Bk. f. 3 (1)

April 6,1939

(Copy)

JOLIOT
COLLEGE DE FRANCE PARIS

REPLYING YOUR CABLE WEISSKOPF STOP ROBERTS PAPERS CONCERNING DELAYED NEUTRON EMISSION WHICH IS MUCH WEAKER THAN HE THINKS AND HARMLESS STOP HOWEVER TUVES GROUP WAS RECENTLY APPROACHED AND PROMISED COOPERATION STOP WE HAVE SO FAR DELAYED PAPERS IN VIEW OF POSSIBLE MISUSE IN EUROPE STOP KINDLY CABLE AS SOON AS POSSIBLE WHETHER INCLINED SIMILARLY TO DELAY YOUR PAPERS OR WHETHER YOU THINK THAT WE SHOULD NOW PUBLISH EVERYTHING STOP

KINGS CROWN HOTEL SZILARD

April 8, 1939

Have on W.

NLT WEISSKOPF
FINE HALL PRINCETON (NJ) USA

YOUR SUGGESTION PASSED TO NATURE AND ROYAL WHO WILL SURELY COOPERATE STOP AWAITING LETTER WITH DETAILS

BLACKETT

April 7, 1939

LC SZILARD
KINGSCROWN HOTEL NY

QUESTION ETUDIEE SUIS D AVIS MAINTENANT PUBLIER AMITIES

JOLIOT

Bk. f. 3 (3)

COPY.

March 31st, 1939

HANS VON HALBAN
11 RUE GUYNEMER
SCEAUX SEINE

Have on W. Union form

KINDLY INFORM JOLIOT THAT PAPERS RELATING TO SUBJECT OF YOUR JOINT NOTE TO NATURE HAVE BEEN SENT BY VARIOUS PHYSICISTS TO PHYSICAL REVIEW BEFORE PUBLICATION OF YOUR NOTE STOP AUTHORS AGREED HOWEVER TO DELAY PUBLICATION FOR REASONS INDICATED IN SZILARDS LETTER TO JOLIOT FEBRUARY SECOND AND THESE PAPERS ARE STILL HELD UP STOP NEWS FROM JOLIOT WHETHER HE IS WILLING SIMILARLY TO DELAY PUBLICATION OF RESULTS UNTIL FURTHER NOTICE WOULD BE WELCOME STOP IT IS SUGGESTED THAT PAPERS BE SENT TO PERIODICALS AS USUAL BUT PRINTING BE DELAYED UNTIL IT IS CERTAIN THAT NO HARMFUL CONSEQUENCES TO BE FEARED STOP RESULTS WOULD BE COMMUNICATE IN MANUSCRIPTS TO COOPERATING LABORATORIES IN AMERICA ENGLAND FRANCE AND DENMARK STOP COMMUNICATING BLACKETT AND DIRAC IN ATTEMPT TO GET COOPERATION OF NATURE AND PROCEEDINGS ROYAL SOCIETY STOP PLEASE CABLE WEISSKOPF FINE HALL PRINCETON NJ

March 31st, 1939

BLACKETT PHYSICS DEPARTMENT VICTORIA UNIVERSITY MANCHESTER

Have on Western Union form

PHYSICISTS HERE HAVE SENT PAPERS TO PHYSICAL REVIEW ON SUBJECT RELATED TO HALBAN JOLIOT LETTER TO NATURE STOP AUTHORS AGREED TO DELAY PUBLICATION IN VIEW OF REMOTE BUT NOT NEGLIGIBLE CHANCE OF GRAVE MISUSE IN EUROPE STOP IT IS SUGGESTED THAT PAPERS BE SENT TO PERIODICALS AS USUAL BUT PRINTING BE DELAYED UNTIL IT IS CERTAIN THAT NO HARMFUL CONSEQUENCES TO BE FEARED STOP RESULTS WOULD BE COMMUNICATED IN MANUSCRIPTS TO COOPERATING LABORATORIES IN AMERICA ENGLAND FRANCE AND DENMARK STOP IS TT POSSIBLE FOR YOU TO OBTAIN COOPERATION OF NATURE AND PROCEEDINGS ? WIGNER WRITING DIRAC STOP WEISSKOPF FINE HALL PRINCETON NJ

April 5 1939

~~DR. LEO SZILARD~~ WEISSKOPF FINE HALL PRINCETON N.J.
~~DEPT OF PHYSICS COLUMBIA UNIV NYC.~~

BIEN RECU LETTRE SZILARD MAIS PAS CABLE ANNONCE STOP PROPOSITION DU 31 MARS TRES RAISONNABLE MAIS VIENT TROP TARD STOP AVONS APPRIS SEMAINE DERNIERE QUE SCIENCE SERVICE AVAIT INFORME PRESSE AMERICAINE 24 FEVRIER SUR TRAVAUX ROBERTS STOP LETTRE SUIT

JOLIOT HALBAN KOWARSKY

April 5, 1939

WEISSKOPF FINE HALL PRINCETON NJ

BIEN RECU LETTRE SZILARD MAIS PAS CABLE ANNONCE STOP PROPOSITION DU 31 MARS TRES RAISONNABLE MAIS VIENT TROP TARD STOP AVONS APPRIS SEMAINE DERNIERE QUE SCIENCE SERVICE AVAIT INFORME PRESSE AMERICAINE U FEVRIER SUR TRAVAUX ROBERTS STOP LETTRE SUIT

JOLIOT HALBAN KOWARSKY

Bl folder No 1 (4)

NLT SZILARD
CARE LIEBOWITZ
420 RIVERSIDE DRIVE
NEW YORK CITY

BERYLLIUM SENT FEBRUARY THIRD REGISTERED POST (2)

LINDEMANN

(4)

NLT SZILARD
CARE OF LIEBOWITZ
420 RIVERSIDE DRIVE
NEW YORK CITY

FROM WHOM WAS BERYLLIUM BORROWED? DO THEY AUTHORIZE IT LEAVING ENGLAND?

LINDEMANN

April 8, 1939

NLT WEISSKOPF

FINE HALL PRINCETON (NJ) USA

YOUR SUGGESTION PASSED TO NATURE AND ROYAL WHO WILL SURELY COOPERATE STOP AWAITING LETTER WITH DETAILS

BLACKETT

April 7, 1939

LC SZILARD

KINGS CROWN HOTEL NY

QUESTION ETUDIEE SUIS D AVIS MAINTENANT PUBLIER AMITIES

JOLIOT

Bk. f. 3. (30)

COPY

March 31st, 1939

HANS VON HALBAN
11 RUE GUYNEMER
SCEAUX SEINE

KINDLY INFORM JOLIOT THAT PAPERS RELATING TO SUBJECT OF YOUR JOINT NOTE TO NATURE HAVE BEEN SENT BY VARIOUS PHYSICISTS TO PHYSICAL REVIEW BEFORE PUBLICATION OF YOUR NOTE STOP AUTHORS AGREED HOWEVER TO DELAY PUBLICATION FOR REASONS INDICATED IN SZILARDS LETTER TO JOLIOT FEBRUARY SECOND AND THESE PAPERS ARE STILL HELD UP STOP NEWS FROM HOLIOT WHETHER HE IS WILLING SIMILARLY TO DELAY PUBLIC* ATION OF RESULTS UNTIL FURTHER NOTICE WOULD BE WELCOME STOP IT IS SUGGESTED THAT PAPERS BE SENT TO PERIODICALS AS USUAL BUT PRINTING BE DELAYED UNTIL IT IS CERTAIN THAT NO HARMFUL CONSEQUENCES TO BE FEARED STOP RESULTS WOULD B E COMMUNICATE IN MANUSCRIPTS TO COOPER-ATING LABORATORIES IN AMERICA ENGLAND FRANCE AND DENMARK STOP COMMUNICATING BLACKETT AND DIRAC IN ATTEMPT TO GET COOPERATION OF NATURE AND PROCEEDINGS ROYAL SOCIETY STOPPLEASE CABLE WEISSKOPF FINE HALL PRINCETON NJ

March 31st, 1939

BLACKETT PHYSICS DEPARTMENT VICTORIA UNIVERSITY MANCHESTER

PHYSICISTS HERE HAVE SENT PAPERS TO PHYSICAL REVIEW ON SUBJECT RELATED TO HALBAN JOLIOT LETTER TO NATURE STOP AUTHORS AGREED TO DELAY PUBLICATION IN VIEW OF REMOTE BUT NOT NEGLIGIBLE CHANCE OF GRAVE MISUSE IN EUROPE STOP IT IS SUGGESTED THAT PAPERS BE SENT TO PERIODICALS AS USUAL BUT PRINTING BE DELAYED UNTIL IT IS CERTAIN THAT NO HARMFUL CONSEQUENCES TO BE FEARED STOP RESULTS WOULD BE COMMUNICATED IN MANUSCRIPTS TO COOPERATING LABORATORIES IN AMERICA ENGLAND FRANCE AND DENMARK STOP IS IT POSSIBLE FOR YOU TO OBTAIN COOPERATION OF NATURE AND PROCEEDINGS? WIGNER WRITING DIRAC STOP WEISSKOPF FINE HALL PRINCETON NJ

Bk.f.2 (30)

1)

Columbia University
in the City of New York

DEPARTMENT OF PHYSICS

April 6, 1939

Dr. Leo Szilard,
Pupin Physics Laboratories,
Columbia University.

Dear Dr. Szilard:

I told you that I would write you a letter to put on record my invitation to you to be a guest of the Department of Physics until June 1, 1939 to work on certain researches with Dr. Zinn and to have the privileges that are appropriate for a guest in our laboratory. Laboratory keys have already been issued to you, and I enclose with this a card by the use of which you can obtain a key to the outer door of the building by calling at Room 111 Low Memorial Library so that you may have access to the laboratory at times when the outer door is closed. The key obtained with this card is to be returned on leaving the building.

Sincerely yours,

George B. Pegram

GBP:H

George B. Pegram

6.

F

(Between March 31 and April 3, 1939) Bk.f3 (A4)
K.W.

Victor Weisskopf
University o~~f/~~ Rochester

Dear Blackett, (March 31, 1939)

I hope you were not too much upset about my telegram But I believe that you realize the great danger which would arise, if one really could construct a bomb with uranium. The probability that this is possible might be small, but the produch of the probability with the graveness of the consequences is high.

I enclose here first a letter which Scilard has written to Joliot Febr. 2. Joliot has not answered this letter and we do not know Joliots attitude to the whole situation after his recent publication. I have sent to Halban a similar telegram as to you urging him to cooperate.

Further I enclose a note which Scilard has sent to Physical Rewiew but the publication of which is being delayed. There are other papers from Columbia sent in and kept back, which could be sent toyou if the cooperation begins to work. I am also enclosing a letter from Scilard to myself which gives you further details about about his experiments.

I would like tell you how far the cooperation here for delaying "dangerous" manuscripts has developed so far. We know that the group around Tuve is now willing to cooperate. Lawrence is coming here on April 3rd. and we shall discuss the matter with him then. Tate (editor of Phys. Rev.) is being approached and it is suggested that authors who may send in manuscripts concerning "dangerous" neutron

c

Bk.f.3 (45)

emissions be advised to communicate with us. We shall send you a ~~xxb~~ cable when a definite procedure has been decided upon in connection with Phys. Rev.

Much love to your family.

Very truly yours

COPY OF LETTER FROM WIGNER TO DIRAC

PALMER PHYSICAL LABORATORY
Princeton University
Princeton, New Jersey

March 30, 1939

Dear Paul:

I am writing to you in a rather serious matter this time. The enclosed letter, sent by Szilard to Joliot on February 2nd is self explanatory. Experiments undertaken since that time by Fermi and by Szilard did not help to dispell the fear which prompted Szilard's letter. In realisation of the danger mentioned in this letter, all efforts are made here to delay publications relating to this subject as there could possibly enhance the danger of a grave misuse by certain powers. The papers of Szilard and of Fermi, although received by the Physical Review some time ago, are withheld from publication and it is intended that they be printed only in the form of reprints to be distributed among the most interested laboratories in England, the U. S., France and Denmark. Similar arrangements are intended for all papers on this subject by other workers in the United States.

Halban-Joliot-Kovarski's letter to Nature prompted the physicists who loyally cooperated here to inquire today by cable concerning Joliot's attitude in this matter. Bohr undertakes to communicate with Copenhagen and a cable is sent simultaneously to Blackett. The proposition made in there communications is to use for the publication of all papers, relating to this subject, the method foreseen for this purpose for workers in the U. S. and described above.

