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QUANTUM EFFICIENCY OF TMAE FOR FAST COMPONENT OF BAF_2 RADIATON

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Abstract

The fast component of a BaF_2 scintillator has been detected by tetrakis (dimethylamino) ethylene (TMAE) in a low pressure wire chamber. The efficiency for detecting BaF_2 light with TMAE is due to the overlap of the tail of the BaF_2 fast emission spectrum with the tail of the TMAE quantum efficiency. It would be useful to parametrise the quantum yield of the BaF_2 – TMAE combination as function of TMAE vapour thickness and temperature. We have calculated this from the quantum efficiency of TMAE vapour as a function of wavelength at different temperatures and the relative emission of the fast component of BaF_2 radiation.

Keyword: TMAE BaF_2 Photosensitive Gaseous Detector.

Introduction

Many modern high energy physics experiments incorporate detectors which use photosensitive gases as a means of detecting ultraviolet photons. The Cerenkov ring-imaging detectors [1] used in the Omega spectrometer [2] and those being designed for SLD [3] and Delphi [4] must detect photons over large areas. A photosensitive gas in a time projection chamber provides large area coverage at a reasonable cost. Another experiment, E787 at the Brookhaven AGS [5], plans to use BaF_2 crystals and a photosensitive gas called tetrakis (dimethylamino) ethylene (TMAE) in a low pressure Multiwire Proportional Chamber (MWPC) as highly efficient photon veto detector. Because of the good low energy photon detection efficiency of BaF_2, this technique also has potential applications for use in Positron Emission Tomography (PET) [6].

It would be useful to parametrise the quantum yield of the BaF_2 – TMAE combination as a function of TMAE vapour thickness and temperature. We have calculated this from the quantum efficiency of TMAE vapour as a function of wavelength at different temperatures and the relative emission of the fast component of BaF_2 radiation.

Calculations

The quantum efficiency of TMAE vapour is calculated from

$$QE = (1 - \exp[-\mu_{Total} x]) \mu_{ph} / \mu_{Total}$$

Where

μ_{ph} is the linear absorption coefficient due to photoionisation.

μ_{Total} is the linear absorption coefficient due to photoionisation and to all other non ionising processes.

x is the vapour thickness in cm.

The absorption coefficient due to photoionisation process μ_{ph} is given by

$$\mu_{ph} = n\sigma \qquad (cm^{-1})$$

where

σ is photoionisation cross-section (cm^2) [7]

N is the number of molecules/cm^3, calculated from
$N=N_A\, PT_O / P_O V_O T$ $(molecules/cm^3)$

where

P is pressure in torr, calculated from

$P=0.5 \exp [6372\ (1/300 - 1/T)]$ (torr) [8]

T is temperature (K)

P_O = 760 (torr)

V_O = 22400 (cm^3)

T_O = 273 (K)

N_A is Avogaddro's Number

The absorption coefficient due to photoionisation and all other non ionising processes,

$\mu_{Total} = \varepsilon C \ln 10$ (cm^{-1})

Where

ε is the extinction coefficient (litre/ mole-cm) [9]

C is the gas concentration in moles/litre

The quantum efficiency for the fast component of BaF_2 radiation (Fig. 2) was calculated from

$$Q.E = \Sigma P(\lambda)\,\Delta\lambda / \Sigma I(\lambda)\,\Delta\lambda$$

Where

P (λ) is QE TMAE as a function of wavelength
I (λ) is the relative emission of the fast component of BaF_2 radiation [13]
$\Delta\lambda$ = 5nm

Results and Discussion

Figure 1 shows the absolute quantum efficiency of TMAE vapour and the fast emission spectrum of BaF_2 scintillator. The calculated quantum efficiency in the region 170 nm to 190 nm is inconsistent with the absolute quantum efficiency measured by Holroyd *et al.* [9]. There is also an increase in calculated quantum efficiency below 170nm. These differences could be related to the high purity of TMAE samples studied by Holroyd *et al.* [9]. Our values of the photoionsation cross-section of a TMAE sample, were obtained from Anderson *et al.* [7]. They used TMAE sample which was not as pure as that used in later reports. The increase in photoionsation cross-section at 170 nm could therefore be due to impurities in the TMAE sample. The shape of the calculated curve is in agreement with most of the other data published on the relative quantum efficiency [10,11]. They were probably also derived from the same set of measurements. In a recent paper], Anderson [12], seems to agree with the absolute quantum efficiency measured by Holroyd *et al.* [9]. Therefore the photoionsation cross-section data used in our quantum efficiency calculations is calculated from the measured quantum efficiency curve [9]. Figure 2 shows the resulting quantum efficiency of TMAE vapour of different thickness and different temperatures.

