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Contract No. W-7405-eng-48

Summary of the Research Progress Meeting

January 6, 1949

Henry P. Kramer

Special Review of Declassified Reports
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Radiation Laboratory
University of California
Berkeley, California

Summary of the Research Progress Meeting

January 6, 1948

Henry P. Kramer

Mesotrons in the Cloud Chamber. Wilson Powell.

For the first time at this laboratory, mesons have been observed which were produced directly in the neutron beam.* A cloud chamber was placed into the beam and 120 photographs were taken. Of all the observed tracks, 7 can most certainly be attributed to mesotrons. These seven tracks are all seen to emanate from the solid glass or lucite portions of the chamber wall.

The assignment of tracks on a photograph of the cloud chamber to certain particles, protons, mesotrons, or electrons, etc. is done by taking into account several factors which differentiate between the tracks of these particles. On the photograph, one can distinguish between light and heavy lines. The strength or intensity and width of a line is a measure of the size and number of the droplets of water which collect around the ions which are produced by the particle. Furthermore, tracks are produced which have different lengths. Protons for example, in passing through the gas with which the chamber is filled, dissipate their energy so rapidly by ionization that the tracks which they produce are short, wide and very intense. An additional means of distinguishing between various particles is the measurement of the radii of curvature of the tracks left on the plate. Charged particles have instantaneously circular orbits because a magnetic field is applied to the space occupied by the cloud chamber. One further method of determining the characteristics of particles, in particular, their energies, consists of inserting a glass plate (a plate of some other material would also serve the purpose) into the chamber and

* Since the "proton conversion" of the cyclotron has been completed, a neutron beam is available whose energy is considerably in excess of 90 Mev, the energy of the former neutron beam. It is estimated that its energy may be as high as 350 Mev.

measuring the radius of curvature of a particle which passes through this glass plate on both sides of the plate. The difference in the radii of curvature on the two sides of the plate must be due to a loss in energy which the particle experiences in passing through the plate. By correlating this loss in energy with the other data which are known about the particle, one is able to estimate its energy.

The identification of seven tracks on the photographic plates with mesotron trajectories is based on the following considerations. The intensity of the observed tracks is about four times the minimum. The tracks of minimum intensity are produced by electrons. And yet the tracks are not distinct enough to be confused with protons. The radii of curvatures of the supposed mesotron tracks were at most of half the radii of curvature of tracks that could with complete assurance be attributed to protons. The clinching argument that one of the observed tracks at least was due to a mesotron is that at the end of this track a star was seen (see plate).

One track was observed which could not be definitely assigned either to a mesotron or an electron. Nevertheless, it is of considerable interest. The track was produced by the passage of a particle through the glass plate which is in the center of the cloud chamber. On the entrance side, its radius is 11 cm and on the exit side it is 9.5 cm. The intensity is four times the minimum and therefore it might be a heavy mesotron. If one calculates the energy which the particle must have had on the assumption that it was an electron, one finds the remarkable energy 169-180 Mev. On the assumption that the particle was a heavy mesotron, the calculated energy was 66-70 Mev.

In the future it is contemplated to insert a lucite plate in the cloud chamber in such a position that the neutron beam will impinge on the edge of the plate. It is hoped that by this expedient, the production of mesotrons in the neutron beam can be increased and that it will be easier to identify the tracks which emanate from the plate.

Radiation Resistance of Bacteria. R. Weatherwax.

Both from the point of view of the pure researcher and with regard to practical applications, it is of great interest to study the effect of radiation on bacteria. In such a study one would like to find out by what process or mechanism radiation kills bacteria. Since bacteria are the simplest of organisms they are relatively easy to manipulate. However, because of the fundamental similarity of all living cells, whether they exist independently or whether they are elements of the complex, highly developed and specialized forms of life, the results of such an investigation need by no means be limited in their application to bacteria alone but may very well enable one to arrive at conclusions about the interaction of radiation with all kinds of organisms.

One hypothesis as to the action of radiation on living cells was that the radiation might produce a poison in the cell. If this were a correct explanation, a small dose of radiation would produce a small amount of poison which, after a period of time, would be dissipated from the cell by the natural processes of metabolism which constantly change the identity of the molecules which make up the substance of the cell. Then, if a lethal dose were given in small portions over a sufficiently long period of time, one would not expect it to kill the organism. Experiments of this nature were carried out but it turned out that nevertheless, the organisms were killed by a lethal dose no matter how thinly spread in time. Therefore, the poison hypothesis was abandoned and instead it was thought that one must look for a particular element or factor in the cell, which if exposed to radiation would be so fundamentally altered as to cause the death of the cell.

This extremely vital element of the cell is, it is now thought, the molecule which imparts hereditary characteristics to a species of life, the gene. A large number of these genes is contained in the nucleus of the cell. The nucleus is a dumbbell shaped body within the cell which, if properly treated with a dye developed by Dr. Gaminow, can be seen in the microscope. This development provides the researcher with a means for observing the changes which are produced by radiation. Another way of deducing the properties of bacteria exposed to radiation is macroscopic in nature.

