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H. Kersten and C. H. Dwight

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Solarization of Glass by Soft X-Rays

H. KERSTEN AND C. H. DWIGHT, *Department of Physics, University of Cincinnati*
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Window glass was solarized (colored brown) with x-rays whose wave-lengths were principally those of the K lines of copper (1.54 and 1.38A). The relative amount of light transmitted by the solarized, with respect to that transmitted by the unsolarized, part of the glass was measured with the aid of a Weston Photronic cell. The effect of x-ray tube current, voltage, time of exposure and the tendency of the solarization to fade with time, at several temperatures, were investigated.

INTRODUCTION

THE coloration of the walls of old x-ray bulbs has been known for years. In 1899 Villard[1] showed that x-rays exert a chemical action not only on the photosensitive salts on a photographic plate but also produce an image in the glass itself. Elster and Geitel,[2] Holzknecht,[3] Goldstein,[4] Dauvillier,[5] Perrine[6] and Bayley[7] have investigated this and related phenomena. The authors became interested in this kind of solarization after observing the ease with which glass cells, used for irradiating biological materials with x-rays, could be solarized.

EXPERIMENTAL

The x-rays were supplied by a gas tube having a copper target. The relative positions of the sample, target and window of the x-ray tube are shown in Fig. 1 (top). The tube was operated on full-wave rectified alternating current. The voltages subsequently mentioned were measured with a spark gap having 20 mm spheres. A photograph taken with an oscillating crystal spectrograph showed that the radiation transmitted through

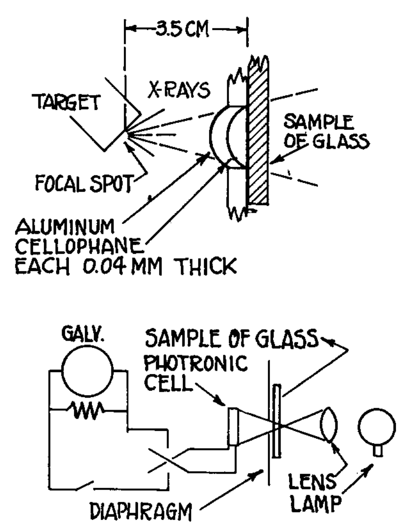

FIG. 1. Top: position of sample with respect to target and window. Bottom: arrangement for measuring percent of light transmitted.

[1] Villard, Comptes Rendus **129**, 882 (1899).
[2] Elster and Geitel, Ann. d. Physik und Chemie **62**, 4, 599–602 (1897).
[3] Holzknecht, Deutsch. Phys. Gesell. Verh. **4**, 2, 25 (1902).
[4] Goldstein, Preuss. Akad. Wiss. Berlin, Sitz. Ber. **10**, 222 (1901).
[5] Dauvillier, Comptes Rendus **171**, 627 (1920).
[6] Perrine, Phys. Rev. **22**, 48 (1923).
[7] Bayley, Phys. Rev. **24**, 495 (1924).

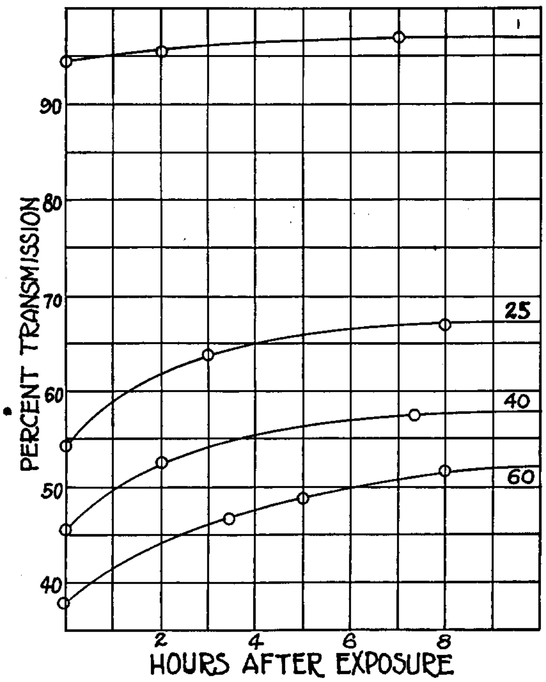

FIG. 2. Variation of transmission with time of recovery for various times of exposure (minutes). Potential difference across x-ray tube, 45 kv; current through the tube, 10 milliamperes. Temperature, 26°C.

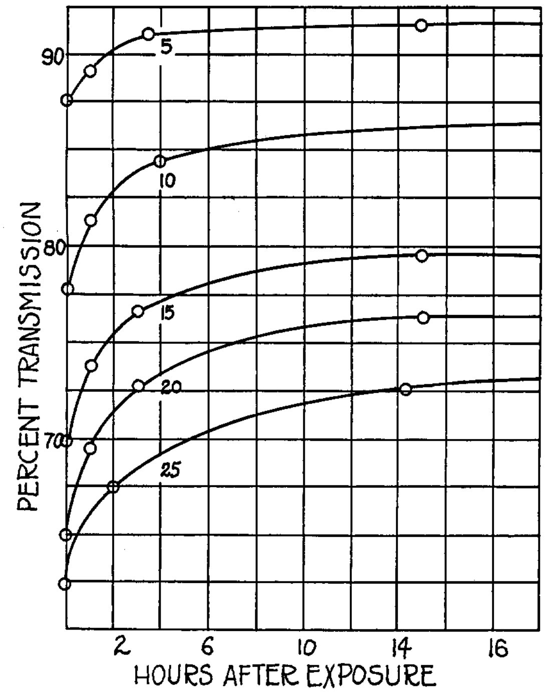

FIG. 4. Variation of transmission with time of recovery for various x-ray tube currents (milliamperes). Potential difference across tube, 30 kv; time of exposure, 15 min.; temperature, 26°C.

