Name: _____ **Date:** _____ **Class:** _____

Let's Make Silly Putty

Student Handout Answers

Design Challenge questions:

1) Did you redesign formulation 1 or 2? Please explain how you redesigned the formulation procedure?

   Examples of student's possible changes to the formulations used in the activity:

   I redesigned the procedure for formulation 1, we changed the polymer to cross-linking ratio from 2:1 and we changed to 1:1 ratio.

   We changed formulation 1 by only adding 5 mL sodium tetraborate.

   Formulation 2 was changed from 1:1:1, to keeping poly(vinyl alcohol) and sodium tetraborate the same as writing, but only adding 5 mL water.

2) Describe the material properties of the imitation silly putty made using your redesigned procedure. Is the formulation more or less rigid or elastic?

   Accept any answer that describes the material that was formed following the redesign of either formulation 1 or 2.

   Ex: Based on the changes that we made to the formulation, we produced a material that was really elastic (stretchy) or our material was brittle and did not stretch.

3) Are these material properties expected based on the changes you made to the original formulation procedure?

   Yes, we increased the presence of sodium tetraborate and create a more dense material.

   No, we made an adjustment to the procedure and our material did not perform as well as we would have liked, as it is really sticky.

4) How did your redesigned formulation 1 or 2 perform in the bounce or stretch test? Please include the exact distance in centimeters.

   Our material was not very stretchy (~ 30 cm), but it bounced much better at a best bounce of 20 cm.

5) How would you redesign your formulation further to improve your material properties so that your putty would perform even better in the design challenge test.

In order to improve the stretchiness of our material, we would have added less sodium tetra borate to reduce the degree of cross-linking,

In order to improve the bounciness of our material, we would have added more sodium tetra borate to reduce the degree of cross-linking,

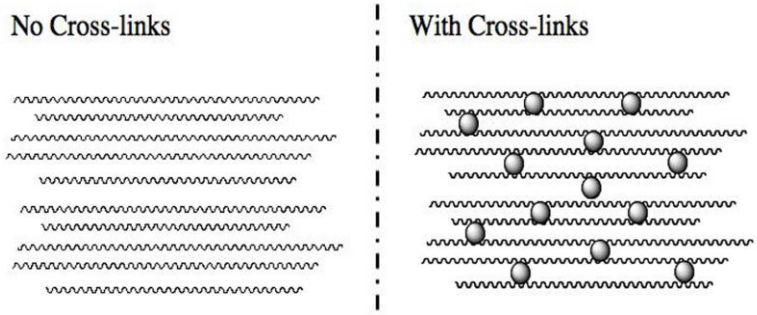
Note: If too much sodium tetraborate is added there will be too much water and the student material will be soupy or very sticky.

Questions:

1) How does the addition of sodium borate change the physical properties of the poly(vinyl alcohol) solution?

By incorporating sodium borate into the poly(vinyl alcohol) backbone, a covalent bond is formed. This bond links the polymer chains together, thereby creating a stretchy material.

2) Draw a schematic of a polymer that would be stretchy or one that would bounce well.



STRETCHY BOUNCY

3) Where can you find polymeric materials?

Polymeric materials are found everywhere and used for many applications.

4) Give an example of a commercial product that is made from a polymer.

Lots of potential answers. Accept any answers where students mention a material used in a commercial product and the chemical name. For example, Gatorade bottles are made from polyethylene.

5) In your own words, describe a polymer.

A polymer is a material that is made up of repeating monomer units.

6) What happens when a cross-linker is added to a polymer material?

A cross-linker forms a covalent bond between two polymer chains.

7) What are the physical properties you observed about saturated sodium tetraborate solution?

Sodium tetraborate appears as a clear solution with a white powdery solid at the bottom of the bottle. (Note: A saturated solution is made by adding a solid to a solvent until it reaches a 'saturation' point, where the solid can no longer be dissolved and solid remains as a precipitate.)

8) Prior to the experiment, what was your hypothesis for how the sodium tetraborate would affect the poly(vinyl alcohol) solution?

There will be a variety of different responses and all hypotheses should be accepted. Examples of student responses are below:
No, a clear colorless solution should have no effect on the poly(vinyl chloride).
Yes, the lesson explained that sodium tetraborate would chemically react with two chain of poly(vinyl alcohol) forming a chemical linkage between the two changes.

9) Do you think the cross-linking event is a physical or chemical reaction? Explain your reasoning.

A chemical reaction is taking place to form the chemical linkages between individual chains of poly(vinyl alcohol).

10) In your own words describe the differences in the material properties between formulation 1 as compared to formulation 2?

Examples of responses:

Formulation 1 is clear and dyed (student's choice of color). Depending on the degree of cross-linking achieved by stirring, this formulation tends to be more brittle, breaking into pieces more easily, but it can be made to bounce very high.

Formulation 2 is opaque and dyed (student's choice of color). This formulation tends to be stretchier and easier to manipulate than formulation 1.