Assuming 2000 photons per MeV produced in the BaF_2 scintillator and 30% enhancement due to an aluminised surface, we have calculated the number of photoelectrons per MeV in BaF_2 per millimeter of TMAE vapour as a function of temperature. Our calculations are in close agreement with the calculations of Woody *et al.* [12] as shown in table 1.

Table: 1. Number of Photoelectrons per MeV in the BaF_2 per millimeter of TMAE vapour as a function of temperature.

Temperature °C	N_{ph} / MeV mm		
	Our Calculation	Calculated [12]	Beam Test [12]
20	1.2	1.5	0.8
40	4.5	5.2	6.1
60	12.1	12.2	7.8

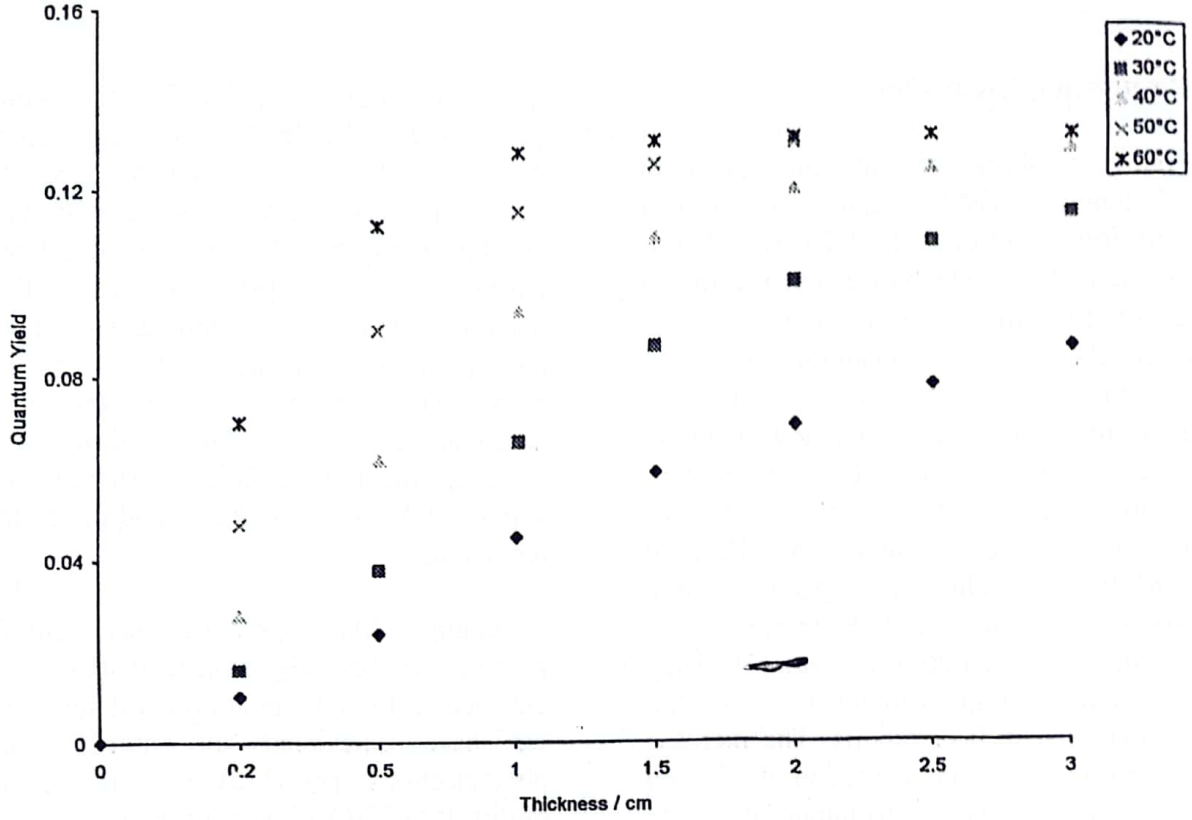


Fig: 2: Q.E. of TAME for the fast component of BaF_2 radiation.

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