

in the condenser. Since the dielectric is not ferroelectric, does not have permanent electric moment, and both plates are grounded before being again put together, the field intensity as well as the polarization should be zero. But the measurement shows that a considerable portion of Σ_t remains in the conductor.⁴ This is possible only if, during the charging of the condenser, this portion of Σ_t is transferred from the silicon plate to the mica surface. During the removal of B , the charge at the mica surface, bound to the field produced by A , still remains on the mica surface. Therefore, Σ_d , the charge density on the mica surface, is obtained by measuring the charge still stored in the condenser. The result of Σ_d versus V is indicated by the broken line in Fig. 2.

The net charge density $\Sigma_c = \Sigma_t - \Sigma_d$ on the silicon plate is represented by the dotted line. The measurement obtained by using copper and 30 ohm cm n -type single-crystal Ge, respectively, as one of the condenser plates also has been made; the result is essentially the same as using Si.

If we assume that the positive ion cores of the lattice points of the semiconductor and the dielectric are fixed, the charge transferred from the semiconductor to the surface of the dielectric is in the form of electrons added or removed from the dielectric surface, depending upon the sign of the potential applied. According to the band theory, the valence band of the dielectric is completely filled and the conduction band is completely empty. If the added electrons had to go into the conduction band, or the abstracted electrons removed from the dielectric had to come from the valence band, conductivity in the dielectric would have resulted. Such is contrary to experience. To explain this fact, we may assume⁵ that, at the dielectric surface, some localized electronic states exist in the forbidden energy gap of the dielectric. These states are partially filled, we can empty or fill them without affecting the insulating properties of the dielectric. The occupation of these states with respect to the applied potential can be fitted within the experimental error by the following empirical form $\Sigma_d = -A \sinh \alpha V$, where A and α are constants.

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MULTIPLE TRAPPING SITES FOR HYDROGEN ATOMS IN SOLID ARGON*

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The electron spin resonance (ESR) spectrum of hydrogen atoms, produced by an electric discharge in H_2 and trapped in an argon matrix at 4.2°K, was shown to be a simple doublet.¹ However, an ESR spectrum of three doublets has recently been observed as a result of photolysis of 1% hydrogen iodide in argon at 4.2°K by resonance radiation from a low-pressure mercury lamp. The low-field components of the three doublets are shown in Fig. 1. One of the doublets, whose low-field component is labelled A in the figure, has a field separation of 507.4 oersteds. This is precisely the same as found in the earlier deposition experiment. The other two doublets (corresponding to B and C) have field separations of 508.4 and 515.8 oersteds, respectively.

The fact that the six lines in the spectrum are identified as three independent doublets follows

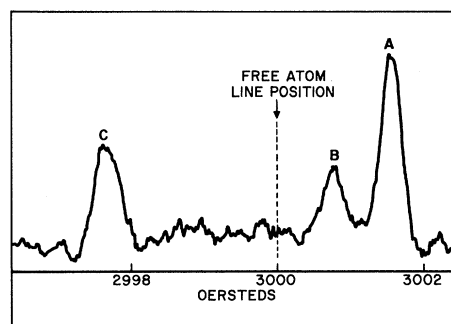


FIG. 1. Low-field components of ESR spectrum of hydrogen atoms from photolysis of hydrogen iodide in argon at 4.2°K. Microwave frequency = 9177.5 Mc/sec.

directly from the observation that each doublet shows a different temperature dependence. When the sample was warmed up very slowly from the initial temperature of 4.2°K, the components of doublet *C* gradually decreased and became unobservable at about 12°K, whereas the remaining lines substantially maintained their peak intensities while becoming somewhat narrower. In a similar manner, the components of doublet *B* disappeared at about 23°K and those of doublet *A* at about 39°K.

Since none of the above-mentioned doublets can be attributed to iodine atoms, which, in their free state, are expected to give an entirely different spectrum in another field region, we treat each of the observed doublets as the ESR spectrum of hydrogen atoms in a specific type of environment. From the field positions for each doublet and the microwave frequency, the effective *g*-factors and hyperfine coupling constants have been calculated by applying the Breit-Rabi formula. The results for all three doublets are tabulated in Table I, together with the known constants for the free hydrogen atom. Doublets *A* and *B* have approximately the same *g*-factor as the free atom, while the *g*-factor for doublet *C* is appreciably smaller. It is particularly noteworthy that doublets *A* and *B* have hyperfine coupling constants smaller than that of the free atom while doublet *C* has a larger hyperfine coupling constant.

It seems reasonable to interpret the three doublets as the ESR spectra of hydrogen atoms in three different lattice sites in an argon matrix. The stable crystalline form of argon at 4.2°K is face-centered cubic. Recent x-ray diffraction data² show that under the conditions of

our experiment, argon is deposited as a polycrystalline material. In a face-centered cubic lattice there are three possible sites for a hydrogen atom: the substitutional, the octahedral, and the tetrahedral. In addition, there are many crystalline defects where hydrogen atoms could be trapped. There are thus a number of non-equivalent sites where hydrogen atoms could be placed. At the present time we are unable to assign the doublets to specific lattice sites.

Since doublet *A* has been observed in both the deposition and the photolysis experiments, it may be assumed that the occupation of site *A* can be achieved by a hydrogen atom with an energy corresponding to room temperature (~0.03 eV) or less. It should be noted for completeness that the line positions of doublet *B* fall very close to those of hydrogen atoms in an H₂ matrix.¹ It is believed that this is an accidental coincidence since it is extremely unlikely that H₂ was present in the experiment. Occupation of the sites giving rise to doublets *B* and *C* is probably made possible by the high energy content (upper limit ~3.6 eV) of the released atom in the photolytic experiment.

