# Quenching and Depolarization of Mercury Resonance Radiation by the Rare Gases

LEONARD O. OLSEN
*Case School of Applied Science, Cleveland, Ohio*

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The quenching and depolarization of mercury 2537A resonance radiation by helium, neon, argon, and krypton has been studied experimentally, the results being displayed in graphical and tabular form. Probable numbers of quenching and depolarizing collisions and cross sections for quenching and depolarization have been calculated and are presented in Table V.

## INTRODUCTION

IN a recent paper[1] (referred to as I hereafter) a theory of quenching and depolarization of resonance radiation by foreign gases was presented. An experimental study of quenching and depolarization of mercury resonance radiation by several diatomic gases was also described.

In deriving formulae for polarization and rotation of the plane of maximum polarization as a function of foreign gas pressure and applied magnetic field, a quenching coefficient and two depolarizing coefficients were introduced. Two depolarizing coefficients were used because the experimental work indicated that a portion of the depolarizing collisions was adiabatic, leaving the excited atoms in states coherent with those which existed before the collisions.

In order to secure more information, especially concerning the depolarizing mechanism, it was decided to perform a series of experiments on the quenching and depolarization of mercury resonance radiation by some of the rare gases. The low quenching ability of these substances should make depolarization effects more discernible.

The formulae presented in paper I have been used to determine the quenching and depolarizing probabilities which are presented in this paper. The experimental procedure is unaltered except for the photometry of the photographic images secured in determining the match position. In this series of experiments the densities were measured with a Schulte photometer which is an ideal instrument for measuring the many images which must necessarily be secured when the Cornu method is used.

The experimental conditions were checked frequently by determining the polarization as a function of magnetic field with no foreign gas present. Good agreement with H. F. Olson's[2] data was always secured before experiments were performed with foreign gases present.

The helium, neon and argon used were spectroscopically pure. The krypton contained 5.4 percent xenon.

## RESULTS

The observed values of polarization of the 2537A mercury line for various pressures of

TABLE I. *Polarization in helium and rotation of plane of polarization for various fields (measured in gauss) and pressures (measured in mm of Hg).*

| $H$ | $p=0.15$ $P_{obs}$ | $P_{calc}$ $\alpha''=0.35$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0.35$ | Tan $2\phi$ calc. $\alpha''=0$ | 0.33 $P_{obs}$ | Tan $2\phi$ obs. |
|---|---|---|---|---|---|---|---|---|
| 0 | 0.66 | 0.66 | 0.66 | | | | 0.55 | |
| 0.203 | 0.54 | 0.55 | 0.56 | | | | 0.50 | |
| 0.406 | 0.37 | 0.37 | 0.39 | *0.91* | *0.83* | *0.79* | 0.38 | *0.74* |
| 0.812 | 0.18 | 0.17 | 0.19 | *1.70* | *1.65* | *1.58* | 0.19 | *1.37* |
| 1.218 | 0.11 | | | *2.27* | *2.22* | *2.17* | | *2.19* |
| 1.624 | | | | | | | 0.06 | |

| $H$ | $p=0.68$ $P_{obs}$ | $P_{calc}$ $\alpha''=0.35$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0.35$ | Tan $2\phi$ calc. $\alpha''=0$ |
|---|---|---|---|---|---|---|
| 0 | 0.41 | 0.41 | 0.41 | | | |
| 0.203 | 0.38 | 0.38 | 0.39 | | | |
| 0.406 | 0.33 | 0.32 | 0.34 | *0.53* | *0.50* | *0.44* |
| 0.812 | 0.21 | 0.20 | 0.22 | *0.97* | *1.00* | *0.88* |
| 1.218 | 0.14 | 0.12 | 0.14 | *1.46* | *1.50* | *1.33* |

| $H$ | $p=0.50$ $P_{obs}$ | $P_{calc}$ $\alpha''=0.35$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | 1.07 $P_{obs}$ | 1.97 $P_{obs}$ | 3.2 $P_{obs}$ | 5.5 $P_{obs}$ |
|---|---|---|---|---|---|---|---|---|
| 0 | 0.48 | 0.47 | 0.47 | | 0.33 | 0.22 | 0.15 | 0.09 |
| 0.203 | 0.45 | 0.45 | 0.45 | | | | | |
| 0.406 | 0.36 | 0.35 | 0.37 | *0.61* | | | | |
| 0.812 | 0.21 | 0.20 | 0.22 | *1.06* | | | | |
| 1.218 | 0.14 | 0.12 | 0.14 | *1.59* | | | | |

[1] A. Ellett, L. Olsen, and R. Petersen, Phys. Rev. **60**, 107 (1941).

