"RADIATION FROM Pt^{192} AND PROPOSED DECAY SCHEME"

By

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in the Faculty of Graduate Studies and Research, McGill University.

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McGill University.

April, 1956.

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ACKNOWLEDGEMENT

The author wishes to express his gratitude to Prof. J. S. Foster, Director of the Radiation Laboratory, for his continued interest and guidance.

The author is indebted to Dr. A. L. Thompson for the preparation of sources and his valuable suggestions.

He appreciates very much his discussions with Dr. G. T. Ewan.

He thanks Mr. R. H. Mills who did most of the operating of the cyclotron during the bombardments.

The valuable suggestions and help given by other members of the Radiation Laboratory are also gratefully acknowledged.

SUMMARY

By bombarding a gold target at a proton energy of 61 Mev the isotopes Pt^{192} and Pt^{191} were indirectly produced. Photographs were taken with the help of a 180° focussing spectrograph. Of the 207 lines examined, 170 were identified. Those assigned to Pt^{192}, and Pt^{191} are given in separate tables.

Assignments were aided by intensity measurements under the high resolution of a 180° beta- ray spectrometer with crystal detector.

A tentative decay scheme for Pt^{192} was also made.

INTRODUCTION

This investigation is concerned with the radiations from the isotopes Pt^{192} and Pt^{191} which have been indirectly produced by Au^{197} (p,6n) Hg^{192} and Au (p,7n) Hg^{191} reactions in the McGill 100 Mev cyclotron. The activated mercury decays to gold by electron capture and gold in its turn decays to Pt by the same process.

A large number of techniques are now available for the study of radioactive decay schemes. The complete investigation of a decay scheme involves getting all information not only about radiations and energy levels, but also spin, polarity, parity and line widths. From this information conclusions about the nuclear behavior may be drawn.

To provide data for such investigations, two methods are generally used. One involves measurement of energy spectra of beta and gamma rays, the other consists of coincidence measurements from which the sequence of emissions from a nucleus can be determined.

The most powerful methods to-day involve mainly the use of spectrographs. First, a gamma ray spectrum may be taken of a radioactive source to give a quick indication of most of the activities. Once these activities are established in a rough way, the result

can be followed up by beta ray spectroscopy. With either magnetic lens or 180° focussing spectrometers accurate half lives and relative intensities can be measured. This leads to the estimates of conversion coefficients and ratios of intensities of internal conversion lines. Finally the high resolution 180° spectrograph is used to establish fine structures and to find the exact energy levels. Additional information concerning the fine structures is supplied by a 180° spectrometer. These last two instruments, by providing conversion line measurements, also give a good check of the results first obtained with the gamma ray spectrometer.

The 180° spectrograph, although an excellent instrument for fine structure studies, has one serious limitation, viz., that intensities can not be assigned to the electron conversion lines. This must be left to the spectrometers. An additional important advantage of the 180° spectrometer is that half-lives of faint lines close to strong lines, which cannot be resolved by the lens spectrometer, can be measured. On the other hand, due to finite size of the slit which defines the beam that falls on the scintillation counter crystal, and also due to the greater errors in measurement of distances, the spectrometer could never give so accurate a value for electron energies as the spectrograph does. Thus in the present investigation the information gained from the plates of the spectrograph is supplemented by runs in the spectrometer.

PREVIOUS WORK

For establishing regularities in energy level spacing, an extensive set of nuclei should be found[3] among the odd isotopes of Ir, Pt, Au, Hg, and Tl, since here both the neutrons and protons are filling up their respective shells. To study this (complete) chain of nuclei, Gillon, Gopalakrishnan, De-Shalit[4] used the high energy accelerators. Reactions of the type (p,x n) were observed in which X varied from 1 to 8. Huber, Joly, Scherrer and Verster[5] studied the decay of Hg^{195m}, produced by 25 Mev deuteron on Au.

As one increases the proton energy above 25 Mev, no new activity definitely ascribed to Hg is observed until the threshold for (p,5n) is reached at an energy slightly below 35 Mev[4].

At proton energy of 45 Mev a new set of conversion lines begin to appear[4]. These lines are assigned to Au^{192} following a 6 hour Hg K-capture or β^+ emission to levels in Pt^{192}.

Moon and Thompson[6] have assigned a 12.4 hour electron capture activity to Hg^{191}. They produced this by Au (p,7n) Hg and reported an abundant yield at 70-80 Mev. Certain conversion lines, which then grow, appeared to be in Pt^{191} (4) (130, 91 and 158.7 Kev). These lines decayed with a 4 hours half life. Moon and Thompson[6]

reported gamma rays of energies 53, 64, 111, 123, 666, 250 and 405 Kev. Ewan and Thompson[7] associated gamma rays of energies 137, 158, 168, 188, 205, 282, 296, 316, 402, 437, 467, 588, 612, 765 and 1135 Kev with Pt^{192} and 99.7, 112.3, 155.5, 173.3, 185.9, 255.1, 267.9, 316.4 and 439.6 Kev with Pt^{193}.

Cork[8] and collaborators observed 45 internal conversion lines in spectroscopic studies of Ir^{192}. A level scheme was drawn for excited Pt^{192} to explain the origin of the ten observed gamma rays (135.9, 156, 173, 294.9, 307.7, 316.1, 415.1, 467.4, 588.6, 603.7 and 611.2 Kev).

K.I. Roulston and R.W. Pringle[9] studied the disintegration of Ir^{192} to Pt^{192} with the help of a scintillation spectrometer and got the evidence for gamma rays of higher energy than those previously reported (611 Kev). Two lines at approximately 775 and 870 Kev were detected with the spectrometer. There were really no distinctive features in the region 900 to 1200 Kev but rather continuum which suggested the presence of several unresolved weak gamma rays.

Further studies of Ir^{192} with a scintillation spectrometer[10] have revealed four higher energy gamma-ray components at 788, 883, 1080 and 1210 Kev, with the possibility of a fifth component near 920 Kev. The Ir^{192} — Pt^{192} ground -ground state transition energy has been

measured as 1490 $\pm$ 20 Kev. Level schemes are proposed for Pt^{192} and Os^{192}, the product nuclei upon the beta decay of Ir^{192}.

M.W. Johns and S.V. Nablo[11] made a further study of Ir^{192} and drew essentially the same level scheme as that suggested by Cork's group and extended by Pringle et. al. Slight modifications of the energies of upper levels have been made by inserting two more levels, 1156 and 1359 Kev. From the studies of gamma-gamma directional correlation in Pt^{192}, Taylor and Pringle[12] proposed the spin sequence of the first five states in Pt^{192} level scheme. They are 0,2,3, (4),4 respectively.

APPARATUS

1. The 180° Spectrograph:

A photograph of the 180° spectrograph used for measuring the energies of different conversion electron lines is shown in plate 1.

Since a detailed description of this inexpensive instrument was given by Dr. F. A. Johnson in his Ph.D. thesis[1] (1952), only a brief outline will be given here.

Pole pieces, 5-½" thick, are turned to semi-circular form of 21" diameter. The faces are grounded and a shoulder is cut to receive the wall of a D-shaped brass vacuum chamber. The poles sit with their diameters on a non-magnetic support. Vertical members of the yoke, 5½" x 7-5/8" in section, are attached to the poles and extend upward 21". Between these and the top cross member of the same section, there is a 2¼" gap to receive a selected number of Alnico 5 permanent magnets 5/8" in diameter. Occasionally these are supplemented by units taken from war time magnetron magnets which are hung from the top cross-piece to make contact with the yokes below the 2¼" gap. This is the main structure of the magnet.

The vacuum chamber wall of the semi-circular contour is made of heavy brass ¾" thick with an inside radius of 9¼" and 18.42" chord.

