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NEW EXPERIMENTS ON GAS TARGET SPECTROSCOPY. ATOMIC LIFE-TIME MEASUREMENTS OF SOME DEUTERIUM LEVELS[1]

Experiments on optical spectra using ion - beams and gas or foil targets were proposed by S. Bashkin in 1963 [1] and L. Kay [2]. The main uses of the new method of ion production and excitation are: to determine which levels are excited in various atomic species, which transitions occur, and above all to measure the mean lives of some of those levels.

None of the major difficulties encountered in the conventional light sources such as collisional deexcitation of levels, the problem of local thermodynamic equilibrium and the negligible efficiency of production of ions in higher stages of ionization play any role in this new[2] technique which makes use of a beam of high energy excited species. Significant development of the method was made basically in the University of Arizona, Tucson, Arizona and in many (30 or so) other laboratories distributed among 9 countries. The progress which has been made since 1963 is summarized in the Proceedings of the Conference held at the University of Arizona in 1967 [4], in the Proceedings of the Second International Conference held in Lysekil, Sweden in 1970 [5] and in Proceedings of the Third International Conference [9] held in Tucson, Arizona in 1972.

Fig. 1 shows the idea of the experiment. A beam of accelerated particles travels from left to right and enters the target /either a thin carbon foil with area density of 10 /cm^2 or a gas target/. In the target the ions undergo the processess of ionization /both electron stripping and electron attachment may occur/ and excitation to higher atomic

[1]The results of the experiments were presented at the Vth National Conference on Spectroscopy, Varna 1973, sponsored by Bulgarian Academy of Sciences.

[2]W. Wien [3] performed the first experiments on light decay in a beam of canal rays.

levels. The beam emerging from the target is composed of the excited ions and their deexcitation results in a decaying luminous beam which is the main object of observation.

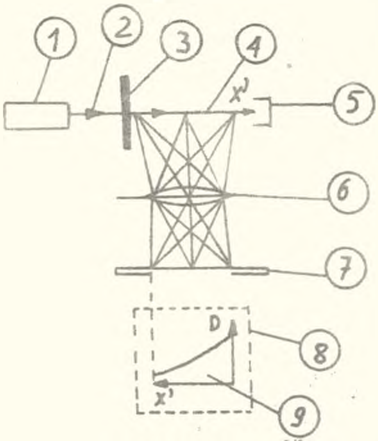

Fig. 1

General idea of the experiment. 1 - accelerator, 2 - accelerator beam, 3 - foil or gas target, 4 - beam of excited, light emitting ions, 5 - Faraday cup, 6 - lens, 7 - spectrograph slit, 8 - spectrograph, 9 - photographic plate and plate density vs distance curve

The emitted light is stigmatically imaged on to a spectrograph slit. The resulting spectral line reproduces the distribution of light intensity in the luminous beam. The dependence of the photographic density of a plate on distance is directly related to the atomic life-time of the level under consideration. Thus life-time value is measured in terms of the accelerator voltage /ion velocity/ and geometry factors /optical image magnification/.

The efficiency of production of higher stages of ionization depends mainly on the accelerator voltage. Fig. 2 presents the dependence for a beam of Neon isotope of mass number 22 incident on a thin carbon foil [6]. For example, if a considerable number of $^{22}Ne^{5+}$ ions are to be produced in the target, the energy of the accelerated neon ions should be roughly 0.20 $\frac{MeV}{A}$ i.e. 4.4 MeV.

The Cracow centre of physics is expecting the delivery of a 10 MeV, tandem type Van de Graaf accelerator and the Beam Foil Spectroscopy is considered as one of the prospective research programmes. However, some preparatory experiments are being carried out on the small 200 keV accelerator of the Institute of Nuclear Physics, Cracow and preliminary results are presented below.

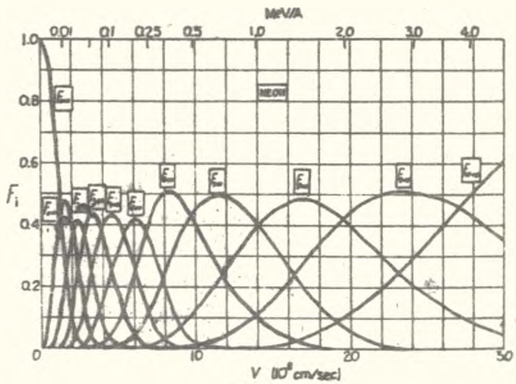

Fig. 2

Ionization efficiency of a carbon target, F_j denotes the fractional number of ionized atoms

