

## Proposed Direct Measurement of Atomic Transition Probabilities

THOMAS HOLZBERLEIN

In 1905 Einstein proposed a very fruitful concept in the theory of electron energy level transition in atoms. He proposed that the transition of electrons out of a certain energy state to the allowable lower states be through purely spontaneous events. Thus:

$$-\frac{dN_j}{dt} = \sum_i A_{ji} N_j$$

where  $A_{ji}$  is the transition probability for a group of excited atoms in the  $j$  state to make the transition to the  $i$  state.

The solution of this equation is:

$$N_j = N_j^0 e^{-\sum_i A_{ji} t}$$

If each  $A_{ji}$  could be determined separately the half life of the  $j$  state could be found.

A gas can be excited electrically or optically to bring atoms into the desired state  $j$ . Since each  $A_{ji}$  is associated with a given state  $j$ , it can be determined by measuring the half life of the line after the excitation energy has been cut off.

Thus if we can devise a method of cutting off the excitation energy instantaneously it would not seem unreasonable to suppose that with modern electronics the actual decay could be observed on an oscilloscope and the half life measured directly.

Landort and Bornstein have cataloged the known transition probabilities which range from  $10^{-8}$  sec. to  $10^{-20}$  sec. Most of these have been obtained from theoretical considerations alone. As far as the speaker has been able to determine the experimental data was all obtained prior to 1940 by apparatus especially designed to measure indirectly a specifically energetic line. This implied that a new piece of apparatus had to be built for each line to be measured. We hope to avoid this. From the known data it is possible to estimate the speed with which our proposed instruments must perform. At  $10^{-10}$  sec. the physical dimensions of the apparatus become a problem and the electronic complications become fantastic. Our present hope is to be able to measure decay times in the  $10^{-7}$  to  $10^{-9}$  sec. range. Below this range there seems to be very little interest. Above this range spectral line broadening studies should prove fruitful.

The light source to be tried first will be a gas filled tube with a coaxial electrode system. There will be electrons accelerated radically inward into the region to be viewed. The acceleration potential will be adjusted to give optical excitation of the state to be studied.

Mechanically closed coaxial relays give the steepest wave fronts now available to man. Rise times of  $2 \times 10^{-10}$  sec. or less are available by this means<sup>1</sup>. If a coaxial relay and coaxial tube are combined a biasing field may be propagated into the excitation region thereby cutting off the electron flow to the region being viewed. One might surmise that the length of the excitation region being cut off might be critical since one cm of motion corresponds to about  $0.3 \times 10^{-10}$  sec. time lapse. But the information produced at the initial end is propagated at the same rate as the cutoff signal so that when the final end is being cut off the information from the

<sup>1</sup> Millimicrosecond Pulse Techniques. By I. A. P. Lewis and F. H. Wells, McGraw Hill Book Company, pp. 102-104.

initial end is just arriving; hence, the "end-on" viewing operation has the effect of telescoping a progressive process into an instantaneous process as far as the light signal is concerned. This is just what is desired. This eliminates one of the manifold time dispersion problems. As the light is propagated out of the window it will be sent through the Bausch and Lomb monochromator available in our department. By means of prisms this device selects the specific spectral line desired. This selected light frequency will then be sent to a photo multiplier stage.

The photo multiplier technique we propose to use was developed by R. F. Post of the University of California.<sup>2</sup> Post has shown that a nine dynode photo multiplier tube may be made to give an amplification of  $10^9$  which is sufficient to display the effect of a single cathode electron when the output is connected directly to an oscilloscope deflection system.

In order to do this Post pulsed the photo multiplier at three to four times its rated voltage for as long as two microseconds. This technique resulted in several favorable effects. Ion noise was practically eliminated because the two microsecond acceleration time did not allow much migration of ions in the multiplier. Also the time spread in the signal due to the randomness of secondary emission velocities is greatly reduced because the transit time is so greatly reduced.

Since the photo multiplier can be in operation for 2M sec. there is ample time to observe events in the  $10^{-7}$  to  $10^{-9}$  sec. range as we hope to do.

In Post's work he observed pulses evidently due to single cathode electrons with a time spread of  $10^{-9}$  sec. for the half maximum width as actually displayed on the oscilloscope.

Thus far this is the greatest time limitation in our proposal. When he calculated the time dispersion in the capacitive shunting effect the actual single cathode electron output pulse width was estimated to be about  $2 \times 10^{-10}$  sec. at the multiplier output. If this is true it will set an ultimate limit on the speed we can attain, but it would be more reasonable to expect  $10^{-9}$  sec. as the upper limit. Thus the  $10^{-7}$  to  $10^{-9}$  sec. transition should be pretty accurately displayed, with  $10^{-8}$  to  $10^{-9}$  region somewhat doubtful.

With the work which has been done the greatest foreseeable problem in the experimental phase is the synchronizing of all the events which must take place.

The mechanical relay in the coaxial tube must close during the time the photo tube is energized. The sweep must be initiated during the time the signal proceeds through the optical system and the photo multiplier; at present this seems well within our grasp.

From the theoretical view point the electron cooling time is the greatest problem under consideration. Once the electron supply has been cut off the electrons inside the accelerating grid are essentially in a Faraday Cage hence they continue to produce excitation so long as there remain some few with sufficient energy. Since the main loss of energy will be in exciting the atoms variation of pressure should give a means of determining the capacitance of this effect so that it may be subtracted off from the actual display that has been photographed.

We hope to have enough flexibility to be able to obtain data for many lines with little more than a readjustment of the sweep time base and the monochromator and the pressures of the gas. Thus we hope to proceed from line to line in a matter of days or weeks. The analysis may take considerably longer but the hope is that we can actually obtain the half life of important energy levels so that discharge calculations can proceed with at least a little more than a guess as to the transition probabilities within the system being studied.

<sup>2</sup> Performance of Pulsed Photo Multipliers. By R. F. Post, *Nucleonics*, May, 1952, Vol. 10, No. 5, pp. 46-50.