Close Encounters of the Polymer Kind

A lesson on Polymers

Outline

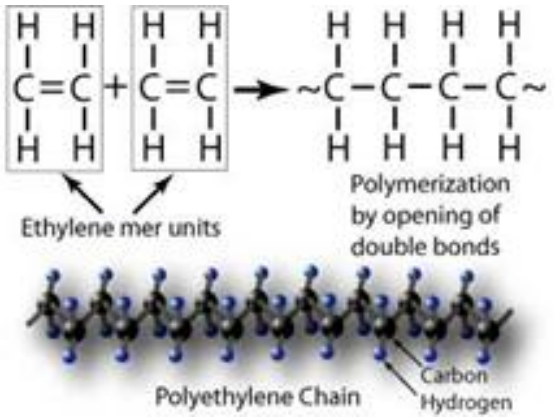
1. **Basics of polymers**
    a. What is a polymer?
    b. What is a thermoplastic?
    c. What is a thermoset?
2. **Unusual Behavior of Polymers (Thermoplastics)**
    a. Weissenberg
    b. Kaye
    c. Barus
    d. Anti-Gravity
3. **Manipulating Thermosets**
    a. How to make a thermoset
    b. What can you manipulate?
    c. Thermoset activity

Polymers

What is a polymer?

(poly-) = many (-mer) = unit

A polymer consists of many repeating chemical units



Polymers

Separated into two classes

Thermosets

Thermoplastics

Polymers

What is a thermoset polymer?

A polymer material that is "cured" into a final form that can not be changed.

The curing reaction creates a 3-D network of covalently bonded molecules.

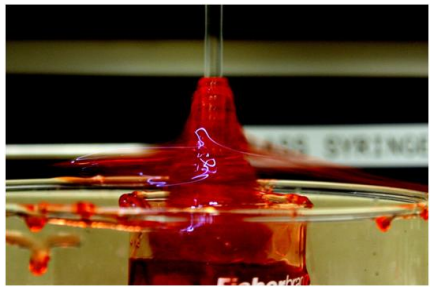
Polymers

What is a thermoplastic polymer?

A polymer material whose final form can be changed through heating and molding.

Typically they consist of many many linear polymers that are held together by their enthalpic interactions and physical entanglements

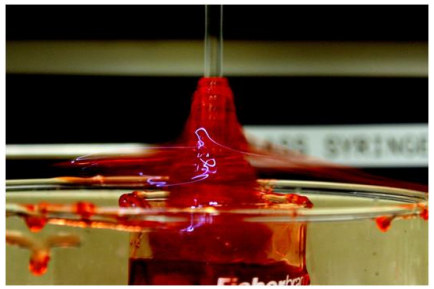
Weissenberg Effect



Take a moment to observe the Weissenberg Effect.

Why do you think the material behaved the way it did?

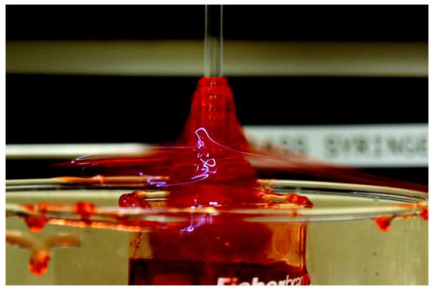
Weissenberg Effect



Now take a moment to observe the macroscopic demo of this molecular phenomenon

Why do you think the material behaved the way it did?

Weissenberg Effect



Life is always a balance.

