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Detection of Rubidium (Rb^{85} & Rb^{87}) Ionized by Ultra-Violet Light

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Abstract

Photo-ions of rubidium were generated due to the interaction of effusive Rb atomic beam with the C.W. UV lamp of 2.5 KW power. The photo-ions isotopic of (Rb^{85} & Rb^{87}) were extracted and analyzed by a quadruple mass filter. The measured photo-ion current was 28 x 10^{-13} Amp.

Keywords: Photo-ionic species detection

الكشف عن أيونات الربيديوم (Rb^{85} و Rb^{87}) المتأينة بالأشعة فوق البنفسجية

الخلاصة

تم توليد أيونات الربيديوم بطريقة التأين الضوئي بأستخدام مصباح ضوئي في المنطقة الفـوق البنفسجية وبقدرة 2.5 كيلو واط. كما سجل الطيف للأيونات الناتجة من التأين الضوئي بأستخدام مطياف الكتلة حيث يتضح فيها نظيري الربيديوم (Rb^{85} و Rb^{87}) وحسب النسب الطبيعيـــة. وتم قياس التيار الايوني في حدود $28x10^{-13}$ امبير.

Introduction

Ion species detection is a field of many interests. It applies to the determination of the ionic collision cross section and for experiments in decay time measurement of various ionic states [1-6].

One of the most important aspects of studying the internal structure of atoms and molecules involves the absorption of quantum of light , for example microwave and infrared spectroscopy yield information about the rotational and vibrational levels in a molecule while optical and ultraviolet absorption spectroscopy probes vibration as well as the electronic degrees of freedom. These techniques are very similar in that they involve resonant absorption of light quanta.

This takes the system from an initial state to a final state with a difference in energy equal to the energy of the photon absorbed.

Thus the experimental techniques used in these types of spectroscopy generally involve exposing the sample to a known photon flux or energy and examining the resultant flux from the sample after the interaction has taken place [1.2].

Photoionization is in principle very similar to the techniques mentioned above. The major difference arises because the final states observed in photoionization lie in the ionization continuum. Absorption of a photon thus results in the ejection of one photoelectron from the system. That is :-

$$A+h\upsilon \rightarrow A^{+} + e \qquad \ldots(1)$$

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The analysis of the ejected particles gives information about the absorption process. In other words, the products of the photoionization lead to the various techniques that have been used to determine specific absorption processes.

Mass spectroscopy is used to identity unambiguously the ions that are produced. Measurements of the ions and electron kinetic energies lead to fields of photoelectron and spectroscopic study [3,7].

The goal in experimental photoionization studies is to determine the absorption cross section that is given by.

$$\sigma = 1/nL \ \ln I/I_0 \qquad \ldots(2)$$

$$I = I_0 \, e^{\sigma n L} \qquad \ldots(3)$$

Where n is the number density of the gas:

L is the path length traversed.

I_0,I are the intensities of the radiation before and after traversing the gas respectively.

From the simple classical definition of photoelectric cross section per atom:

$$I' = \sigma I'' \qquad \ldots(4)$$

Where I' is the number of photons absorbed per second per atom in a beam of I'' photons per second per square centimeter [2]. Also Dunning has shown that the photo current i for quantum yield Q is approximately[5]:

$$i = Q \, I_0 \, n\sigma L \qquad \ldots(5)$$

Where I_0 is the incident photon intensity.

L is the path length of substance containing n atoms per unit volume.

and σ is the photoionization cross section.

This report explains the generation of photo ions and the facility of ionic species detection of Rb isotopes. (Verification of the ion optics design trends of transferring the charged particles from the ionization region to the head of the mass analyzer quadruple filter type QMG 511 of Balzers Company). The (Rb^{85} & Rb^{87}) ions were generated in this investigation due to the interaction of UV photons (2.5 KW power) with rubidium atomic beam.[7]

Experiment & Results

Atomic Rb beam is produced by heating the metal in an effusive source to 850°C and atomic beam is effused through 1mm throat diameter cell Rubidium of 4.17 eV ionization potential, was photo-ionized due to the interaction region of the focused UV lamp at wavelength 2967Å whose photon energy is equal to the photoionzation energy of rubidium atom see fig (1) [8].

The photo-ions were extracted by an extracting and accelerating potential. The electrodes were constructed from stainless steel grids.

The applied grid voltages were optimized for rubidium ion current signal detection due to the focusing effect of the electrostatic lens (see fig.2).

