

Effects of Temperature on Ultrasonic Velocity of Gelatin Solutions

Changfei Zhu¹ Jinrui Su² Suwen Liu³ Wei Liu¹ and Zhengang Zhu^{2, 1} *Lab. of Internal Friction & Defects in Solids, Univ. of Science & Technology of China, ²Institute of Solid State Physics, Chinese Academy of Sciences, ³Chemical Physics Dept., Univ. of Science and Technology of China, Hefei, PRC*

Abstract

Longitudinal ultrasonic velocity of aqueous gelatin on different concentrations were measured at the temperature range of 30°C~90°C. All the curves conform to parabola. The ultrasonic velocity of gelatin is larger than that of deionized water and increases with concentration. Molecular weight of gelatin plays an less important role in ultrasonic velocity of gelatin solution than concentration. According to these ultrasonic properties of aqueous gelatin, the interaction between gelatin and water molecules were discussed.

Introduction

Gelatin is a biopolymer which has been widely investigated in the past because of its important applications in pharmacology, food, cosmetic, and other different fields¹. Previous experimental methods include static and dynamic light scattering, wide-angle x-ray scattering, electron microscopy, nuclear magnetic resonance, etc.¹⁻⁴ Although great progress has been made in studies on sol-gel transition of gelatin, structure of gelatin chains and other mechanical properties of gelatin, it is still not very clear that how gelatin molecules interact with the solvent water. In recent years, the measurements of ultrasonic parameters in liquids has been used for the studying of molecular structure and other physical properties, some authors had been tried to understand the role of macromolecules in living organisms by investigating the interactions between solute and water using ultrasonic method⁵⁻⁶. In this paper, we measured ultrasonic velocity of aqueous gelatin during heating and cooling process over the temperature range of 30°C~90°C, and made some discussions about the interaction between gelatin and water molecules.

Experimental

Gelatin samples for the experiments were produced by Qinghai Gelatin Factory. Its molecular weight distribution is showed in Table 1. The aqueous gelatin solutions were prepared by first dispersing the gelatin granules in deionized water for about one and a half hours at room temperature, then put the soaked granules in water-bath about 50°C with stirring for 20 minutes to make it dissolved completely. After that, the solution was cooled in air to room temperature. At last, it was put in refrigerator at 5°C for 14 hrs.

Temperature in experiment was controlled by water-bath, using thermopair with accuracy $\pm 0.1^\circ\text{C}$. The heating rate was about $0.25^\circ\text{C}/\text{min}$. Ultrasonic velocity was measured by a conventional pulsed spectrometer (Matec 7700 Series) using Pulse Echo Overlap method with relative accuracy 0.01%. The frequency of the ultrasonic wave was 5Mhz.

Table 1. Molecular weight distribution of gelatin

α_p	$\alpha_1 + \alpha_2$	β	γ	$\gamma\gamma$
14.9	48.4	18.8	8.1	9.8

Results and Discussions

Longitudinal ultrasonic velocities of four different concentration aqueous gelatin solutions concentration were measured. The ultrasonic velocity-temperature curves are shown in Figure 1. We found that all the curves conform to parabola, just like that of deionized water. This result is consistent with some others' work. The curve can be expressed as

$$V_T = V_m - A(T_m - T)^2$$

where A is a constant, V_m is the maximum ultrasonic velocity, T_m is the temperature at V_m . The relationship between these parameters and concentration is listed in Table 2. According to Table 2 and Figure 1, it is clear that V_m increases with concentration, while T_m decreased with concentration.

Table 2. The relationship between ultrasonic parameters and concentration of gelatin solutions

C(wt%)	0	6	8	12	16
$V_m(\text{m/s})$	1555.2	1567.6	1572.8	1577.2	1583.5
$T_m(^\circ\text{C})$	71.1	69.2	66.3	68	62.7
A	0.02				

For an ultrasonic wave transmitting in a liquid with density ρ , its ultrasonic velocity can be written as

$$V = \sqrt{\frac{1}{\rho\beta}}, \text{ where } \beta \text{ is isothermal compressibility.}$$

In liquids, the temperature dependence of ultrasonic velocity mainly due to the temperature dependence of isothermal compressibility. Compressibility relate to mole-

cular compression (may be considered instantaneous) and structural compression, which is relaxational comparable with the applied pressure⁷. Water has been characterized as having a broken-down ice-structure, this structure is maintained by intermolecular hydrogen bonds, consisting principally of strong dipole forces. The structure can differ on some extent while at different temperature. The molecular compression should increase with temperature according to thermal expansion of the liquid and structure changes. However, the structural compressibility should decrease due to the breaking of hydrogen bonds with the temperature increases. The density of water will decrease a little while temperature increases. According to the presence of increasing components and decreasing components, the ultrasonic velocity of water increases to a maximum then decreases, the ultrasonic velocity-temperature curve can be fit for a parabola.