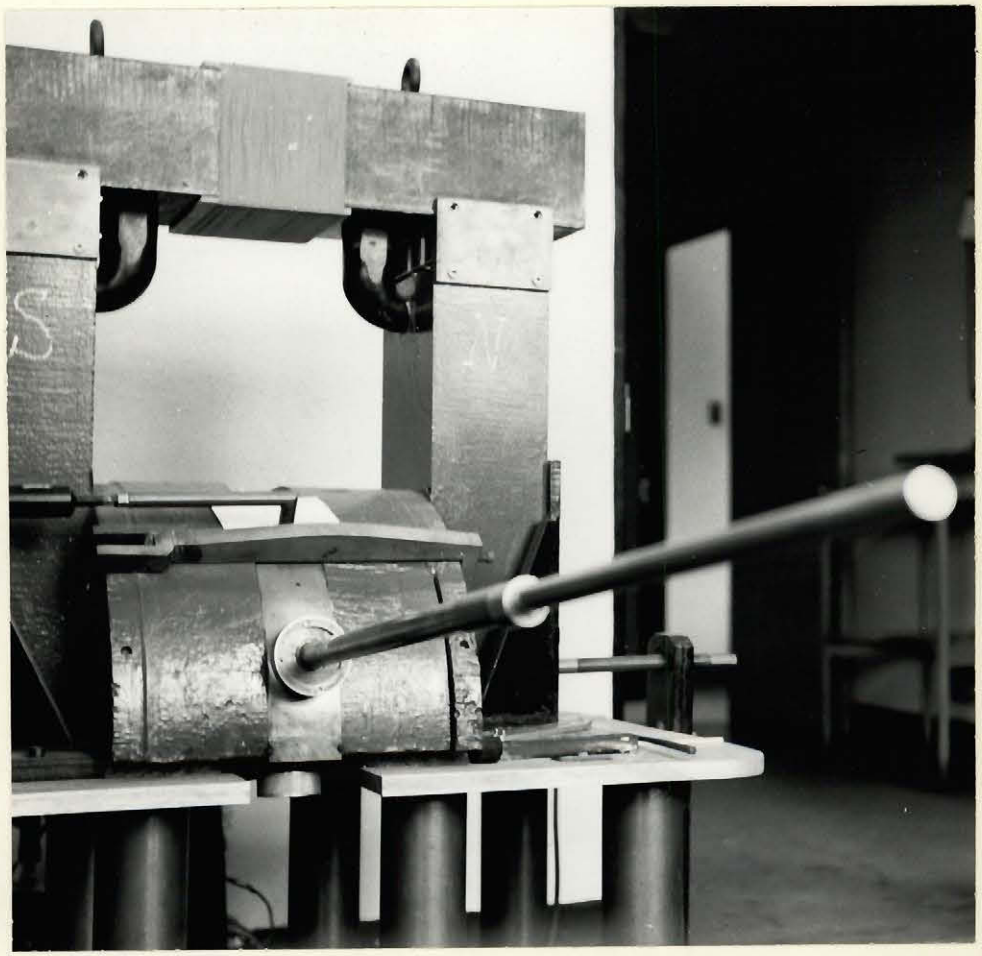


PLATE 1

Two circular ports are cut at right angles to one another into the chamber. The principal port of 1-5/8" internal diameter is made through the curved wall to receive the mount carrying the slit system and plate holders. A second port of 1" diameter, for the source holder, is directed through the flat surface at right angles to the plate holder. Each holder is accurately oriented by pins and held firmly in operating position by hand nuts. A long and heavy plate holder system which is perfectly light-tight is used. It can be taken to the dark room for loading.

The slit system consists of a rectangular opening through the dural plate holder over which the lips of the slit extend. Throughout the investigation the slit width remains fixed at 0.100".

The actual photographic plate is inserted from the far end of the dural holder. In order to facilitate measurements of the distances of the electron lines from the slit, a photographic plate marker is used to put index marks on the plate after an exposure and before it is removed from the holder.

"Eastman X-ray no screen" emulsion on glass plates is used throughout the investigation.

The source holder consists of a 1" diameter brass plug with a wide shoulder. A groove is made on the shoulder and an aluminium block containing the line-

activity on its top surface can be slipped into it. The slit lips are positioned with respect to the central line on the block so that the center of the slit is directly over the line of activity on the block.

A line corresponding to any moderate energy can be made to fall anywhere on the photographic plate by an appropriate choice of the magnetic field strength. The largest value of ρ that can be accommodated on the plate is 18 cm, but in practice no greater than 17 cm is measured. The magnetic fields used for these measurements are 150 gauss/cm and 90 gauss/cm approximately.

The vacuum chamber of total volume 2.4 litres is evacuated by means of a small Welch-mechanical pump and a small two stage oil diffusion pump.

2. The 180°-ray Spectrometer

A detailed account of design and construction of this apparatus has been given by M.A. Badior in his M.Sc. thesis[2] (1954). A brief description is considered to be sufficient for the present work. A photograph of this apparatus is given in Plate No. 2

This spectrometer is of the same type as the spectrograph i.e. a pure 180° focussing spectrometer with homogeneous magnetic field supplied by permanent magnets. The spectrometer is built of special low carbon ARMCO iron. The final diameter after machining is 26¼", the two pole faces being machined to exact semi-circles. The pole pieces are not suspended with the straight edge horizontal, but rather at an angle of 25° to bring the probe horizontal.

The spectrometer rests on the straight bottom edges of the yokes which are placed on an 1" thick sheet of aluminium as a level support.

The magnetic field for the pole pieces is provided by war-time magnetron magnets which are placed in the two corners between the bar and the inside faces of the yokes.

Two brass ports are silver-soldered on the vacuum chamber, one for the probe to enter the chamber and the other for the source holder plug. Between the source plug and the rest of the chamber there is a lead block acting as a shield to prevent radiation emitted by the source from

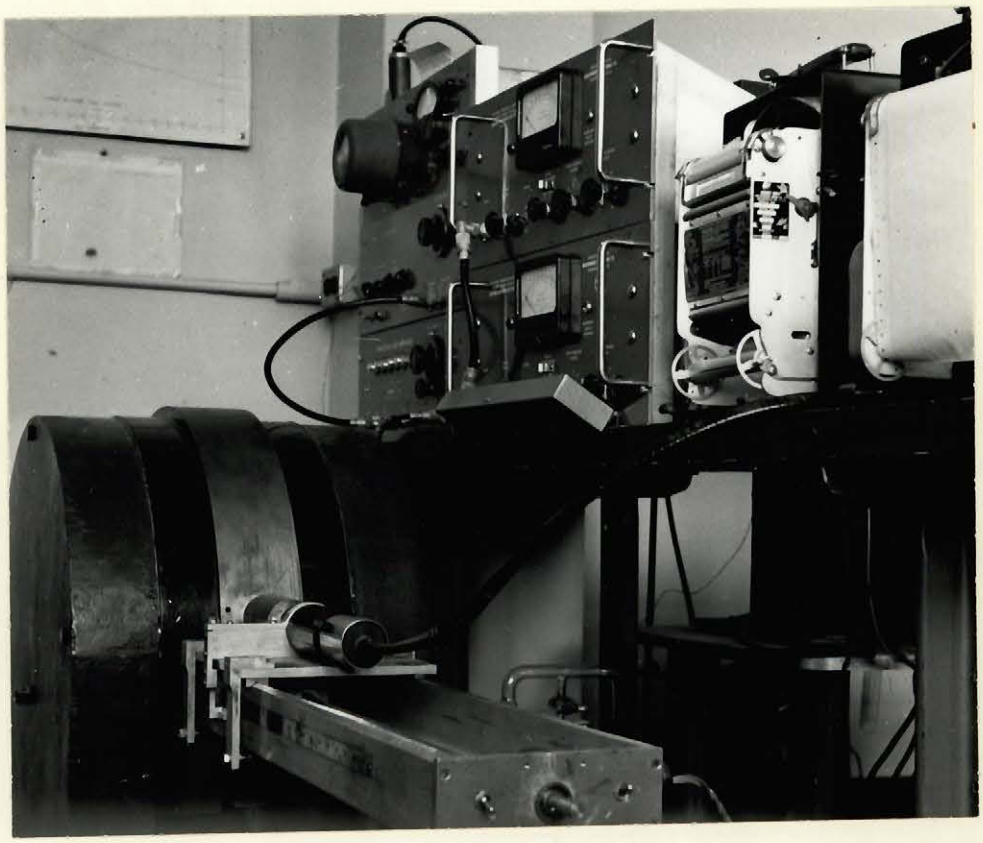


PLATE 2

reaching the counter directly.

