One thing we (yet) want to know about impurities in LAr

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A Procedure To Define the Sources of Finite Electron Lifetimes in LAr

Measure Lifetime as a Function of O_2, N_2, and H_2O Concentrations

The relationship between electron attachment rate r_A (the inverse of electron lifetime) and concentration *c* is

$$\vec{r}_A = \vec{k}_A \bullet \vec{c}$$

where k_A is the vector of the attachment coefficient for each of the three impurities

$$\vec{k}_A = \{k_{A,O_2}, k_{A,H_2O}, k_{A,N_2}\}$$

We perform *n* experiments, each measuring the electron lifetime for a different set of the three concentrations

$$c_n = \{c_{O_2,n}, c_{H_2O,n}, c_{N_2,n}\}$$

$$\vec{c} = \begin{Bmatrix} c_{O_2,1} & c_{O_2,2} & c_{O_2,3} & \cdots \\ c_{H_2O,1} & c_{H_2O,2} & c_{H_2O,3} & \cdots \\ c_{N_2,1} & c_{N_2,2} & c_{N_2,3} & \cdots \end{Bmatrix}$$

and determine *r*, the vector composed of the measured attachment rate for each of the *n* experiments

$$\vec{r} = \{r_1, r_2, r_3, \ldots, r_n\} \equiv \{\tau_1^{-1}, \tau_2^{-1}, \tau_3^{-1}, \ldots, \tau_n^{-1}\}$$

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The relationship between attachment rate r_A (the inverse of electron lifetime) and concentration is

$$\{r_1, r_2, r_3, \ldots, r_n\} = \{k_{A,O_2}, k_{A,H_2O}, k_{A,N_2}\} \begin{Bmatrix} c_{O_2,1} & c_{O_2,2} & c_{O_2,3} & \cdots \\ c_{H_2O,1} & c_{H_2O,2} & c_{H_2O,3} & \cdots \\ c_{N_2,1} & c_{N_2,2} & c_{N_2,3} & \cdots \end{Bmatrix}$$

This is a linear relationship. A least-squares minimization procedure can be used to find the unknown k_A vector that best represents the measured rate vector, r_A, and the measured concentration matrix, c.

It is easy (and fast) to add impurities but difficult (and slow) to remove impurities; therefore it is advantageous to perform experiments by filling the cryostat with purified LAr and then making successive small additions of each of the three impurities, measuring the electron lifetime after each addition. The successive additions should be planned to make the concentration vectors span the entire space and be as linearly independent as possible. To do this, it will of course be necessary to empty and refill the cryostst with purified LAr one or two times

Measure Lifetime as a Function of O_2, N_2, and H_2O Concentrations

$$\vec{r}_A \equiv \vec{\tau}_A^{\,-1} = \vec{k}_A \bullet \overleftrightarrow{c}$$

$$\vec{r}_A = \{r_{A,1}, r_{A,2}, r_{A,3}\}$$

$$\vec{k}_A = \{k_{A,O_2}, k_{A,H_2O}, k_{A,N_2}\}$$

$$\overleftrightarrow{c} = \begin{Bmatrix} c_{O_2}(1) & c_{O_2}(2) & c_{O_2}(3) \ldots \\ c_{H_2O}(1) & c_{H_2O}(2) & c_{H_2O}(3) \ldots \\ c_{N_2}(1) & c_{N_2}(2) & c_{N_2}(3) \ldots \end{Bmatrix}$$

Use a minimization procedure to find the unknown k_A vector that best represents the measured rate vector, r_A, and the measured concentration matrix, c. This procedure gives the best estimate of the three attachment rates with their uncertainties.

Can We Determine a "Residual Impurity" Concentration and Attachment Rate?

We can also consider that there may be some unknown impurity (impurities) that lead to a non-zero electron attachment rate with zero oxygen, water, and nitrogen concentrations. In this case we can write

$$\vec{k}_A = \{k_{A,O_2}, k_{A,H_2O}, k_{A,N_2}, k_{A,X}\}$$

$$\overline{c} = \begin{Bmatrix} c_{O_2}(1) & c_{O_2}(2) & c_{O_2}(3) & \dots \\ c_{H_2O}(1) & c_{H_2O}(2) & c_{H_2O}(3) & \dots \\ c_{N_2}(1) & c_{N_2}(2) & c_{N_2}(3) & \dots \\ c_X & c_X & c_X & \dots \end{Bmatrix}$$

We assume that the unknown impurity does not change with time or from cryostat filling to filling. Can we find the product $k_{A,X} c_X$ that best represents inner product of the measured rate vector and measured concentration matrix with a constant unknown additional impurity concentration?

Perhaps, with high precision measurements of the electron lifetimes and concentrations. At least we can set an upper limit.