The Franck-Hertz Experiments, 1911–1914

Experimentalists in Search of a Theory

James Franck

Gustav Hertz

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Physics Interest Group
History of Science Program
University of Minnesota
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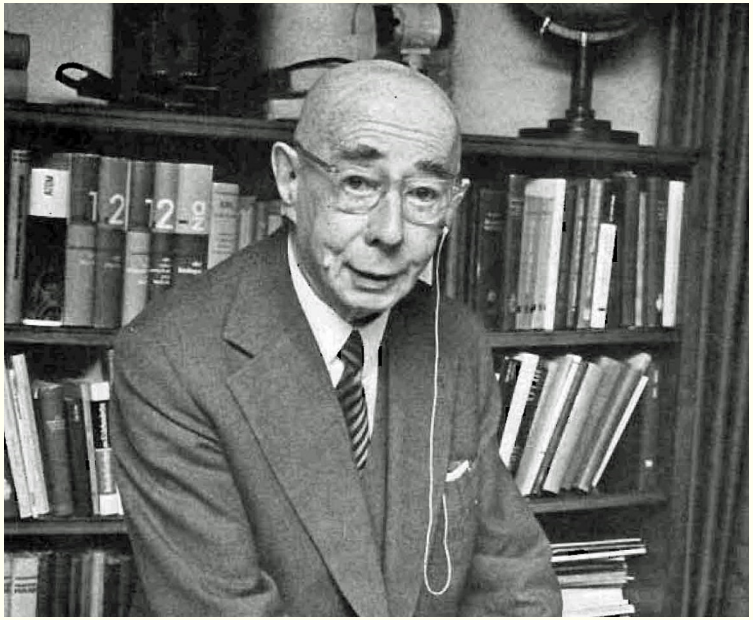
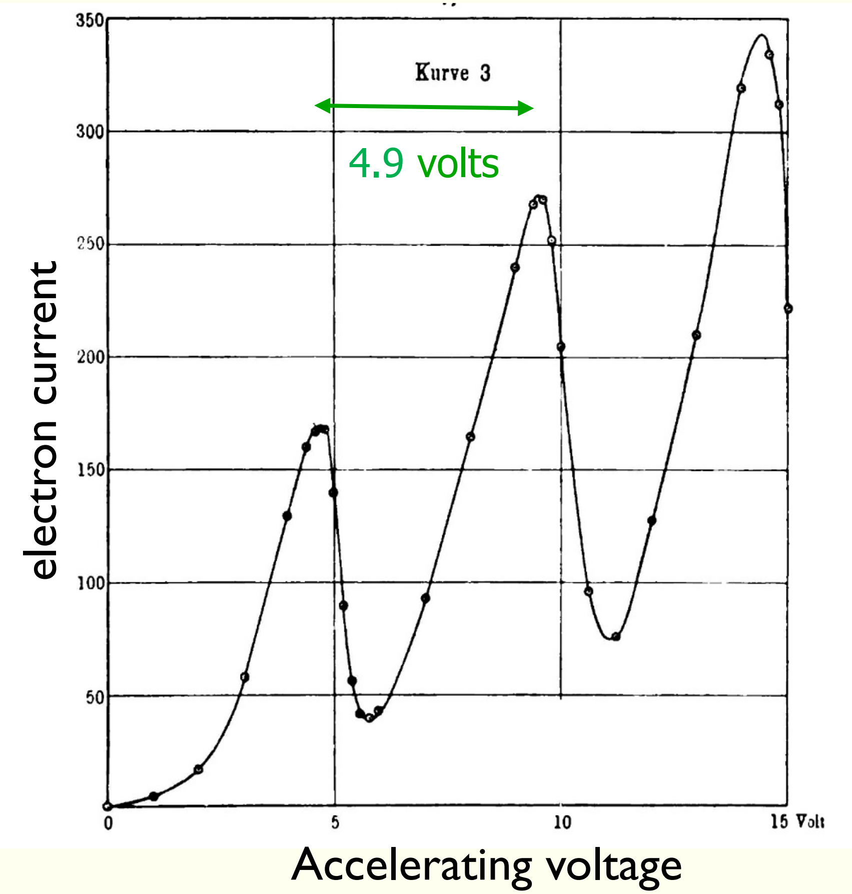
EXPERIMENTAL PHYSICS

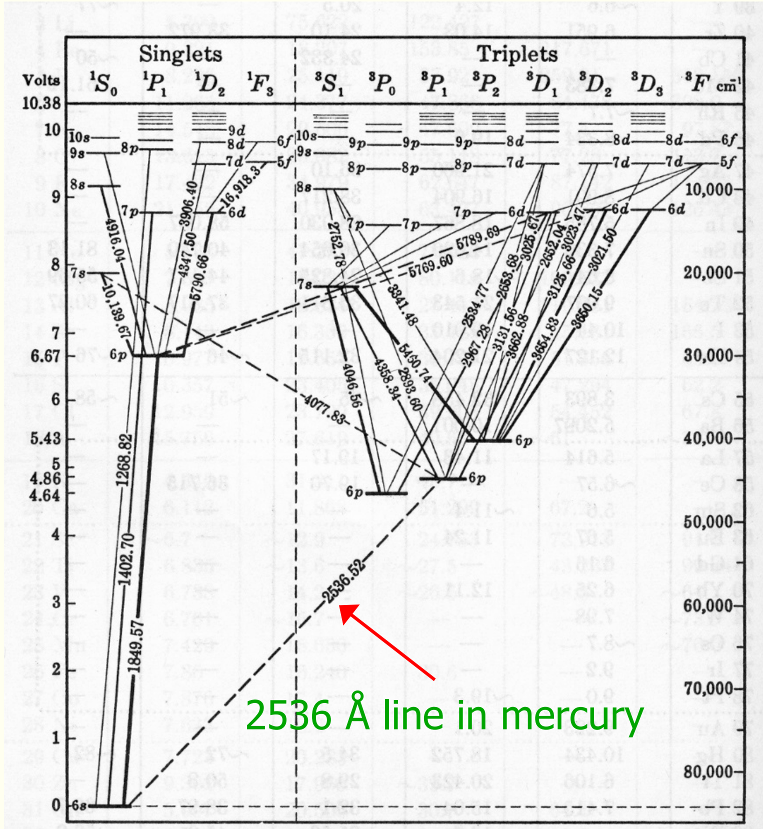


Now, the whole situation was of course entirely different then. A physicist worked essentially with the hands. I mean, also some with the head, but the greatest part of the day, it was certainly manual work.

Gustav Hertz
Lindau lecture, 1968

Franck and Hertz in 1914: The Textbook View

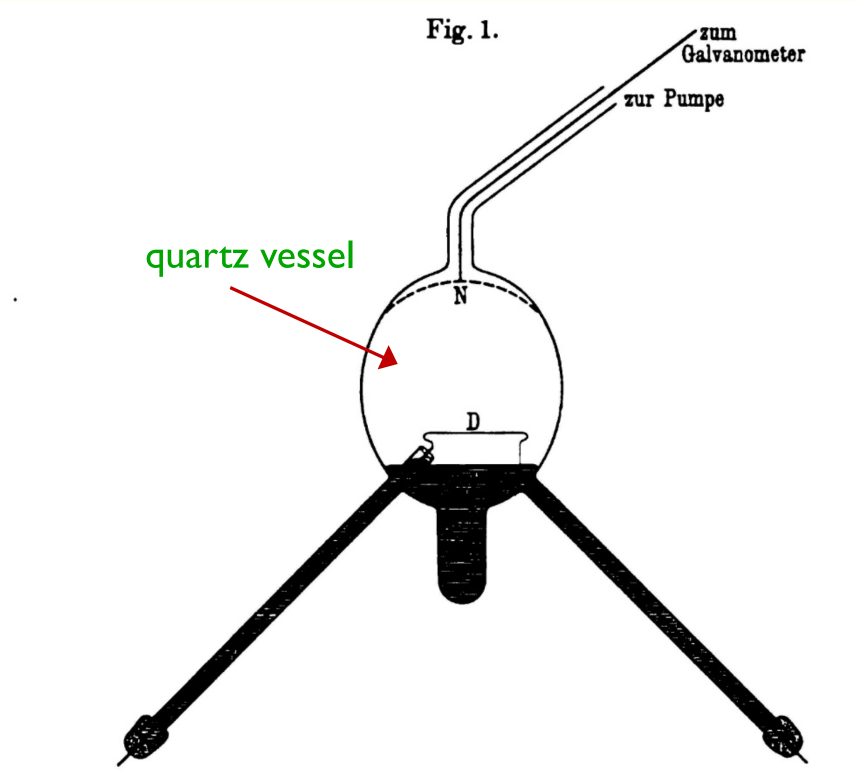




In 1914, Franck and Hertz bombarded mercury vapor atoms with slow electrons.

- the peaks in their graph of electron current vs. accelerating voltage as the onset of inelastic collisions, in which energy was transferred to the mercury atom.
- This energy, 4.9 eV, corresponds to the 2536 Å resonance line in mercury
- Conclusion: The transferred energy raised the mercury atom to an excited state, just as the Bohr picture of stationary states predicts.

The Textbook View: Bohr's Theory Confirmed



Franck and Hertz confirmed (with a borrowed ultraviolet spectrometer) the presence of the 2536 Å line of mercury (and only that line), as they raised the accelerating voltage of the electrons in the quartz vessel through 4.9 volts.

UNFORTUNATELY …

- Franck and Hertz did not so much as mention Bohr's theory in 1914
- They began their collaboration in 1911, well before Bohr's theory.
- They thought they were measuring ionization potentials, *not* excited states.
- They had an entirely different picture of electrons in atoms

… in every mercury atom an electron is present that can oscillate with a frequency corresponding to the wavelength 253.6 μμ.