A strain of bacteria is divided into two portions. One portion is set aside for control and the other portion is irradiated. After the exposure, a drop of each portion is placed on a plate spread with a nutrient. After about twenty-four hours the plates are examined and specks, colonies of bacteria, are seen. Each speck is attributed to a family of bacteria consisting of the descendants of one bacterium. By comparing the number of specks which are seen on the two plates, the irradiated culture and the control culture, one can deduce the number of bacteria which were killed by the action of the radiation.

A typical survival curve is shown in Fig. 1. It is an exponential curve $y = e^{-\alpha x}$ whose slope α has been shown to depend on the type of radiation. It has been found that heavily ionizing particles are not as lethal as lightly ionizing particles. The reason for this seems to be that heavily ionizing particles dissipate their energy more rapidly and in smaller amounts and thus do not tend to produce a very powerful effect in any single ionization.

If one examines the gene hypothesis, some interesting problems arise which one must attempt to solve. For example, one distinguishes between stagnant cultures and growing cultures. When a culture has exhausted its food supply the cells no longer tend to reproduce and therefore each cell contains only one nucleus. However, if more food is supplied to the culture, the cells will again reproduce by fission. Before a cell divides into two, however, the nuclei divide and may multiply to such an extent that one cell may contain four nuclei (Fig. 2). Therefore, the cells of a growing culture may contain as many as four times the number of genes which the cells of a stagnant culture contain. The question which must be answered is: does a cell of a growing culture present four times the target to lethal radiation as a stagnant cell? Furthermore, will it be sufficient to hit only one of the nuclei in order to kill the cell or will it be necessary to hit all of them with radiation particles? This sort of situation is characterized by a survival curve of the form $y = 1 - (1 - e^{-\alpha x})^n$ which is sketched in Fig. 3. In this equation n is the number of hits which are necessary to destroy the cell.

It was decided to conduct an experiment to find out whether or not the sensitivity to radiation of growing cultures is greater than that of stagnant cultures. A strain of bacteria and a radiation resistant mutant of this strain were used. They were irradiated with ultraviolet light. Stagnant cultures were placed in batches of new broth so that they would start to grow and their cells would acquire as many nuclei as possible. (Cytologically, four nuclei is the maximum number for a cell). The cultures were allowed to grow for different periods of time, twenty-four hours, twenty-four and a half hours, twenty-five hours, etc. Presumably, if a culture is allowed to grow for a longer period of time in fresh nutrient it will contain a larger number of multi-nuclear cells. The batches of culture which had been allowed to grow for varying periods of time were then irradiation with ultraviolet light and their survival constants α were measured. Fig. 4 shows the behaviour of the radiation sensitive strain and Fig. 5 depicts the corresponding set of curves for the resistant mutant. In view of the fact that the two strains which were used are distinguished from each other only by their sensitivity to radiation the radical difference in their behaviour is quite remarkable. For, it can be seen from the figures that the sensitive strain increases in sensitivity. This result was expected on the basis of the gene hypothesis, although it is thought that other factors, in addition to the increased target size, operate in increasing the sensitivity. However, the resistant strain increases in its resistance to radiation with the length of growth in a nutrient broth. It is planned to search for an explanation of this behaviour.

Rare Earth Isotopes. G. Wilkinson.

The investigation is an attempt to interpret the results of the bombardment of tantalum in the 184" cyclotron. It was thought that some of the unidentified activities belonged to rare earth isotopes. Therefore, in order to make definite assignments, bombardments of samples of rare earth elements which had been purified by ion exchange separation were carried out both in the 184" cyclotron and the 60" cyclotron of Crocker Laboratory.

Holmium 165 was bombarded with 38 Mev, 30 Mev and 20 Mev α particles. (The energy of the beam was controlled by tantalum foils). Three radioactive thulium isotopes were produced. They were assigned the mass numbers 166, 167, and 168. Their activities had half-lives of 7.7 h, 9.6 d, and 85 d. The results are summarized in Table I. The 85 d activity shows a rather complex absorption scheme. In aluminum, a soft and a hard electron component were observed. The soft electrons have an energy of about .1 Mev and the hard component has an energy of about .5 Mev.

Results of the bombardment of praeseodymium are shown in Fig. 6. Fig. 6 also shows the products of bombardment of lutecium. One of these is a new isotope of hafnium, Hf^{175}, with a 70 d half-life. The cross section for the production of Hf^{175} by the reaction $Lu^{175}(d-2n)Hf^{175}$ is 3 x 10^{-2} barns. The 37 h isomer of Lu^{176} (see Fig. 5) is produced by the reaction $Lu^{175}(d-p)Lu^{176}$ whose cross section is 4 x 10^{-2} barns.

The details of the production, analysis, and identification of the isotopes and their activities are presented in "Hf^{175}, A New Radioactive Isotope of Hafnium," UCRL-233, by Geoffrey Wilkinson and Harry G. Hicks, and "Radioactive Isotopes of the Rare Earths, Part I. Experimental Techniques and Thulium Isotopes," UCRL-253, by Geoffrey Wilkinson and Harry G. Hicks.