What we would like to ask you at this time is to get in touch with Blackett and to actively support him in his endeavours if you find our position to be the reasonable one.

It is my impression that there is some urgency in the matter. Although there exists apparently a great willingness for cooperation here, it is realised that the interests of the scientific workers in the U. S. may be prejudiced to some extent if America abeyed alone by the proposed procedure.

Hoping to hear from you soon and with best regards to all,

Sincerely,

(signed) Jeno

C
O
P
Y

Found in envelope postmarked C.A.A. March 4, 1939

CLAIMS:

1. Production of radioactive elements comprising the step of maintaining a neutron radiation and exposing to the said neutron radiation a layer containing uranium, the thickness of the said layer being slightly below the critical thickness.

2. Production of radioactive elements comprising the step of exposing a layer containing uranium the thickness of which is slightly below the critical thickness to a radiation which will liberate neutrons from elements contained in the said layer and maintaining the said radiation.

3. Production of radioactive elements like 1 or 2, ... and the step of separating at intervals from the layer the radioactive elements produced from uranium.

4. Production of radioactive elements like 1 or 2, and the step of exposing another element to the neutrons emitted from the uranium in the layer under the action of the said radiation, and chemically separating the radioactive element produced by the neutrons from the said element.

5. Like 1 to 4, ... a layer containing uranium which has a larger relative abundance of the isotope 235 than natural uranium...

6. Like 1~~2~~ to 4, ... a layer containing uranium in which the relative abundance of the isotope 235 is ~~12%~~ 10% or greater...

7. Process for the production of uranium in which the relative abundance of the isotope 235 is increased, comprising the step of preparing a halogen compound of uranium such as for instance UF_6 from a uranium compound or uranium element, the step

of subjecting the said halogen compound to a diffusion process which will lead to a concentration of the isotope 235, ~~and the step of converting the product of this diffusion process into metallic uranium.~~

8. Like 7,... a halogen compound of uranium, in particular a chlorine compound, for instance U Cl_4, from a uranium compound and a sample of chlorine which consists mainly of one of the two chlorine isotopes (preferably Cl 35) and which sample can for instance be obtained by a diffusion process applied to HCl through which one of the two Cl isotopes has been enriched.

E-1885
LS-I

IN TESTIMONY WHEREOF I affix my signature

sgd Leo Szilard

OATH

STATE OF NEW YORK)
) ss:
COUNTY OF NEW YORK)

I, LEO SZILARD, the above-named petitioner, being duly sworn, depose and say that I am a subject of Hungary and reside at 420 West 116th Street, New York, New York and that I verily believe myself to be the original, first and sole inventor of the improvements in APPARATUS FOR NUCLEAR TRANSMUTATION as described and claimed in the annexed specification; that I do not know and do not believe that the same was ever known or used before my invention or discovery thereof, or patented or described in any printed publication in any country before my invention or discovery thereof;

That as to those features of the said invention which are not disclosed in my prior application Serial No. 10,500, filed March 11, 1935, of which the present application is a continuation in part, I do not know and do not believe that they were patented or described in any printed publication in any country more than two years prior to this application or patented in any foreign country on an application filed by me or my legal representatives or assigns more than twelve months prior to this application or in public use or on sale in the United States for more than two years prior to this application; and that no application for patent on said features of this invention has been filed by me or my legal representatives or assigns in any foreign country;

That as to those features of the said invention disclosed in this and in said prior application Serial No. 10,500, [filed March 11, 1935,] I do not know and do not believe that they were patented or described in any printed publication in any country more than two years before the filing of said prior application or patented in any foreign country on an application filed by me or my legal representatives or assigns more than twelve months before the filing of said prior application, or in public use or on sale in the United States for more than two years before this present application; and that no application for patent on said features of the invention was filed by me or my legal representatives or assigns in any foreign country before the filing of said prior United States application except as follows: England, March 12, May 9, June 14, June 28, July 4, September 20 and September 25, 1934.

sgd Leo Szilard

Subscribed and sworn to before me this 9th day of March, 1939.

Marie Loftus
Notary Public

C-4A

Neutrons slowed down

Found in envelope postmarked March 3, 1939

Native uranium, or uranium in which the relative abundance of U 235 has been artificially increased, may be used mixed with a hydrogen containing substance to form the chain reaction layer, or alternatively the chain reaction layer may be built up from alternating layers of uranium and the hydrogen containing substance. As a hydrogen containing substance water, paraffin wax or calcium hydride appear to be suitable. If the hydrogen containing substance is not mixed with uranium, but alternating layers are used, the layers should be as thin as possible. In particular the thickness of the hydrogen containing layer should be as small as possible, and if paraffin, water, or a hydrogen containing substance of about the same hydrogen concentration is used, the thickness of the layer should not exceed about 7 mm.

In such a chain reaction layer the neutron emitted from the uranium is slowed down after traveling in the chain reaction layer an average distance $\bar{b}$ from its origin. At the distance $\bar{b}$ from its origin the neutron will therefore be so slow that its mean free path-a-for scattering is much smaller than the value $\bar{b}$. In paraffin wax this mean free path a would be about $2\ 1/_2$ mm, and in the chain reaction layer it will be somewhat larger, i.e. by a factor k which gives the ratio of the concentration of hydrogen in paraffin to the concentration of hydrogen in the chain reaction layer. This reduction of the mean free path for scattering is due to the large scattering cross-section of hydrogen for room temperature neutrons. In addition, the neutrons which have been slowed down at an average distance $\bar{b}$ from their origin have now, being slow, a large cross-section for those transmutations of uranium which lead to the liberation of neutrons. The combined effect of the large scattering cross-section of the slow neutrons in the chain reaction layer and the large transmutation cross-section of the slow neutrons for uranium is that a neutron which is emitted by uranium and which becomes slow at the average distance $\bar{b}$ from its point of origin will transmute a uranium nucleus at a point which is at an average distance q from the point at which the neutron became slow, and the distance q is small compared to $\bar{b}$, so that the neutron will transmute a uranium nucleus at a distance $\bar{b}$ not very different from $\bar{b}$ from the point of its origin.

In these circumstances the previously given equation does no longer hold, and the critical thickness is approximately given in the following way. For the stationary state the neutron density within the spherical chain reaction layer obeys now the equation:

$$(\bar{b})^2 \frac{d^2(r\delta)}{dr^2} + \frac{6(w_2 - w_0)}{w_1 + 2w_2}(r\delta) = 0$$

In this equation w_0 is the probability for a slowed down neutron to cause a transmutation of uranium in which the slow neutron disappears and no fast neutron is emitted; w_1 is the probability for a slowed down neutron to cause a transmutation of uranium in which the slow neutron disappears and one fast neutron is emitted; w_2 is the probability for a slowed down neutron to cause a transmutation of uranium in which the slow neutron disappears and two fast neutrons are emitted.

For the special case: $w_2 = 1$; $w_1 = 0$; $w_0 = 0$, the above equation gives

$$(\bar{l})^2 \frac{d^2(rs)}{dr^2} + 3(rs) = 0$$

The critical thickness is given by

$$l_0 = \frac{\pi}{2}\,\bar{l}\left(\frac{(w_2 - w_0)}{3(w_1 + 2w_2)}\right)^{1/2}$$

in the general case and by

$$l_0 = \frac{\pi}{2}\,l\sqrt{\frac{1}{3}}$$

in the special case.

Obviously, the above diffusion equation presupposes for its validity a small value of w_2, but even for large values of w_2 it gives at least the order of magnitude for the critical thickness.

The critical thickness will in practice always be determined empirically for instance in the following way: a neutron source is surrounded by the chain reaction layer of an approximately correct thickness which is safely below the critical thickness. The radiations emitted from the chain reaction layer while exposed to this neutron source are observed by means of an ionization chamber. Then the thickness of the chain reaction layer is brought closer to the critical thickness by gradually increasing either the quantity of uranium or the quantity of hydrogen containing substances mixed with the uranium. The amount of ionizing radiation which is emitted is again observed and the thickness of the chain reaction layer is again brought closer to the crtical thickness in the same way as before. In this way, by observing the increase of the emitted radiation as a function of the increasing effective thickness of the chain reaction layer the critical thickness can be extrapolated from the observed curve by plotting the intensity of the emitted neutron radiation against the effective thickness of the chain reaction layer. Instead of an ionization chamber which registers the neutron intensity by means of recoil ions in the gas of the chamber, induced activity caused by the neutrons can be used as a measure of the radiation intensity.

The maximum ratio of concentration of the hydrogen containing substance to the concentration of uranium is determined by the capture cross-section of the hydrogen atom which is about $^1/_3\ 10^{-24}$ cm^2 to the average cross-section for the emission of two neutrons of the uranium which is used. This cross-section is about $10^{-24} cm^2$. Therefore, if native uranium is used, the number of gm Mols of uranium in the mixture must be at least $^1/_3$ of the number of gm Moles of hydrogen.

If a uranium is used in which the rare isotope has been concentrated, the amount of uranium used can be smaller in ratio of the increased average cross-section for the emission of two neutrons in the transmutation of uranium.

C-4A

In envelope postmarked Mar 3, 1939

Variation of Critical Thickness.

If slow neutrons are used the critical thickness can be increased by having a slow neutron absorber within the hollow sphere in the center of the spherical arrangement. If the inner radius of the spherical shell of the chain reaction layer is much larger than the critical thickness (to be accurate we should have said the minimum critical thickness given by the above formulas), and if all slow neutrons are absorbed, for instance by a cadmium layer covering the inner surface of the spherical chain reaction layer, the critical thickness of the arrangement is increased. By suddenly removing such absorbing matter ~~xxx~~ from the inside of the chain reaction layer, the critical thickness may be reduce below the actual thickness, and thus an explosion may be brought about. The explosion will be all the more violent the more quickly the absorbing substance is removed. A similar increase in the critical thickness of a spherically symmetrical chain reaction layer can be brought about by removing a section of the layer and thereby producing an opening through which the neutrons can escape. For instance a conical section corresponding to a few % of the spherical chain reaction layer can be so arranged as to be easily moved out of its place and replaced, and thereby the critical thickness may be reduced or increased.

C-4A

In envelope postmarked March 3rd, 1939

REGULATION.

As we have seen, the ratio of neutron input to neutron output becomes infinite for the critical thickness of the arrangement. The neutron input is in practice limited by the accuracy of the arrangement, since the thickness of the chain reaction layer must be extremely close to the critical thickness, and yet must remain below it in order to avoid an explosion. Fortunately, it is possible to overcome this difficulty by reason of the following fact:

In reality we have to deal not with one critical thickness only, but with two/different critical thicknesses which we shall call the instantaneous critical thickness and the delayed critical thickness. The arise by virtue of the fact that, while the bulk of neutrons is emitted instantaneously when uranium is transmuted by neutrons, there is also a delayed emission of neutrons, the delay being of the order of magnitude of a few seconds. If the thickness of the chain reaction layer is larger than the delayed critical thickness, but smaller than the instantaneous critical thickness, the neutron output increases to infinity, but does not increase too rapidly. This makes it possible that by moving an object which forms part of the arrangement and which has an influence on the critical thicknesses (for instance, by having a slow neutron absorber in the interior of the hollow sphere of the spherical chain reaction layer, and by partially withdrawing it from there, we can reduce the critical thickness, and in a similar way we can also increase it by the opposite movement), we can vary the critical thickness in time.

We shall call objects which are used in this way regulator objects, and according to our invention the neutron output can be kept very high by moving the regulator object in such a way that part of the time the critical thickness the critical thickness for delayed emission should be below, and part of the time it should be above, the real thickness of the spherical layer. It is only necessary for safe functioning to have an instrument which is sensitive to the emitted radiation or the temperature of some part of the chain reaction layer, and thix instrument can control the position of the regulator object. Obviously, in order to have stable functioning, the regulator object will have to be moved in direction of an increase of the critical thickness with increasing neutron radiation, and it has to be moved in the opposite way with decreasing neutron radiation. While the thickness of the chain reaction layer will still have to be accurately chosen, since it has to be within narrow limits, i.e. between the critical thickness for instantaneous neutron emission and the critical thickness for delayed neutron emission, the latter being only slightly larger than the former. Yet the above described regulation makes it possible to get a very much higher neutron output without reaching an explosion.

