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# CALCULATION ON THE ATOMIC LINE RADIATION EXCITED BY LONGITUINALLY SPIN POLARIZED ELECTRONS IN ELECTRON-CESIUM SCATTERING

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## ABSTRACT

The stokes parameter formulation has been used to describe the polarization state of the light emitted in the transition

$$6p\ ^2P_{1/2,3/2} \longrightarrow 6s\ ^2S_{1/2}$$

in atomic cesium. The incident electrons are assumed to be longitudinally polarized.

## INTRODUCTION

The problem of polarization of the atomic line radiation is treated theoretically. By Percival and Seaton [1] reducing the O-P expressions for the two extreme cases (the line width is much larger or much smaller than the fs or hfs separations). Flower and Seaton [2] calculated the threshold polarization of the resonace lines of $^6Li$, $^7Li$ and $^{23}Na$, excited by electron impact, using the theory developed by Percival and Seaton [1].

Fano and Macek [3] presented a new formulation for the angular distribution and the polarization of light excited by atomic and electronic collisions. They reviewed the theoretical connection between the radiating atom and the relevant parameters ( the three parametric components of the orientation vector which are proportional to the average angular momentum of the radiating system and the five parametric components of the alignment tensor which are proportional to the quadratic combinations of the angular momentum components of the radiating system ).

The Stokes' parameters required to describe the emitted light from an atom excited by spin polarized electron impact are presented by Bartschat et al., [4] where the spin-orbit coupling effects during the excitation are taken into account. Also they invistigated the case when the scattered electrons are undetected driving some additional selection rules to reduce the number of independent parameters selection rules to reduce the number of independent parameters introduced into the description of the collimated light.

Later, Bartschat et al., [5] and Nagy et al., [6] used the relativistic R-matrix method developed by Scott and Burke [7] to study Stokes' parameters describing the light emitted

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from excited mercury and cesium atoms, respectively. The calculations therein are done under the assumption that the atoms are excited by transversally spin polarized electrons incident on the target atoms.

In the present calculation we assume that the incident electrons are longitudinally spin polarized with energies close to the threshold energies.

THEORY :

The degrees of linear and circular polarization of the emitted light are given by equating eq. (1.2.2) and eq. (5.5.1) in ref. [8]. We assume that the direction of the incident beam and the electronic spin polarization vector to be along Z-axis. In this calculation we set $\phi = \pi/2$, where $\phi$ is the azimuth angle of the photon dector.

(a) cs: $6p\ ^4P_{1/2} \longrightarrow 6s\ ^2S_{1/2}$

the degree of circular polarization, $_2$, takes the form

$$_2 = \frac{c(w)\, |\langle \tfrac{1}{2} \| r \| \tfrac{1}{2} \rangle|^2}{I} \left[ \frac{\sqrt{2}}{3}\, G_1\, (1/2) \langle \mathcal{T}(1/2)^{+}_{10} \rangle \right] \cos 0 \qquad (1)$$

where $C(\omega) = (e^2\ \omega^4 / 2\pi c^3)\, d\Omega_\gamma$ is the leading factor, $d\Omega_\gamma$ is the element of solid angle into which photons with

frequency $\omega$ and speed c are collimated. $\theta$ is the polar angle of the photon detector.
the intensity I is given by:

$$I = c(w) \left| < \tfrac{1}{2} \| \underline{r} \| \tfrac{1}{2} > \right|^2 \frac{\sqrt{2}}{3} G_o\,(1/2) < \mathcal{T}(1/2)^{+}_{oo} > \qquad (2)$$

the perturbation coefficients G(1/2),$G_1$(1/2), are calculated from the equation [10] of renference [8]

$$G_k(J) = \frac{1}{2I + 1} \sum_F (2F + 1) \begin{Bmatrix} J & F & I \\ F & J & K \end{Bmatrix}^2 \qquad (3)$$

to give

$$G_o(1/2) = \tau$$

$$G_1(1/2) \approx 0.343\,\tau$$

Where $\tau$ is the life time of the excited staste. I in eq. [3] refers to the nuclear spin which is equal to 7/2 in case of cesium.

$\begin{Bmatrix} .. & .. & .. \\ .. & .. & .. \end{Bmatrix}$ is the will known 6j-symbol. $< \mathcal{T}(J)^{+}_{kQ} >$ stands for the integrated state multipoles, for details see ref. [4].

The degree of linear polarization with respect to Z- and X-axis, $\eta_3$, and with respect to two axes make an angle equals to 45 degrees with x-axis, $\eta_1$, are vanished in this case.

(b) CS: $6P\ ^2P_{3/2} \longrightarrow 6S\ ^2S_{1/2}$

In this case we get

$$I = C(\omega) \left| \langle \tfrac{1}{2} \| \underline{r} \| \tfrac{3}{2} \rangle \right|^2 \Big[ \tfrac{1}{3} G_0 (\tfrac{3}{2}) \langle \mathcal{T}(\tfrac{3}{2})^{+}_{00} \rangle + \tfrac{1}{12} G_2 (\tfrac{3}{2}) \langle \mathcal{T} (\tfrac{3}{2})^{+}_{20} \rangle (3 \cos^2\theta - 1) \Big] \tag{4}$$