<u>Radioactivies of Ag^{111}, Cd^{111}, and In^{111}. C. Helmholz.</u>

Work has been carried on with the beta-ray spectrograph to construct a rational decay scheme for Ag^{111}, Cd^{111}, and In^{111}. A tentative scheme is set down in the diagram of Fig. 7. Cd^{111} is a stable isomer of Cd. An intermediate state Cd was observed to decay in a cascade to Cd with the emission first of a 149 kv gamma-ray and then of a 247 kv gamma-ray. It has a half-life of 48 min. Ag^{111} has a half-life of 7.5 d and decays by beta emission without any accompanying gamma activity. The beta-ray spectrum indicated an energy of 1.06 Mev. Because the Ag^{111} does not show gamma radiation, it is thought that it decays directly to Cd. In order to identify the mechanism by which In^{111} decays, the energy threshold of the reaction Cd(p,n)In was measured and it was found that there was sufficient energy available for a β^+ emission of 300 kv. No evidence of this decay could be found however. It is therefore thought that In^{111} decays to the adjacent level in the Cd scheme by K capture. A spin of 1/2 has been assigned to the ground state of Cd. In accordance with this one must assign the spins which are shown in Fig. 7 to the other states.

The scheme as shown in Fig. 7 is unsatisfactory for several reasons. One of these is that it does not explain why one does not observe occasionally a direct transition of In^{111} to Cd. The difficulty may be due to inaccuracies in the conversion coefficients which were used.

Thulium Isotopes

Isotope	Reaction by which produced (tentative)	Half-life	Calculated Cross Section for Production at Different Energies (in barns)		
			38 Mev	30 Mev	20 Mev
Tm^{166}	Ho-α-3n	7.7 h	1.1	5×10^{-4}	- - -
Tm^{167}	Ho-α-2n	9.6 d	7×10^{-3}	.1	10^{-3}
Tm^{168}	Ho-α-n	85 d	10^{-4}	3×10^{-3}	0.2

Table I.

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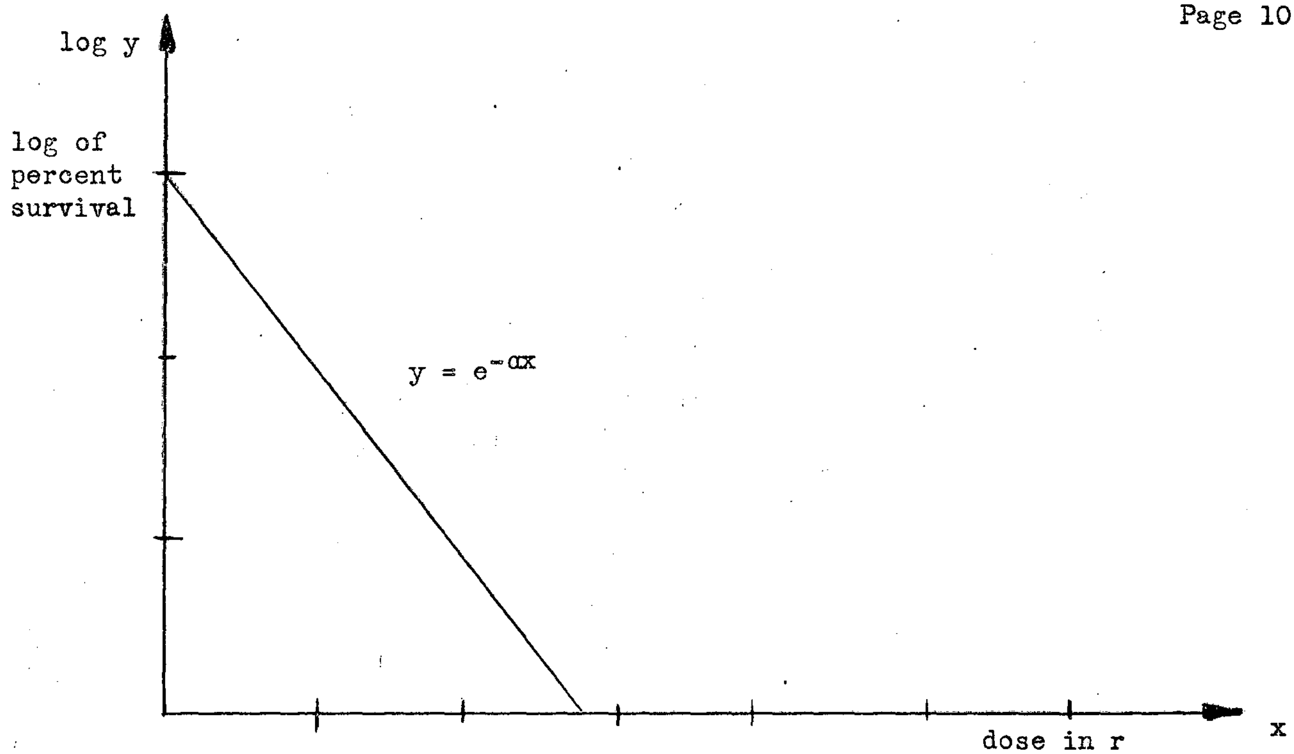