The critical thickness for delayed emission could also be conveniently called the total critical thickness because it corresponds to the total neutron emission, both instantaneous and delayed. It can be easily determined emperically by varying the thickness of the chain reaction layer and observing for each thickness the emitted neutron radiation as a function of time. Below the critical thickness for delayed emission the neutron radiation is a function of time which resembles a growth curve in the field of radioactivity, i.e. it approaches an upper limit practically reaching saturation after some time. Above the critical thickness for delayed emission, but below the critical thickness for instantaneous emission, the observed neutron emission increases more and more rapidly with time, and the arrangement has quickly to be changed in order to avoid overheating. The value of the critical thickness for delayed emission is reached when one type of curve goes over into the other, and at the critical thickness itself the neutron intensity as a function of time is a straight line.

February 27, 1939.

E-1512

Dr. Leo Szilard,
Kings Crown Hotel,
420 West 116th Street,
New York City, N. Y.

Dear Dr. Szilard:

In accordance with your request I am returning herewith the three photostats of Figs. 7, 8, and 9 of your U. S. Application Ser. No. 10,500. I have had these photostats copied and have given the copies to the draftsman to use in making new drawings for your divisional application.

As you requested, the cost of these drawings will be charged to your personal account.

Very truly yours,

Baldwin Guild

Encs.

SPECIAL DELIVERY

PENNIE, DAVIS, MARVIN AND EDMONDS

COUNSELLORS AT LAW
165 BROADWAY
NEW YORK
WASHINGTON OFFICES
NATIONAL PRESS BUILDING

E1512

Washington, D.C.
January 25, 1939

Mr. Leo Szilard
Kings Crown Hotel
420 West 116th Street
New York City, N.Y.

Dear Mr. Szilard:

At the request of Mr. R.M. Adams I am enclosing a photostatic copy of Figures 7, 8 and 9 of the drawings as originally filed in your application, Serial No. 10,500.

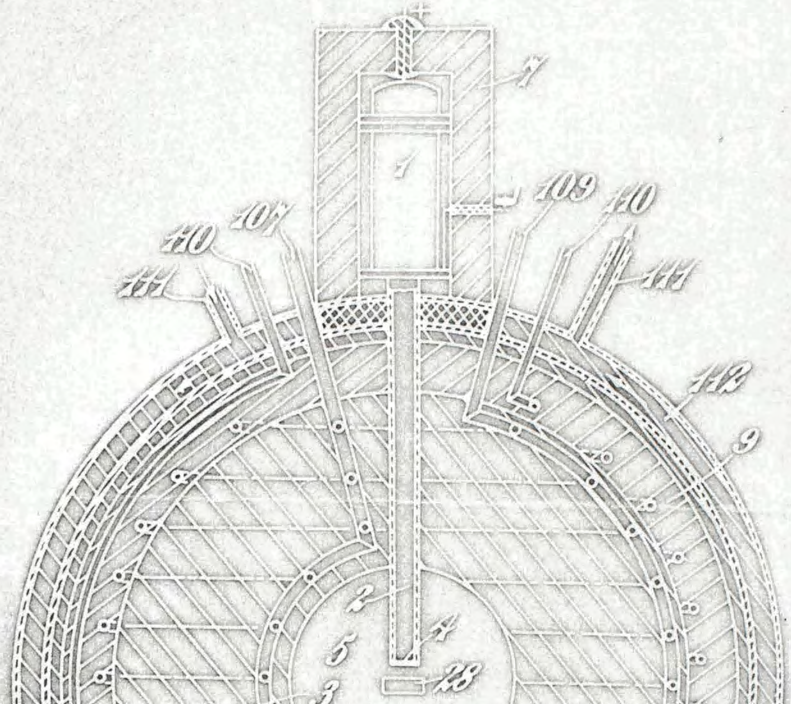
Very truly yours,
[signature]

Med. Supp. Co.
15
119 St R
College Point
L.I.

CMF:dr
att.

10500

Print of drawing as originally filed



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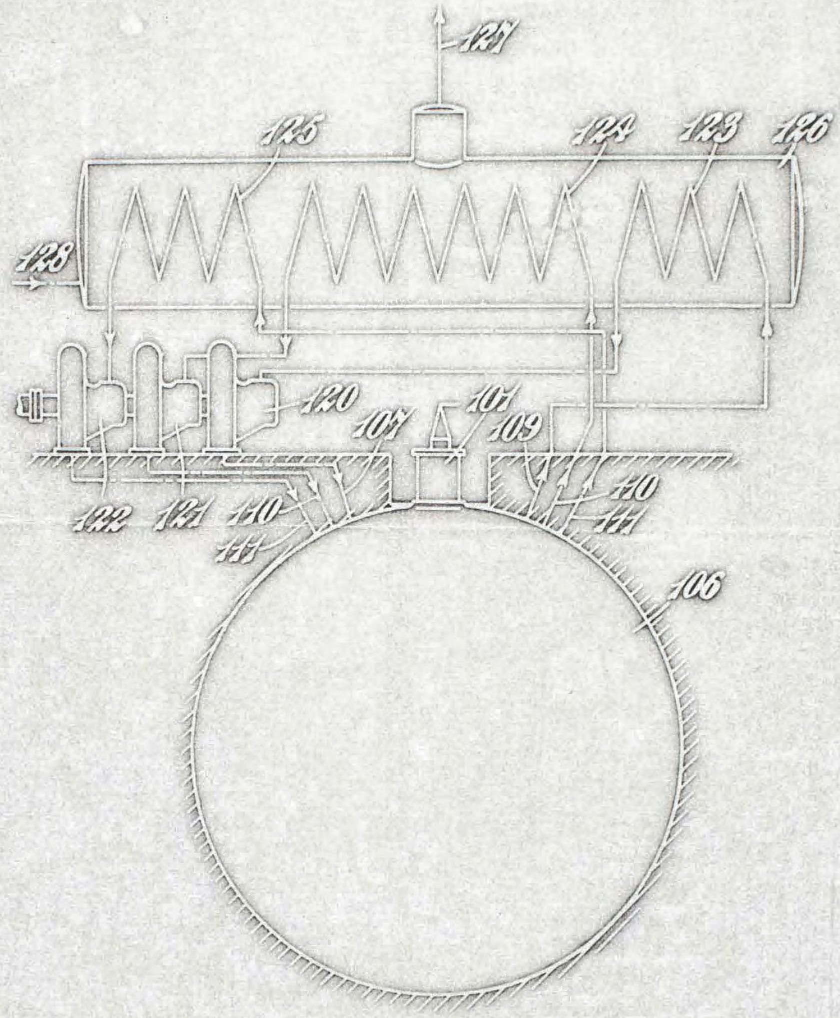

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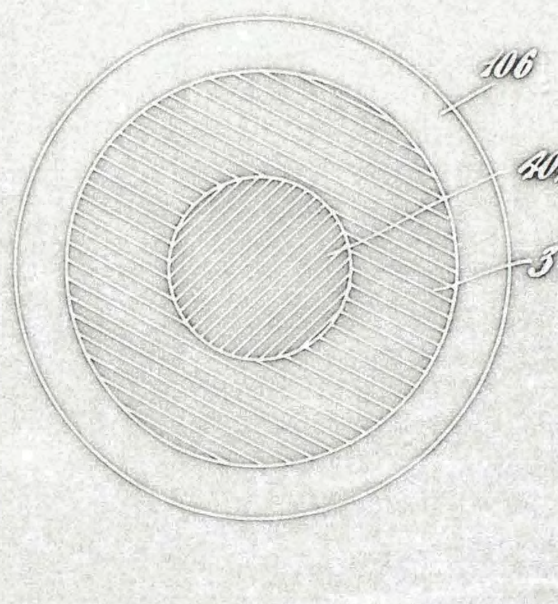
Print of drawing as originally filed.



In envelope sent by L.S. to himself postmarked Feb. 24, 1939 C-4A

If a uranium is used which contains a high percentage of uranium 235 it is of advantage to use this uranium either mixed with a hydrogen containing substance, or to have the chain reaction layer built up from intermittent layers of uranium and the hydrogen containing substance. As a hydrogen containing substance water, paraffin, or calcium hydride appear to be suitable. The ratio of the amount of hydrogen to the amount of uranium may be anything up to about 10 grams of hydrogen for 235 grams of uranium. This ratio would roughly correspond to 100 cc paraffin wax for every 10 cc of solid uranium or about 20 cc of uranium powder.

If uranium is used in the form of an oxide the volume of uranium will be larger corresponding to the smaller density of the oxide. If the hydrogen containing substance is not mixed with the uranium, but if alternative layers of the two are used, the layers should be as thin as possible. If paraffin or a hydrogen containing substance of similar density is used the thickness of the paraffin layers should be as small as possible and should not exceed say 7 mm.

If uranium which contains a high percentage of uranium 235 is used it is of advantage to slow down the neutrons by using hydrogen containing substances, since these hydrogen containing substances reduce the mean free path for scattering in the chain reaction layer and thereby make it possible greatly to reduce the critical thickness of the chain reaction layer. This reduction of the mean free path is due to the high scattering cross-section of hydrogen. In addition to the decreased mean free path there is also a decrease in the number of collisions which a neutron has to make with uranium nuclei in order to produce on the average one transmutation of the uranium nucleus which leads to the liberation of neutrons. This is simply due to the fact that the transmutation of uranium 235 has a larger cross-section for slow neutrons than for fast neutrons. Practically every collision of a neutron slowed down to room temperature with a uranium nucleus leads to a transmutation process. Under these extreme circumstances the critical thickness is no longer given by the formula which we have previously described and which was derived without regard of the fact that the mean free path of the neutrons for scattering may strongly decrease with decreasing velocity.

It is in these circumstances sometimes convenient to use compounds of heavy hydrogen, such as for instance heavy water or heavy paraffin wax or heavy calcium hydride instead of similar compounds of light hydrogen. The ratio of the amount of heavy hydrogen to the amount of uranium 235 may be

If alternative layers of the heavy hydrogen compounds and uranium are used the thickness of the layers of the heavy hydrogen compound, such as heavy paraffin wax may be anything up to ...

"Neutrons slowed down" (Mar. 3, 1939)
very similar to p. 13-16 of Mar 9. appl.

"Variations of Critical Thickness" (Mar 3, 1939)
very similar to p. 16 of Mar. 9. appl.

"Regulation" " " " p. 17-20 " "
(Mar 3, 1939)

(March 9th application filed March 20, 1939)

In envelope sent by L.S. to himself,
postmarked March 3, 1939

neutrons slowed down

C-4A

Native uranium, or uranium in which the relative abundance of U 235 has been artificially increased, may be used mixed with a hydrogen containing substance to form the chain reaction layer, or alternatively the chain reaction layer may be built up from alternating layers of uranium and the hydrogen containing substance. As ~~the~~ a hydrogen containing substance water, paraffin wax or calcium hydride appear to be suitable. If the hydrogen containing substance is not mixed with uranium, but alternating layers are used, the layers should be as thin as possible. In particular the thickness of the hydrogen containing layer should be as small as possible, and if paraffin, water, or a hydrogen containing substance of about the same hydrogen concentration is used, the thickness of the layer should not exceed about 7 mm.

In such a chain reaction layer the neutron emitted from the uranium is slowed down after traveling in the chain reaction layer an average distance $\bar{b}$ from its origin. At the distance $\bar{b}$ from its origin the neutron will therefore be so slow that its mean free path-a-for scattering is much smaller than the value $\bar{b}$. In paraffin wax this mean free path a would be about $2\ 1/_2$ mm, and in the chain reaction layer it will be somewhat larger, i.e. by a factor k which gives the ratio of the concentration of hydrogen in paraffin to the concentration of hydrogen in the chain reaction layer. This reduction of the mean free path for scattering is due to the large scattering cross-section of hydrogen for room temperature neutrons. In addition, the neutrons which have been slowed down at an average distance $\bar{b}$ from their origin have now, being slow, a large cross-section for those transmutations of uranium which lead to the liberation of neutrons. The combined effect of the large scattering cross-section of the slow neutrons in the chain reaction layer and the large transmutation cross-section of the slow neutrons for uranium is that a neutron which is emitted by uranium and which becomes slow at the average distance $\bar{b}$ from its point of origin will transmute a uranium nucleus at a point which is at an average distance q from the point at which the neutron became slow, and the distance q is small compared to $\bar{b}$, so that the neutron will transmute a uranium nucleus at a distance $\bar{b}$ not very different from $\bar{b}$ from the point of its origin.

