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DEMO ON HYDROGEN BONDING

Maria Vlassi[1], George Korakakis[2] and Alexandra Lymperopoulou-Karaliota[1]

[1]Department of Chemistry, University of Athens
Panepistimioupolis Zografou, 15771, Athens / Greece
mvlassi@yahoo.com, akaraliota@chem.uoa.gr
[2] School of Chemical Engineering, National Technical University of Athens
9, Heroon Polytechniou Street, Zografos Campus, 15780, Athens / Greece
gkor@chemeng.ntua.gr

Abstract

In this study we present a demonstration on hydrogen bonding during the polymerization of collagen in the jelly. The students can observe through the microscope how the gelatin grains interact with water and how these grains are connected together due to the hydrogen bonding in order to produce the polymer. The key frames of the video that was captured from the microscope demonstrate the existence of these intermolecular forces.

Keywords - First-Year Undergraduate / General, Demonstrations, Intermolecular forces, Hydrogen Bonding, Polymerisation, Proteins / Peptides.

1 INTRODUCTION

The effect of intermolecular forces has been explored in a number of chemistry experiments. The common topics include melting and boiling points, vapor pressure and enthalpy of vaporization, surface tension, viscosity and acid ionization. [1] Important applications of intermolecular forces are in various chromatographic separations. [2, 3] In another experiment, the "hydrophobizing" and organophilic properties of silicones are examined. [4] Crystals of naphthalene form on the surface of an acetone solution and dance about in an animated fashion illustrating the intermolecular forces. [5]

The DNA double helix provides a beautiful and easy to understand example of how intermolecular forces combine to determine macromolecular structure. [6] Hydrogen bonding, which is one kind of these forces, has many applications in all areas of chemistry. Chemistry students need to be able to analyze situations where hydrogen bonding can occur in order to understand reaction mechanisms, many physical properties, solubility, molecular interactions, and some spectroscopic information. [7-8]

There are many excellent laboratory experiments, activities and demonstrations especially for hydrogen bonding. [9-13] In a laboratory exercise the students compared the powerful of the hydrogen bonds in maleic and fumaric acid. [1] The strength of these bonds are also demonstrated when a 12-oz aluminum soft drink filled with ammonia or hydrogen chloride gas is inverted and dipped into water, the rapidly dissolving gas evacuates the can and the can is crushed before water can be drawn into it. [14]

A computational experiment is reported for the organic chemistry laboratory that allows students to estimate the relative strengths of the intramolecular hydrogen bonds of usnic and isousnic acids. [15] Velcro-Polarized Molecular Models were used to illustrate the unique characteristics of weak intermolecular interactions, specifically hydrogen bonds. [16, 17]

In this study we present a demonstration on hydrogen bonding during the polymerization of collagen in the jelly. The attending audience for this demonstration is undergraduate students who can observe through the microscope how the gelatin grains interact with water and how these grains are connected together due to the intermolecular forces in order to produce the polymer.

2 BACKGROUND INFORMATION

The main ingredient of jelly is gelatin, which consists of collagen molecules. Each one of its molecules consists of three polypeptide chains stratified in such a way that form a triple helix. As far as its structure is concerned, collagen is characterized by a high percentage of certain amino acids and in particular glycine and proline. The amino acid sequence is such that every third amino acid is glycine.

This frequent presence of this amino acid is caused by the fact that it occupies a small space and therefore it allows the polypeptide chains to come closer to each other. The triple helix is stabilized by hydrogen bonds developed from the NH group of a glycine, to the C=O group of proline or another amino acid of an adjacent strand. [18] When collagen is processed with warm water and acid, all the weak bonds break. The product (gelatin) is soluble, and contains, except from the proteins, approximately 12% water. When cold water is added to gelatin, it swells due to the absorption of a significant volume of water. The protein molecules, in which gelatin exists in the form of sheets in a zigzag pattern, after the absorption of water form a three-dimensional lattice that is detected as gelatin expansion. [19]

3 PROCEDURE

A school microscope, gelatin grains, ethanol 95 vol, water and solid indigo carmine are required for the experiment. (Methyl blue can be used instead of indigo carmine).