There are three speeds for moving the scintillation counter probe across the chamber. Very slow speed is used for studying very weak lines, since it would be important to scan long enough over the lines to be able to distinguish them from the background.

Fast speed is used for quickly scanning the whole spectra specially in the case of short half-lived samples. The combined action of a motor and gear box mounted on the bottom of the channel is responsible for the movement of the counter probe across the chamber.

The scintillation counter probe consists of a lucite rod, chosen as the most efficient means of getting the light pulses outside the chamber, and an anthracene crystal as a beta ray detector. The reason for using the anthracene crystal is its capacity for producing the greatest scintillation pulse height of the known organic phosphors. The lucite pipe is slightly under 1" in diameter and 24" long. The crystal end is so shaped as to get as much light as possible directly into the pipe. Arrangement has been made for an adjustable detector slit over the crystal. The light pipe is contained in a polished stainless steel tube of 1-1/8" outside diameter, which acts as a light shield and slides through 'O' ring seals. It does not make contact with the lucite rod.

The pulse counting equipment consists of a photo-

multiplier tube with a cathode follower, a linear amplifier with a pulse height descriminator, a scalar and a counting rate meter which can be connected to a recorder. An R.C.A. 6199 photo-multiplier tube is placed against the end of the lucite light pipe, with silicon oil improving the transmission.

The 6199 tube is held in place by an O ring around the glass envelope of the tube and by its socket. The socket is extended by a thin bakelite tube 4" long which also fits into the probe tube. It contains the necessary resistors for the 6199 tube and a cathode follower circuit using a 6AK5 tube for matching the output impedance of the 6199 tube to the impedance of the scalar or linear amplifier. Three cables emerge from the end of the probe tube. One provides the high voltage supply for the photo-multiplier tube; one supplies the plate voltage, heater current and ground for the 6AK5 tube, and a third takes the pulses out to the amplifier and scalar. Two counting rate meters are used in parallel, one set at the lower counting range for weak lines and the other at higher range for recording strong lines. The scanning speeds and the time constant for the counting rate meter are used according to the need i.e. for the fast speed short time constant is used and vice versa.

EXPERIMENTAL

Adjustment of the 180° Spectrograph:

The McGill apparatus has an improved type of focussing arrangement shown in Fig. 1. It is particularly well suited to the photographic registering of a large part of the spectrum. With its 0.2% resolution it surveys a large number of conversion lines simultaneously.

The field of the spectrograph varies slightly. Therefore calibrations were made with standard lines of Thorium (A,F,I-lines) keeping the magnets at fixed positions. The calibration curve is shown in Fig. 2.

It was observed that there was a slight shifting of the lines when the cyclotron magnet was on from the positions of the lines when the cyclotron magnet was off. A compensating coil was therefore used on the spectrograph yoke to counteract the effect of the cyclotron magnet.

An active gold source gave 165 lines on a plate at a field strength of about 90 gauss/cm. 100 more lines were observed when the field was changed to about 150 gauss/cm. For each source, exposure times were varied from half an hour to three days. From the resulting plates the decay of different lines was studied. Energy values corresponding to these lines on the plate were calculated from the formula

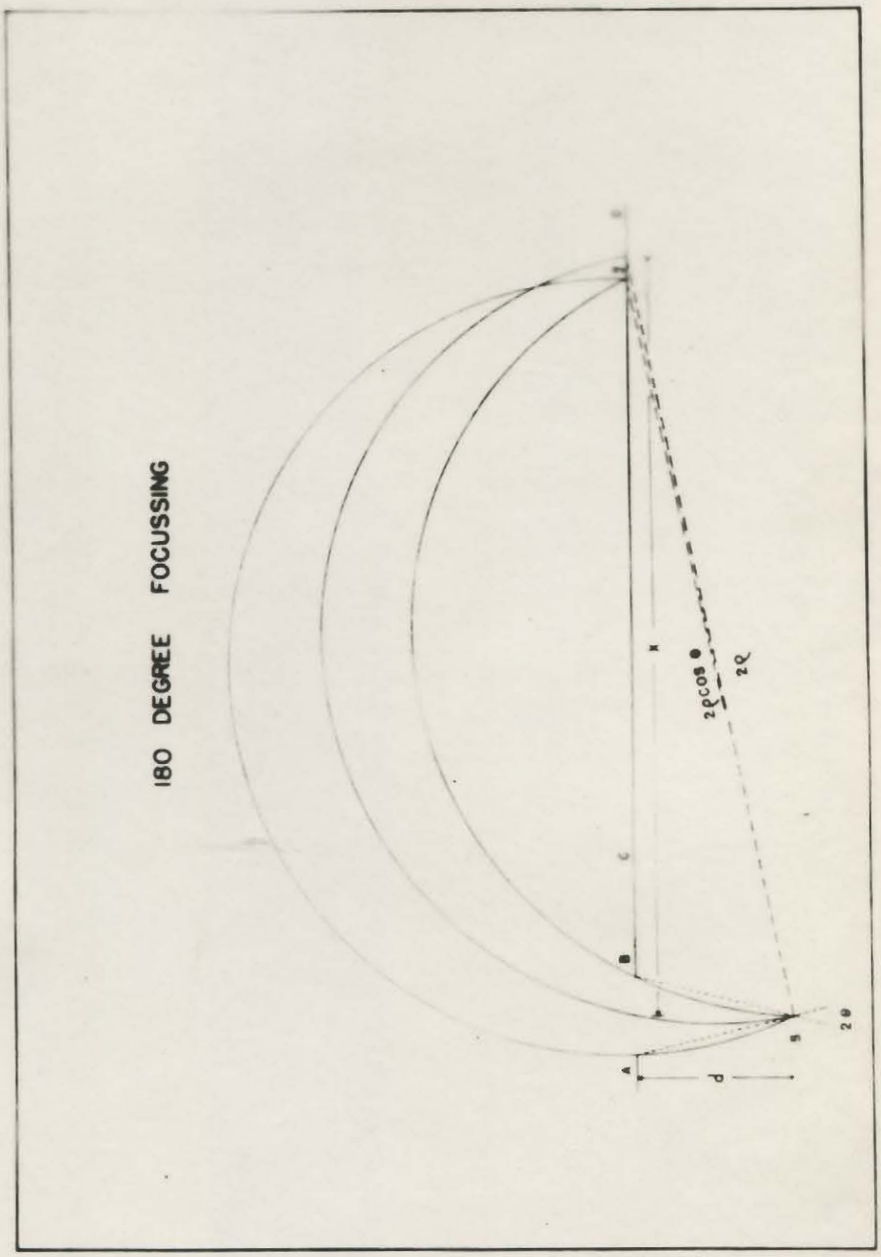
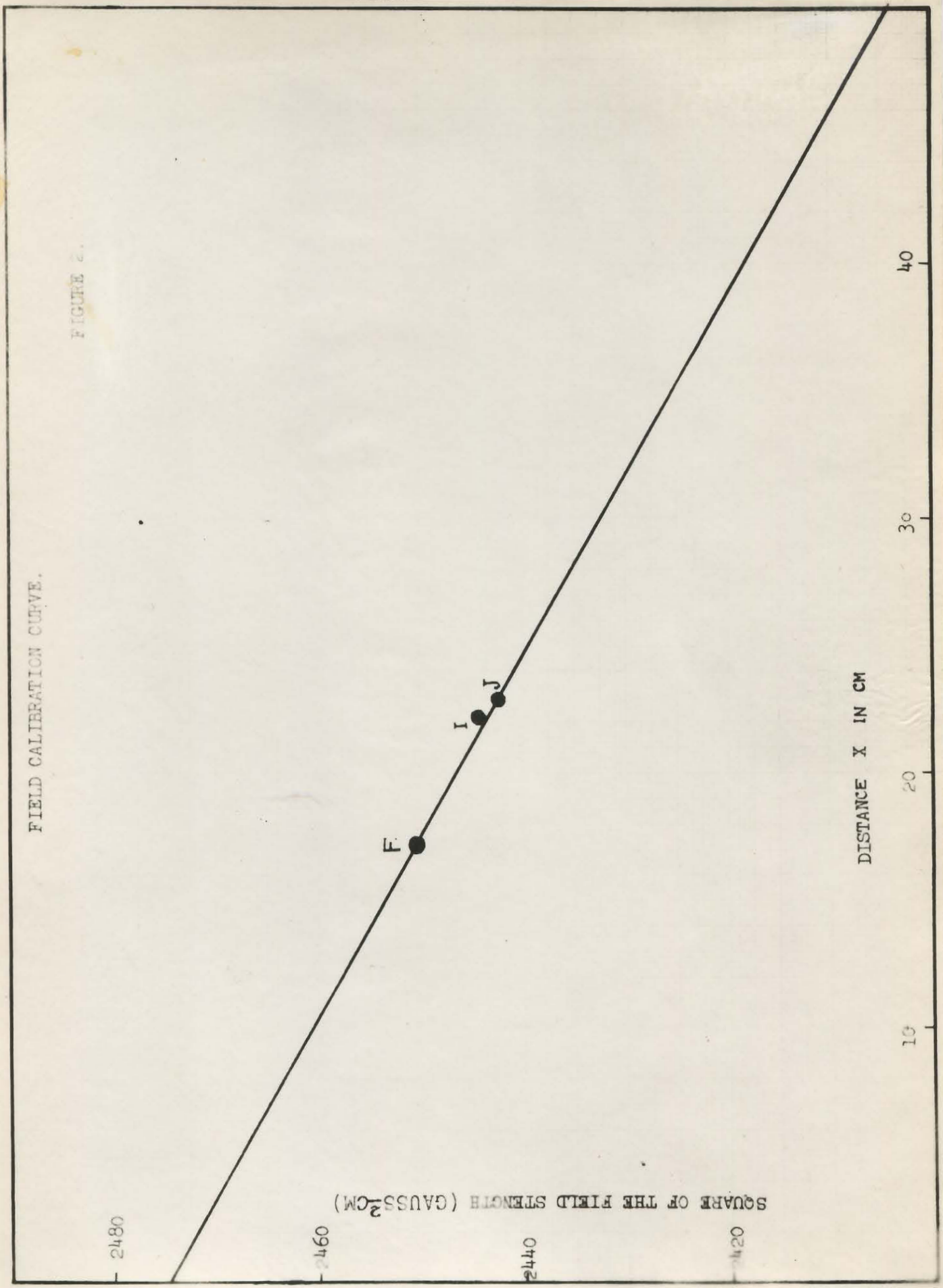


