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A STUDY OF THE EFFECTS OF ^{15}N ION BEAM ON ORGANIC COMPOUNDS *

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Abstract

Organic compounds EDTA, EDTA-Na and biological samples Bovine Liver and DNA, were irradiated with ^{15}N ions at the energy of 8.5 MeV and the hydrogen lost during bombarding was monitored via the $H(^{15}N,\alpha\gamma)^{12}C$ resonance reaction. The hydrogen loss curves were fited using a multiple exponential function which indicates different mechanisms with which hydrogen is lost.

1. Introduction

The stability of organic and biological specimens under charge particle bombardment is one of the most important problems in elemental analysis using ion beams. The reason is that an amount of some elements contained in the examined samples is lost during bombarding so a significant error is inserted in the concentrations of the analysed elements [1,2].

On the other hand the modifications which take place in such specimens exposed to a certain dose of charge particles, have great biological interest.

In the present work the ^{15}N ion beam was utilized at the energy of 8.5 MeV in order to monitor the behaviour of hydrogen (which is one of the basic elements of the organic and biological specimens) during bombardment, via the $^{1}H(^{15}N,\alpha\gamma)^{12}C$ reaction. Yields of hydrogen as a function of the beam total charge are presented for the following samples; a)EDTA, b)EDTA-Na, c) Bovine Liver d)DNA.1 and DNA.2.

The EDTA (Ethylenediamine tetraacetic acid $C_{10}H_{16}N_2O_8$) and EDTA-Na (Ethylenediamine tetraacetic disodium salt, $C_{10}H_{14}N_2Na_2O_8 \cdot 2H_2O$) were chosen because are organic compounds with well known stoichiometry. On

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the other hand it is interesting to compare the behaviour under bombardment of an organic compound which contains bound water (EDTA-Na) with another similar (EDTA) which does not have water. DNA ($C_{10}H_{12}N_4O_8P\cdot 10H_2O$) was selected because of is great biological interest. Bovine Liver is a biological sample which is usually used as a standard in analytical methods using charge particles (i.e PIXE).

2.Experimental Part

The target used were thick (100 - 400 mg) pellet of powdered material of diameter 1.3 cm. No initial treatment of the samples was done before bombardment, except of DNA.2 which was placed in a drying compound (P_2O_5) for three days. The samples were bombarded with $^{15}N^{+3}$ ions at 8.5 MeV energy using low beam current (4-8 nA) and the yield of the 4.43 MeV γ-ray associated with the $^1H(^{15}N,\alpha\gamma)^{12}C$ reaction was measured using a high efficiency NaI detector placed at 90° with respect to the beam. The samples were positioned at 45° with respect to the beam. The yield measurement were taken in steps of 1 μC total beam charge for all the samples except of the Bovine Liver sample for which the step was 3 μC.

3.Results and Discution

The experimental results are presented in figs. 1(a,b) and 2(a,b,c) in which the hydrogen yields as a function of the beam total charge are shown for EDTA .EDTA-Na . DNA.1 . DNA.2 and Bovine Liver respectively.

The data seem to have multiple exponential shape. In all cases except of the case of Bov.Liver the experimental data can be best fitted with two exponential terms. In the case of Bov.Liver a constant term was added.

The yield expression used to fit the experimental data taken after bombarding the sample with total charge ΔQ is given as;

$$Y(Q) = K \cdot \int_{Q-\Delta Q}^{Q} \frac{m_H(Q)dQ}{m_H(Q)\cdot S_H + (1-m_H)\cdot S_{res}}$$

where:

Y(Q): the yield produced after bombarding with total beam charge QμC.
K : Normalization constant which can be calculated using a standard (Kapton).
$M_H(Q) = m_1 \exp(-\lambda_1 Q) + m_2 exp(-\lambda_2 Q)$ for all the samples except of Bov.Liver in which a term m_3 is added.
m_1, m_2 mass of hydrogen which leaves the sample with rate λ_1, λ_2 respec-

tively and $m_H = \Sigma m_i$.
m_3: mass of hydrogen which remains in the sample after bombarding with Q μC.
S_H, S_{res} : the stopping power of hydrogen. and all other residual elements contained in the samples respectively.
Masses are expressed in weight % .

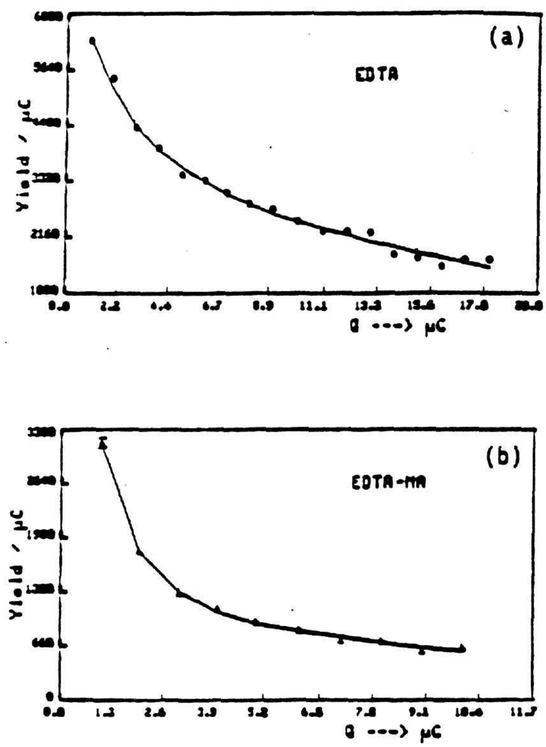

Fig 1. Hydrogen yield as a function of total beam charge for (a)EDTA and (b)EDTA-Na

Fitting the above expression of yield to the experimental results we can get the values of m_i and λ_i. The values of the above parameters which results from the best fit are given below.