Figure 1

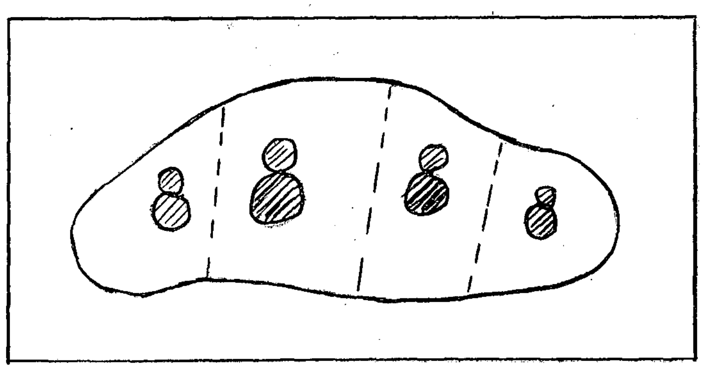
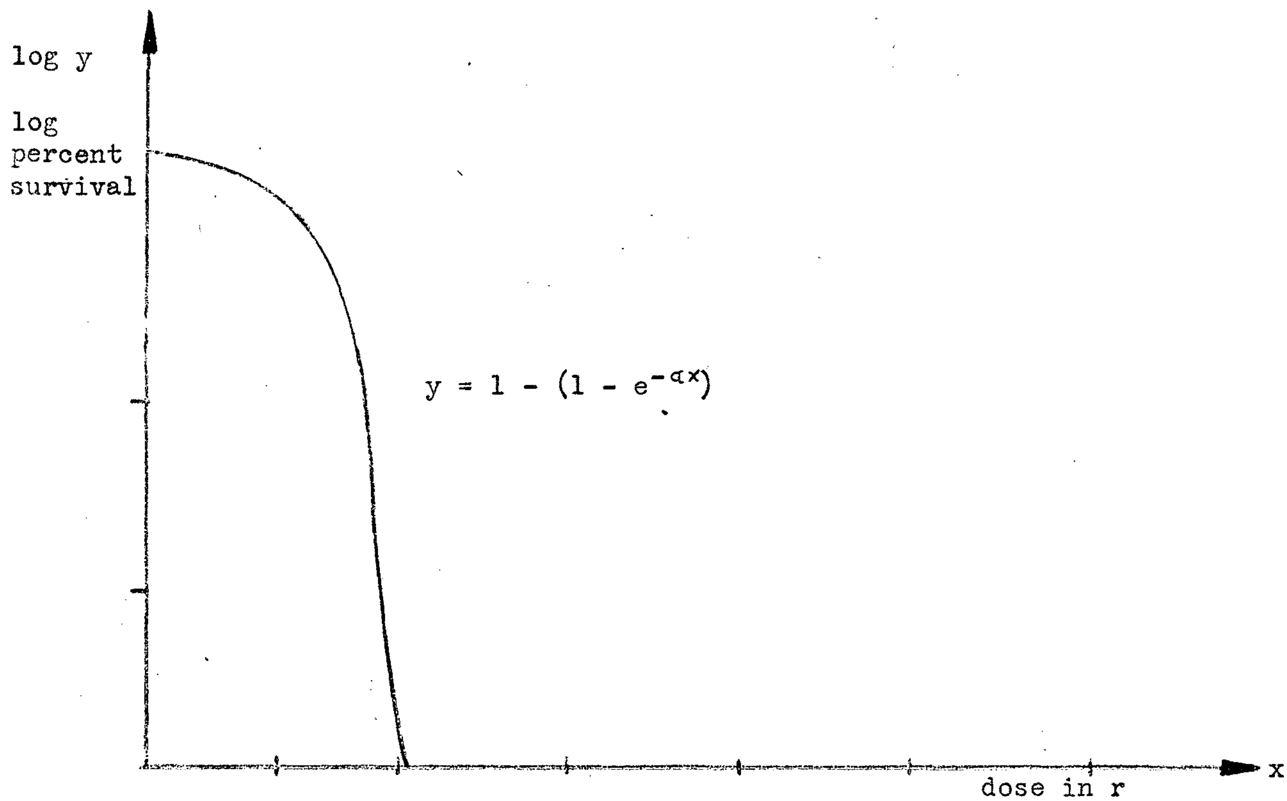


