Polarization and pressure dependence of $2p$-$1s$ transitions in He-like and Li-like neon recoil ions

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The pressure dependences of $2p$-$1s$ transitions in He-like and Li-like neon recoil ions produced in collisions with 1.4-MeV/amu Ar ions were studied for the purpose of assessing effects of polarization and nonstatistical population mechanisms on the relative intensities of prompt and metastable lines. A Johansson-type curved-crystal spectrometer was employed as an x-ray polarimeter by taking spectra with the plane of the focal circle oriented both parallel and perpendicular to the Ar-ion beam. The data indicate that the He-like ^1P and ^3P lines are only slightly polarized and that the intensity ratio $I(^1P)/I(^3P)$ is not a linear function of pressure. Both of these results appear to be a direct consequence of serious contamination of the spectral region of interest by unresolved spectator-electron transitions.

I. INTRODUCTION

Several years ago, Beyer, Mann, and Folkmann[1,2] studied the pressure dependence of x-ray emission from the $1s2p$ states in He-like neon ions populated by impact of 1.4-MeV/amu uranium ions and 3.6-MeV/amu krypton ions. This work provided estimates of the rate constants for electron capture in low-energy secondary collisions between He-like neon recoil ions (produced in primary collisions) and neutral atoms or molecules present in the gas target. The method involved the determination of the intensity of the metastable $2\,^3P_1-1\,^1S$ transition ($\tau=1.85\times10^{-10}$ s) (Ref. 3) relative to that of the prompt $2\,^1P-1\,^1S$ transition ($\tau=1.13\times10^{-13}$ s) (Ref. 3) as a function of the target pressure. The lifetime of the ^3P state is sufficiently long that, at pressures of a few torr, there is an appreciable probability this state will be quenched by electron capture in a secondary collision instead of decaying by x-ray emission.

Another feature of the above-mentioned experiments was that extrapolation of the intensity ratio $I(2\,^1P-1\,^1S)/I(2\,^3P_1-1\,^1S)$ [hereafter referred to as the $I(1P)/I(3P)$ ratio], which was observed to depend linearly on pressure, to the limit of zero pressure yielded considerably higher values than the value of unity expected for a statistical population of the $1s2p$ states. This observation suggests that the ^1P state may be preferentially populated in the primary collision process.

The formation of a $1s2p$ He-like Ne state in a heavy-ion—atom collision is a very complicated process in that it requires the removal of eight electrons from the target atom in a single collision. The principal mechanisms for accomplishing electron removal are Coulomb ionization and electron transfer to the projectile (capture). These processes can also play an important role in the production of the $1s2p$ states by populating higher-lying two-electron states which cascade down to the $1s2p$ states or by producing three-electron excited states which subsequently undergo autoionization to the $1s2p$ states. However, it is difficult to conceive of many mechanisms which would preferentially populate the ^1P state over the $^3P_1$ state. Cascade transitions, for example, tend to produce an enhanced population of the ^3P state.[4] One process that would selectively populate the ^1P state is ejection of all electrons outside the K shell together with simultaneous $1s$-$2p$ excitation, since in the absence of spin-dependent interactions excitation of the $1s^2\,^1S$ state leads exclusively to the $1s2p\,^1P$ state.

Another complicating factor in any comparison of x-ray intensities is that the cross sections for populating magnetic substates having different $|m_j|$ values are typically not equal. When this condition exists, the state is said to be aligned and radiation resulting from its decay is polarized and anisotropic. Therefore, another possible explanation for the nonstatistical intensity ratio might be that one or both of the transitions involved are highly polarized. This would offer the potential of an additional experimental means for characterizing the mechanisms which contribute to production of these states.

The present work was carried out in an attempt to shed more light on the question of the nonstatistical population of the $1s2p$ states of He-like neon recoil ions and to determine the extent to which polarization affects the $I(^1P)/I(^3P)$ intensity ratio. In the course of this work, the pressure dependences of $2p$-$1s$ transitions from both He-like and Li-like Ne recoil ions excited by 54-MeV Ar ions were studied.

II. EXPERIMENTAL METHODS

A beam of 80-MeV Ar^{5+} ions was extracted from the Texas A&M variable-energy cyclotron and directed at a closed cell containing the neon target gas. The beam entered and exited the gas cell through 2-mg/cm^2 Ni windows. After passing through the entrance window, the Ar ions had an energy of 54 MeV and an average charge of 13 +. The pressure in the gas cell was controlled manually by a needle valve and measured with a capacitance manometer.