Here we have a balance between the enthalpic interactions and the entropic interactions

Enthalpic interactions - How much you like the person next to you

Entropic interactions - How close you are sitting together

Barus Effect (Die Swell)

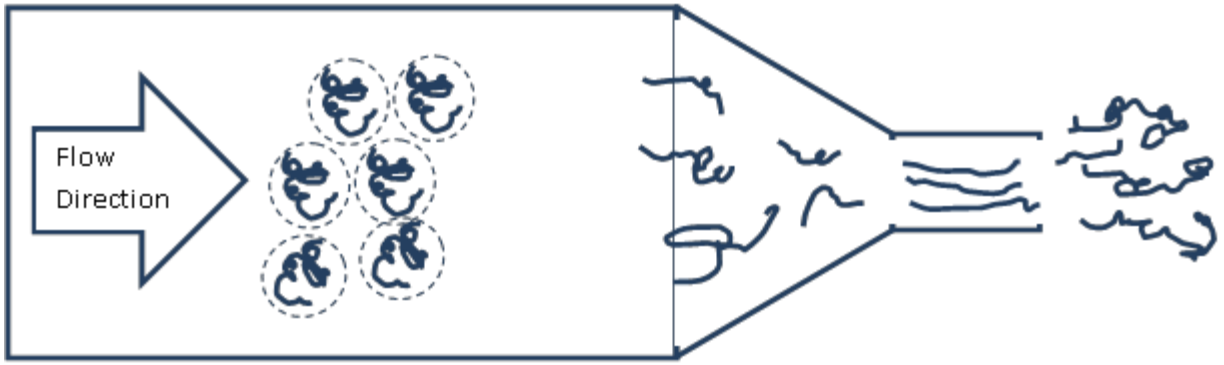
Take a moment to watch the Barus Effect video below.

Why do you think that happens?

Barus Effect (Die Swell)

How does the moving wall analogy relate to the Barus Effect?

As the plunger (our classroom wall) is pushed, the molecules are forced in a confined space (decreasing entropy). They exit the die and increase entropy by spreading out.



Kaye Effect

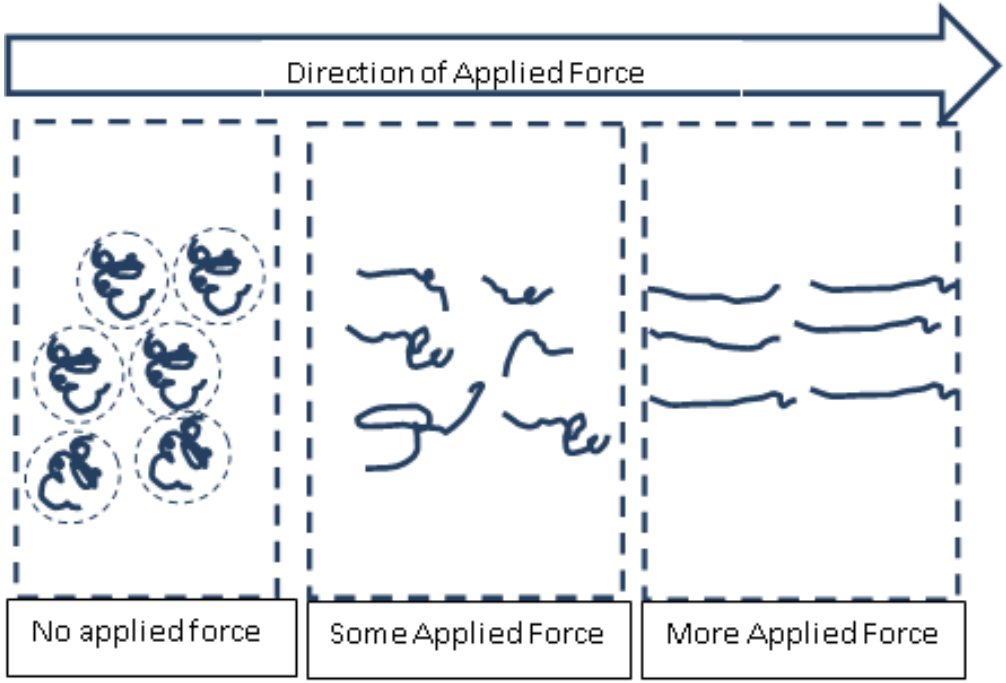
Watch the Kaye Effect video.

Kaye Effect

Polymers undergo a similar process if they are pushed too quickly. They go too quickly to keep their bulky original shape and are forced to stretch out.

