**Introduction:**

Silly Putty is a classic toy which we all know and love. It is squishy and gooey and just plain fun! The putty can be formed and moulded into whatever shape imaginable. You can also make a bouncing ball! However, if the putty is left on the counter, it will become a puddle \( \oplus \). The original Silly Putty is an inorganic compound made of organosiloxy groups, however there are organic versions which are safe and non-toxic.

Safety and non-toxicity are two properties that are very important in a field called **Green Chemistry**. This subsection of the field allows researchers to make compounds which do not produce environmental pollution. The idea behind Green Chemistry is to prevent potential pollution sources. This also includes avoiding potential environmental contamination via spills, leaks and other types of accidents. By using environmentally friendly materials, the risk for contaminating the environment is substantially reduced if an accident should occur. It is for this reason that it is important to develop a green ideology and methodology when pursuing the synthesis of compounds (Lech, 2008).

In our experiment, we will be creating an organic version of silly putty by linking glue molecules of polyvinyl acetate or PVA together. The “connectors” will be Borax molecules. Figure 1 shows the linking portion of the reaction illustrated in our laboratory exercise. The reaction we are studying is called a **polymerization reaction** because many single units join to form a larger molecule. The new, larger molecule that formed is called a **polymer** (poly = many) because it is composed of many single units or **monomers** (mono = one).

![Figure 1. Polymerization of polyvinyl acetate with Borax.](image-url)
Safety:
- Even though the chemicals which are used are non-toxic, you should not consume the product
- Borax is a powder and an irritant, so ensure to avoid direct inhalation and contact with eyes.

Materials:
- Styrofoam Cup
- Ziploc Bag
- Paper Towel
- Food Colouring
- Container with Borax
- PVA Glue
- Water

Procedure:
1. Obtain a container with Borax per pair of students.
2. In your notebook, describe the physical properties of Borax.
3. Mix the Borax with water until it just dissolves. It is okay, if a few particles remain undissolved.
4. Pour the solution into a Styrofoam cup until it is approximately half to three quarters full. The remaining solution can be used by your partner.
5. Pick a food colouring which you would like your putty to be and add it to approximately a tablespoon’s worth of glue. You can use another Styrofoam cup to facilitate this.
6. Add your coloured glue to the Borax solution. It is okay if you are a little over or under. Try to use long strings of glue instead of one big glob.
7. Use your finger to mix the contents.
8. Mix until a rubbery substance forms. This can take up to five minutes depending on the amount of glue used.
9. When you are done mixing, take out your silly putty and dry it with a paper towel.
10. You now have your completed silly synthetic product! Ensure that you have recorded all observations that were made for the experiment by checking with your laboratory partner.
11. Dispose of liquids by first diluting with water and then pouring them down the drain. The other solid materials can be placed in the garbage.
12. If you would like to keep your silly putty, you can take it home in the Ziploc bag provided. Otherwise, return the silly putty to your teacher.
Discussion Questions:

1. What is the composition of the Original Silly Putty?
2. Why is Green Chemistry important?
3. What was significant about the Borax solution?
4. Why is the formation of our silly synthetic product considered a polymerization reaction?
5. What was the purpose of the addition of the Borax-water solution?

References:


Solutions:

1. U: What is the chemical name for Borax and what is the chemical formula?
   a. Na₂B₄O₇ • 10H₂O
   b. sodium borate, or sodium tetraborate, or disodium tetraborate

2. U: What is the composition of the Original Silly Putty?
   c. From introduction: organosiloxy groups
   d. Silly Putty is composed of 65% dimethyl siloxane (hydroxy-terminated polymers with boric acid), 17% silica (crystalline quartz), 9% Thixatrol ST (castor oil derivative), 4% polydimethylsiloxane, 1% decamethyl cyclopentasiloxane, 1% glycerine, and 1% titanium dioxide

3. U: What do you think would happen if an unsaturated solution of borax was used?
   e. Less viscous product

4. U/C: Why is Green Chemistry important?
   f. Answers may vary, consult introduction.

5. U/C: PVA is a monomer of vinyl acetate. Draw a single monomer of vinyl acetate. Hint: Vinyl is a C=C functional group.

   \[
   \begin{align*}
   &\text{vinyl acetate} \\
   &\text{O} \\
   &\text{O} \\
   &\text{C=C}
   \end{align*}
   \]

6. U/C: What was significant about the Borax solution? Hint: You used just enough water to dissolve the reagent
   h. Saturated solution of Borax

7. C: Why is the formation of our silly synthetic product considered a polymerization reaction?
   i. The reaction involves the linking of many individual units

8. C: What was the purpose of the addition of the Borax-water solution?
   j. Borax acts as the connector molecule.

9. U/C: What are the two functional groups that are reacting?
   k. The –OH (alcohol) group on Borax with the –C-O-C- on the PVA
Teacher’s Notes:
You can alter the procedure by varying the concentration of Borax

Chemistry:
Glue is made up of polyvinyl acetate, which reacts with water to some extent to replace some of the acetate groups with OH (alcohol) groups. The B-OH groups on the borax molecules react with the acetate groups on the glue molecules (relatively long polymer chains) to eliminate acetic acid and form new bonds between the borax and two glue molecules. The linking of two glue molecules via one borax molecule is called polymer cross-linking and it makes a bigger polymer molecule, which is now less liquid-like and more solid.

Real silly putty is an organosiloxane polymer that doesn’t have any water in it so it doesn’t dry out.
Silly Synthetics: Wrap-Up

Complete the following questions regarding the Silly Synthetics laboratory exercise.

Introduction:
What are three interesting points regarding this laboratory exercise?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Purpose:
In one or two sentences, write a purpose for doing this exercise.
________________________________________________________________________
________________________________________________________________________

Procedure and Observations:
Write how you performed the exercise in a numbered list and in the past tense. Also note any observations.
Examples:
1. I retrieved the materials for the experiment.
2. The glue was a sticky, white, opaque liquid with a slight bitter scent.
Continue…
3. 
**Discussion:**
Answer the discussion questions from the lab in the space provided.

**Conclusion:**
What did you learn from this lab?
# Marking Scheme

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