A 12.7-cm Johansson-type curved-crystal spectrometer employing a rubidium acid pthalate (RAP) crystal was mounted on the vacuum chamber that contained the gas cell. The vacuum chamber was configured in such a way that the spectrometer, which observed x rays at 90° with respect to the Ar-ion beam, could be rotated so that the plane of its focal circle was oriented either parallel or perpendicular to the Ar-ion beam without breaking vacuum. The details of this system and its use as an x-ray polarimeter are described in Ref. 5.

X rays produced in the gas cell passed through a 65-$\mu g/cm^2$ stretched polypropylene window and a 3-mm-diam collimator to the crystal. X rays diffracted by the crystal were detected with a flow proportional counter (90 vol % argon—10 vol % methane) having a stretched polypropylene window of approximately 65 $\mu g/cm^2$. An automatic spectrometer-control system incremented the Bragg angle each time a preset amount of charge was collected in a Faraday cup located directly behind the exit window of the gas cell.

In order to determine the polarizations of the ^1P and ^3P transitions, it was necessary to measure the relative change in the intensity of each peak at both spectrometer orientations [i.e., it was not sufficient to just measure the change in the $I(^1P)/I(^3P)$ intensity ratio]. Since curved-crystal spectrometers are extremely sensitive to geometry changes, it was essential to accurately account for a small change in the geometry which occurred when the spectrometer was rotated from the parallel to the perpendicular orientation. This was accomplished by carefully measuring the intensity of the (unpolarized) $K\alpha_{1,2}$ line of Ne, excited by 5.5-MeV He ions, in both spectrometer orientations.[5] The correction factor was found to be independent of pressure.

Spectra of the $K\alpha$ x-ray region spanning the $2p$-$1s$ transitions in Be-like through He-like neon, taken at four different pressures, are compared in Fig. 1. The effect of quenching of the metastable $1s2p\,^3P$ states in secondary collisions is clearly visible in Fig. 1 as the pressure increases. Although the $^3P_2$ state has a small $M2$ decay branch to the ^1S ground state, its contribution to the ^3P peak intensity is less than 3%. The peaks labeled KL^6 are from the x-ray decay of Li-like $1s2l2p$ configurations. The predominant lines in these peaks originate from $1s2p^2$ and $1s2s2p\,^2P$ and ^4P states. The ^4P states are also metastable [$1s2s2p$: $\tau(^4P_{3/2})=1.11\times10^{-9}$, $\tau(^4P_{1/2})=2.76\times10^{-9}$; $1s2p^2$: $\tau(^4P_{5/2})=4.22\times10^{-10}$, $\tau(^4P_{3/2})=4.59\times10^{-10}$, $\tau(^4P_{1/2})=5.43\times10^{-10}$ sec] (Ref. 6) and therefore are severely quenched at the higher pressures. As indicated in Fig. 1, Be-like (KL^5) lines overlap with the Li-like ^4P lines.

Spectra were taken at numerous pressures ranging from 0.1 to 200 torr using both spectrometer orientations. Three complete sets of measurements were carried out. The major components in each spectrum were resolved by means of a least-squares peak-fitting program (FACELIFT) employing Voigt functions.

III. RESULTS AND DISCUSSION

The intensity ratios for the He-like ^1P and ^3P transitions and the Li-like ^2P and ^4P transitions are shown plotted as a function of pressure in Fig. 2 for both spectrometer orientations. It is readily apparent from Fig. 2(a) that, contrary to expectations based on the previous results of Beyer, Mann, and Folkmann,[1,2] the present data do not display a linear pressure dependence. A similar behavior is observed for the $I(^2P)/I(^4P)$ intensity ratio. It is also shown in Fig. 2(a) that the ratios are significantly different for the two spectrometer orientations. This is pri-