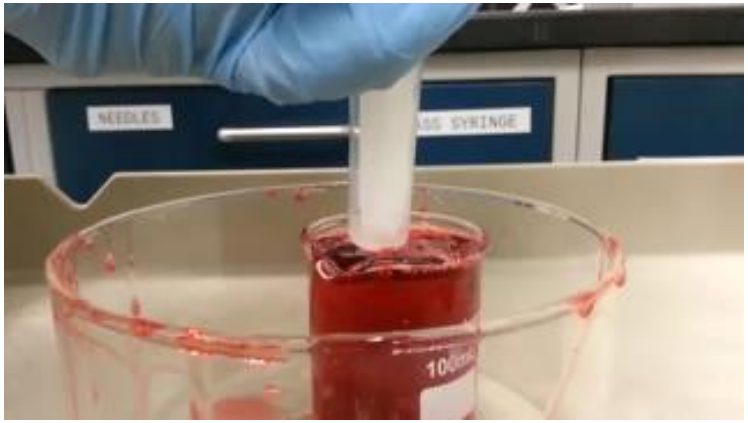
Kaye Effect

If it is easier to flow past each other, is the viscosity low or high?



“Anti-Gravity”

What if I told you that I could defy gravity?



What happened?

“Anti-Gravity”

How do the rubber bands relate to polymers?

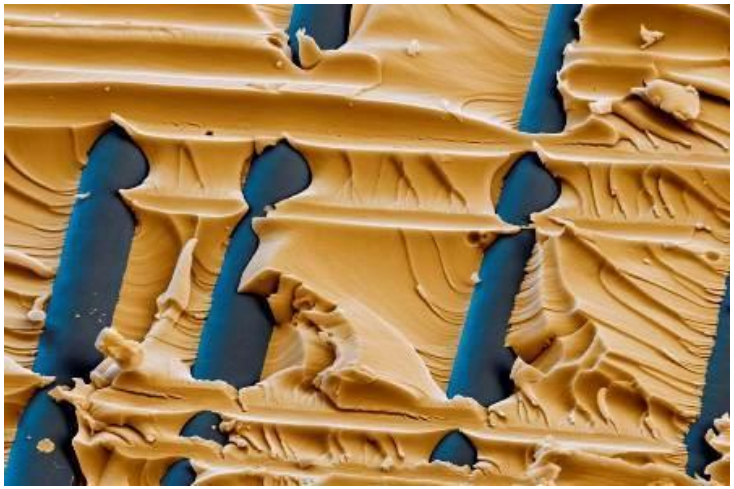
As the syringe pulls up polymers, the polymers already in the syringe pull up other polymers due to physical entanglements.

Thermosets and Their Uses

Thermosets are polymer systems that have gone through a curing reaction and are “set” in its final shape. A thermoset cannot be reshaped by heating.

Possible uses are?