FIGURE 1

FIGURE 2.

FIELD CALIBRATION CURVE.



$$E = 510.98 \ (\sqrt{1 + 0.3443 H^2 \rho^2 x 10^6} - 1)$$

We got the different values of H^2 from the calibration curve. ρ^2 is related to x^2 by the formula $\rho^2 = \frac{x^2 + 15.0435}{4}$. The values of x come from the distances of different lines on the plate.

It might be mentioned here, however, that the photographic plate is not so sensitive as an anthracene crystal and that it is of somewhat limited value when dealing with the delicate problem of measuring intensities. One has to convert photographic blackening into true intensity which is a tedious procedure. To avoid this difficulty, we next used the 180° spectrometer with electric recording arrangements.

<u>180° β-ray Spectrometer</u>.

It has already been said that in the 180° β-ray spectrometer the photographic plate is replaced by an anthracene crystal detector and electric recording apparatus.

The Thorium F-line was used as a test line during the adjustments of the spectrometer. Since for high resolution the transmission falls off rapidly and with a high transmission the resolution becomes poorer, these tests were to reveal the best compromise. The problem is complicated by the presence of two independent factors, viz., the width of the source slit and the width of the

probe slit. As an optimum condition the source and detector slits were set at 0.14" and 0.02" respectively and thus we got a resolution of about 0.3% and transmission was satisfactory. Nevertheless, this adjustment failed to resolve the L_I and L_{II} lines.

Intensity varies with x and bears almost an inverse relation. To get a correct relation, a wide range was explored by shifting the position of thorium F line. This was done by changing the field strength. A curve with intensity versus $\frac{1}{x}$ is shown in Fig. 3.

After mounting the source, the spectrometer was evacuated and the recordings were made. Two counting rate meters with two recorders were connected in parallel. One was set at 25000c/m and the other was at 5000 c/m with time constants 3 seconds in each case. Two ranges were used because some lines were strong and some were very weak.

Of the three scanning speeds provided in the apparatus the medium one was used in the present work. It took about 5 hours to scan a range of x from 33 cm to 12 cm. Times were denoted on the chart at the beginning and at the end of each scan. The same process was repeated three or four times. Thus a number of charts were obtained. Lines were identified from the observed values of x. Decay rates and intensities of different lines were computed from the charts.

