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Publication Date
1972-03-01
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March 1972

AEC Contract No. W-7405-eng-48

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Submitted to J. Chem. Phys. (Notes)

Lifetime of CO($a^3\Sigma$) Following
Electron Impact Dissociation of CO$_2$

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March 1972

The same time-of-flight technique previously employed to measure the lifetime$^1$ of the $a^3\Pi$ metastable state of CO produced by electron bombardment of a molecular beam of ground state CO has been used to investigate, for several electron bombardment energies, the lifetime of CO($a^3\Pi$) following electron impact dissociation$^2,3$ of CO$_2$. Knowledge of the lifetime and velocity distribution of CO($a^3\Pi$) following its dissociative excitation is of interest not only because of the observation$^4$ of CO Cameron band emission in the Martian upper atmosphere by Mariner 6 and 7, but also in connection with measurement$^5$ of the dissociative excitation cross section for production of CO($a^3\Pi$) by electron impact on CO$_2$.

A complete description of our apparatus, data-collection scheme, data analysis, and time-of-flight theory has been given previously.$^6$
The experiment is based on the time-of-flight technique where an atom or molecule is assumed to leave the metastable state only by radiative decay as it drifts over a 5-m path between two fixed detectors. Neutral, ground-state CO\(_2\) molecules effuse from a source slit and are immediately excited by a pulse of magnetically focused electrons. The metastable CO(a\(^3\Pi\)) molecules resulting from the dissociation\(^2,3\) of the excited CO\(_2\) molecules are then collimated while passing through three buffer chambers and finally detected at both ends of the 5-m drift region.

The data-taking and timing aspects of the experiment are controlled by an on-line PDP-8 computer. An example of the data collected is shown in Fig. 1. The electron gun is pulsed on only during channel 0 and counts are then collected simultaneously at both detectors into 199 channels, not all of which are shown. The 20-V distribution, representing 48 hr of data collection, contains about 3000 counts at the peak, while in contrast the 200-V distribution has about 27,000 peak counts and was collected in only 4 hr.

Taking the ratio R of detector-2 counts to detector-1 counts for metastable CO molecules of the same velocity gives a decay plot of \(\ln R\) vs time of flight \(t\), as shown in Fig. 2. If only one component were present, as in our previous discussion\(^6\) of the time-of-flight technique, \(\ln R\) vs \(t\) would be a straight line, and the lifetime \(\tau\) of the metastable state would be obtained from the slope = \(-1/\tau\) of this straight line. But since several vibrational and rotational levels of CO(a\(^3\Pi\)) are
metastable and have different radiative lifetimes,\(^1\),\(^7\) the decay plots of Fig. 2 have curvature, as expected for the decay of a multicomponent metastable beam. Only an average lifetime \(\overline{T}\) of \(\text{CO}(a^3\Pi)\) can be obtained from the "average" slope of the decay plot for each electron bombardment voltage, since, unlike our earlier lifetime measurement\(^1\) of \(\text{CO}(a^3\Pi)\) produced by direct electron excitation of CO, the relative populations of the various \(\text{CO}(a^3\Pi)\) rotational levels are unknown for dissociative excitation of \(\text{CO}_2\). In fact, the change in average lifetime at about 35 V apparent in Fig. 2 implies a corresponding change in the relative populations of the \(\text{CO}(a^3\Pi)\) levels.

The author would like to thank Dr. W. C. Wells for suggesting these measurements.

References

+ Work supported by USAEC.

Figure Captions

Fig. 1. CO(a^3Π) time-of-flight distributions taken at detector 2, 6.62 m from the electron gun used to bombard the CO\textsubscript{2} molecular beam. The shoulder on the distribution for an electron bombardment energy of 200 eV first appears at about 120 eV and is a new feature not reported in refs. 2 or 3.

Fig. 2. Decay plots. The ratio of detector-2 to detector-1 metastable CO distributions versus time of flight between detectors is plotted on a logarithmic plot for several electron bombardment voltages. The average lifetime $\tau$ of CO(a^3Π) at each voltage represents -1/average slope of the decay plot; the solid curves are only for comparison purposes.
Fig. 1

CO (a $^3\Pi$)

200 VOLTS

80 VOLTS

30 VOLTS

INENSITY (Arbitrary Units)

CHANNEL NUMBER

ARRIVAL TIME (msec)

XBL 722-220
Fig. 2
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