107° CONGRESSO NAZIONALE
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Il protone, cento anni dopo

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1. L'origine

2. L'anomalia
3. La scoperta
4. Il nome

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ACCADDE QUELL'ANNO

La prima trasmutazione artificiale del nucleo e la scoperta del protone (Rutherford 1919)
The first nuclear artificial transmutation and the discovery of the proton (Rutherford 1919)

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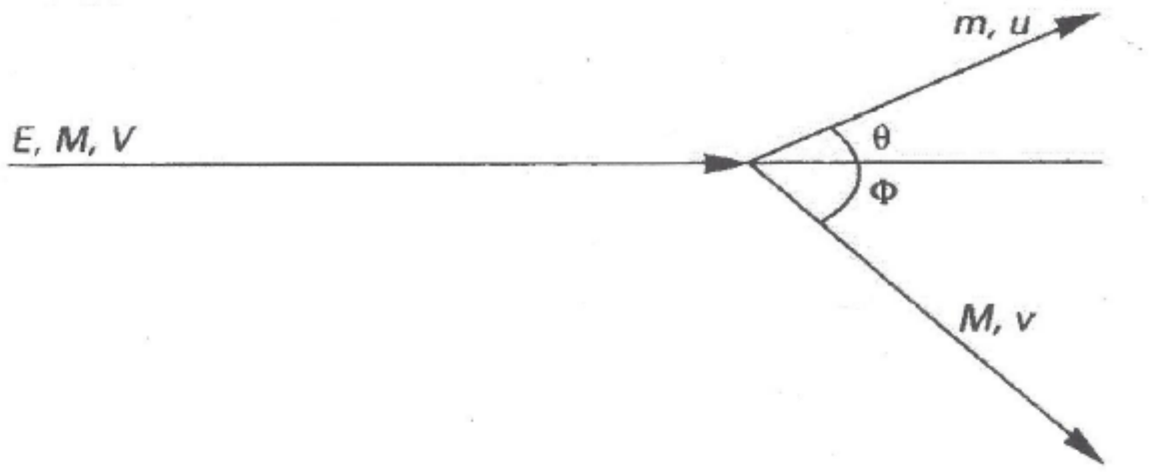
1911: la teoria di Rutherford del nucleo atomico

$\Rightarrow$ **una nuova teoria dello scattering**: "It seems reasonable to suppose that the deflexion through a large angle is **due to a single atomic encounter**, for the chance of a second encounter of a kind to produce a large deflexion must in most cases be exceedingly small. A simple calculation shows that the atom must be a seat of an intense electric field in order to produce such a large deflex-ion at a single encounter" (*Phil. Mag.* **21** 669)

$\Rightarrow$ **modello di atomo con carica positiva concentrata in un nucleo centrale di piccolissime dimensioni ($\sim 10^{-12}$ cm)**

$\Rightarrow$ numero particelle diffuse ad angolo ϕ rispetto direzione originale $\propto$ **$\text{cosec}^4(\phi/2)$**

1914: Charles Galton Darwin (nipote di Charles Darwin) **generalizza la teoria di Rutherford** al problema dello **scattering α su nuclei di massa qualunque …**



E, M, V: carica, massa, velocità della α
e, m: carica, massa di un nucleo in quiete
θ, ϕ: angoli di deflessione di nucleo e α
u, v: velocità, dopo l'urto, di nucleo e α

… e prevede che nel caso m < M (cioè α su H):

- **la deflessione della particella urtata (H) dipenda da sec$^3\theta$** (legge molto diversa dal **cosec$^4(\phi/2)$** trovato da Rutherford per la diffusione delle α contro nuclei pesanti)
- **nel caso di urto il più favorevole possibile** (α di velocità massima che urta frontalmente contro nucleo di H), in caso di α del RaC (Po-214), un ***range* ca. 4 volte maggiore del *range* delle α in idrogeno**

Thus the H particles ought to be easily observable provided they can be made to occur in sufficient numbers.

(*Phil. Mag.* **27** 499)

1914: Rutherford chiede a Ernest Marsden di verificare se si producano "particelle H"

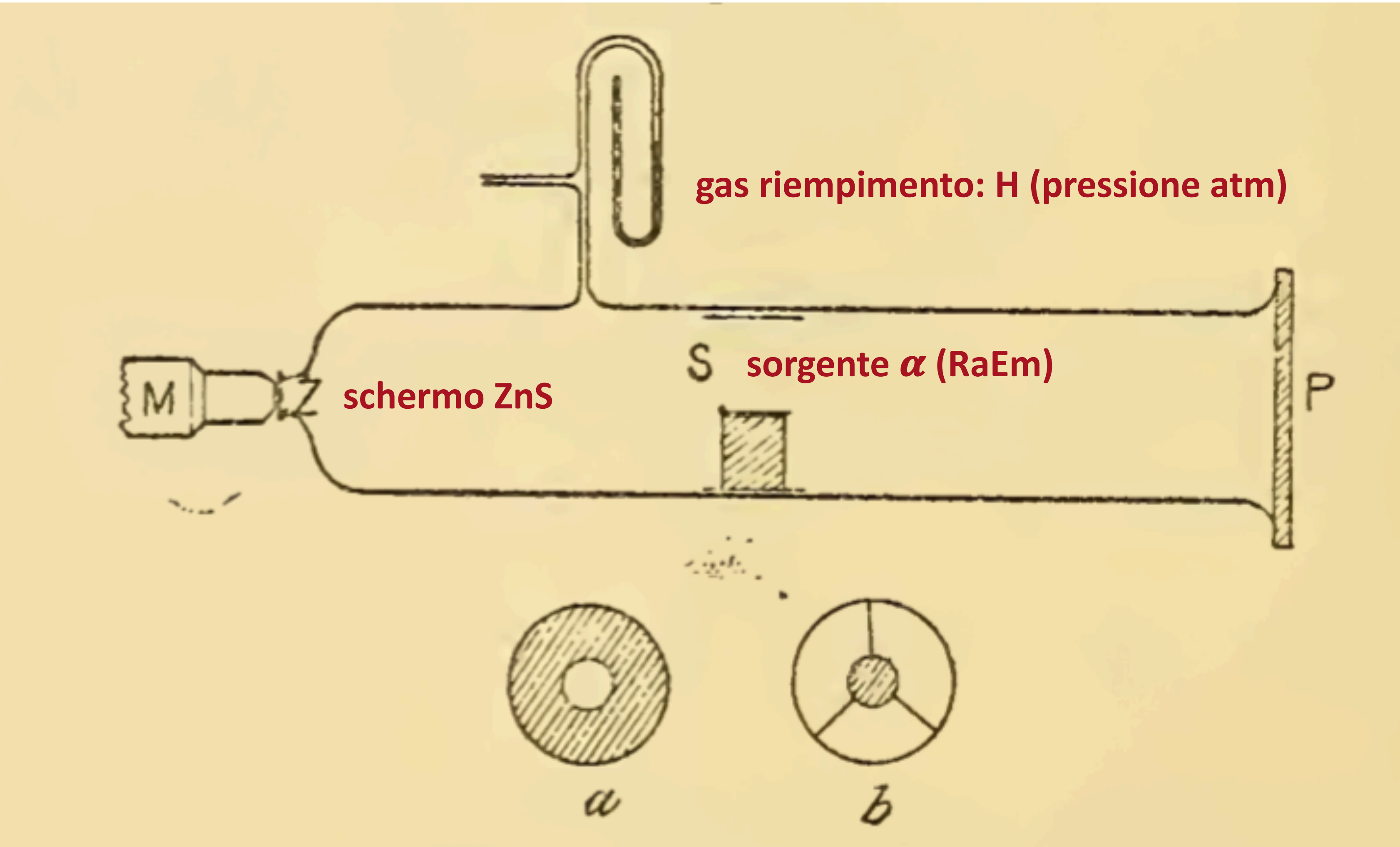
> Mr. Marsden has kindly made experiments for me to test whether the presence of such hydrogen atoms can be detected. A detailed account of his experiments will appear later, but it suffices to mention here that undoubted evidence has been obtained by him that some of the hydrogen atoms are set in such swift motion that they are able to produce a visible scintillation on a zinc sulphide screen and are able to travel through hydrogen a distance three or four times greater than the colliding α particle.