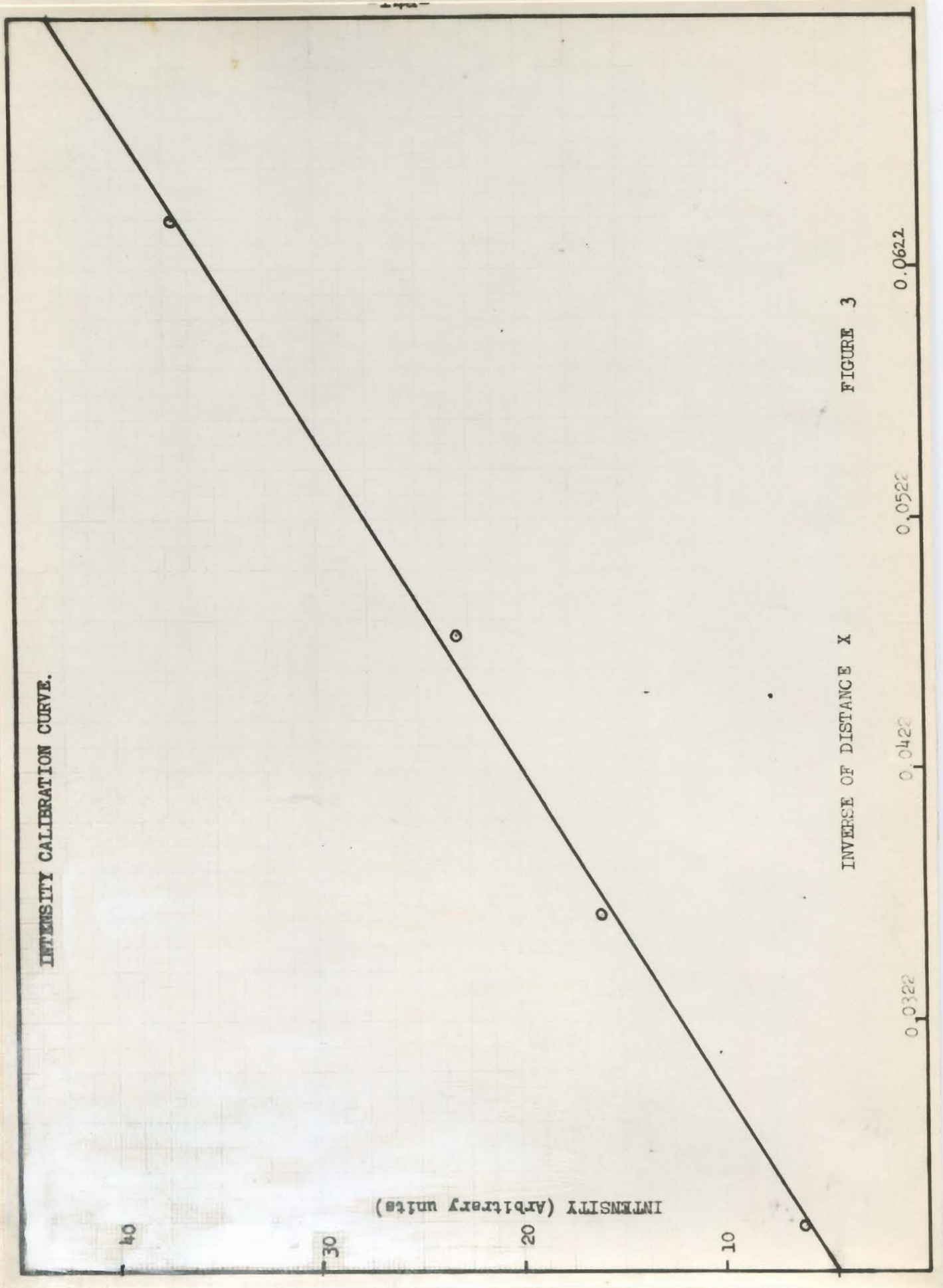

INTENSITY CALIBRATION CURVE.
INTENSITY (Arbitrary units)
40
30
20
10
0.0322
0.0422
0.0522
0.0622
INVERSE OF DISTANCE X

FIGURE 3

Source:

Chemically pure gold (197) sheets of 0.001" thickness were used as target material. These sheets were bombarded in the 100 Mev McGill Proton Cyclotron at different energies. Initially the target was bombarded for 15 minutes; but the activity was rather low. Bombardment for one hour gave strong activity and therefore was used in all subsequent work.

As a result of the bombardment, reactions of the type Au (p,x n) Hg take place. Within fifteen minutes after bombardment, Dr. A.L. Thompson had evaporated the active mercury and deposited it on an aluminium block along a central line of width 0.002". This central line of active Hg served as a line source. After deposition, a period of two hours was allowed for the decay of active mercury in every case. Then the source was heated for 15 minutes. Hg by K capture and β^+- emission decays to gold, gold decays to Pt and active Pt decays to Ir. The use of Al-block instead of silver or Al-wire for preparing line source has a great advantage as regards the activity of the source. Sometimes the source on Al-block is about four times more active than that on a wire.

Sources prepared in this way were placed inside the 180° β -ray spectrograph. After the evacuation of the chamber of the spectrograph the plates were exposed.

Sources for the 180° β - ray spectrometer were prepared in the same way.

Proton energies up to 70 Mev were used for activation. The problem became complicated, since at the threshold of a new reaction, say (p,6n), all the previous reactions requiring a lower energy were still present in some degree. For example, the Hg^{195} activity is present in all targets from 25 Mev to 105 Mev[4] rising to a maximum and finally receding to a low value. In order to find out a suitable exciting voltage necessary for the highest activity of a particular isotope Hg^{192}, the target was bombarded at 50, 55, 60, 65, 70 Mev proton energy. A typical excitation curve is shown in Fig. 4. For a bombarding energy of 61 Mev, isotopes of mass A=192 seem to show the highest activity. Thus in all subsequent works the excitation voltage was set at 61 Mev.

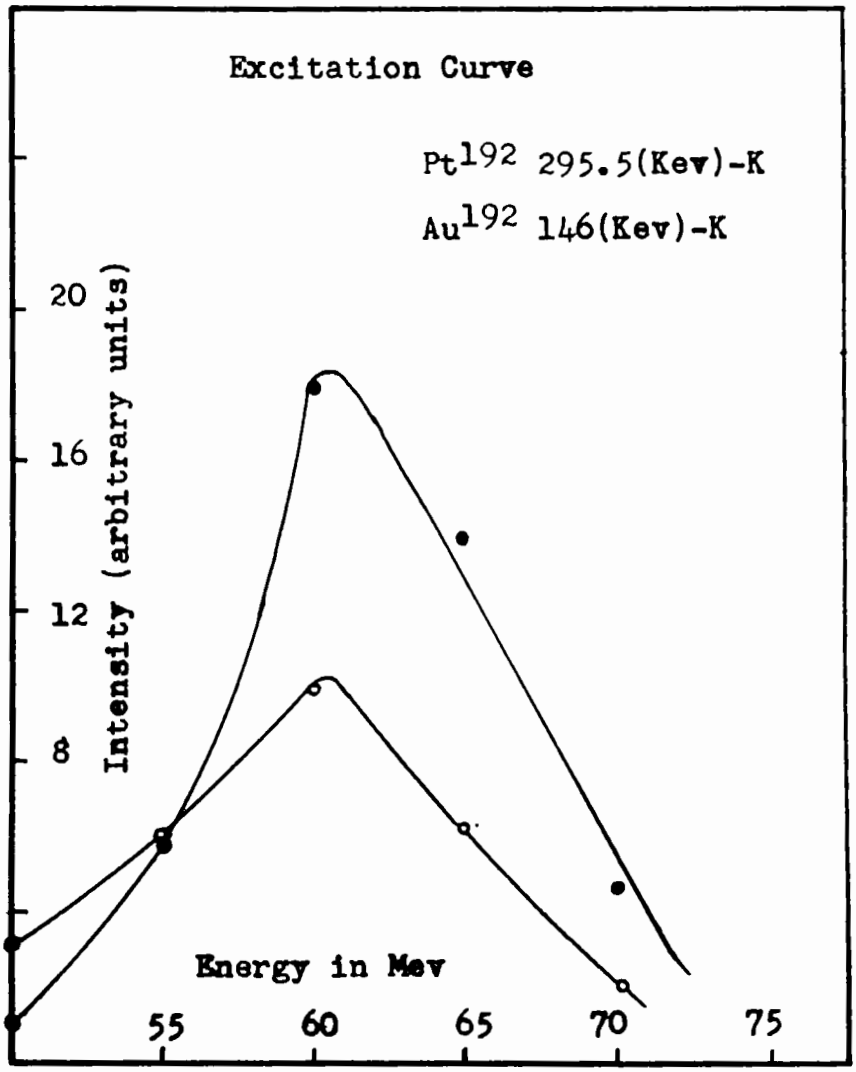

Excitation Curve
Pt192 295.5(Kev)-K
Au192 146(Kev)-K
Intensity (arbitrary units)
20
16
12
8
Energy in Mev
55
60
65
70
75

FIGURE 4

Results:

Altogether there were 207 lines on the plates for a source excited at a proton energy of 61 Mev. Some of these lines were very strong and some very weak. Most lines were of intermediate intensity. We were not able to estimate the intensity of very weak lines.

The observed half lives and the correspondence of different lines with conversion K,L,M,N electrons of different isotopes helped us in making the assignments of different lines. About 170 lines were assigned. Most of them corroborate the results previously obtained. Electron lines emitted by a source irradiated at a proton energy of 61 Mev correspond to conversion lines of Au^{195}, Au^{193}, Au^{192}, Au^{191}, Pt^{193}, Pt^{192}, Pt^{191} and Ir^{191}. The absence of Hg lines is due to the fact that the sources were allowed to decay for two hours and then heated for about fifteen minutes before introduction into the spectrometer or spectrograph. A few lines belonging to Ir^{191} also were observed. During the process of observation, gold decayed to platinum and platinum in its turn decayed to iridium. Hence we see the obvious reason for the existence of so many isotopes in the samples. Only a few lines, however, were left unassigned. Most of these were very weak. Results of our observations are shown in table I.

In the present work our idea was to observe the radiations from Pt^{192} and if possible, from Pt^{191}. With

this end in view we tried to deduce as many gamma rays as possible for Pt^{192}. Especially we tried in the low energy region. Ewan and Thompson[10] reported the presence of 16 gamma rays in Pt^{192}. In the lower energy region we observed a few more, viz., 45, 97, 105, 167 and 308 Kev gamma rays, of which 45, 97, 308 Kev gamma rays fit nicely into the latest decay scheme proposed for Pt^{192} by Taylor and Pringle[12] following the study of irradiated Ir with the help of a scintillation spectrometer. Further study may help in finding some other level for fitting 105 and 167 Kev new gamma rays. Observed gamma rays with their possible polarity are given in Table II and proposed decay scheme is shown in Fig. 5.

