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A SHORT FLASH OF MERCURY RESONANCE LINE AT 253.7 NM

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When helium gas containing mercury vapor was irradiated by the electron pulse from a Febetron 706, an emission of mercury resonance line at 253.7 nm was observed, which consisted of two parts. The lifetime of the first emission agreed with the calculated apparent lifetime of the 6^3P_1 state of mercury atoms. The second emission, the peak of which appeared at a few μsec, was completely quenched upon the addition of a small amount of sulfur hexafluoride. The first emission may be due to the direct excitation of mercury atoms by subexcitation electrons produced in helium, while the second emission probably results from the neutralization reaction of mercury ions produced.

When helium gas containing mercury vapor is irradiated by ionizing radiation, emissions from the excited states of mercury atoms are expected. Recently we have theoretically calculated the G-value of photons at 253.7 nm emitted from 1 atm helium containing 10^{-3} Torr mercury vapor irradiated by 100 keV electrons.[1] According to this calculation, the emission consists of two parts; one is due to the direct excitation of mercury atoms by subexcitation electrons produced in helium and the other results from the neutralization reaction between mercury ions produced and electrons. If a very short pulse of high-energy electrons is available, two parts of the emissions at 253.7 nm could be separately observed. We really observed two emissions by using a Febetron 706 as the electron pulse source.

The reaction vessel is made of a cylindrical Suprasil quartz tube, 27 mm in diameter. The window for electron beams is an 80 μ thick aluminum foil which is attached to the vessel with epoxy resin. The Febetron 706 used gives a triangle electron pulse, the duration time being several nsec depending on the charging voltage. The emission from the reaction vessel has been measured by the optical set-up consisting of a monochromator (Ritsu Applied Optics MC-20), a photomultiplier (Hamamatsu TV R456-UR), an oscilloscope (Tektronix 454A MOD 163D), and a Polaroide camera. The detail of the measurement has been described elsewhere.[2]

When 100 Torr helium containing a drop of mercury at room temperature (18 ± 2 °C) has been irradiated by the electron pulse, two emissions at 253.7 nm could be observed on the oscilloscope. Figure 1 shows the oscillograms of the two emissions.

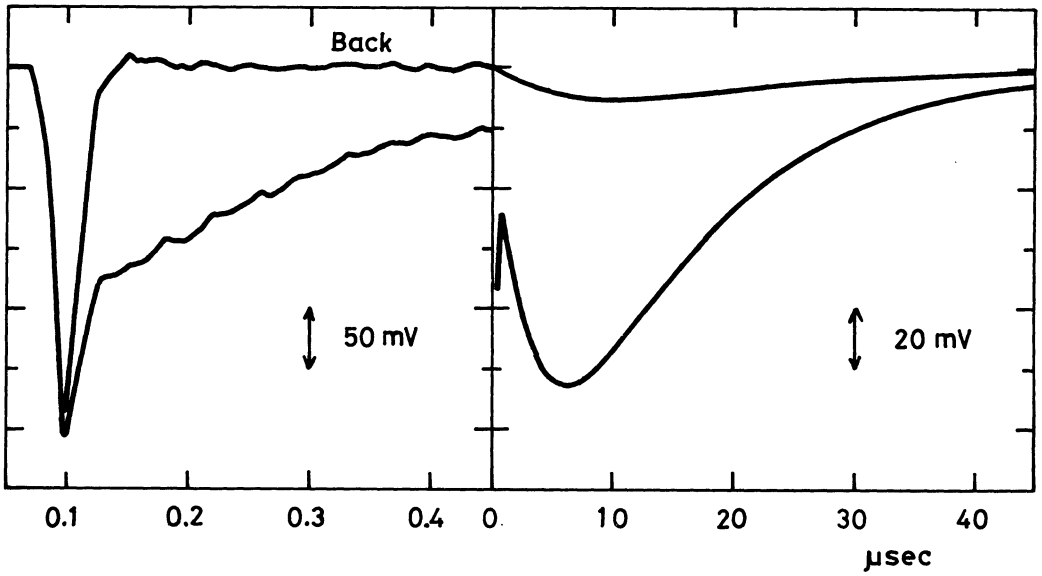

Fig. 1. The oscillograms of the two emissions. The peak of the background at 0.1 μsec is the noise from the apparatus.

The decay rates of both emissions were in first orders. The lifetimes and the positions of the peaks of the second emissions observed at different pressures are summarized in Table 1. The lifetime of the first emission at 760 Torr could not be estimated because of the overlap with the second emission.

Table 1. The observed lifetimes of the two emissions (τ_1 and τ_2), the positions of the peaks of the second emissions (τ_m), and the calculated apparent lifetimes of $Hg(^3P_1)$ atoms (τ_a) at different pressures of helium

P (Torr)	First emission τ_1 (nsec)[a]	Second emission τ_2 (μsec)[b]	τ_m (μsec)	$Hg(^3P_1)$ τ_a (nsec)[c]
50	300	17.6	9.5	339
100	240	12.9	7.2	265
300	200	5.7	3.8	198
760	---	3.0	1.3	198

[a] Experimental error ± 15%. [b] Experimental error ± 10%. [c] Calculated at 18°C.

Upon the addition of a small amount of sulfur hexafluoride (0.5 mol%), the second emission disappeared, while the first emission was scarecely affected.[3)]

These results suggest that the second emission results from the neutralization reaction and that the first emission is due to the direct excitation of mercury atoms by the electrons which have the energies higher than 4.9 eV (the energy of the lowest triplet state of mercury). If the energy of the electrons is higher than 19.8 eV (the lowest triplet state of helium), main energy loss of the electrons should result from the collision with helium atoms. Therefore, the electrons responsible for the first emission must be subexcitation electrons in helium.

The natural lifetime of the 6^3P_1 state of mercury atoms is reported to be 114 nsec;[4] however, the apparent lifetime is prolonged by the so-called radiation imprisonment. According to Milne's theory,[5] the ratio between the apparent lifetime, τ_a, and the natural lifetime, τ_0, in an infinite slab is expressed as a function of the optical density, kl.

$$\tau_a/\tau_0 = 1 + (kl/\lambda)^2$$

where, λ is a solution between 0 and $\pi/2$ of the following equation,

$$kl = x \tan x.$$

Samson examined Milne's theory and recommended to use the averaged optical density $\overline{kl}$ instead of kl.[6]

$$\exp(-\overline{kl}) = \frac{\int_{-\infty}^{\infty} F(\omega) \exp\{-k_0 l F(\omega)\}\, d\omega}{\int_{-\infty}^{\infty} F(\omega)\, d\omega}$$

where, $\omega = \{2(\nu-\nu_0)/\Delta\nu_D\}(\ln 2)^{1/2}$, and ν_0 is the frequency at the center of the line, $\Delta\nu_D$ is the width of a Doppler-broadened line, k_0 is the absorption coefficient at the center of a Doppler-broadened line, and $F(\omega)$ is the absorption line-shape function including the Lorentz broadening.[7]

Using the collision broadening cross-section to be 36 A^2,[8] we can calculate τ_a's at different pressures. The results are shown in the last column in Table 1. The τ_a's thus calculated are in good agreement with the lifetimes of the first emissions. This agreement suggests that the time needed for the deactivation of the electron from 19.8 eV to 4.9 eV must be much shorter than the radiative lifetime of the Hg 6^3P_1 state in the present system.

Further investigations are being carried out.

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