Fig. 3 shows the gas target applied /length 4 cm, furnished with 4 mm dia. apertures/ and its typical working conditions. The production of fast excited atoms inside the target is given by:

$$\frac{dn^*}{dx} = -\frac{n^*}{v\tau} + Q\rho F/v$$

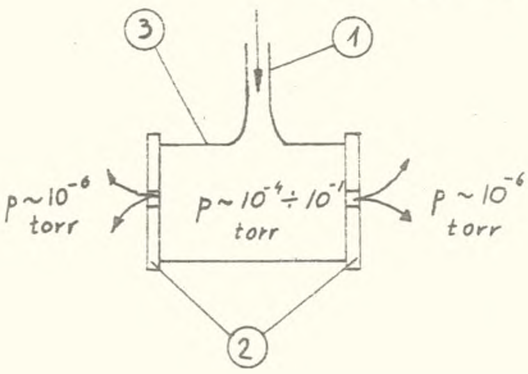

Fig. 3

Gas target: 1 - gas inlet, 2 - brass side walls /the inlet and outlet apertures ~ 4 mm dia./, 3 - glass cell

where n^* is the excited atom density, x is the distance measured from the entrance aperture along the beam, v is the velocity and τ is the radiative life- time of the excited state, Q is the excitation cross section, ρ is the target gas density, and F is the ion beam flux [4]. Under simplified conditions /single mode decay and low pressure approximation/ the excited atoms build-up in the gas target is given by

$$n^* = n_o \left(1 - e^{-x/v\tau}\right) \qquad (1)$$

Outside the gas target

$$n^* = n_o e^{-x'/v\tau} \qquad (2)$$

where $n_o = F\rho Q\tau \; 1-e^{-L/v\tau}$ and L is the length of the gas target. In the experiment reported here, cf. [8], deuterium ion impact on argon and nitrogen gaseous targets was observed within ion energy range 40-60 keV. The process of electron capture by the incident ion into an excited state of the resulting fast atom is given by

$$D^+ + T = D^* + T^+ \qquad (3)$$

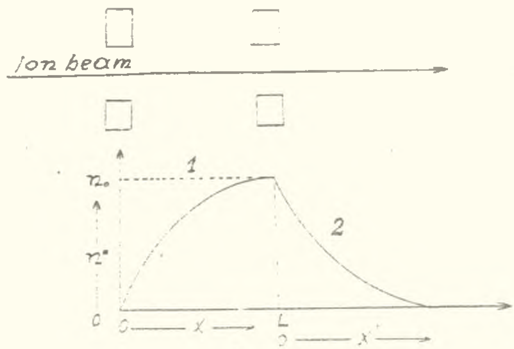

Fig. 4

Excited atoms build-up inside the target and the decay curves in vacuo

where D^+ represents the incident ion, D^* the resulting excited fast atom, and T the target.

The gas target pressure is varied within 10^{-3} - 10^{-1} torr range. The overall optical radiation pattern follows the curve in fig. 4.

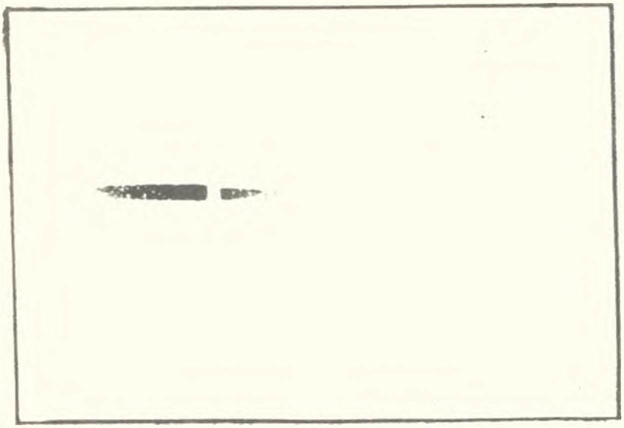

Fig. 5

Radiation of the beam of deuterium neutrals

The curve in fig. 6 is based on Allison's electron capture and excitation cross sections for hydrogen or deuterium ion beam incident on a nitrogen target [7]. $F_{o\infty}$ stands for excited neutrals of deuterium concentration in the target. The experimental data on radiation intensity dependence on the gas-target pressure are in fair accordance with the curve in Fig. 6.