In these circumstances the previously given equation does no longer hold, and the critical thickness is approximately given in the following way. For the stationary state the neutron density within the spherical chain reaction layer obeys now the equation:

$$(\bar{b})^2 \frac{d^2(r\delta)}{dr^2} + \frac{6(w_2 - w_0)}{w_1 + 2w_2}(r\delta) = 0$$

In this equation w_0 is the probability for a slowed down neutron to cause a transmutation of uranium in which the slow neutron disappears and no fast neutron is emitted; w_1 is the probability for a slowed down neutron to cause a transmutation of uranium in which the slow neutron disappears and one fast neutron is emitted; w_2 is the probability for a slowed down neutron to cause a transmutation of uranium in which the slow neutron disappears and two fast neutrons are emitted.

For the special case: $w_2 = 1$; $w_1 = 0$; $w_0 = 0$, the above equation gives

$$+ (\bar{l})^2 \frac{d^2(rs)}{dr^2} + 3(rs) = 0$$

The critical thickness is given by

$$l_0 = \frac{\pi}{2}\bar{l}\left(\frac{(w_2 - w_0)}{3(w_1 + 2w_2)}\right)^{1/2}$$

in the general case and by

$$l_0 = \frac{\pi}{2}\bar{l}\sqrt{\frac{1}{3}}$$

in the special case.

Obviously, the above diffusion equation presupposes for its validity a small value of w_2, but even for large values of w_2 it gives at least the order of magnitude for the critical thickness.

The critical thickness will in practice always be determined empirically for instance in the following way: a neutron source is surrounded by the chain reaction layer of an approximately correct thickness which is safely below the critical thickness. The radiations emitted from the chain reaction layer while exposed to this neutron source are observed by means of an ionization chamber. Then the thickness of the chain reaction layer is brought closer to the critical thickness by gradually increasing either the quantity of uranium or the quantity of hydrogen containing substances mixed with the uranium. The amount of ionizing radiation which is emitted is again observed and the thickness of the chain reaction layer is again brought closer to the crtical thickness in the same way as before. In this way, by observing the increase of the emitted radiation as a function of the increasing effective thickness of the chain reaction layer the critical thickness can be extrapolated from the observed curve by plotting the intensity of the emitted neutron radiation against the effective thickness of the chain reaction layer. Instead of an ionization chamber which registers the neutron intensity by means of recoil ions in the gas of the chamber, induced activity caused by the neutrons can be used as a measure of the radiation intensity.

The maximum ratio of concentration of the hydrogen containing substance to the concentration of uranium is determined by the capture cross-section of the hydrogen atom which is about $^{1}/_{3}\ 10^{-24}$ cm^2 to the average cross-section for the emission of two neutrons of the uranium which is used. This cross-section is about $10^{-24} cm^2$. Therefore, if native uranium is used, the number of gm Mols of uranium in the mixture must be at least $^{1}/_{3}$ of the number of gm Mols of hydrogen.

If a uranium is used in which the rare isotope has been concentrated, the amount of uranium used can be smaller in ratio of the increased average cross-section for the emission of two neutrons in the transmutation of uranium.

In envelope sent by L.S. to himself, postmarked Mar 3, 1939 C-4A

Variation of Critical Thickness.

If slow neutrons are used the critical thickness can be increased by having a slow neutron absorber within the hollww sphere in the center of the spherical arrangement. If the inner radius of the spherical shell of the chain reaction layer is much larger than the critical thickness (to be accurate we should have said the minimum critical thickness given by the above formulas), and if all slow neutrons are absorbed, for instance by a cadmium layer covering the inner surface of the spherical chain reaction layer, the critical thickness of the arrangement is increased. By suddenly removing such absorbing matter from the inside of the chain reaction layer, the critical thickness may be reduce below the actual thickness, and thus an explosion may be brought about. The explosion will be all the more violent the more quickly the absorbing substance is removed. A similar increase in the critical thickness of a spherically symmetrical chain reaction layer can be brought about by removing a section of the layer and thereby producing an opening through which the neutrons can escape. For instance a conical section corresponding to a few % of the spherical chain reaction layer can be so arranged as to be easily moved out of its place and replaced, and thereby the critical thickness may be reduced or increased.

In envelope sent by L. S. to himself postmarked

C-4A

March 3rd, 1939

REGULATION.

As we have seen, the ratio of neutron input to neutron output becomes infinite for the critical thickness of the arrangement. The neutron input is in practice limited by the accuracy of the arrangement, since the thickness of the chain reaction layer must be extremely close to the critical thickness, and yet must remain below it in order to avoid an explosion. Fortunately, it is possible to overcome this difficulty by reason of the following fact:

In reality we have to deal not with one critical thickness only, but with two different critical thicknesses which we shall call the instantaneous critical thickness and the delayed critical thickness. The arise by virtue of the fact that, while the bulk of neutrons is emitted instantaneously when uranium is transmuted by neutrons, there is also a delayed emission of neutrons, the delay being of the order of magnitude of a few seconds. If the thickness of the chain reaction layer is larger than the delayed critical thickness, but smaller than the instantaneous critical thickness, the neutron output increases to infinity, but does not increase too rapidly. This makes it possible that by moving an object which forms part of the arrangement and which has an influence on the critical thicknesses (for instance, by having a slow neutron absorber in the interior of the hollow sphere of the spherical chain reaction layer, and by partially withdrawing it from there, we can reduce the critical thickness, and in a similar way we can also increase it by the opposite movement), we can vary the critical thickness in time.

We shall call objects which are used in this way regulator objects, and according to our invention the neutron output can be kept very high by moving the regulator object in such a way that part of the time the critical thickness the critical thickness for delayed emission should be below, and part of the time it should be above, the real thickness of the spherical layer. It is only necessary for safe functioning to have an instrument which is sensitive to the emitted radiation or the temperature of some part of the chain reaction layer, and thix instrument can control the position of the regulator object. Obviously, in order to have stable functioning, the regulator object will have to be moved in direction of an increase of the critical thickness with increasing neutron radiation, and it has to be moved in the opposite way with decreasing neutron radiation. While the thickness of the chain reaction layer will still have to be accurately chosen, since it has to be within narrow limits, i.e. between the critical thickness for instantaneous neutron emission and the critical thickness for delayed neutron emission, the latter being only slightly larger than the former. Yet the above described regulation makes it possible to get a very much higher neutron output without reaching an explosion.

The critical thickness for delayed emission could also be conveniently called the total critical thickness because it corresponds to the total neutron emission, both instantaneous and delayed. It can be easily determined emperically by varying the thickness of the chain reaction layer and observing for each thickness the emitted neutron radiation as a function of time. Below the critical thickness for delayed emission the neutron radiation is a function of time which resembles a growth curve in the field of radioactivity, i.e. it approaches an upper limit practically reaching saturation after some time. Above the critical thickness for delayed emission, but below the critical thickness for instantaneous emission, the observed neutron emission increases more and more rapidly with time, and the arrangement has quickly to be changed in order to avoid overheating. The value of the critical thickness for delayed emission is reached when one type of curve goes over into the other, and at the critical thickness itself the neutron intensity as a function of time is a straight line.

C-4A.

In envelope addressed by L.S. to himself postmarked March 4, 1939

CLAIMS:

Tobin says these form basis of claims in appl. of Mar 20

1. Production of radioactive elements comprising the step of maintaining a neutron radiation and exposing to the said neutron radiation a layer containing uranium, the thickness of the said layer being slightly below the critical thickness.

2. Production of radiaactive elements comprising the step of exposing a layer containing uranium the thickness of which is slightly below the critical thickness to a radiation which will liberate neutrons from elements contained in the said layer and maintaining the said radiation.

3. Production of radioactive elements like 1 or 2, ... and the step of separating at intervals from the layer the radioactive elements produced from uranium.

4. Production of radioactive elements like 1 or 2, and the step of exposing another element to the neutrons emitted from the uranium in the layer under the action of the said radiation, and chemically separating the radioactive element produced by the neutrons from the said element.

5. Like 1 to 4, ... a layer containing uranium which has a larger relative abundance of the isotope 235 than natural uranium...

L. L.

6. Like 1 to 4, ... a layer containing uranium in which the relative abundance of the isotope 235 is 10% or greater...

7. Process for the production of uranium in which the relative abundance of the isotope 235 is increased, comprising the step of preparing a halogen compound of uranium such as for instance UF6 from a uranium compound or uranium element, the step

of subjecting the said halogen compound to a diffusion process which will lead to a concentration of the isotope 235, ~~and the step of converting the product of this diffusion process into metallic uranium.~~

8. Like 7,... a halogen compound of uranium, in particular a chlorine compound, for instance $U\,Cl_4$, from a uranium compound and a sample of chlorine which consists mainly of one of the two chlorine isotopes (preferably Cl 35), and which sample can for instance be obtained by a diffusion process applied to HCl through which one of the two chlorine isotopes has been enriched.

Found in envelope postmarked Feb 24, 1939 C-4A D = Blair Memo ad 2

If a uranium is used which contains a high percentage of uranium 235 it is of advantage to use this uranium either mixed with a hydrogen containing substance, or to have the chain reaction layer built up from intermittent layers of uranium and the hydrogen containing substance. As a hydrogen containing substance water, paraffin, or calcium hydride appear to be suitable. The ratio of the amount of hydrogen to the amount of uranium may be anything up to about 10 grams of hydrogen for 235 grams of uranium. This ratio would roughly correspond to 100 cc paraffin wax for every 10 cc of solid uranium or about 20 cc of uranium powder.

If uranium is used in the form of an oxide the volume of uranium will be larger corresponding to the smaller density of the oxide. If the hydrogen containing substance is not mixed with the uranium, but if alternative layers of the two are used, the layers should be as thin as possible. If paraffin or a hydrogen containing substance of similar density is used the thickness of the paraffin layers should be as small as possible and should not exceed say 7 mm.

If uranium which contains a high percentage of uranium 235 is used it is of advantage to slow down the neutrons by using hydrogen containing substances, since these hydrogen containing substances reduce the mean free path for scattering in the chain reaction layer and thereby make it possible greatly to reduce the critical thickness of the chain reaction layer. This reduction of the mean free path is due to the high scattering cross-section of hydrogen. In addition to the decreased mean free path there is also a decrease in the number of collisions which a neutron has to make with uranium nuclei in order to produce on the average one transmutation of the uranium nucleus which leads to the liberation of neutrons. This is simply due to the fact that the transmutation of uranium 235 has a larger cross-section for slow neutrons than for fast neutrons. Practically every collision of a neutron slowed down to room temperature with a uranium nucleus leads to a transmutation process. Under these extreme circumstances the critical thickness is no longer given by the formula which we have previously described and which was derived without regard of the fact that the mean free path of the neutrons for scattering may strongly decrease with decreasing velocity.

It is in these circumstances sometimes convenient to use compounds of heavy hydrogen, such as for instance heavy water or heavy paraffin wax or heavy calcium hydride instead of similar compounds of light hydrogen. The ratio of the amount of heavy hydrogen to the amount of uranium 235 may be

If alternative layers of the heavy hydrogen compounds and uranium are used the thickness of the layers of the heavy hydrogen compound, such as heavy paraffin wax may be anything up to ...

Bk.f.2 (22)

Hotel King's Crown
420 West 116th Street
New York City

February 13th, 1939

Mr. Lewis L. Strauss
Brandy Rock Farm
Brandy, Va.

Dear Mr. Strauss:

I hope you and Mrs. Strauss enjoyed staying at Palm Beach and that you are now having a nice time at your farm.

After I left your train in Washington I spent a day with Dr. Teller there and another day with Dr. Wigner at Princeton and told both of them of our tentative plan to make use of the form of an "association" and let such an association take action if it seems desirable that something should be done along the lines which we discussed. Dr. Teller, who is Professor for Theoretical Chemistry at George Washington University, will be at our disposal if it becomes necessary to keep some person close to the Administration informed of the developments, and he also can get the cooperation of his colleagues in Washington if this will be required. Dr. Wigner thought that some of the experiments which we discussed could be done at Princeton. As he is an old friend of mine and has much influence in the department there is very much in favor of following his suggestion, but I feel that it will be necessary to see what the position is from the point of view of equipment, and whether some younger members of the department could

6.

~~Not sent~~

cooperate without abandoning work in which they are at present engaged.

On my return to New York I went to see Fermi to tell him of all these conversations and also to discuss some of the small scale experiments which might be made in the near future.