Gelatin is denatured collagen, its average molecular weight is about one hundred thousand. The gelatin chains are believed to be in the coil conformation while in its aqueous solution. The main interaction forces between gelatin molecules in its solution come from covalent bonds, hydro-gen bonds and electrostatic attraction, etc. In this associated liquids, ultrasonic velocity must be temperature dependent.

The huge amount of amino acid residues on the gelatin chains exist in the dipolar form and have a stronger interaction with the water molecules, then the increasing electrostrictive compression of water around the gelatin molecules results in a larger decrease in the compressibility of solutions. So, the ultrasonic velocity of aqueous gelatin is larger than that of water, and increases with concentration. We noted that T_m decrease with concentration increasing, this can be easily understand from the fact that the ultrasonic velocity increase with concentration.

As we know, heating can lead to the break of covalent bonds of gelatin molecules and result in an irreversible decrease of molecular weight. In order to investigate the effect of molecular weight of gelatin on ultrasonic velocity of aqueous gelatin, a cooling process after heating to 90°C for a sample of 6% wt was measured (showed in Figure 2). It can be seen that ultrasonic velocities during cooling process are slightly smaller than previous heating process. When temperature rises, hydrogen bonds, peptide bonds and other interaction would be changed. One type of bonds such as hydrogen bonds and electrostatic interactions can be easily recovered while the temperature decrease again, while another type of bonds can't be recovered even the temperature change to the same as before. From Figure 1. and Figure 2, we concluded that molecular weight of gelatin has some influence on ultrasonic velocity in gelatin solution, but concentration play a more important role in the ultrasonic velocity. These results indicated that the change of ultrasonic velocity in aqueous gelatin is mainly due to the interaction between gelatin molecules and bound water.

In conclusion, according to our experimental results, we believe that the interaction between gelatin molecules and water play an important role in the experimental process. Lots of amino acid residues of gelatin molecules

have stronger interaction with water, this lead to a decrease of compressibility and a increase of ultrasonic velocity of solution. Meanwhile, the ultrasonic velocity increases with concentration of gelatin solution, the maximum ultrasonic velocity move to lower temperature while concentration increase.

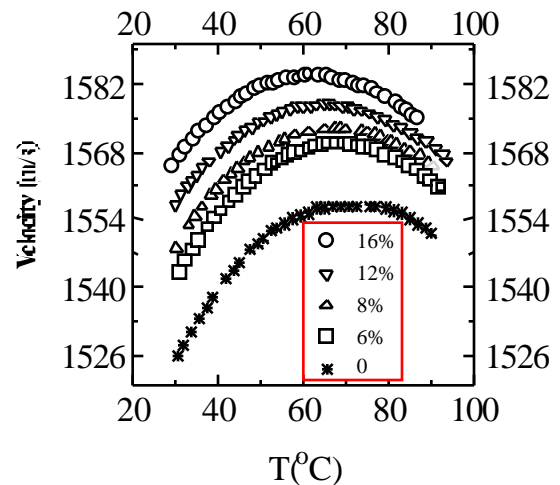


Figure 1. Longitudinal ultrasonic velocity of aqueous gelatin for different concentration

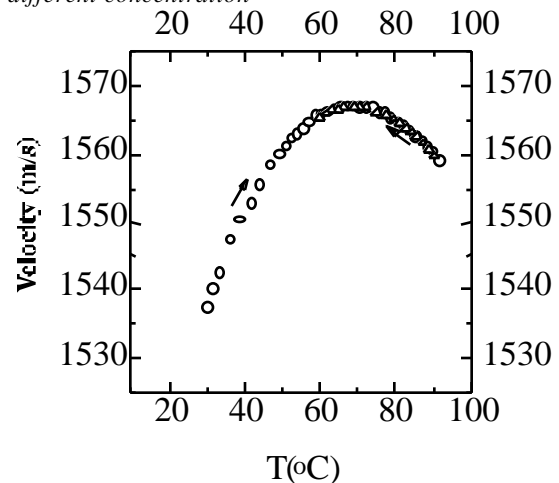


Figure 2. Longitudinal ultrasonic velocity of aqueous gelatin during temperature increasing and decreasing process

References

1. Madeleine D.B, Jacques L.B. and Pierre P.P, *J. Phys.France.*, **48**, 319-332(1988).
2. Bot A, Scham R.P.C and Wegdam G.H, *Colloid Polym.Sci.*, **273**, 252-256(1995).
3. S.Z. Ren and C.M.Sorensen, *Physical Review Letters.*, **70**, 11,1727-1730(1993).
4. M.Itoh, Y.Okawa, etc., *J. Photogr. Sci.*, **42**, 14-17(1994)
5. M.Alagar, M. Ponnasamym and Krishnasamy V, *Ultrasonics.*, **28**,386-390 (1990).
6. Wang J, and Feng R, *Ultrasonics.*, **28**, 37-39(1990)
7. Leonard H, *Physical Review.*, **73**, 775-781 (1948).