mean excitation energies of "level groups" according to whether they be assigned to Zn^{64} or Zn^{66}, unambiguous assignment being possible only if experiments are made with separated Cu isotopes.

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Fading of Proton Tracks in Vacuum*,**

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The fading of the latent images due to protons has been compared for photographic emulsions maintained in air and in vacuum after the exposure was made. The fading in vacuum was found to be approximately 10 percent of that in air indicating a purely chemical origin for the phenomenon of fading. At the present time it is speculative whether the residual 10 percent arises from the same source in which case it could be eliminated by merely improving the vacuum, or comes from an altogether distinct process. Some suggestions are advanced concerning a possible Ag atom evaporation process.

THE fading of tracks caused by charged particles has been well established by the Bristol group *et al.* Although it is improbable that the phenomenon is confined exclusively to latent images formed by charged particles as distinct from photons, in the former case it has proved more consequential by imposing a limit on the effective exposure times which can be utilized (notably in cosmic-ray research).

A significant question arises as to whether the dissipation of the latent image has a chemical or physical origin or involves two distinct processes. There could be a reoxidation of the Ag of the latent image by the atmosphere, possibly involving the water vapor, CO_2, etc. Alternatively the Ag atoms may "evaporate" from the Ag speck[1] constituting the latent image, and rediffuse into the AgBr lattice. The former alternative seems to be favored by the following observations:

(a) The rate of fading of alpha and proton tracks was conspicuously greater in summer than in winter in St. Louis. (Summer temperature $\backsimeq$30°C and relative humidity $\backsimeq$75 percent, winter $\backsimeq$22°C and $\backsimeq$39 percent.)

(b) Under constant temperature conditions ($\backsimeq$30°C) fading was accelerated by artificially raising the humidity and retarded by lowering the humidity.[2]

(c) Elevating the temperature sufficiently, produces rather than destroys a latent image.[3] Evidence for this comes from two sources,—the spontaneous "fogging" of an emulsion which increases rapidly with temperature and also the latent image resulting from frictional contacts[4] with an emulsion, explainable by a thermal mechanism.

A logical *coup de grace* to either theory would be supplied by comparing the rate of fading of tracks in vacuum and in air under the same temperature conditions.

Kodak Nuclear Track Plates NTB and Ilford Nuclear Research Plates C2, both 50μ, were exposed to fast neutrons from the Washington University cyclotron providing abundant proton recoils in each emulsion. Some of these plates were developed immediately. The remainder were divided into two groups and were allowed to stand as follows: (1) In vacuum. The container was evacuated with a mechanical pump every few days. The pressure varied from $\simeq$0.1–10-mm Hg. These plates were exposed to atmospheric pressure only for the initial half hour after bombardment and for the few minutes necessary to occasionally remove a plate for developing. (2) In air. The experiment was performed during the winter (temperature $\simeq$22°C, relative humidity $\simeq$39 percent). Both groups of plates were at the same temperature. A developing technique was standardized to permit identical development of successive plates.

The plates were scanned for proton tracks ending in the emulsion and having a range of at least 300μ (corresponding to a proton energy $\simeq$7 Mev). Grain counts per unit length were made on each track commencing from the end of the track where the protons stopped. However, it was found that the grain density towards the end of the track was too great to permit accurate counting. Less subjective data were obtained by excluding the ends of the tracks. In the final analysis

* A more comprehensive account of fading experiments will be published in *Review of Scientific Instruments*.

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[1] Consider the latent image mechanism in this case to comprise at least two competing primary processes—thermal liberation of electrons, and evaporation of Ag atoms from sensitivity specks.

[2] Dependence on seasonal humidity has recently been verified for alpha-tracks: R. Coppens, J. de phys. et rad. **10**, 11 (1949).

[3] However this could well be the net effect of the two primary processes and does not exclude the possibility of fading by evaporation proceeding simultaneously.