Figure 2



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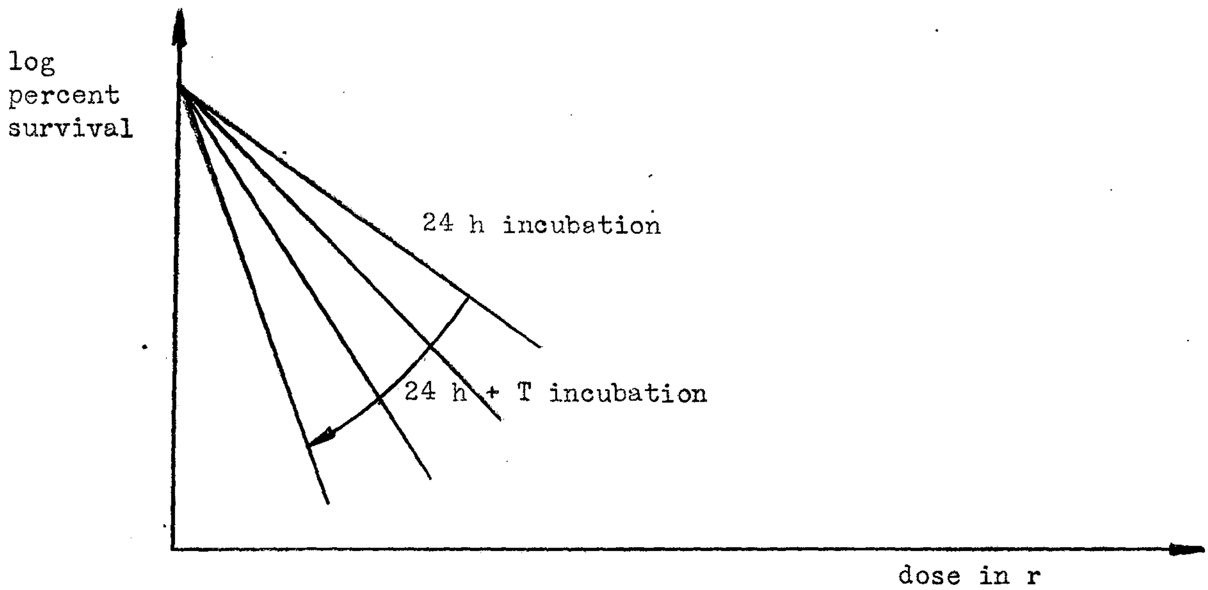