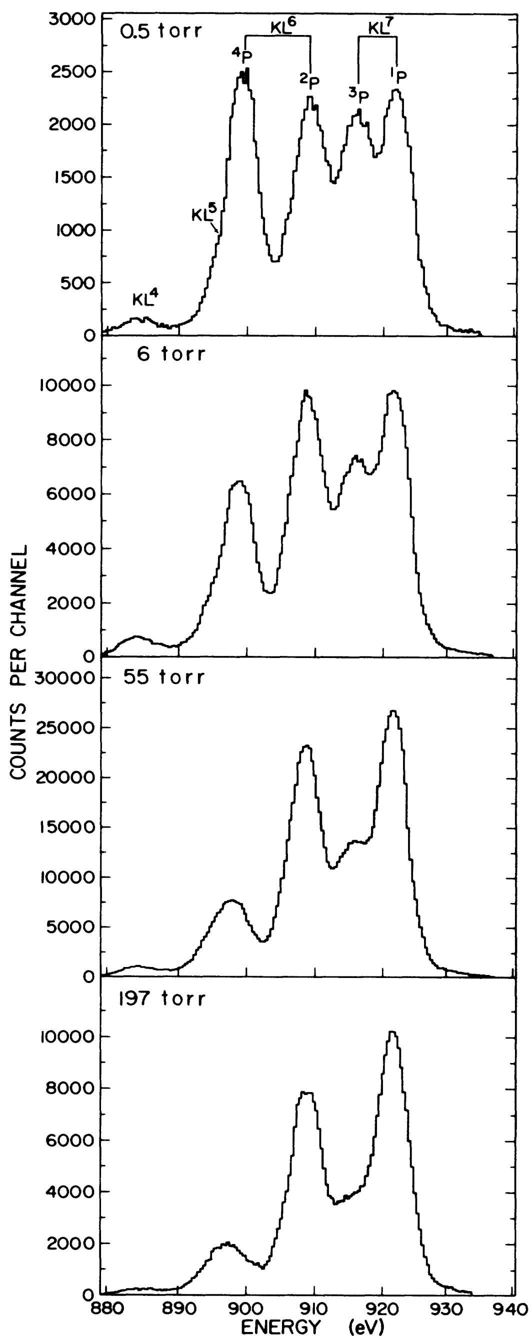

FIG. 1. Spectra of $2p$-$1s$ transitions in He-, Li-, and Be-like Ne recoil ions produced by 1.4-MeV/amu Ar-ion impact, taken at different target pressures.

marily a consequence of polarization, as will be discussed later.

A comparison of the prompt Li-like transition intensity with the prompt He-like transition intensity [the $I(^2P)/I(^1P)$ intensity ratio] and a comparison of the metastable Li-like transition intensity with the metastable He-like transition intensity [the $I(^4P)/I(^3P)$ intensity ratio] are shown in Figs. 3(a) and 3(b), respectively. The pressure dependence of the $I(^2P)/I(^1P)$ ratio shows a slight decrease at low pressures with a leveling off at a pressure of around 70 torr. This behavior may indicate that some fairly-long-lived transitions overlap with the ^2P peak and contribute to its apparent intensity at low pressures. The ratio of the metastable peak intensities $[I(^4P)/I(^3P)]$ in Fig. 3(b) decreases with increasing pressure until around 40 torr and then becomes constant. This behavior is consistent with the presence of long-lived transitions from the $1s2s2p\,^4P$ states and simply reflects the fact that the lifetimes of these components are longer than the lifetime of the $^3P_1$ state. A more detailed analysis of these data, however, is hindered by the fact that prompt KL^5 transitions overlap with the ^4P peak and, as will be discussed later, it is highly probable that prompt transitions also contribute to the ^3P peak.

A. Polarization analysis

The determination of the polarizations of the ^1P and ^3P transitions in the present experiments relies upon the fact that at a given x-ray energy the reflection coefficient R_1 for radiation with electric vector perpendicular to the spectrometer focal circle is higher than the reflection coefficient R_2 for radiation with electric vector parallel to the spectrometer focal circle.[7] According to the theory of reflection from an ideal mosaic crystal, the two reflection coefficients are related by

$$R_1 = R_2\,|\cos(2\theta)|^2 , \quad (1)$$

where θ is the Bragg angle corresponding to the x-ray wavelength.[7] The polarization of a transition is defined by

$$P = \frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + I_{\perp}} , \quad (2)$$

and the relationship between the measured polarization P_m and the actual polarization is

$$P_m = PQ , \quad (3)$$

where $I_{\parallel}$ and $I_{\perp}$ are the intensities of radiation emitted at