(*Phil. Mag.* **27** 488)

1914: Marsden cerca le "particelle H"

Consequently, in the passage of α particles through hydrogen the "H" particles may be looked for well beyond the range of the ordinary α particles, and in the experiments to be described evidence of their existence has been found. More detailed experiments are in progress to investigate whether the distribution of their velocities and relative motions with regard to the α particles producing them is in agreement with the calculations from the simple assumptions; but, owing to the probable lengthy series of observations necessary, it appears advisable to publish a preliminary account of the experiments so far made.

(*Phil. Mag.* **27** 824)


gas riempimento: H (pressione atm)
S
sorgente α (RaEm)
M
Z
schermo ZnS
P
a
b

Distance of α-ray tube to screen Z.	Scintillations per minute.
24 cm.	End of range of α particles.
38 „	10·0 per minute.
50 „	5·5 „ „
82 „	0·5 „ „

Evidenza di **particelle di *range* ca. 3,5 volte superiore al *range* delle *α***

With air at a pressure adjusted to give the same range of the α particles, *i. e.* about 17 cm. Hg, the number of scintillations decreased very rapidly after the end of the range, falling to 0·5 per minute at 26 cm. The results show that in hydrogen, particles capable of producing scintillations are produced which can travel at least 3½ times as far as the α particles.

L’effetto **non si produce in aria**

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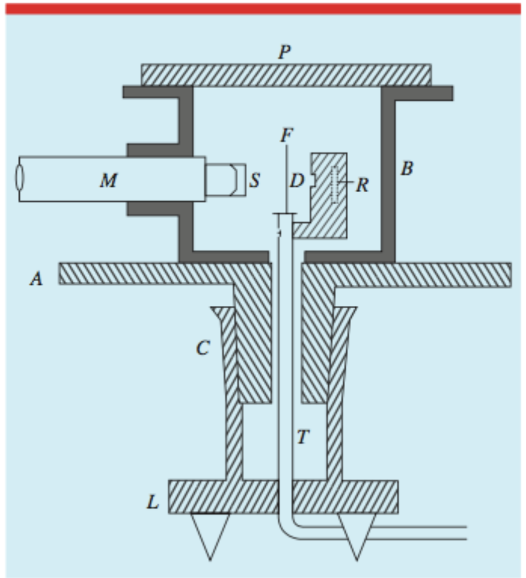
A more convenient method of making a comparison between theory and experiment is furnished by the use of a thin film of some substance rich in hydrogen, such as paraffin wax or indiarubber. When α particles fall on such films, H particles may be expected to be ejected, and experiments have shown that this is actually the case. The observations are at present being continued so as to study the distribution and number of ejected H particles when a parallel beam of α particles of known velocity passes through these films.

In conclusion I beg to express my indebtedness to Mr. W. C. Lantsberry for his very efficient help in many of the observations, and to Sir Ernest Rutherford for his many kind suggestions.

1915: Marsden e Lantsberry cercano le "particelle H" con l'apparato di Geiger-Marsden (1913) ⇒ l'anomalia



To make measurements, the same apparatus was used as in the experiments of Geiger and Marsden * on the scattering of α particles, minor alterations being introduced owing to the smallness of the effect to be expected. A pencil of α particles from an α-ray tube containing radium emanation fell on a thin sheet (10μ) of wax, and the H particles projected from the hydrogen in the wax were counted in different directions by means of a zinc-sulphide screen. The α particles were eliminated by placing sheets of aluminium, sufficient to absorb them, between the wax and the zinc sulphide.

(*Phil. Mag.* **30** 240)

The effects observed were several times greater than anticipated by formula. It was found, however, that the source itself was emitting long-range particles capable of scintillating, and that these were scattered in the wax, thus causing the disturbance. Consequently an investigation of these long-range particles had to be undertaken.

- "**effects** observed [...] **several times greater** than anticipated by formula"
- "**source** itself [...] emitting **long-range particles**"

(*Phil. Mag.* **30** 240)

Long-Range Particles emitted from the source of Radium Emanation.

The α-ray tube was placed in air at a distance of 8 cm. from a zinc-sulphide screen, the path between the two being in a transverse magnetic field to get rid of disturbing luminosity due to β particles. Although the α particles did not penetrate more than 5·8 cm. from the α-ray tube, yet scintillations were observed on the screen. These scintillations were similar in appearance to those produced by H particles. On moving the zinc-sulphide screen further from the source, the numbers fell off in the same way as

(*Phil. Mag.* **30** 240)

- Exp in **aria** (senza cera) ⇒ "particelle H"?