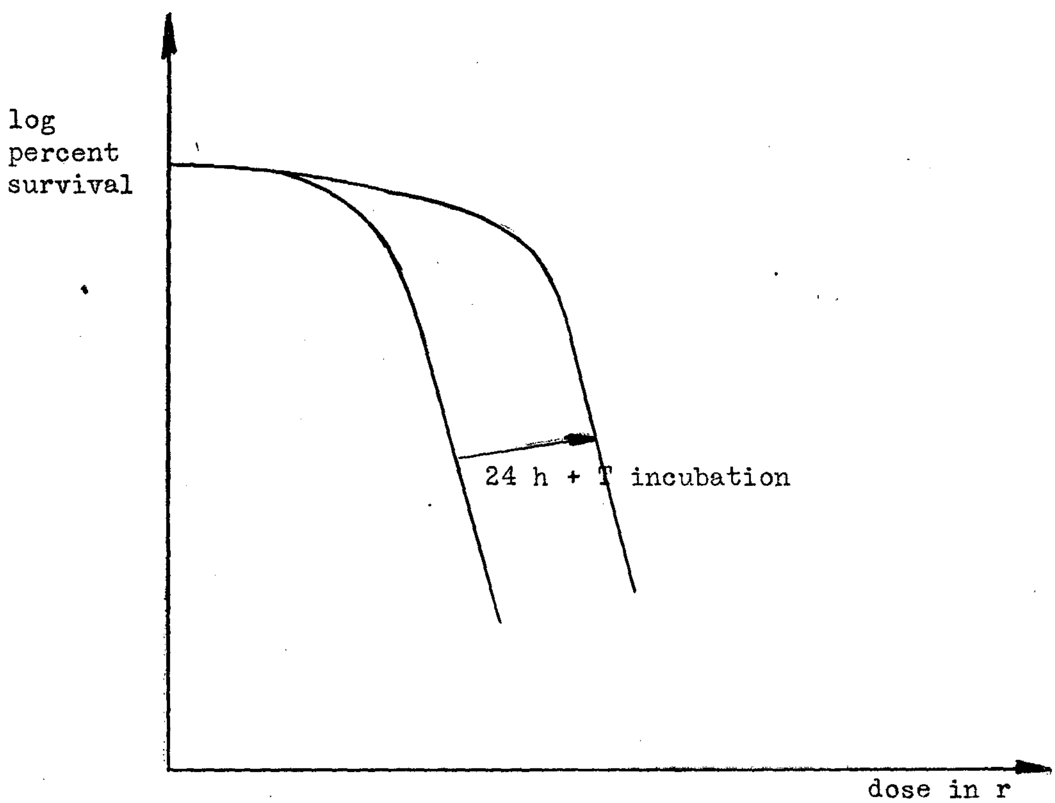
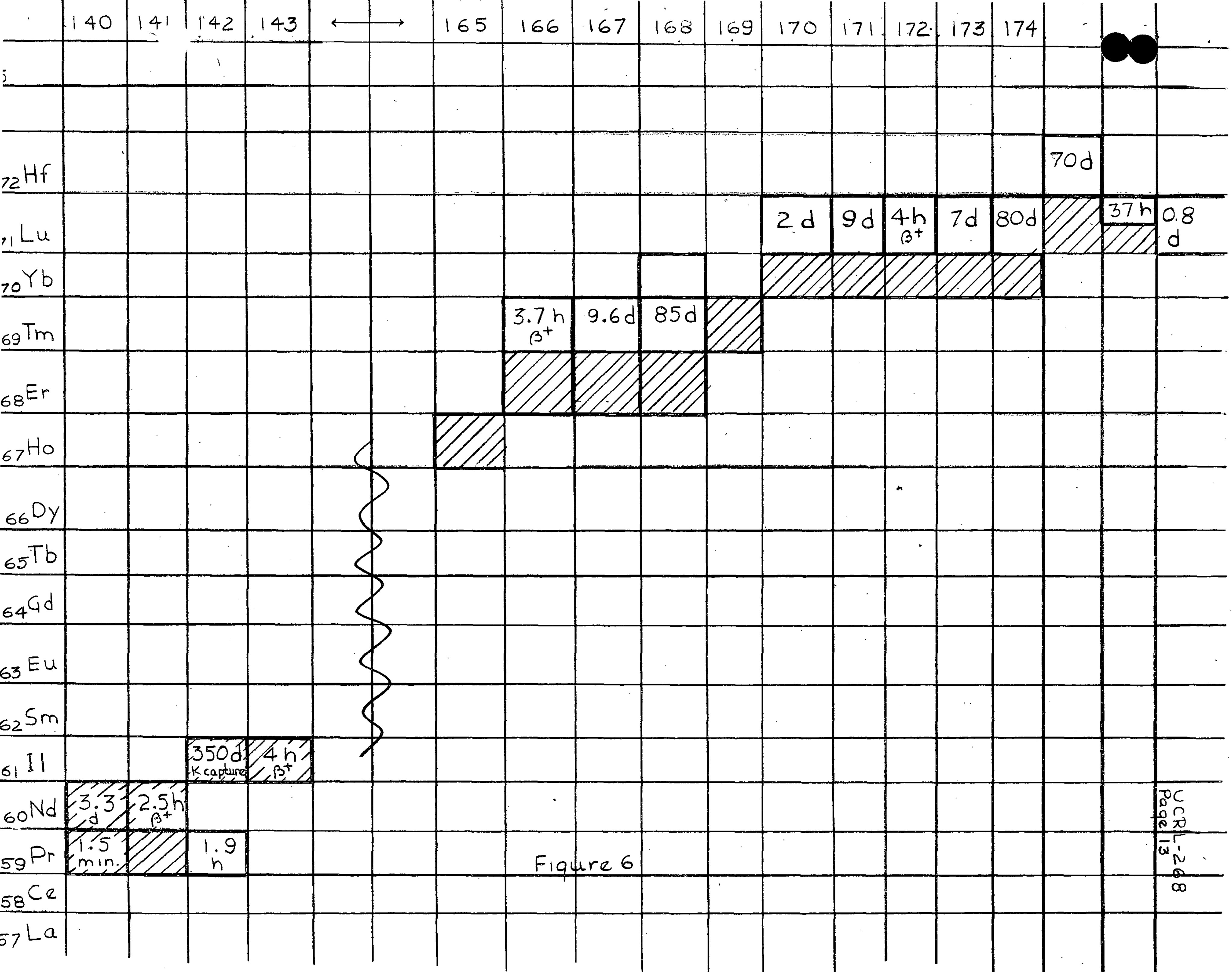


