Title of Lesson Plan	The Exceptional Nature of Cellulose
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Grade Level(s)	High School Grades (10 – 12)
Keywords (subjects covered)	The Challenge of Converting Biomass to Energy
Brief Description	Extracting more energy from wood and agricultural biomass is a major challenge facing industrialists today. They seek to development a more efficient means to break down cellulose into simple sugars from which ethanol may be produced.
Total Time Required	1 block of 80 minutes
Setting	High School Chemistry laboratory classroom
Lesson Objectives/Goals	1. Students will observe the affect a substance's composition and structure have on its solubility. 2. Students will investigate the unique chemical nature of cellulose in comparison to other members of the carbohydrate family. 3. Students will compare the amount of energy required to dissolve monosaccharides and oligosaccharides with that required to dissolve polysaccharides. 4. Finally, a comparison of the nature of the solvents used to dissolve the members of these groups is made.
Materials Needed	distilled water lab apron food coloring hot plate bleach (Clorox) corn starch vegetable oil (Canola oil) beakers beaker tongs ethanol cotton balls sucrose glucose petroleum jelly (Vaseline) goggles flasks dropper pipette sodium hydroxide stirring rod
Standards Addressed	Know that the properties of a mixture depend on its composition. Declarative Knowledge: 1. The proportion of components in a mixture can be varied. Each component in a mixture retains its original properties.

	2. A solution is a homogeneous mixture of a solute dissolved in a solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, pressure and chemical natures of the solute and solvent. 3. An electrolyte is a substance which, when dissolved in water, forms a solution capable of conducting an electric current. The ability of a solution to conduct an electric current depends on the concentration of ions. Procedural Knowledge: 1. Apply the adage "like dissolves like" to real- world situations. 2. Classify substances as strong electrolytes, weak electrolytes, or non-electrolytes, based on lab tests, bond type and solution concentration.
Procedure	Miscible and Immiscible Liquids (Similar and Dissimilar Liquids) 1. Pour 50 mL. of distilled water into a 250 mL. beaker. Then add five drops of a food coloring to it and stir. Observe and descriptively record what type of mixture results. 2. Add 50 mL. of vegetable oil, slowly, to the water. Observe and descriptively record what type of mixture results. 3. Using a dropper pipette add 50 mL. of ethanol, dropwise, to the mixture. Or, add the ethanol in a slow but constant stream down the wall of the beaker. Observe and descriptively record what type of mixture is present in the beaker. 4. Pour this mixture into another 250 mL. beaker and back into the original 250 mL. beaker. Repeat this step, three to five times, to achieve thorough mixing of all parts of the total mixture. Observe and descriptively record what type of mixture results.

Procedure con't.	5. Describe any changes that took place. Explain why the changes occurred. Dissolving Solids in Like Liquids 1. Prepare the following solutions in different 250 mL. beakers: A. Place 1 g. of glucose in 50 mL. of H_2O and gently stir. Observe and descriptively record what type of mixture results. B. Repeat this step making a solution of 1 g. of sucrose in 50 mL. of H_2O and gently stir. Observe and descriptively record what type of mixture results. **Teacher Demonstration Portion – (only to be done in a fume hood)** A. Place 1 g. of cornstarch into 50 mL. of bleach. Heat the mixture to 90 °C. Then allow to cool. Have students repeat this step with 1 g. of cornstarch in H_2O and compare their results with those received with the glucose and sucrose solutions. Students should explain their results. B. Place 0.5 g. of cellulose (cotton balls) into 100 mL. of bleach, then slowly add 100 mL. of 2.5 M. NaOH (aq) using a dropper pipette. Heat the mixture to 90 °C. Then allow to cool. Repeat this step with 1 g. of cellulose (cotton balls). C. Qualitatively discuss the solubility of cellulose and how its structure affects its solubility. Have students experiment with 0.5 g. of cellulose in 200 mL. of H_2O and compare their results with those received with the glucose and sucrose solutions. Students should explain there results.

	D. Place 100 mL. of vegetable oil in a 250 mL. beaker and 100 mL. of distilled H_2O in another 250 mL. beaker. Add 5 g. of petroleum jelly (Vaseline) to both beakers, stir and heat both on a hot plate to no more than 80 °C. Have students discuss the results of this experiment and explain the solubility of the petroleum jelly (Vaseline) in both liquids in light of the chemical composition and structure of oil, water and petroleum jelly (Vaseline).
Assessment	Conclusion Questions: 1. What patterns of dissolution between solvents and solutes do you notice? 2. Why doesn't cellulose dissolve in pure water like glucose and sucrose? 3. Draw the structural formulas for glucose, sucrose, cellulose, a fatty acid (oleic acid) and a long straight chain hydrocarbon like decane. 4. Define the terms: saturated, unsaturated and supersaturated. 5. Describe all of the mixtures made in this activity as homogeneous or heterogeneous. 6. What is the difference in structure between cornstarch and cellulose molecules? 7. What characteristic of a solute will best determine its solubility in a given solvent? 8. Which substances require more energy to be dissolved mono- and oligo- saccharides or polysaccharides? Why? 9. Which group of carbohydrates required more ionic character in the solvent to dissolve mono- and oligo- saccharides or polysaccharides? Why? 10. Consider some reaction conditions which might facilitate the break down of cellulose to simple sugars? 11. Would achieving this enable us to use wood and

	agricultural biomass “waste” to generate energy? How?
Literature Cited/References	1. Chemistry: the central science/ Theodore L. Brown, H. Eugene LeMay, Jr., Bruce E. Bursten; with contributions by Julia R. Burdge – 9th ed. 2. “Biomass for Energy and Forest Fuel Reduction”. Eco-Link. Temperate Forest Foundation. Vol. 13, Number 3. Beaverton, Oregon: Temperate Forest Foundation, 2003.
Forestry Tour Attended	2007 Northeastern Forestry Teacher Tour