Further, on interposing sheets of aluminium between the source and screen, the curve of absorption was the same, within the experimental error, as the curve for H particles given in the previous paper. These results show that H particles are given off from the source, and that, unlike α particles, their velocities are not uniform, but are distributed in the same manner as those of H particles produced during the ordinary transmission of α particles through hydrogen.

(*Phil. Mag.* **30** 240)

- **"H particles given off from the source"**
- **"unlike α particles, their velocities are not uniform** but are distributed [as] H particles produced during ordinary transmission of α particles through H"

> These results would be explained if we were to assume that there is sufficient hydrogen either in the gas inside the α-ray tube, or in the material of the glass of the tube, or in any water-vapour or hydrogen occluded in the surface of the glass.

- ❑ H contenuto nel gas interno al tubo a raggi α?
- ❑ H nel vetro del tubo?
- ❑ H occluso nella superficie del vetro?

(*Phil. Mag.* **30** 240)

Marsden e Lantsberry stimano quanto H servirebbe per dar luogo al numero di "particelle H osservate":

- Rivestono il tubo a raggi α con un film di cera da 10 μ di spessore e scoprono che il numero di "particelle H" raddoppia $\Rightarrow$ **"about the same amount of H must be associated with the α-ray tube as with the wax"**

⬇

- massa per unità di area della cera ≈ $1{,}0 \times 10^{-3}$ g/cm^2
- cera = $C_{27}H_{56}$

$\Rightarrow$ **massa per unità area di H ≈ $0{,}15 \times 10^{-3}$ g/cm^2**

- **H nel vetro? No!** $\Rightarrow$ massa per unità di area del vetro ≈ 1,6 x 10^{-3} g/cm^2 ma vetro contiene solo 0,5% di H; inoltre, fenomeno si verifica anche con tubo di quarzo
- **H nel gas? No!** La massa di H richiesta equivale a uno spessore di 1,6 cm di H a NTP, valore non compatibile con H contenuto in un tubo con emanazione di Ra
- **H o vapore acqueo occluso nel vetro? No!** Le "particelle H" si osservano anche, addirittura "in greater number", con una sorgente a RaC depositato su Nickel scaldato a 150 °C

Thus there seems a strong suspicion that H particles are emitted from the radioactive atoms themselves, though not with uniform velocity. This does not necessarily disagree with the nuclear hypothesis unless it were further assumed that α particles are ejected not only with definite velocities from the radioactive atoms, but also in definite directions relative to the nuclear and electronic arrangements *.

⇒ "strong suspicion that H particles are emitted from the radioactive atom themselves"

(*Phil. Mag.* **30** 240)

Ma…
1914: Rutherford e Robinson avevano dimostrato che un tubo a raggi α non sembra emettere altro che raggi α

It is well known that a helium atom is expelled in many cases in the transformation of radioactive matter, but no evidence has so far been obtained of the expulsion of a hydrogen atom. In conjunction with Mr. Robinson, I have examined whether any other charged atoms are expelled from radioactive matter except helium atoms, and the recoil atoms which accompany the expulsion of α particles. The examination showed that if such particles are expelled, their number is certainly less than 1 in 10,000 of the number of helium atoms.

(*Phil. Mag.* **27** 488)

Summary.

(1) An accurate determination has been made of the deflexion of the α rays in a magnetic and electrostatic field of known intensities by the photographic method. A thin-walled tube filled with emanation was used as a source of α rays.

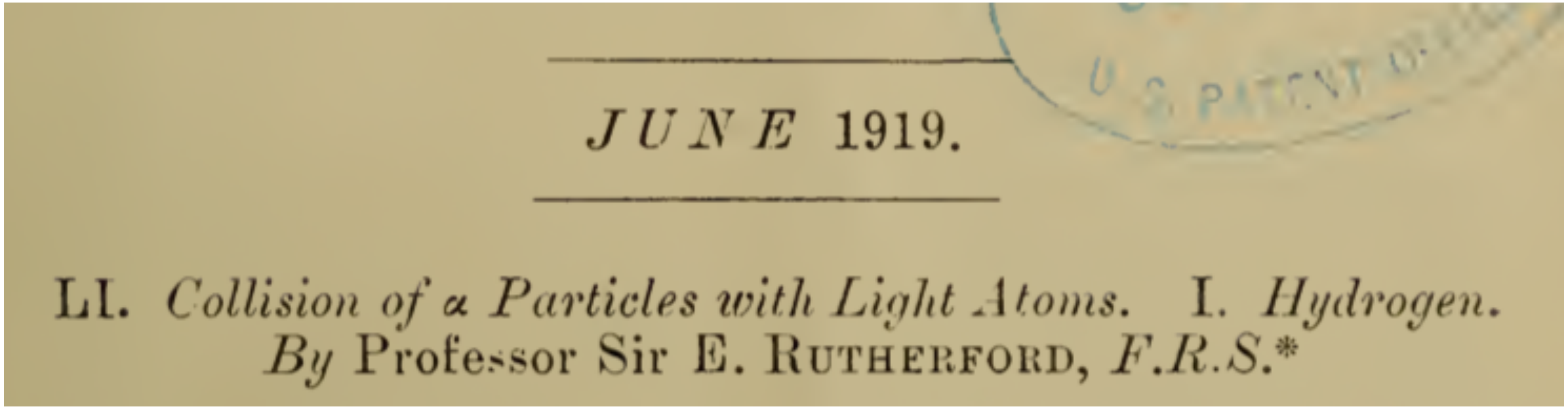
(7) No evidence has been found that particles differing in mass or charge from the α particle are emitted from an α-ray tube.

University of Manchester,
June 1914.

(*Phil. Mag.* **28** 552)

1915-1918: è (Grande) Guerra

- ❑ 1915: Marsden interrompe i propri esperimenti essendo nominato Professore di Fisica al Victoria College di Wellington (New Zealand)
- ❑ 1915-1918: attività di Rutherford molto frammentaria per il suo coinvolgimento nella ricerca militare (es. progettazione di un sistema di rilevamento acustico dei sottomarini nemici attraverso la piezoelettricità)


JUNE 1919.