Example Usage

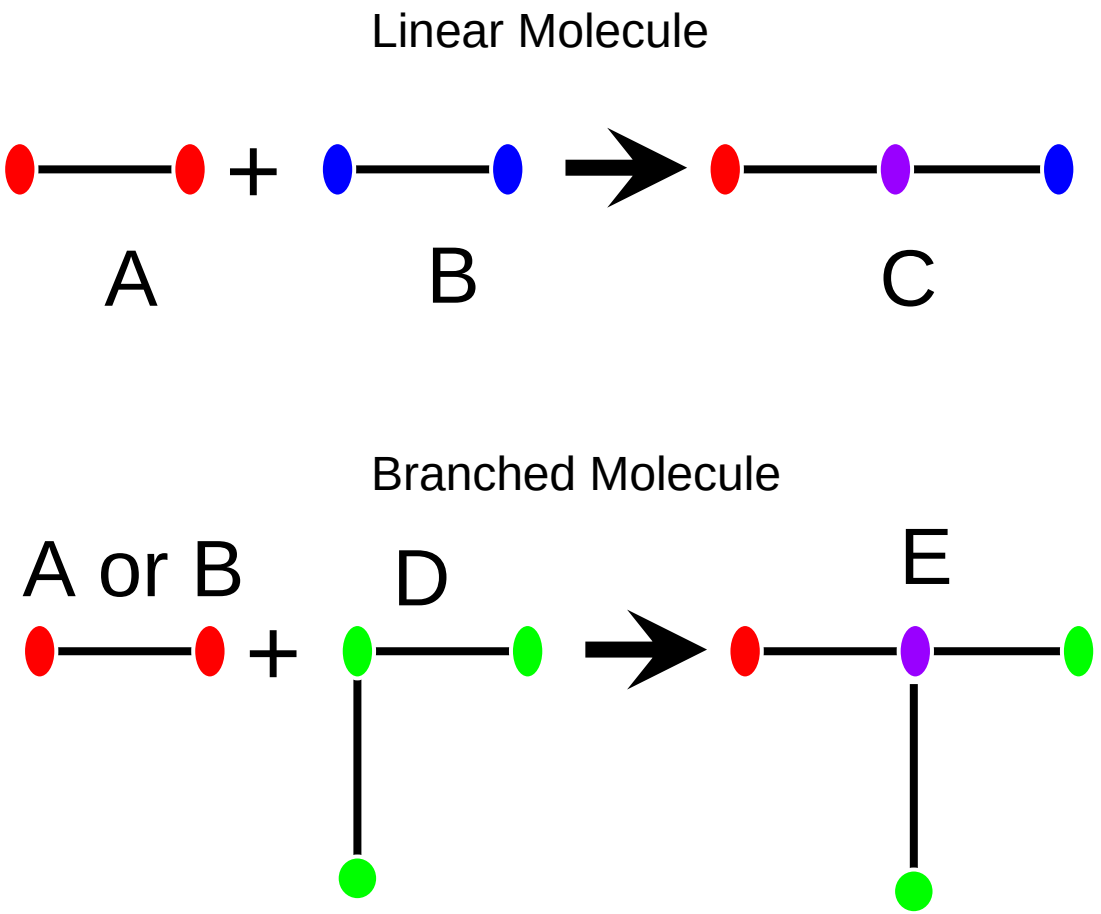


Close-up of an thermoset (Yellow) Fiber (Blue) composite

Possible end use of such a composite, the *Koenigsegg* super car

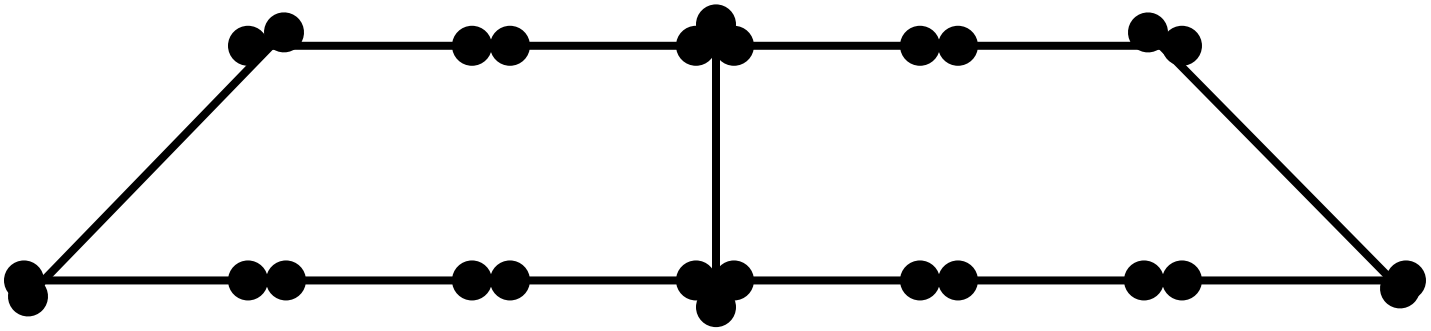
Chemical Bridges

By varying the ratio of Molecules. we can vary the number of Connections.