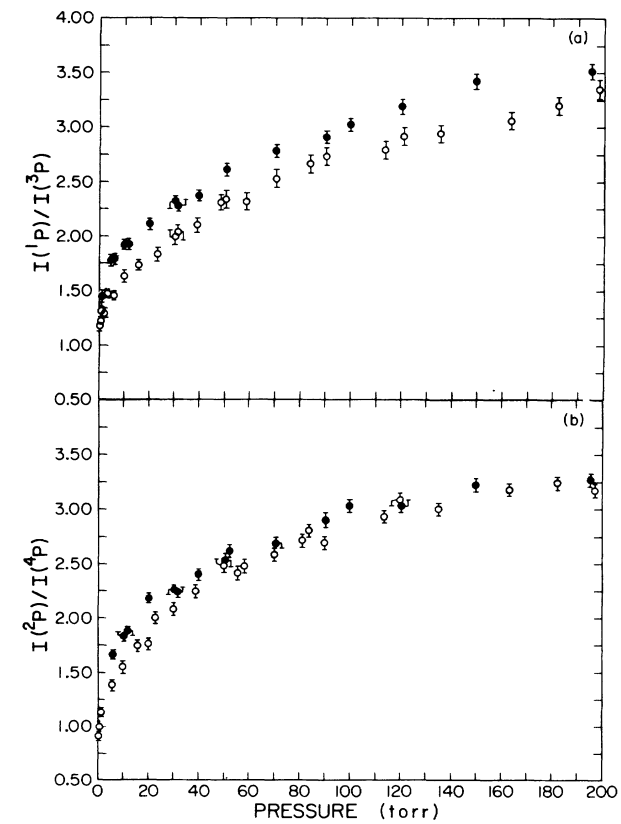

FIG. 2. Pressure dependence of (a) the intensity ratio $I(^1P)/I(^3P)$ for He-like neon ions, and (b) the intensity ratio $I(^2P)/I(^4P)$ for Li-like neon ions. The open circles denote data taken with the spectrometer focal circle oriented perpendicular to the beam direction and solid circles denote data taken with the spectrometer focal circle oriented parallel to the beam direction.

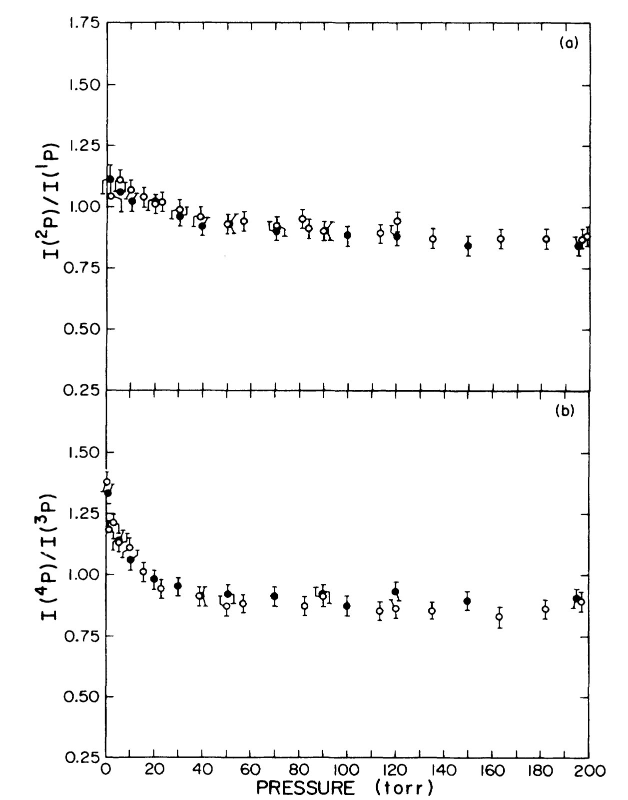

FIG. 3. Comparison of the Li-like to He-like transition intensity ratios for (a) prompt transitions—$I(^2P)/I(^1P)$, and (b) metastable transitions—$I(^4P)/I(^3P)$. The open circles denote data taken with the spectrometer focal circle oriented perpendicular to the beam direction and solid circles denote data taken with the spectrometer focal circle oriented parallel to the beam direction.

90° with respect to the projectile beam with electric vector parallel and perpendicular to the beam, respectively. The polarization sensitivity Q is given by

$$Q=\frac{1-R_1/R_2}{1+R_1/R_2} . \tag{4}$$

The results of the polarization analysis are presented in Table I. It is evident that the small degree of polarization exhibited by the ^3P transition cannot account for the large deviation of the $I(^1P)/I(^3P)$ ratio from the statistical value of 1 reported by Beyer, Mann, and Folkmann.[1] Furthermore, if the ^1P and ^3P states are populated by a single mechanism, their polarizations should be related by[8]

$$P(^1P)=\frac{-2P(^3P)}{1-P(^3P)} . \tag{5}$$

Using the measured value of the ^3P polarization in Eq. (5) results in a predicted value of -0.17 for the ^1P polarization, which clearly does not agree with the measured polarization for this transition.