LI. *Collision of α Particles with Light Atoms. I. Hydrogen.* By Professor Sir E. RUTHERFORD, *F.R.S.**

Rutherford cerca di capire se le "particelle H" provengono solo dal decadimento del RaC (Marsden aveva trovato un numero maggiore di scintillazioni con questa sorgente α) o anche da quello di RaEm e RaA

(*Phil. Mag.* **27** 488)

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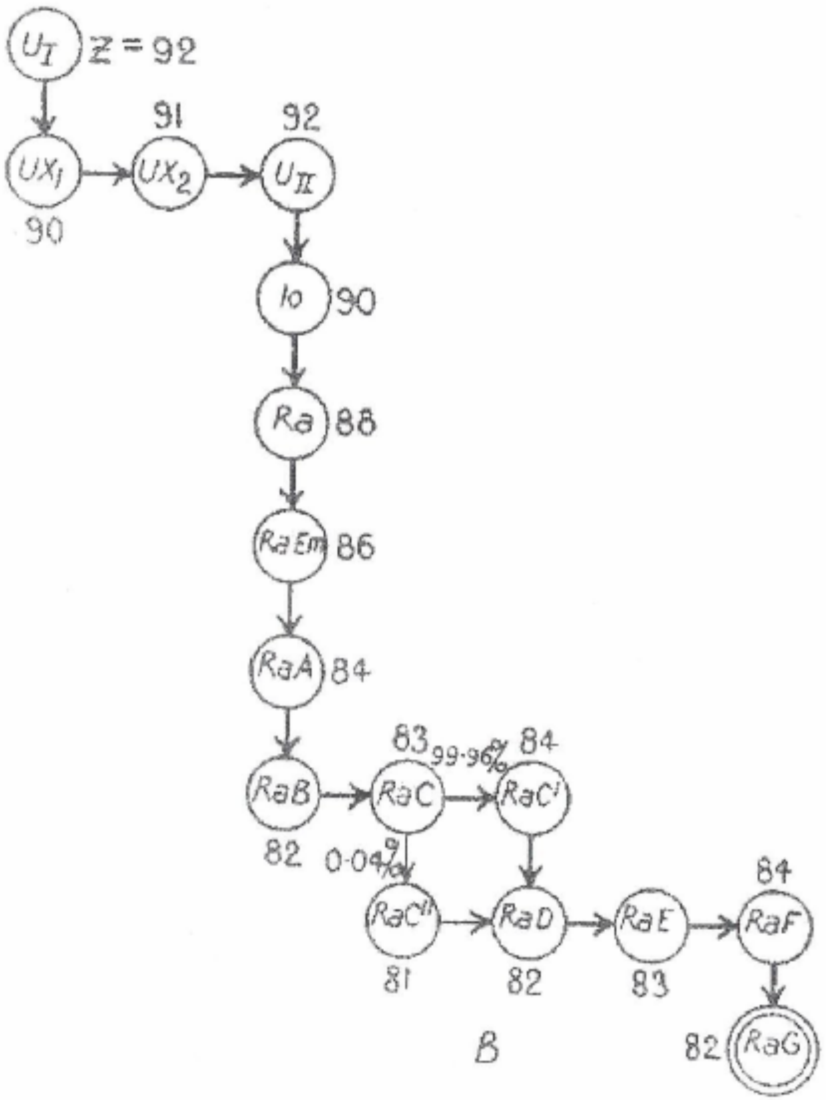

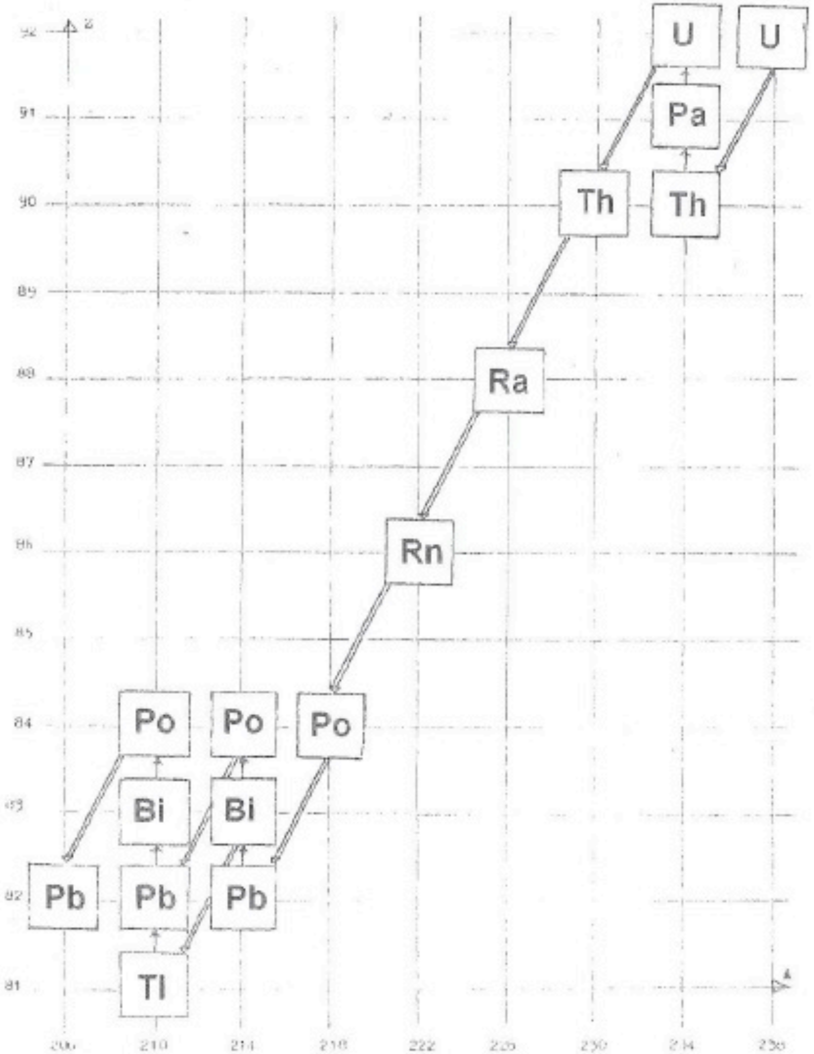

after it was filled with emanation. It is well known that the amount of radium C in such a tube increases at first very slowly. For example, after filling a tube with emanation, the fraction of the final amount of radium C present after 10 minutes is only 2 per cent., but reaches 9 per cent. after 20 minutes *. Consequently, observations made on the number of scintillations within 10 minutes after filling should decide definitely whether the scintillations arise from radium C alone and not from the other α-ray products present, viz. the emanation and radium A. In the latter case, the number of scintillations after 10 minutes should be only 2 per cent. of the final number reached about three hours later when radium C is in transient equilibrium with the emanation.

