# A METHOD FOR THE MEASUREMENT OF THE ABSOLUTE VALUE OF w FOR X-RAYS IN NOBLE GASES : RESULTS AT 5.9 keV IN XENON [1]

Filipa I. G.M.Borges[2] and C.A.N.Conde
Physics Department, University of Coimbra, P-3000 Coimbra, Portugal

## *Abstract*

A method is described that allows the measurement of the absolute value of the average energy to produce an ion pair, w, in noble gases for soft X-rays and its energy dependence. It uses a specially designed gas proportional scintillation counter working under electric fields below the ionization threshold. The spectrum of the radiation absorbed, and so the number of photons detected at each energy for a period of time of the order of the minute, is measured with the scintillation counter and at the same time the total primary electron charge produced is collected in one of the grids and measured with an electrometer. For pure xenon at 1030 mbar a value of $w = 24.2 \pm 2.5$ eV was measured with 5.9 keV X-rays.

## I. INTRODUCTION

The measurement of the absolute value of the average energy to produce an ion pair in matter with ionizing radiation, the so called w value, is of fundamental importance in a variety of fields like dosimetry and radiation detection. Although w for a certain medium is usually assumed to be independent of the radiation energy, recent detailed Monte Carlo calculations[1] have shown that, at least for soft X-rays in xenon, w can vary with the photon energy by as much as 12% for the 0.1 to 25 keV range. The energy dependence of w implies a non-linearity relation between the average number, n, of primary electrons produced and the radiation energy. These non-linearity effects have already been confirmed experimentally for X-rays[2]. Also there seems to be a relation between w and F, the Fano factor for a gas[3]. Therefore the measurement of the absolute value of w for a gas or gaseous mixture, might lead to the development of improved performance gaseous detectors.

The experimental determination of the absolute value of w , even for non-electronegative gases like the noble ones is difficult, and to our knowledge no direct measurement of w for X-rays has ever been published. This is due not only to the small number of primary electrons produced per photon, but also to a number of physical effects that can increase the experimental errors, sometimes in an unpredictable way. Indeed, effects like X-ray line impurities, backscattered coherent radiation and loss of primary electrons to the detector window[4], may be responsible for large errors; for example loss of photons will occur when X-rays are backscattered by a heavy noble gas or when fluorescent photons escape from this gas.

A solution for this problem is to do the measurements with an experimental system that provides the spectral analysis of all the detected radiation, and so measures the number of photons absorbed at each energy, and at the same time measures the integrated primary electron charge produced in the gas by a few tens or hundreds of thousand photons.

Radiation detectors of the three following types can provide spectral analysis when a noble gas is being studied: gas scintillation counters (with no electric field), gas proportional counters and gas proportional scintillation counters. However, while the first type of counter offers a poor energy resolution, the second type, due to the charge multiplication processes involved cannot be used for the integrated charge measurements. Only gas proportional scintillation counters offer good spectral analysis without charge multiplication provided they work below the threshold for ionization (i.e. below about 5 $\text{Vcm}^{-1}\text{torr}^{-1}$ for the case of xenon).

In the present work we describe a method for the measurement of w in noble gases based on a specially designed gas proportional scintillation counter.

## II. EXPERIMENTAL METHOD

The schematic of the gas proportional scintillation counter used for the experimental measurement of w for X-rays is shown in Fig.1. An X-ray source (a radioactive one, as shown, or else a target excited by electrons emitted by a hot filament and accelerated) emits photons that are absorbed in the noble gas (xenon at the pressure of 1030 mbar in the present work). The cathode with the aluminized Kapton window is polarized at a negative potential (about -4900V) with the $HV_1$ power supply. The primary electrons produced by an X-ray photon drift towards grid $G_1$, at about -4400V, and thereafter towards grid $G_2$ at near ground potential where they are collected and transferred to the electrometer. As the electric field between $G_1$ and $G_2$ is below the ionization

---

[1] Support is acknowledged from INIC (Instituto Nacional de Investigação Científica); from JNICT (Junta Nacional de Investigação Científica e Tecnológica) and from LNETI (Laboratório Nacional de Engenharia e Tecnologia Industrial) trough project EUREKA EU.39.
Our thanks are also due to Mr. António Marques and Mr. Carlos J.N. Gomes for technical support.

[2] F.I.G.M.B. was supported by JNICT through Programa Ciência.