Decrease of Resistance to Radiation
with Increase of Incubation Period
for Sensitive Strain

Figure 4



Increase in Resistance with
Increase of Incubation Period for Resistant Strain
Figure 5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173
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72Hf
71Lu
70Yb
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68Er
67Ho
66Dy
65Tb
64Gd
63 Eu
62Sm
61 Il
60Nd
59Pr
58Ce
57La
70d
2 d
9d
4h β+
7d
80d
37 h
0.8 d
3.7 h β+
9.6d
85d
350d K capture
4 h β+
3.3 d
2.5h β+
1.5 min.
1.9 h

Figure 6

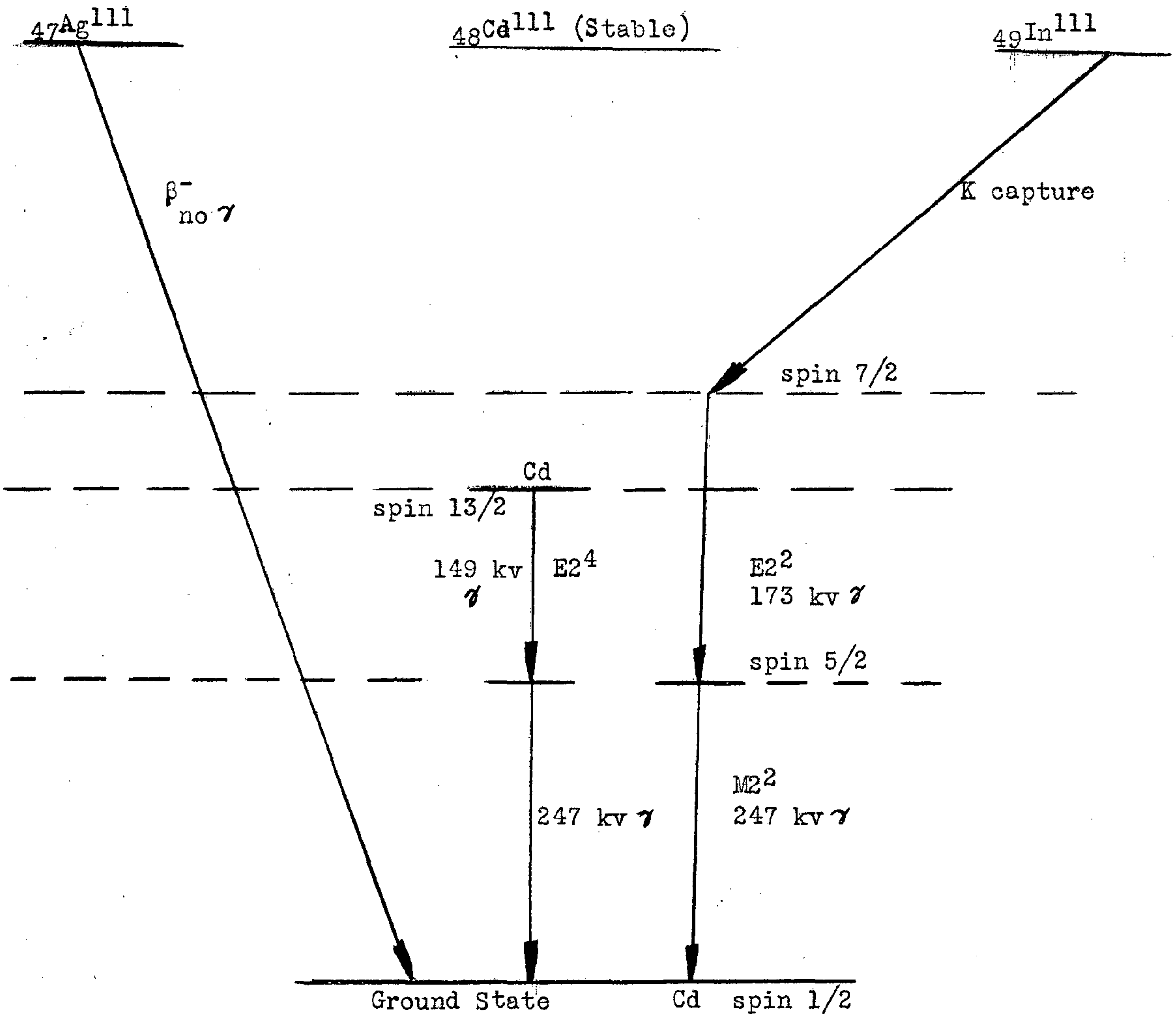
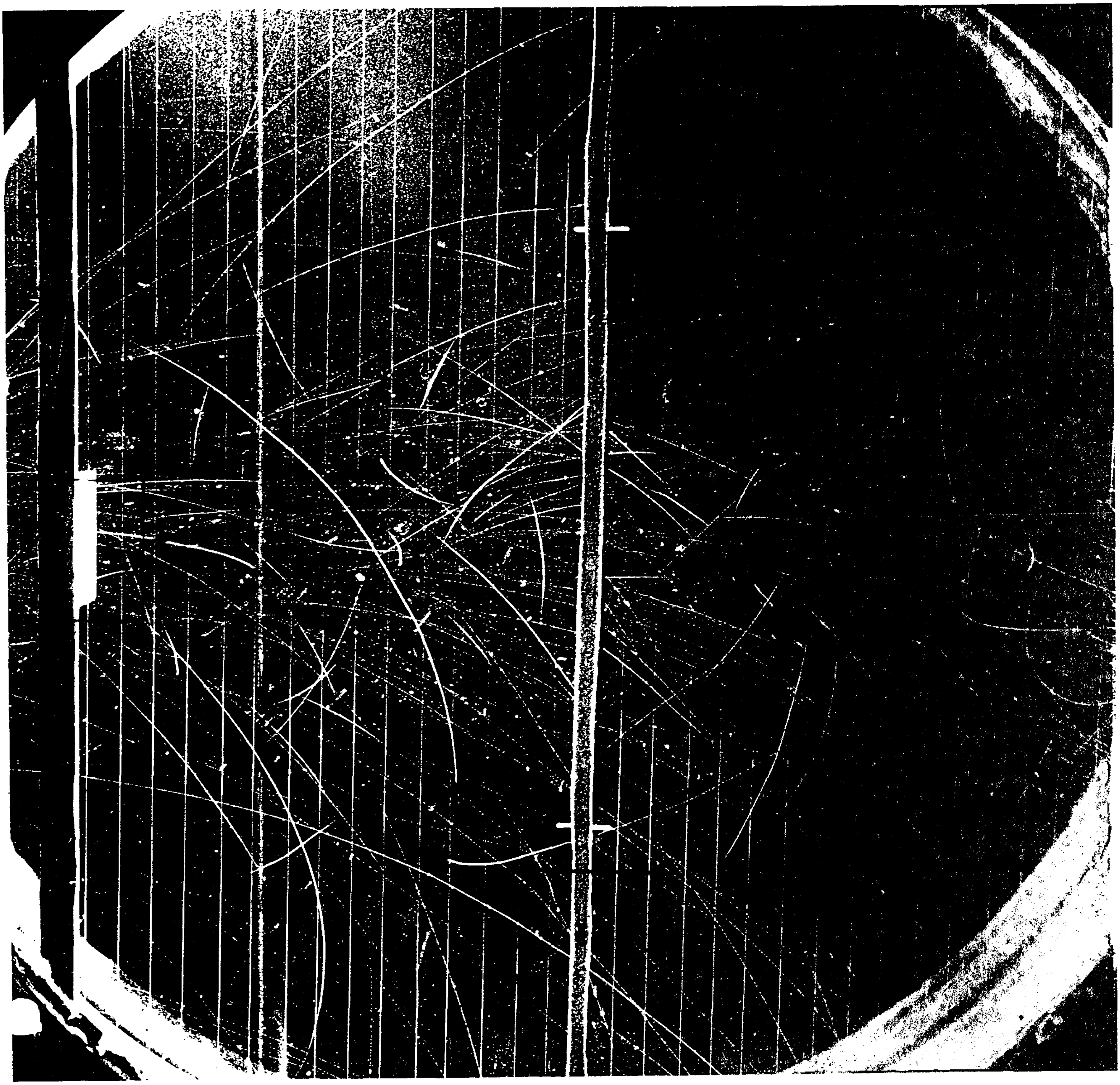