B. Pressure dependence

The net rate of production of a particular excited state can be expressed as follows:

$$\frac{dn}{dt}=\sigma_e Nj-\tau^{-1}n-\sigma_q vnN , \tag{6}$$

where σ_e is the total cross section for exciting the state of interest, τ is its mean lifetime for decay (x ray and Auger), σ_q is the cross section for quenching the state of interest in a secondary collision, n and N are the number densities (cm^{-3}) of ions in the state of interest and of the target gas, respectively, v is the recoil velocity, and j is the incident particle flux. The first term of Eq. (6) is the production rate in primary collisions, the second term is the deexcitation rate (x-ray and Auger decay), and the third term is the quenching rate in secondary collisions. This equation, which can be rewritten in the form

$$\frac{dn}{dt}=\alpha-\beta n , \tag{7}$$

has the solution

$$n=(\alpha/\beta)(1-e^{-\beta t}) . \tag{8}$$

The x-ray emission rate is

$$\frac{dn_x}{dt}=\tau_r^{-1}n , \tag{9}$$

where τ_r is the mean lifetime for radiative decay of the state of interest. The total number of x rays per cm^3 produced as a result of a single beam pulse is given by the integral of Eq. (9) over the duration of the beam pulse ($t=0$ to t') plus the integral

$$n_x'=\tau_r^{-1}\int_{t'}^{\infty} n(t')e^{-\beta t}dt , \tag{10}$$

which gives the contribution to the yield from decays occurring after the beam pulse has ended. The result is

$$N_x=n_x+n_x'=(\alpha/\beta)\tau_r^{-1}t'$$

or

$$N_x=(\tau/\tau_r)(\sigma_e Njt')[1+\tau\sigma_q vN]^{-1} . \tag{11}$$

The quantity $\sigma_q vN$ has a value of approximately $9.7\times10^7 p$, where p is the target pressure in torr.[1] Therefore the expression in Eq. (11) contained within the square brackets is negligible up to pressures of the order of 10^4 torr for prompt transitions having lifetimes of 10^{-13} s or less. Under these conditions, the $I(^1P)/I(^3P)$ intensity ratio reduces to

$$N_x(1)/N_x(3)=[\sigma_e(1)/\sigma_e(3)][1+\tau(3)\sigma_q vN] , \tag{12}$$

where the labels 1 and 3 denote the $2p$-$1s$ transitions from the ^1P and $^3P_1$ states, respectively (for this case $\tau_r=\tau$). This result, which is the same as that obtained by Beyer, Mann, and Folkmann,[1] predicts a linear dependence on target pressure.

The results of the present study of the pressure dependence of the $I(^1P)/I(^3P)$ ratio are compared with those of Beyer, Mann, and Folkmann[1,2] for 1.4-MeV/amu U and 3.5-MeV/amu Kr in Fig. 4. The previous measurements were reported to be linear over the pressure range 3—99 torr. As shown by the dashed straight line labeled 1.4 MeV/amu Ar, the present data are also reasonably linear over this same pressure range. However, when the measurements are extended below and above these limits, it

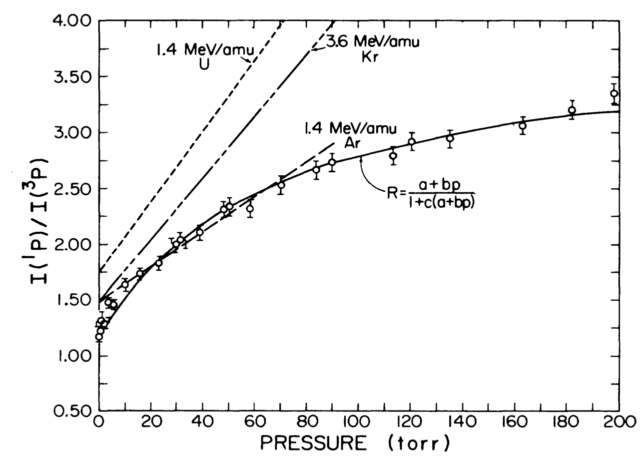

FIG. 4. Comparison of the present data (spectrometer focal circle oriented perpendicular to the beam) for the pressure dependence of the He-like neon transition intensity ratio $I(^1P)/I(^3P)$, obtained using 1.4-MeV/amu Ar ions, with the previous results of Beyer, Mann, and Folkmann (Refs. 1 and 2). The dashed line drawn through the data is a linear representation of the data over the pressure range 3—99 torr. The solid curve shows a fit of the indicated function to the data (see text).

TABLE I. Experimental polarizations of the He-like lines of Ne recoil ions produced by 1.4-MeV/amu Ar projectile ions.