0018-9499/93$03.00 © 1993 IEEE

Authorized licensed use limited to: Universidade de Coimbra. Downloaded on March 15,2010 at 13:18:33 EDT from IEEE Xplore. Restrictions apply.

threshold no charge multiplication takes place and so the electrometer measures the actual charge initially produced. At the same time while the electrons drift between $G_1$ and $G_2$ they produce a large intensity secondary scintillation pulse that, when measured with the VUV photomultiplier and a multichannel analyser, allows full spectral analysis of the X-rays actually detected; for work with xenon a high purity quartz window photomultiplier (EMI D319 QNA/FL) was used, but for other rare gases a photomultiplier (EMI 9266 $MgF_2B$) sensitive to wavelengths below 160nm is required. Guard rings are used to reduce leakage currents mainly between grid $G_1$ (at high voltage) and grid $G_2$.

The detector is made vacuum tight by compressing its parts (Teflon insulators, metal guard rings, grid support rings and cathode) against each other with a metal cylinder (not shown) with a flat top that has an aperture, which is fixed to the lower part with screws. This way the detector can be easily disassembled and is electrostatically shielded.

The noble gas is continuously purified (Fig.2) with getters (S.A.E.S. ST707) and circulates by convection.

The electronic counter measures the total number of photons detected. At counting rates as low as $10^3$ photons per second the number of primary electrons produced by a beam of 5.9 keV X-rays is about $2.7x10^5$ per second to which corresponds a collected charge of about $2.6x10^{-12}$ C per minute, whithin the sensitivity of the Keithley Model 614 electrometer.

## III. RESULTS AND DISCUSSION

The experimental results were obtained with a 0.11mCi $^{55}$Fe radioactive source producing 5.9 and 6.4keV X-ray photons that were detected in the scintillation counter. The higher energy X-rays were absorbed with a cromium filter. The integrated charge for multiple periods of 5 minutes was measured with the Model 614 electrometer and averaged.

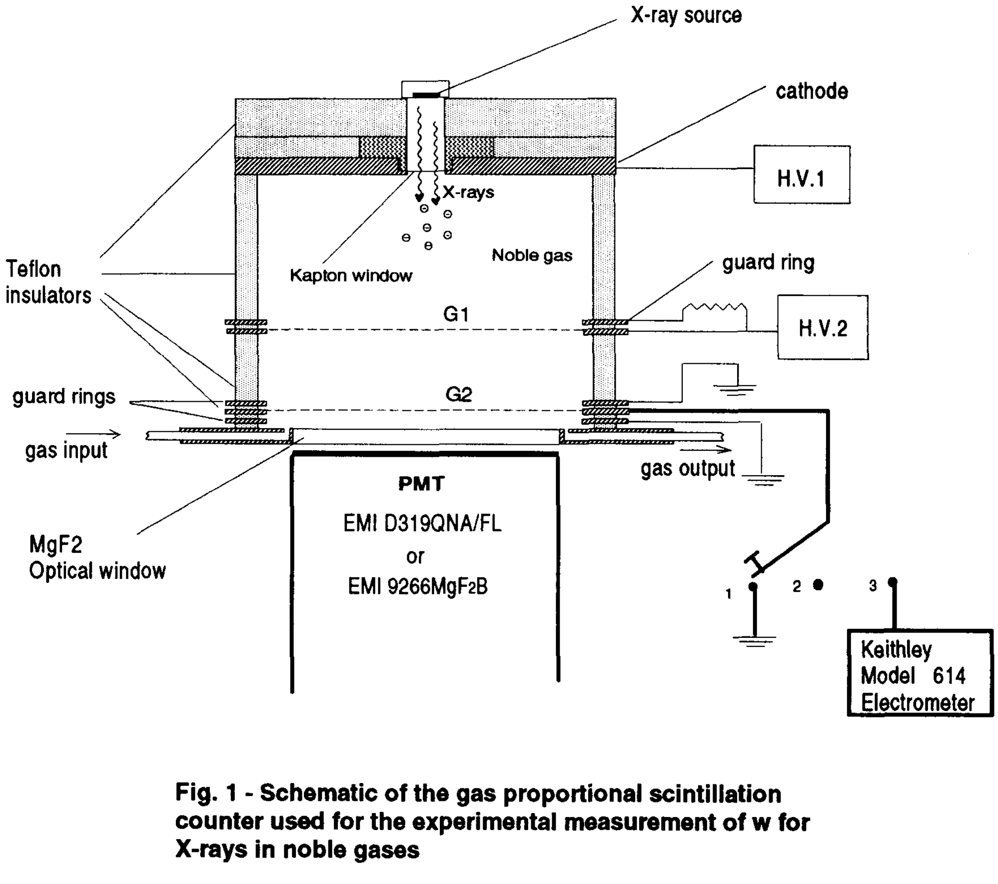

**Fig. 1 - Schematic of the gas proportional scintillation counter used for the experimental measurement of w for X-rays in noble gases**

Authorized licensed use limited to: Universidade de Coimbra. Downloaded on March 15,2010 at 13:18:33 EDT from IEEE Xplore. Restrictions apply.