Indigo carmine has blue colour below pH 11.4, so it is used as a soluble pigment. For the soluble pigment's preparation, dissolve 0.01g of the solid indigo carmine in 20 mL of water. This pigment dyes gelatin and water as a large number of hydrogen bonds are formed between the indigo carmine and the collagen and water molecules.

4 DEMONSTRATION

Place 4 of 5 gelatin grains on a microscope slide. Focus on the grains using magnification of 50X Add a drop of the soluble pigment on the grains. Observe the dissolving of the outer surface of the grains and their approaching movement due to the attractive forces in order to form the polymer. The key frames of the video captured by the microscope are shown in Figure 1.

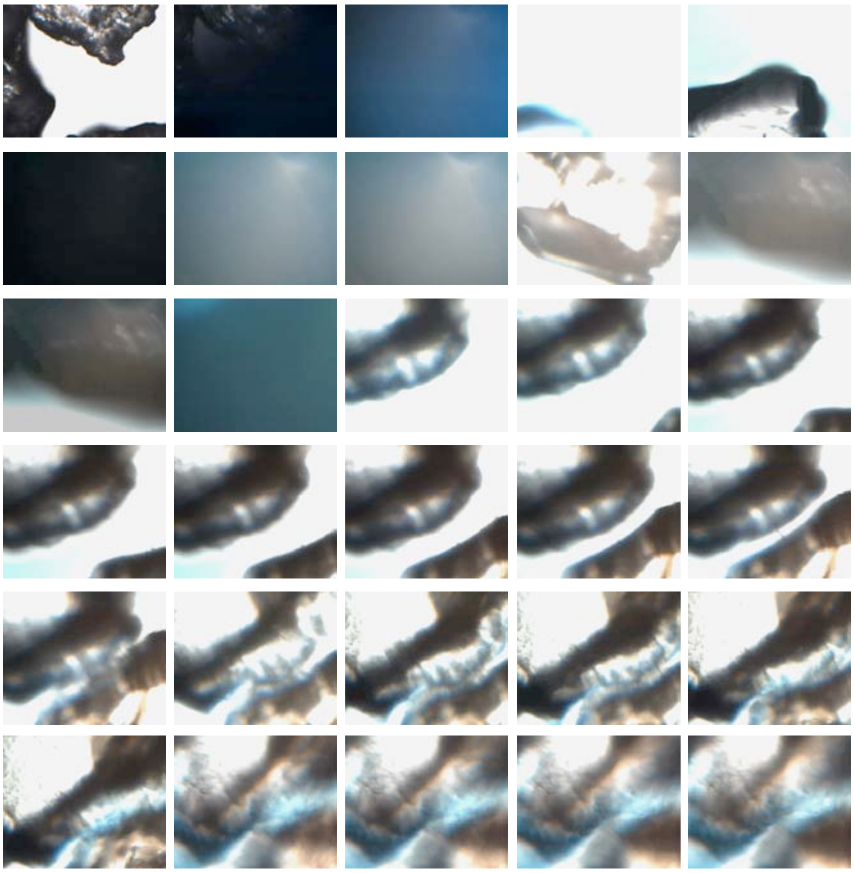

Fig. 1 The key frames of the video that demonstrate the combination of the grains.

This demonstration can be shown through a video projector if the microscope includes PC eyepiece with USB connection. The observation of the gelatin formation is more visible if the pigment solution is replaced by 1:1 ratio mixture of the pigment solution and ethanol 95 vol. The surface of the grains dissolves and the aggregates molecules of collagen are moving rapidly to the bigger grains (Figure 2).