- Even worse:

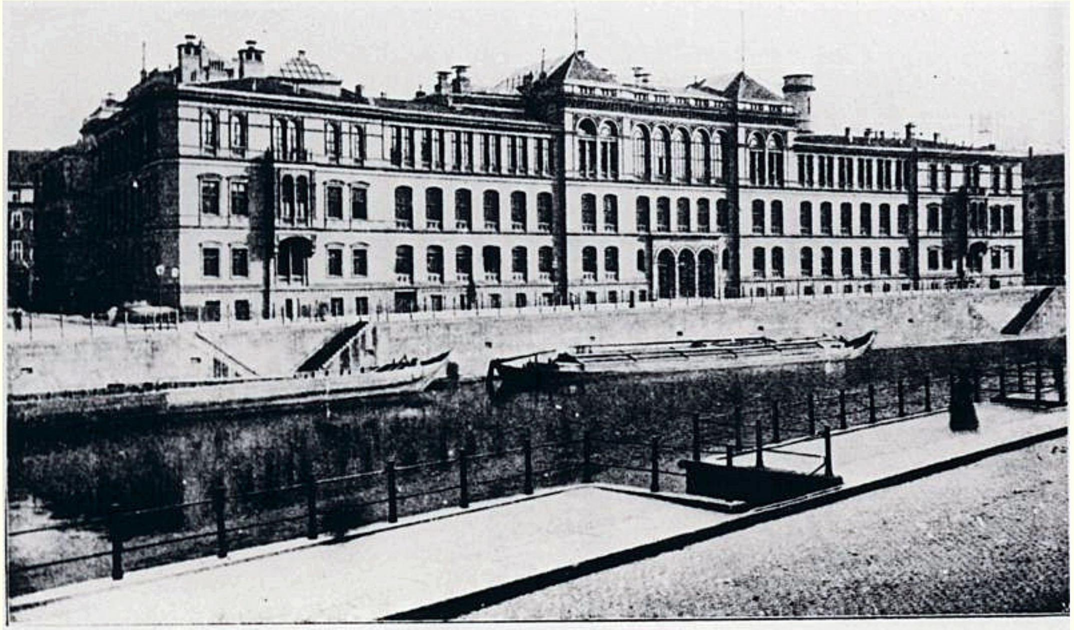
The original goal of our experiments had nothing to do with atomic or quantum physics.

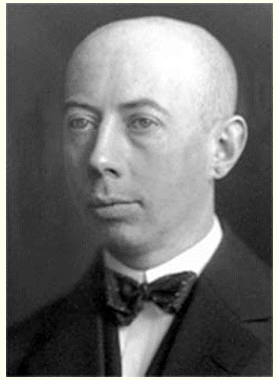
Gustav Hertz, 1975

WHAT WAS THEIR ORIGINAL GOAL?

WHAT WAS THE CONCEPTUAL AND EXPERIMENTAL CONTEXT?

The Physical Institute, University of Berlin


Die naturwissenschaftlichen und medicinischen Institute der Universität.



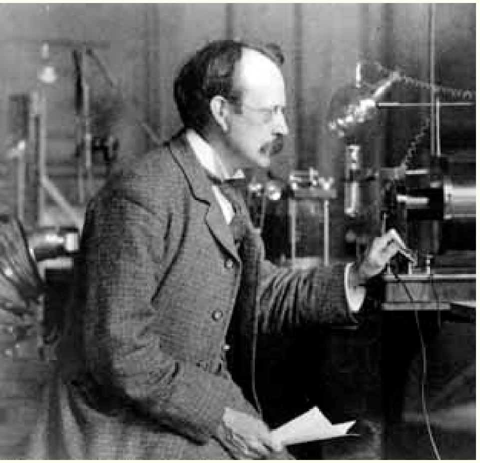
James Franck
Ph.D. 1906
gas discharge;
then ion mobility

Physics in Berlin, early in the 20th century:

- close-knit group of young, enthusiastic experimentalists (Robert Pohl, Wilhelm Westfall, Lise Meitner, …)
- J. J. Thomson, the Cavendish, and the electron
- quantum theory (Planck, Nernst, Einstein ...)

Gustav Hertz
Ph.D. 1911
ir absorption
in CO_2

Thomson, Rutherford, and the Cavendish



J. J. Thomson

Ernest Rutherford
Arrived at
Cavendish in 1895

The study of the electrical properties of gases seems to offer the most promising field for investigating the Nature of Electricity and the Constitution of Matter ….

J. J. Thomson
Conduction of Electricity through Gases (1903)

J. J. Thomson was our physical Bible. We had to look at his things and to read it and reread it.

James Franck
AHQP Interview

Rutherford and Ion Mobility

The newly discovered electron and other equally new phenomena—x-rays, radioactivity, and the photoelectric effect—not only opened new and exciting windows into nature, but also made possible an unexpected range of new experimental techniques. **Electrical conductivity in gases** became a central theme.

Thomson and his students, including Ernest Rutherford, the American John Zeleny, and John Sealy Townsend, **had ionized gases using x-rays, ultraviolet light, and alpha emitters.** Thus, a positive ion is formed by removing an electron from an atom or molecule. A negative ion is formed if an electron attached itself to a neutral molecule.

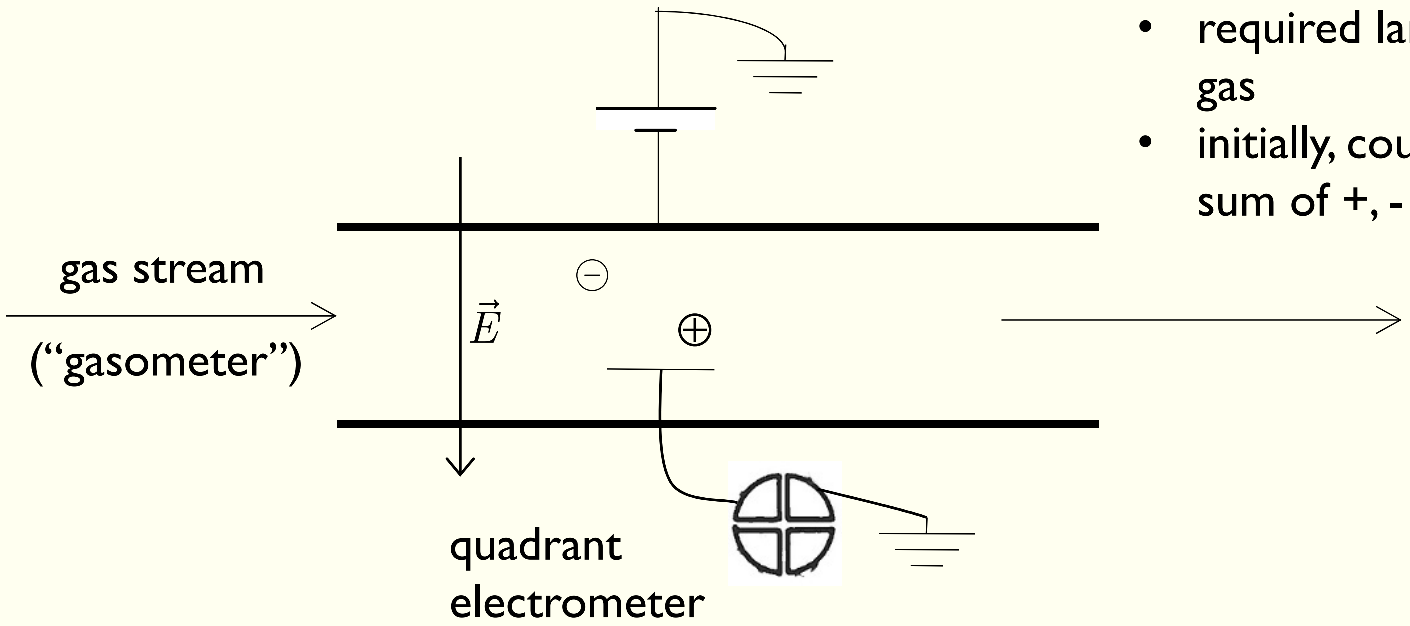
Ion mobility: The constant speed at which an ion moves under an electric field of 1 volt/cm. For common gases at **atmospheric pressure**, these mobilities are on the order of a few cm/sec, with negative ions having slightly larger mobilities than positive ones. **These negative ions were not "corpuscles" (aka electrons).**

Rutherford had in fact developed two different experimental techniques for measuring ion mobilities (1897 and 1898), following joint paper with J. J. (1896).

This history is not especially well known.

RUTHERFORD AND ION MOBILITY

Method 1: Subject a gas streaming down a tube to a perpendicular electric field.



Disadvantages:

- required large quantities of gas
- initially, could measure only sum of +, - ion currents

Rutherford and Ion Mobility

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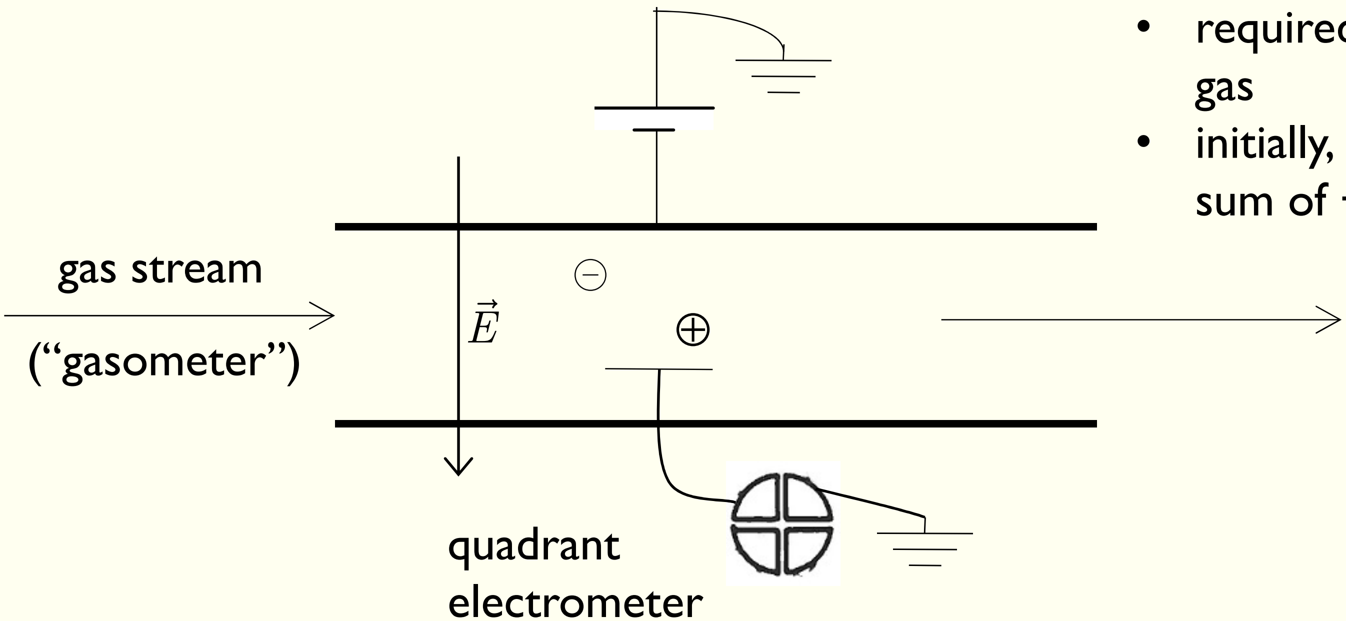