After subtraction of the background, measured without the source, the calculated value for the average charge rate is equal to $1.29\times10^{-13}$ c per second, with counting rates of 3300 photons per second. To these figures corresponds a w value for 5.9keV X-rays in xenon at 1030 mbar of 24.2 ± 2.5 eV in agreement with the published results[1].

The accuracy of the results (estimated at ±10%) is limited mainly by the calibration of the electrometer ( ±5% ), the stability of the high voltage supply HV2, the background measurements and the leakage currents.

Problems like transmission of grid $G_1$ to electrons and the contribution of electrons released from the detector inner walls by the scintillation VUV light, need further research but do not seem to play a significant role in the accuracy of the results.

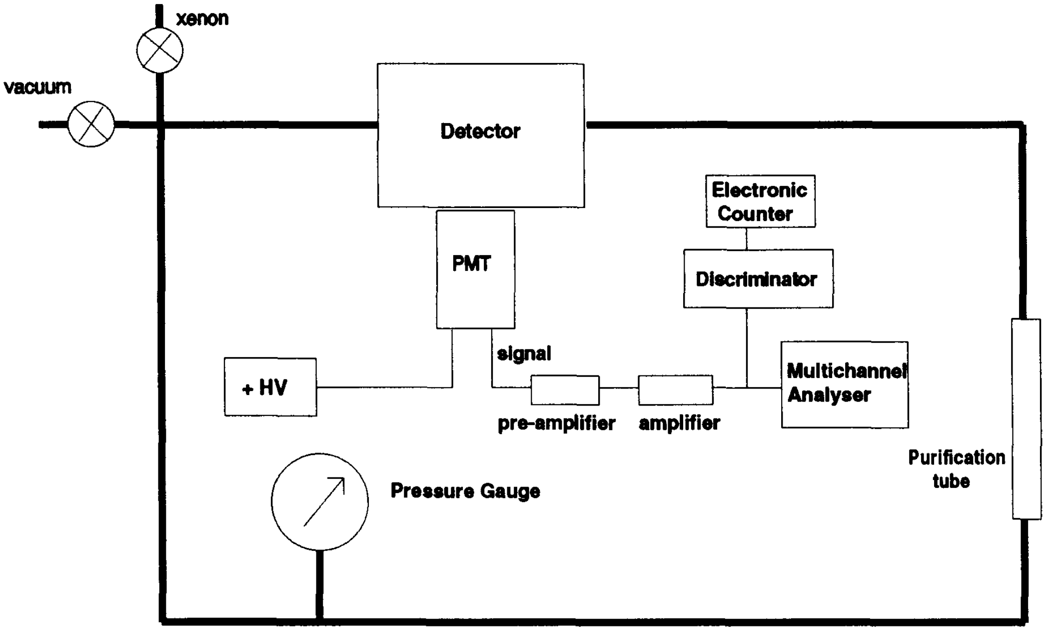

**Fig .2 - Schematic of the gas handling system and electronics**

REFERENCES

[1] - F.P. Santos, T.H.V.T. Dias, A.D. Stauffer and C.A.N. Conde, "Variation of Energy Linearity and w Value in Gaseous Xenon Radiation Detectors for X-rays in the 0.1 to 25keV Energy Range: a Monte Carlo Simulation Study", Nucl.Instrum.Meth.A307(1991) 347.

[2] - J.M.F. dos Santos, C.A.N.Conde and A.C.S.S.Bento, "The Energy Linearity of Gaseous Xenon Radiation Detectors For X-rays with Energies between 2 and 60 keV : Experimental Results", to be published in Nucl. Instrum.Meth. A (1992).

[3] - I.K. Bronic, "On a Relation Between the w Value and the Fano Factor", J. Phys. B: At. Mol. Opt. Phys. 25(1992) L215-L218.

[4] - T.H.V.T. Dias, F.P. Santos, A.D. Stauffer and C.A.N. Conde, "Distortion Effects in Soft X-ray Energy Spectra for Xenon Gaseous Detectors: a Monte Carlo Simulation Study", Phys. Rev. A46(1992)237.

Authorized licensed use limited to: Universidade de Coimbra. Downloaded on March 15,2010 at 13:18:33 EDT from IEEE Xplore. Restrictions apply.