Dopo 10 min n. scintillazioni è > 20% del valore finale → se "atomi H" sono prodotto di disintegrazione radioattiva non provengono solo da RaC ma anche da RaEm e RaA

Rutherford formula comunque hp che gran parte delle "particelle H" osservate da Marsden non fossero tali

It will be seen later that the number of scintillations from hydrogen is much greater than is to be expected on the simple theory, and it is difficult to be sure of the absence of hydrogen as a contamination in the source and absorbers of the radiation. In addition, both nitrogen and oxygen atoms are set in such swift motion by collision with α particles that they cause scintillations outside the range of the α particles. It seems probable that the large number of scintillations observed by Marsden (*loc. cit.*) from a nickel plate coated with radium C were mainly due, not to H atoms, but to high-velocity N and O atoms produced from the air between the source and the screen.

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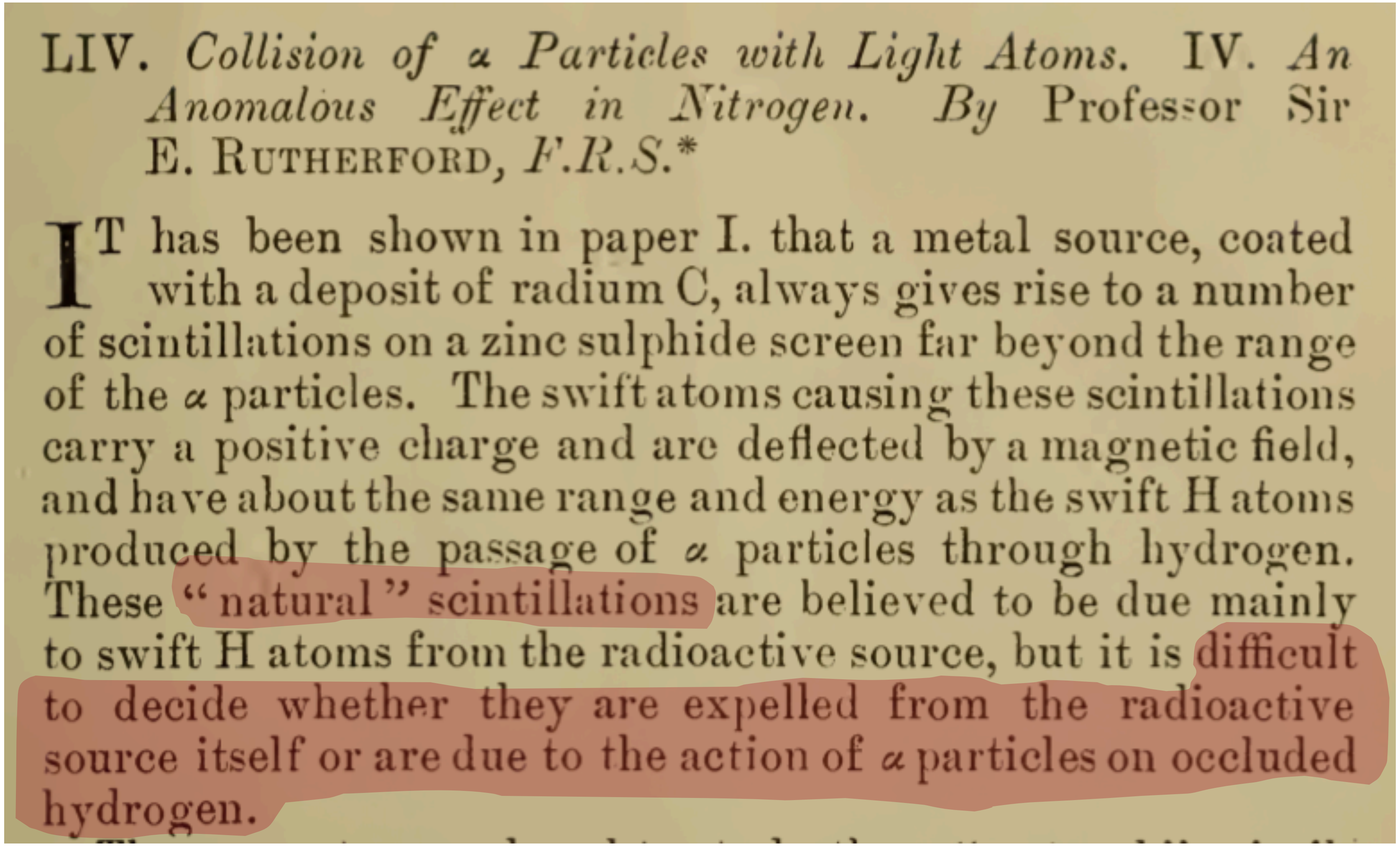
Secondo Rutherford, tuttavia, una piccola parte delle "particelle H" di Marsden proviene dalla sorgente α