The focal length of the electrostatic lens is calculated according to the following equation.

$$\frac{1}{f} = \frac{V_2 - V_1}{4\,dV_2} \qquad ..(6)$$

Where V1 & V2 are the absolute values of the electrode voltages and d is the spacing between the electrodes.[9]

The lens of 30 cm focal length and the optimized potentials of the ions optics (Fig.2) ensured the photo-ion bunching at the entrance of the mass filter.

The background spectrum was maintained at pressure of 10^{-7} mbar (with two stages vacuum system (Turbo molecular pump and Rotary pump)), where the atomic beam was not generated in Fig.3.a. Fig.3.b, shows the generation of the effusive atomic beam of Rb at source temperature of 850 ºC , and chamber pressure of 5 x 10^{-5} mbar.

The Rb isotopic spectrum was only reproduce as in Fig.4 by using quadruple ion source where the detection current was $20x10^{-11}$ Amp.

Fig.5 the cross beam ionizer of the quadruple mass filter was switched off, and the voltages of the ion lens and ion optics where optimized to get a maximum photo ion current i as explained in expression (5) for rubidium ion species which ionized by ultra violet light and the detection current was $28x10^{-13}$Amp.

Conclusions

The detected ionic current was recorded at maximum sensitivity of the electrometer around 10^{-13} Amp. The signal might be enhanced by improving the photon atomic beam interaction and also improving the ion transfer optics. The ion loss rate to the boundaries can be reduced by screening with ion repeller electrodes.

There was no indication of ion current detection when the electrostatic lens was switched off or when the UV lamp was blocked, which assures the detection of the photo-ions.

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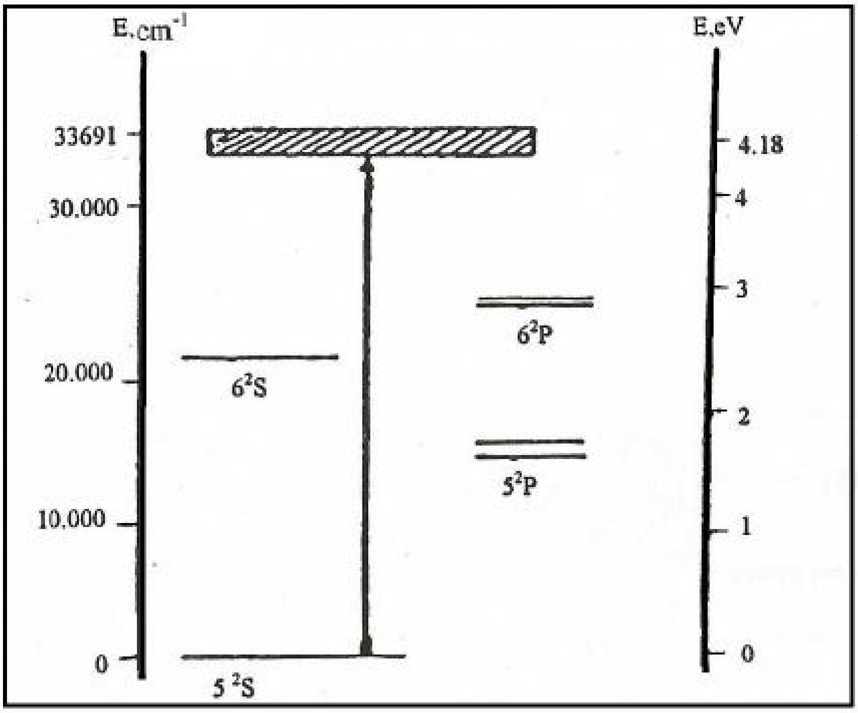

Figure (1) Energy level Scheme for Rb Atom [8]

