The Chemical Revolution

Not so-useful Chemistry

Useful to Know

Scientific Revolution

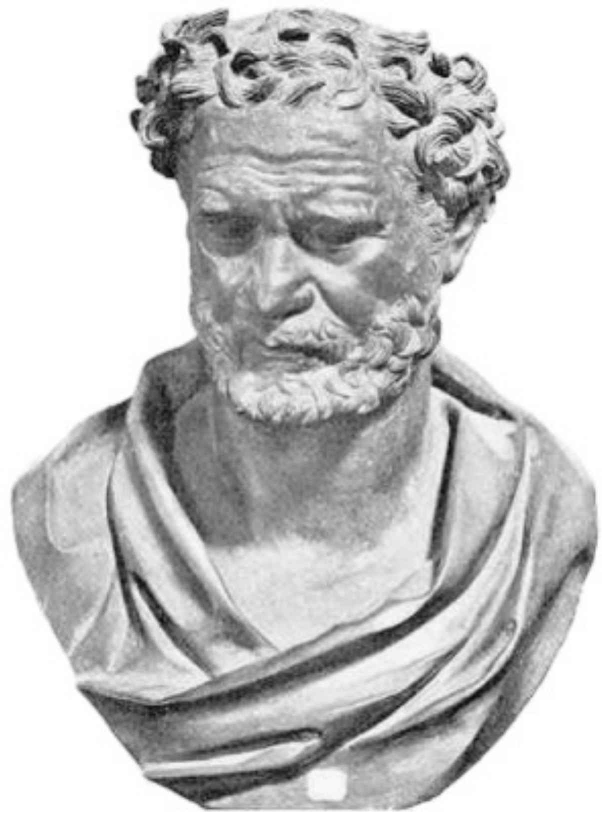
The Scientific Revolution is a term commonly referring to the transformation of thought about nature through which the Aristotelian tradition was replaced by so-called "modern" science.

Chemical Revolution

The Greek Philosopher Democritus

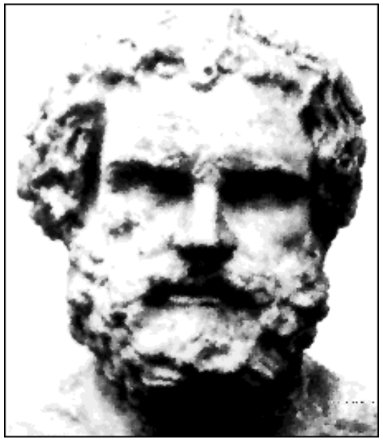
- The Greek philosopher Democritus began the search for a description of matter more than 2400 years ago.

- He asked: Could matter be divided into smaller and smaller pieces forever, or was there a limit to the number of times a piece of matter could be divided?



Democritus
c. 460 – c. 370 BC

Atomos



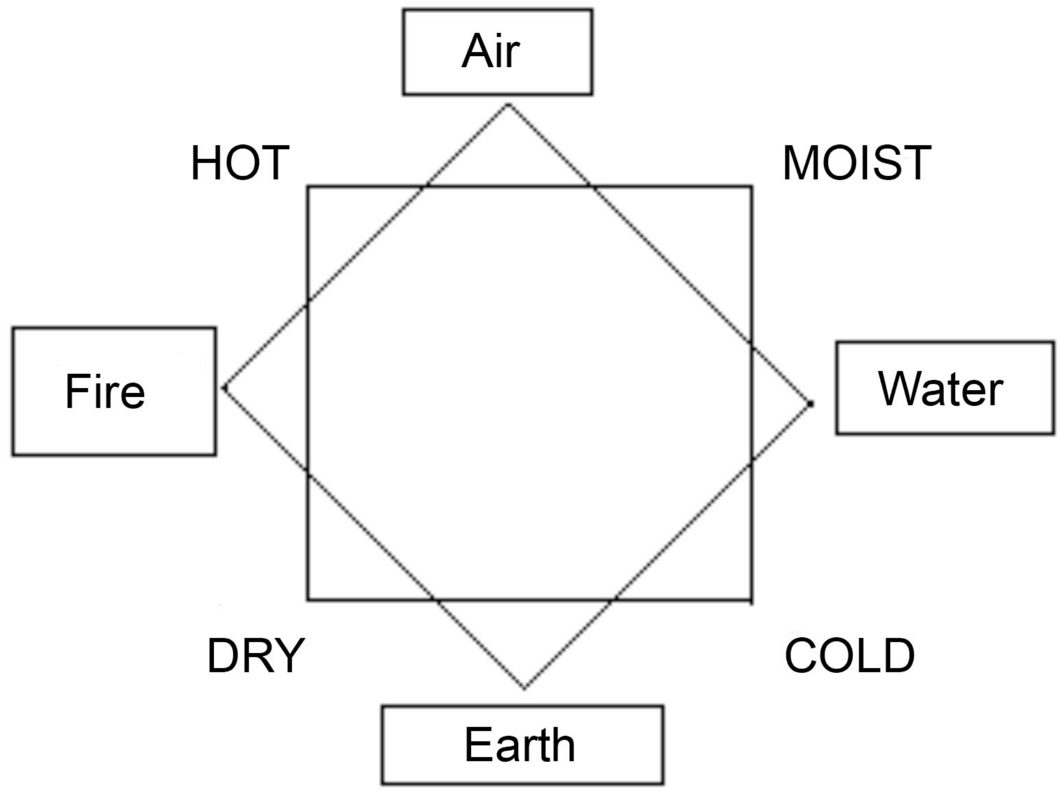
Democritus

- His theory: Matter could not be divided into smaller and smaller pieces forever, eventually the smallest possible piece would be obtained.
- This piece would be indivisible.
- He named the smallest piece of matter "atomos," meaning "can not be cut."

Atomos

- To Democritus, atoms were small, hard particles that were all made of the same material but were different shapes and sizes.
- Atoms were infinite in number, always moving and capable of joining together.

The four elements of ancient times (Greek)



- All matter is made up of these four elements
- The above four elements are <u>transmutable</u>

The Indian View

(*Taittirīya Upanishad* and *Aitareya Upanishad*, 6th century BC)

Even before Aristotle

Five interconvertible elements make up the earth

Pancha Bhoota (Sanskrit: पञ्चभूत), five great elements, which, according to Hinduism, is the basis of all cosmic creation.

- **Prithvi** (Sanskrit: पृथ्वी:, Earth),
- **Jal** (Sanskrit: अप:, Water),
- **Agni** (Sanskrit: अग्नि, Fire),
- **Vayu** (Sanskrit: वायु:, Air),
- **Akasha** (Sanskrit: आकाश, Space).

Ancient Indian Atomistic Thoughts

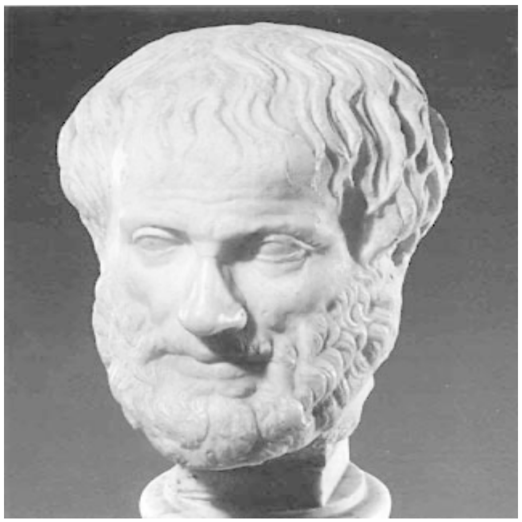
Kashyap (Acharya Kanada)

- Vaisheshika school of philosophy
- *Vaisheshika Sutras*
- 6^{th} century BC

Every object of creation is made of atoms (paramāṇu) which in turn connect with each other to form molecules (aṇu). Atoms are eternal, and their combinations constitute the empirical material world.

The similarity of the early Indian views of matter with the Greek models have led historians to wonder if communication occurred between the philosophers in these early civilizations.

The Greek Philosopher Aristotle



384-322 BC

- Believed that matter could be continuously divided without end (the “continuous” idea of matter).
- There is no need for empty space.
- There are no atoms. All matter is made of the natural elements (**earth, water, air and fire**.

Alchemy (next 1500 years)

- Mixture of science and mysticism.
- Lab procedures were developed, but alchemists did not perform controlled experiments like true scientists.

The Four Basic Elements

🜁	Air
🜃	Earth
🜂	Fire
🜄	Water

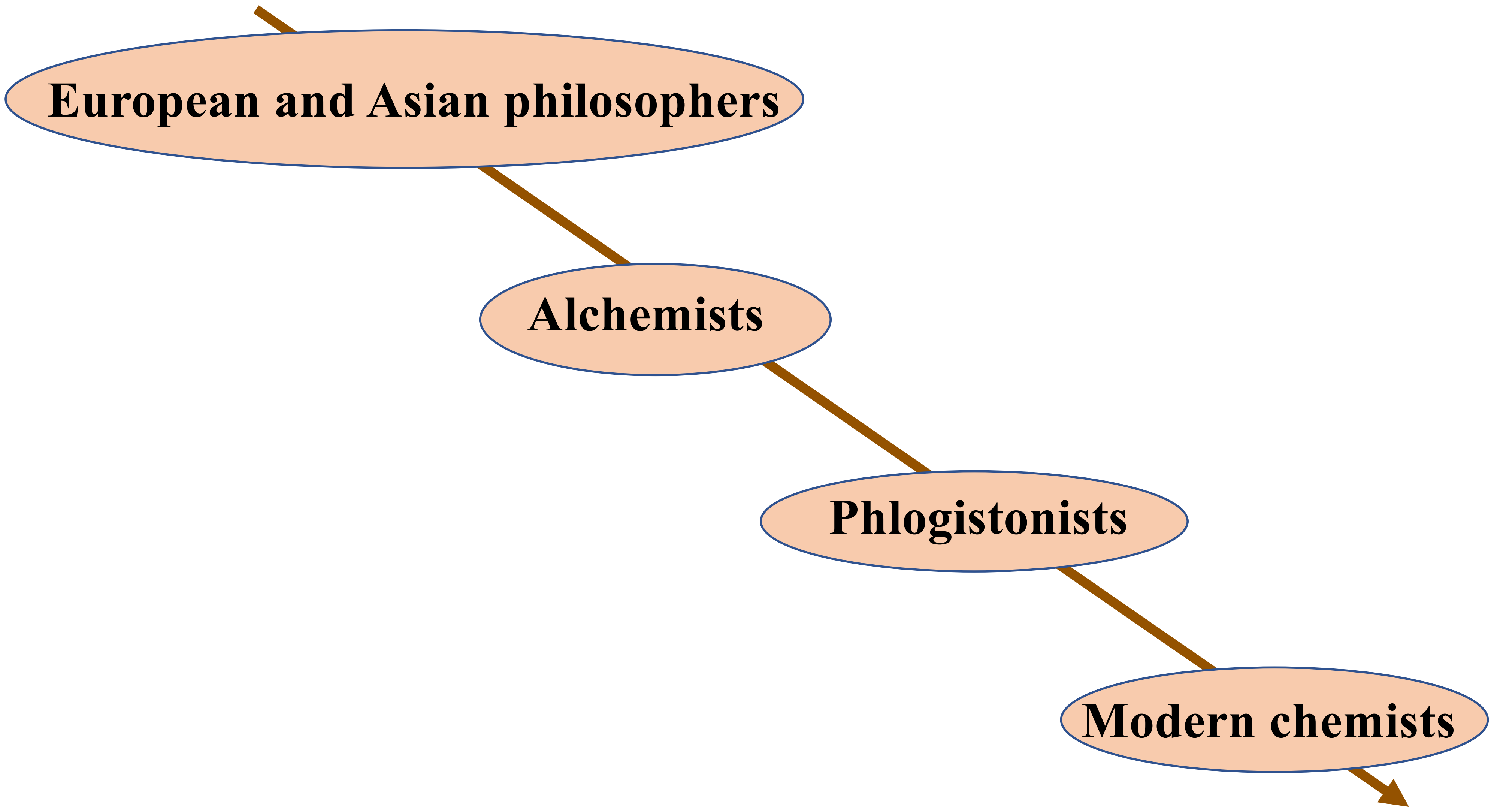
The Seven Planetary Metals

☉	Gold	Sol	Sunday
☽	Silver	Luna	Monday
♀	Copper	Venus	Friday
♂	Iron	Mars	Tuesday
☿	Mercury	Mercury	Wednesday
♄	Lead	Saturn	Saturday
♃	Tin	Jupiter	Thursday

Basic Operations

To filter
To mix
To dissolve
To boil
To distill
To precipitate
To melt or liquify

The Aristotelian tradition and medieval alchemy eventually gave rise to modern chemistry



Alchemists to Phlogistonists

Ancient Greeks:	
5^{th} century BC to 17^{th} century	Earth, Water, Air and Fire
Asians:	
5^{th} century BC to 17^{th} century	Earth, Water, Air, Fire and Space
Middle Eastern: Abu Mus-Hayyan	
8^{th} century AD	Elements + sulfur + mercury
European: Paracelsus (Swiss alchemist)	
16^{th} century AD	Elements + {sulfur + mercury+salt}

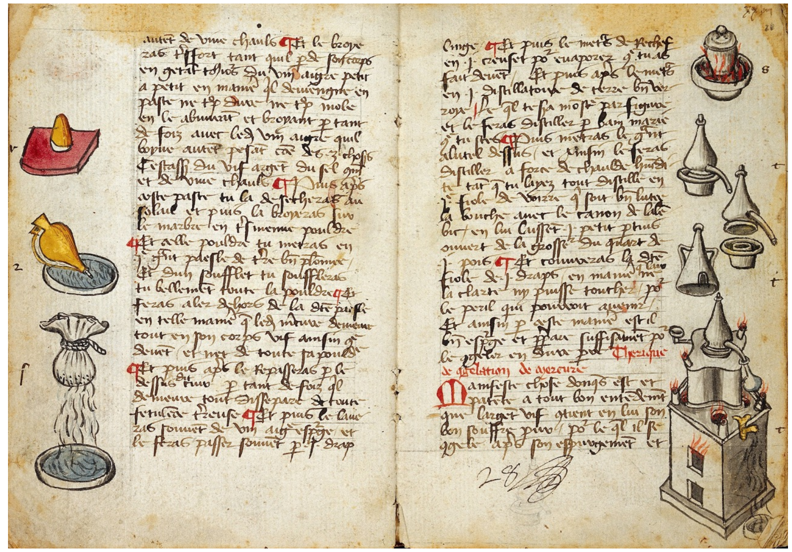
Alchemists laid the groundwork for many chemical processes, such as the refining of ores, the production of gunpowder, the manufacture of glass and ceramics, leather tanning, and the production of inks, dyes, and paints. Alchemists also made the first attempts at organizing and classifying substances so that they could better understand their reactions and be able to predict the products of their experiments.

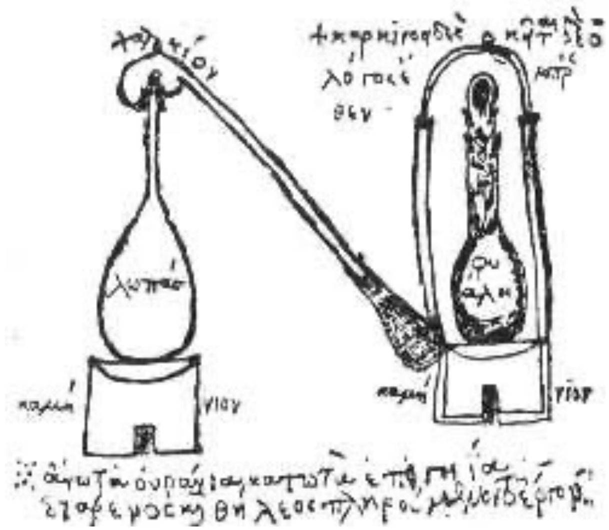
Alchemists
300 BC to 17th century
Arabian origin but was prevalent world over

- **Transmutation of metals**
- **Philosophers stone**
- **Elixir of life**
- **Interconversion of minerals**
- **Looking for medicines**

Alchemists attempted to transmute cheap metals to gold. The substance used for this conversion was called the *Philosopher's Stone*.

Alchemists: Middle-East, Greeks, Romans, Asia, Europe
300 BC-17th century





Beginnings of Phlogistonists

Johann Joachim **Becher**
1635 – 1682

Replaced Greek and Paracelsus (Swiss alchemist) elements (4+3) with two,
Seven elements became two: earth and water, air used only as a mixer.

Proposed that when a substance burned, a combustible earth was liberated.

Georg Ernst **Stahl**
1659-1734

Kept the proposals of Becher except changed the name of flammable earth to **phlogiston**.

Phlogiston Theory

17 & 18th centuries

Johann Joachim Becher
1635 – 1682

Georg Ernst Stahl
1659-1734

According to the phlogiston theory a colorless, odorless and weightless substance called phlogiston, present in every material was released while it burnt and the 'ash' that remained was considered as 'dephlogisticated' material.

In addition to air, earth, water and fire, the materials contain phlogiston.

What is fire?

THEN: Release of phlogiston is the definition of burning. The flame indicates the rapid escape of phlogiston.

NOW: Fire is a chemical reaction that converts a fuel and oxygen into carbon dioxide and water.

Questions about Combustion

- In early 18th Century, an attempt was made to understand combustion (burning, fire).
- Why do some materials burn, while others don't?
- When a piece of wood burned, it turned into ash with much less mass than the original wood.
- What happens to the rest of the wood mass?