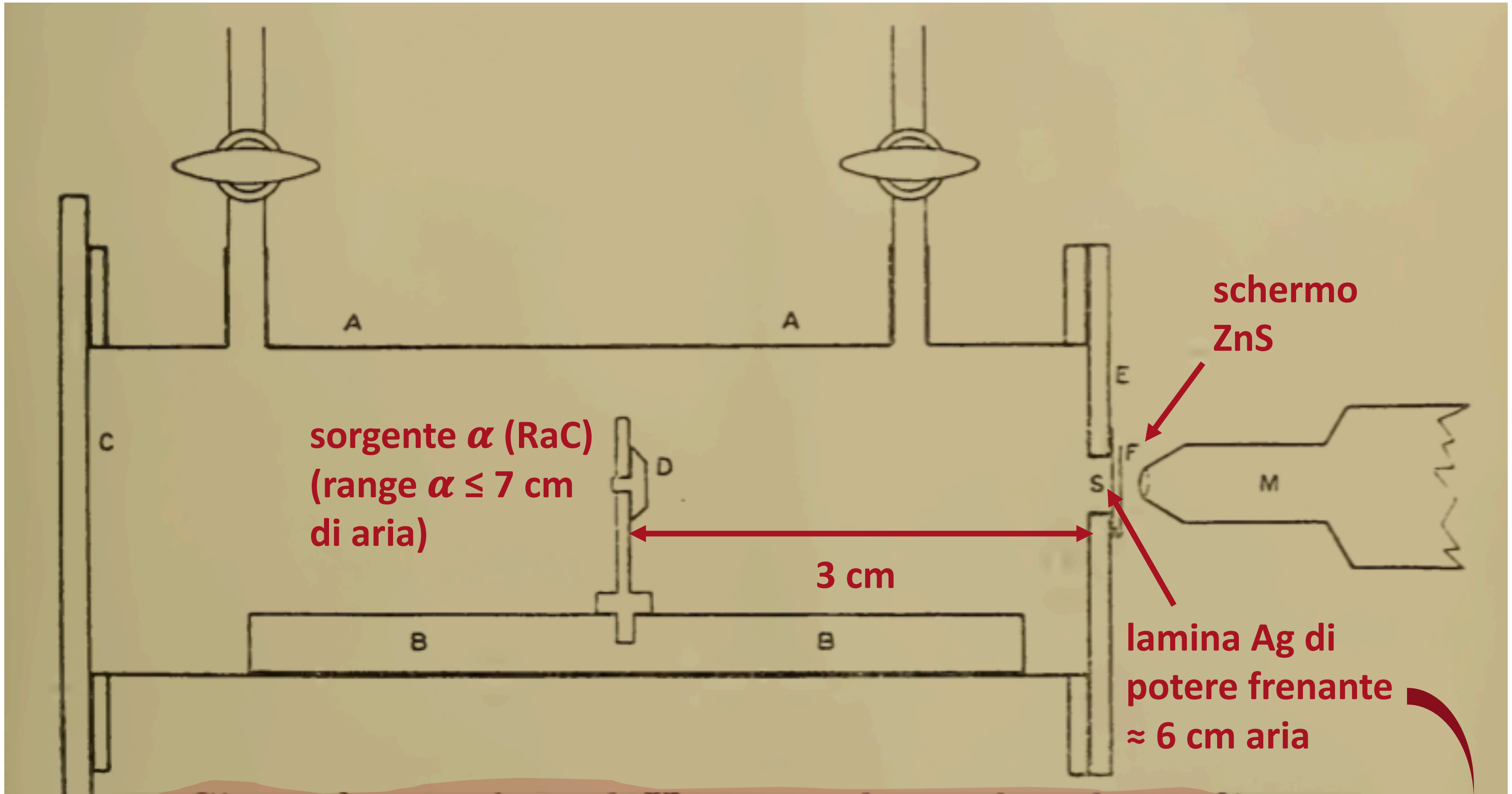
6. As observed by Marsden, hydrogen atoms are emitted by the radioactive source. The number observed is small, and it is difficult to decide whether these H atoms arise from the radioactive transformation or from occluded hydrogen in the source.

"An Anomalous Effect on Nitrogen"

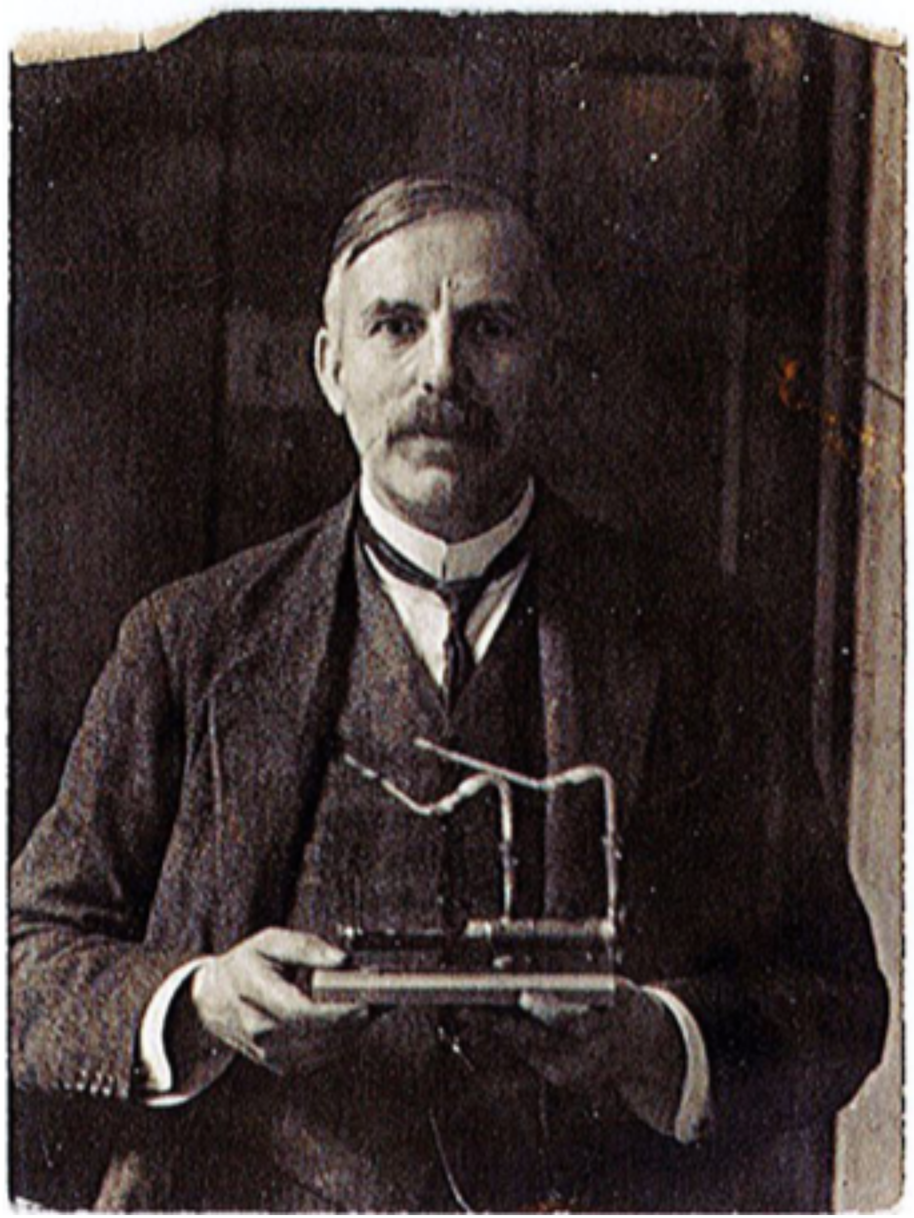


LIV. *Collision of α Particles with Light Atoms.* IV. *An Anomalous Effect in Nitrogen.* *By* Professor Sir E. RUTHERFORD, *F.R.S.**

IT has been shown in paper I. that a metal source, coated with a deposit of radium C, always gives rise to a number of scintillations on a zinc sulphide screen far beyond the range of the α particles. The swift atoms causing these scintillations carry a positive charge and are deflected by a magnetic field, and have about the same range and energy as the swift H atoms produced by the passage of α particles through hydrogen. These "natural" scintillations are believed to be due mainly to swift H atoms from the radioactive source, but it is difficult to decide whether they are expelled from the radioactive source itself or are due to the action of α particles on occluded hydrogen.