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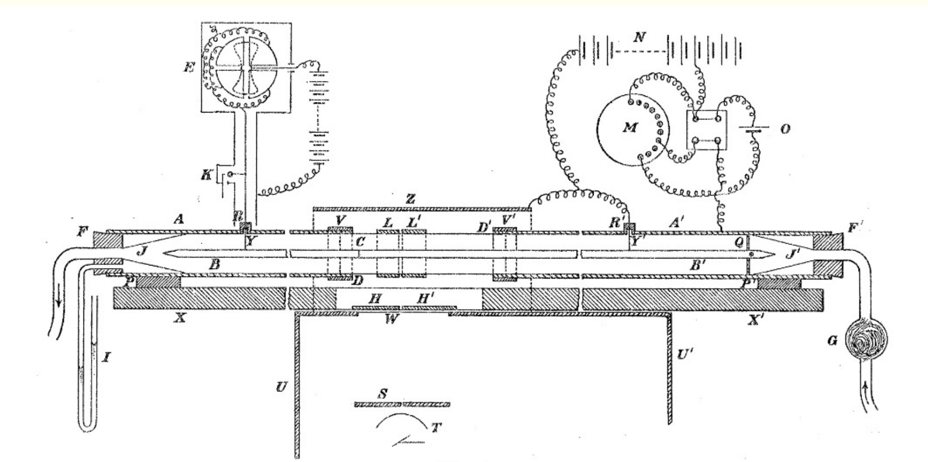
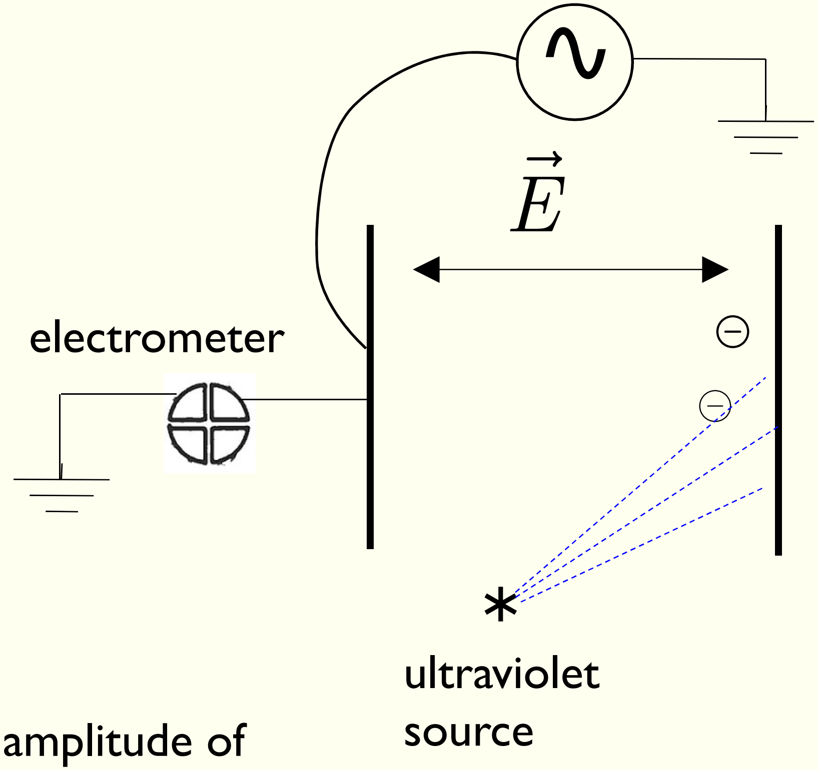


Fig. 2.

Of course, some versions were a little more complicated … (Zelany, 1900)—measured positive and negative mobilities separately; negative slightly larger

Rutherford and Ion Mobility



Method 2 (1898 version):

- uv light liberated photoelectrons electrons, which immediately formed negative ions
- so only mobilities of negative ions measured
- Ions entered a chamber in which they moved under the influence of an electric field that rapidly changed direction.
- Thus, depending on the frequency and amplitude of the electric field and the distance between the electrodes, the ions might or might not reverse direction before striking a collecting electrode that was connected to an electrometer.
- The rapid increase in the electrometer reading when ions were collected allowed an straightforward calculation of the mobility.
- apparatus enclosed in a bell jar ⇒ pressures lower than atmospheric possible

Franck and Ion Mobilities: 1906

James Franck

Franck began Ph.D. research with Emil Warburg at the Berlin Physical Institute, working on "point discharges" in gases

- decided to work on ion mobilities for ions created by point discharges
- first tried Rutherford's method 1; results inconsistent with Zelany
- then turned to Rutherford's method 2

Emil Warburg

point discharge

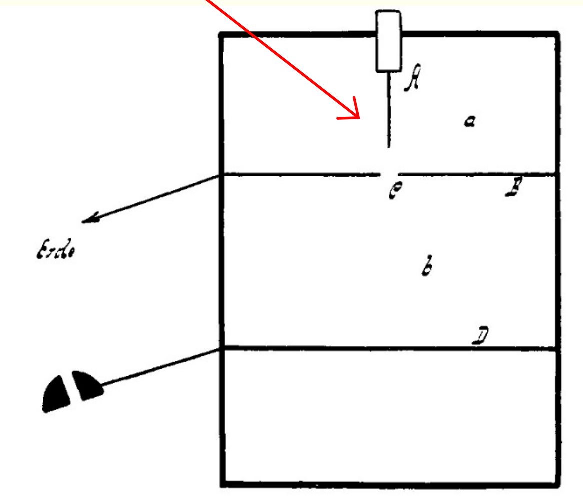


Fig. 4.

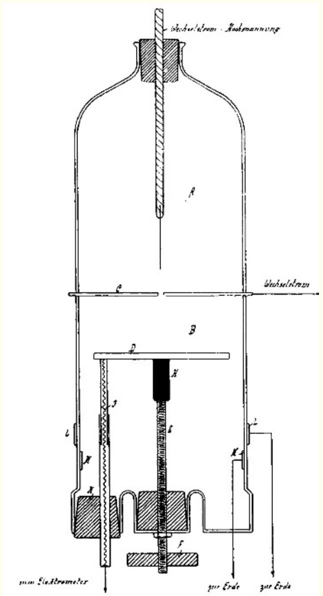


Fig. 5.

This time, Franck found mobilities in air consistent with Zelany's results.

- measured mobilities of both positive and negative ions
- note technique: ions created by discharge in separate (top) region; migrated into measurement region through small opening in top plate

Franck and Robert Pohl: Ion mobilities, 1907

James Franck

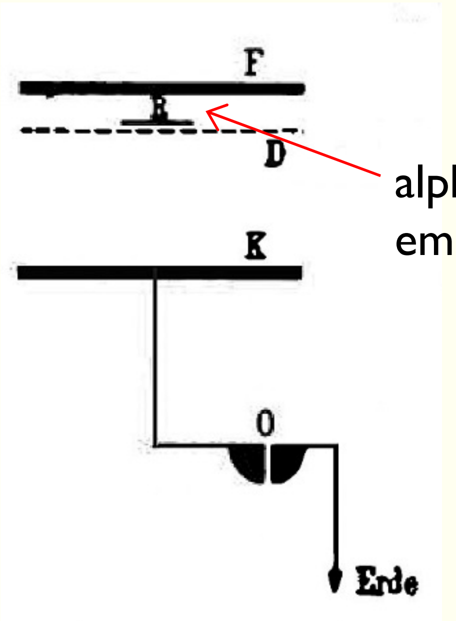
In 1907, Franck and Robert Pohl measured ion mobilities using a new version of Rutherford's Method 2:

- used small amounts of *highly purified* gas (~ 30 cm^3)

  ⇒ could measure mobilities for rare and expensive gases such as helium

- used alpha emitter to create ions ⇒ could measure **both** positive and negative mobilities

Robert Pohl



alpha emitter

Note similar technique: ions created in separate (top) chamber; moved into lower measurement chamber through mesh top electrode.

- confirmed Zelany's results for a few gases (e.g., air)
- measured mobilities for helium—similar to above (a few cm/sec)

To this point, Franck had shown himself to be a clever and innovative experimentalist; but results were hardly earth-shaking.

Franck and Ion Mobilities: 1910

In 1910, Franck returned to this technique to measure mobilities in mixtures of argon and diatomic gases.

- picked argon because its mobilities had not been previously measured.
- mobility of positive ion in argon about as expected, 1.37 cm/sec); BUT
- mobility of negative ion was huge, about 200 cm/sec

This investigation produced an extraordinary [*merkwürdig*] result …

- mobility slowly decreased over several days
- addition of 1.5% oxygen decreased mobility to about expected value (1.7 cm/sec)
- similar behavior in nitrogen
- Franck asked: Why not in helium? (later turned out: more sensitive to contaminants)

Conclusion: Electrons in argon remained free; they did not immediately combine with neutral molecules to form negative ions.

Hertz stated emphatically in his 1963 AHQP interview that this result led directly to their experiments on **ionization by collision**. To see why …

John Sealy Townsend

John Sealy Townsend

Educated at Trinity College Dublin, where he studied mathematics and physics; graduated in 1890.

