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EXCHANGE COLLISIONS BETWEEN THE IONIC GROUND STATE AND THE NEUTRAL METASTABLE STATE OF ATOMS FORMED AND ALIGNED BY ELECTRON IMPACT

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July 5, 1967

The radio-frequency paramagnetic resonance method was used to observe the exchange collisions between the Xe ionic ground state having a $^2P_{3/2}$ configuration and the neutral metastable state having a $^3P_2$ configuration. The ionic ground-state and the metastable-state atoms are both formed and aligned by unidirectional-low energy, high flux electron beam impact. The magnetic resonance of the ionic ground-state atoms was observed by monitoring changes in the transparency of the resonance radiation to the metastable state.

By unidirectional-low energy electron impact excitation of Xe atoms from the $^1S_0$ ground state to the $^3P_2$ metastable state, the magnetic sublevels $M_J = 0$ and $\pm 1$ are more selectively excited than those with $M_J = \pm 2$. This is also experimentally verified from the paramagnetic resonance experiment of the metastable state. Similarly, certain magnetic sublevels of Xe$^+(^2P_{3/2})$ are expected to be selectively excited by the electron impact. Suppose if one would produce a high concentration of the aligned Xe$^+(^2P_{3/2})$ and Xe($^3P_2$) state atoms by high flux electron beam, a certain population equilibrium will be reached in a steady state. A destruction of the alignment of Xe$^+(^2P_{3/2})$ would result in a new population re-distribution of the Xe($^3P_2$) metastable state. Such a phenomenon is observable by monitoring
the change of transparency of linearly polarized resonance radiation due to
the absorption of the light by the metastable state.

The high flux, low energy-unidirectional electron beam was obtained by
means of space charge neutralized electron flow using a planar diode structure
electron tube with an indirectly heated "hot" cathode operating under the
Xe gas pressure of about $5 \times 10^{-4}$ torr at 70 mA/cm$^2$ electron current density
at slightly above the ionization potential of Xe. The first slide shows the
relevant energy level diagram. The second slide shows the experimental
arrangement.

The third slide shows an experimental result which gives the $3P_2$ as
well as $2P_{3/2}$ magnetic resonances. The fourth slide shows the magnetic
resonances of Xe$^{129}(3P_2)$, Xe$^{131}(3P_2)$, and even isotope Xe$^+(2P_{3/2})$.

Recently we observed that the nucleus of Xe$^{131}$ having $I = 3/2$ can
also be aligned by metastability exchange between an initially randomly
oriented nucleus in the $1S_0$ ground state and aligned Xe$^{131}(3P_2)$ by electron
impact. The fifth slide shows the experimental result of nuclear alignment
by metastability exchange collisions.

Thus by means of an extremely simple apparatus, we have found that:
(1) it is possible to observe alignment of the ionic ground state and (2)
it is possible to align the nucleus in the $1S_0$ ground state. A more detailed
investigation is presently in progress to study the mechanisms involved
more precisely.
Electron-impact excitation

Relevant energy level used in Xe ($^{3}P_{2}$) resonance absorption

Slide 1.
Slide 2.
Slide 3.

\[ H(\text{gauss}) \]

\[ \begin{align*}
2.422 & \quad 2.719 \\
\end{align*} \]

- Relative signal (1000 counts)
- Channel number

- \( ^3P_2 \) of Xe I rf resonance
- \( ^2P_{3/2} \) of Xe II rf resonance
Slide 4.

The graph shows the relative signal (in 10^3 counts) as a function of channel number, with magnetic field (H in gauss) on the top axis. The peaks at 5.508 and 5.275 gauss correspond to identified resonances of Xe^{129} (3P_2) and Xe^{131} (3P_2), respectively. The peak at 4.944 gauss is an unidentified resonance. The channel number ranges from 10 to 200.
Magnetic field (gauss)

\( \nu = 15.45590 \text{ MHz} \)
\( H = 7.3577 \text{ G} \)

\( \nu = 2.5680 \text{ kc} \)
\( H = 7.3516 \text{ G} \)

\( \nu = 2.5680 \text{ kHz} \)

Relative signal

Slide 5.
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