Since the number of H atoms observed under ordinary conditions is less than one in a hundred thousand of the number of α particles, H atoms, projected in the direction of the α particles, can only be detected when the α rays are stopped by the absorbing screens.

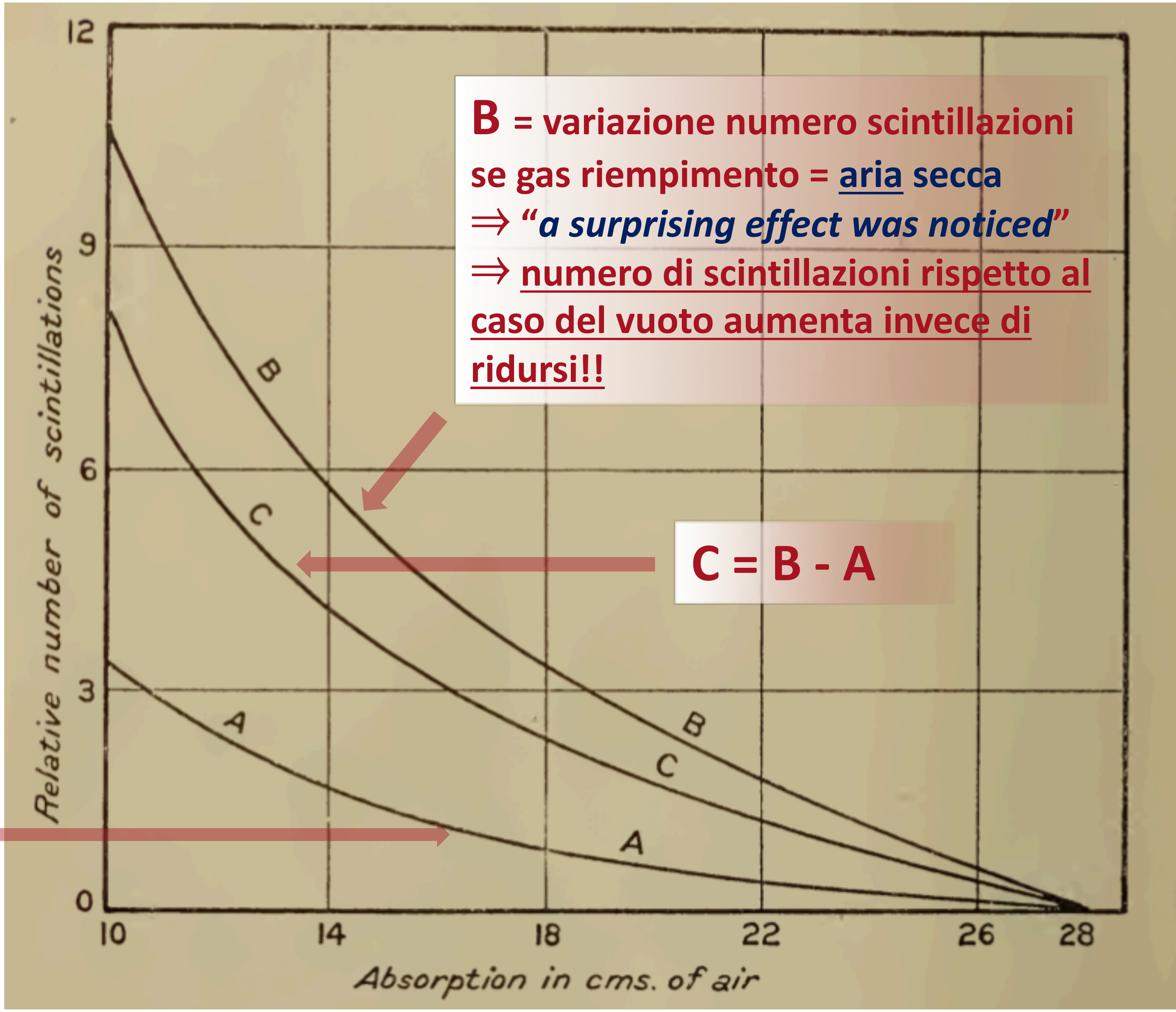


Fonte: S. Weinberg, “The Crisis of Big Science”; The New York Review of Books

http://www.nybooks.com/articles/archives/2012/may/10/crisis-big-science/

A = variazione numero scintillazioni "naturali"

- <u>vuoto</u> nell'apparato
- assorbimento in cm d'aria ottenuto con lamine di Al
- se gas riempimento = O_2 o CO_2 disseccato, num. scintill. si riduce in base a colonna di gas)



B = variazione numero scintillazioni se gas riempimento = <u>aria</u> secca
⇒ *"a surprising effect was noticed"*
⇒ <u>numero di scintillazioni rispetto al caso del vuoto aumenta invece di ridursi!!</u>

C = B - A

"Long-range scintillations" non spiegabili con

- ❑ **atomi N o O messi in movimento dalle** $\boldsymbol{\alpha}$ $\Rightarrow$ exp con assorbimenti > di 9 cm (*range* di N e O)
- ❑ **vapore acqueo nell'aria** $\Rightarrow$ risultati non cambiano se si usa aria disseccata
- ❑ **atomi H in pulviscolo nell'aria** $\Rightarrow$ risultati non cambiano se si filtra l'aria
- ❑ **altri gas presenti in aria ≠ N** $\Rightarrow$ risultati non cambiano con N preparato chimicamente

Discussion of results.

From the results so far obtained it is difficult to avoid the conclusion that the long-range atoms arising from collision of α particles with nitrogen are not nitrogen atoms but probably atoms of hydrogen, or atoms of mass 2. If this be the case, we must conclude that the nitrogen atom is disintegrated under the intense forces developed in a close collision with a swift α particle, and that the hydrogen atom which is liberated formed a constituent part of the nitrogen nucleus. We have

XXIV. *The Constitution of Atoms.* *By* Professor ORME MASSON, *F.R.S., University of Melbourne* *.

SINCE it must now be conceded that all material atoms are compounded of positive and negative electrical atoms, it is surely time that each of these fundamental and universal constituents were known by some distinctive name. This compliment has been paid to the one, but not,

* Communicated by Professor Sir E. Rutherford, F.R.S.

as yet, to the other. For convenience of reference and notation, if for nothing else, it is just as necessary to have a name for positive electrical atoms as for the electrons.