Basics of phlogiston theory

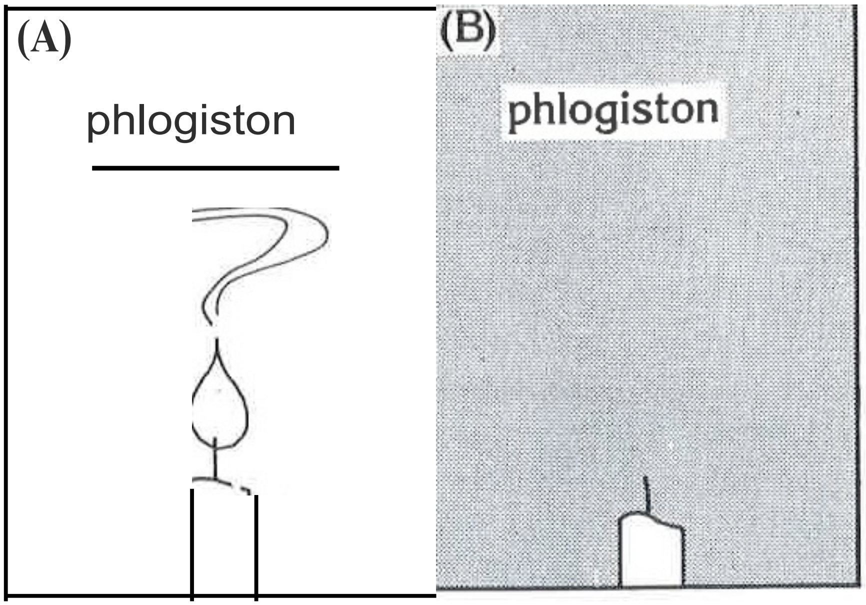
- All combustible substances contain phlogiston.
- Non-combustible substances do not contain *phlogiston*.
- The more phlogiston a substance contains, the better and more completely it burns.
- When wood burns there is a decrease in weight.
- Release of phlogiston results in weight loss.

Where is phlogiston going upon burning?

- Air is necessary for combustion because it absorbs the escaping phlogiston.
- The air becomes saturated with phlogiston – it becomes phlogisticated air.
- When a candle burns in a closed jar, it burns for a while before the flame goes out; this is because the air in the jar is saturated with *phlogiston*.
- Observation: Combustion does not occur in a vacuum.
- Explanation: There was no air present to carry off the phlogiston.

Phlogiston Theory explained why things stopped burning

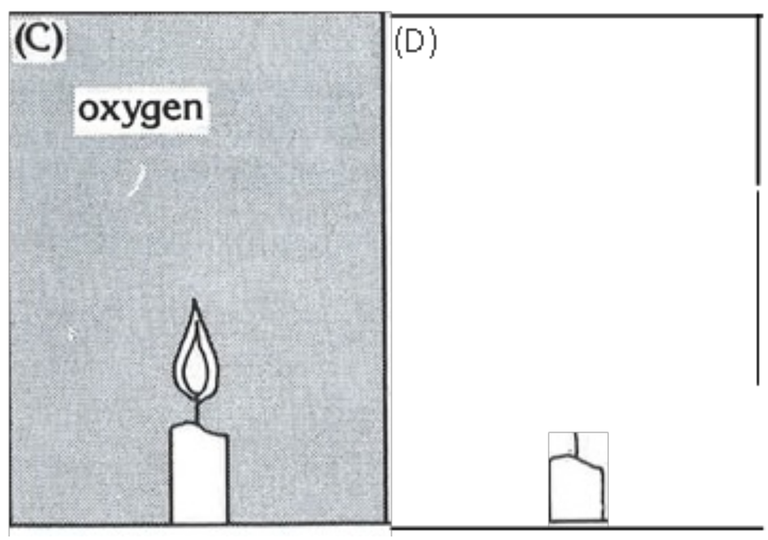
Phlogiston theory of burning. (A) When an object burns, it gives off a substance called phlogiston. (B) When the space surrounding the burning object is filled with phlogiston, the object will no longer be able to burn.



Do you support or refute the hypothesis?

Modern theory of burning

- When an object burns, it uses up a substance (oxygen) in the surrounding space.
- When the space surrounding the burning object has too little oxygen in it, the object will no longer be able to burn.



Metals don’t burn but get rusted
Metal to metal calx

Phlogiston theory:

Metal ⟶ Calx + Phlogiston

Wood ⟶ Ash + Phlogiston

Metal ⟶ Calx + Phlogiston

Fire to Rust: Minor hitch in the theory

- Typically, metal calx weighed more than the original metal.
    - How can this be if the calcification process drives off the phlogiston in the metal?
    - Answer: Phlogiston possesses levity; *i.e.*, it is lighter than nothing; it has negative weight (?)

Levity is an ancient idea

- Levity, or inherent lightness, is an idea invented by Aristotle.
  - Air and fire rise because they possess levity, while earth and water fall because they possess heaviness.
  - These are qualitative notions. They do not fit in quantitative, mechanist explanations.

The logic of phlogiston

https://edu.rsc.org/feature/the-logic-of-phlogiston/2000126.article

Place an empty balloon, about 10 cm of string and a few centimetres of sticky tape on a top-pan balance.

Tare the balance to read zero.

Fill the balloon with ‘phlogiston’ (flamable hydrogen), tie the neck and tape it down onto the balance pan.

The balance will now show a negative reading; *ie* the mass of phlogiston added to the balloon is negative.

Metal calx to metal

Metal calx are powders, like ash, resulting from heating metals in a fire.

Mercury → Mercury calx + phlogiston

Stahl's idea was that phlogiston was driven out of the metal when the calx was produced.

Mercury reacts with oxygen to form mercuric oxide

Mercury calx + Phlogiston → (Charcoal) Mercury

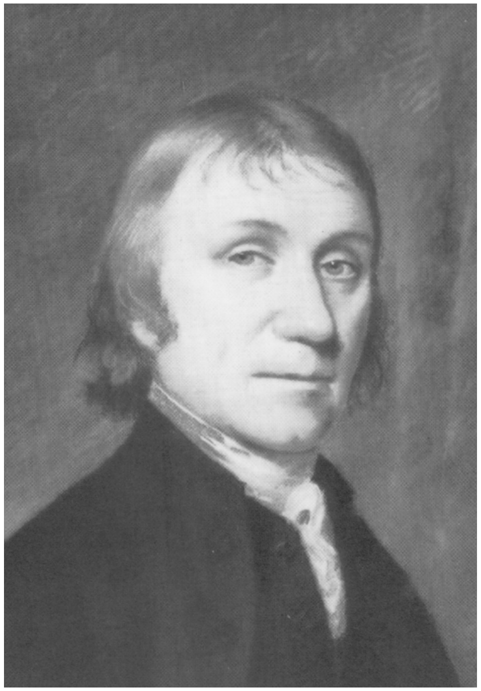
If calx is reheated in an oven filled with charcoal the calx turned back into the original metal.

An excellent source of phlogiston is charcoal, which therefore could reconvert a calx to its metal.

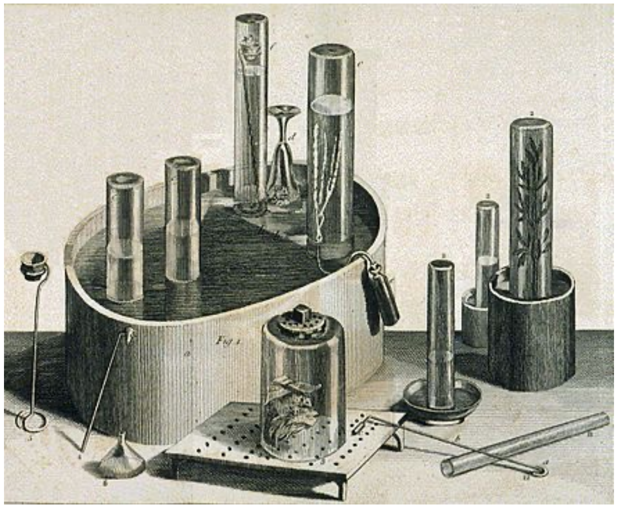
Charcoal absorbs the released oxygen and reacts to form carbon dioxide

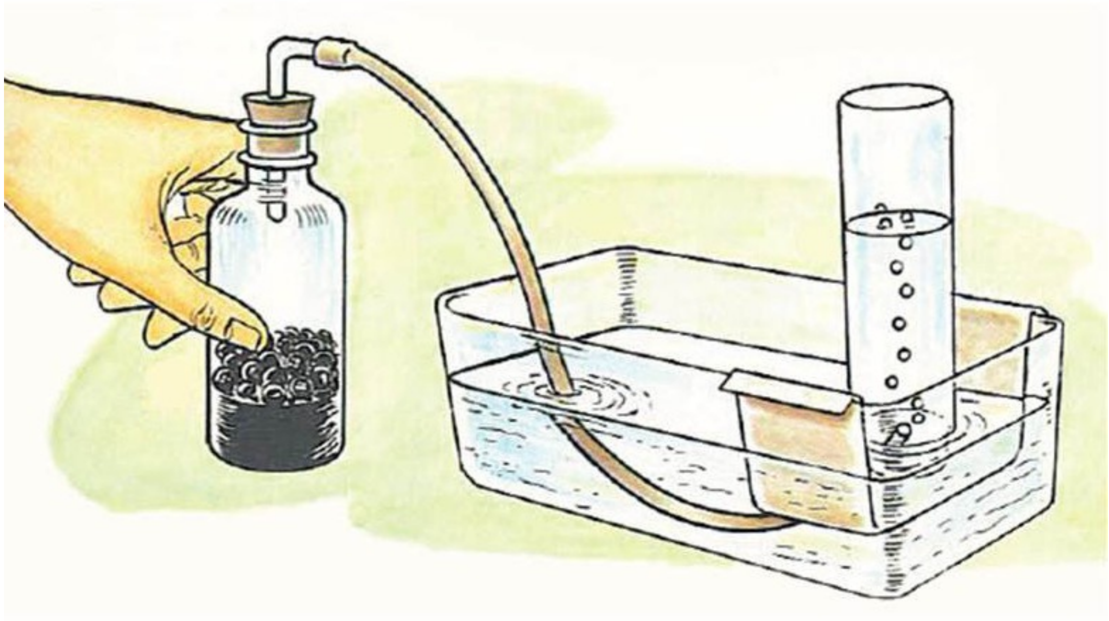
Dephlogisticated air

- Joseph Priestley produced different gases by performing chemical reactions and collecting the gases produced with a pneumatic trough.
- He produced a new gas by heating mercuric calx by concentrating the sun's rays on it.



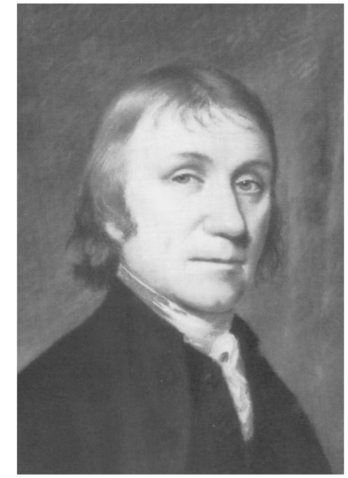
Joseph Priestley

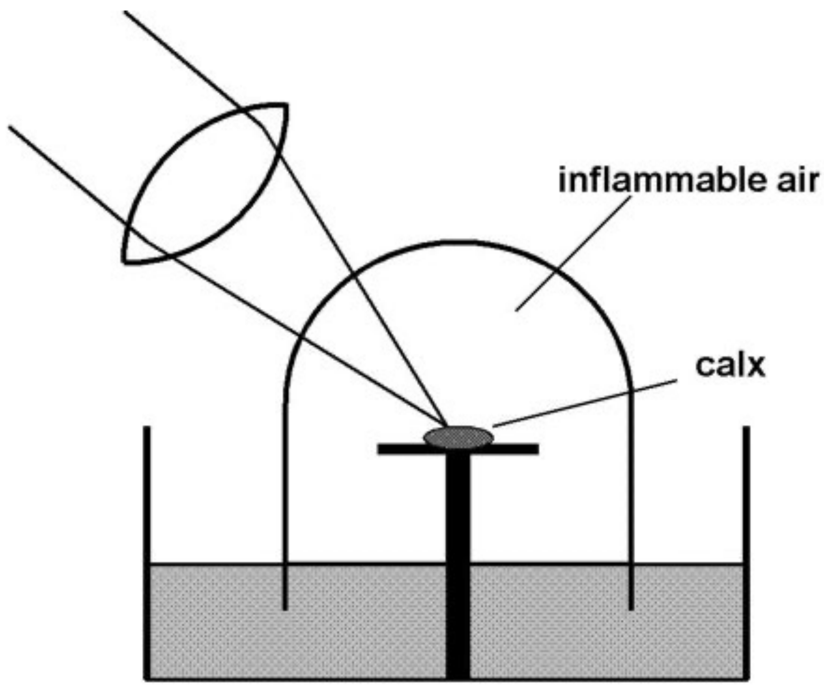




Dephlogisticated air

Mercury calx + Phlogiston $\xrightarrow[\text{Air}]{}$ Mercury





Left out air "dephlogisticated air"

No charcoal

Priestley declared: "*I could not doubt but that the calx was actually imbibing something from the air; and from its effects in making the calx into metal, it could be no other than that to which chemists had unanimously given the name of phlogiston.*"

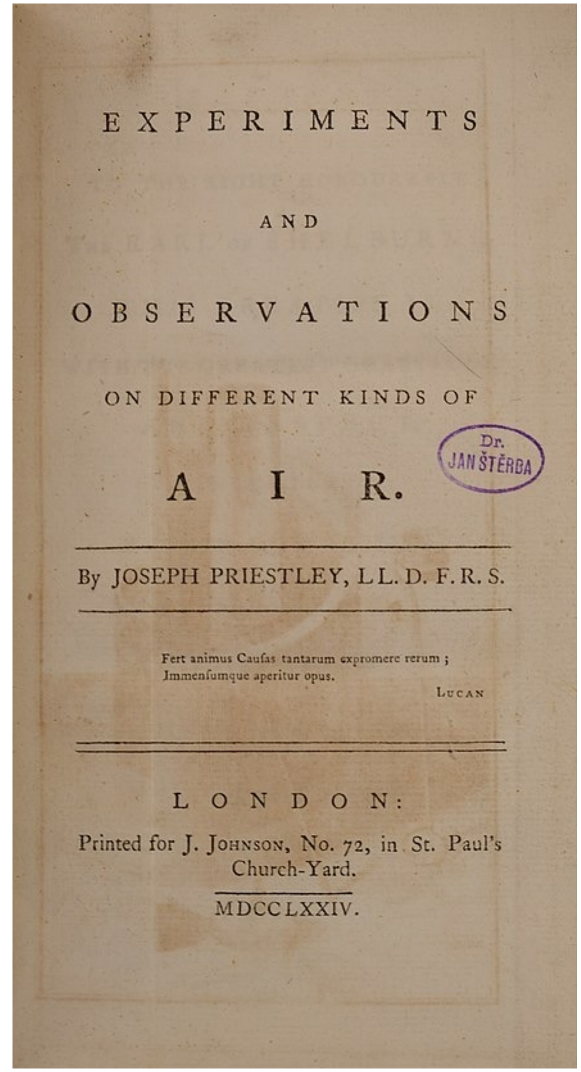
Dephlogisticated air

- Mercury calx + Phlogiston $\xrightarrow[\text{Air}]{}$ Mercury

- According to phlogiston theory, he was re-impregnating the mercury calx with phlogiston, taken from the surrounding air.

- Hence, the air that remained was deficient in phlogiston. He called it "dephlogisticated air".

- Earlier charcoal was used instead of air as a source of phlogiston.



EXPERIMENTS

AND

OBSERVATIONS

ON DIFFERENT KINDS OF

AIR.

By JOSEPH PRIESTLEY, LL.D. F.R.S.

Fert animus Cauſas tantarum expromere rerum ;
Immenſumque aperitur opus.