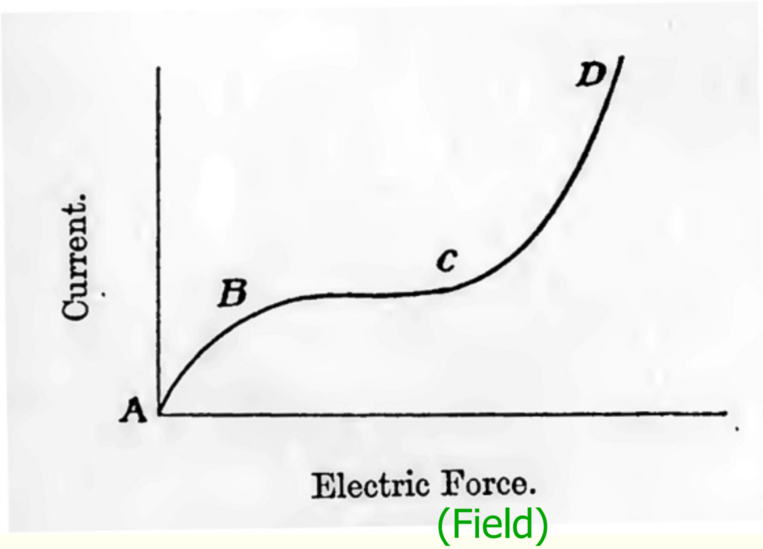
Came to the Cavendish in 1895, at the same time as Rutherford

Quickly made a name for himself as an experimentalist:

- did the first measurement of the charge on the electron; his technique influenced later experiments, including Robert Millikan's—as Millikan acknowledged in his book.
- experiments on the diffusion of ions, combined with Rutherford's experiments on ion mobilities, showed that their average charge was the same as that of the hydrogen atom in electrolysis
- in the early 1920s, he discovered that very low energy electrons had extraordinarily long mean free paths in a number of gases, an effect independently discovered by Carl Ramsauer.
- in 1899, was made a fellow of Trinity College, Cambridge
- became the Wyckham Professor at Oxford in 1900

He never accepted either relativity or quantum theory, and never accepted the Franck-Hertz discoveries. His reputation probably suffered as a result.

John Sealy Townsend and Ionization by Collision



In 1900, Townsend published the first in a series of papers investigating collisions of low-energy electrons ("negative ions") with gas molecules.

The graph, taken from the first page of his 1910 book, illustrates his results.

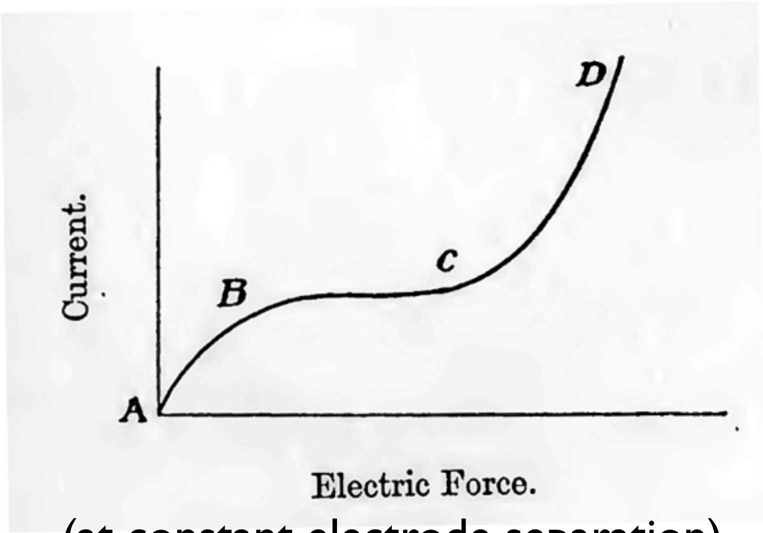
He created electrons using the photoelectric effect or x-rays and accelerated them in an electric field, at **pressures of, typically, a few mm of mercury**.

The current rose steadily and then leveled off: In the region BC, *all* newly created electrons were collected at the positive electrode, so an increase in electric field could not increase the current. This much had been discovered earlier by Thomson and Rutherford.

Townsend discovered that at higher fields, collisions created new electrons, thus starting a cascade effect at C in which the current rose rapidly. These cascades took place at electron energies **much lower** than those typical of cathode rays.

> **… it is necessary to attribute to ions moving with comparatively small velocities the property of producing ions from molecules of the gas …** (Townsend 1915)

John Sealy Townsend and Ionization by Collision



(at constant electrode separation)

Townsend found he could describe the current produced in these cascades with a function involving an exponential term $e^{\alpha x}$

where α is the number of new "ions" (electrons) created by collision as the original ion moves 1 cm in an electric field of 1 volt/cm and *x* is the distance through which the electron moves.

This scheme described his data reasonably well; but in addition, Townsend derived a **theoretical** expression for α:

$$\alpha = \frac{1}{\lambda} e^{-\frac{V}{\lambda X}}$$

where λ = mean free path
X = electric field
V = ionization potential

Plausible guesses for *V* and λ led to reasonably good numerical agreement with his experimental values for α. These values of *V*, for different gases, were his reported ionization potentials. **BUT**

His derivation assumed that electrons lost all of their energy in collisions, even when the electron kinetic energy was smaller than the ionization potential.

Franck and Townsend

- Hertz said that Franck's discovery of enormous negative-ion mobilities had set the stage for their collaboration.
- Those large mobilities $\Rightarrow$ free electrons that do not form negative ions even at high pressures
- Franck in 1910 (and later) also cited British papers showing that at high (atmospheric) pressures, helium conducts electricity comparatively easily $\Rightarrow$ easy to strike arc/glow discharge $\Rightarrow$ easy to ionize
- Townsend's theory: Electrons lose all energy in collisions, even when kinetic energy less than ionization energy

How did Franck put all these themes together?

Franck and Townsend

How did Franck put all these themes together?

Hertz's reconstruction:

- Franck quickly became dubious about Townsend's theory
- If Townsend were right, then an electron must take on ionization energy as it runs through a **single** mean free path

  ⇒ only two ways in which easy conductivity of helium possible

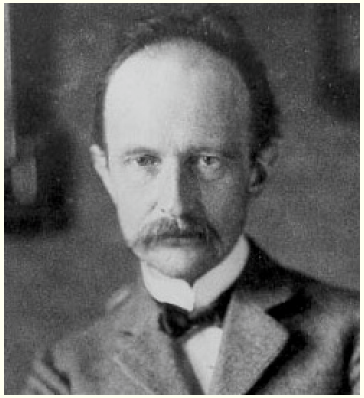
  - low ionization potential
  - very long electron mean free path

In addition, if Townsend wrong, and given large negative mobilities in noble gases

- electrons were apparently "reflected" from molecules, and not absorbed to form negative ions
- And if they were reflected, how much energy did they lose?

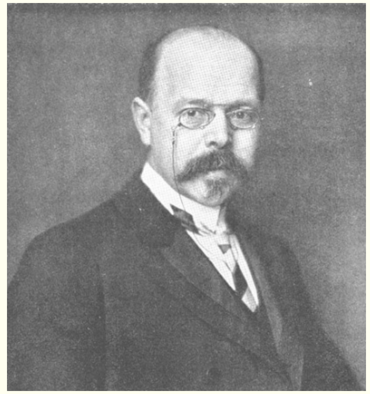
Franck and Hertz set out to measure just these quantities: ionization potential, electron mean free path, and energy loss in collisions. But first …

Quantum Theory



Max Planck

Physical Institute
University of Berlin



Walther Nernst

That colloquium was the greatest event in my life. There all the professors of physics, and not only of the University but also of the Technische Hochschule and also of the Bureau of Standards -- everyone who was interested in science came to these things…

I believe the reason that many of us who went into physics at that time tried to do something with quantum theory, is that we went to that colloquium.

James Franck, 1962

Franck and Hertz, October 1911

On a Connection between the Quantum Hypothesis and the Ionization Potential

Not quite an afterthought, but *not* the central motivation

ionization energy = $h\nu$

But what is the frequency ν ?

Franck and Hertz suggested the frequency of the "**selective photoelectric effect**" in alkali **metals** (discovered by Robert Pohl and Peter Pringsheim) might apply to **gases**. (spurious "resonance" effect; don't ask)

A theory by Friedrick Lindemann related the selective photoeffect frequency to **atomic radius**.

Pohl, Pringsheim, and Lindemann were all at the University of Berlin.

calculate or measure $\nu_{selective\ photoeffect}$

measure ionization potential, see if

ionization energy = $h\nu_{selective\ photoeffect}$

In the near future, we will attempt to determine the ionization potential of a series of gases directly ... , and hope thus to contribute to an experimental clarification of the question.

Franck and Hertz, October 1911

On a Connection between the Quantum Hypothesis and the Ionization Potential

In their later years, both Franck and Hertz seemed a little embarrassed by this paper.

Franck, in his 1962 AHQP interview, said he could not remember it.

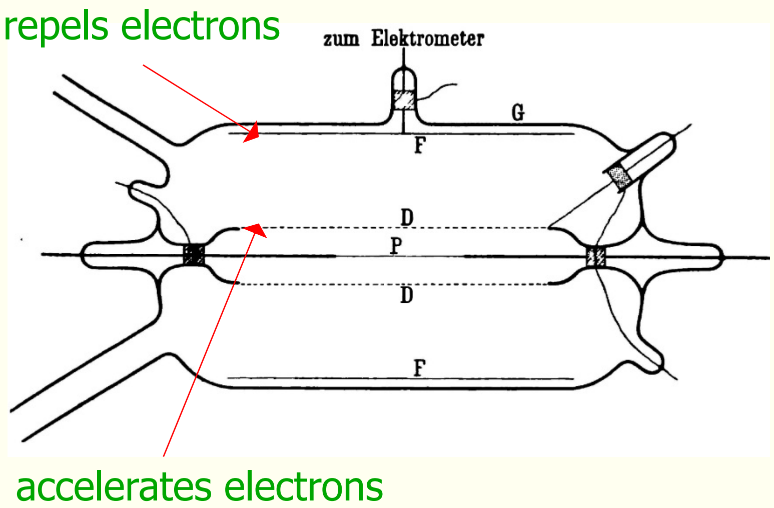
Hertz, in his 1963 AHQP interview, was positively dismissive:

> **Franck was always aiming to publish something … I believe we do not need to go into it any further.**

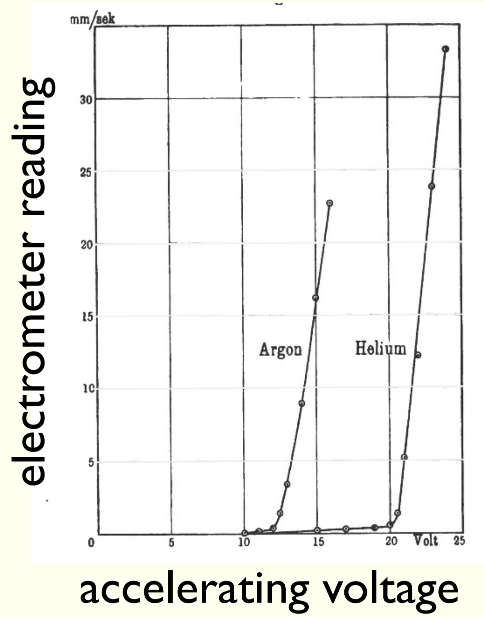
Nevertheless, they kept coming back to this scheme and possible alternatives, and thus were fully prepared when in 1914 they found a more plausible quantum effect.

