulation, food containers, pond liners used for oil containment, etc. On the other hand, PVC improves ozone, thermal aging, and chemical resistance of NBR in applications like feed hose covers, gaskets, conveyor belt covers, printing roll covers, etc. PVC also vastly improves abrasion resistance, tear resistance, and tensile properties. It also adds gloss and improves finish of the extruded stock and imparts flame-retardant character. NBR/PVC blends can be conveniently milled, extruded, and

compression-molded using traditional processing equipments for natural and synthetic rubbers., One difficulty in forming successful blends of NBR and PVC is the lack of suitable stabilizers for PVC which do not affect NBR. Although the barium stearate/cadmium stearate combination, the commonly used PVC stabilizer in NBR/PVC blends,, does not seem to produce any obvious deterioration in the physical properties, it does produce a yellowish tint which limits the color flexibility of the blends. Recently it was shown that magnesium oxide and zinc oxide combination along with stearic acid could efficiently stabilize plasticized PVC. These conventional ingredients in rubber compounding do not produce any color. Hence magnesium oxide and zinc oxide along with stearic acid were tried as the stabilizer for PVC in this study on NBR/ PVC blends.

PVC – ABS Blend:

Poly(vinyl chloride) and acrylonitrile-butadiene-styrene terpolymer blends made via melt blending. Blends were characterized by various thermal, morphological methods of analysis. Two distinct glass transitions were recorded by differential scanning calorimetry (DSC).This suggested the need for a compatibilizer. Incorporation of ABS had marginal effect on rate, chemistry, and overall pattern of decomposition of poly(vinyl chloride).

Polymer blending is one of the fastest growing areas of polymer technology. Blending of polymer has become an increasingly important technique because it is an economical, viable and versatile way in which new material can be produced with a wide range of properties by merely using conventional processing equipment such as extruder or internal mixer.

Polyvinyl chloride is most versatile material in plastic family and second largest consumption material in plastic industries compared to polyolefin's. It is characterized by rigidity, hardness, excellent tensile modulus and low cost. However, it has low impact strength and poor thermal stability. Which limit's it's used.

Similarly, Acrylonitrile-Butadiene-Styrene (ABS) is one of most largely used engineering plastics. It has excellent mechanical, thermal, electrical &chemical properties. Followed by inferior properties such as poor weather resistance, highly flammable and merely high cost.

Polyvinyl chloride is largely blended with number of polymers and rubbers. In most cases, to improve properties of PVC and rarely to improve properties of other materials.

One of most inferior properties of PVC is low impact strength. To overcome this problem, it is blended with many rubbery materials. It has been shown that impact strength of PVC increases by blending with rubbery material such as NBR, SBR etc. But, it follows the decrease in tensile strength, rigidity and in most cases thermal stability.

Hence to achieve high impact strength, better thermal properties along with rigidity, PVC is blended with ABS. The blend of PVC and ABS posses their advantage of impact strength, rigidity, chemical resistance, electrical properties and overall low cost.

In ABS, generally the rubbery phase is made of emulsion polymerized polybutadiene, which constitutes the main polymer chain .The glassy phase is made of styrene and acrylonitrile grafted on Polybutadiene. Thus, it combines the impact strength of rubber and tensile strength, heat stability of styrene Acrylonitrile (SAN) Matrix. Thus properties of styrene acrylonitrile (SAN) and polybutadiene are imparted in PVC/ABS blend.

PP-EPDM Blend:

Polypropylene (PP) is one of the most widely used polyolefin polymers. The toughening has been one of the most active and significant theme in the field of the modification for PP resin. Ethylene-propylene copolymer (EPR) or ethylene-propylene-diene copolymer (EPDM) copolymer has been often used to toughen PP. At present, the impact strength of the modified resin can be enhanced by four times relative to

the matrix by adding elastomers. In recent years, blends of PP containing soft elastomer and rigid fillers are of ever-increasing interest because both their stiffness and toughness can be partly controlled and materials with balanced mechanical properties can be formulated.

If a material can be generated at a lower cost with properties meeting the specifications, the manufacturer must exploit it to remain competitive. Blending of PP/EPDM are the most common combination for impact strength improvement of PP.

This blend has been used as material in the manufacture of car bumpers, fender extensions and rubber strips. Many recent works reported the structure property relationship of impact modified PP through its melt blending with EPDM . However, EPDM is a synthetic rubber and generally must be imported. This means that the cost is expensive. Therefore this research was carried out to investigate the possibility of replacement or partial replacement of EPDM by NR or ENR.

Ethylene-propylene diene terpolymer (EPDM) is obtained by polymerizing ethylene and propylene with small amount of a non-conjugated diene (3 to 9%). Due to the unsaturated positions in the terpolymers, which lie outside the main chain, the good ageing characteristics, the ozone and cold resistance and the excellent electrical resistance of a saturated olefin remain. EPDM has a broad resistance to chemicals but not to oil and other hydrocarbons .Meanwhile, an isotactic polypropylene is a stiff material, highly crystalline with high melting point. Typical uses of polypropylene include sterilizable hospital items, dishes, appliance parts, dishwasher components, containers, automotive ducts, trim, etc.

In the past decade, polymer blend technology has achieved an important position in the field of polymer science. With increased academic and industrial research interest, the application of polymer blend technology to commercial utility has grown significantly. This review on the applications of polymer blends will cover the major commercial blends in the categories of styrene-based polymer blends, poly(vinyl chloride) blends, polyacrylate blends, polyester and polycarbonate blends, polyolefin blends, elastomer blends, polyelectrolyte complexes, and interpenetrating polymer networks. New developments in polymer blend applications will be discussed in more detail. These systems include linear low-density polyethylene blends with either low- or high-density polyethylene, styrenemaleic anhydride terpolymer/ABS (acrylonitrile-butadiene-styrene) blends, polycarbonate/poly(butylene tetephthalate) blends, new PPO/polystyrene blends, and tetramethyl bisphenol A polycarbonate/impact polystyrene blends. Areas for future research to enhance the potential for polymer blend applications will be presented. The need for improved methods for predicting miscibility in polymer blends is discussed. Weldline strength is a major property deficiency of two-phase systems (even those with mechanical compatibility), and future research effort appears warranted to resolve this deficiency. The use of polymeric compatibilization additives to polymer blends has shown promise as a method to improve mechanical compatibility in phase-separated blends, and will be expected to be the subject of future research programs. Finally, the reuse of polymer scrap is discussed as a future application area for polymer blends. Unique applications recently proposed for polymer blends include immobilization of enzymes, permselective membranes, reverse osmosis membranes, selective ion-exchange systems, and medical applications using polyelectrolyte complexes.