be ±15 MHz; that of K, to be ±100 MHz. It should be pointed out that this analysis has been facilitated by the large quadrupole coupling constant of iodine and the high value of J observed in this spectrum. At lower values of J the magnetic and NEQ interactions should become more nearly equal and the second-order NEQ interactions will become more significant. Thus, at low J the spectrum may be much more difficult to analyze.

This saturated absorption spectrum represents the highest resolving power (10^8) yet achieved in electronic spectroscopy. The technique should be applicable to other spectroscopic problems which require extremely high resolving power.

The author has benefited from discussions with Professor K. K. Innes.

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VACUUM-ULTRAVIOLET PHOTON PRODUCTION IN LOW-ENERGY COLLISIONS BETWEEN TWO NEUTRAL ARGON ATOMS*

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We describe the first observation of extreme-ultraviolet photons produced during collisions between two ground-state neutral argon atoms. The energy dependence of the relative cross section for photon production is found to exhibit structure at about 70 eV c.m. energy, similar to that observed in the cross section for ionization in argon collisions.

During an energetic collision between two neutral argon atoms, excitation may occur to a metastable level, or to a level which decays by emission of a photon. Photons from transitions of these excited states to the ground state, the argon resonance series, have wavelengths from 1067 to 778 Å, the ionization limit.[1] This Letter describes the first measurements made of the relative cross section for emission of photons of these wavelengths after an atom-atom encounter. The c.m. energies examined were from near threshold to 500 eV.

Ground-state argon ions formed in an electron-impact ion source were electrostatically accelerated and focused into a charge-transfer cell.[2] This cell contained a low-pressure hydrogen target which allowed the formation of argon neutral atoms entirely in the ground state for all incident ion energies below 230 eV. In this interval there is insufficient energy available in the c.m. system for excitation to occur during the charge-transferring collision. This method of producing a neutral atomic beam with energies between 30 and 1000 eV in the laboratory system has been previously described.[3] After passing through the charge-transfer cell, the ionic component of the beam was electrostatically removed from the beam by a parallel-plate repeller assembly and the neutral beam was allowed to pass into a target chamber. The incident argon-atom beam intensity was determined by measuring the current of slow hydrogen ions formed in the charge-transfer region and applying a measured correction for beam loss at the exit aperture of the charge-transfer cell and at the entrance aperture of the target chamber. The beam intensity was known to ±30%.

The target chamber contained argon at a pressure of about 1×10^{-4} Torr and a Bendix magnetic electron multiplier (MEM). The 0.25-in.^{2} cathode of the MEM is sensitive to photons of wavelength less than 1500 Å but greater than 2 Å, or to any entering particle capable of dislodging an electron from its metallic surface. In order to protect the MEM from scattered neutral particles, it was placed against the front end of the target chamber, viewing only photons. (No backscattering of particles will occur in the laboratory system after collisions between equal masses.) Although the problem of scattered neutrals was thus avoided, the geometry of the situation was seriously complicated, making possible only a relative measurement of the cross section and an estimate of its absolute magnitude. Argon ions formed by ionizing atom-atom collisions could be drawn into the very negatively charged MEM cathode. Thus a screen, biased at a potential at least equal to the accelerating potential for the beam, was placed around the MEM to prevent the counting of ions. The counting rate was independent of the screen potential above this value. Electrons drawn through the positively biased screen were not counted since the MEM cathode was biased about 1 kV below the screen potential, driving any entering electrons to the screen.

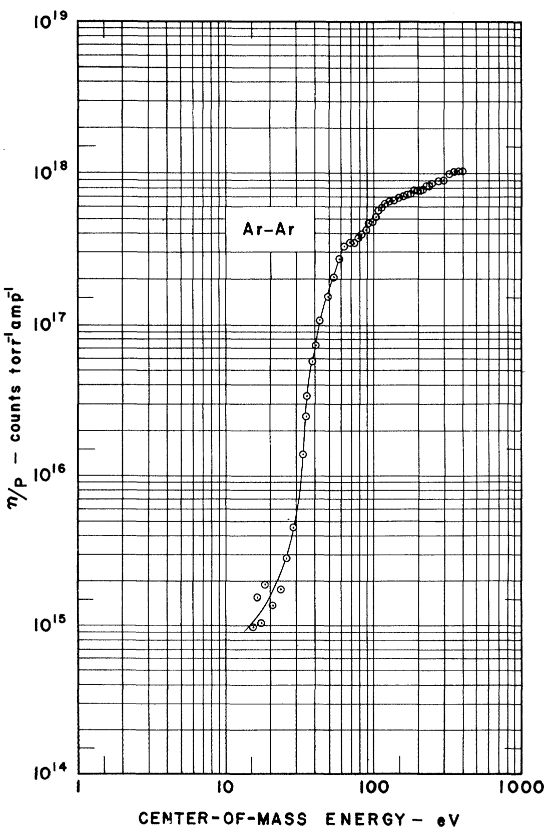

FIG. 1. Relative cross section for v-uv–photon production in collisions between two ground-state argon atoms.