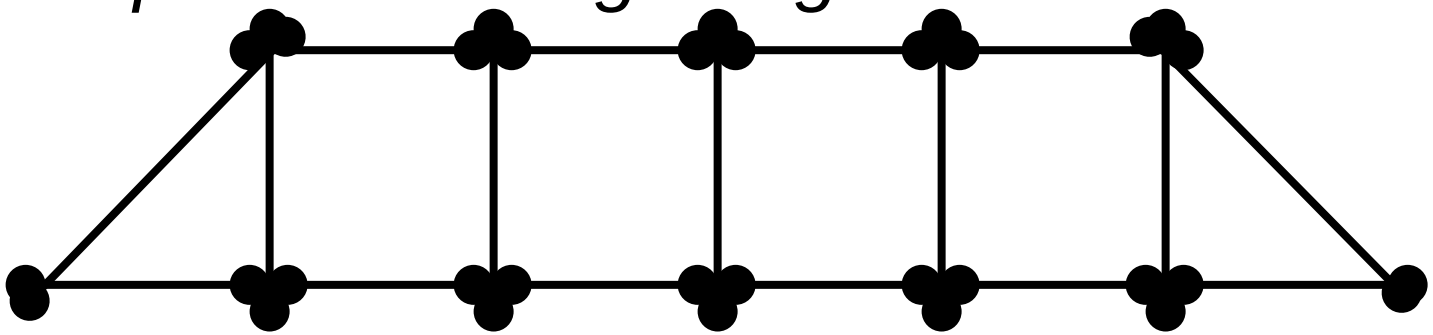


Classical Bridge

Example of a weak bridge



Example of a strong bridge



Chemical Bridges

Assume: Starting point is 500 A and 500 B

Discuss the extremes.