Since my return almost every day some new information about uranium became available, and whenever I decided to do something one day it appeared foolish in the light of the new information on the next day. I found that the Radium Chemical Co. had in stock 200 mgm of radium mixed with beryllium, which is a nice constant source of fast neutrons. The rent for six months amounts to $ 500,00. As Fermi thought that he would like to use such a neutron source for his experiment I felt that I ought to get it for him. It did not seem fair to ask you to take any decisions from a distance, and so I thought it might be best that I should advance $ 500,00 for expenses of this type and to see later whether you could sanction the expenditures afterwards. A few days later it turned out that this neutron source was too bulky to be suitable for Fermi's experiment, and Fermi said that for the present he is quite satisfied with the radon sources which he is getting anyway once a week at Columbia. In these circumstances I arranged with the Radium Chemical Co. that they will let me have one gram of radium on loan instead. This radium used in conjunction with the beryllium block sent from Oxford represents an intense source of photo-neutrons which can be used for a number of experiments. The rent is $ 125,00 per month, and we have to rent it for a minimum period of three months.

The outlook has changed in some important respects since I last saw you. It is now known that fast neutrons split both uranium and thorium, but slow neutrons do not split thorium, and they probably do not split the bulk of uranium either. If enough neutrons are emitted when fast neutrons split thorium or uranium it will still be necessary to see whether or not the emitted neutrons are slowed down to a velocity at which they are ineffective before they had a chance to split enough nuclei to make the maintenance of a chain reaction possible.

On the other hand, slow neutrons seem to split a uranium isotope which is present in an abundance of about 1% in uranium. If this isotope could be used for maintaining chain reactions, it would have to be separated from the bulk of uranium. This, no doubt, would be done if necessary, but it might take five or ten years before it can be done on a technical scale. Should small scale experiments show that the thorium and the bulk of uranium would not work, but the rare isotope of uranium would, we would have the task immediately to attack the question of concentrating the rare isotope of uranium.

As you see, the number of possibilities has increased since you left town. Some of the experiments which were devised, in particular the experiment which Fermi first planned, appear now to be much more difficult than before. Other experiments, such as those with photo-neutrons, are not affected, but of course they have somewhat the character of preliminary experiments.

I am enclosing a clipping which might interest you, as it shows the state of mind of some physicists on February 4th. The man who inspired this article did his best to hide what he thought, but his dementi is somewhat clumsy, and he almost gives himself away in the last paragraph.

Anyway, things have calmed down to some extent in the last few days, and the newspapers at least might soon forget about uranium.

With best wishes,

Yours very sincerely

(Leo Szilard)

Copy

Probably draft

Bk. f. 2 (26)

Kings Crown Hotel
420 West 116th Street
New York City.

February 13, 1939

Mr. Lewis L. Strauss,
Brandy Rock Farm,
Brandy ~~Rock~~, Va.

Dear Mr. Strauss :

Wigner

with the effects of the grippe fading out and the redults of some further experiments about the splitting of uranium becoming available, things have calmed down a little bit since I left aou in Washington. The chances for a too violent development have somewhat diminished.

After I left your train in Washington I spent a day with Dr. Teller there; and another day with Dr. Wigner at Princeton. I tol both of them of our tentative plans and that we thought the form of an association might be used if any action has to be taken. On my return to New York I had another talk with Fermi about the experiment he had in mind, and the experiments which I proposed to make. Since then almost every day new facts have become available about the explosion of uranium, and whatever I decided to do one day was likely to look foolish in the light of the information available the next da

When I talked to Fermi on my return, it seemed desirable that he should have a steady source of neutrons , and when I found that th Radium Chemical Co. had 200 mg of radium mixed with beryllium (a mixture prepared by Professor O. Stern in Pittsburgh) in stock, I decided to lend our hypothetical association S 500 right away, in order to enable it to borrow this radium source for six months. Later it turned out that the source was too bulky to be useful to Fermi who, for the present, seems to be satisfied with the radon

6.

~~Not sent~~

source he can get a t Columbia. And so I used the money to borrow one gram of radium for three months with the possibility of extending the arrangement on monthly terms (the charges S 125 permmonth. This for three months together with some equipment for storing and carrying the radium will not exceed S 500.)

The situation at present seems to be as follows : slowwneutron seem to split not the main constituent of uranium (Ur 238) itself but a constituent which is contained in uranium in the abundance of only 1% (Ur 235). If there is a sufficient neutron emission in the process of splitting slow neutrons will probably not be able to maintain reaction chains in uranium, unless Ur 235 is separated from the bulk of uranium. To do this in the laboratory may prove difficult, and on a technical scale it may take five to ten years, if it is possible at all. No doubt, if we could establish that a sufficient number of neutrons is emitted in the splitting, we would have to attack this question of separating the two isotopes, and would then probably have a good chance to be the first to achieve it , even if it takes us ten years to do so. Any way we could feel safe for some time to come.

Fast neutrons split both , thorium and the bulk of uranium, and it is quite possible that fast neutrons can form a chain reaction in uranium. But there is a chance, that if such chain reactions works the amount of uranium necessary for an explosion will be so large, th the "bombs" will be too heavy to carry.

As it is, the experiments which would show the possibilityes of chain reactions will be more difficult and lengthy in these circumstances than it seemed a week ago.

In these circumstances a total abscence of neutron emission which would settle the question once for all, may fairly soon be demonstrated , but if a neutron emission is present it will not be easy to show in a small scale experiment that it is sufficient to make chain reaction possible.

Using one gram of radium and the beryllium block which has bee sent from Oxford it should be possible to make a few useful experimen and I shall look round in the course of this week to find out which laboratory wouldbe suitable from the point of view of equipment and readiness to co-operate.

I hope you and Mrs. Strauss had a nice time at Palm Beach, and will have some more sunshine at your farm.

With best wishes,

Yours very sincerely,

Receipt for Beryllium block

M-27

U.S. Appraiser Stores
201 Varick Street
7th Sub. West Houston St.

POST OFFICE, NEW YORK, N.Y.
DIVISION OF MAILS
FOREIGN SECTION, MORGAN ANNEX

NO. V14687 FEB 18 1939 193

Received from Dr Leo Szilard c/o Liebowitz

-- Dollars 18 cents in payment of storage charges and Customs Clearance and delivery charges 1 parcels held at Customs Department, Foreign Section (5th Floor), Morgan Annex.

Due stamps affixed by

ALBERT GOLDMAN,
Postmaster.

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per _______________

D-575
10/20/36

orig. carbon

c/o Liebowitz
420 Riverside Drive
New York City

February 2nd, 1939

Professor M. Joliot
Laboratoire de Chemie Nucléaire
Collège de France
Paris.

Dear Professor Joliot:

The only reason for my writing to you this letter to-day is the remote possibility that I shall have to send you a cable in some weeks, and if that happens this letter will help you to understand what the cable is about. This letter is therefore merely a precaution, and we hope an unnecessary precaution.

When Hahn's paper reached this country about a fortnight ago, a few of us got at once interested in the question whether neutrons are liberated in the disintegration of uranium. Obviously, if more than one neutron were liberated, a sort of chain reaction would be possible. In certain circumstances this might then lead to the construction of bombs which would be extremely dangerous in general and particularly in the hands of certain governments. ~~[illegible]~~

It is of course not possible to prevent physicists from discussing these things among themselves, and, as a matter of fact, the subject is fairly widely discussed here. However, so far, every individual exercised sufficient discretion to prevent a leakage of these ideas into the newspapers.

In the last few days there was some discussion here among physicists whether or not we should take action to prevent anything along this line from being published in scientific periodicals in this country, and also ask colleagues in England and France to consider taking similar action. No definite conclusions have so far been reached in these discussions, but if and when definite steps are being taken I shall send you a cable to tell you what is being done.

We all hope that there will be no, or at least not sufficient, neutron emission and therefore nothing to worry about. Still, in order to be on the safe side, efforts are made to clear up this point as quickly as possible. Experiments at Columbia University are in charge of Fermi and will perhaps be the first to give reliable results.

Perhaps you have also thought of the same things and have contemplated or started such experiments. Maybe you are able to get definite results at an earlier date, which, of course, would be very valuable help towards ending the present disquieting uncertainty. Whatever information on the subject you might case to transmittby letter or cable at some later date will, I am sure, be greatly appreciated. Also, should you come to the conclusion that publication of certain matters should be prevented, your opinion will certainly be given very serious consideration in this country.

~~We all hope that there will not be sufficient neutrons and nothing to worry about,~~

Yours sincerely, (Leo Szilard)

Receipt for Beryllium block

M-27

U.S. Appraiser Stores
201 Varick Street
7th Subs. West Houston St.

POST OFFICE, NEW YORK, N.Y.
DIVISION OF MAILS
FOREIGN SECTION, MORGAN ANNEX

NO. V14687

FEB 18 1939 193

Received from Dr Leo Szilard c/o Columbia University

— Dollars 15 cents in payment of ~~storage charges~~ and Customs Clearance and delivery charges 1 parcels held at Customs Department, Foreign Section (5th Floor), Morgan Annex.

Due stamps affixed by

____
Clerk

ALBERT GOLDMAN,
Postmaster.

per ______________________

D-575
10/20/35

No dupl. in Ran. tex

BOOK 1960

COPY

Hotel King's Crown
420 West 116th Street
New York City

January 25th, 1939

Mr. Lewis L. Strauss
c/o Kuhn, Loeb & Co.
52 William Street
New York City

Dear Mr. Strauss:

I feel that I ought to let you know of a very sensational new development in nuclear physics. In a paper in the "Naturwissenschaften" Hahn reports that he finds when bombarding uranium with neutrons the uranium breaking up into two halves giving elements of about half the atomic weight of uranium. This is entirely unexpected and exciting news for the average physicist. The Department of Physics at Princeton, where I spent the last few days, was like a stirred-up ant heap.

Apart from the purely scientific interest there may be another aspect of this discovery, which so far does not seem to have caught the attention of those to whom I spoke. First of all it is obvious that the energy released in this new reaction must be very much higher than in all previously known cases. It may be 200 million volt instead of the usual 3-10 million volt. This in itself might make it possible to produce power by means of nuclear energy, but I do not think that this possibility is very exciting, for if the energy output is only two or three times the energy input, the cost of investment would probably be too high to make the process worth while. Unfortunately, most of the energy is released in the form of heat and not in the form of radioactivity.

I see, however, in connection with this new discovery potential possibilities in another direction. These might lead to a large-scale production of energy and radioactive elements, unfortunately also perhaps to atomic bombs. This new discovery revives all the hopes and fears in this respect which I had in 1934 and 1935, and which I have as good as abandoned in the course of the last two years. At present I am running a high temperature and am therefore confined to my four walls, but perhaps I can tell you more about these new developments some other time. Meanwhile you may look out for a paper in "Nature" by Frisch and Meitner which will soon appear and which might give you some information about this new discovery.

With best wishes,

Yours sincerely,

/s/ Leo Szilard

COPY

Prof Wachsmann

Hotel King's Crown
420 West 116th Street
New York City

January 25th, 1939.

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c/o Kuhn, Loeb & Co.
52 William Street
New York City

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6.

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With best wishes,

yours sincerely

(Leo Szilard)

sbs 5

Oxford

c/o Liebowitz
420 Riverside Drive
New York City

January 18th, 1939

Dear Tuck:

Please write me as soon as you get this letter 1) whether you got the long letter which I wrote you between October 20th and 30th, and in which among other things I explained to you why your argument about the instability of the electron path in the electron transformer was no good. 2) whether you answered my letter or whether you have written to me at all between October and today, as I have had no news from you during this period. 3) What did you decide about your cystein paper? 4) Whether you have a fellowship or what other arrangements you have got at Oxford.

Dr. Fransi Weiss, who is at present in England but who will sail for New York some time in February, will call on you, and you can give her all the things for me which she wants to take along with her.

Our image amplifier may get some importance in connection with the electron microscope which is now being worked out by the R.C.A. I may therefore send you some documents relating to an American patent application which you would have to sign at the American Consulate, Cavendish Square, London.

Hoping to hear from you soon,

yours,

orig. coll.

BK f3 (9)

c/o Liebowitz
420 Riverside Drive
New York City

February 2nd, 1939

Professor M. Joliot
Laboratoire de Chemie Nucléaire
Collège de France
Paris.

Dear Professor Joliot:

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It is of course not possible to prevent physicists from discussing these things among themselves, and, as a matter of fact, the subject is fairly widely discussed here. However, so far, every individual exercised sufficient discretion to prevent a leakage of these ideas into the newspapers.

Not sent to Harvard.

Bk.f.3 (10)

In the last few days there was some discussion here among physicists whether or not we should take action to prevent anything along this line from being published in scientific periodicals in this country, and also ask colleagues in England and France to consider taking similar action. No definite conclusions have so far been reached in these discussions, but if and when definite steps are being taken I shall send you a cable to tell you what is being done.