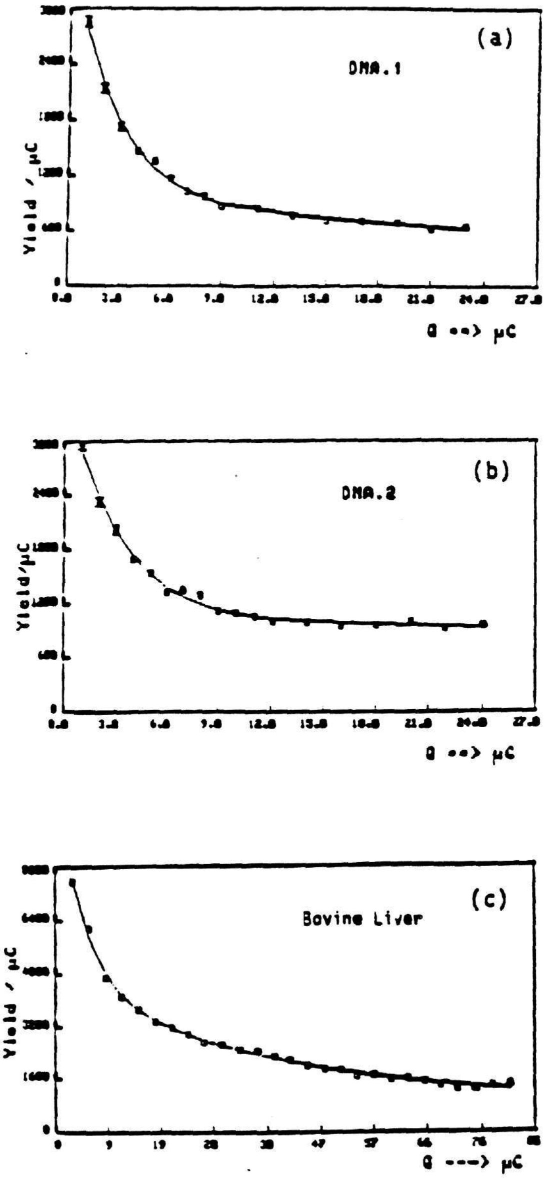

Fig 2. Hydrogen yield as a function of total beam charge for (a)DNA.1. (b)DNA.2 and (c)Bovine Liver

Sample	λ_1	λ_2	m_1	m_2	m_3	χ^2
EDTA	0.52	0.06	3.2	3.9	-	7.36
EDTA-Na	1.07	0.08	3.0	1.1	-	2.0
DNA.1	0.38	0.02	2.2	0.9	-	1.44
DNA.2	0.32	0.03	2.3	0.9	-	1.96
BOV.LIV.	0.24	0.04	4.5	3.5	0.7	3.43

The solid line in Figs 1,2 represents the best fit to the data.

The two exponential terms contained in the yield function, suggest different mechanisms with which hydrogen is released. In the mechanism the rate of loss of hydrogen is fast and is connected with the low fluences. In the other mechanism the rate of loss is slow and dominates at higher fluences.

These mechanisms may be related to possible evaporation of bound water contained in the samples which happens due to heating effects of the dissipated beam , or to the breaking of H bonds of different energy (which may results to hydrocarbon or hydrogen losses). Especially in EDTA-Na it can be noticed that the rate of loss of hydrogen assosiated with the low fluence is greater that the corresponding rate in EDTA. This may indicate that the bound water contained in this compound is quickly lost at the beginning of the bombardment.

The DNA.2 seems to have similar behavior as DNA.1 althought it was plased in the drying compound before bombardment.

In the following table, the initial mass of H (in weight %) m_H^e deduced from the compounds empirical form and the values resulted from fit m_H^f are given.

Sample	m_H^e	m_H^f
EDTA	5.4	7.1
EDTA-Na	4.8	4.1
DNA.1	3.8	3.1
DNA.2	3.8	3.2
Bov.Liv.	—	8.7

The values resulted from the fit are in good agreement with the values deduced from the empirical form of the compounds.

The study of organic compounds is continued in order to establish a more complete systematics of the behavior under bombardment. A study of the behavior of polymers has also started and recently we obtained interesting results from PVC. Gamma rays from H and X-rays from Cl were simultaneously measured and showed similar behavior. This study is in progress.

References

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