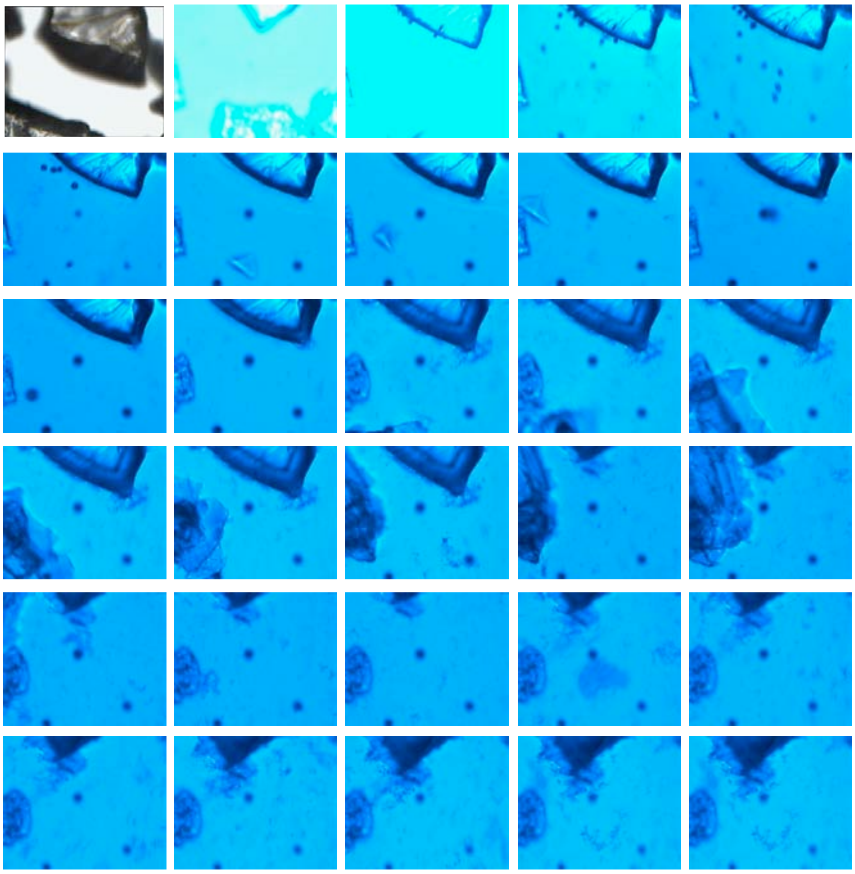

Fig. 2 The key frames of the video that demonstrate the formation of aggregates molecules of collagen with the presence of ethanol.

5 EXPLANATION

The molecules of the water soluble pigment are interacted with collagen molecules with hydrogen bonds. The colour of the pigment is getting dark blue at the points that the above interactions are stronger. The approach of the gelatin grains is attributed to these strong attractive forces.

Water has two hydrogen atoms and two oxygen lone pairs per molecule; thus each water molecule has four possible hydrogen-bonding sites. Ethanol, in contrast, has only a single polar O-H group, allowing just three possible hydrogen-bonding sites per molecule. [20] As a result, collagen is more soluble in the water than in the ethanol due to the less number of hydrogen bonds between the collagen and the ethanol molecules. The collagen molecules are obliged to move rapidly to the more polar water, so that the formation of the polymer to be more visible.

6 CONCLUSION

Even though the theoretical background of the collagen polymerization requires advanced undergraduate knowledge, the above demonstration can be also illustrated to 11th and 12th grade high school students. At that level the students are introduced in basic concepts about the hydrogen bonding and the other forms of intermolecular forces. They are also taught about the structure of the proteins and the nature of peptidic bonds in biology course.

7 HAZARDS

Indigo carmine is harmful to the respiratory tract if swallowed. It is also an irritant to the skin and eyes. Proper laboratory cautions (Lab coat, gloves, goggles) are advised.

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