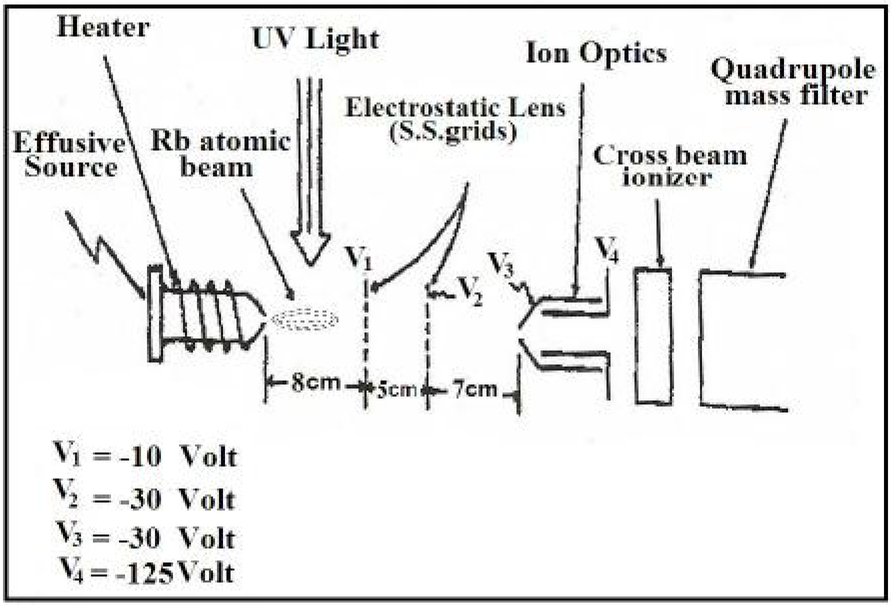

Figure (2) Experimental Setup

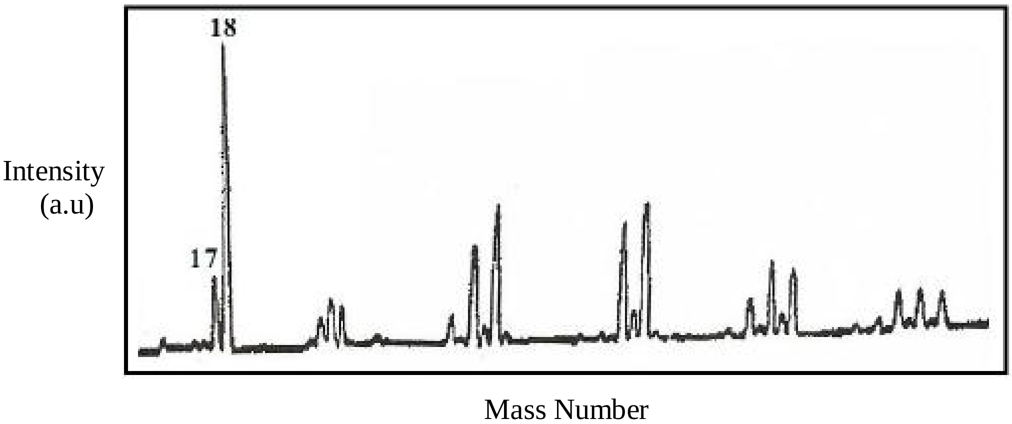

Figure (3a) Background Spectrum at a chamber pressure of 10^{-7} mbar

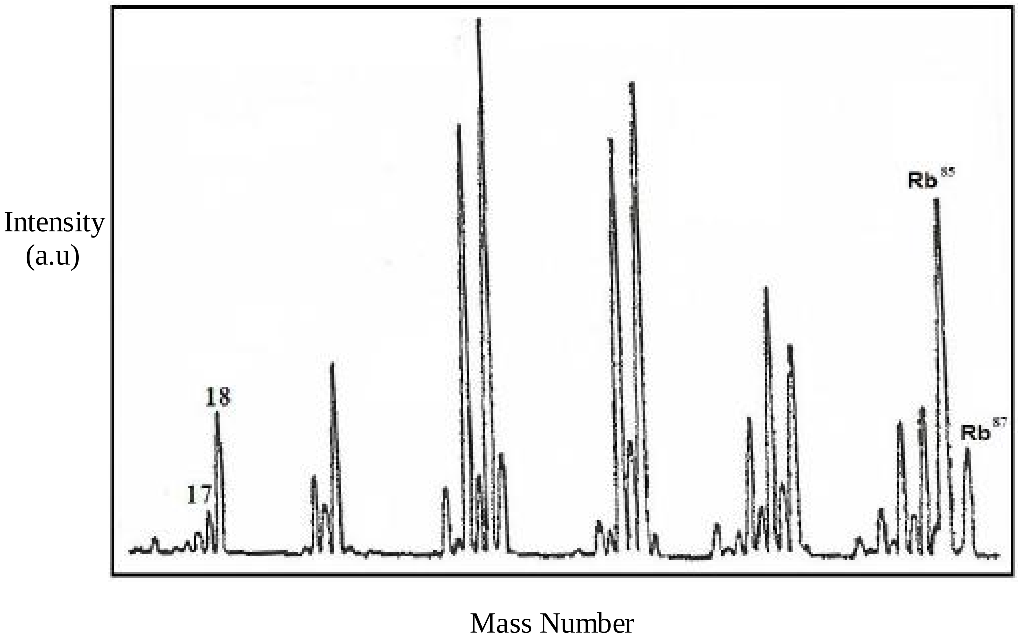

Figure (3b) Effusive atomic beam spectrum at T= 850 °C, Rb^{85} & Rb^{87} are shown