Gamma rays observed in Pt^{191} are shown in Table III. Some of them were previously reported by Moon and Thompson[6].

Furthermore, a gamma ray of energy 76 Kev was observed in this study. It is an addition to the gamma rays already reported by Ewan[7] for Pt^{193}.

Figure 6 shows the lines observed on the photographic plates.

TABLE I

Conversion lines observed under 61 Mev bombardment

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
16.88	18	31.23-$Au^{192}L_I$
18.32	12	32.00-$Au^{193}L_{II}$
18.56	3.5	96.90-$Pt^{192}K$
18.97	V.W	
19.50	4.0	31.41-$Au^{192}L_{III}$
20.24	18.0	32.15-$Au^{193}L_{III}$
21.22	1.5	99.57-$Pt^{193}K$
22.07	1.5	36.91-$Hg^{195}L_I$
23.70	12	37.56-$Pt^{193}L_I$
24.22	15	37.48-$Pt^{193}L_{II}$
24.50	6	38.85-$Au^{193}L_I$
25.14	1.5	38.87-$Au^{193}L_{II}$
26.31	6	104.66-$Pt^{192}K$
26.93	0.5	38.84-$Au^{193}L_{III}$
27.99	9	31.41-$Au^{192}M_I$
28.22	2.1	31.40-$Au^{192}M_{II}$
28.53	3	
28.87	5	31.30-$Au^{193}M_I$
29.17	5	31.31-$Au^{193}M_{II}$
29.77	3	

Electron Energy (kev)	Intensity (Arbitrary Units)	Assignments
30.35	3	31.11-$Au^{192}N_1$
31.11	8	44.97-$Pt^{192}L_1$
31.42	17	32.17-$Au^{193}N_1$
31.62	0.5	32.26-$Au^{193}N_{11}$
31.91	2.0	45.17-$Pt^{192}L_{II}$
33.17	2.0	111.50-$Pt^{191}K$
33.50	7.0	45.05-$Pt^{192}L_{III}$
33.95	2.0	112.3-$Pt^{193}K$
34.33	2.0	48.20$Pt^{191}L_I$
34.59	2.0	37.90-$Pt^{193}M_I$
34.91	3.0	48.20-$Pt^{191}L_{II}$
35.35	2.5	37.98-$Pt^{193}M_{III}$
35.68	10.0	114.00-$Pt^{193}K$
36.68	2.0	48.23-$Pt^{191}L_{III}$
37.30	3.0	115.65-$Pt^{191}K$
37.50	3.0	38.26-$Au^{193}N_I$
37.86	V.W	
39.24	15.0	53.10-$Pt^{191}L_I$
39.49	12.0	117.84-$Pt^{193}K$
39.85	2.0	53.11-$Pt^{191}L_{II}$
40.87	4.5	
41.13	4.5	119.50-$Pt^{193}K$
42.17	1.0	45.20-$Pt^{192}M_{II}$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
42.82	4.5	56.55-$Au^{195}L_{II}$
43.48	V.W	
44.10	1.0	122.50-$Pt^{191}K$
44.50	4.5	56.40-$Au^{195}L_{III}$
44.91	1.0	48.20-$Pt^{191}M_{I}$
45.52	2	
46.90	15	61.26-$Au^{195}L_{I}$
47.56	14	61.29-$Au^{195}L_{II}$
49.30	13	61.22-$Au^{195}L_{III}$
50.27	15	64.10-$Pt^{191}L_{I}$
50.94	18	64.20-$Pt^{191}L_{II}$
51.60	6	129.95-$Pt^{191}K$
52.40	9	$L_IL_I \rightarrow K_\infty$ Auger
52.57	10	$L_IL_{II} \rightarrow K_\infty$ Auger
53.01	20	$L_{II}L_{II} \rightarrow K_\infty$ Auger
53.39	15	56.50-$Au^{195}M_{II}$
54.46	9	$L_IL_{III} \rightarrow K_\infty$ Auger
54.82	9	$L_IL_{III} \rightarrow K_\infty$ Auger
55.15	12	133.50-$Pt^{191}K$
57.78	6	61.20-$Au^{195}M_{I}$
58.10	6	136.50-$Pt^{192}K$
58.55	6	61.30-$Au^{195}M_{III}$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
59.7	4.5	
60.18	1.5	74.50-$Au^{192}L_I$
60.96	6	74.7-$Au^{192}L_{II}$
61.15	3	K-LM+K-LN Auger
61.60	18	142.30-$Au^{192}K$
61.92	9	75.78-$Pt^{193}L_I$
62.50	9	75.77-$Pt^{193}L_{II}$
63.10	4.5	
63.60	9	
64.10	7	Auger
64.47	6	76.00-$Pt^{193}L_{III}$
65.29	15	146.00-$Au^{192}K$
66.20	7	
68.00	V.W.	
68.31	3	
69.30	1.5	82.7-$I_r^{191}L_I$
70.07	2.5	82.9-$I_r^{191}L_{II}$
70.96	2.5	82.2-$I_r^{191}L_{III}$
71.58	V.W.	
72.03	V.W.	
72.71	1.5	75.99-$Pt^{193}M_I$
74.33	V.W.	
74.90	V.W.	75.60-$Pt^{193}N_I$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
75.25	V.W	
76.53	30	157.20-$Au^{192}K$
77.19	4.5	155.50-$Pt^{193}K$
77.80	8	91.00-$Pt^{191}L_{II}$
79.50	9	91.00-$Pt^{191}L_{III}$
80.40	4	158.70-$Pt^{191}K$
81.49	1.0	82.20-$I_r{}^{191}N_I$
82.92	1.0	96.80-$Pt^{192}L_I$
84.24	6.0	97.60-$I_r{}^{191}L_I$
85.01	6.0	97.80-$I_r{}^{191}L_{II}$
85.39	1	96.90-$Pt^{192}L_{III}$
86.39	2.5	97.60-$I_r{}^{191}L_{III}$
86.90	1.5	101.20-$Hg^{193}L_{II}$
88.25	2	99.78-$Pt^{193}L_{III}$
88.75	18	101.00-$Hg^{193}L_{III}$
89.46	3	167.8-$Pt^{192}K$
90.89	2	104.75-$Pt^{192}L_I$
91.45	0.5	104.71-$Pt^{192}L_{II}$
95.10	25	173.5-$Pt^{193}K$
95.85	1.5	96.6-$Pt^{192}N_I$
97.66	2.0	111.5-$Pt^{191}L_I$
98.60	6	112.4-$Pt^{193}L_I$
99.15	2	112.40-$Pt^{193}L_{II}$
100.10	6	113.9-$Pt^{193}L_I$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
100.90	2	112.4-$Pt^{193}L_{III}$
101.6	1.5	115.46-$Pt^{191}L_{I}$
102.40	1.5	113.9-$Pt^{193}L_{III}$
103.95	2.5	117.8-$Pt^{193}L_{I}$
104.56	6	
105.3	4	
105.85	21	184.1-$Pt^{193}K$
107.75	12	186.2-$Pt^{193}K$
109.45	2	112.75-$Pt^{193}M_{I}$
109.95	2	
110.98	3	122.5-$Pt^{191}L_{III}$
111.47	1.5	112.20-$Pt^{193}N_{I}$
114.77	3.0	
115.75	4.5	129.60-$Pt^{191}L_{I}$
117.31	0.7	130.5-$Pt^{191}L_{II}$
119.00	2.5	132.8-$Pt^{191}L_{I}$
119.52	1.5	132.8-$Pt^{191}L_{II}$
121.40	2.2	135.30-$Pt^{193}L_{I}$
122.00	0.6	135.30-$Pt^{193}L_{II}$
123.61	8.0	137.47-$Pt^{192}L_{I}$
124.15	2.5	137.40-$Pt^{192}L_{II}$
126.38	3	204.73-$Pt^{192}K$
128.2	6	142.55-$Au^{192}L_{I}$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
129.74	1.5	
130.86	1.2	
131.60	3	145.95-$Au^{192}L_I$
133.70	V.W	
136.59	V.W	214.88-$Pt^{191}K$
137.23	5.0	218.00-$Au^{193}K$
141.53	0.6	155.40-$Pt^{193}L_I$
142.91	16.0	156.77-$Pt^{192}L_I$
143.38	2	156.64-$Pt^{192}L_{II}$
147.44	4	161.30-$Pt^{191}L_I$
148.38	V.W	161.70-$Pt^{191}L_{II}$
149.92	V.W	161.50-$Pt^{191}L_{III}$
152.30	V.W	
153.52	1.5	167.40-$Pt^{192}L_I$
156.26	1.0	167.80-$Pt^{192}L_{III}$
159.60	4.5	173.50-$Pt^{193}L_I$
160.24	0.8	173.50-$Pt^{193}L_{II}$
164.56	4	
165.68	1.5	
170.11	2.5	248.50-$Pt^{191}K$
171.13	3.0	184.40-$Pt^{193}L_{II}$
171.91	12.0	256.60-$Au^{191}K$
172.17	2.5	186.00-$Pt^{193}L_I$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
172.86	4.0	186.12-$Pt^{193}L_{II}$
176.96	16	255.30-$Pt^{193}K$
177.10	15	257.77-$Au^{193}K$
180.60	1.5	
181.60	2.0	
182.70	1	186.00-$Pt^{193}M_I$
189.82	3	268.17-$Pt^{193}K$
190.93	1	204.80-$Pt^{192}L_I$
192.87	V.W	
193.93	5	274.60-$Au^{191}K$
199.02	V.W	
201.76	V.W	215.02-$Pt^{191}L_{II}$
202.94	1.5	
203.13	4	282.50-$Pt^{192}K$
204.05	1.5	
205.54	V.W	
205.95	1.5	217.85-$Au^{193}L_{III}$
208.44	V.W	
211.73	V.W	115.02-$Pt^{191}M_I$
214.62	V.W	115.30-$Pt^{191}N_I$
215.95	1.5	
217.20	16	295.55-$Pt^{192}K$
229.65	9	308.00-$Pt^{192}K$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
235.51	1.0	248.80-$Pt^{191}L_{II}$
237.80	35.0	316.20-$Pt^{192}K$
238.54	V.W	252.90-$Au^{191}L_{I}$
240.83	V.W	252.74-$Au^{191}L_{III}$
241.40	3.0	258.26-$Pt^{193}L_{I}$
244.39	1.5	258.12-$Au^{193}L_{II}$
246.08	1.2	257.99-$Au^{193}L_{III}$
254.83	0.5	257.25-$Au^{193}M_{I}$
256.06	V.W	
258.24	V.W	
269.68	9.0	282.94-$Pt^{192}L_{II}$
281.34	4.0	295.20-$Pt^{192}L_{I}$
281.96	5.0	295.22-$Pt^{192}L_{II}$
283.62	3.0	295.20-$Pt^{192}L_{III}$
292.12	3.0	295.40-$Pt^{192}M_{I}$
294.40	4.0	308.26-$Pt^{192}L_{I}$
301.93	6.0	315.80-$Pt^{192}L_{I}$
302.40	7.0	315.70-$Pt^{192}L_{II}$
304.20	5.0	315.80-$Pt^{192}L_{III}$
312.80	4.0	315.80-$Pt^{192}M_{II}$
314.95	2.0	315.70-$Pt^{192}N_{I}$
326.90	V.W	405.25-$Pt^{191}K$
359.00	1.5	437.35-$Pt^{192}K$