Franck and Hertz, January 1913

Measurement of the Ionization Potential in different Gases



design adapted from Phillip Lenard, who had tried to measure ionization potentials by directly detecting positive ions



The experiment was designed to measure the ionization potentials of helium, argon, and several other gases by detecting (**what they thought were**) positively charged ions. In fact, were seeing photoelectrons ejected from the collecting electrode.

Design emphasized cleanliness, eliminating contaminants

- electrical leads fused into the glass tube—no vacuum grease seals
- carefully purified gases
- platinum electrodes
- carefully washed; filament degassed under high vacuum (Gaede pump, liquid air cold traps)

Franck and Hertz, January 1913

	helium	neon	argon	hydrogen	oxygen	nitrogen
Townsend	14.5		17.3	26		27.6
Franck-Hertz	20.5	16	12	11	9	7.5
Lenard	about 11 volts for all gases measured					

Franck and Hertz's results were **… strange to say, in almost the opposite sequence to Townsend's: Helium has the greatest ionization potential, nitrogen the smallest.**

Arnold Sommerfeld, 1914

From our measurements we drew the in fact correct conclusion that the noble gases helium and neon had the highest ionization potentials of all gases, and that therefore their behavior in gas discharge can by no means be explained by extremely low values of the ionization potential in the sense of Townsend's theory. Hence there remained only the possibility of extremely large mean free paths of electrons in noble gases.

Gustav Hertz, 1966

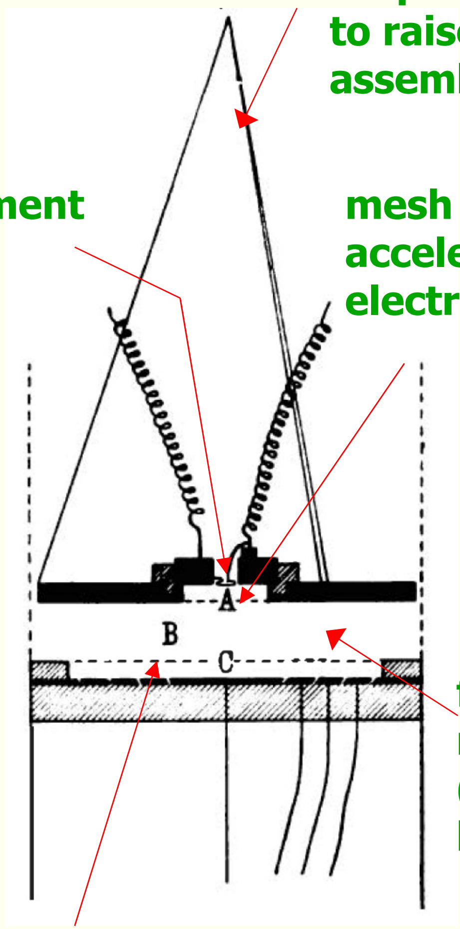
Above all the monatomic metal vapors of mercury and the alkalis should be investigated, since Pohl and Pringsheim found the frequency of the selective photoeffect for them.

Franck and Hertz, January 1913

NATURE OF THE COLLISIONS: 1913

On Collisions between Gas Molecules and Slow Electrons (April 1913)

On Collisions between Gas Molecules and Slow Electrons. II. (July 1913)



suspending chains, to raise/lower top assembly

filament

mesh accelerating electrode

field-free region (adjustable height)

decelerating region and collecting electrode

MEAN FREE PATH

Electrons are accelerated, pass through mesh into field-free region, under pressures $\sim$ 0.1 mm Hg

- height of field-free region adjustable *under vacuum*, with chains

Kinetic theory: The number *n* of electrons that continue towards collector (i.e., not "reflected" or absorbed in collisions) as function of vertical distance *x* is

$$n = n_0 e^{-\frac{x}{\lambda}}$$

It is found in agreement with Lenard that the mean free paths of electrons … is very close to the free path calculated from kinetic theory.

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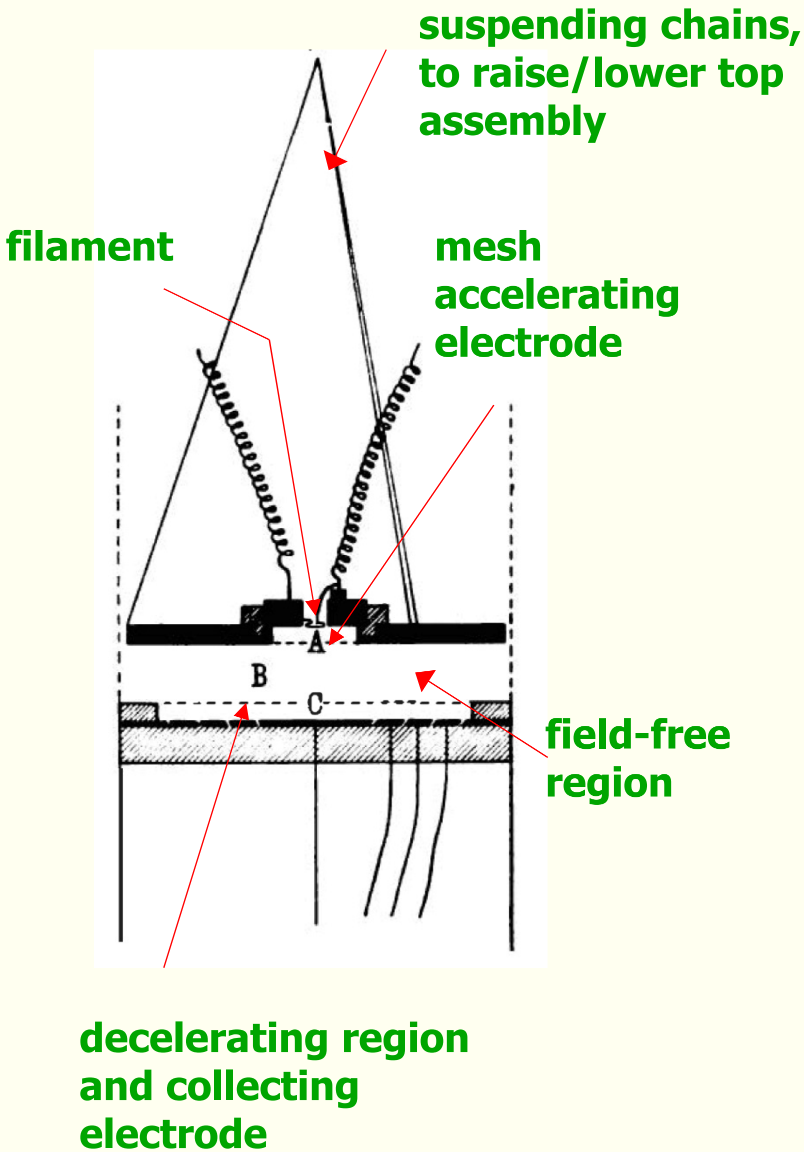


REFLECTED OR ABSORBED?

If one compares this result with a few other phenomena in gas discharge, then one is compelled to conclude that it is impossible that electrons ... suffer so inelastic a collision that they give up all energy to the gas molecule and eventually are absorbed by the molecule.

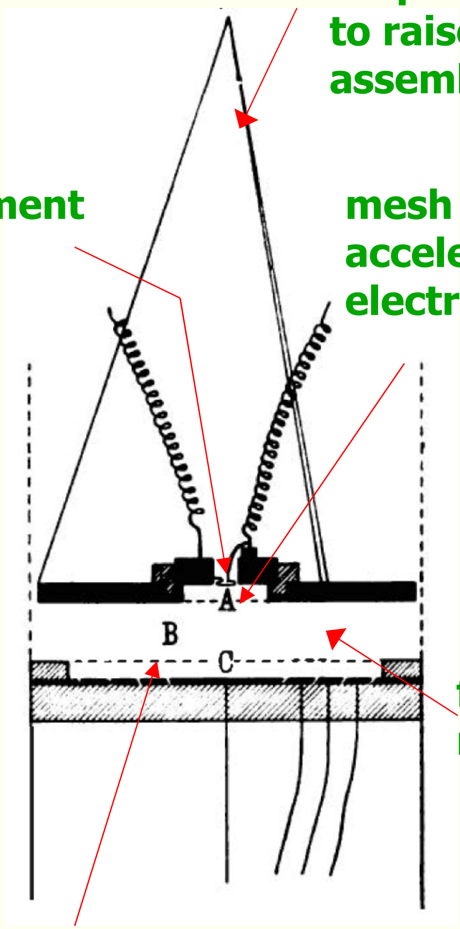
That absorption cannot exist in helium, at least, follows from measurements of ion mobility by one of us, that shows that in helium, argon, and nitrogen the electrons in general are not absorbed...

Likewise, an entirely inelastic collision without absorption appears impossible.

Nature of the collisions: 1913

On Collisions between Gas Molecules and Slow Electrons (April 1913)

On Collisions between Gas Molecules and Slow Electrons. II. (July 1913)



Reflected or Absorbed?

A second experiment in the April paper that I am leaving out gave preliminary evidence that in helium, at least, electrons lost little if any energy in collisions.