We exchange A molecules with D molecules

1 A for 1 D - Linear with branches

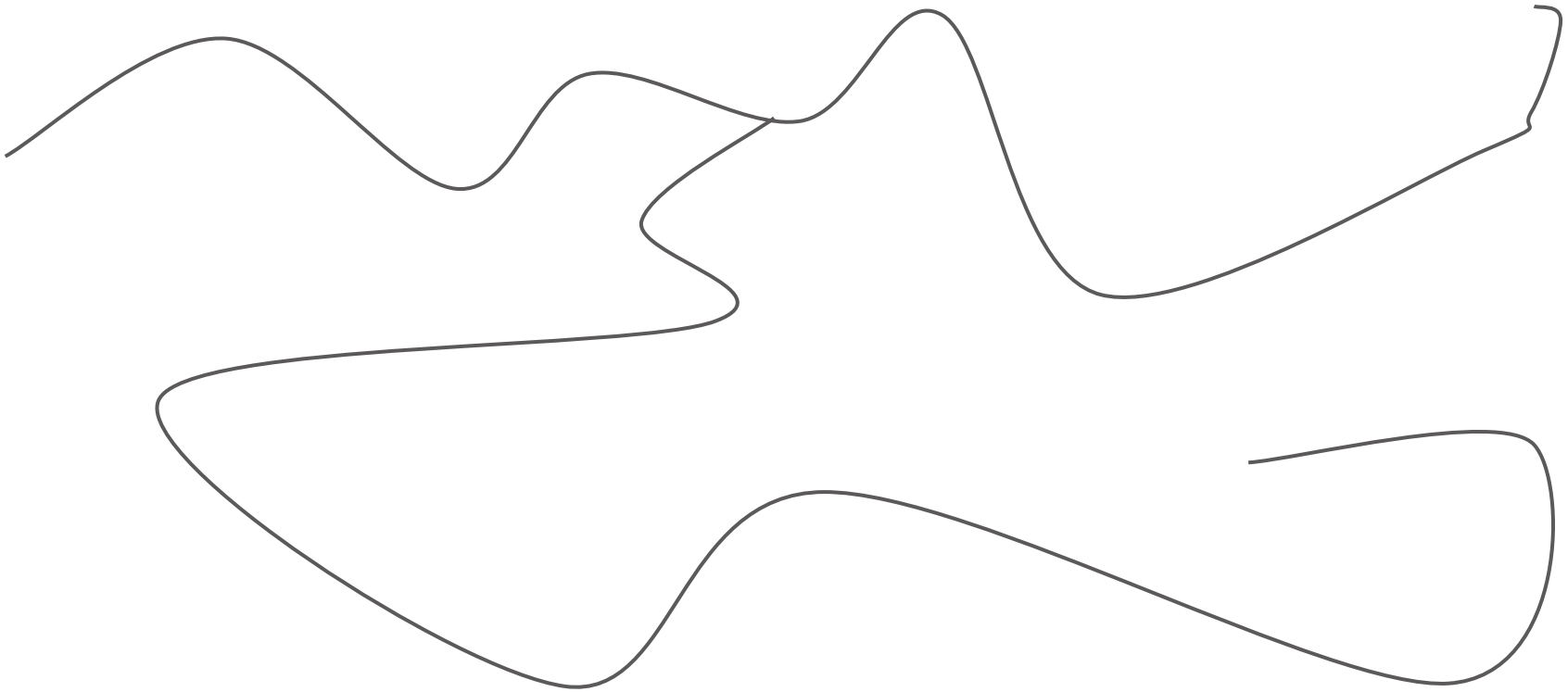
10 A for 10 D - A few more connections…

500 A for 333 D - (Stoichiometry)

500 A for 10000 D - (Loose ends)

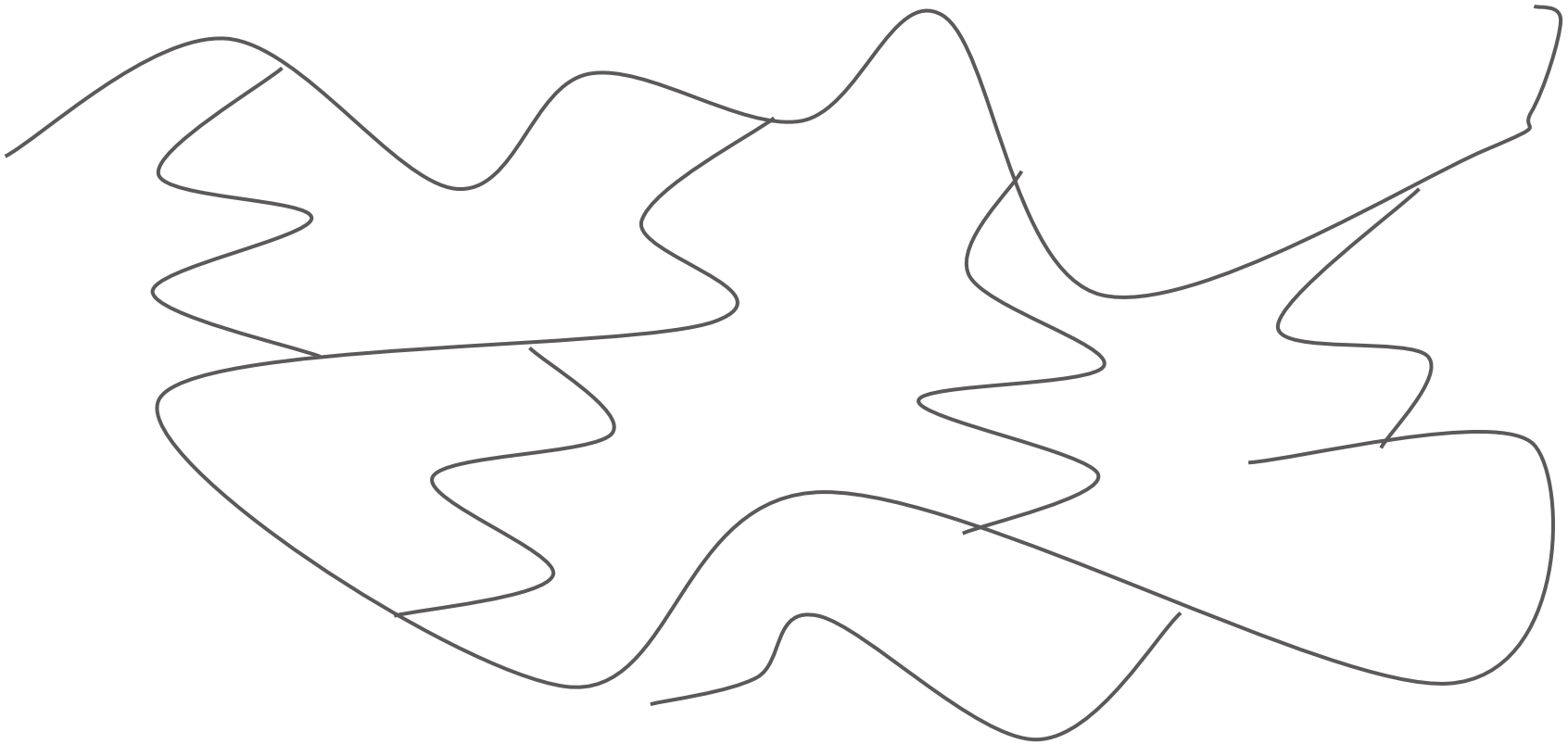