Electron Energy (Kev)	Intensity (Arbitrary Units)	Assignments
386.89	V.W	400.75-$Pt^{192}L_I$
387.76	V.W	401.00-$Pt^{192}L_{II}$
388.62	1.5	467.00-$Pt^{192}K$
401.24	4	415.10-$Pt^{192}L_I$

TABLE II

Conversion line designation for Pt^{192}

Electron Energy (Kev)	Rays (Kev)	Designation	Intensity (Arbitrary Units)	Polarity
31.11	44.97	L_I	8	
31.91	45.17	L_{II}	2.0	M_3
33.50	45.05	L_{III}	7.0	
42.17	45.30	M_{II}	1	
18.56	96.90	K	3.5	
82.92	96.80	L_I	1	E_2+M_1
85.39	96.90	L_{III}	1	
95.85	96.60	N_I	1.5	
26.31	104.66	K	6	
90.89	104.75	L_I	2	M_2
91.45	104.71	L_{II}	0.5	
58.10	136.50	K	6	
123.61	137.47	L_I	8	E_2
124.15	137.41	L_{II}	2.5	
142.91	156.77	L_I	16	E_1 or M_1
143.38	156.64	L_{II}	2	

Electron Energy (Kev)	Rays (Kev)	Designation	Intensity (Arbitrary Units)	Polarity
89.46	167.80	K	3	
153.52	167.40	L_I	1.5	M_3
156.26	167.80	L_{III}	1.0	
126.38	204.73	K	3	
190.93	204.79	L_I	1	$E_2 + M_1$ or M_2
203.13	282.50	K	4	
269.68	282.98	L_{II}	9	E_3
217.20	295.55	K	16	
281.34	295.20	L_I	4	
281.96	295.22	L_{II}	5	E_2
283.62	295.17	L_{III}	3.0	
292.12	295.40	M_I	3	
229.65	308.00	K	9	
294.40	308.26	L_I	4	E_2

Electron Energy (Kev)	Rays (Kev)	Designation	Intensity (Arbitrary Units)	Polarity
237.78	316.13	K	35	
301.93	315.80	L_I	6	
302.40	315.70	L_{II}	7	E_2
304.20	315.80	L_{III}	5	
312.89	315.80	M_{II}	4	
314.95	315.70	N_I	2	
386.89	400.75	L_I	V.W	
387.76	401.00	L_{II}	V.W	
401.24	415.10	L_I	4	
359.00	437.35	K	1.5	
388.62	467.00	K	1.5	