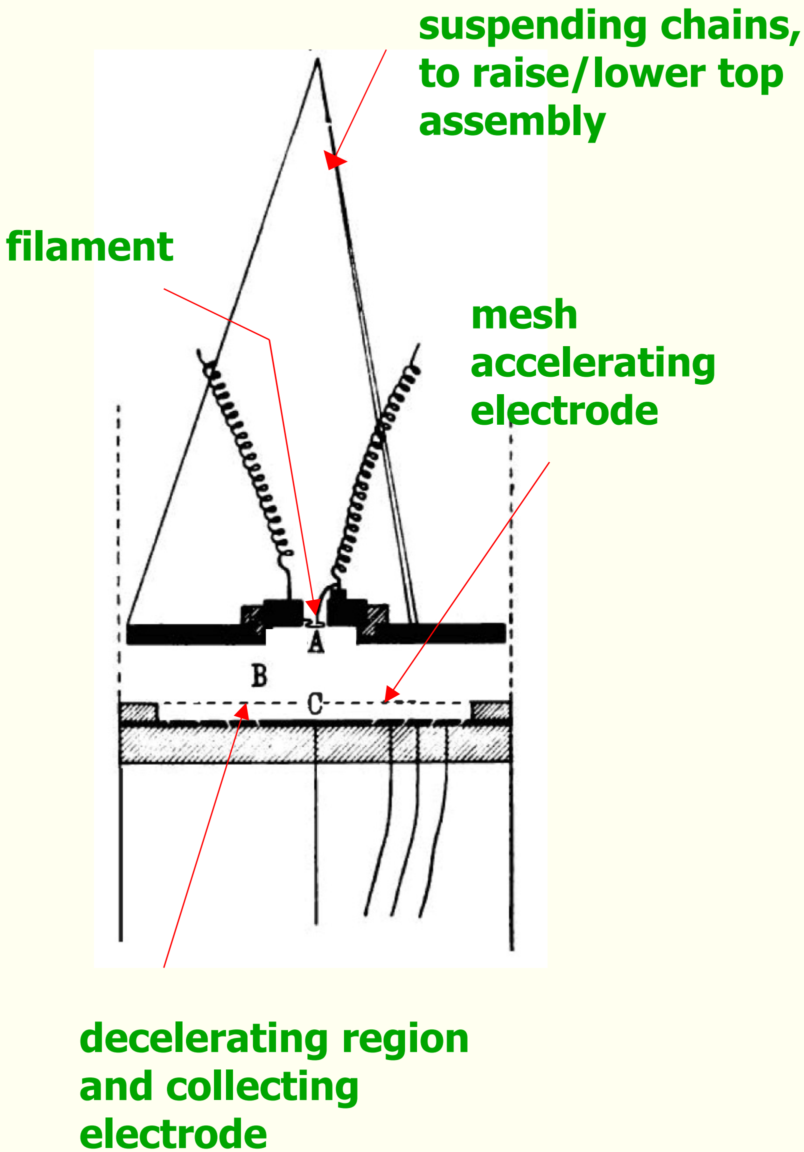
This experiment suggested qualitatively that electrons lost some energy in collision with hydrogen molecules, and even more in collisions with oxygen.

A calculation that grew out of this experiment (and that they didn't give in detail) confirmed that (again, in helium) collisions resulted in reflection, not absorption.

Nature of the collisions: 1913

On Collisions between Gas Molecules and Slow Electrons (April 1913)

On Collisions between Gas Molecules and Slow Electrons. II. ((July 1913)



Energy Lost in Collisions?

They were not satisfied with their April measurements of energy loss, and so redesigned their mfp apparatus to measure energy loss as well. (Diagram is a little misleading.)

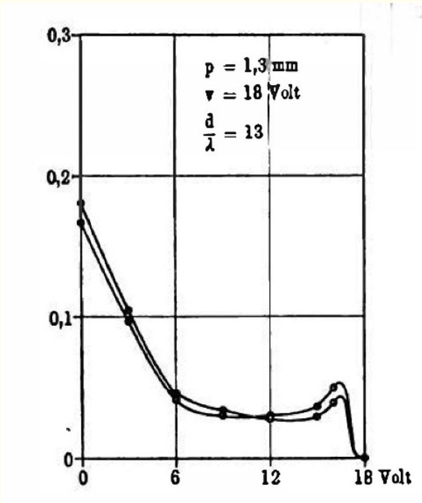
- Height of region B adjustable with chains
- electrons accelerated from filament to mesh electrode
- then, subjected to decelerating field in region C
- measurements of of current vs. decelerating voltage for different heights gave energy distributions.

NATURE OF THE COLLISIONS: 1913

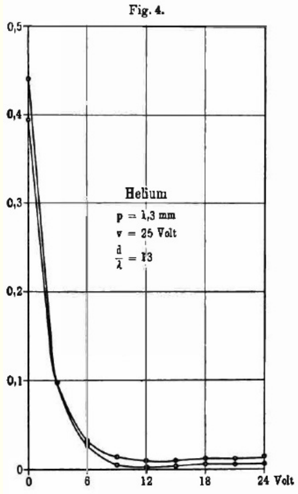
On Collisions between Gas Molecules and Slow Electrons. II. (July 1913)

Energy distribution curves

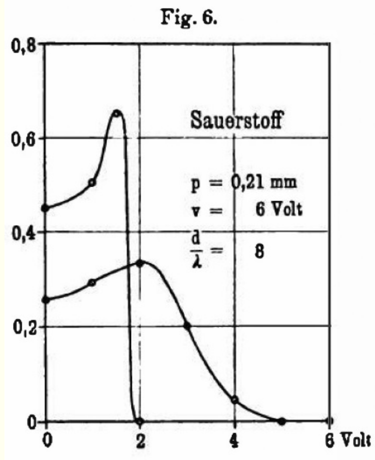
helium: V_{accel} = 18 V



helium: V_{accel} = 25 V



oxygen



The two curves on each graph represent different heights of region B. (Curves not easy to interpret.)

The collisions between electrons and gas molecules are the more elastic, the smaller the electron affinity of the struck gas molecule.

The collisions between electrons and helium atoms are nearly or entirely elastic…. In helium the energy needed for ionization can be gained over arbitrarily many collisions.

… the hypothesis of completely inelastic collisions on which Townsend's theory of ionization by collision essentially rests, does not agree with the facts for helium and hydrogen.

Nature of the collisions: 1913

On the Connection Between Ionization by Collision and Electron Affinity (Sept. 1913)

review paper given at the annual meeting of the German Scientists and Physicians

	ionization potential volt	molecular radius cm
He	20.5	0.9×10^{-8}
Ne	16.0	1.1×10^{-8}
Ar	12.0	1.35×10^{-8}
H_2	11.0	1.09×10^{-8}
O_2	9.0	1.36×10^{-8}
N_2	7.5	1.48×10^{-8}

It appears for monatomic as well as diatomic gases that the ionization energy is inversely proportional to the molecular radius, something that is also explained theoretically in various ways.

The reference is to their 1911 (and later) speculations about ionization and molecular radius, most of them related to quantum theory.

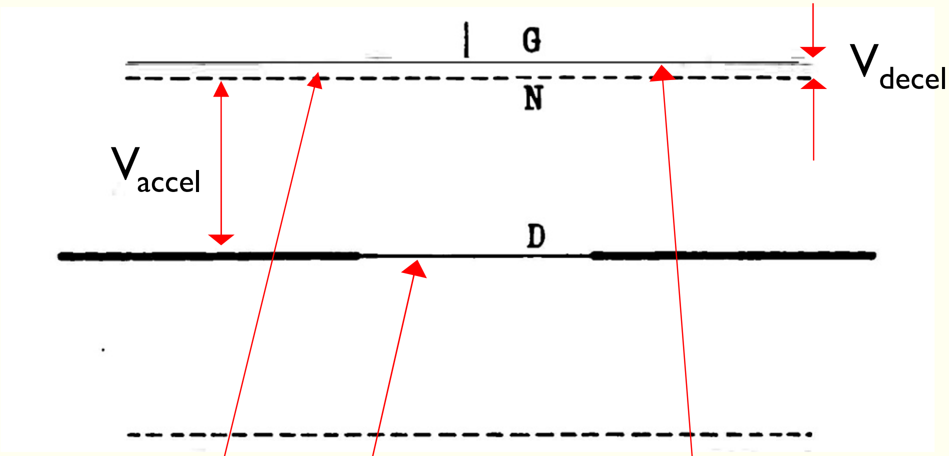
Quantum theory was on a back burner, but they had not forgotten about it.

Franck and Hertz, April 1914

On Collisions between Electrons and Molecules of Mercury Vapor and the Ionization Potential of the Same

- could not use their 1913 method (detect positive ions) for mercury
- suspected that mercury vapor behaved like helium (elastic collisions, no energy loss)

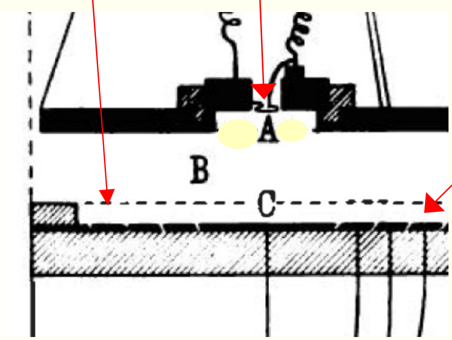
  ⇒ used velocity distribution technique from 1913—note similarity of apparatus
- measured current vs. **decelerating** voltage, at **constant** accelerating voltage