We all hope that there will be no, or at least not sufficient, neutron emission and therefore nothing to worry about. Still, in order to be on the safe side, efforts are made to clear up this point as quickly as possible. Experiments at Columbia University are in charge of Fermi and will perhaps be the first to give reliable results.

Perhaps you have also thought of the same things and have contemplated or started such experiments. Maybe you are able to get definite results at an earlier date, which,of course, would be very valuable help towards ending the present disquieting uncertainty. Whatever information on the subject you might case to transmittby letter or cable at some later date will, I am sure, be greatly appreciated. Also, should you come to the conclusion that publication of certain matters should be prevented, your opinion will certainly be given very serious consideration in this country.

~~[illegible]~~

~~emitted by uranium. [illegible]~~

Yours sincerely (Leo Szilard)

Bk f5 x

REPLY IN DUPLICATE
AND REFERENCE TO

WILL BE APPRECIATED

NAVAL RESEARCH LABORATORY

ANACOSTIA STATION
WASHINGTON, D. C.

RG/ejh

10 July 1939

Dr. Leo Szilard,
Department of Physics,
Columbia University,
New York, N.Y.

Dear Dr. Szilard:

The matter which we discussed at the Princeton meeting of the Physical Society has been carefully considered. As I indicated to you at that time, it seems almost impossible, in light of the restrictions which are imposed on Government contracts for services, to carry through any sort of an agreement that would be really helpful to you. I regret this situation but see no escape. We are anxious, however, to cooperate with you in every respect and appreciate your assistance on this important problem.

Very truly yours,

Ross Gunn

Ross Gunn,
Technical Adviser.

First Approach to the President of the United States

August - October 1939

In July 1939 I reached the conclusion that the chain reaction might be set up in a uranium/graphite system, and that this possibility had to be considered as an imminent danger. In a conference with Wigner and Teller, we examined the situation and came to the conclusion that we ought to approach the United States Government through some new channel. For this purpose we enlisted the assistance of Professor Einstein, to whom we explained the situation in great ddail. I also approached Dr. Alexander Sachs, at that time economic advisor and vice-president of the Lehman Corporation.

Professor Einstein wrote a letter addressed to the President in which I enclosed a memorandum. These documents were handed to Dr. Alexander Sachs who submitted them to the President in a personal interview together with a memorandum of his own. In response the President appointed Dr. Briggs as chairman of a committee subsequently called the Uranium Committee.

The enclosed copy of a letter written by Dr. Sachs to Dr. Wigner relates this phase of the development. Copies of my memorandum and Professor Einstein's letter to the President are also enclosed.

The last paragraph of my memorandum raised again the question of secrecy. This question was further stressed at the meeting held under the chairmanship of Dr. Briggs, October 21, 1939, but as far as I know, Dr. Brigg report to the President contained no recommendation concerning this point.

Rx replace 406-410 public domain

October 11, 1939

Dear Mr. President:

With approaching fulfillment of your plans in connection with revision of the Neutrality Act, I trust that you may now be able to accord me the opportunity to present a communication from Dr. Albert Einstein to you and other relevant material bearing on experimental work by physicists with far-reaching significance for National Defense.

Briefly, the experimentation that has been going on for half a dozen years on atomic disintegration has culminated this year (a) in the discovery by Dr. Leo Szilard and Professor Fermi that the element, uranium, could be split by neutrons and (b) in the opening up of the probability of chain reactions, - that is, that in this nuclear process uranium itself may emit neutrons. This new development in physics holds out the following prospects:

1. The creation of a new source of energy which might be utilized for purposes of power production;

2. The liberation from such chain reaction of new radioactive elements, so that tons rather than grams of radium could be made available in the medical field;

3. The construction, as an eventual probability, of bombs of hitherto unenvisaged potency and scope: As Dr. Einstein observes, in the letter which I will leave with you, "a single bomb of this type carried by boat and exploded in a port might well destroy the whole port together with some of the surrounding territory!"

In connection, then, with the practical importance of this work - for power, healing and national defense purposes - it needs to be borne in mind that our supplies of uranium are limited and poor in quality as compared with the large sources of excellent uranium in the Belgian Congo and, next in line, Canada and former Czechoslovakia. It has come to the attention of Dr. Einstein and the rest of the group concerned with this problem that Germany has actually stopped the sale of uranium from the Czechoslovakian mines it seized. This action must be related to the fact that the son of the German Under-Secretary of State, Karl von Weizsaecker, had been an assistant at the Kaiser Wilhelm Institute in Berlin to some of the great physicists now resident in this country who are carrying forward these experiments on uranium.

Mindful of the implications of all this for democracy and civilization in the historic struggle against the totalitarianism that has exploited the inventions of the free human spirit, Dr. Szilard, in consultation with Professor E. P. Wigner, head of the physics department of Princeton, and Professor E. Teller of George Washington University, sought to aid this work in the United States through the formation of an association for scientific collaboration, to intensify the cooperation of physicists in the democratic countries - such as Professor Joliot in Paris, Professor Lindemann of Oxford and Dr. Dirac of Cambridge - and to withhold publication of the progress in the work on chain reactions. As the international crisis developed this summer, these refugee scholars and the rest of us in consultation with them unanimously agreed that it was their duty, as well as desire, to apprise you at the earliest opportunity of their work and to enlist your cooperation.

In view of the danger of German invasion of Belgium, it becomes urgent to make arrangements - preferably through diplomatic channels - with the Union Miniere du Haut-Katanga, whose head office is at Brussels, to make available abundant supplies of uranium to the United States. In addition, it is necessary to enlarge and accelerate the experimental work, which can no longer be carried out within the limited budgets of the departments of theoretical physics in our universities. It is believed that public-spirited executives in our leading chemical and electrical companies could be persuaded to make available certain amounts of uranium oxide and quantities of graphite, and to bear the considerable expense of the newer phases of the experimentation. An alternative plan would be the enlistment of one of the foundations to supply the necessary materials and funds. For either plan and for all the purposes, it would seem advisable to adopt the suggestion of Dr. Einstein that you designate an individual and a committee to serve as a liaison between the scientists and the Executive Departments.

In the light of the foregoing, I desire to be able to convey in person, in behalf of these refugee scholars, a sense of their eagerness to serve the nation that has afforded them hospitality, and to present Dr. Einstein's letter together with a memorandum which Dr. Szilard prepared after some discussion with me and copies of some of the articles that have appeared in scientific journals. In addition, I would request in their behalf a conference with you in order to lay down the lines of policy with respect to the Belgian source of supply and to arrange for a continuous liaison with the Administration and the Army and Navy Departments, as well as to solve the immediate problems of necessary materials and funds.

With high regard,

Yours sincerely,

The President,
The White House,
Washington, D. C.

From Alexander Sachs
(K. W.)

Replace by 461-462
public domain

March
~~October~~ 15, 1940

Dear Mr. President:

As a sequel to the communication which I had the honor to submit to you on October 12, Professor Albert Einstein sent me another regarding the latest developments touching on the significance of research on uranium for problems of national defense. In that letter he suggests that I convey to you the information that has reached him that since the outbreak of the war, research with uranium is being carried out in great secrecy at the Berlin Institute of Physics, which has been taken over by the Government and placed under the leadership of C. F. von Weizsaecker, son of the German Secretary of State.

In the realization that these further views of Dr. Einstein have a definite bearing on the favorable report submitted to you by Dr. Briggs as Chairman of the Committee which conferred with experimental scientists concerned and myself, I am enclosing his communication for your kind perusal. May I also ask whether and when it would be convenient for you to confer on certain practical issues brought to a focus by the very progress of the experimental work, as indicated in the concluding paragraph of Dr. Einstein's letter.

In view of your original designation of General Watson in this matter, I am transmitting it through his good offices.

Yours sincerely,

The President
The White House
Washington, D. C.

April 15, 1940

Dear Dr. Einstein:

In connection with your important communication of March 7th in regard to the research in uranium and its bearing on national defense, I wrote to the President on March 15th, as per enclosed copy, and have at first received an acknowledgment from his secretary, General Watson. It would appear that upon his return to Washington after his trip to the Canal Zone, he decided to adopt the procedure suggested in my original communication. Accordingly, I received on Saturday, April 13th, a letter of his dated April 5th which was postmarked from Washington on April 12th, 5:30 P.M., - a delay which is understandable in view of the tragic international occurrence of the intervening week. In the wake of that letter I also received on the 13th a note from General Watson dated the 5th, and, in furtherance of a telephone call on Saturday, Dr. Briggs's letter of the 13th.

Naturally, having been brought into the orbit of this problem by Dr. Szilard, I have been in continuous touch with him at every stage of the developments and over this weekend and particularly today we have discussed aspects of the appropriate procedure for the forthcoming conference which the President has instructed General Watson and Dr. Briggs to arrange in conformity with the ideas implicit in your original letter. May I add that in the interest of assuring an adequate scale for the experimentation and a right tempo for the work it will be most helpful if you could see your way to attending, along with Drs. Wigner and Szilard, as I am sure that the President would feel all the more confident and would be delighted to know that any program that is worked out will have had your sagacious cooperation and your approval.

I am looking forward to seeing you and conferring with you before the meeting which, owing to the exigencies of conference and the development of a coordinate policy, might require postponement.

Yours sincerely,

Dr. Albert Einstein,
112 Mercer Road,
Princeton, N. J.

N

October 11, 1939

Dear Mr. President

With approaching fulfillment of your plans in connection with revision of the Neutrality Act, I trust that you may now be able to accord me the opportunity to present a communication from Dr. Albert Einstein to you and other relevant material bearing on experimental work by physicists with far-reaching significance for National Defense.

Briefly, the experimentation that has been going on for half a dozen years on atomic disintegration has culminated this year (a) in the discovery by Dr. Leo Szilard and Professor Fermi that the element, uranium, could be split by neutrons[1] and (b) in the opening up of the probability of chain reactions, -- that is, that in this nuclear process uranium itself may emit neutrons. This new development in physics holds out the following prospects:

1. The creation of a new source of energy which might be utilized for purposes of power production;
2. The liberation from such chain reaction of new radio-active elements, so that tons rather than grams of radium could be made available in the medical field;
3. The construction, as an eventual probability, of bombs of hitherto unenvisaged potency and scope: as Dr. Einstein observes, in the letter which I

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1 This discovery was in fact by Hahn and Strassmann.

will leave with you, "a single bomb of this type carried by boat and exploded in a port might well destroy the whole port together with some of the surrounding territory!"...[2]

In view of the danger of German invasion of Belgium, it becomes urgent to make arrangements - preferably through diplomatic channels - with the Union Minière du Haut-Katanga, whose head office is at Brussels, to make available abundant supplies of uranium to the United States. In addition, it is necessary to enlarge and accelerate the experimental work, which can no longer be carried out within the limited budgets of the departments of theoretical physics in our universities. It is believed that public-spirited executives in our leading chemical and electrical companies could be persuaded to make available certain amounts of uranium oxide and quantities of graphite, and to bear the considerable expense of the newer phases of the experimentation. An alternative plan would be the enlistment of one of the foundations to supply the necessary materials and funds. For either plan and for all the purposes, it would seen advisable to adopt the suggestion of Dr. Einstein that you designate an individual and a committee to serve as a liaison between the scientists and the Executive Departments.

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2 We omit two paragraphs.

In the light of the foregoing, I desire to be able to convey in person, in behalf of these refugee scholars, a sense of their eagerness to serve the nation that has afforded them hospitality, and to present Dr. Einstein's letter together with a memorandum which Dr. Szilard prepared after some discussion with me and copies of some of the articles that have appeared in scientific journals. In addition, I would request in their behalf a conference with you in order to lay down the lines of policy with respect to the Belgian source of supply and to arrange for a continuous liaison with the Administration and the Army and Navy Departments, as well as to solve the immediate problems of necessary materials and funds.

With high regard,

Yours sincerely,

Alexander Sachs

The President,
The White House,
Washington, D. C.

March 15, 1940

Dear Mr. President:

As a sequel to the communication which I had the honor to submit to you on October 12, Professor Albert Einstein sent me another regarding the latest developments touching on the significance of research on uranium for problems of national defense. In that letter he suggests that I convey to you the information that has reached him that since the outbreak of the war, research with uranium is being carried out in great secrecy at the Berlin Institute of Physics, which has been taken over by the Government and placed under the leadership of C. F. von Weizsaecker, son of the German Secretary of State.