[2] H. F. Olson, Phys. Rev. **32**, 443 (1928).

TABLE II. *Polarization in neon and rotation of plane of polarization for various fields (measured in gauss) and pressures (measured in mm of* Hg).

| $H$ | $p=0.13$ $P_{obs}$ | $P_{calc}$ $\alpha''=0.14$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0.14$ | Tan $2\phi$ calc. $\alpha''=0$ | 0.145 $P_{obs}$ | Tan $2\phi$ obs. |
|---|---|---|---|---|---|---|---|---|
| 0 | 0.71 | 0.71 | 0.71 | | | | 0.69 | |
| 0.203 | 0.56 | 0.57 | 0.57 | | | | 0.54 | |
| 0.406 | 0.35 | 0.37 | 0.37 | *1.02* | *0.91* | *0.89* | 0.34 | *1.08* |
| 0.812 | 0.18 | 0.17 | 0.17 | *1.83* | *1.79* | *1.76* | 0.16 | *1.86* |
| 1.218 | 0.10 | | | *2.78* | | *2.32* | 0.10 | *3.08* |

| $H$ | $p=0.395$ $P_{obs}$ | Tan $2\phi$ obs. | 0.62 $P_{obs}$ | 0.76 $P_{obs}$ | $P_{calc}$ $\alpha''=0.14$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0.14$ | Tan $2\phi$ calc. $\alpha''=0$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.59 | | 0.54 | 0.52 | 0.51 | 0.51 | | | |
| 0.203 | 0.50 | | 0.48 | 0.47 | 0.46 | 0.47 | | | |
| 0.406 | 0.34 | *0.89* | 0.36 | 0.36 | 0.36 | 0.37 | *0.69* | *0.62* | *0.58* |
| 0.812 | 0.17 | *1.52* | 0.20 | 0.20 | 0.20 | 0.21 | *1.29* | *1.22* | *1.16* |
| 1.218 | 0.11 | *1.88* | 0.13 | 0.13 | 0.12 | 0.13 | *1.63* | *1.81* | *1.72* |

| $H$ | $p=1.08$ $P_{obs}$ | Tan $2\phi$ obs. | 1.49 $P_{obs}$ | 2.31 $P_{obs}$ | 2.54 $P_{obs}$ | 3.51 $P_{obs}$ | 4.85 $P_{obs}$ | 7.45 $P_{obs}$ |
|---|---|---|---|---|---|---|---|---|
| 0 | 0.44 | | 0.39 | 0.30 | 0.30 | 0.25 | 0.19 | 0.13 |
| 0.203 | 0.41 | | | 0.29 | | | | |
| 0.406 | 0.34 | *0.59* | | 0.25 | | | | |
| 0.812 | 0.23 | *1.01* | | 0.20 | | | | |
| 1.218 | 0.14 | *1.48* | | 0.14 | | | | |

helium, neon, argon, and krypton and for various magnetic field intensities are given in Tables I to IV. In addition, the tangents of twice the angle of rotation of the plane of maximum polarization for various pressures and field intensities are listed in italics.

Quenching coefficients and depolarizing coefficients ($\alpha$, $\alpha'$ and $\alpha''$) have been chosen which give the best over-all agreement between the polarizations, etc., calculated from Eqs. (10) and (11) of paper I and those observed experimentally. Typical calculated results are also displayed in Tables I to IV.

In view of the rather small values of the adiabatic depolarizing coefficient $\alpha''$, it was deemed desirable to determine the values of polarization calculated on the assumption that all the depolarizing collisions were non-adiabatic, that is, $\alpha''$ equals zero and $\alpha'$ is the total depolarizing coefficient. Typical results have been included in the tables. The data are displayed graphically in Figs. 1 to 6, inclusive. The circles, squares, etc., locate the experimentally determined values and the solid curves are drawn through the points calculated from Eqs. (10) and (11) of paper I. The best values of $\alpha$, $\alpha'$ and $\alpha''$ have been used. In Fig. 6 only one plot of rotation of the plane of maximum polarization is shown for each gas in order to avoid confusion.