LUCAN

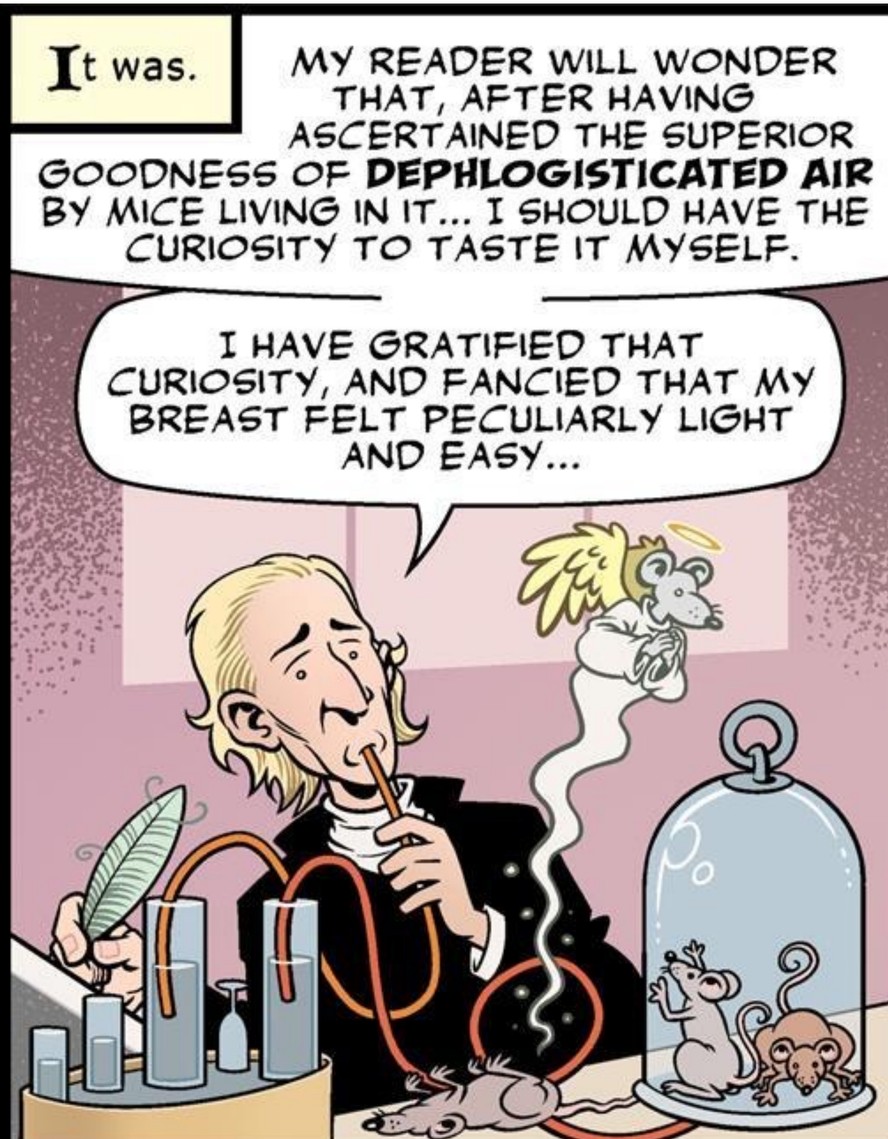
LONDON:

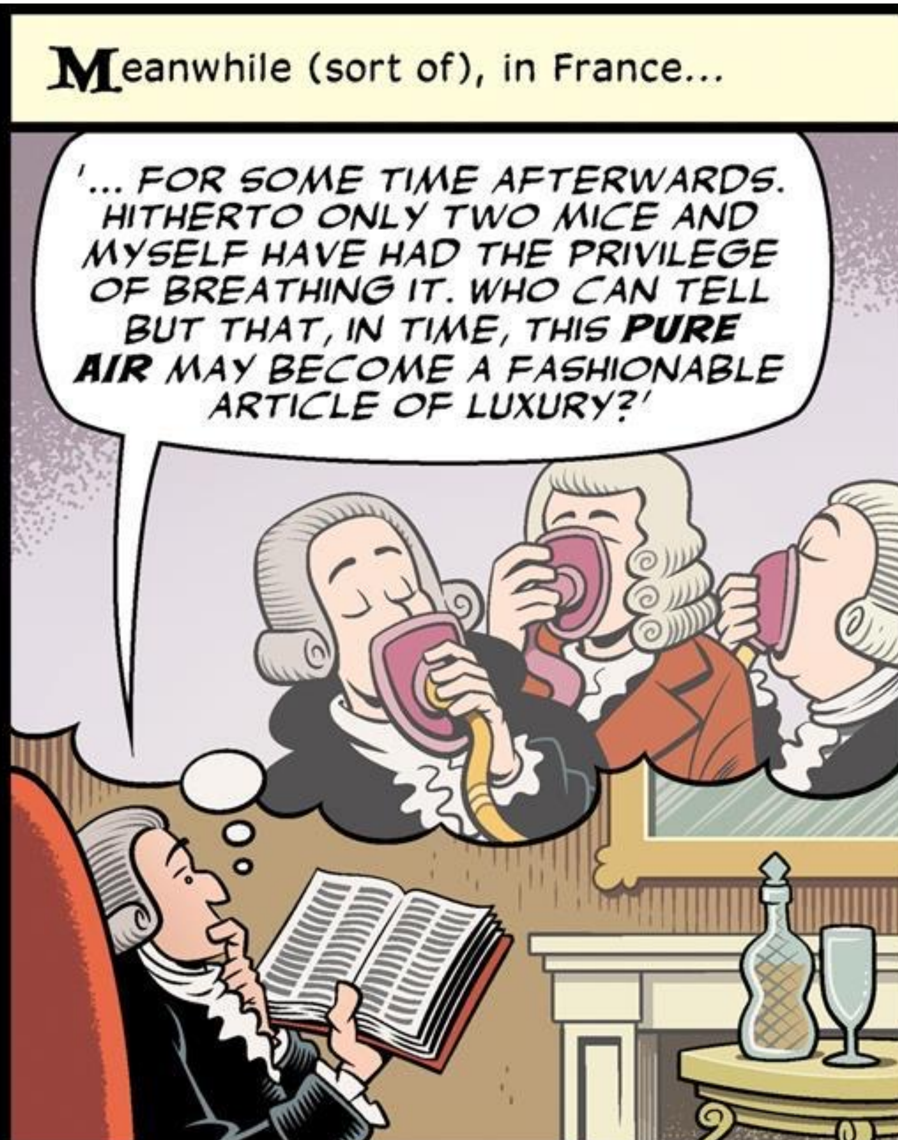
Printed for J. JOHNSON, No. 72, in St. Paul's Church-Yard.

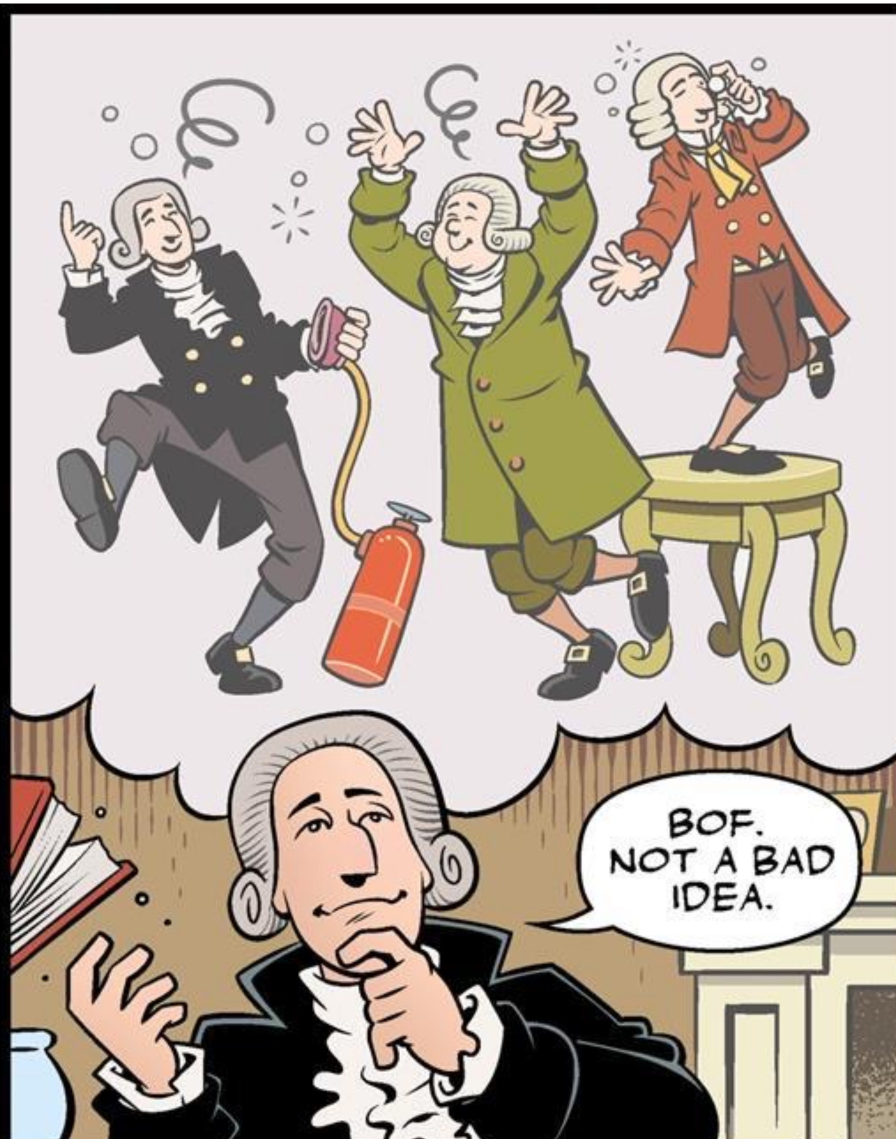
MDCCLXXIV.

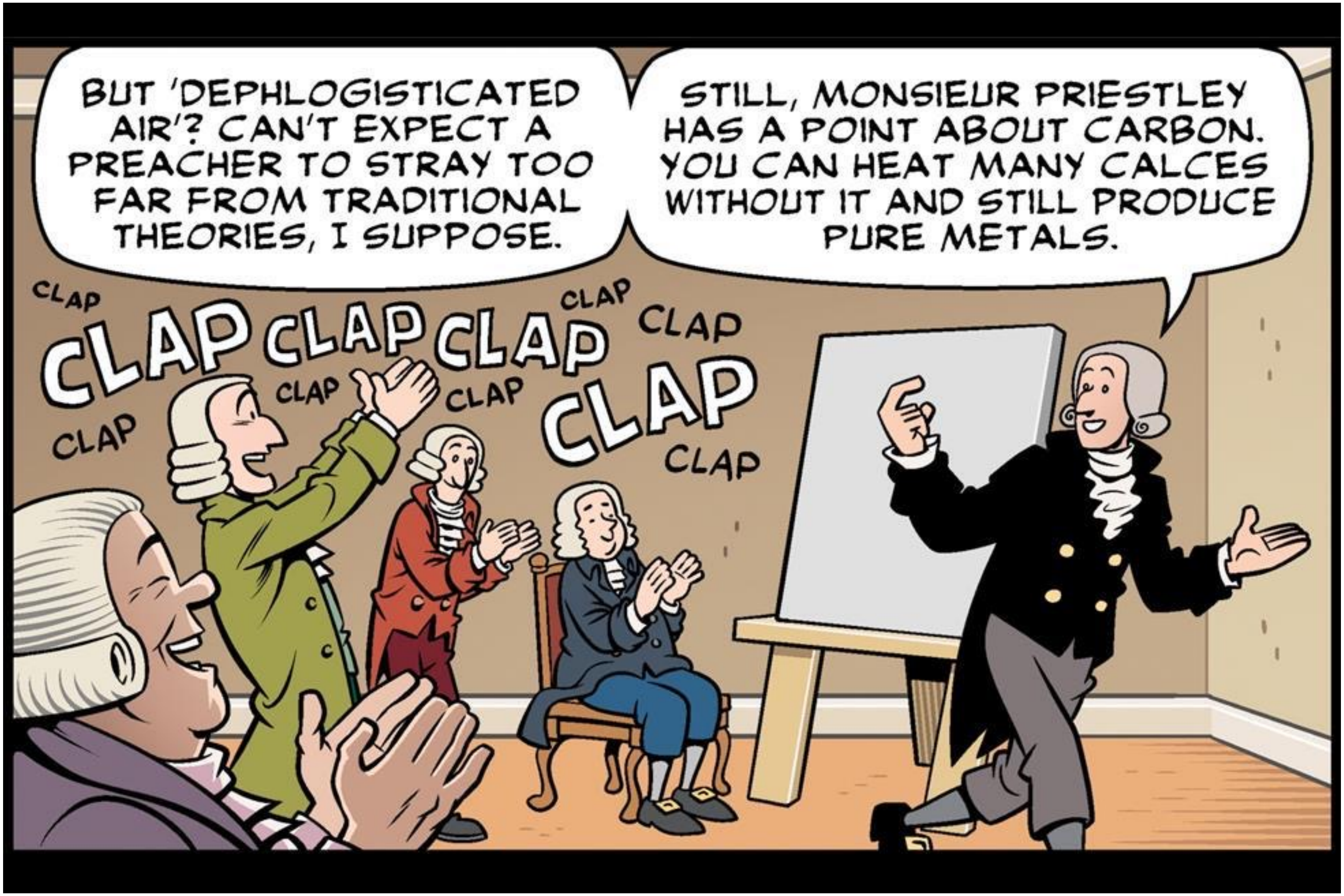
Dephlogisticated air

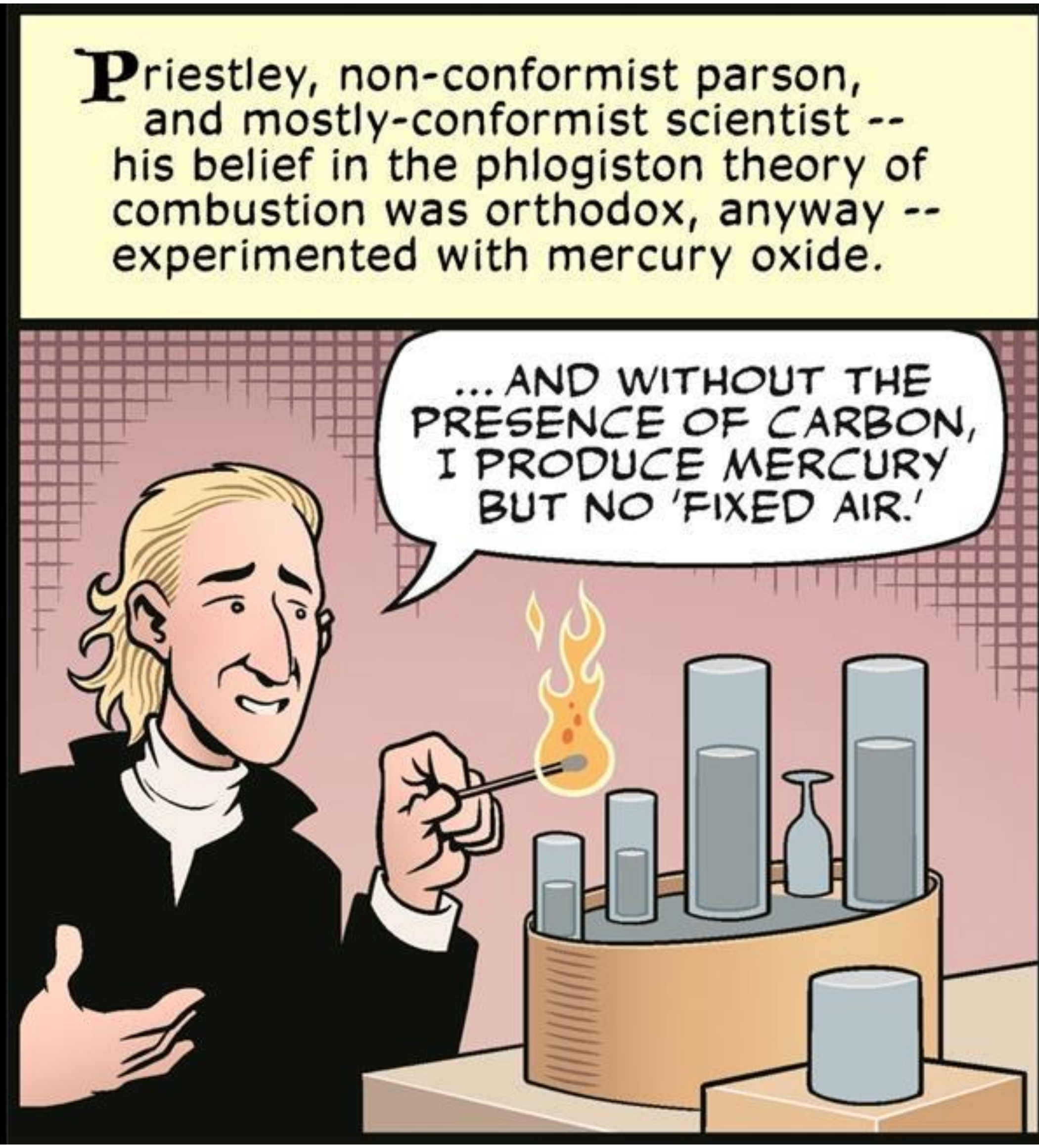
- Experimenting with his new air, Priestley found that:
  - A candle burned brighter in it.
  - A mouse put in a closed flask of the air lived longer than one in a flask with ordinary air.
  - He tried breathing it himself, and it made him feel great.

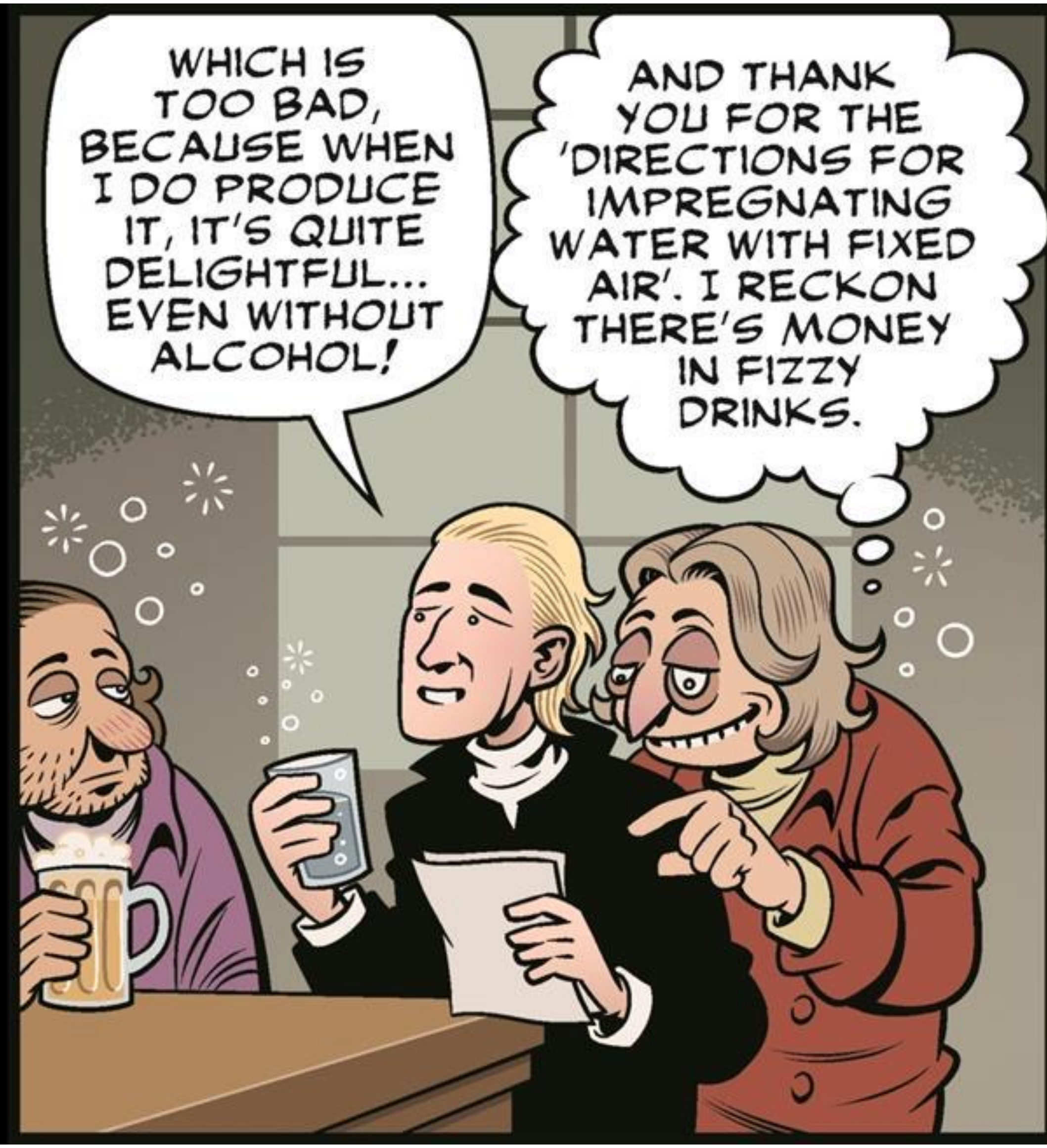

It was.
MY READER WILL WONDER THAT, AFTER HAVING ASCERTAINED THE SUPERIOR GOODNESS OF **DEPHLOGISTICATED AIR** BY MICE LIVING IN IT... I SHOULD HAVE THE CURIOSITY TO TASTE IT MYSELF.
I HAVE GRATIFIED THAT CURIOSITY, AND FANCIED THAT MY BREAST FELT PECULIARLY LIGHT AND EASY...