X-ray line	P_m	Q	P
$2\,^1P-1\,^1S$	-0.003 ± 0.030	0.64	-0.005 ± 0.046
$2\,^3P-1\,^1S$	0.050 ± 0.030	0.65	0.077 ± 0.046

becomes obvious that the data significantly deviate from a linear pressure dependence. Moreover, the $I(^1P)/I(^3P)$ ratio in the limit of zero pressure is estimated from the low-pressure data to be 1.1, whereas a linear extrapolation of the data over the pressure range 3–99 torr predicts the value of 1.5. In this regard, it is reassuring to note that previous low-pressure (~ 30 mtorr) measurements of Ne K x-ray spectra excited by 1.3-MeV/amu Cl ions employing a differentially pumped gas cell also yielded a $I(^1P)/I(^3P)$ ratio of 1.1.[9,10]

The only viable explanation for the observed nonlinear pressure dependence of the $I(^1P)/I(^3P)$ ratio is that a significant amount of the intensity in the ^3P peak must come from prompt transitions. This hypothesis is strengthened by the fact that the ratio of Li-like transition intensities, $I(^2P)/I(^4P)$ displays a pressure dependence that is very similar to that of the $I(^1P)/I(^3P)$ ratio [Fig. 2(b)]. In this case, it is known that prompt Be-like Ne transitions (KL^5 satellites) overlap with the Li-like Ne ^4P peak and it is estimated that they contribute approximately 22% of the total intensity of the ^4P peak in the zero-pressure limit. Possible sources of prompt lines which would lie under the ^3P peak are the following.

(1) The Li-like Ne transitions $1s2s2p(^2P_+)$-$1s^22s(^2S)$ and $1s2p^2(^2S)$-$1s^22p(^2P)$ at predicted energies[11] of 914.8 and 912.6 eV, respectively.

(2) Transitions of the type $1s2pnl$-$1s^2nl$ involving a spectator electron in levels having $n>2$.

From the measured intensity of the Li-like Ne ^2P peak and the theoretical fluorescence yields of Chen and Crasemann,[12] it is estimated that the transitions identified as source (1) above contribute less than 3% of the total intensity in the ^3P peak in the zero-pressure limit and therefore may be ruled out as the cause of the nonlinear pressure dependence. Spectator-electron transitions, on the other hand, do contribute substantially to the present spectra and will be considered further in the following section.

Assuming for the moment that contributions from prompt spectator-electron transitions are indeed the cause of the nonlinear pressure dependence of the $I(^1P)/I(^3P)$ ratio, the model outlined above may be modified to take this into account. In this case, the total number of x rays contributing to the ^3P peak will be the sum of the number of x rays from the $2\,^3P$–$1\,^1S$ transitions plus the number of x rays from spectator-electron transitions, $N_x(S)$. Since the spectator-electron transitions are assumed to be prompt (i.e., have lifetimes comparable to the transition from the ^1P level), their intensity will be proportional to the intensity of x rays from the $2\,^1P$–$1\,^1S$ transition. Thus, it follows from Eq. (11) that

$$N_x(1)=\sigma_e(1)Njt' ,$$

$$N_x(3)=\sigma_e(3)Njt'[1+\tau(3)\sigma_q vN]^{-1}+k\sigma_e(1)Njt' .$$

Using the above equations to obtain the ratio $N_x(1)/N_x(3)$ and performing a little algebra leads to the expression

$$N_x(1)/N_x(3)=\frac{a+bp}{1+c(a+bp)} , \qquad (13)$$

where p is the pressure and

$$a=\sigma_e(1)/\sigma_e(3) ,$$

$$b=3.24\times10^{16}a\tau(3)\sigma_q v \quad (\text{for } p \text{ in torr}) ,$$

$$c=[\tau(S)/\tau_r(S)][\sigma_e(S)/\sigma_e(1)] .$$

The solid curve in Fig. 4 shows a fit of Eq. (13) to the data. The results of this analysis are that (a) Eq. (13) represents the experimental pressure dependence quite well, and (b) the values of a, b, and c are 1.64, 8.41×10^{-2}, and 0.259, respectively. Since parameter c is just the intensity of the prompt component contributing to the ^3P peak relative to the intensity of the ^1P peak, it is evident that the spectator-electron transitions would have to be rather intense to account for the observed pressure dependence. The rate constants for quenching the ^3P level, $k_q=\sigma_q v$, obtained from (a) parameter b of the prompt component formulation, and (b) the slope of the straight-line approximation (dashed line in Fig. 4), are

$$(a)\ k_c=8.6\times10^{-9}\ \text{cm}^3/\text{s} ,$$

$$(b)\ k_c=1.7\times10^{-9}\ \text{cm}^3/\text{s} .$$

A comparison of the values yielded by methods (a) and (b) demonstrates that blending of the ^3P transition with other (prompt) transitions can have a large effect on the quenching rate constant.

