## Title

THE EFFICIENCY OF 7LIF THERMOLUMINESCENT DOSIMETERS TO HIGH LET-PARTICLES, RELATIVE TO 60 Co-RAYS



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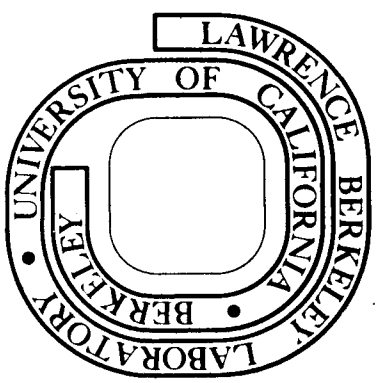


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## DISCLAIMER

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# THE EFFICIENCY OF $^{7}$LIF THERMOLUMINESCENT DOSIMETERS TO HIGH LET-PARTICLES, RELATIVE TO $^{60}$Co $\gamma$-RAYS

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## INTRODUCTION

In a previous note (Patrick et al. 1975), we reported a measurement of the efficiency, $\varepsilon$, of $^{7}$LiF thermoluminescent dosimeters, relative to $^{60}$Co $\gamma$-rays, for measuring 250 MeV/amu $C^{+6}$ ions. The value of $\varepsilon = 0.89 \pm 0.04$ obtained, was dependent upon the value assumed for average energy required to create an ion pair, W, in nitrogen (the gas filling of the ionization chamber used to determine absorbed dose in the $^{7}$LiF). The present note describes an extension of this work to oxygen and neon ions over a range of linear energy transfer (LET) in $^{7}$LiF from 11.2 to 25.9 keV/$\mu$m. Efficiencies reported here have been determined absolutely and are not dependent upon any assumed value for W.

## EXPERIMENTAL TECHNIQUE

Lif TLD-700 chips (0.125 X 0.125 X 0.035 in.,25 mg mass) manufactured by the Harshaw Chemical Company were used in these measurements. The manufacturer's recommended annealing procedures—including a post-irradiation annealing at 100° C for 10 minutes—were adopted. Dosimeters were either read with a Mark IV series, 110 TLD reader manufactured by the Radiation Detection Company, or with a Harshaw Series 3000 TLD reader.

### Dosimeter Response to Heavy Ions

The Bevalac is capable of producing heavy ions as heavy as $Ar^{+}$, up to energies as high as 2.1 GeV/amu (Grunder 1973). $^{7}$LiF dosimeters were exposed to carbon, oxygen, and neon ions of energies shown in Table 1.

The energy absorbed in the dosimeters can be calculated from the expression

$$D = 1.602 \times 10^{-7} \, L \, \Phi \text{ rads} \qquad (1)$$

where L is the linear energy transfer in LiF (keV/μ) and $\Phi$ is the incident heavy ion fluence. (The dosimeter package is so thin that heavy ion interactions may be ignored.)

Determinations of the incident heavy ion fluence were made by exposing the thermoluminescent dosimeters simultaneously either with nuclear emulsions (Kodak Type NTA) or Ag-Cl crystal detectors of the type developed by Schopper and his colleagues (Schopper 1972).

The carbon and neon ion irradiations used nuclear emulsion as the absolute particle detector and were carried out with two thermoluminescent dosimeters placed roughly at the center of the NTA film. A wide beam (FWHM ~ 12 cm) was used so that the beam intensity was uniform over the dosimeters to about 0.2%. The films were exposed at an angle of 45° to the incident beam and the large specific ionization of the heavy ions produced dense tracks which were readily identifiable. Optimum exposures produced 40-120 tracks in a 245 μm square field when viewed by an optical microscope. Details of the scanning data for the carbon and neon ion exposures have been reported elsewhere (McCaslin et al. 1974).

In the case of irradiations with oxygen ions the absolute incident ion fluence was measured using Ag Cl crystals. Experimental details have been reported elsewhere (Patrick 1975).

Table 2 summarizes values of thermoluminescent dosimeter sensitivity, $\tau$, in arbitrary units (TLU) per unit incident fluence divided by the sensitivity to $^{60}$Co $\gamma$-rays, R, in TLU/roentgen. While the absolute values of $\tau$ and R depend strongly on dosimeter reading settings and may therefore vary from experiment to experiment, the values of $\tau$/R (roentgen/unit fluence) presented in Table 2 are independent of reader settings. The

response to $^{60}$Co γ-rays was determined by exposing dosimeters at the irradiation facility of the Biomedical Division of the Lawrence Berkeley Laboratory (Patrick et al. 1975).

Calculation of Dosimeter Efficiency, ε. The dosimeter efficiencies relative to $^{60}$Co γ-rays is given by:

$$\varepsilon = \frac{0.805}{1.602 \times 10^{-7} L} \left(\frac{\tau}{R}\right)$$

$$= \frac{5.025 \times 10^{6}}{L} \left(\frac{\tau}{R}\right) \qquad (2)$$

where L is the linear energy transfer of the ions in $^{7}$Lif and the factor 0.805 arises from the fact that an exposure of 1 roentgen deposits 0.805 rads in $^{7}$LiF (Attix 1969).