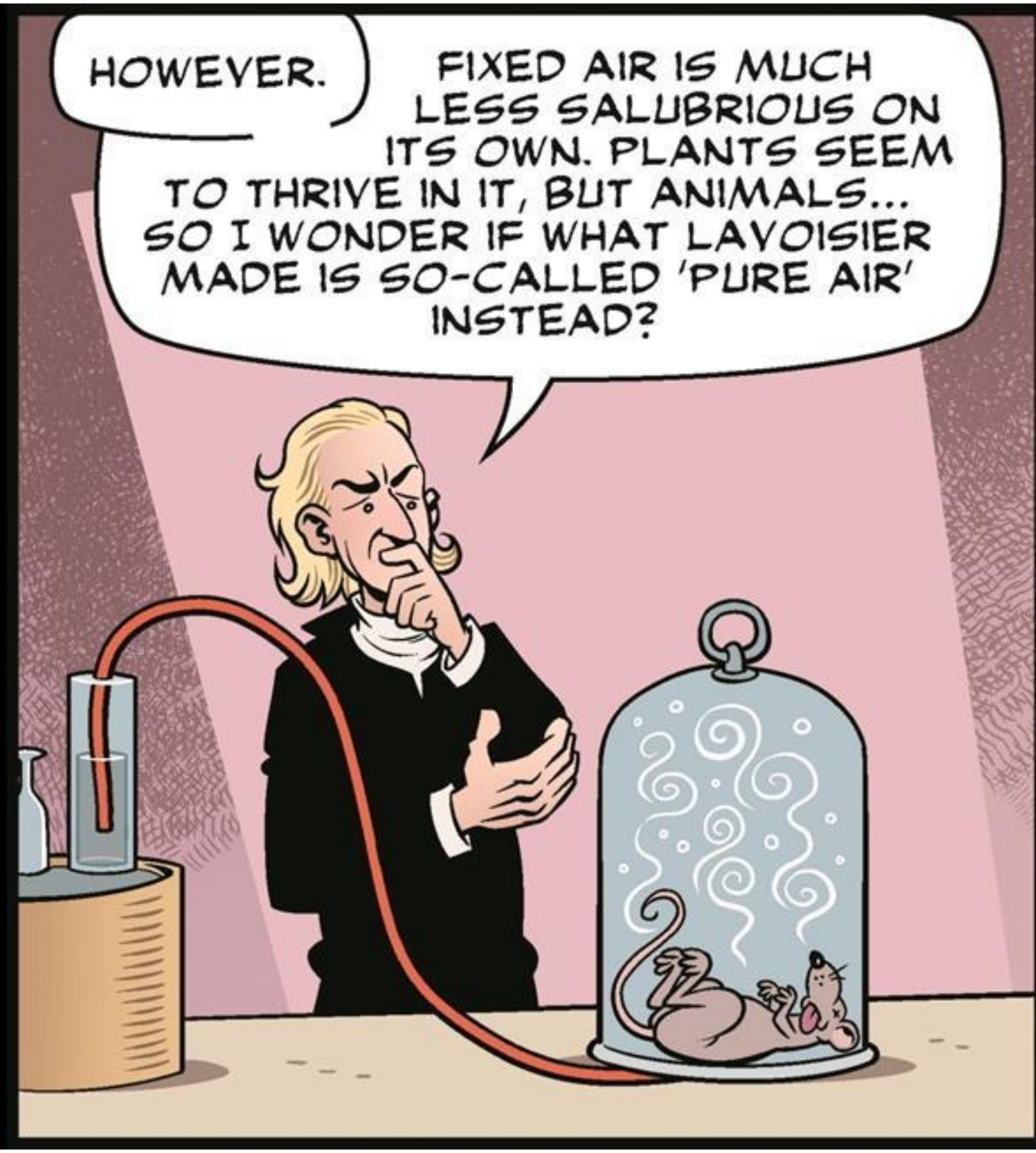

Meanwhile (sort of), in France...
'... FOR SOME TIME AFTERWARDS. HITHERTO ONLY TWO MICE AND MYSELF HAVE HAD THE PRIVILEGE OF BREATHING IT. WHO CAN TELL BUT THAT, IN TIME, THIS PURE AIR MAY BECOME A FASHIONABLE ARTICLE OF LUXURY?'

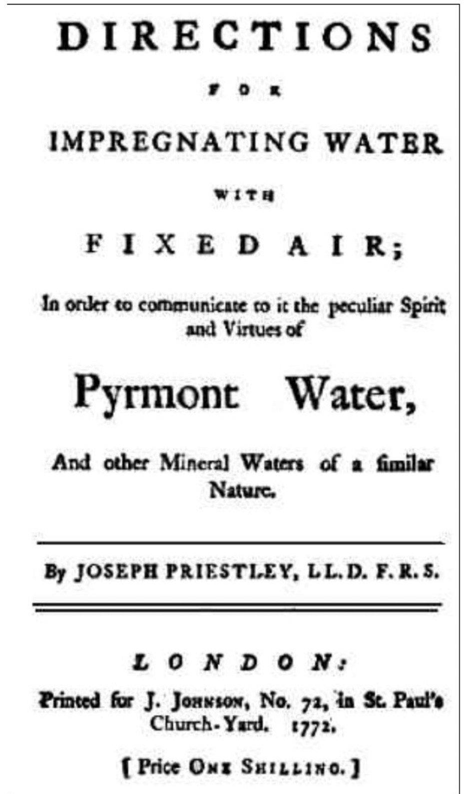

BOF. NOT A BAD IDEA.


BUT 'DEPHLOGISTICATED AIR'? CAN'T EXPECT A PREACHER TO STRAY TOO FAR FROM TRADITIONAL THEORIES, I SUPPOSE.
STILL, MONSIEUR PRIESTLEY HAS A POINT ABOUT CARBON. YOU CAN HEAT MANY CALCES WITHOUT IT AND STILL PRODUCE PURE METALS.
CLAP CLAP CLAP CLAP CLAP CLAP CLAP CLAP CLAP CLAP CLAP CLAP


Priestley, non-conformist parson, and mostly-conformist scientist -- his belief in the phlogiston theory of combustion was orthodox, anyway -- experimented with mercury oxide.
...AND WITHOUT THE PRESENCE OF CARBON, I PRODUCE MERCURY BUT NO 'FIXED AIR.'


WHICH IS TOO BAD, BECAUSE WHEN I DO PRODUCE IT, IT'S QUITE DELIGHTFUL... EVEN WITHOUT ALCOHOL!
AND THANK YOU FOR THE 'DIRECTIONS FOR IMPREGNATING WATER WITH FIXED AIR'. I RECKON THERE'S MONEY IN FIZZY DRINKS.


HOWEVER.
FIXED AIR IS MUCH LESS SALUBRIOUS ON ITS OWN. PLANTS SEEM TO THRIVE IN IT, BUT ANIMALS... SO I WONDER IF WHAT LAVOISIER MADE IS SO-CALLED 'PURE AIR' INSTEAD?



DIRECTIONS
FOR
IMPREGNATING WATER
WITH
FIXED AIR;
In order to communicate to it the peculiar Spirit and Virtues of
Pyrmont Water,
And other Mineral Waters of a similar Nature.

By JOSEPH PRIESTLEY, LL.D. F.R.S.

LONDON:
Printed for J. JOHNSON, No. 72, in St. Paul's Church-Yard. 1772.
[Price ONE SHILLING.]

Impregnating Water with Fixed Air

In order to communicate to it the peculiar Spirit and Virtues of
Pyrmont Water,
And other Mineral Waters of a similar Nature,

By Joseph Priestley, L.L.D. F.R.S.

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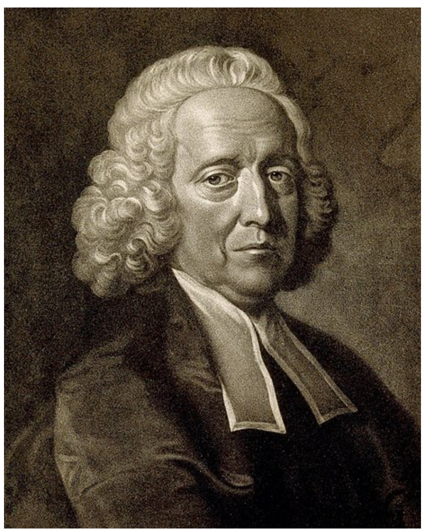
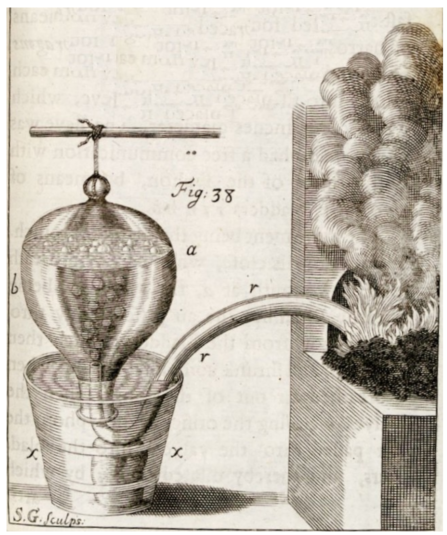
[Price ONE SHILLING.]

All air are not the same

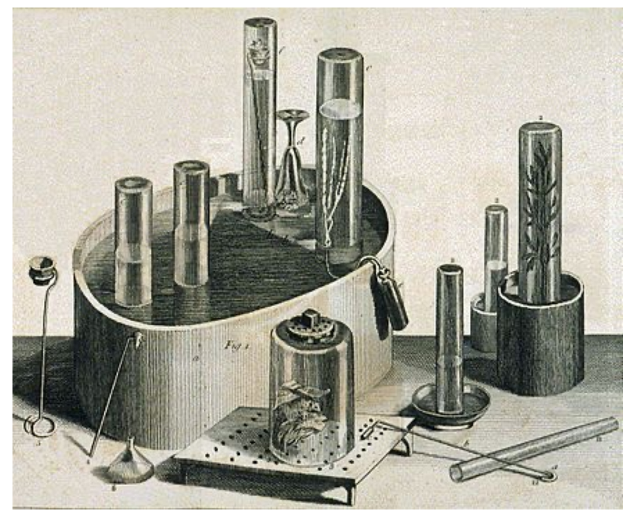
Parallel to phlogiston theory, another concept entered chemistry about the same time: the notion of "air" and that "air" is not just one thing, but that there are different kinds of air (many many air?)"



Stephen Hales
(1677 –1761)



Hales's



Priestly's

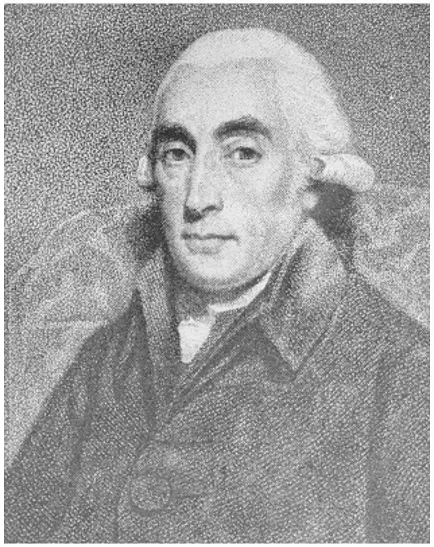
Pneumatic troughs

New air(s)

- Joseph Black identified several new gases, giving them names consistent with phlogiston theory.
  - "fixed air,"

    carbon dioxide
- Other researchers identified other new "airs."
  - "flammable air"

    hydrogen



Joseph Black
1728-1799

https://www.youtube.com/watch?v=AE0kuHKoitE

http://mysteryofmatter.net/Lavoisier.html

Antoine Lavoisier
The Father of Modern Chemistry

1743–1794

Status of chemistry during the lifetime of Lavoisier (1743–1794)

- Four elements theory is accepted for want of a better one.
- Boyle's definition of element did not get accepted; so, fire, water, air and earth are still the basic elements.
- The phlogiston theory dominated chemical philosophy.
- The composition of air and water unknown.
- Hydrogen and oxygen are yet to be discovered.
- The mechanism of respiration and metabolism understood in the context of phlogiston.

Phlogiston Theory – no longer valid!

Some materials burn because they contain phlogiston.

Phlogiston is released into the air when material burns.

Major flaw…some materials weigh more after they are burnt.

Wood → Ashes + Phlogiston; ashes weigh less…okay…

But…Iron → Rust + Phlogiston; rust weighed more than the iron

Lavoisier noticed the inconsistencies of the phlogiston theory and came up with a better explanation of combustion.

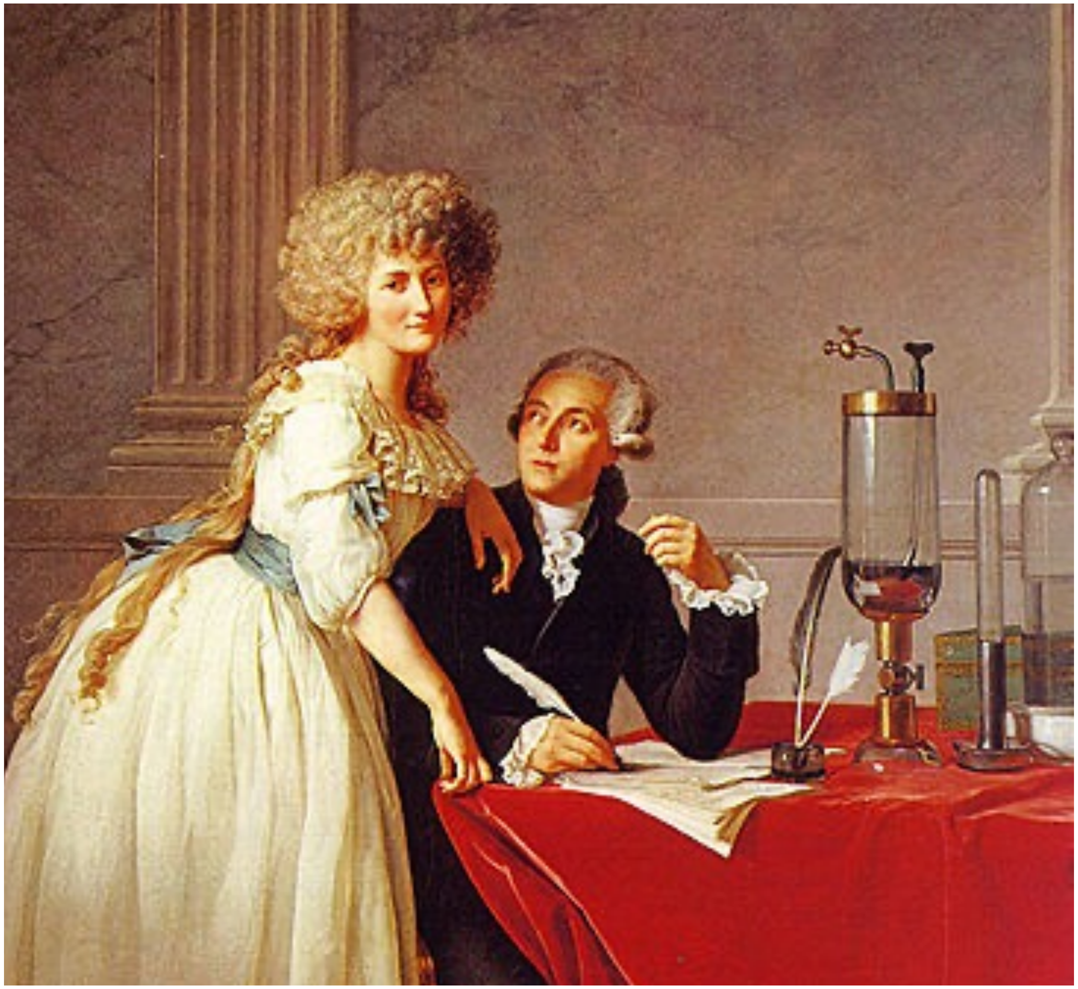
Lavoisier saw the opportunity

- Built a self-financed well-equipped laboratory.
- Invented and invested on new instruments: a burner that used ‘amplified Sunlight’ (heater), calorimeter, analytical balances, etc.
- Performed quantitative experiments to study chemical reactions, including combustion process.
- Established concepts as needed.