Though the hydrogen nucleus has been identified with the positive particle, it would not be well to adopt a name specially indicative of the fact; for hydrogen has no monopoly in these particles, which are also present in the nucleus of every other atom. Moreover, the electron is just as essential a constituent of hydrogen itself, though not of its nucleus, as is the positive particle.

(*Phil. Mag.* **41** 281)

4. Il nome

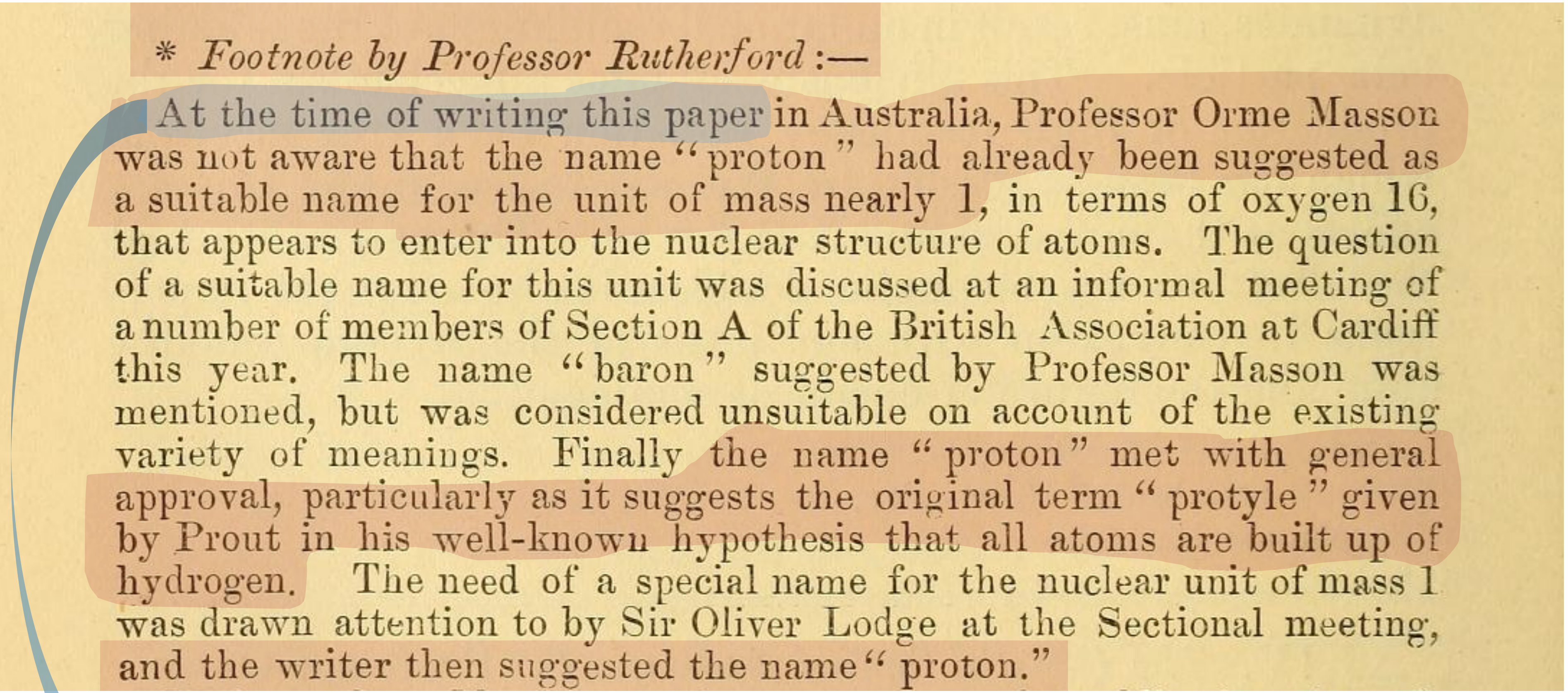
The outstanding characteristic of the electrons is that they mainly determine the electro-chemical characters of the atom; so they are well named. The outstanding characteristic of the positive particles is that they mainly determine the mass of the atom. I therefore suggest that they should be called *barons* (*βάρος*, weight)*.

If this name be adopted, we can conveniently symbolize the baron as *b*, using *e* for the electron. We thus have, in what follows,

b = one baron (charge +1, mass 1),

e = one electron (charge −1, mass negligible).

A may stand for the mass of any elementary atom with the atomic number N.



* *Footnote by Professor Rutherford* :—

At the time of writing this paper in Australia, Professor Orme Masson was not aware that the name "proton" had already been suggested as a suitable name for the unit of mass nearly 1, in terms of oxygen 16, that appears to enter into the nuclear structure of atoms. The question of a suitable name for this unit was discussed at an informal meeting of a number of members of Section A of the British Association at Cardiff this year. The name "baron" suggested by Professor Masson was mentioned, but was considered unsuitable on account of the existing variety of meanings. Finally the name "proton" met with general approval, particularly as it suggests the original term "protyle" given by Prout in his well-known hypothesis that all atoms are built up of hydrogen. The need of a special name for the nuclear unit of mass 1 was drawn attention to by Sir Oliver Lodge at the Sectional meeting, and the writer then suggested the name "proton."

Ottobre 1920 ⇒ pubblicato su Phil. Mag. 41 (1921)
… 100 anni fa!

Case-study importante anche in chiave didattica per lavorare sulla *Nature of Science*

- scoperta p ha **lunga** storia
- è il risultato del contributo di **molti**
- illustra il ruolo complesso delle **anomalie**
  - scoperta di **long-range scintillations** simili a H anche quando non ci sono (abbastanza) atomi H …
  - conduce a idea di **nuova forma di decadimento (naturale)** $\Rightarrow$ idea di **disintegrazione (artificiale)** $\Rightarrow$ scoperta **protone**
  - ma … gran parte delle scintillazioni viste inizialmente probabilmente dovute ad atomi di N e O in moto…

GRAZIE DELL’ATTENZIONE!