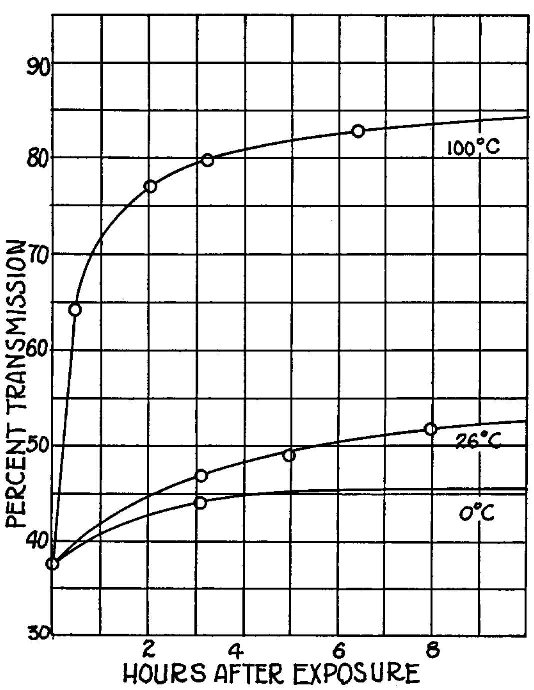

FIG. 3. Variation of transmission with time of recovery for various temperatures during recovery. Normal temperature, 26°C; potential difference across x-ray tube, 45 kv; current through tube, 10 milliamperes; time of exposure, 1 hour.

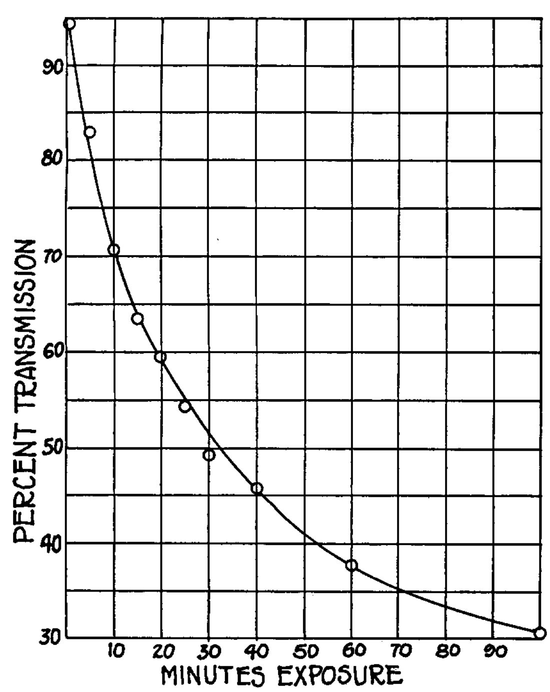

FIG. 5. Variation of initial transmission with time of exposure. Potential difference across the x-ray tube, 45 kv; current through tube, 10 milliamperes; temperature, 26°C.

the window consisted principally of the K lines of copper (1.54 and 1.38A).

The relative amount of light transmitted by the solarized, with respect to the unsolarized, part of the glass was measured with the aid of a Weston photronic cell arranged in a way similar to that described by Storey and Kalichevsky[8] and shown in Fig. 1 (bottom). The percentage of the light transmitted was taken to be $(r/r_0)\times 100$, where r is the mean deflection of the galvanometer to the right and left when the light came through the solarized portion and r_0 that for the unsolarized portion. It was assumed that the error in deflection caused by the change in sensitivity of the cell due to the coloration was small in comparison with the deflection that arose because of the light actually reaching the cell through the glass specimen and spot. The transmission of the clear glass, referred to air, was 91 percent. The current sensitivity of the shunted galvanometer was 41.45 microamperes per cm at a scale distance of 50 cm. The resistance of the circuit external to the cell was about 5.5 ohms. It was inferred that the current was proportional to the intensity of illumination incident on the cell. Readings were reproducible with greater accuracy and convenience than those taken on a spectrophotometer, where the intensity of two fields had to be compared visually. Between readings the samples were kept in subdued incandescent light. The pieces of glass[9] used were all cut from the same plate and were about 0.3 cm thick, 10 cm long, and 2.5 cm wide.

[8] Storey and Kalichevsky, Ind. Eng. Chem., An. Ed., **5**, May 15 (1933).

Conclusions

Under all conditions, the recovery of the material from solarization seems to be logarithmic. The rate of increase of transmission after irradiation is increased by (1) reducing the exposure time (Fig. 2), (2) heating the specimen during recovery (Fig. 3) and (3) decreasing the current through the x-ray tube (Fig. 4). The initial transmission, i.e., the transmission immediately after irradiation, increases nearly exponentially as the exposure time decreases (Fig. 5). Preliminary tests with a spectrophotometer showed that, for a sample of glass similarly irradiated, recovery is more rapid for the longer wave-lengths and that the initial transmission is greater also in this case. Typical spectral regions used were 6500, 5500, and 4600A.

[9] Samples of window glass manufactured by the Libbey-Owens-Ford Glass Co.