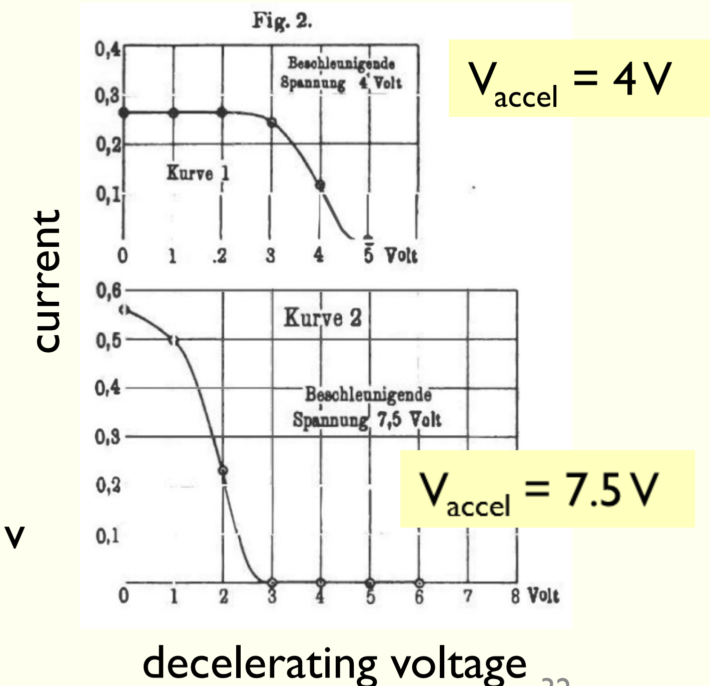


mesh accelerating electrode

filament

decelerating region and collecting electrode



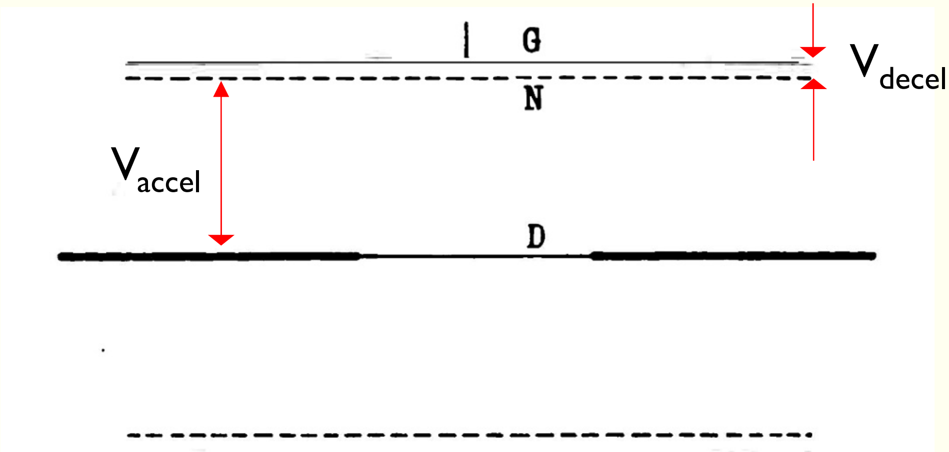


Results:

- collisions elastic below ∼ 5 v
- "ionization" potential ∼ 5 v

Franck and Hertz, April 1914

On Collisions between Electrons and Molecules of Mercury Vapor and the Ionization Potential of the Same

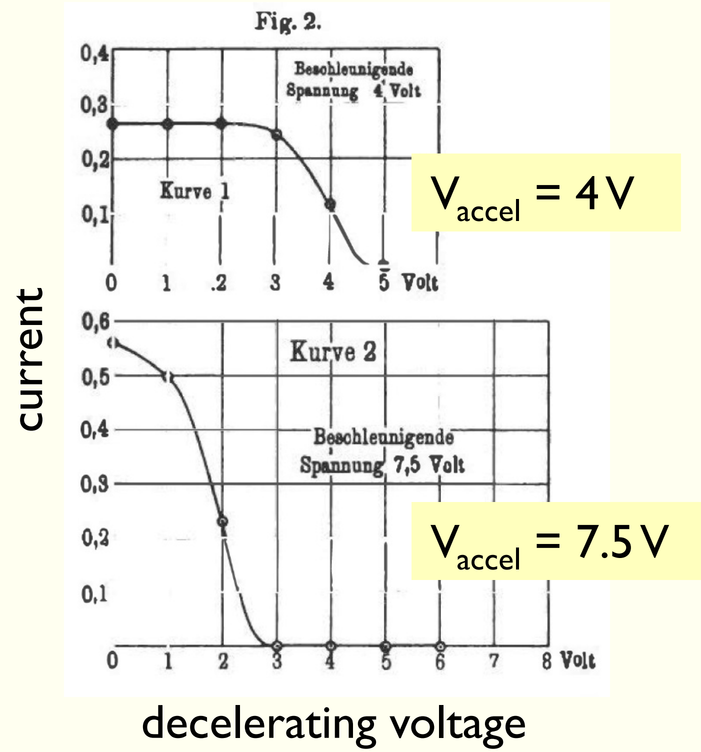


And now comes such a little trick, a small point …

Gustave Hertz, 1968

Change: instead, measure

current vs. **accelerating** voltage, at **constant** decelerating voltage



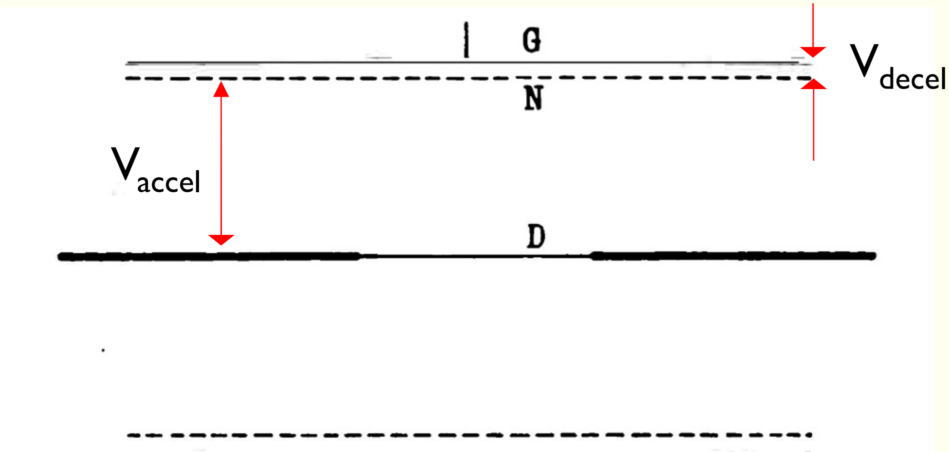
current vs. **decelerating** voltage, at **constant** accelerating voltage

Results:

- collisions elastic below ~ 5 v
- "ionization" potential ~ 5 v

Franck and Hertz, April 1914

On Collisions between Electrons and Molecules of Mercury vapor and the Ionization Potential of the Same



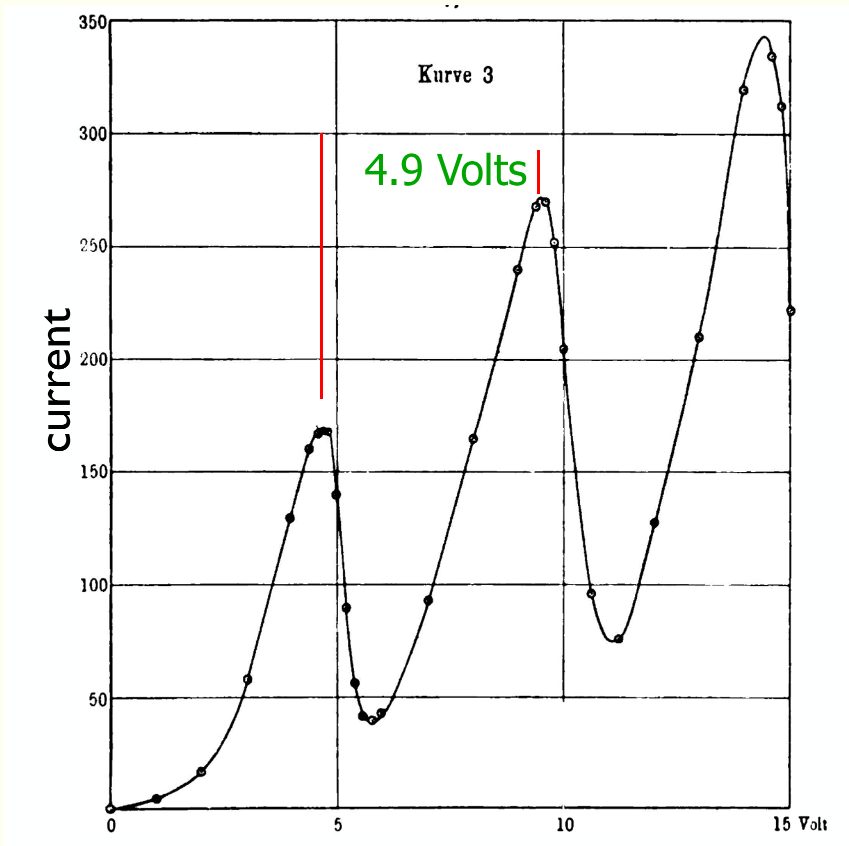
And now comes such a little trick, a small point …

Gustave Hertz, 1968

Change: instead, measure

current vs. **accelerating** voltage, at **constant** decelerating voltage

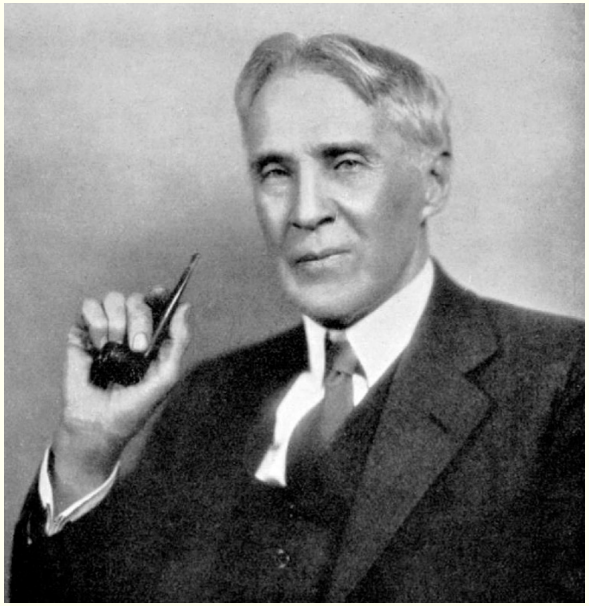
⇒ much higher accuracy



accelerating voltage

They immediately connected this 4.9 volt spacing to the 2536 Å "resonance" line in mercury.

Resonance Fluorescence



Robert W. Wood

Illuminate sodium vapor at low pressure with a beam of light from sodium D lines. The vapor absorbs the light, and fluoresces (radiates in all directions) with light of the same wavelength. Discovered by the American spectroscopist Robert W. Wood in 1904.

Ditto in 2536 Å line in mercury.

In other words, we take hold of, and shake, so to speak, but one of the many electrons which make up the molecule.