Personal Life of Lavoisier

- In 1768, at a young age of 25, he accepted office as a Farmer–General of Taxes, and as a chemist at the Royal Academy of Sciences, the most elite science society.
- Accepting Farmer-General of Taxes; he used his income to finance his experiments.
- A few years later he married the daughter of another tax farmer, Marie Anne who was only 13 at the time.
- Antoine Lavoisier was appointed regional inspector for the Tobacco Commission.
- Lavoisier became an important landowner by successive acquisition of land, in 1778.

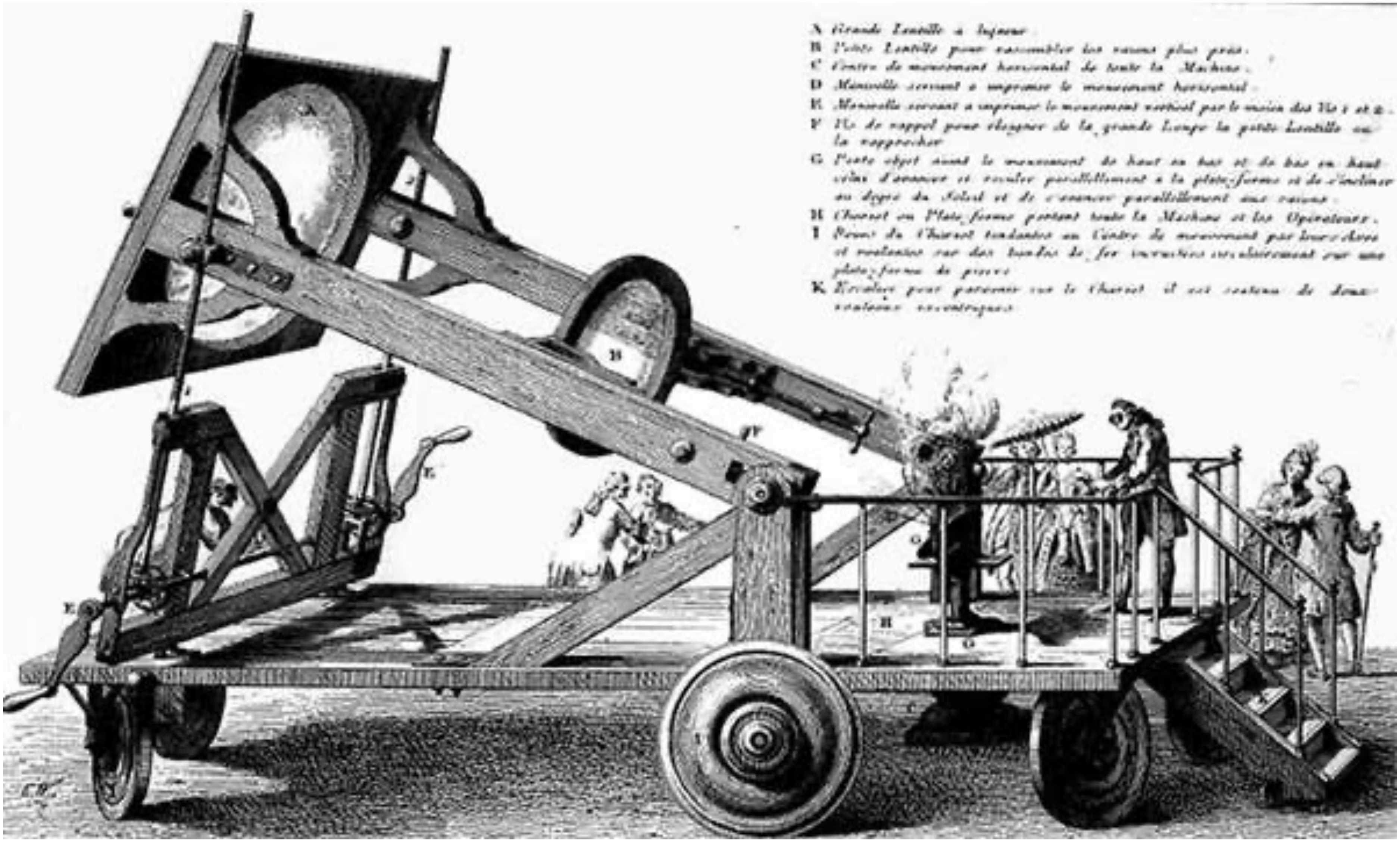
Madam Lavoisier



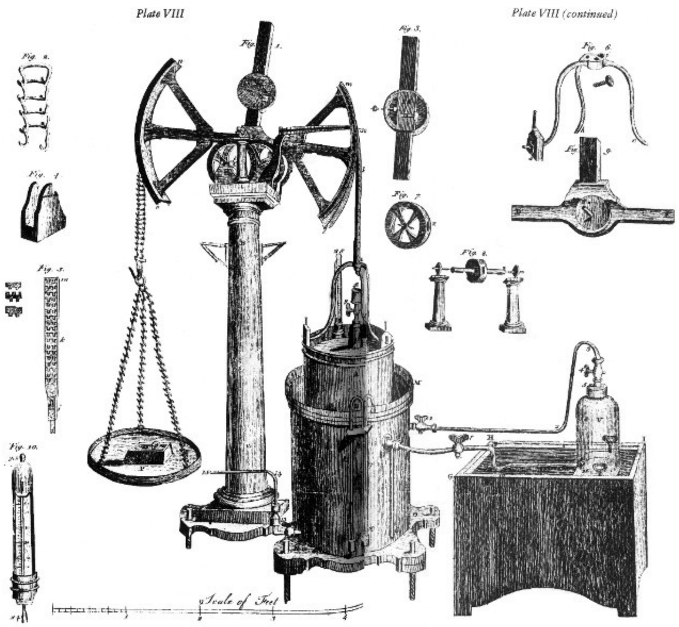
Marie-Anne would translate these English papers into <u>French</u> for her husband to be able to understand them

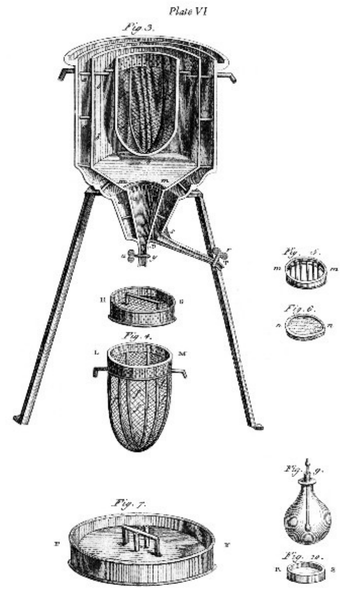
She also translated her husband's work from French into English so he could <u>share</u> his ideas.

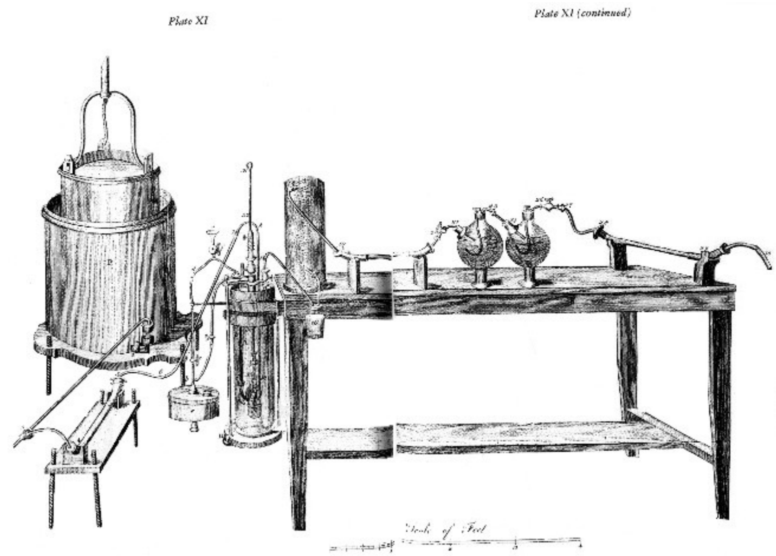
Her sketching skills were used to produce engravings of the apparatus and methods he used.

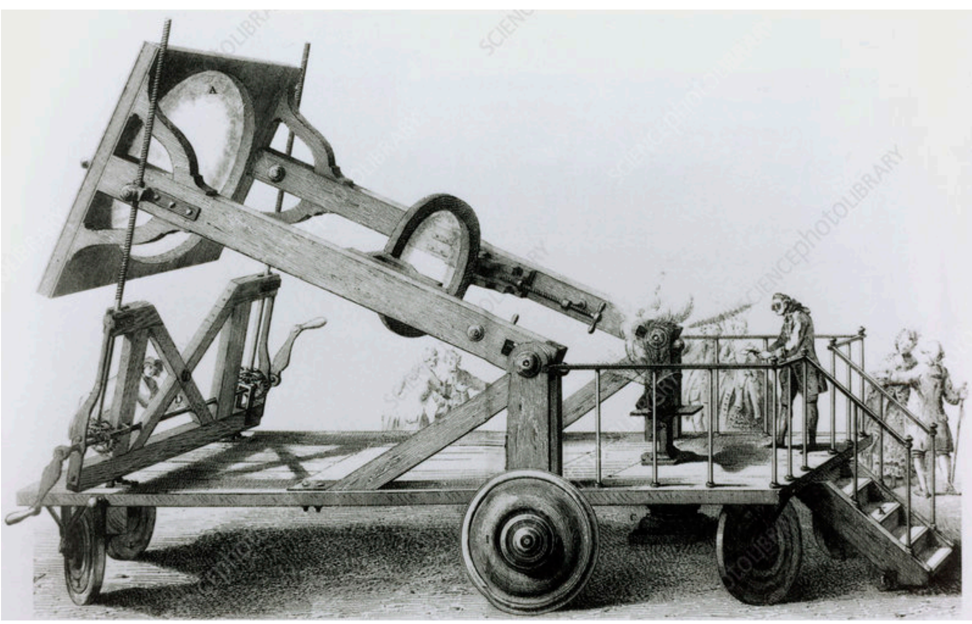

A Grande Lentille à liqueur.
B Petite Lentille pour rassembler les rayons plus près.
C Centre de mouvement horizontal de toute la Machine.
D Manivelle servant à imprimer le mouvement horizontal.
E Manivelle servant à imprimer le mouvement vertical par le moien des Vis 1 et 2.
F Vis de rappel pour éloigner de la grande Loupe la petite Lentille ou la rapprocher
G Porte objet ayant le mouvement de haut en bas et de bas en haut celui d'avancer et reculer parallèlement à la plate-forme et de s'incliner au degré du Soleil et de s'avancer parallèlement aux rayons.
H Chariot ou Plate-forme portant toute la Machine et les Opérateurs.
I Roues du Chariot tendantes au Centre de mouvement par leurs Axes et roulantes sur des bandes de fer incrustées circulairement sur une plate-forme de pierre
K Escalier pour parvenir sur le Chariot il est soutenu de deux roulettes excentriques

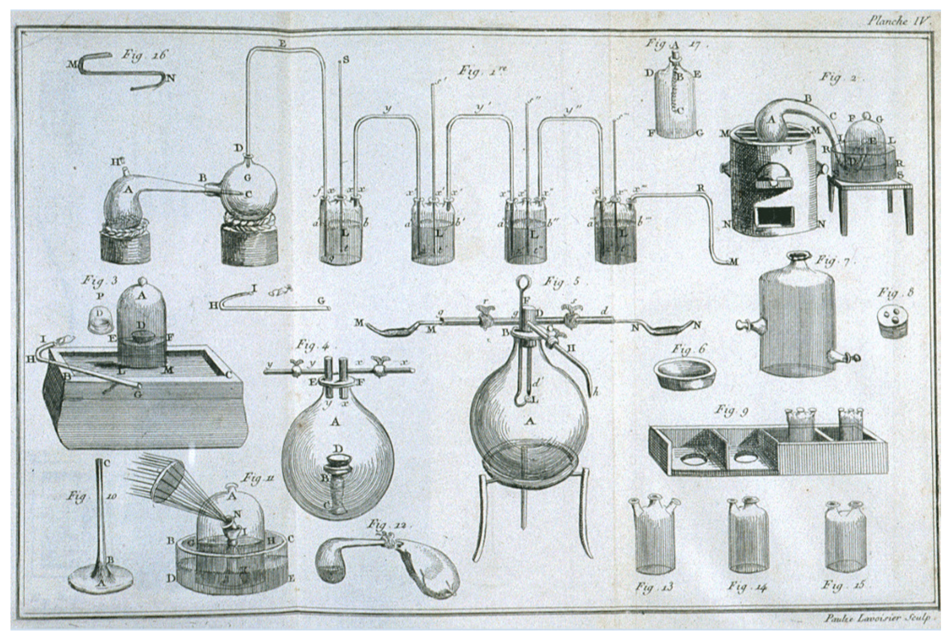
Home built laboratory equipments





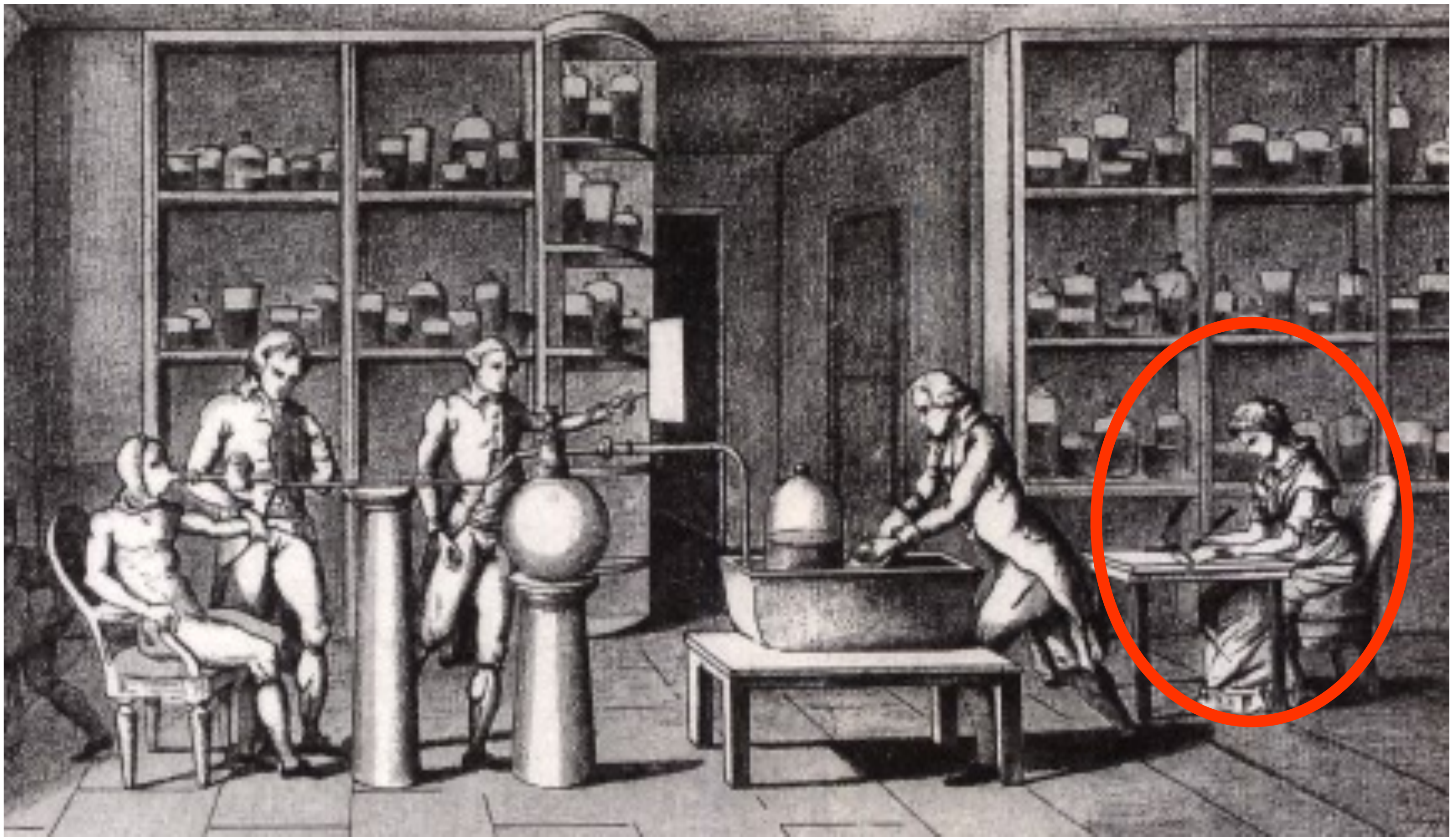






Married Marie-Anne in 1771

Helped to make sketches and take notes. She has drawn herself taking notes at the right-hand table.