In the realization that these further views of Dr. Einstein have a definite bearing on the favorable report submitted to you by Dr. Briggs as Chairman of the Committee which conferred with experimental scientists concerned and myself, I am enclosing his communication for your kind perusal. May I also ask whether and when it would be convenient for you to confer on certain practical issues brought to a focus by the very progress of the experimental work, as indicated in the concluding paragraph of Dr. Einstein's letter.

In view of your original designation of General Watson[1] in this matter, I am transmitting it through his good offices.

Yours sincerely,

[A. Sachs]

The President
The White House
Washington, D.C.

---

1 Edwin M. Watson, secretary to President Roosevelt.

Bk.f.5

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October 17, 1939

Dear Professor Wigner:

In keeping with our conversation on your recent visit to my office and in furtherance of later developments reported to you by Dr. Szilard, I had a conference in Washington on October 11th with a committee appointed by the President, headed by General Watson, his executive secretary and military aide. After that conference I had the honor to present the matter to the President and to leave with him a dossier consisting of Dr. Einstein's letter, Dr. Szilard's memorandum, and my own original letter-memorandum on the subject addressed to him.

On the following day the President appointed a small committee representing the Army, the Navy and the Bureau of Standards, in the persons of Colonel Adamson, Commander Hoover and Dr. Lyman Briggs. Dr. Briggs then, in consultation with me, arranged and formally issued an invitation on the following day for a conference to be held this week at Washington with your good self and Dr. Szilard, as the scientific complement, and myself as the intermediary, and the informal committee above mentioned. To suit your joint preferences, as conveyed to me by Dr. Szilard, the date was shifted from Wednesday to Saturday morning, October 21st, at 9:30 at the office of the Bureau of Standards in the U.S. Department of Commerce. This afternoon Dr. Briggs warmly approved the suggestion of Dr. Szilard regarding the inclusion of Professor E. Teller of George Washington University and indicated that he would add two scientists conversant with this subject. Such, then, is the diary of the events since our last talk.

Will you be good enough to confirm to me your acceptance and will you also indicate whether you would wish to have a conference prior to our departure, or, alternatively, that we meet Friday night on the 12:50 train from Pennsylvania Station to Washington. In either event, I should like to have you and Dr. Szilard as my guests at breakfast at the Carlton Hotel Saturday morning, and we would thereafter proceed to the Department of Commerce building for our appointment.

Yours sincerely,

Alexander Sachs

Professor E. P. Wigner
Fine Hall
Princeton University
Princeton, New Jersey

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COPY

MEMORANDUM OF LEO SZILARD

submitted to Dr. Briggs

October 26, 1939

THE POSSIBILITY OF A LARGE-SCALE EXPERIMENT
IN THE IMMEDIATE FUTURE

At present it appears quite possible that a nuclear chain reaction could be set up in a system composed of uranium oxide (or uranium metal) and graphite. The graphite would have to be piled up in a space of perhaps 4 x 4 x 4 metres and might weigh about 100 metric tons. Perhaps 10 to 20 tons of uranium oxide would have to be used, embedded in some such pile of graphite.

The probable success or failure of such a large-scale experiment cannot be forecase at present with any degree of assurance. The properties of a system composed of uranium and graphite have been calculated independently, for a homogeneous mixture, by Fermi, and, for a lattice of spheres of uranium oxide, or uranium metal, embedded in graphite, by myself. The results of these two independent calculations are in reasonable agreement and show that the two arrangements have different properties. For instance, in the case of using a lattice of spheres a great advantage could be obtained by using uranium metal instead of uranium oxide, whereas in the case of the homogeneous mixture the use of uranium metal would be of no great advantage. In spite of these calculations, we cannot foretell with certainty whether or not a nuclear chain reaction can be maintained in such a system because the absorption cross section of carbon for slow neutrons is not sufficiently known.

In order to remove this uncertainty Fermi and I have devised two different experiments by means of which the absorption cross section of carbon, which is very small, could be measured. It is assumed that one of these experiments, or both of them, will be started at Columbia University as soon as the facilities required can be obtained.

If the absorption of carbon should turn out to be comparatively large we could conclude that the large-scale experiment is bound to fail, and in this case it need not be started. If the absorption of carbon should prove to be exceedingly small the large-scale experiment would appear to very promising, and it can be assumed that everybody will then be in favor of starting it without delay.

Unfortunately, we must be also prepared to find an intermediate value for the carbon absorption. In this case a large-scale experiment will have to be performed in order to find out whether or not a nuclear chain reaction can be achieved with a combination of uranium and graphite. So we may have to make the experiment and risk its possible failure.

It should be borne in mind that a negative result of the large-scale experiment could also be of value by showing with certainty that a chain reaction cannot be achieved with simple means in the near future. Otherwise there remains an ever-present potential threat arising out of experiments on uranium, which are carried out in certain other countries. Therefore, in my personal opinion, a large-scale experiment ought to be performed unless the possibility of its success can be excluded with reasonable assurance on the basis of experiments which are designed to determine the absorption of carbon, or other similar experiments which can be carried out on a moderately small scale.

RECOMMENDATIONS CONCERNING LARGE-SCALE EXPERIMENTS.

No expenses need be incurred in connection with large-scale experiments until the absorption of carbon has been measured. On the other hand, steps ought to be taken now in order to prepare the ground for a large-scale experiment, so that this can be started without delay at the proper time. For instance, the possibility of converting uranium oxide into uranium metal ought to be explored. An attempt ought to be made to obtain a promise on the part of certain industrial corporations to supply at the proper time the quantities of the materials, which are required. If possible, these materials ought to be loandd without any financial consideration. Barring an accident in the case of a successful large-scale experiment, most of the materials used would remain unaffected and could be returned after the experiment is completed.

100 metric tons of graphite represent a value of about $33.00—at the rate of 15¢ per pound. If a purer brand of graphite has to be used, which rates at 24¢ per lb. the value involved would be $53.000.

20 metric tons of uranium oxide represent a value of $ 100.000.—at the rate of $2.50 per lb. If it need hot be converted into uranium metal but can be used in the form of oxide in the large-scale experiment, this material could be kept pure and could be returned undamaged. It would be desirable to have up to 50 tons of uranium oxide readily available for experiments in the United States.

STATEMENT CONCERNING THE POTENTIAL ASSISTANCE OF THE
UNION MINIERE DU HAUT KATANGA

It would be of particular value to enlist the assistance of this Belgian corporation which is to some extent controlled by the Belgian Government. It appears to be the only corporation which could supply at short notice 20 metric tons of uranium oxide, and probably even 50 tons. I understand that the Managing Director, Mr. E. Sengier, is on a short visit in America.

From conversations which Professor G. B. Pegram of Columbia University had with a representative of the Eldorado Gold Mines, Ltd. it appears that this Canadian corporation might be able to supply uranium oxide for our purposes at the rate of 1 ton per week. If the uranium oxide were to be bought rather than obtained as a gift or a loan, it might be secured from Canada probably just as easily as from Belgium. On the other hand, the Canadian corporation is rather small and can hardly be asked to give away large quantities of material without financial compensation.

So far, radium up to about 2.5 gms. was used in our experiments, and we had to pay a high rent to a subsidiary of the Union Miniere, the only corporation from which large quantities of radium can be readily rented in this country. An attempt ought to be made to obtain radium for the purposes of such experiments rent-free from the Union M,niere in the future.

Carnotites containing uranium are mined in the U.S.A by the U. S. Vanadium Corporation which is owned by the Union Carbon and Carbide Corporation. A conversation which I recently had with William F. Barrett, Vice-President of this corporation, did not encourage the hope of obtaining large quantities of uranium oxide from this firm, but the issue could perhaps be reopened.

STATEMENT ABOUT URANIUM ORE

As far as I was able to find out, pitchblend, which is an ore rich in uranium, is mined in Czechoslovakia, Canada and Belgian Congo. The total content of uranium in the deposit in Czechoslavakia is estimated to be between 1000 and 1500 tons. The Canadian deposit visibly contains a total of 3000 tons. The amount of pitchblend in the Belgian Congo is not known, but it is believed to be very much larger. In the United States uranium occurs chiefly in the form of carnotites, which is an ore poor in uranium, and is mined for the sake of its vanadium content. The total deposit is estimated to contain 3000 tons of uranium oxide. (Perhaps there are in the United States larger quantities of ore containing a very small amount of uranium which are not included in the above estimate.)

RECOMMENDATION CONCERNING URANIUM ORE

Steps to secure a stock of uranium ores for the government can hardly be recommended at the present time if such steps would involve financial commitments on the part of the government. It might, however, be advisable to begin to study the question in what manner the government could secure such a stock at a later date if required.

For instance, the question has been raised whether it might not be possible to obtain for the government a large quantity of pitchblend from Belgium as a token reparation payment. Such a transaction would not cause alarm abroad if it were arranged before the world learns of the results of some successful large-scale experiment. The transaction could be justified without reference to the uranium content of the ore. Pitchblend is also the ore of radium, and action could be taken on the ground of securing the ore for the sake of its radium content, with a view of extracting the radium at some future date for medical purposes. Action taken on this ground alone might in fact be entirely justified.

First Approach to France, Febr. 1939

About one month before Fermi and I actually observed the neutron emission of uranium I wrote to Joliot advising him of the projected experiments and suggesting that he collaborate with us in keeping any positive results secret.

The text of the letter which speaks for itself is inclosed.

Bk.f.3

COPY

c/o Liebowitz
420 Riverside Drive
New York City

February 2nd, 1939

Professor M. Joliot
Laboratoire de Chemie Nucleaire
College de France
Paris

Dear Professor Joliot:

The only reason for my writing to you this letter to-day is the remote possibility that I shall have to send you a cable in some weeks, and if that happens this letter will help you to understand what the cable is about. This letter is therefore merely a precaution, and we hope an unnecessary precaution.

When Hahn's paper reached this country about a fortnight ago, a few of us got at once interested in the question whether neutrons are liberated in the disintegration of uranium. Obviously, of more than one neutron were liberated, a sort of chain reaction would be possible. In certain circumstances this might then lead to the construction of bombs which would be extremely dangerous in general and particularly in the hands of certain governments.

It is of course not possible to prevent physicists from discussing these things among themselves, and, as a matter of fact, the subject is fairly widely discussed here. However, so far, every individual exercised sufficient discretion to prevent a leakage of these ideas into the newspapers.

In the last few days there was some discussion here among physicists whether or not we should take action to prevent anything along this line from being published in scientific periodicals in this country, and also ask colleagues in England and France to consider taking similar action. No definite conclusions have so far been reached in these discussions, but if and when definite steps are being taken I shall send you a cable to tell you what is being done.

We all hope that there will be no, or at least not sufficient, neutron emission and therefore nothing to worry about. Still, in order to be on the safe side, effortsare made to clear up this point as quickly as possible. Experiments at Columbia University are in charge of Fermi and he will perhaps be the first to give reliable results.

Perhaps you have also thought of the same things and have contemplated or started such experiments. May be you are able to get definite results at an earlier date, which, of course, would be very valuable towards ending the present disquieting uncertainty. Whatever information on the subject you might care to tansmit by letter or cable at some later date will, I am sure, be greatly appreciated. Also, should you come to the conclusion that publication of certain matters should be prevented, your opinion will certainly be given very serious consideration in this country.

Yours sincerely,

signed: (Leo Szilard)

EARLY EMPHASIS ON THE GRAPHITE-URANIUM SYSTEM

July to October 1939

Enclosed are copies of letters sent to Fermi in July 1939 and of a memorandum submitted to Dr. Briggs in October 1939. This memorandum puts on record the recommendations which I made orally at the first meeting of the Uranium Committee, under the chairmanship of Dr. Briggs, on October 21, 1939.

Bk. f. 3. (32)

COPY OF LETTER FROM WEISSKOPF TO BLACKETT, ENGLAND, MARCH 1939

[March 31 to Apr 2] K.W.

Victor Weisskopf
University of Rochester

Dear Blackett,

I hope you were not too much upset about my telegram but I believe that you realize the great danger which would arise, if one really could construct a bomb with uranium. The probability that this is possible might be small, but the product of the probability with the graveness of the consequences is high.

I enclose here first a letter which Szilard has written to Joliot Febr. 2. Joliot has not answered this letter and we do not know Joliot's attitude to the whole situation after his recent publication. I have sent to Halban a similar telegram as to you urging him to cooperate.

Further I enclose a note which Szilard has sent to Physical Review but the publication of which is being delayed. There are other papers from Columbia sent in and kept back, which could be sent to you if the cooperation begins to work. I am also enclosing a letter from Szilard to myself which gives you further details about his experiments.