C. Spectator-electron transitions

Returning now to a consideration of spectator-electron transitions as a possible source of the prompt transitions contributing to the ^3P peak, it is instructive to examine a more extensive spectral scan of the K x-ray region of Ne recoil ions, as shown in Fig. 5. The feature of particular

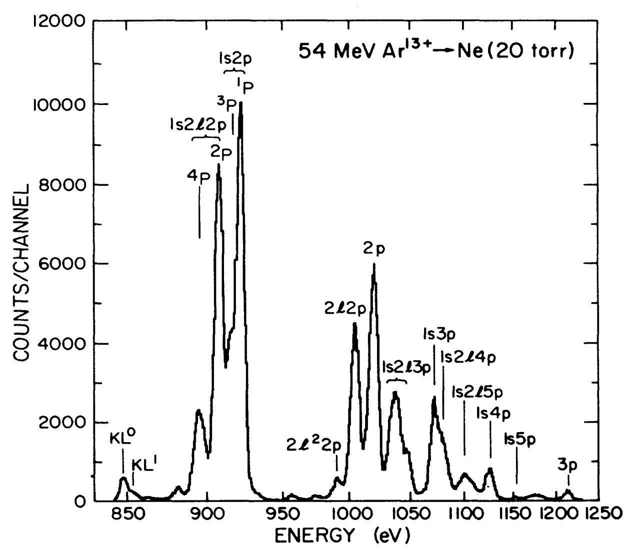

FIG. 5. An expanded view of the neon recoil ion K x-ray spectrum showing substantial contributions from $1s2lnp$ three-electron states.

interest is the peak around 1040 eV labeled $1s\,2l\,3p$. This peak, which is fairly well resolved from other nearby transition groups, clearly indicates that substantial populations of spectator-electron states of the type $1s\,2l\,3l$ are produced in the primary and secondary collision processes. This peak may be used in conjunction with recent theoretical transition rates and energies, calculated by Chen,[6] to estimate the contribution to the ^3P peak from $1s\,2p\,3l$-$1s^2 3l$ spectator-electron transitions.

Using Chen's tables,[6] the energies and rates of the various $1s\,2p\,3l$-$1s^2 3l$ and $1s\,2l\,3p$-$1s^2 2l$ transitions were obtained. The electron configurations and term values of the transitions involved are shown schematically in Fig. 6. Then, from the experimental intensity of the $1s\,2l\,3p$ peak and theoretical transition rates, the relative intensities of the various $1s\,2p\,3l$ transitions were estimated assuming that all of these states are populated statistically. A spectral simulation was constructed by representing each transition with a Voigt function having a width corresponding to the experimental resolution, a centroid corresponding to the theoretical energy, and an area corresponding to the predicted relative intensity. The simulated spectrum of these two transition groups is shown in Fig. 7 superimposed on a measured spectrum. The predicted position, width, and shape of the simulated $1s\,2l\,3p$ peak agree well with the corresponding structure in the measured spectrum, and this fact lends credibility to the proposition that the simulated $1s\,2p\,3l$ structure is also a reasonable facsimile of the real structure. This analysis indicates that both the ^3P and the ^1P peaks contain large contributions from $1s\,2p\,3l$ spectator-electron transitions, and therefore supports the hypothesis put forward in the preceding section.

In the present spectra, obtained with 1.4 MeV/amu Ar ions, the intensity of the $1s\,2l\,3p$ peak relative to the intensity of the $1s\,2p\ ^1P$ peak was 0.49. By comparison, from spectra presented in Refs. 13 and 14, it is estimated that the relative intensities of these same peaks are roughly 0.25 for 3.6-MeV/amu Kr ions and less than 0.1 for 1.4-MeV/amu U ions. However, both the Kr- and U-ion spectra display prominent $1s\,2l\,4p$ peaks arising from $1s\,2l\,4p$-$1s^2 2l$ transitions. In fact, the formation of a $1s\,2l\,4l'$ state is a direct consequence of the quenching of a $1s\,2l$ metastable state in a secondary collision by selective electron capture.[13] Since substantial numbers of $1s\,2l\,4l'$ states must be produced, it follows that the $1s\,2p\ ^3P$ and ^1P peaks in the U- and Kr-ion spectra contain significant contributions from $1s\,2p\,4l$-$1s^2 4l$ spectator-electron transitions. This would have the effect of causing the $I(^1P)/I(^3P)$ pressure dependence to be nonlinear at low and high pressures and could explain why the linearly extrapolated intensity ratios at zero pressure (1.5 for Kr and 1.75 for U) are so much larger than the statistical prediction.