The number of photons arising from argon-argon collisions per 5-min interval, normalized to unit beam flux and unit target pressure, is shown in Fig. 1. On the abscissa is plotted the c.m. energy of the collision partners. The normalized counts are proportional to the absolure cross section for vacuum-ultraviolet (v-uv) photon production resulting from collisions between two neutral argon atoms.

Even though complexities in geometry and detection efficiency did not permit calculation of absolute cross sections, it was desirable to make approximations from which some idea of the magnitude of the cross sections could be inferred. Geometrical approximations were made which would overestimate the fraction of photons formed that strikes the MEM cathode. Use of these approximations and an absolute detector efficiency of 6% at 1060-Å wavelength[4] allowed the calcula-

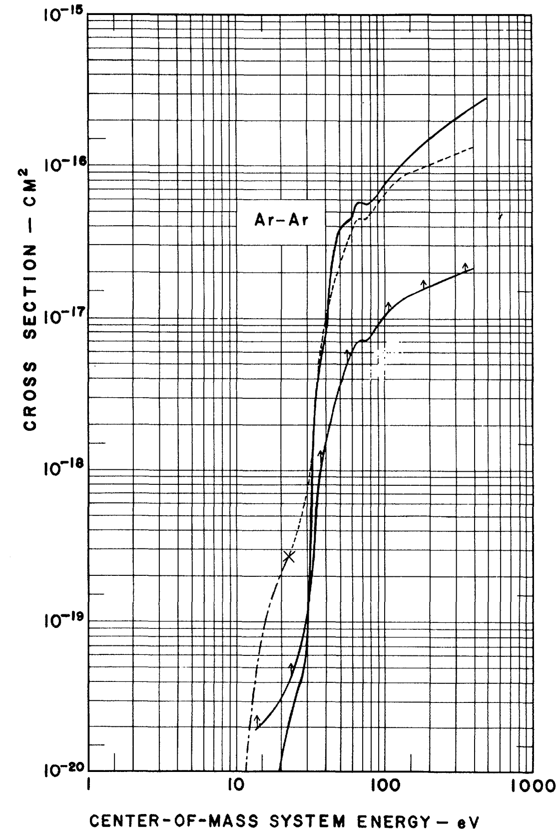

FIG. 2. The solid line with vertical arrows represents estimated lower limit to v-uv–photon production cross section (see text). The dotted line shows photon production cross section normalized to extrapolation of McLaren and Hobson's linear function for excitation, shown as lower dashed line. The solid line represents the cross section for negative-charge production.

tion of a lower limit for the absolute magnitude of the cross section for v-uv photon production. This lower limit is shown in Fig. 2 along with a second estimate of the cross section. The second estimate is obtained by normalizing the value for the photon production cross section at 22 eV in the c.m. system to that obtained by extrapolating McLaren and Hobson's[5] linear function for the excitation cross section. They report shock-tube measurements of the threshold behavior of excitation, in argon-argon collisions, to levels in the $(^2P)4s$ configuration. Their experiment does not distinguish between excitation to metastable states and those which decay by allowing transitions. Therefore, this second estimate may serve as an upper limit to the absolute cross section if it is assumed that the observed photons originate principally from states below 13.8 eV (the energy of the next excited state which may decay by v-uv photon emission).

It is very interesting to compare the photon production cross section with the cross section for negative-charge production[6] in collisions between neutral agron atoms, also shown in Fig. 2. One notes that the photon-production cross section remains below the cross section for ionization as the energy is increased. The most striking feature of the present results is the structure between 60- and 80-eV c.m. energy. This structure is of the same form and over the same interval as that found in the negative-charge production cross section, shown in Fig. 2 as a solid line. The meaning of this similarity between ionization and photon production is not yet clear. It may be the result of an energy resonance for the formation of some excited state, atomic or molecular in character, which decays either by ionization or photon emission or both. In any case, it is apparent that energetic photons, produced in considerable abundance even at low energies, may provide valuable information pertaining to inelastic atomic collisions.

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MICROWAVE SCATTERING DUE TO ELECTRON PLASMA-WAVE INSTABILITY*

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An experimental analysis is made of the scattering of microwaves by the density fluctuations due to electron plasma-wave instability in a beam-plasma system. Reasonably good (i.e., within an order of magnitude) agreement is obtained with the Shapiro-Drummond-Pines theoretical estimate of the energy associated with the "linearly unstable" electron plasma waves at "quasilinear" steady state.

According to theory, a beam-plasma system will become unstable against a growing plasma oscillation due to a two-stream instability mechanism when the beam density is sufficiently large and the beam velocity is approximately equal to the phase velocity of the plasma wave. Shapiro[1] has shown that even if initially the beam is not a gentle bump, such a "linearly unstable" beam-plasma system will in time reach a "quasilinear" steady state of Drummond and Pines[2] provided the density of beam electrons is very much less than that of the plasma electrons so that the growth rate of the plasma waves due to the beam electrons is less than the frequency of the plasma