TABLE III. *Polarization in argon and rotation of plane of polarization for various fields (measured in gauss) and pressures (measured in mm of* Hg).

| $H$ | $p=0.12$ $P_{obs}$ | $P_{calc}$ $\alpha''=0.13$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0.13$ | Tan $2\phi$ calc. $\alpha''=0$ | 0.15 $P_{obs}$ |
|---|---|---|---|---|---|---|---|
| 0.0 | 0.72 | 0.71 | 0.71 | | | | 0.68 |
| 0.203 | 0.56 | 0.58 | 0.58 | | | | 0.55 |
| 0.406 | 0.38 | 0.38 | 0.38 | *1.01* | *0.89* | *0.88* | 0.36 |
| 0.812 | 0.17 | 0.17 | 0.18 | *1.68* | *1.76* | *1.74* | 0.17 |
| 1.218 | 0.09 | | | *2.20* | | *2.34* | 0.10 |

| $H$ | $p=0.35$ $P_{obs}$ | Tan $2\phi$ obs. | 1.51 $P_{obs}$ | 2.30 $P_{obs}$ | 3.60 $P_{obs}$ | 5.00 $P_{obs}$ | 8.25 $P_{obs}$ |
|---|---|---|---|---|---|---|---|
| 0.0 | 0.58 | | 0.33 | 0.25 | 0.20 | 0.15 | 0.10 |
| 0.203 | 0.51 | | | | | | |
| 0.406 | 0.35 | *0.80* | | 0.26 | | | |
| 0.812 | 0.17 | *1.41* | | 0.20 | | | |
| 1.218 | 0.11 | *1.83* | | 0.14 | | | |

| $H$ | $p=0.56$ $P_{obs}$ | 0.67 $P_{obs}$ | $P_{calc}$ $\alpha''=0.13$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | 1.12 $P_{obs}$ | Tan $2\phi$ obs. |
|---|---|---|---|---|---|---|---|
| 0.0 | 0.52 | 0.50 | 0.50 | 0.50 | | 0.41 | |
| 0.203 | 0.46 | 0.45 | 0.45 | 0.45 | | 0.38 | |
| 0.406 | 0.35 | 0.36 | 0.35 | 0.36 | *0.64* | 0.33 | *0.43* |
| 0.812 | 0.19 | 0.21 | 0.20 | 0.21 | *1.14* | 0.21 | *0.93* |
| 1.218 | | 0.13 | 0.12 | 0.13 | *1.48* | 0.16 | *1.18* |

TABLE IV. *Polarization in krypton and rotation of plane of polarization for various fields (measured in gauss) and pressures (measured in mm of* Hg).

| $H$ | $p=0.17$ $P_{obs}$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0$ | $p=0.43$ $P_{obs}$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0$ |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.68 | 0.68 | | | 0.56 | 0.57 | | |
| 0.203 | 0.55 | 0.56 | | | 0.50 | 0.50 | | |
| 0.406 | 0.38 | 0.38 | *1.04* | *0.84* | 0.38 | 0.38 | *0.75* | *0.67* |
| 0.812 | 0.19 | 0.18 | *1.68* | *1.66* | 0.22 | 0.20 | *1.37* | *1.34* |
| 1.218 | 0.12 | | *2.42* | *2.23* | 0.13 | 0.12 | *2.02* | *1.92* |

| $H$ | $p=0.75$ $P_{obs}$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0$ | 1.14 $P_{obs}$ | $P_{calc}$ $\alpha''=0$ | Tan $2\phi$ obs. | Tan $2\phi$ calc. $\alpha''=0$ |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.49 | 0.48 | | | 0.40 | 0.40 | | |
| 0.203 | 0.44 | 0.44 | | | 0.39 | 0.38 | | |
| 0.406 | 0.37 | 0.37 | *0.54* | *0.54* | 0.34 | 0.33 | *0.42* | *0.43* |
| 0.812 | 0.23 | 0.22 | *0.97* | *1.06* | 0.23 | 0.22 | *0.82* | *0.85* |
| 1.218 | 0.18 | 0.14 | *1.29* | *1.59* | 0.17 | 0.15 | *1.10* | *1.28* |

| $H$ | $p=1.70$ $P_{obs}$ | 2.27 $P_{obs}$ | 3.25 $P_{obs}$ | 4.91 $P_{obs}$ | 7.30 $P_{obs}$ |
|---|---|---|---|---|---|
| 0.0 | 0.31 | 0.27 | 0.21 | 0.16 | 0.13 |

