Polymers: A Silly Polymer
Cross-Linking a Polymer to Create Everyone's Favorite Childhood Toy, Silly Putty

Objective: The objective of this experiment is to cross-link a polymer and observe the changes in the physical properties as a result of this cross-linking. The changes in physical properties of a cross-linked polymer are also studied as the temperature is varied.

Review of Scientific Principles:
If a substance springs back to its original shape after being twisted, pulled, or compressed, it is most likely a type of polymer called an elastomer. The elastomer has elastic properties (i.e., it will recover its original size and shape after being deformed). An example of an elastomer is a rubber band or a car tire. The liquid latex (Elmer's glue) which you use contains small globules of hydrocarbons suspended in water. The silly putty is formed by joining the globules using sodium borate (a cross-linker). The silly putty is held together by very weak intermolecular bonds that provide flexibility around the bond and rotation about the chain of the cross-linked polymer. If the cross-linked bonds in a polymer are permanent, it is a thermosetting plastic, even if above the glass-transition temperature (Tg). If the bonds are non-permanent, it can be considered either thermoplastic or an elastomer. Time: A 20-25 minute period is required to perform the mixing/making of the silly putty.

Materials and Supplies:

- 55% Elmer's glue solution in water
- 4% borax solution (sodium borate)
- Styrofoam cups
- zip lock bags
- food colors

General Safety Guidelines:
Since borax solid (a bleaching agent) and solution will burn the eyes. Be Careful!! Hands should always be washed after kneading the silly putty and finishing the experiment.

Procedure:

Pour 20 ml of the Elmer's glue solution into a Styrofoam cup. Add 10 ml of the cross-linker (borax solution) to each cup. Immediately begin stirring the solutions together using the wooden stick. After a couple of minutes of mixing, the silly putty should be taken out of the cup and kneaded in the hands. Don't worry about the material sticking to your gloves as these pieces will soon mix with the larger quantity with which you are working. Continue to knead until the desired consistency is reached. Using a ruler to measure, drop the ball from a height of 30 centimeters. To what height does it rebound? Stretch the silly putty slowly from each side. Compress the silly putty back into a ball.
Pull the silly putty quickly from each side and compare the results. Place the silly putty on some regular news print and press down firmly. Remove the silly putty from the news print and make observations. Repeat the same procedure on a comic section of the newspaper. The silly putty is non-toxic and safe to handle so you can put it in a zip-lock bag and take it home.

Follow good laboratory procedure and wash your hands with soap and water when you have finished the experiment.

**Data and Analysis:**

Height of the rebound _________ cm.
Observations of pulling the silly putty slowly:
Observations of pulling the silly putty quickly:
Observations of the silly putty on newsprint:
Observations of the silly putty on the comic's section of the newspaper:

**Questions:**

How do the physical properties of the glue, water mixture change as a result of adding the sodium borate?

What would be the effect (your thoughts) of adding more sodium borate solution?

What is the ratio of the height of the drop to that of the rebound distance?

Who in the class had the ball with the most elasticity?

How did you come to the conclusion of whose ball was most elastic?

At Home:
-Place your ball in the refrigerator for 10 minutes. Recheck the bouncing portion of this experiment.

What are your observations?

Why do you think this was observed?

-Now place your ball about 6 inches from a light bulb for about 5 minutes and again recheck the bouncing portion of this experiment.

What are your observations?

Why do you think this happened?
Explain the Following:

Why does a car tire appear to be flat in the summer even though the gas inside is hotter than in the winter.

Why does a basketball bounce differently inside a gym than it does outside on a cold wintry day.

Why will a tire sometimes bump during the winter as a car is moving, only to smooth out its ride after the car has been traveling for a distance.