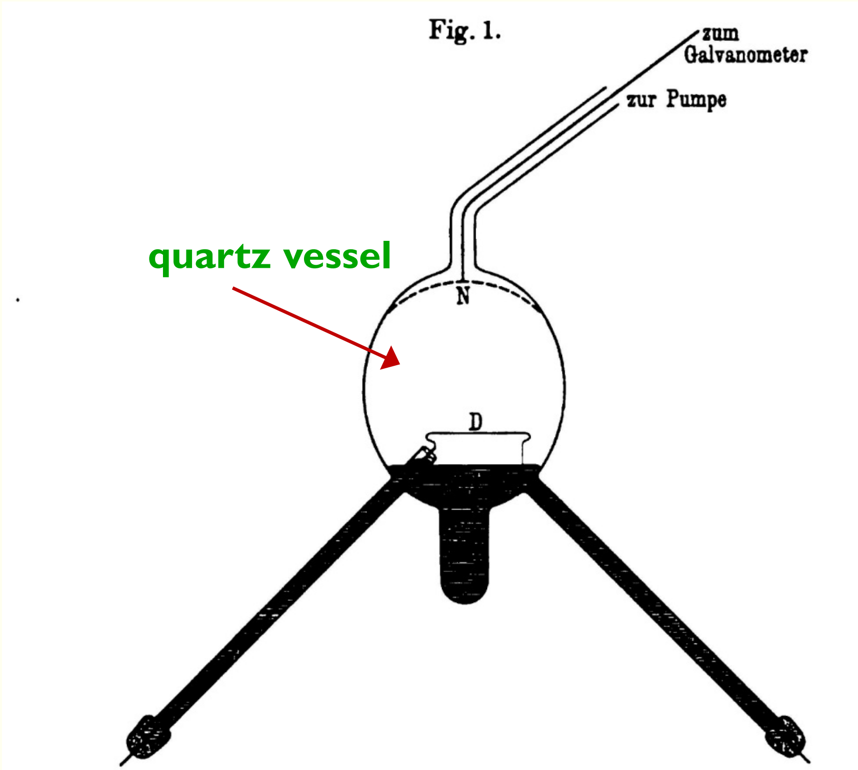
Robert W. Wood, 1911

Franck and Hertz both said in later years that they knew little about spectroscopy.

But Wood was a frequent visitor to Berlin, and he and Franck had published two papers together.

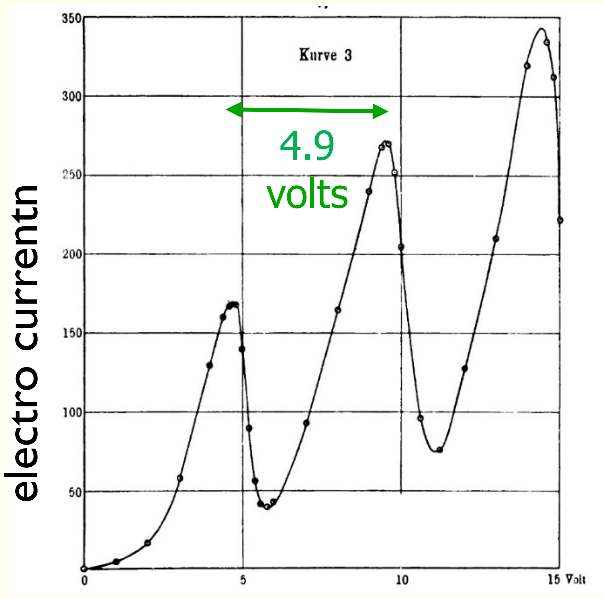
Franck and Hertz, May 1914

On the Stimulation of the 253.6 μμ Mercury Resonance Line by Electron Collisions

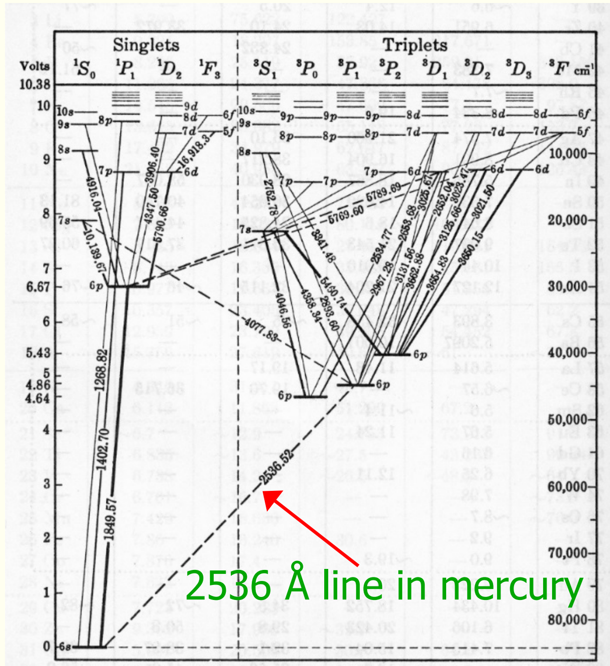


Franck and Hertz confirmed (with a borrowed ultraviolet spectrometer) the presence of the 2536 Å line of mercury (and only that line), as they raised the accelerating voltage of the electrons in the quartz vessel through 4.9 volts.

Franck and Hertz, April–May 1914



Accelerating voltage



Franck and Hertz:

- thought they were seeing ionization

  … as proven through Wood's experiment on mercury resonance radiation, in every mercury atom an electron is present that can oscillate with a frequency corresponding to the wavelength 253.6 μμ.

Bohr model (1913 had appeared about a year earlier):

- excited state, but NOT ionization; experiments (mostly in U.S.) confirmed during war

What did Franck and Hertz know about Bohr's model in 1914?

Bohr's Theory in Berlin, 1914

There is independent evidence that physicists in Berlin knew about Bohr's theory in 1914; for example

- Rudolf Seeliger, then at PTR in Berlin (Charlottenburg), mentioned Bohr's theory, albeit briefly, in a paper cited by Franck and Hertz in 1914.
- Seeliger discussed Bohr's theory in more depth in a two-part article in *Die Naturwissenschaften* in 20 and 27 March, 1914.
- Emil Warburg, who had been Franck's first advisor, gave a paper summarizing Bohr's theory and presenting his own related theory of the newly discovered Stark effect to the Physical Institute colloquium in December 1913.

In later years, Franck and Hertz both talked about why they had not mentioned Bohr's theory in 1914.

The Perils of Memory

One therefore welcomes any straightforward autobiographical statement if only to destroy the wrong traditions which are apt to grow up around any great achievement. An excellent example of this is James Franck's remark in a recent interview [1961] he recorded concerning the Franck Hertz experiments of 1914.

It might interest you that when we made the experiments that we did not know Bohr's theory. We had neither read nor heard about it. We had not read it because we were negligent to read the literature well enough-and you know how that happens. On the other hand, one would think that other people would have told us about it. For instance we had a colloquium at that time in Berlin at which all the important papers were discussed. Nobody discussed Bohr's theory. Why not? The reason is that fifty years ago one was so convinced that nobody would, with the state of knowledge we had at that time, understand spectral line emission, so that if somebody published a paper about it, one assumed, 'Probably it is not right.' So we did not know it.

James Franck, 1961 interview, quoted in AJP article

The Perils of Memory

And you see it also, that when Hertz and I wrote our paper on mercury, we had not read Bohr's article which was published maybe already 2 or 3 months before. When we wrote our paper, we had not seen it. And nobody told us. It took longer time. And there was also a kind of bias against it. Nobody could make models for atoms.

James Franck, Interview with Thomas Kuhn, 1962

The Perils of Memory

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James Franck, Interview with Thomas Kuhn, July 1962

Most astonishing it was to me, that I mentioned in this Nobel lecture, that apparently we had seen Bohr's paper before Hertz and I published our paper on electron impacts and had not paid any attention to it. I told you and Maria that we had not seen it at all at that time. I suppose that the talk I gave thirteen years after we wrote the paper does not make as many demands on my memory as that what I told you last summer.

Franck to Thomas Kuhn, November 1962

The Perils of Memory

Subsequently it appeared to me to be completely incomprehensible that we had failed to recognize the fundamental significance of Bohr's theory, so much so, that we never even mentioned it once in the relevant paper.

James Franck, Nobel Lecture, 1926

The Perils of Memory

Subsequently it appeared to me to be completely incomprehensible that we had failed to recognize the fundamental significance of Bohr's theory, so much so, that we never even mentioned it once in the relevant paper.

James Franck, Nobel Lecture, 1926

Bohr's theory was at that time unknown to the authors, even though Bohr's first work had appeared half a year earlier.

James Franck and Pascual Jordan,
Excitation of Quantum Jumps by Collision, 1926

The Perils of Memory

In Germany, Bohr's work in the first year after its appearance was not read all that much. One skimmed through the literature, and since one at the time had a pronounced mistrust against attempts, given the state of our current understanding, to construct atomic models, one took less trouble to read the work carefully. It is especially to be emphasized, that Gustav Hertz and the writer of these lines were initially unable to understand the great significance of Bohr's work. … We read Bohr's work before we sent in our manuscript to the press, but we decided to send it off without mentioning Bohr's work, since we found an apparent difficulty in understanding the strong ionization in the mercury arc.

James Franck, Bohr obituary, *Die Naturwissenschaften*, 1963

The Perils of Memory

Only a few weeks before his death, I spoke with James Franck, going into our initial interpretation of our results, and into the reasons that at first prevented us from recognizing the truth of the matter. …

The first work of Bohr on the theory of the hydrogen atom had appeared a year before the completion of our work, and there was a lively discussion in the colloquium of the Berlin Physical Institute. The fact that this theory yielded the exact value of the Rydberg constant was so astonishing, that one had to look into the new theory seriously, even if the picture of the atom with its non-radiating orbiting electrons seemed unacceptable from the standpoint of classical physics. But the interest was concentrated entirely on the hydrogen atom, and that might have been the reason that we did not understand the significance of the new theory for the phenomena that we investigated.

Gustav Hertz, 1966, unpublished,
in the James Franck papers, University of Chicago Library

Hertz elaborated on this theme in subsequent essays, but did not essentially alter what he said in 1966. Note what he does, and does not, say!

Now, perhaps there is still a question that one can ask. Bohr's theory had appeared in 1913, and here it is 1914. Why did you not notice it? … I can perhaps conclude here with the answer that Franck himself gave me at our last conversation, shortly before his death. I said to him then, "Franck, how is it really possible, since Bohr's theory was in fact there, that we didn't notice it?" And he said to me, "Well, Hertz, we were just too dumb."

Gustav Hertz, Lindau lecture, 1968

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