VIETNAM ATOMIC ENERGY COMMITTEE
DALAT NUCLEAR RESEARCH INSTITUTE

DETERMINATION OF PARTIAL PRESSURE RATIO OF KRYPTON AND ARGON IN THE MIXTURE OF GASES INSERTED IN FLUORESCENT LAMPS

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The authors wish to express their thanks to Professor Pham Duy Hien, Director of Dalat Nuclear Research Institute for his interest in this work

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1989

I. INTRODUCTION

In the last few years, instead of argon, a mixture of krypton and argon is used to insert fluorescent lamps in order to decrease the dimension of the lamps and increase lighting efficiency. Of course,for a certain type of fluorescent lamp, the partial pressure of krypton and argon is quite defined. Consequently, control of this ratio is an important factor of lamp production technology. This present investigation proposes a simple method for the determination of partial pressure ratio of krypton and argon in the mixture of gases used in the chain production of fluorescent lamps.

It is clear that, neutron activation analysis is a suitable method for the determination of krypton and argon. In these gases there exist isotopes, that are convenient for neutron activation and gamma radiation measurement. Table I presents some of their activation features.

Table I
Some activation features of Ar-41 and Kr-85m isotopes

Isotope	Abundance activ.isot (%)	Thermal neutron cross.sect (mb)	Half_life (h)	Energy of radiat. (keV)	Absolute intensity ( )
Kr-85m	57	90	4.48	151	0.75
-	-	-	-	304	0.14
Ar-41	99.6	660	1.83	1293	0.991

II. EXPERIMENT

Low pressure gas probe in fluorescent lamps is transformed into a gas bubble at the pressure of about one atmosphere bysubmerging one of the lamp ends in a suitable liquid (for example, silicon oil) and breaking the capillary. Then, the gas bubble is transferred into an ampoule of high purity polyethylene. this ampoule is put in another larger one for opposing the diffusion of inert gases. Similarly, two samples of liquid are prepared (one before, the other after gas sampling) to check the solution of krypton and argon in liquid used for sampling and to control the background of argon existing in the air between the walls of ampoules. Sampling procedure takes about twenty minutes.

Gas and liquid samples are irradiated in the core of Dalat Nuclear Reactor with neutron flux density of $\sim 4.10^{12} n.cm^{-2}.s^{-1}$ in $\sim$ 300 seconds and measured on 65 cm Hp Ge detector after delayed time of two hours. Data are collected by multichannel analysator Canberra Series 35.

Because of the gamma peak 151 keV and 304 keV of radioisotope Kr-85m located on the compton scattering slope of 1293 keV radiation, hence, it is necessary to choose irradiating time and delayed time to decrease the error of full-energy peak area. Table II presents some results of full-energy peak area obtained in different variants of sample irradiating and measurement.

Table II.

Full energy peak area of Kr-85m and Ar-41, obtained in different variants of sample irradiating and measurement.

Sample:	Time (s)			Full energy peak area - error		
	irrad	delay	meas	151 keV	304 kev	1293 keV
FL I	300	4980	2200	103519-241	9805-185	374398-623
FL II	300	6940	983	19871-317	2828- 66	152536-700
FL III	300	7680	562	9414-256	1326-144	72002-730
FL IV	905	57600	2000	44677-233	4542-117	3654- 62

All the results shown in table II have been regulated by background of argon remaining between the walls of sample ampoules

Partial pressure ratio of krypton and argon is calculated by activation equation

$$N = \frac{n}{\lambda}\theta\sigma\phi(1-e^{-\lambda t_i})\,e^{-\lambda t_d}(1-e^{-\lambda t_m})\,\gamma\varepsilon$$

and fundamental equation of ideal gases dynamic

$$p = n\,kT$$

where, N is full energy peak area, n is density of activated nuclides, λ is decay constant of radioisotope, θ is abundance of activated isotope, σ is thermal neutron cross-section (in b

ϕ is neutron flux (in $n.cm^{-2}.s^{-1}$), t_i, t_d, t_m is irradiating, delayed and measurement time, γ is absolute intensity of gamma radiation, ε is gamma registration of detector, p is partial pressure of gases, k is Boltzmann constant and T is absolute temperature of gas sample.

From these equations the partial pressure ratio of krypton and argon is deduced :

$$\frac{P_k}{P_a} = \frac{N_k\theta_a\sigma_a\lambda_k\gamma_a\varepsilon_a}{N_a\theta_k\sigma_k\lambda_a\gamma_k\varepsilon_k}\,\frac{(1-e^{-\lambda_a t_i})}{(1-e^{-\lambda_k t_i})}\,e^{-(\lambda_a-\lambda_k)t_d}\,\frac{(1-e^{-\lambda_a t_m})}{(1-e^{-\lambda_k t_m})}$$

where k and a subscript shown parameter belonged to Kr-85m or Ar-41 consequently. Results of p_k/p_a shown in Table III are obtained by putting the data in Table I in this expression.

Table III

Partial pressure ratio of krypton and argon obtained by neutron activation analysis gas sample of four fluorescent lamps selected from various production series.

Sample:	Energy of gamma radiation used in calculation (keV)				p_k/p_a ratio and error		mean value of p_k/p_a	
FL I	151	Kr-85m	1293	Ar-41	1.1	0.1		
	304	-	1293	-	1.2	0.1		
FL II	151	-	1293	-	1.2	0.2	1.2	0.1
FL III	151	-	1293	-	1.3	0.2		
FL IV	151	-	1293	-	1.2	0.2		
	304	-	1293	-	1.4	0.2		

III. DISCUSSION

The method of determination of the partial pressure of krypton and argon presented in this investigation is a simple one. The use of double-wall polyethylene ampoules as sample containers gives fine gamma spectrum and high accuracy of full energy peak area, but it can not prevent quitely the diffusion of inert gases. A special experiment was carried out for checking the diffusion of krypton and argon through the walls of polyethylene ampoule, in which the analysis was repeated two weeks after the sampling. the result obtained was 30% lower than that shown in Table III. Hence, the optimal procedure of analysis is 20 minutes of sampling, 5 minutes of irradiating, 2 hours of delayed time and 15 minutes of measurement.

The main source of error shown in Table III are the uncertainty of neutron cross section, and absolute gamma radiation intensity, the accuracy of registration efficiency of Hp Ge-detector. The error of mean value of p_k/p_a is the root mean square deviation of experimental results.