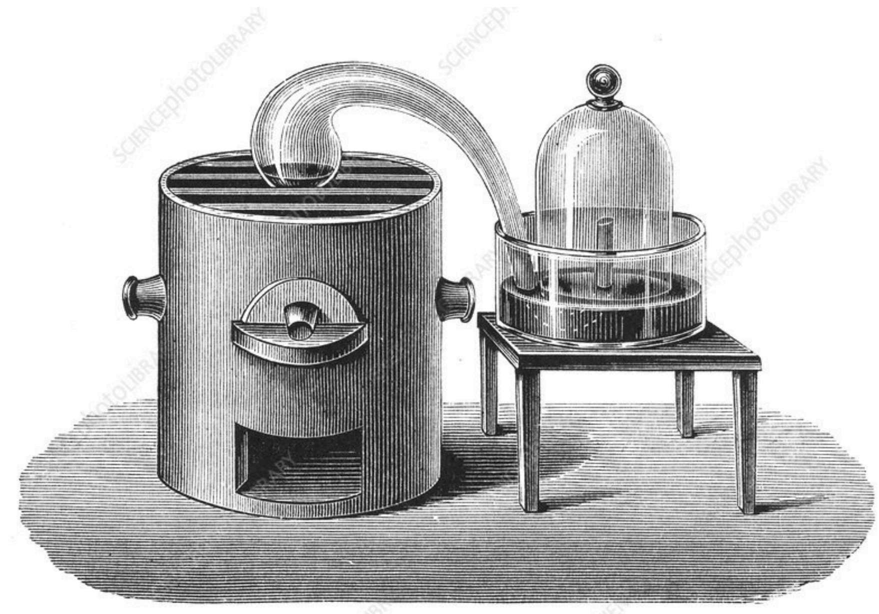


Lavoisier's ideas

- Lavoisier viewed heat as one of the elements, "caloric."
- Air he thought was a compound of different substances.
- He thought that Priestley's "dephlogisticated air" was actually an element.

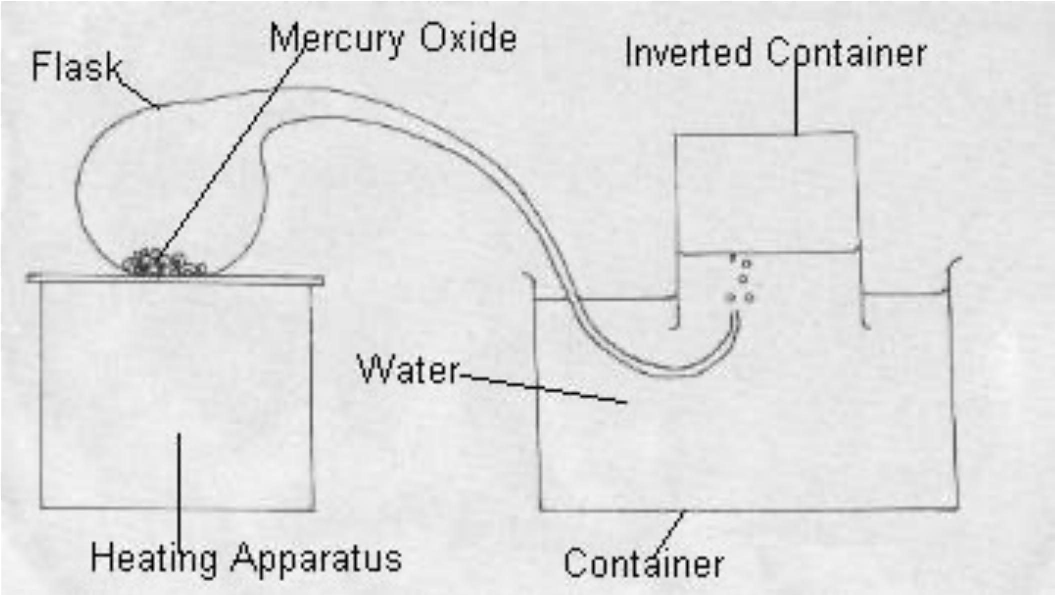
Lavoisier's classic experiment-1

- Lavoisier took mercury and a measured volume of air and heated them together.
- This produced a mercuric calx and reduced the volume of the air.



Lavoisier's classic experiment-2

- He then reheated the mercuric calx by itself at a lower temperature and saw it go back to mercury.
- In the process it produced a gas, equal in volume to the amount lost from the first procedure.



Lavoisier's classic experiment-3

- *Observation: water is raising in the tube indicating the amount of air decreasing as mercury goes to calx*

- Lavoisier concluded that instead of the original heating driving off phlogiston from the mercury, the mercury was combining with some element in the air to form a compound, which was the mercuric calx.

- He called that element "oxygen," meaning "acid maker."

- He classified all acids to contain oxygen; (wrong generalization).

Oxygen displaces phlogiston

- Phlogiston theory had everything upside down.
- Instead of driving off phlogiston during combustion, burning causes a compound to combine with the gas oxygen.
  - In the case of a metal, the compound is the calx produced (weight increases).
  - In the case of wood (rich in carbon) the weight decreases because carbon combines with something in the air and leaves. (Carbon plus oxygen is converted to carbon dioxide).

...even modern scientific theories are just theories, not absolute fact

Oxygen *vs* Phlogiston

"All the facts of combustion and calcination are explained in a much simpler and much easier way without phlogiston than with it.

I do not expect that my ideas will be adopted at once; the human mind inclines to one way of thinking and those who have looked at Nature from a certain point of view during a part of their lives adopt new ideas only with difficulty - - -."

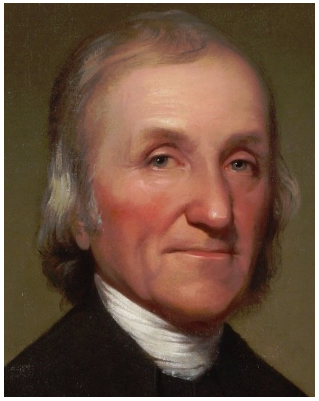
Lavoisier

Discovery of Oxygen

Lavoisier announced in 1775 that he has discovered a new gas resulting upon decomposition of Hg calx and Pb calx. He named it oxygen (meaning ‘acid maker’).

Lavoisier demonstrated (1779) its importance in respiration and glowing of candles and the left-over part of air being toxic to animal. Thus, he established for the first time that air is made up of two elements (one essential and another toxic for life).

Priority dispute: Who discovered oxygen?

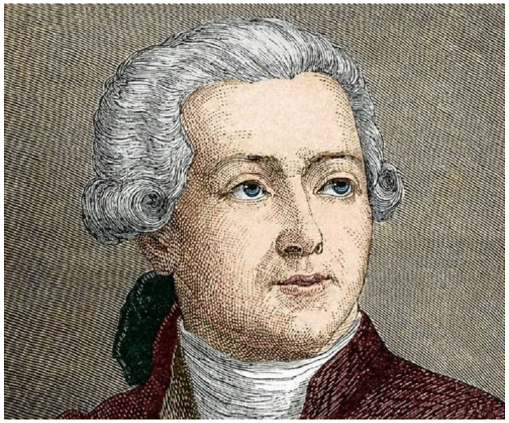


Joseph Priestley
1733 – 1804

He mentioned to Lavoisier in **1774** about the discovery during a visit to Paris. Published the results in **1775**.

Carl Scheele
1742 - 1786

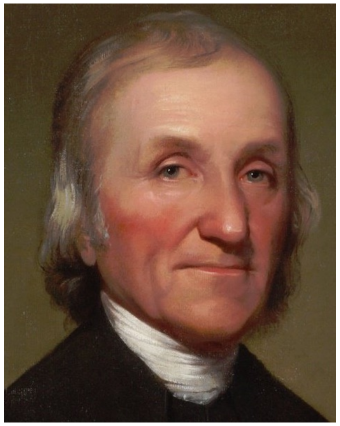
Swedish chemist **Scheele**, identified it **several years before** Priestley (1770-1773). Unfortunately, his scientific report sat in a printer's office for two years and got published in **1777**.



Antoine Lavoisier
1743—1794

In **1775 Lavoisier** announced to the Academy of Science in Paris that he had isolated a component of air that he called "eminently breathable air" by decomposition of mercuric oxide.

Who discovered oxygen?
Do you really need three?

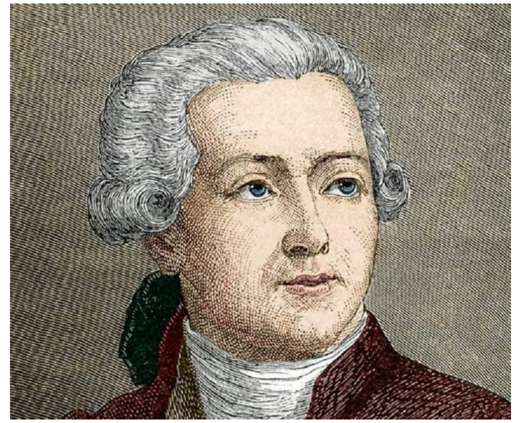


Joseph Priestley
1733 – 1804

Furious free thinker and scholar. Published every observation. His mind was inflexible with respect to phlogiston.

Carl Scheele
1742 - 1786

A great chemist, discovered 7 elements. Slow in publishing results.

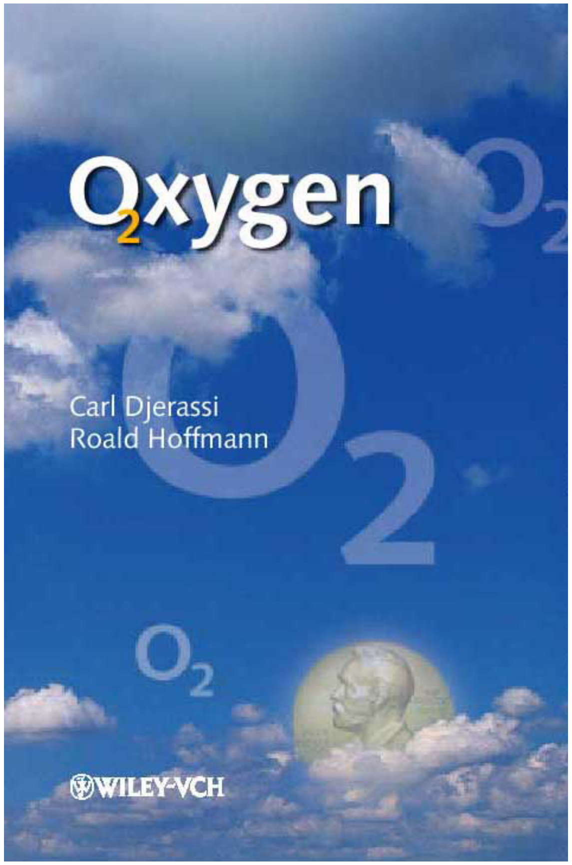


Antoine Lavoisier
1743—1794

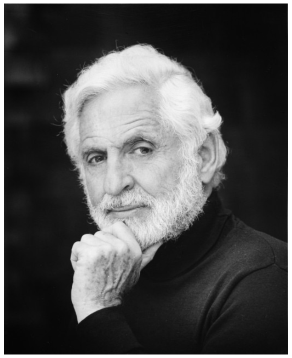
Brilliant economist, great and meticulous scientist. Mind was flexible to discard old ideas. Lacked professional integrity.

A popular Broadway play

On an evening in October 1774, **Antoine Lavoisier**, the architect of the chemical revolution, learned that the Unitarian English minister, **Joseph Priestley**, had made a new gas. Within a week, a letter came to Lavoisier from the Swedish apothecary, **Carl Wilhelm Scheele**, instructing the French scientist how one might synthesize this key element, the life-giver oxygen.



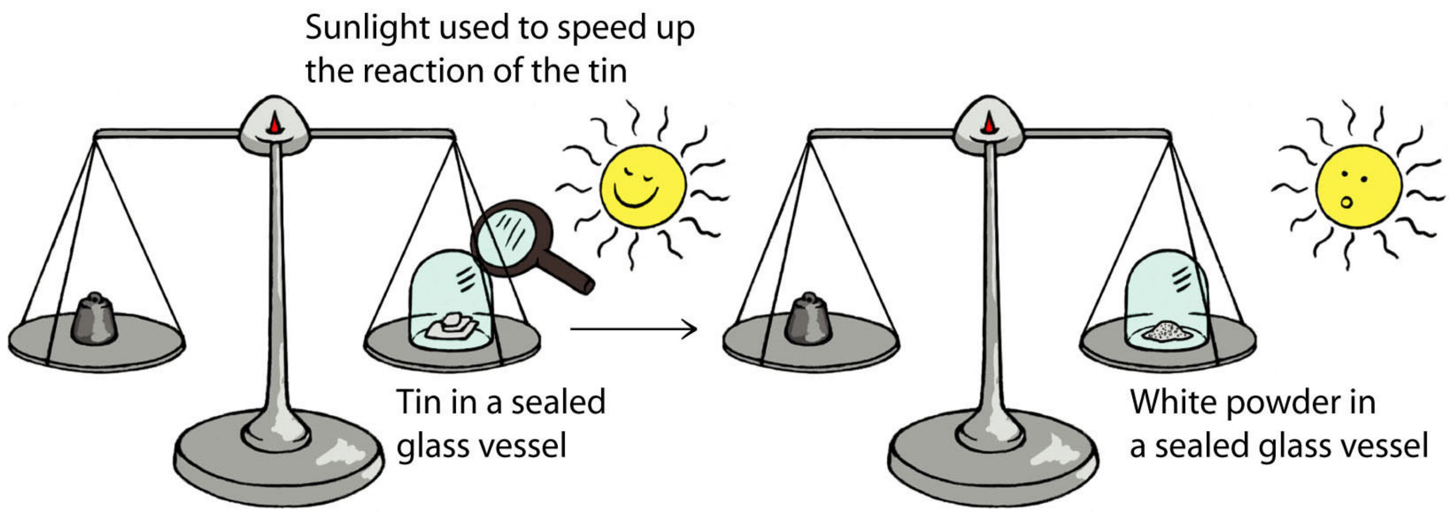
Scheele's work was carried out years before but remained unpublished until 1777. Scheele and Priestley fit their discovery into an entirely wrong logical framework—the phlogiston theory—that Lavoisier is about to demolish. How does Lavoisier deal with the Priestley and Scheele discoveries? Does he give the discoverers their due credit? And what is discovery after all? Does it matter if you do not fully understand what you have found? Or if you do not let the world know?



The Law of Conservation of Matter

By paying close attention to the weights of his experimental ingredients, Lavoisier made the *Conservation of Matter* a fundamental principle of chemistry.

The Law of Conservation of Mass



Magnesium + oxygen = magnesium oxide

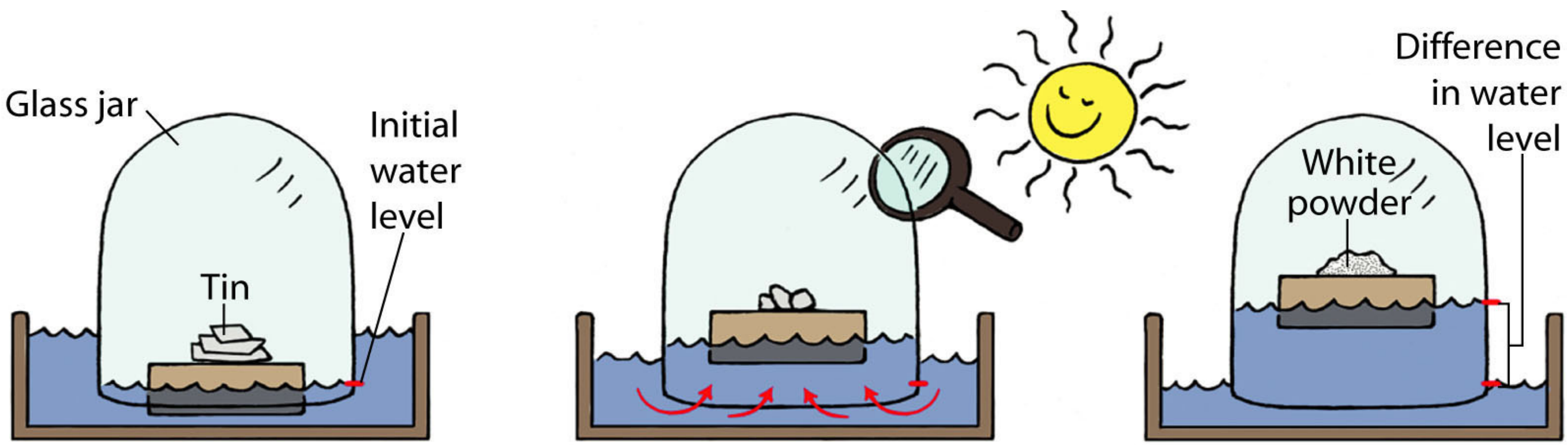
(Reactants) (Products)

Total mass is the same

Explain how the experiment in this picture demonstrates the Law of Conservation of Mass.

Air is not an element but a mixture.

- Lavoisier was sure that air contained more than one element.
- Determined the amount of the “reacting component” in the air. He named this reacting component oxygen.



① Lavoisier placed a piece of tin on a block of wood floating in water and covered it with a glass jar.

② Focused sunlight caused the tin to react and the water level in the jar to rise.

③ When the reaction was complete, there was 20 percent less air in the jar.

What is an element?

Robert Boyle's (1627-1691) definition of element
"An element is a substance that cannot be decomposed into anything simpler"

Cavendish: **"**When inflammable and common air are exploded in a proper proportion, almost all the inflammable air, and near one-fifth of the common air, lose their elasticity, and are condensed into dew (water)." (Done in 1781 and *Published in 1784)*.

Water is not an element. It is a mixture.

Lavoisier (1783)

- Combustion of inflammable air with oxygen carried out in a closed vessel yielded water in a very pure state.
- Water can be decomposed to inflammable air (hydrogen) and oxygen. Iron filings in water rusted and released inflammable air. Rusting occurred through the reaction of released oxygen with iron filings.
- Thus, water can be decomposed to two elements and can also be formed from the same two elements. **Water is not an element, it is a compound.**

Water and air are not elements: Four element theory is not valid

Priority disputes and Lavoisier's reaction

Cavendish's experiments were done in 1781 and published in 1784. In the meantime, his assistant Blagden visited Paris in 1783 and mentioned about Cavendish's results to Lavoisier. The latter published the water results in 1783. There was some feeling that Lavoisier might have used the information given to him by Blagden to anticipate the publication of a discovery made by Cavendish.