$$\eta_3 = - \frac{c(w) \left| \langle \tfrac{1}{2} \| \underline{r} \quad \tfrac{3}{2} \rangle \right|^2}{I} \Big[ \tfrac{1}{4} G_2(\tfrac{3}{2}) \langle \quad (\tfrac{3}{2})^{+}_{20} \rangle \sin^2\theta \Big] \tag{5}$$

$$\eta_2 = c(w) \left| \langle \tfrac{1}{2} \| \underline{r} \| \tfrac{3}{2} \rangle \right| \Big[ \tfrac{\sqrt{5}}{6} G_1( \tfrac{3}{2}) \langle \mathcal{T} (\tfrac{3}{2})^{+}_{10} \rangle \cos \theta \Big] \tag{6}$$

in which

$G_o(3/2) = \tau$

$G_1(3/2) = 0.37 \ \tau$

$$G_2(3/2) = 0.219\,\tau$$

## RESULTS AND DISCUSSION

In figures 1-3 we present our numerical results for the integrated Stokes' parameters. As expected from the values of the perturbation coefficients, the absolute values of the Stokes' parameters are rather small. It can be seen, from eq. (3), that the large nuclear spin, I = 7/2 in case of cesium, causes a significant depolarization of the emitted radiation. The structure seen in figures 1-3 is caused dy resonances analysed in ref. [9]. These results show what effects can be expected and may be useful for planning for future experiments.

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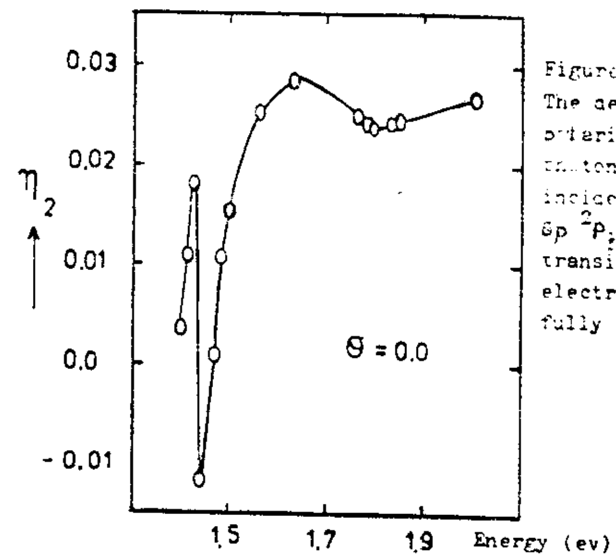


Figure I
The degree of circular polarization of the emitted photons of the electronic incident energy in Cs : $6p\ ^2P_{\frac{1}{2}} \longrightarrow 6s\ ^2S_{\frac{1}{2}}$ transition. The incident electrons are longitudinally fully polarized.

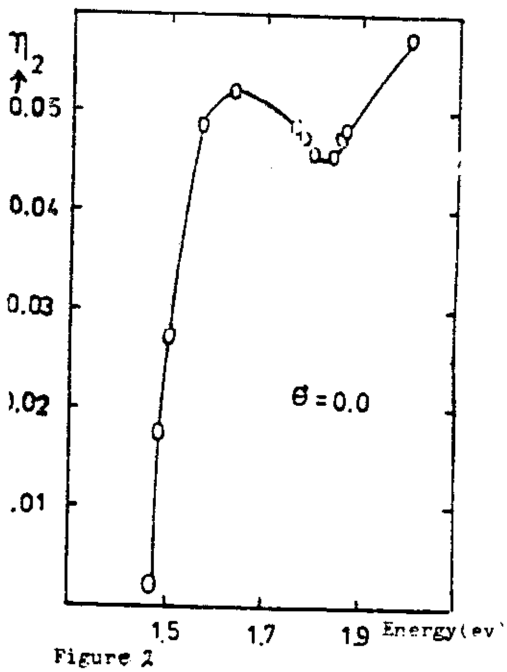


Figure 2
As figure I for Cs : $6p\ ^2P_{\frac{1}{2}} \longrightarrow 6s\ ^2S_{\frac{1}{2}}$ transition.

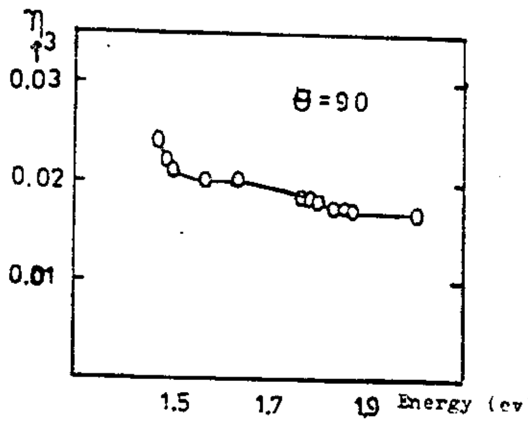


Figure 3
As figure 2 for the linear polarization.

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**حسابات على الاشعاع الخطى الذرى المثار بواسطة**
**الكترونات مستقطبة مغزليا استقطابا خطيا فى**
**استطارة الالكترون ــ سيزيوم**

+ اسامة زيد ابراهيم ناجى ــ × جلال الدين حسن
+ كلية التربية ــ قسم الطبيعة والكيمياء ــ كفر الشيخ ــ مصر
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استخدمت طريقة بارمترات ستوك لوصف الحالة القطبية للضوء المنبعث فى الانتقال فى ذرة السيزيوم ، على فرض أن الالكترونات الساقطة مستقطبة استقطابا خطيا٠