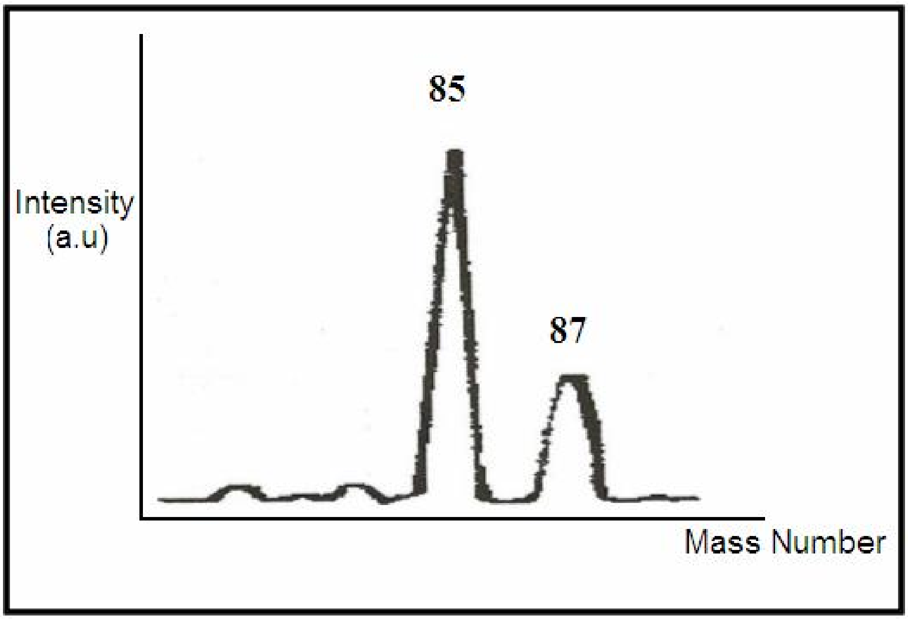

Figure (4) Rubidium isotopes (Rb^{85} ,Rb^{87}) at T= 850 °C using quadruple ion source (I=20 x 10^{-11} Amp.)

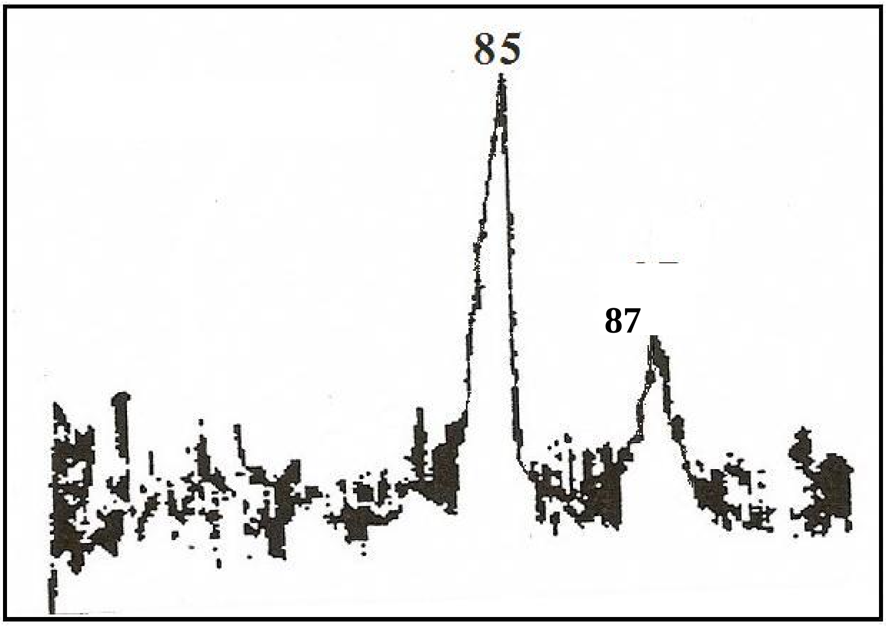

Figure (5) UV photo – ionization spectrum of (Rb^{85} & Rb^{87}) at T=850 °C (I=28 x 10^{-13} Amp.)