Lavoisier: "There was no principle of scientific conduct that forbade him to give better explanations of other men's discoveries than those they could provide themselves, an attitude to which no man of science could take exception.

This theory is not, as I hear it called, the theory of the French chemists. It is mine. It is a right that I claim by the Judgment of my contemporaries and at the bar of history."

Lavoisier recognized the opportunity

"The importance of the end in view prompted me to undertake all this work, which seemed to me destined to bring about a revolution in . . . chemistry. An immense series of experiments remains to be made."

Lavoisier, Lab Notebook entry dated Feb. 20, 1773

30 yrs old

Order in chaos

Law of the conservation of Mass

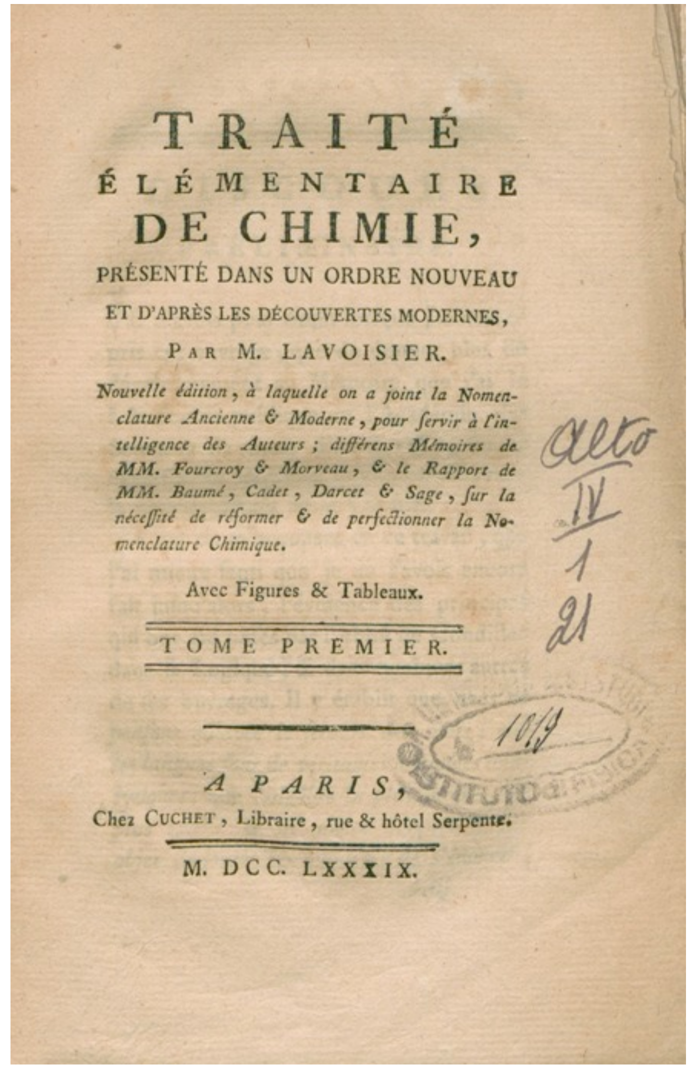
Law of the indestructibility of matter applied to chemical change

In every operation an equal quantity of matter exists both before and after operation.

Established the field of thermochemistry

Established a system of nomenclature

Conceived oxygen-based acid principle


TRAITÉ
ÉLÉMENTAIRE
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PAR M. LAVOISIER.

Nouvelle édition, à laquelle on a joint la Nomenclature Ancienne & Moderne, pour servir à l'intelligence des Auteurs; différens Mémoires de MM. Fourcroy & Morveau, & le Rapport de MM. Baumé, Cadet, Darcet & Sage, sur la nécessité de réformer & de perfectionner la Nomenclature Chimique.

Avec Figures & Tableaux.

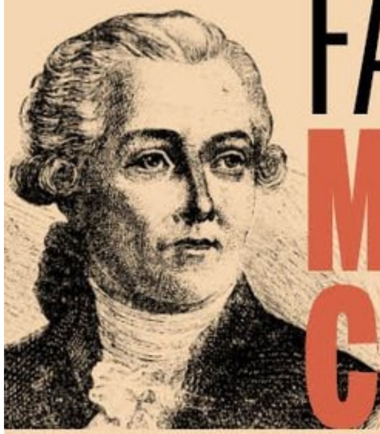
TOME PREMIER.

A PARIS,
Chez CUCHET, Libraire, rue & hôtel Serpente.
M. DCC. LXXXIX.

Antoine Lavoisier
1789

"In nature nothing is created, nothing is lost, everything changes."

French chemist **Antoine Lavoisier** died on May 8, 1794

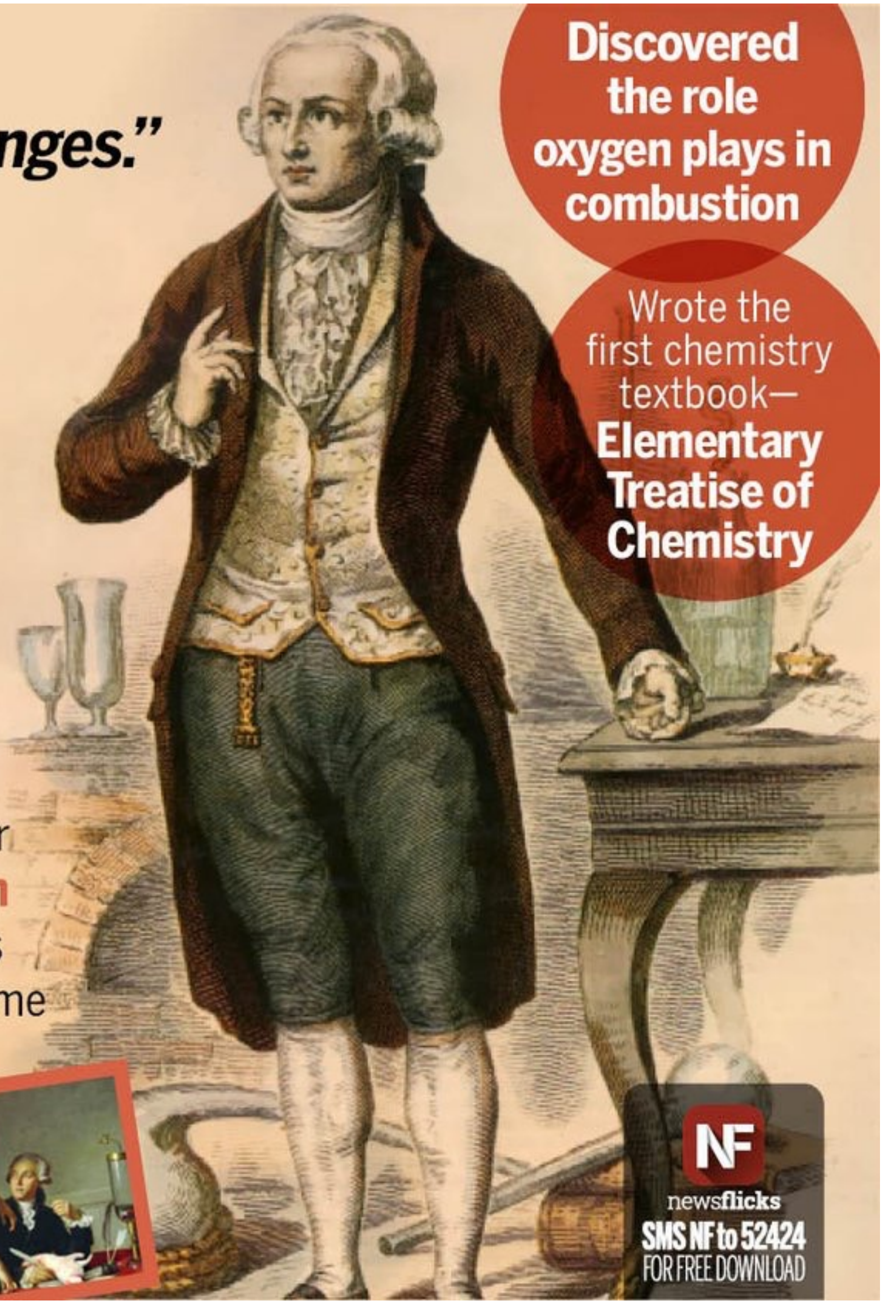


FATHER OF MODERN CHEMISTRY

Recognized and named oxygen and hydrogen; first person to establish that that water is a compound

Discovered that matter may **change its form or shape** but its mass always remains the same

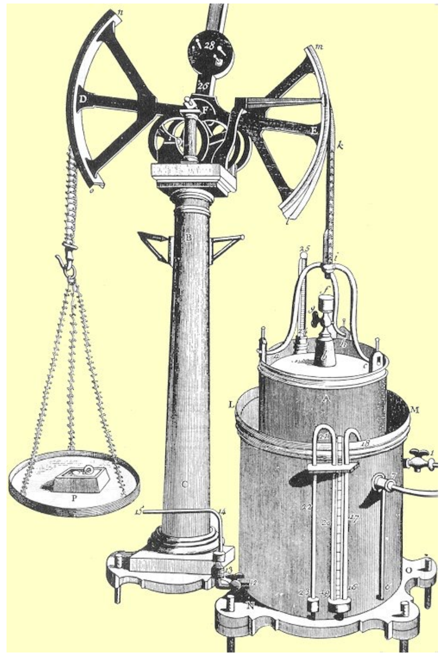
His wife, Marie-Anne, helped his research by translating English doc uments to French and drew illustrations for his scientific papers

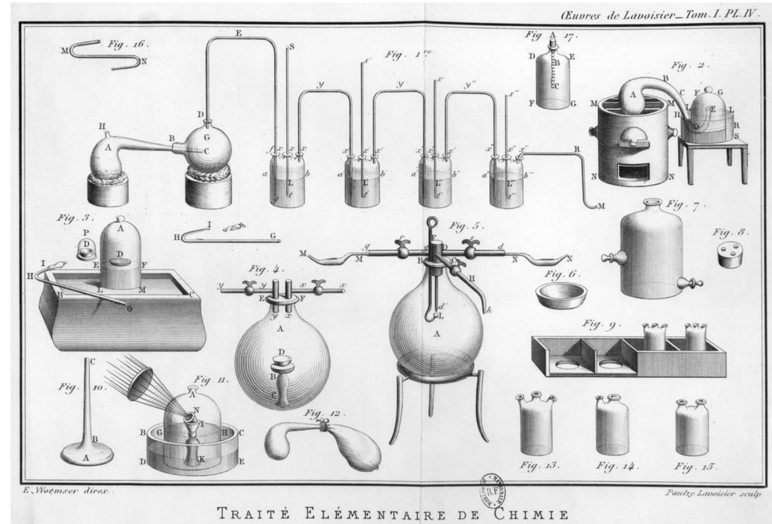


Discovered the role oxygen plays in combustion

Wrote the first chemistry textbook—**Elementary Treatise of Chemistry**

Marie-Anne Paulze
Lavoisier





Marie had spent her teen years studying chemistry and learning to read English. She also learned art from the revolutionary painter David. As Roald Hoffmann traces old records, he finds Marie managing the schedule of her husband's laboratory and creating fine detailed drawings of apparatus. She receives no credit, ----- *Was she the perfect secretary or a scientific collaborator?*

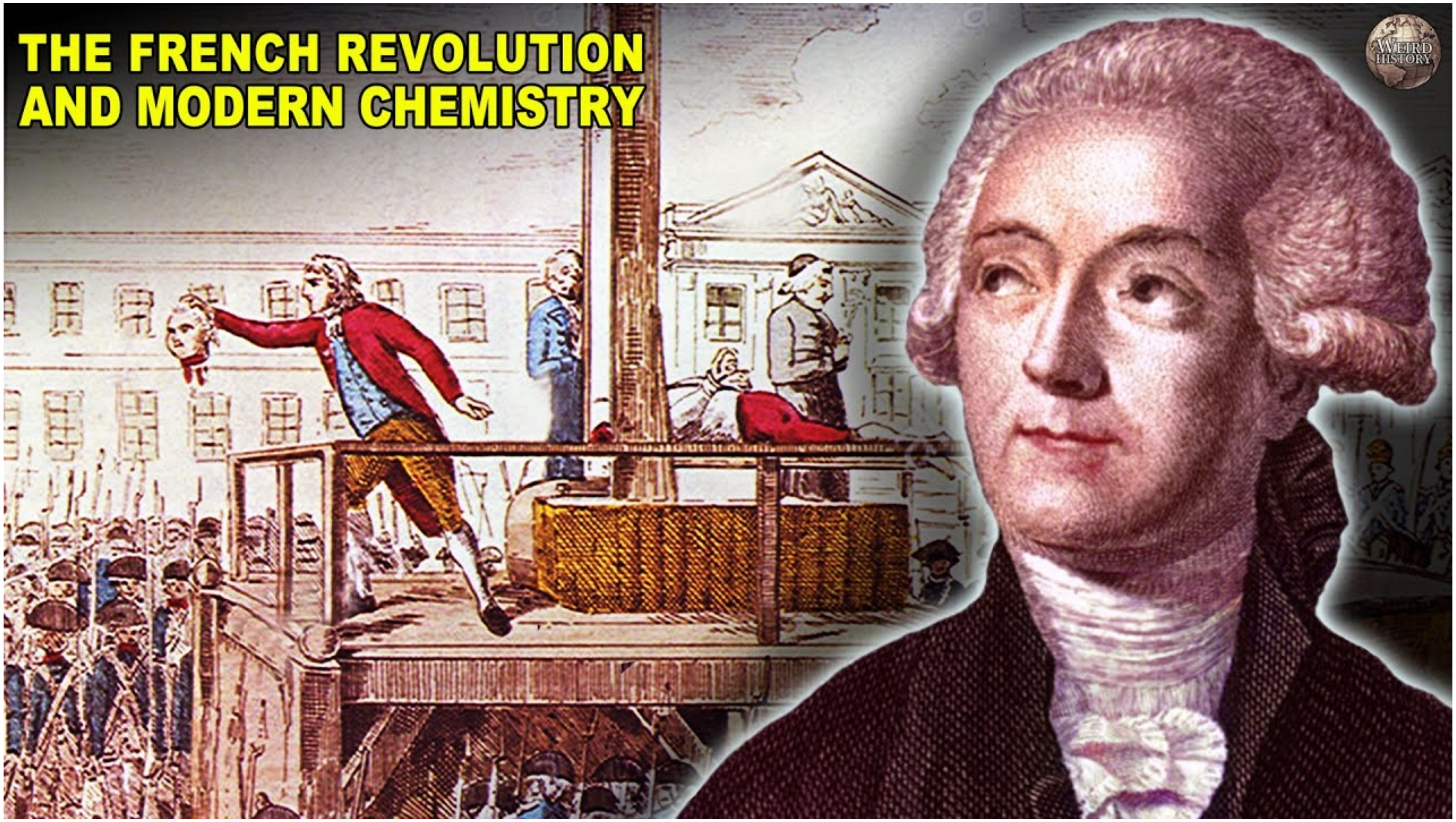
Antoine Lavoisier – Sad Ending

(Marie Anne Pierrette Paulze, 1758–1836)
MET, NewYork Collection

A landmark portrait presents a modern, scientifically minded couple in fashionable but simple dress, their bodies casually intertwined. Antoine Laurent Lavoisier is often referred to as the "father of modern chemistry" and Marie Anne Lavoisier is known as a key collaborator in his experiments—aspects of the couple's personality that have been well served by this famous image.


MMA-69
Genie

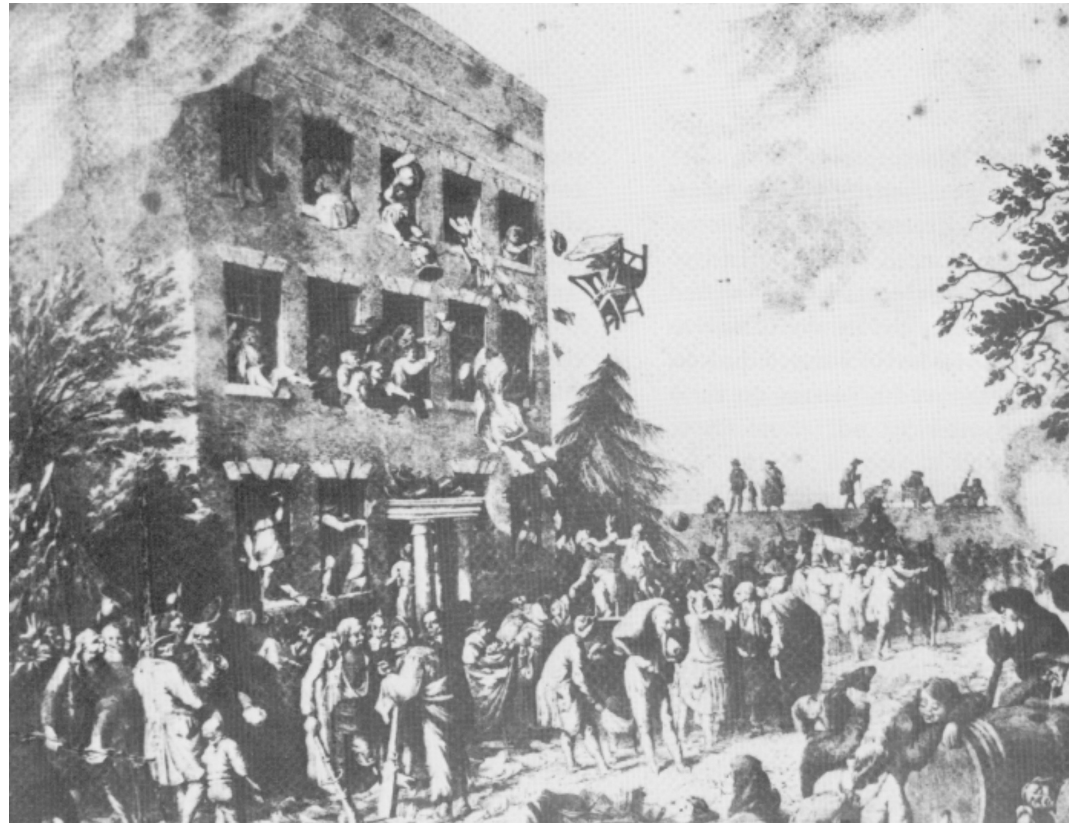
Despite his eminence and his services to science and France, he came under attack as a former farmer-general of taxes and was guillotined in 1794 (51 yrs old).



