NaCl-Ag remains thus far the most satisfactory crystal for general purposes.

As often mentioned in the earlier communications, the counters have been of the gauze cathode-type and have been usually sensitized by a method described by Scherb.[4] However, counters are now being produced without sensitization of any kind which are sensitive enough to detect scintillations induced by alpha- and beta-rays. The discharge at liquid air temperatures does of course increase the counter sensitivity and hence efficiency of detection. It has always been necessary to sensitize the counters for detection of gamma-rays.

Several remarkable characteristics of treated photon counters have been observed in a qualitative fashion. For example, after the discharge treatment, the counters will withstand very high counting rates over a long period of time (greater than five hundred thousand counts per minute) without "breaking down." It is possible that points and rough spots on both the wire and the cathode are removed by the discharge. Although accurate observations have not been carried out, the counter sensitivity appears to remain constant over long time intervals. It also appears that photo-sensitivity increases as the diameter of the cathode of the counter is decreased. It is assumed, of course, that the operating voltage is kept constant by adjusting the counter pressure. The increased activity is explained by the fact that with smaller diameters, a stronger electric field is maintained adjacent to the cathode of the counter so that more of the soft ultraviolet photoelectrons are attracted into the counting volume of the counter.

Experiments with various counter geometries and crystals are continuing.

* Assisted by the joint program of the ONR and AEC.
[1] C. E. Mandeville and H. O. Albrecht, Phys. Rev. **79**, 1010 (1950).
[2] C. E. Mandeville and H. O. Albrecht, Phys. Rev. **80**, 117 (1950).
[3] C. E. Mandeville and H. O. Albrecht, Phys. Rev. **80**, 300 (1950).
[4] M. V. Scherb, Phys. Rev. **73**, 86 (1948).

The Detection of Gamma-Ray-Induced Scintillations from Crystals in a Photo-Sensitive Geiger-Müller Counter*

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IN two previous communications,[1,2] the writers have discussed the detection in photon Geiger counters of scintillations from alpha-particles and beta-rays on NaCl-Ag. The photo-sensitive counters have been constructed of wire gauze cathodes and Corning 9741 glass. The cathode materials have been usually copper and tinned steel. Sometimes, the counters have been sensitized by a discharge technique previously described by Scherb,[3] formerly of this laboratory.

It has been shown[2] previously that short-lived fluorescent pulses are also produced in the deep ultraviolet when NaCl-Ag is irradiated by gamma-rays.[2] Scintillations from gamma-rays on NaCl-Ag have been detected until recently only in a 1P28 photomultiplier tube.[2] However, sufficient quantum efficiency has now been obtained to detect them in a photo-sensitive Geiger counter.

Photon counters have now been produced which are far more sensitive to the ultraviolet than are those used for detection of scintillations from alpha-particles and beta-rays. One of these very sensitive counters was placed within concentric cylinders of NaCl-Ag and Textolite, Textolite being innermost, and was irradiated by the million-volt gamma-rays of Sc^{46}. The wall thickness of the NaCl-Ag cylinder was 1.27 cm, and the wall thickness of the Textolite was 0.32 cm. When the Textolite shield was removed, the counting rate was observed to increase by a factor of 2.5. Precautions were taken to ascertain that the change in counting rate was a genuine effect and was not one brought about by stray light admitted with removal of the shield. The measurements were repeated subsequently with the use of a paper shield rather than Textolite, and the same result was obtained. When the cylinder of NaCl-Ag was removed, the effect disappeared. When the photon counter was replaced by an untreated one in a Nonex envelope, no effect was observed. All of these tests of the experimental arrangement point to the fact that the increased counting rate could be explained only by counting ultraviolet fluorescence when the crystals of NaCl-Ag were irradiated by gamma-rays.

The factor of 2.5 in increase of efficiency was obtained in a relatively poor geometric arrangement. For example, the inner diameter of the cylinder of NaCl-Ag was several times greater than the diameter of cathode of the photon counter. This unfavorable situation resulted from the shape of the counter at its ends and from the fact that sufficient space was allowed for easy removal of the Textolite light shield. It is estimated that were the side walls of the cylinder of NaCl-Ag contiguous with the counter, an efficiency factor of 4 or 5 would have been obtained.

The limit of photo-sensitivity has not yet been reached. It is anticipated that the efficiency factor for gamma-rays will be increased.

* Assisted by the join program of the ONR and AEC.
[1] C. E. Mandeville and H. O. Albrecht, Phys. Rev. **79**, 1010 (1950).
[2] C. E. Mandeville and H. O. Albrecht, Phys. Rev. **80**, 117 (1950).
[3] M. V. Scherb, Phys. Rev. **73**, 86 (1948).

A Variational Principle for Time-Dependent Problems

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RECENTLY variational methods have been used particularly by Schwinger and his school[1] in connection with different kinds of physical problems.

It seems worth while to show that a similar variational principle holds for problems concerning the evolution of a quantum-mechanical system due to the action of an arbitrary time- and space-dependent potential. Let $f(\mathbf{x}, t)$ be the initial state of the system, $\psi(\mathbf{x}, t)$ the perturbed wave function, and $g(\mathbf{x}, t)$ an arbitrary final state. Then the probability amplitude for the transition from the state f to the state g is stationary with respect to small variations of $\psi(\mathbf{x}, t)$. This is easily seen using Feynman's[2] integral formulation, as the variational principle is derived by transformation of the differential equation into an integral equation containing a suitable Green's function.

Let us restrict ourselves for simplicity to the case of the motion of only one electron in a given potential $A(\mathbf{x}, t)$. (A is the four-vector matrix defined by Feynman[3].) If at time t_1 the electron is in the state f, the transition amplitude for finding the electron in the state g at time t_2 is

$$\alpha=\int \bar{g}(2)\beta K^{(A)}(2,1)\beta f(1)d^3\mathbf{x}_1 d^3\mathbf{x}_2. \tag{1}$$

The potential acts on the electron transforming the initial wave function $f(1)$ into $\psi(2)$ which obeys the integral equation

$$\psi(2)=f(2)-i\int K_+(2,1)A(1)\psi(1)d\tau_1. \tag{2}$$

In a similar way we define the wave function $\chi(2)$ as

$$\bar{\chi}(2)=\bar{g}(2)-i\int \bar{\chi}(1)A(1)K_+(1,2)d\tau_1. \tag{3}$$

If g and f are orthogonal states, using Eqs. (2) and (3), Eq. (1) becomes

$$a=-i\int \bar{g}(2)A(2)\psi(2)d\tau_2=-i\int \bar{\chi}(2)A(2)f(2)d\tau_2. \tag{4}$$