IV. CONCLUSIONS

The polarization and pressure dependence of $2p$-$1s$ transitions in He-like neon recoil ions and the pressure dependence of $2p$-$1s$ transitions in Li-like neon recoil ions have been examined using 1.4-MeV/amu Ar ions. In contrast to previous measurements on neon employing considerably higher-Z projectiles, the present work revealed a serious deviation from the linear pressure dependence predicted for the ratio of the transition intensities from the He-like neon $1s\,2p\ ^1P$ and ^3P states [the $I(^1P)/I(^3P)$ ratio]. It was shown that this nonlinear behavior is probably caused by large contributions of prompt transition intensity from $1s\,2p\,3l$-$1s^2 3l$ spectator-electron transitions that overlap with the ^3P peak. The present findings cast

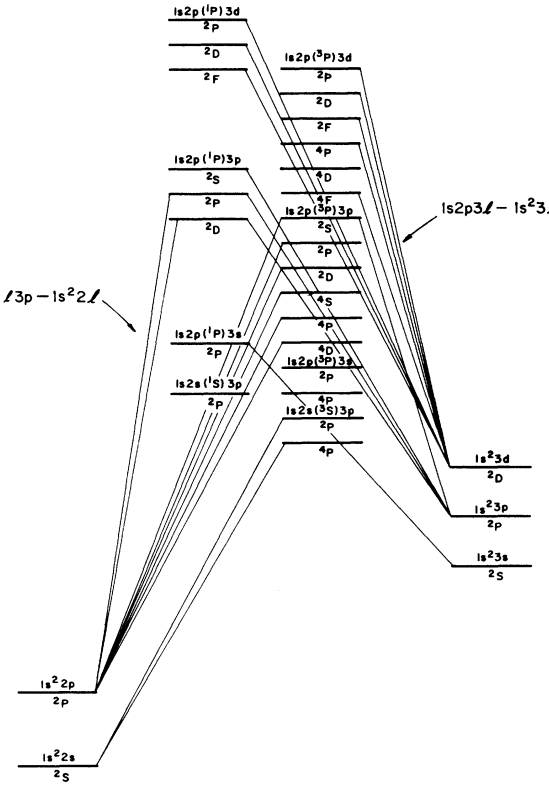

FIG. 6. A schematic diagram showing the principal transitions which contribute to the $1s\,2l\,3p$ and $1s\,2p\,3l$ structures.

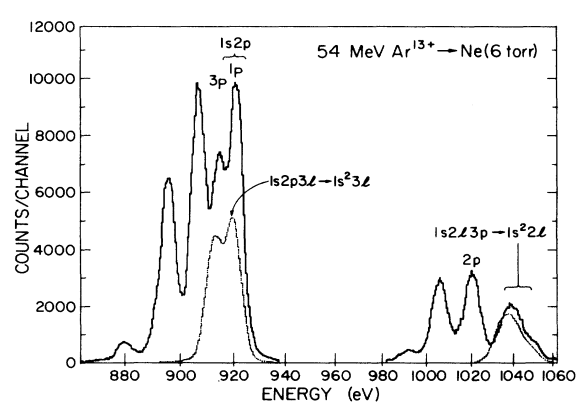

FIG. 7. A spectral simulation of the structures associated with K x-ray transitions from $1s\,2l\,3p$ and $1s\,2p\,3l$ states, superimposed on a measured spectrum.

some doubt on the reliability of the quenching-rate constants obtained by Beyer, Mann, and Folkmann[1,2] since it is likely that their data are significantly distorted by contributions from $1s\,2p\,4l$ spectator-electron transitions.

At first sight, the polarization analysis of the ^1P and ^3P transitions suggests that these states are not appreciably aligned in the collision process. Since previous work has shown that few-electron states produced in the projectile during such collisions are highly aligned,[15] this would be a surprising result were it not for the likelyhood that the ^1P and ^3P peaks are seriously contaminated by spectator-electron transitions. Because there are so many transitions involved, it is to be expected that most of the polarization would be averaged out.

Although the primary motivation for this work was the question of the apparent deviation of the $I(^1P)/I(^3P)$ ratio from the value of unity expected for a statistical population of the ^1P and $^3P_1$ states, the interference by spectator-electron transitions precludes reaching very definite conclusions. Nevertheless, the simulated $1s\,2p\,3l$ structure in Fig. 7 indicates that more intensity contributes to the ^1P peak than to the ^3P peak, thereby tending to make the $I(^1P)/I(^3P)$ ratio appear to be larger than it really is. It is reasonable to assume that this causes the observed ratio (1.1 in the zero-pressure limit) to be slightly greater than the statistical value of 1 and eliminates the need to postulate the existence of mechanisms for selectively populating the ^1P level.

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