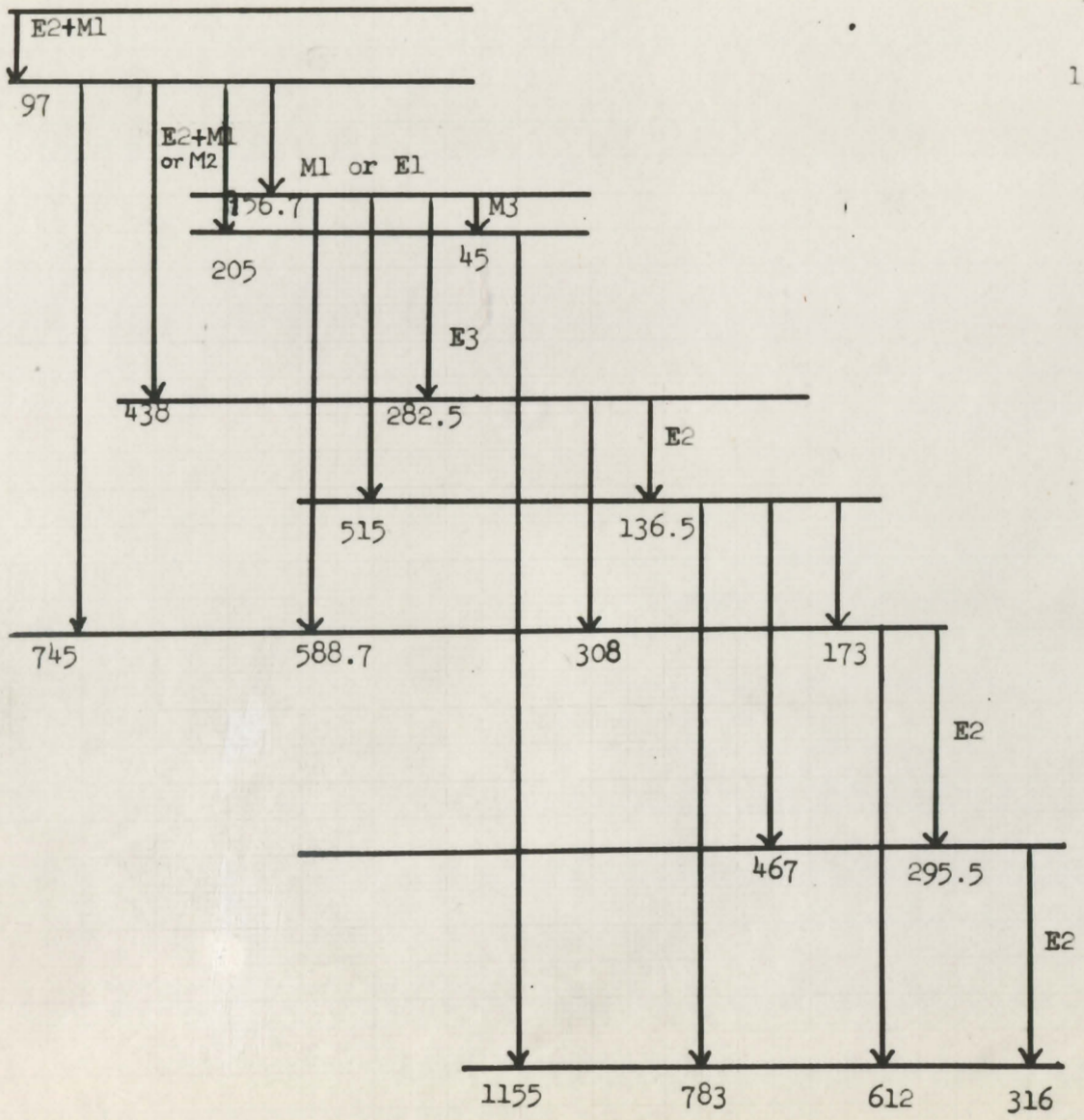
TABLE III

Conversion line designation for Pt^{191}

Electron Energy (Kev)	rays (Kev)	Intensity (Arbitrary Units)	Designation
34.33	48.20	2	L_I
34.91	48.20	3	L_{II}
36.68	48.23	2	L_{III}
44.91	48.20	1	M_I
39.24	53.10	15	L_I
39.85	53.11	2	L_{II}
50.27	64.10	15	L_I
50.94	64.20	18	L_{II}
77.80	91.00	8	L_{II}
79.50	91.00	9	L_{III}
44.10	122.50	1	K
110.98	122.50	3	L_{III}
33.17	111.50	2	K
97.65	111.50	2	L_I

Electron Energy (Kev)	rays (Kev)	Intensity (Arbitrary Units)	Designation
37.30	115.65	3	K
101.60	115.46	1.5	L_I
51.60	130.00	6	K
115.75	129.60	4.5	L_I
55.13	133.50	12	K
119.00	132.86	2.5	L_I
119.53	132.80	1.5	L_{II}
80.40	158.70	4	K
147.44	161.30	4	L_I
148.38	161.70	V.W	L_{II}
149.92	161.50	V.W	L_{III}
136.53	214.88	V.W	K
201.76	215.02	V.W	L_{II}
211.73	215.02	V.W	M_I
214.62	215.30	V.W	N_I
170.11	248.50	2.5	K
235.51	248.80	1	L_{II}
326.90	405.25	V.W	K

TENTATIVE DECAY SCHEME
FOR Pt^{192}



Energy (kev)	Spin	Parity
1456		
1359		
1201		
1155		
920	4	+
784	3(4)	+
612	2	+
316	2	+
0	0	+

FIGURE 5

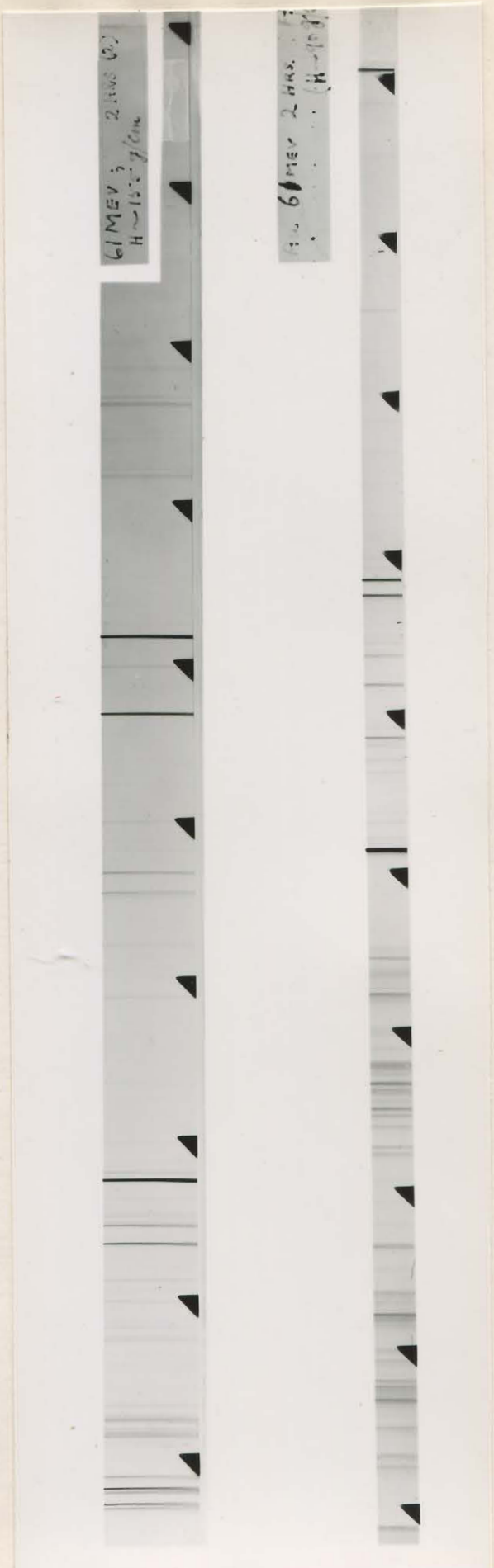


FIGURE 6

CONCLUSION

The main results of this investigation are the measurements and assignments of the conversion lines emitted by Pt^{192} and Pt^{191}. These results confirm and extend the data obtained by previous authors.

As already mentioned, new gamma rays at 45, 97 and 308 Kev fit nicely into the level diagram for Pt^{192} proposed by Taylor and Pringle.

Further work is necessary for fitting the gamma rays, 105, 167 and 401 Kev, into the scheme for Pt^{192}.

BIBLIOGRAPHY

1. F. A. Johnson, Ph.D. Thesis, McGill University (1952).
2. M. A. Badior, M.Sc. Thesis, McGill University (1954).
3. A. De-Shalit, O. Huber and H. Schneider, Helv. Phys. Acta 25, 279 (1952).
4. L. P. Gillon, K. GopalaKrishnan and A. De-Shalit, Phys. Rev. 93, 124 (1954).
5. O. Huber, R. Joly, P. Scherrer and N. F. Verster, Helv. Phys. Acta 25, 621 (1952).
6. J. H. Moon and A. L. Thompson, Phys. Rev. 83, 892 (1951).
7. G. T. Ewan and A. L. Thompson, Trans. Roy. Soc. Canada, 47, 126 (1953).
8. J. M. Cork, J. M. Leblanc, A. E. Stoddard, W. J. Childs, C. E. Branyan and D. H. Martin, Phys. Rev. 82, 258 (1952).
9. K. I. Roulston and R. W. Pringle, Phys. Rev. 87, 930 (1952)
10. R. W. Pringle, W. Turchinetz and H. W. Taylor, Phys. Rev. 95, 115 (1954).
11. M. W. Johns and S. V. Nablo, Phys. Rev. 96, 1599 (1954).
12. H. W. Taylor and R. W. Pringle, Phys. Rev. 99, 1345 (1955).