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Radiation Chemical Studies of Protein Reactions: Effect of Protectors against Radiation

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Synopsis

Sodium glutamate and sodium benzoate were found to protect protein reactions from radiation damage. The behavior of the viscosity changes was determined. The experimental equation for the protective effect is given by $\eta_{red(\infty)} = a(\log X)^2 + b(\log X) + c$, where $\eta_{red(\infty)}$ is the reduced viscosity of the solution at infinite time, X is the concentration of the radiation protectors, and a, b, and c are adjustable constants.

Introduction

It is well known that some amino acids (such as cysteine) and some benzene-series hydrocarbons (such as sodium benzoate) protect protein molecules from radiation damage.[1–4] Sodium glutamate being a well-known salt of amino acid, it was thought desirable to see, first, whether it showed such a protective property and, second, since the problem is one of general interest, what would be the effect of its concentration on protein reactions.

The urea denaturation of protein was selected as the protein reaction, since it was described in a previous paper.[5] The determination may be followed conveniently by measuring the reduced viscosity of the solutions as a function of the concentration of the protector.

Experimental

The sodium glutamate used in this work was a commercial material produced by Kanto Chemical Co., Inc. The sodium benzoate was a commercial material produced by Koso Chemical Co., Ltd. The albumin and urea were the same as those described in a previous paper.[5]

The irradiation source contained about 300 curies of ^{60}Co. The dose rate in this work was 1.7×10^3 r./hr. The irradiated solid albumin was dissolved with distilled water and mixed with the urea solution containing the protector. Then the viscosity was measured.

Results

The changes, with time, in reduced viscosity of albumin and protector (sodium glutamate or sodium benzoate) were studied with 3% albumin in 10M urea, 10^3 r., and 30°C.

The results are shown in Figures 1 and 2. It is clear that the reduced viscosity does not go to an infinite value but approaches a limiting value with increasing percentages of protector. The initial decrease, the subsequent minimizing, and the final increase in the reduced viscosity indicate that in the minimizing of the reduced viscosity at infinite time the most efficient protective effect shows in the denaturation of protein. When the reduced viscosities at infinite time shown in Figures 1 and 2 are plotted against the percentage of protector, the relationship shown in Figures 3 and 4 is obtained. From these it is clear that the effect of the protector

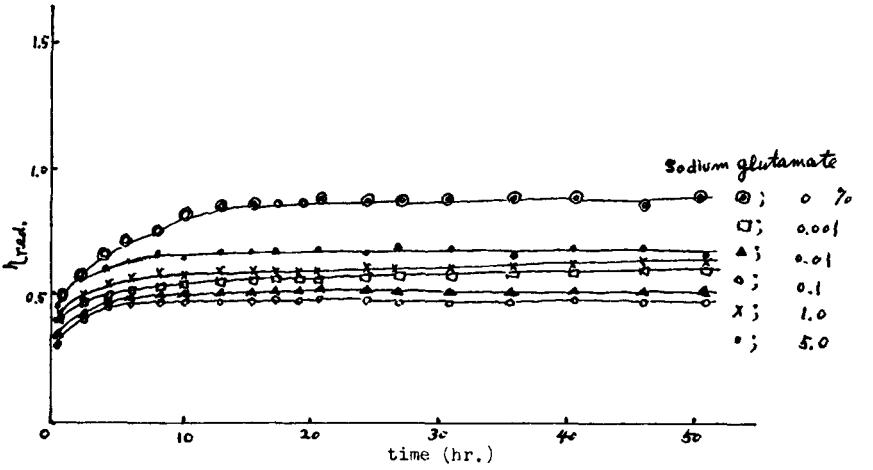

Fig. 1. Reduced viscosity versus time: 3% albumin in 10M urea, 10^3 r., and 30°C., in the presence and in the absence of sodium glutamate.

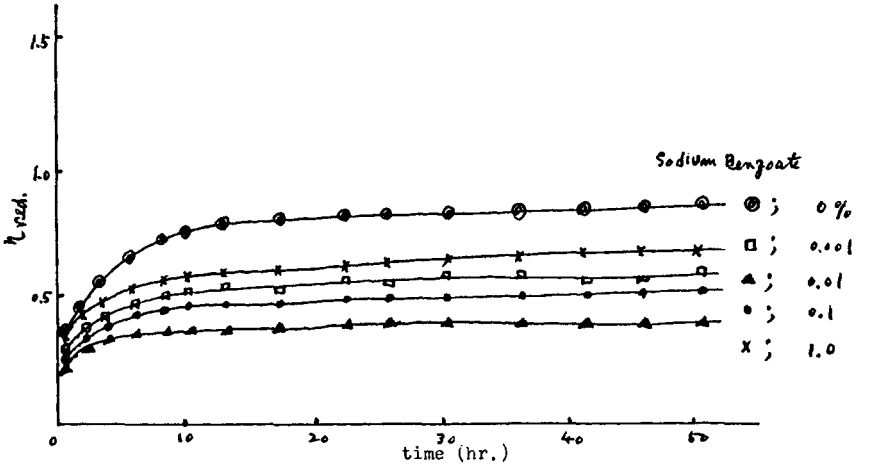

Fig. 2. Reduced viscosity versus time: 3% albumin in 10M urea, 10^3 r, and 30°C., in the presence and in the absence of sodium benzoate.