Chemical Bridges

We exchange 1 A molecules with 1 D molecules



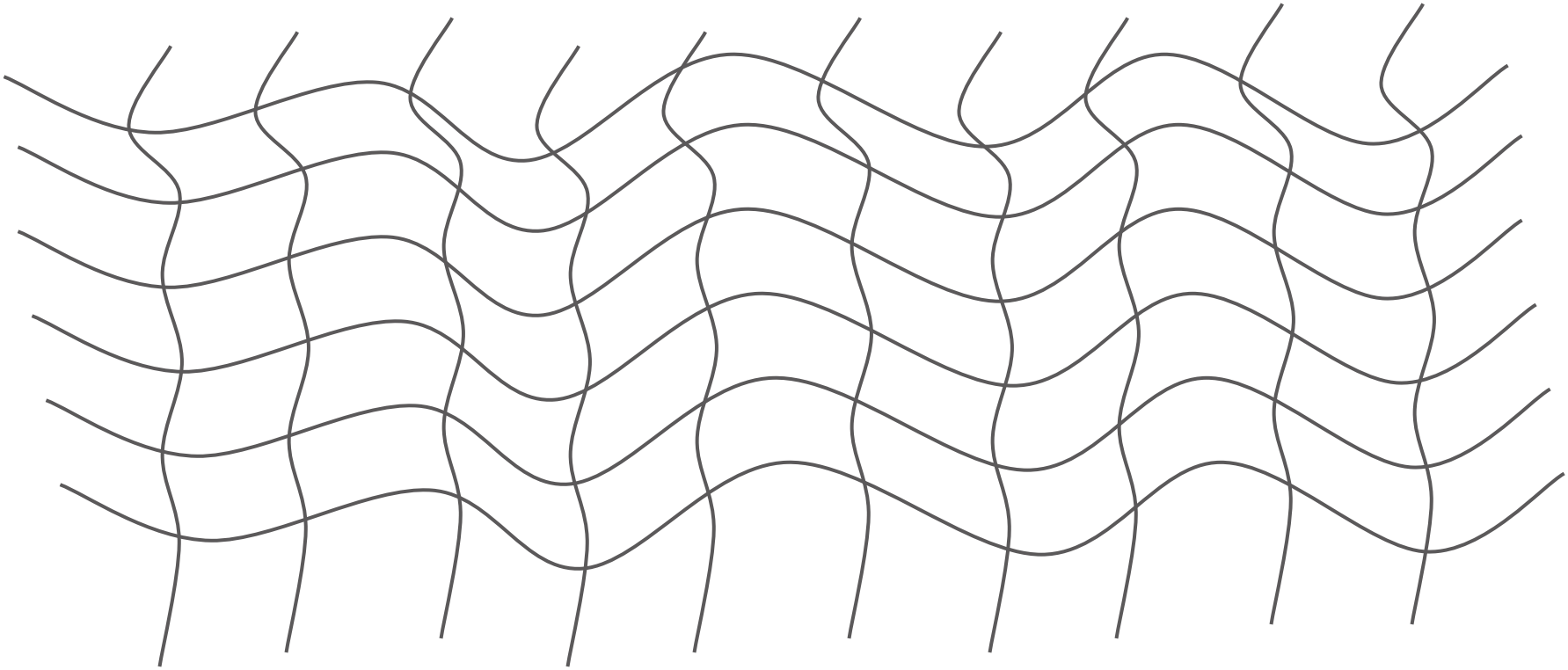
Chemical Bridges

We exchange 10 A molecules with 10 D molecules



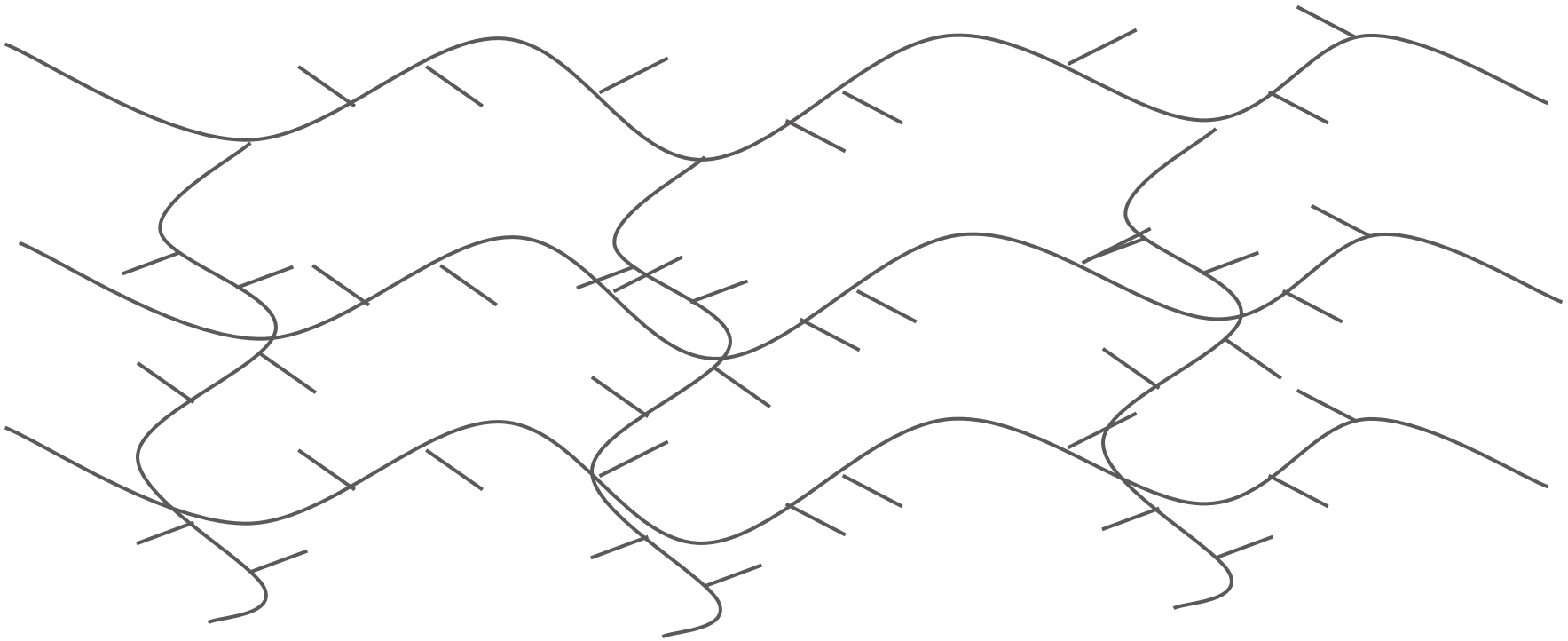
Chemical Bridges

We exchange 500 A (difunctional) molecules with 333 D (trifunctional) molecules



Chemical Bridges

We exchange 500 A molecules with 10000 D molecules



Chemical Bridges

Epoxy = Di-functional

Amine = Hexa-functional

We can manipulate the thermosets properties by varying the ratio of epoxy to amine.