Table 2 summarizes the values of ε so determined.

## CONCLUSIONS

Figure 1 shows the values of ε reported in this note plotted as a function of linear energy transfer in $^{7}$LiF, together with measurements reported by Jähnert (1972) made with protons and alpha particles. Also shown on the figure are two theoretical models proposed by Jähnert. The new data reported here are compatible with both models over the range of LET studied. Nevertheless, there is a suggestion that ε may not be a function of LET alone, but also depend upon the charge of the particle depositing energy in the crystal. More accurate measurements of ε as a function of both these parameters are planned.

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## FIGURE CAPTION

Figure 1. Measured values of TLD efficiency relative to $^{60}$Co $\gamma$-rays and comparison with theoretical models.

Table 1. Summary of heavy ion exposure.

| Ion species | Energy (MeV/amu) | Linear energy transfer in $^{7}$Li F (keV/μm) | Absolute detector |
|---|---|---|---|
| $C^{+6}$ | 252 | 11.6 | NTA |
| $O^{+8}$ | 300 | 18.6 | AgCl |
| $O^{+8}$ | 1050 | 11.2 | AgCl |
| $Ne^{+10}$ | 372 | 25.9 | NTA |

Table 2. Measurements of ε.

| Ion species | LET in $^{7}$LiF (keV/ μ) | τ/R (roentgen/unit ion fluence) | ε |
|---|---|---|---|
| $C^{+6}$ | 11.6 | $2.06\ 10^{-6}$ | 0.89 ± 0.02 |
| $O^{+8}$ | 11.2 | $2.01\ 10^{-6}$ | 0.90 ± 0.05 |
| $O^{+8}$ | 18.6 | $3.03\ 10^{-6}$ | 0.82 ± 0.05 |
| $Ne^{+10}$ | 25.9 | $3.76\ 10^{-6}$ | 0.73 ± 0.03 |

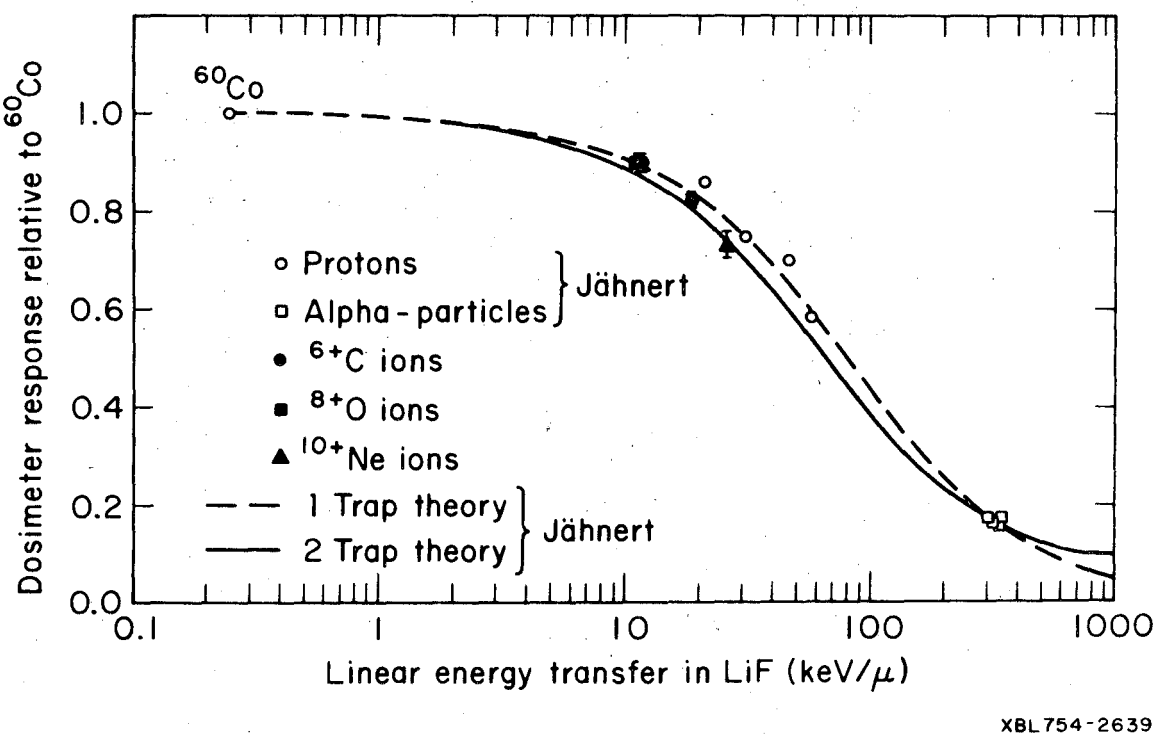


Fig. 1

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