Figure 7

Tentative Decay Scheme for Ag^{111}, Cd^{111}, In^{111}



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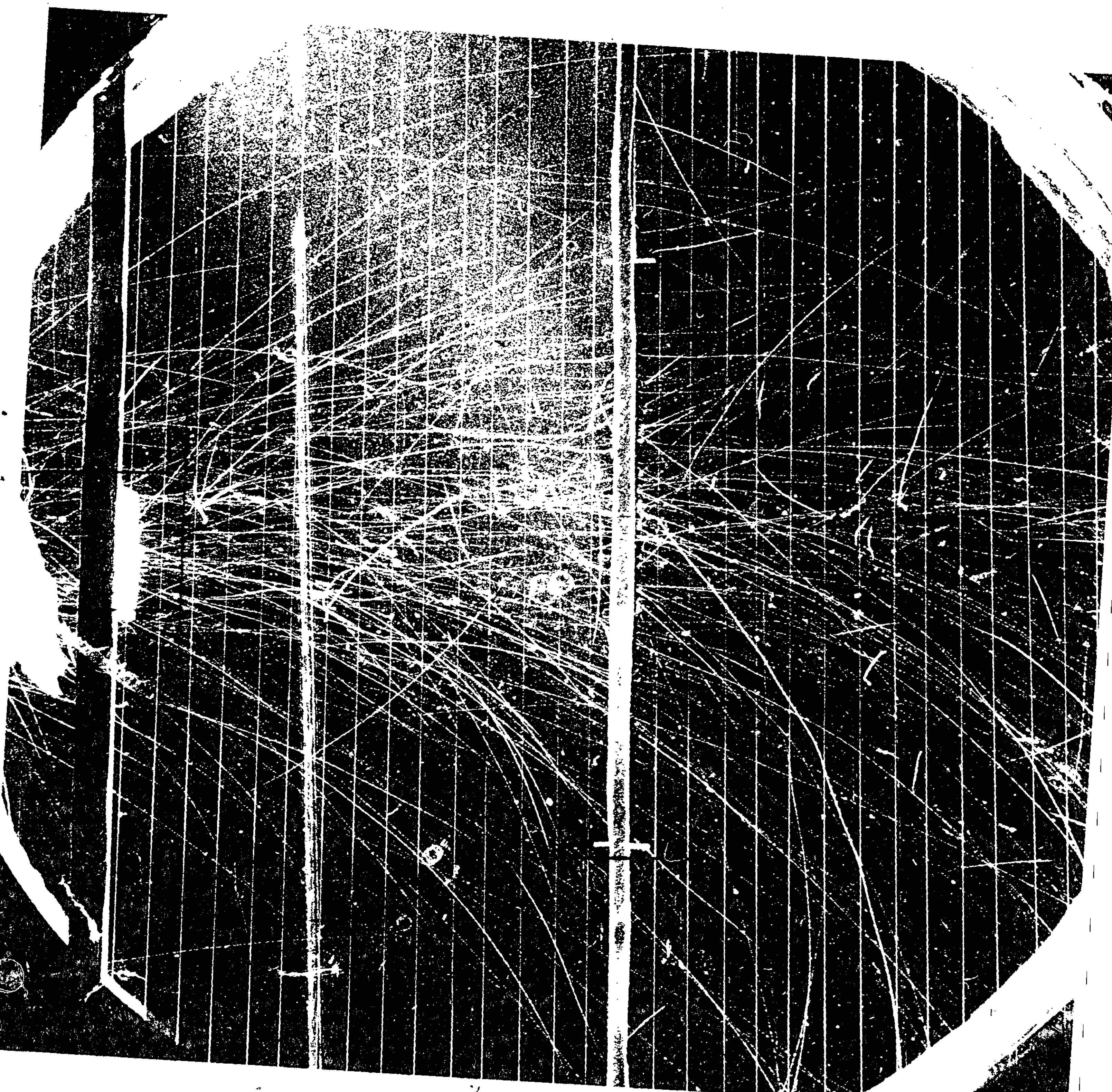

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