One major difference among the sites is revealed by their different effects on the hyperfine coupling constants of trapped hydrogen atoms. By the relation between the hyperfine coupling constant and electron density at the nucleus, one class of sites (*A* and *B*) gives a decreased electron density (negative shift) and the other class (*C*) gives an increased electron density (positive shift) as compared with the free state value. These two classes of sites must cause very different perturbations to the electronic wave function and, perhaps not too surprisingly, show

Table I. *g*-factors, hyperfine energy separations (ΔW), and upper temperature limits (T_l) for hydrogen atoms at various sites in solid argon.^a

Site	g_J	ΔW (Mc/sec)	Deviation of ΔW from free value	T_l
free state ^{b, c}	2.002256(24)	1420.40573(5)
<i>A</i>	2.00220(8)	1413.82(40)	-0.46%	39°K
<i>B</i>	2.00224(12)	1416.31(80)	-0.29%	23°K
<i>C</i>	2.00161(8)	1436.24(40)	+1.15%	12°K

^aThe numbers in parentheses indicate experimental and/or conversion errors in the last figures of the associated values.

^bP. Kusch, Phys. Rev. 100, 1188 (1955).

^cR. Beringer and M. A. Heald, Phys. Rev. 95, 1474 (1954).

different degrees of thermal stability (see Table I). That a similar phenomenon can happen to S-state atoms in a different manner is brought out by recent reports³ on the positive and negative frequency shifts produced by various buffer gases on the hyperfine coupling constant of Cs. Photolytic experiments with hydrogen atoms in other inert matrices are in progress.

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MEASUREMENT OF FAST LUMINESCENCE DECAY TIMES*

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Measurement of luminescence-decay curves of organic scintillators has important applications both for radiation chemistry and for nuclear physics. The basic problems of such work are amplification of a light signal and time measurement. The usefulness of the measurements depends on the time resolution and the number of half-decay intervals over which a decay curve may be measured. In all previous work¹⁻⁴ in this field, essentially the first stage of the measurement apparatus has involved amplification via a photomultiplier. Such technique limits subsequent time resolution to the transit-time spread of the signal in a photomultiplier⁵ (i.e., at least $1 \mu\text{sec}$). In experiments in which the time measurement is effected by display of the scintillation signal on a cathode-ray tube, the signal is always markedly deteriorated after a decay of about one decade because of processes inside the photomultiplier and the connecting cable.^{6,7} On the other hand, the so-called phase-shift method involves an assumption as to the form of the decay curve.

In the method here reported, which represents a new approach to the problem, the time "point"

of the light signal is first established and the signal is thereafter amplified. In this way both time resolution and measurements at the far tail of the decay-curve are improved.

Figure 1 shows the apparatus used: the pulse generator, *PG* (Spencer-Kennedy Laboratory Model 203) delivers fast-rising positive square pulses into two 95-ohm coaxial lines. One of these pulses opens the grid of a 30-kv x-ray tube.² X-rays penetrate through a thin target into the scintillators. The scintillation light passes through an aperture *A*₁ (4 mm × 12 mm) and strikes the photocathode of an image converter, *IC* (RCA developmental type C73435B).⁸ The photoelectrons there produced are accelerated and focused onto the luminescent screen. If the resultant light signal on the screen is directly in front of aperture *A*₂ (3 × 10 mm), the photomultiplier, *PM*, is energized. Normally, a dc bias voltage on the deflection plates of the image converter so controls the electron beam

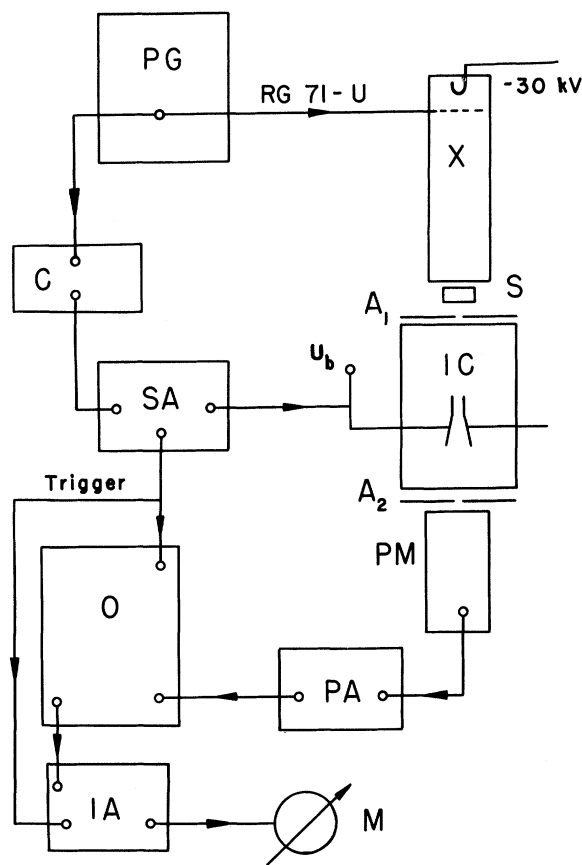


FIG. 1. Block diagram of apparatus for measurement of decay curves.