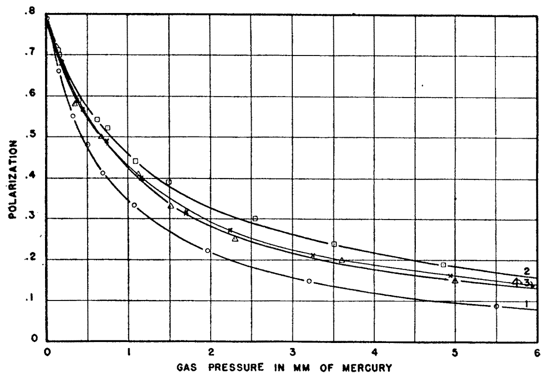


FIG. 1. Polarization of mercury resonance radiation as a function of gas pressure. The curves are drawn with the $\alpha$'s given in Table V. Curve 1 (○), helium; 2 (□), neon; 3(△), argon; 4 (×), krypton.

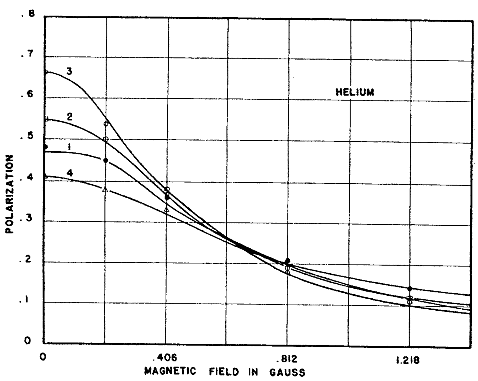


FIG. 2. Effect of magnetic fields on polarization of mercury resonance radiation at fixed helium pressures. The curves are drawn with $\alpha=0$, $\alpha'=1.4\times10^7$ and $\alpha''=0.35\times10^7$. Curve 1 (●), helium pressure $=0.50$ mm of Hg; 2 (□), $p=0.33$ mm of Hg; 3 (○), $p=0.15$ mm of Hg; (△), $p=0.68$ mm of Hg.

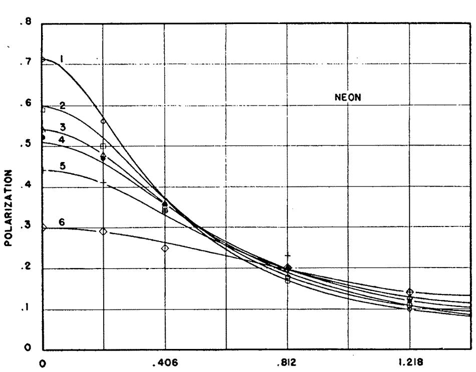


FIG. 3. Effects of magnetic fields on polarization of mercury resonance radiation at fixed neon pressures. The curves are drawn with $\alpha=0.02\times10^7$, $\alpha'=0.77\times10^7$ and $\alpha''=0.14\times10^7$. Curve 1 (○), neon pressure $=0.13$ mm of Hg; 2 (□), $p=0.395$ mm of Hg; 3 (△), $p=0.62$ mm of Hg; 4 (●), $p=0.76$ mm of Hg; 5 (+), $p=1.08$ mm of Hg; 6 (◇), $p=2.31$ mm of Hg.

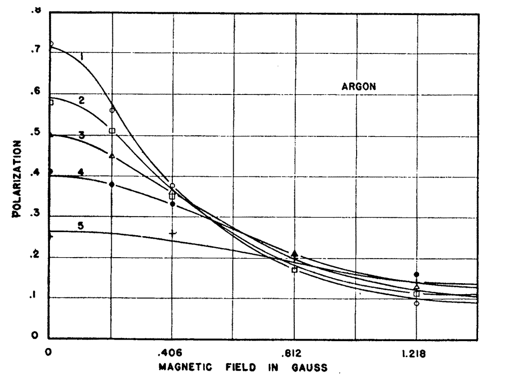


FIG. 4. Effect of magnetic fields on polarization of mercury resonance radiation at fixed argon pressures. The curves are drawn with $\alpha=0.01\times10^7$, $\alpha'=0.97\times10^7$ and $\alpha''=0.13\times10^7$. Curve 1 (○), argon pressure $=0.12$ mm of Hg; 2 (□), $p=0.35$ mm of Hg; 3 (△), $p=0.67$ mm of Hg; 4 (●), $p=1.12$ mm of Hg; 5 (+), $p=2.30$ mm of Hg.