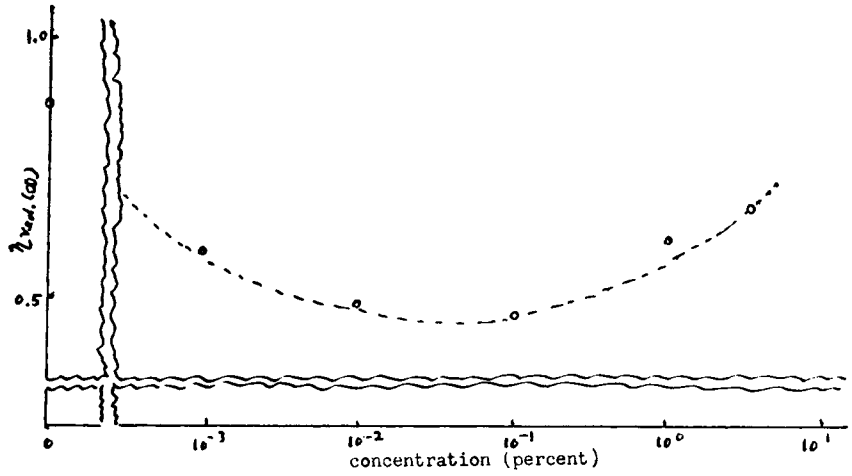

Fig. 3. Dependence of protective effect on concentration of sodium glutamate; 3% albumin in 10*M* urea, 10^3 r., 30°C.

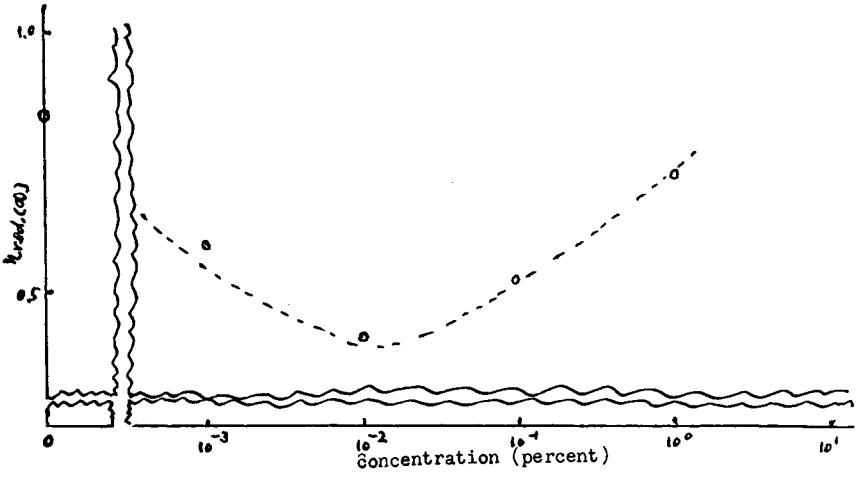

Fig. 4. Dependence of protective effect on concentration of sodium benzoate; 3% albumin in 10*M* urea, 10^3 r., 30°C.

on the viscosity change is apparently related to its inhibition of the denaturation of the protein.

Discussion

As stated above, it is known that some amino acids (such as cysteine) and some benzene-series hydrocarbons (such as sodium benzoate) protect protein molecules from radiation damage.[1–4] A discussion of the effects of concentration of sodium glutamate and of sodium benzoate on the protective action in a protein reaction follows. The protein reaction is esti-

mated from the change in viscosity this change is given in Figures 1–4. The relation between the change in viscosity and the concentration of the protector is related to that between the protein reaction and the protective reaction. When the concentrations of protein and of urea and the radiation dose all are constant, a change in the concentration of protector results in the change in viscosity required for protein reaction; see Figures 3 and 4. The reaction mechanism must, therefore, depend on the concentration of the protector. If the main processes in the protective action are assumed to be

$$\mathrm{P{-}P} \xrightarrow{h\nu} \mathrm{P^*} + \mathrm{P^*} \tag{1}$$

$$\mathrm{P^*} + \mathrm{P^*} \rightarrow \mathrm{P{-}P} + E_a \tag{2}$$

$$E_a + \mathrm{S} \rightarrow \mathrm{S^*} \tag{3}$$

$$\mathrm{S^*} \rightarrow \mathrm{S} + E_a \tag{4}$$

where P—P is the protein molecule, E_a is the activation energy of the gamma rays, and S is the protector, then the protective step is reaction (3), which means that the observed protective effect is expressed as a parabolic curve, a logarithmic abscissa being the concentration of the protector. Therefore the response of albumin molecule to the protector may be determined by measuring the reduced viscosity.

If in the system X is the concentration in per cent, and a, b, and c are adjustable constants, then the following equation expresses the protective effect:

$$\eta_{\mathrm{red}(\infty)} = a(\log X)^2 + b(\log X) + c \tag{5}$$

This formula agrees with the experimental data that describe the curves in Figures 3 and 4.

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