I would like tell you how far the cooperation here for delaying "dangerous" manuscripts has developed so far. We know that the group around Tuve is now willing to cooperate. Lawrence is coming here on April 3rd. and we shall discuss the matter with him then. Tate (editor of Phys. Rev.) is being approached and it is suggested that authors who may send in manuscripts concerning "dangerous" neutron emissions be advised to communicate with us. We shall send you a cable when a definite procedure has been decided upon in connection with Phys. Rev.

Much love to your family.

Very truly yours

COPY OF LETTER FROM WIGNER TO DIRAC

PALMER PHYSICAL LABORATORY
Princeton University
Princeton, New Jersey

March 30, 1939

Dear Paul:

I am writing to you in a rather serious matter this time. The enclosed letter, sent by Szilard to Joliot on February 2nd is self explanatory. Experiments undertaken since that time by Fermi and by Szilard did not help to dispell the fear which prompted Szilard's letter. In realisation of the danger mentioned in this letter, all efforts are made here to delay publications relating to this subject as there could possibly enhance the danger of a grave misuse by certain powers. The papers of Szilard and of Fermi, although received by the Physical Review some time ago, are withheld from publication and it is intended that they be printed only in the form of reprints to be distributed among the most interested laboratories in England, the U. S., France and Denmark. Similar arrangements are intended for all papers on this subject by other workers in the United States.

Halban-Joliot-Kovarski's letter to Nature prompted the physicists who loyally cooperated here to inquire today by cable concerning Joliot's attitude in this matter. Bohr undertakes to communicate with Copenhagen and a cable is sent simultaneously to Blackett. The proposition made in there communications is to use for the publication of all papers, relating to this subject, the method foreseen for this purpose for workers in the U. S. and described above.

What we would like to ask you at this time is to get in touch with Blackett and to actively support him in his endeavours if you find our position to be the reasonable one.

It is my impression that there is some urgency in the matter. Although there exists apparently a great willingness for cooperation here, it is realised that the interests of the scientific workers in the U. S. may be prejudiced to some extent if America abeyed alone by the proposed procedure.

Hoping to hear from you soon and with best regards to all,

Sincerely,

(signed) Jeno

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Bk. f. 3

COPY

March 31st, 1939

HANS VON HALBAN
11 RUE GUYNEMER
SCEAUX SEINE

KINDLY INFORM JOLIOT THAT PAPERS RELATING TO SUBJECT OF YOUR JOINT NOTE TO NATURE HAVE BEEN SENT BY VARIOUS PHYSICISTS TO PHYSICAL REVIEW BEFORE PUBLICATION OF YOUR NOTE STOP AUTHORS AGREED HOWEVER TO DELAY PUBLICATION FOR REASONS INDICATED IN SZILARDS LETTER TO JOLIOT FEBRUARY SECOND AND THESE PAPERS ARE STILL HELD UP STOP NEWS FROM HOLIOT WHETHER HE IS WILLING SIMILARLY TO DELAY PUBLIC* ATION OF RESULTS UNTIL FURTHER NOTICE WOULD BE WELCOME STOP IT IS SUGGESTED THAT PAPERS BE SENT TO PERIODICALS AS USUAL BUT PRINTING BE DELAYED UNTIL IT IS CERTAIN THAT NO HARMFUL CONSEQUENCES TO BE FEARED STOP RESULTS WOULD B E COMMUNICATE IN MANUSCRIPTS TO COOPER-ATING LABORATORIES IN AMERICA ENGLAND FRANCE AND DENMARK STOP COMMUNICATING BLACKETT AND DIRAC IN ATTEMPT TO GET COOPERATION OF NATURE AND PROCEEDINGS ROYAL SOCIETY STOPPLEASE CABLE WEISSKOPF FINE HALL PRINCETON NJ

March 31st, 1939

BLACKETT PHYSICS DEPARTMENT VICTORIA UNIVERSITY MANCHESTER

PHYSICISTS HERE HAVE SENT PAPERS TO PHYSICAL REVIEW ON SUBJECT RELATED TO HALBAN·JOLIOT LETTER TO NATURE STOP AUTHORS AGREED TO DELAY PUBLICATION IN VIEW OF REMOTE BUT NOT NEGLIGIBLE CHANCE OF GRAVE MISUSE IN EUROPE STOP IT IS SUGGESTED THAT PAPERS BE SENT TO PERIODICALS AS USUAL BUT PRINTING BE DELAYED UNTIL IT IS CERTAIN THAT NO HARMFUL CONSEQUENCES TO BE FEARED STOP RESULTS WOULD BE COMMUNICATED IN MANUSCRIPTS TO COOPERATING LABORATORIES IN AMERICA ENGLAND FRANCE AND DENMARK STOP IS IT POSSIBLE FOR YOU TO OBTAIN COOPERATION OF NATURE AND PROCEEDINGS? WIGNER WRITING DIRAC STOP WEISSKOPF FINE HALL PRINCETON NJ

April 5, 1939

WEISSKOPF FINE HALL PRINCETON NJ

BIEN RECU LETTRE SZILARD MAIS PAS CABLE ANNONCE STOP PROPOSITION DU 31 MARS TRES RAISONNABLE MAIS VIENT TROP TARD STOP AVONS APPRIS SEMAINE DERNIERE QUE SCIENCE SERVICE AVAIT INFORME PRESSE AMERICAINE U FEVRIER SUR TRAVAUX ROBERTS STOP LETTRE SUIT

JOLIOT HALBAN KOWARSKY

Bk. f. 3

COPY

April 6, 1939

JOLIOT
COLLEGE DE FRANCE PARIS

REPLYING YOUR CABLE WEISSKOPF STOP ROBERTS PAPERS CONCERNING DELAYED NEUTRON EMISSION WHICH IS MUCH WEAKER THAN HE THINKS AND HARMLESS STOP HOWEVER TUVES GROUP WAS RECENTLY APPROACHED AND PROMISED COOPERATION STOP WE HAVE SO FAR DELAYED PAPERS IN VIEW OF POSSIBLE MISUSE IN EUROPE STOP KINDLY CABLE AS SOON AS POSSIBLE WHETHER INCLINED SIMILARLY TO DELAY YOUR PAPERS OR WHETHER YOU THINK THAT WE SHOULD NOW PUBLISH EVERYTHING STOP

KINGS CROWN HOTEL SZILARD

April 8, 1939

NLT WEISSKOPF
FINE HALL PRINCETON (NJ) USA

YOUR SUGGESTION PASSED TO NATURE AND ROYAL WHO WILL SURELY COOPERATE STOP AWAITING LETTER WITH DETAILS

BLACKETT

April 7, 1939

LC SZILARD
KINGS CROWN HOTEL NY

QUESTION ETUDIEE SUIS D AVIS MAINTENANT PUBLIER AMITIES

JOLIOT

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COLLEGE DE FRANCE

Paris 19 avril 1939

Monsieur L. SZILARD
Kings Crown Hotel
420 West 116th Street
New York

Mon cher Szilard,

J'ai bien recu votre lettre du 7 avril et votre interessante note sur la liberation des neutrons. Nous avons continue les recherches sur cette question et vous trouverez ci-joint le texte manuscrit d'une note que nous avons envoye a Nature. Il est malheureusement trop tard pour que nous puissions ajouter en reference votre communication, cependant nous ne manquerons pas de le faire dans un article general qui sera publie prochainement.

J'etais tres embarrasse en ce qui concerne l'ajournement des publications sur ce sujet, etant certainement l'un des permiers a comprendre vos raisons. Cependant vous pouvez compendre que nous ne sommes pas, ainsi que ceux que vous avez pu prevenir, les seuls a nous occuper de cette question, et rapidement nous avons pu lire dans des publications scientifiques et dans la presse d'information, en France et a l'etranger, des articles ou etaient clairement expliquees les consequences energetiques du phenomene en question. Ce sont les seules raisons qui ont motive les termes de mon dernier. cable. Je suis certainement d'accord avec le principe d'une entente, mais pour qu'elle soit efficace il faut qu'elle soit etendue a <u>tous</u> les laboratoires susceptibles de s'occuper de la question.

Je vous serais reconnaissant de bien vouloir faire part de considerations aux collegues americains que vous avez pu touches.

Avec mes sinceres salutations,

G. Joliot

COPY

April 6, 1939

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COLLEGE DE FRANCE PARIS

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April 7, 1939

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QUESTION ETUDIEE SUIS D AVIS MAINTENANT PUBLIER AMITIES

JOLIOT

April 23, 1939

Memorandum

By comparing the values for the fission cross section, the absorbing cross section and the balance of neutron production and absorption, as manifested in experiments in which neutrons emitted from uranium are slowed down and the total number of the slow neutrons present is measured, it appears at present almost certain that the number of neutrons emitted per fission from uranium is about two. I believe that experiments which are now being carried out will confirm this in the near future. It seems to me that it should then be possible to decide the question whether or not a chain reaction with fast neutrons is possible. The following simple experiments will decide this question, perhaps not with certainty, but with a high degree of probability.

An uranium compound is to be exposed to thermal neutrons, the radioactive uranium having a 25 minute period which is produced by radiative capture, and is separated from the other activities which are produced by fission. Both activities are measured by a beta ray counter or by a ionisation chamber, and the ratio ($A = \frac{\text{activity due to capture}}{\text{activity due to fission}}$) of the two - in arbitrary units - is determined. The same uranium compound is then exposed to photo neutrons from a radon-beryllium source, and the ratio ($B = \overline{\qquad\qquad}$) of the two activities, observed in the same way as before and expressed in the same arbitrary units, is again determined.

The quotient $\frac{B}{A} = C$ is a measure of the shift in balance between neutron absorption and neutron production by changing over from thermal neutrons to photo neutrons. If C is small, for instance if it is smaller than one could be almost certain that a chain reaction can be maintained in uranium in the absence of hydrogen containing substances.

It seems therefore reasonable to perform the above mentioned experiments,and, if the outcome is positive, to take at once steps in the direction of a large scale experiment in the absence of hydrogen containing substances. It is to be expected that neutrons emitted from uranium will be slowed down by inelastic collisions in uranium to velocities between 10.000 to 100.000 volt, and therefore behave in a way very similar to photo neutrons from a radon- beryllium source. It may be added that the number of neutrons emitted by fission with energies above 200.000 volt seems to be only about one per fission, and that we therefore suspect a large number of neutrons to be emitted with energies below 200.000 volt. We suspect therefore that the slow neutron density at the surface of a sample of uranium will be appreciably increased by these comparatively slow fission neutrons, and this point is now being checked by comparing the apparent absorption of a sample of uranium metal with a sample of boron, both in a narrow and in a wide paraffin cavity.

Asynchronous and Synchronous Transformers for Particles.

The invention concerns methods and apparatus for the production of fast charged particles, e.g. electrons or protons. All these methods, described below, are based on multiple acceleration, i.e. the velocity of the particle is exceeding the maximum voltage which arises between any two parts of the apparatus. We shall have to deal with two different methods - the method of the asynchronous transformer, and the method of the synchronous transformer. In the first case we shall deal with single action and multiple action transformers, and we shall start by dealing with the asynchronous transformer method which is based on the acceleration of a charged particle in the electric field induced around ~~the~~ a changing magnetic flux. SIC.

Fig. 1 shows the principle of a method in which a magnetic flux is produced in an iron core 1, and the flux is rapidly changing its magnitude. This flux is produced [by means of] ~~through~~ the coil 2, this coil being built so as to consist of one or two windings only, and a rapidly changing electric current being sent through the coil ~~xxx~~ 2. SIC. If an electron encircles [the iron core] in its path several times ~~the iron core~~ while the flux in the core is changing its value the energy of the electron will increase at each revolution. The value of this increase in energy is determined by the

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February 6, 1940

John T. Tate, Editor
Physical Review
University of Minnesota
Minneapolis, Minn.

Dear Dr. Tate:

Enclosed you will find a manuscript which I am sending you with the request that you have it printed in the Physical Review as a "letter".

Since this manuscript deals with a matter in which the government has shown a certain amount of interest from the point of view of national defense it is felt that inquiries should be made in Washington as a matter of courtesy before the letter is actually printed. Would you, therefore, perhaps be kind enough to ask the Lancaster Press not to print this manuscript until they have a telegram from me releasing the matter for publication. I trust this way of proceeding will not cause any undue inconvenience.

Yours very truly,

(Leo Szilard)

Encl.