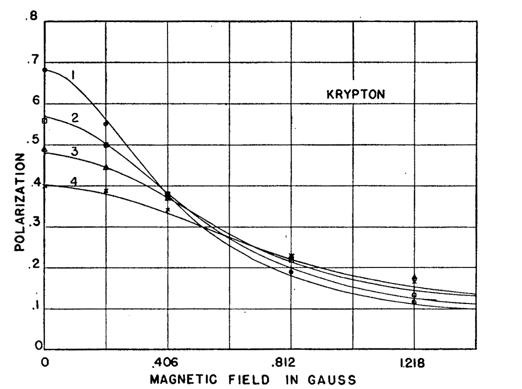


FIG. 5. Effect of magnetic fields on polarization of mercury resonance radiation at fixed krypton pressures. The curves are drawn with $\alpha=0.0$, $\alpha'=1.11\times10^7$ and $\alpha''=0.0$. Curve 1 (○), krypton pressure $=0.17$ mm of Hg; 2 (□), $p=0.43$ mm of Hg; 3 (△), $p=0.75$ mm of Hg; 4 (×), $p=1.14$ mm of Hg.

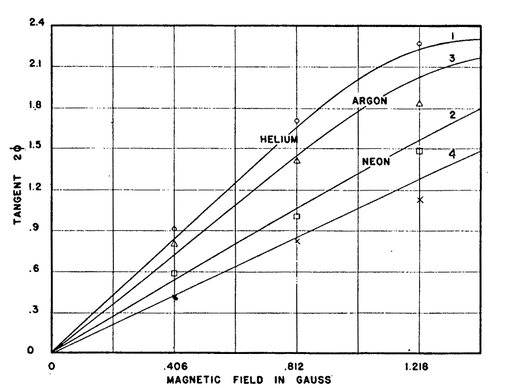


FIG. 6. Rotation of the plane of maximum polarization as a function of magnetic fields for the gases studied. The curves are drawn with the $\alpha$'s given in Table V. Curve 1 (○), helium at $p=0.15$ mm of Hg; 2 (□), neon at $p=1.08$ mm of Hg; 3 (△), argon at $p=0.35$ mm of Hg; 4 (×), krypton at $p=1.14$ mm of Hg.

TABLE V. *Collision probabilities* ($\times 10^{-7}$ sec.$^{-1}$) *and cross sections* ($\times 10^{16}$ cm$^2$).

| Gas | Quenching $\alpha$ | Quenching $\sigma_{\alpha}{}^2$ | Non-Adiabatic Depolarizing $\alpha'$ | Non-Adiabatic Depolarizing $\sigma_{\alpha'}{}^2$ | Adiabatic Depolarizing $\alpha''$ | Adiabatic Depolarizing $\sigma_{\alpha''}{}^2$ | Total Depolarizing $\sigma^2{}_{\alpha'+\alpha''}$ |
|---|---|---|---|---|---|---|---|
| He | negligible | negligible | 1.40 | 10.6 | 0.35 | 2.66 | 13.26 |
| Ne | 0.02 | 0.325 | 0.77 | 12.6 | 0.14 | 2.30 | 14.90 |
| A | 0.01 | 0.222 | 0.97 | 21.6 | 0.13 | 2.89 | 24.49 |
| Kr | negligible | negligible | 1.11 | 32.7 | 0.00 | 0.00 | 32.70 |

Table V displays the choices of quenching and depolarizing coefficients for each gas as well as the cross sections computed from the kinetic theory formula presented in paper I.

## Conclusions

A comparison of the observed polarizations and rotations of plane of polarization with the calculated values leaves one in some doubt concerning the necessity of introducing a probability of adiabatic depolarization. As far as the polarization *vs.* magnetic field intensity is concerned, there is little difference between the calculations with $\alpha''$ unequal to zero and those for which it was zero. With regard to the rotation of the plane of polarization *vs.* magnetic field data, considerably better agreement is secured in most instances by using $\alpha''$ unequal to zero.

A similar comment could be made regarding the data presented for nitrogen in paper I. The necessity of introducing adiabatic depolarization is chiefly apparent in securing agreement between calculated and experimental values of the rotation of the plane of polarization, although a slight improvement is also produced in the agreement of the polarization data.

The quenching efficiencies listed in Table V range from zero for helium and krypton to $0.02\times 10^7$ sec.$^{-1}$ for neon. These gases are thus poor quenchers, as would be expected. Probably no significance should be attached to the small variation in quenching ability which the table displays as it is undoubtedly within experimental error.

Further experimental work on additional gases will be undertaken.

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