Fig. 5 presents the radiation of the beam of deuterium neutrals /the picture is taken using an apropriate narrow band interference fil-

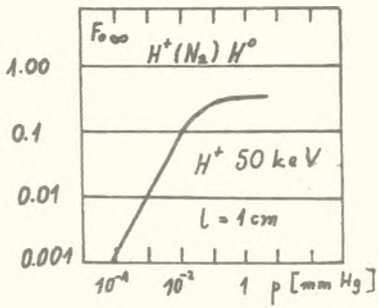

Fig. 6

Concentration of the hydrogen or deuterium neutrals produced in the nitrogen target vs target pressure

ter for the Balmer D_α line/. Excited atoms build-up and their deexcitation is clearly seen in the picture. The spectrum of the spontaneous deexcitation of the radiation accompanying the processes described by Equ. (3) was measured and the line wave-lengths are listed in the Table below.

TABLE

Line wave length nm	Identification	Remarks
806	unidentified	t
656	D_α n = 3 $\rightarrow$ n = 2	
550	molecular	t
497	molecular	t
486	D_β	
471	C I	
469	molecular	t
465	C III	
463	molecular	t
434	D_γ	
420	C	
410	D_δ	
391	C II	
389	D_ζ	t

Note: "molecular" denotes molecular deuterium identification, t denotes occurrence of a line in the gas target only. Carbon lines belong to the residual gas pressure of the vacuum oil.

The evidence of the D_ζ member of the Balmer series in deuterium has not previously been reported in the literature of gas target spectroscopy.

Measurements of life-times of the upper levels of the corresponding transitions were carried out on the D_α λ= 656 nm /n=3 level/ and the D_γ λ= 434 nm lines. The time of flight method and photographic registration were applied. Interference filters were used for spectroscopic separation of the lines of interest. Spectrophotometric evaluation of line intensity vs distance resulted in the following life times τ_{656} = (17.5 ± 2) nsec and τ_{434} = (13 ± 4) nsec.

Some preliminary results were obtained also on neon ions excitation on argon target. The first multiline spectra are being examined. The experiment is in progress.

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R E F E R E N C E S

1 S. Bashkin, Nuclear Instrum. Methods, 28, 88 /1964/.

2 L. Kay, Phys. Letters, 5, 36 /1962/.

3 W. Wien, Ann. Phys., 30, 369 /1909/; 60, 597 /1919/.

4 S. Bashkin, /ed./, Beam-Foil Spectroscopy, Vol. 1 and 2, Gordon and Breach, New York 1968.

5 I. Martinson, J. Bromander and H.G. Berry /eds./, in Nuclear Instrum. Methods, 90, 1-367 /1970/.

6 J.B. Marion, F.C. Young, Nuclear Reaction Analysis, North-Holland Publ. Co., Amsterdam 1968, p. 45.

7 S.K. Allison, Rev. Mod. Phys., 30, 1137 /1958/.

8 J. Chmiela, K. Melzacki, J. Pietruszka, in Progress Report of the Institute of Nuclear Physics, Cracow 1972, p. 72.

9 S. Bashkin /ed./, Nuclear Instrum. Methods, 110, 1 /1973/.

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NEW EXPERIMENTS ON GAS TARGET SPECTROSCOPY. ATOMIC LIFETIME MEASUREMENTS OF SOME DEUTERIUM LEVELS[1]

The impact of heavy ions on various gaseous targets was observed within the energy range available in the Institute of Nuclear Physics, Cracow 200 keV accelerator. The ions passing through a gas target were recharged and excited. The spontaneous deexcitation radiation was measured. New transitions in ionic species were observed and the time of flight method of life-time measurements applied. The results of the experiments on the deuterium spectrum are discussed. Measurements of life-times of upper levels of the corresponding transitions are described in detail on the D_α $\lambda = 656$ nm /n=3/ and D_γ $\lambda = 434$ nm lines.

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Новые эксперименты в спектроскопии газовых мишеней

Проводились наблюдения над бомбардированием тяжелыми ионами различных газовых мишеней в диапазоне, получаемом в акселераторе 200 кэв, находящемся в Институте ядерной физики в Кракове. Ионы, прошедшие через газовую мишень, были вторично заряжены и возбуждены. Регистрировалось излучение, возникающее при спонтанном развозбуждении. Замечены новые ионовые переходы. Применялся метод "времени перелета" для измерения времени жизни. Обсуждены результаты экспериментов, проведенных в спектре тяжелого водорода. Детально описаны измерения времени жизни верхних уровней переходов соответствующих линиям D_α λ = 656 нм /n=3/ и D_γ λ 434 нм.

I/. Результаты экспериментов были представлены на V всеобщей конференции спектроскопии, Варна 1973 г., организованной под патронатом Болгарской Академии наук.