[4] K. B. Mather, J. Opt. Soc. Am. **38**, 1054 (1948).

grain counts were summed over only half the track i.e., over the next to last 150μ of range. (The number of grains over this length of track was $\simeq$180 in the unfaded Kodak plates.) Between six and ten tracks were counted on each plate. Figure 1 compares the results of (1) and (2) in terms of relative grain counts normalized to unity at zero time.

The rate of fading in vacuum is $\simeq$0.55 percent per week as compared with an average rate of fading (averaged over 76 days) $\simeq$4.8 percent per week in air. On this basis it appears that at least $\simeq$90 percent of the fading had a chemical origin. The rate of fading of Ilford plates in vacuum was almost the same as for the Kodak, but the fading in air was somewhat less rapid. It is evidently profitable to maintain nuclear emulsions in vacuum whenever fading may be deleterious. The result is more significant for meson and electron tracks which can be expected to fade more rapidly than proton tracks. It is suggested that cosmic-ray exposures be made in vacuum vessels maintained at $\simeq$1-mm Hg.

The physical interpretation of Fig. 1 is still somewhat in question. While the experiments were in progress it was found that emulsions placed in a vacuum of 10^{-4}–10^{-5} mm Hg became much more brittle and generally peeled off completely indicating that with vacua used in the fading work an appreciable amount of moisture was retained by the emulsion. In view of the reduction in the rate of fading effected by excluding $\simeq$99 percent of the atmosphere it would be interesting to know the result of a similar test in high vacuum.[5] It is quite possible that no fading exists in an isolated emulsion. Until this is established discussion is necessarily speculative.

However, if indeed there is a small residual fading even in high vacuum its magnitude is indicative of the true stability of the latent image against escape of Ag atoms. The problem is then to reconcile the existence of an evaporation process with the observed fact that a positive latent image builds up with increasing temperature. It is conceivable that Ag atoms be evaporated from shallow traps at temperatures too low for appreciable production of electrons. However this state of affairs implies that the atom-evaporation process be much less temperature-dependent than the electron-liberation process allowing the latter to predominate, as it seemingly does, at higher temperatures. From this point of view an investigation of the temperature dependence of the residual fading should be highly illuminating. With decreasing temperature, residual fading could be expected to decrease more or less rapidly depending on the exact picture of the evaporation mechanism. Similarly with increasing temperature the rate of fading presumably increases but becomes subordinate to the process of electron-liberation which evidently increases more rapidly. This seems to imply that true fading could be frozen out by maintaining the emulsion at a sufficiently low temperature, or at some higher temperature a state of equilibrium could be found at which the evaporation process balanced the thermally liberated electrons. Above this temperature the emulsion should fog by domination of the latter process.

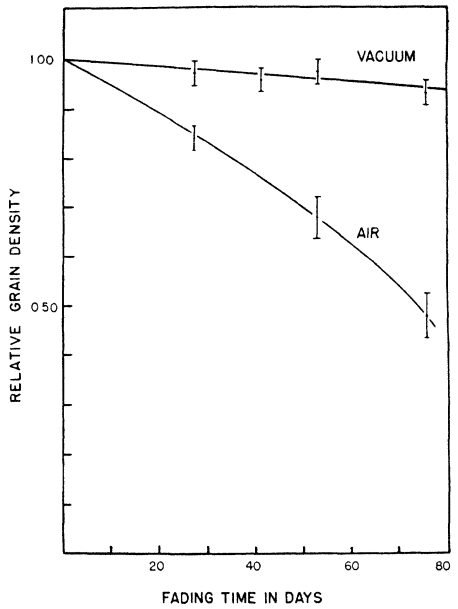

FIG. 1. Comparison of rates of fading of Kodak NTB plates in air and in vacuum.

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[5] Such an experiment would not be easy to carry out because of the peeling of the emulsion. It should be added that in the present tests with Kodak plates a large percentage of each emulsion flaked off even in this comparatively poor vacuum. Tracks were examined on the patches of undisturbed emulsion still adhering to the glass. Ilford emulsions did not peel off in the fading tests but did at 10^{-4} mm Hg. It was chiefly the latter circumstance which convinced us that the emulsions were not being dehydrated sufficiently by the present tests for a categorical verdict to emerge.