"It took them only an instant to cut off that head, and a hundred years may not produce another like it."

Joseph-Louis Lagrange

Priestley fled to the U.S.



- Priestley was an enthusiastic supporter of the American and French revolutions. His outspoken radical views enraged a mob that burned down his house and library. Priestley escaped to the United States where he lived for the remainder of his life.

Readings

Antoine Lavoisier, Douglas McKie, 1952

An International Historic Chemical Landmark, The Chemical Revolution, ACS, pamphlet, 1999

Antoine Lavoisier, H. Hartley, Proc. Royal Soc. A, 189, 427-454, 1947

http://mysteryofmatter.net/Lavoisier.html

"Well, certainly, Lavoisier was one of the great, great masters of all time."

Humphry Davy

The Chemical Revolution

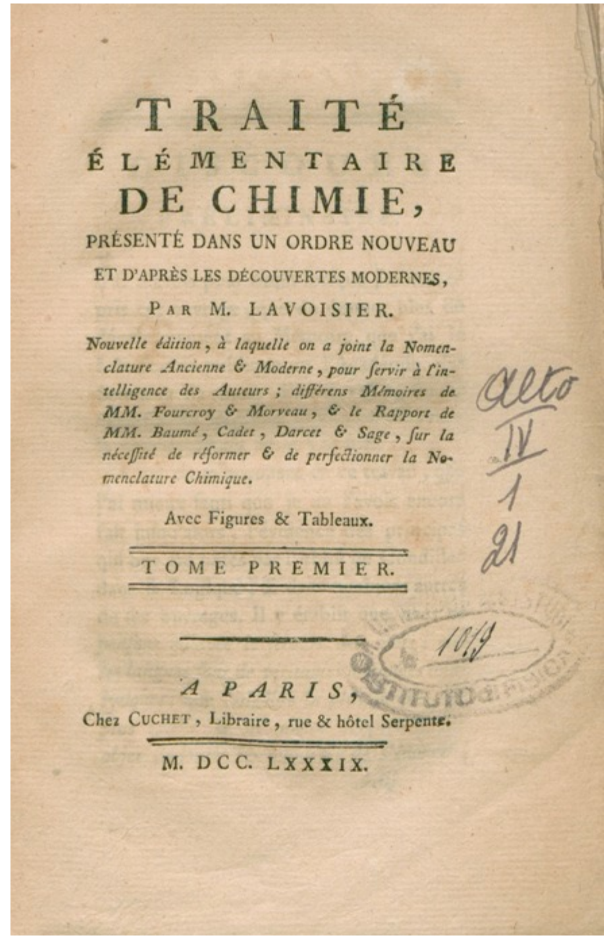
Lavoisier, Davy and Faraday

"Well, certainly, Lavoisier was one of the great, great masters of all time."

Humphry Davy

Humphry Davy: Chemistry's First Showman

Humphry Davy
1778-1829



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Antoine Lavoisier
1789

***The Age of Wonder*, Ch 6 & 8, R. Holmes, 2010**

Beginning

"I have neither riches, nor power, nor birth to recommend me. Yet if I live, I trust I shall not be of less service to mankind and my friends, than had I been born with these advantages"

Notebook entry at age 17

End

"Fortune had smiled on Davy, perhaps too kindly in his younger years, and left him eager for praise, jealous of rivals and anxious to shine in every field. Those were his failings, but withal his romantic genius made an enduring mark."

H. Hartley,

Humphry Davy, Nelson, London, 1966

A land of promise

“There is now before us a boundless prospect of novelty in science; a country unexplored, but noble and fertile in aspect; a land of promise in philosophy.”

When Davy started his exploration electricity was popularly regarded as an invisible and volatile fluid stored in glass Leyden jars, ever ready to leap out with a bang.

Born in Penzance on Dec 17, 1778

John Tonkin, Family benefactor

John B. Borlase, Local doctor

Thomas Beddoes opens 'The Pneumatic Institute' in Bristol, Appoints Davy (19 yrs old) as Laboratory Operator.

- Gas research 1798 – 1801

Royal Institution, London, 1801-1825, Director

- Electrochemistry, Isolation of elements, Davy Lamp invention

The Pneumatic Institute

Thomas Beddoes

Nitrous oxide

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

Priestly, 1772

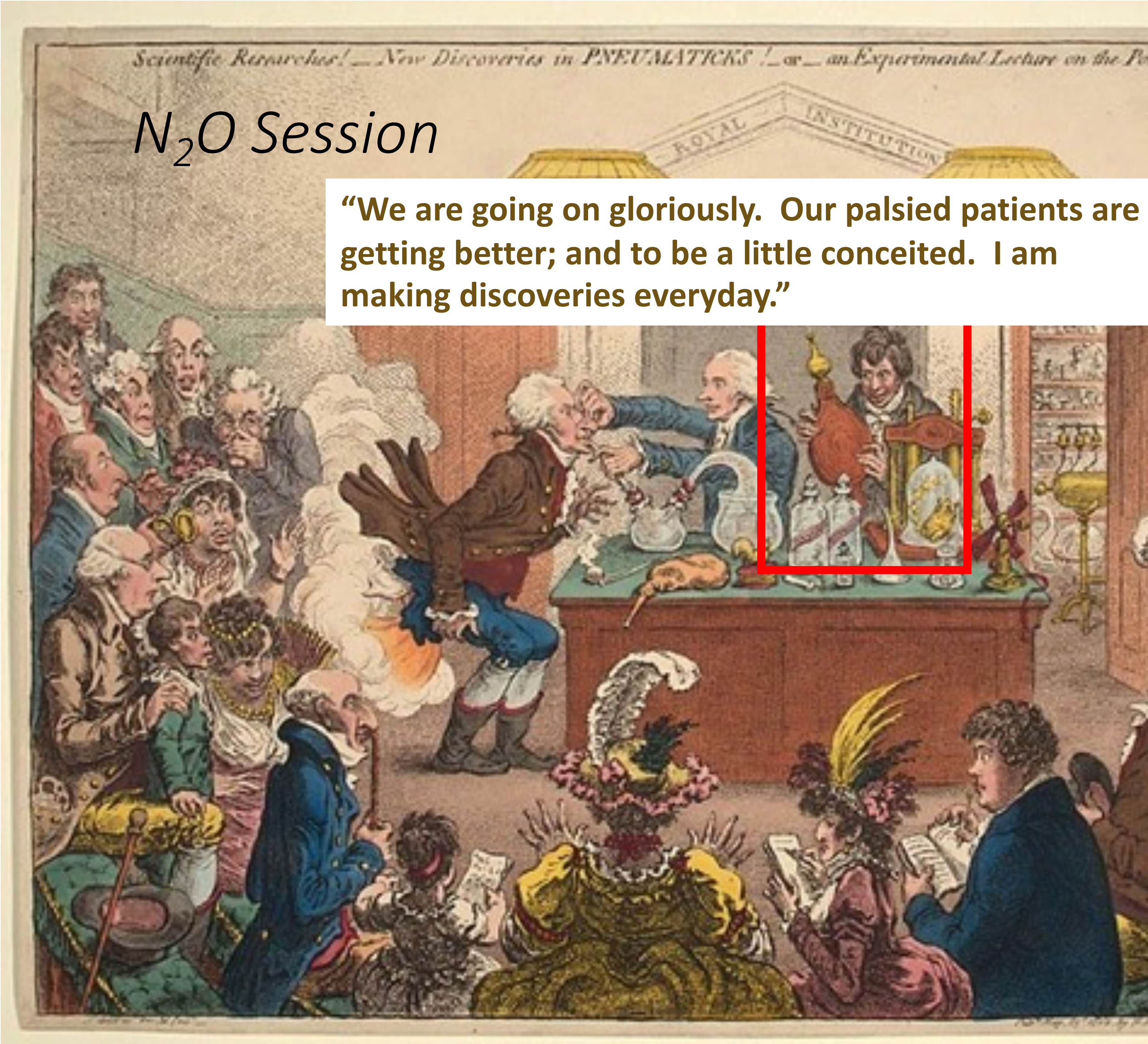
Davy has actually invented a new pleasure, for which language has no name.

Oh Tom! I am going for more this evening; it makes one strong, and so happy!…Tom, I am sure the air in heaven must be this wonder-working gas of delight!—

Letter to Thomas Southey, July 12, 1799

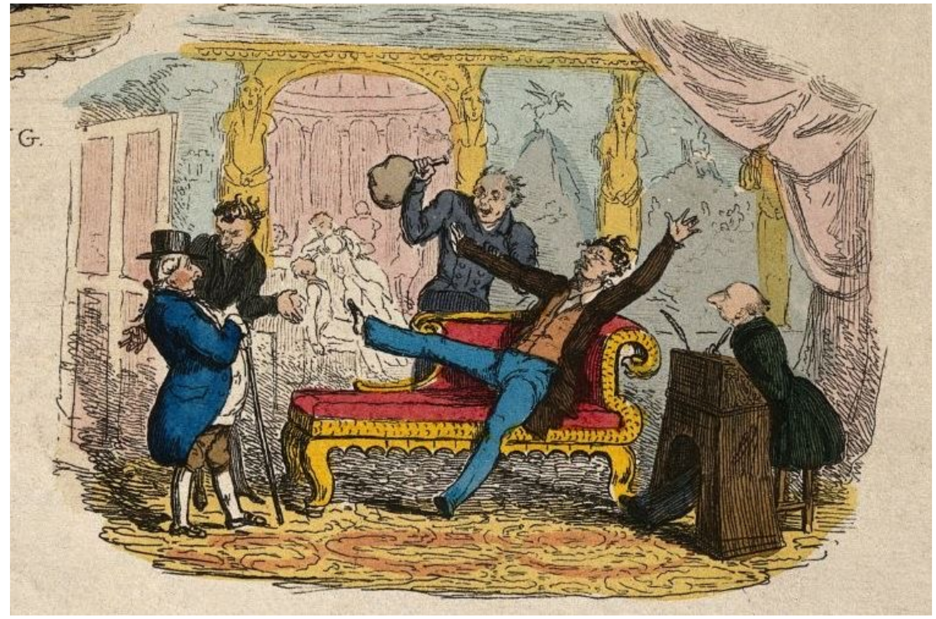
N_2O Session

"We are going on gloriously. Our palsied patients are getting better; and to be a little conceited. I am making discoveries everyday."



Humphry Davy

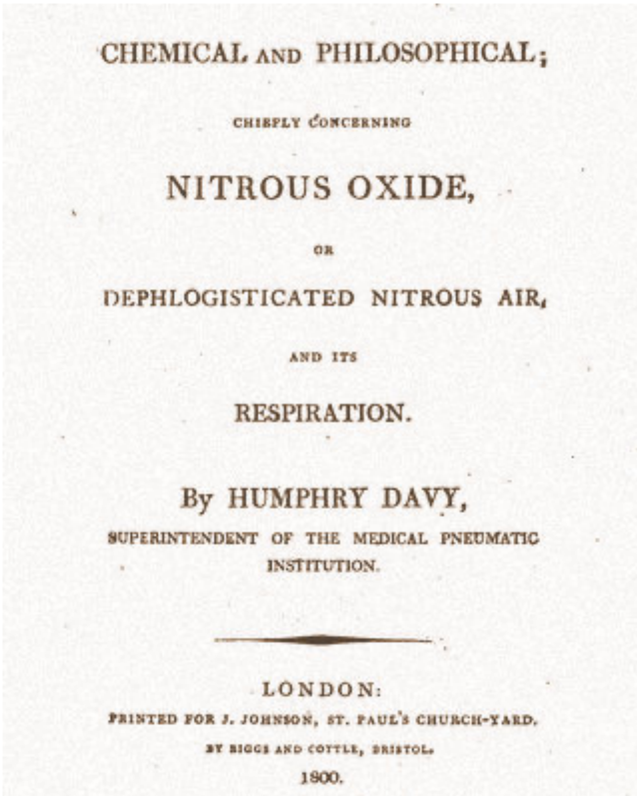
Nitrous oxide parties, early 18th century



Humphry Davy invited friends to try laughing gas so he could observe their responses.

"Give me more, give me more; this is the most pleasurable thing I've ever experienced."

Missed opportunity



CHEMICAL AND PHILOSOPHICAL;

CHIEFLY CONCERNING

NITROUS OXIDE,

OR

DEPHLOGISTICATED NITROUS AIR,

AND ITS

RESPIRATION.

By HUMPHRY DAVY,

SUPERINTENDENT OF THE MEDICAL PNEUMATIC INSTITUTION.

LONDON:

PRINTED FOR J. JOHNSON, ST. PAUL'S CHURCH-YARD,

BY BIGGS AND COTTLE, BRISTOL.

1800.

Davy's failure to capitalize on his discovery of anesthesia doomed thousands to needless surgical pain.

"As nitrous oxide appears capable of destroying physical pain, it may probably be used with advantage during surgical operations ----."

Davy never followed up on the idea that nitrous oxide could be an anesthesia, his attention was diverted by Volta's discovery of the battery.

Humphrey Davy

Moves on from nitrous oxide to carbon monoxide

Animal electricity and Battery (1791)

Luigi Galvani
1737-1798

Lucia Galvani

In 1791 Luigi Galvani announced that the contact of two different metals with the leg muscles of a skinned frog resulted in the leg to twitch. Galvani interpreted that as a new form of electricity found in living tissue, which he called "animal electricity."

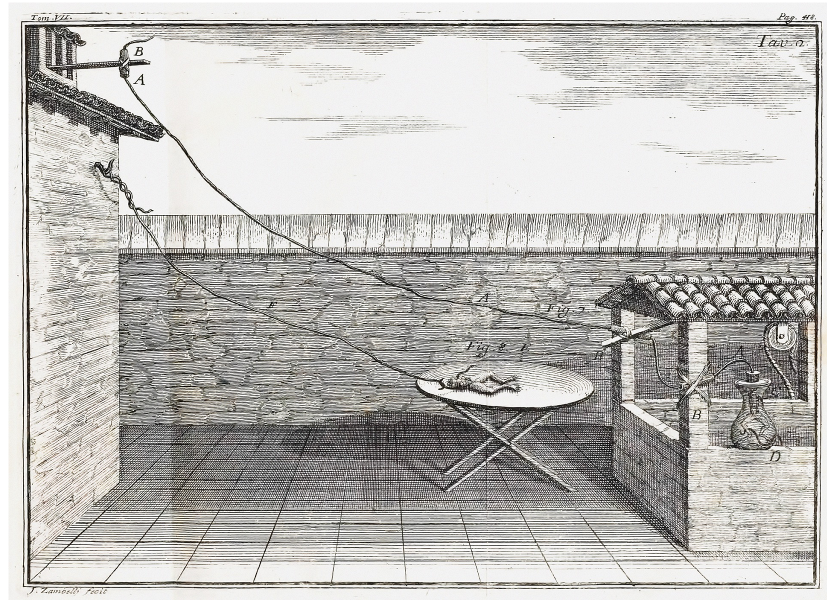
Galvani believed such occurrences suggested the existence of "animal electricity," a phenomenon related to "artificial electricity" (produced by an electrostatic machine or simple friction) and "natural electricity" (associated with lightning, electric eels, etc.).

Frogs and Animal Electricity

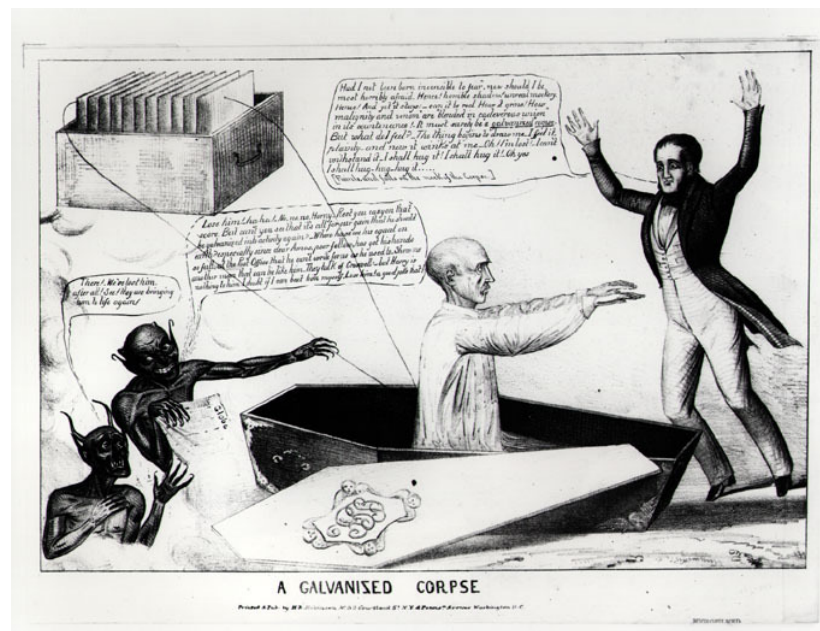
In 1786 **Luigi Galvani** hung the legs of a dead frog on a railing in a thunderstorm to see if lightning would make them twitch….

Frogs and Animal Electricity

However, one day Galvani made the legs twitch without any charge.



Galvani believed he had created "**Animal Electricity**" – and many people began to believe that this was the secret of life itself. By creating a static charge, he and other scientists could get the dead frog's legs to twitch… later on dead people too!

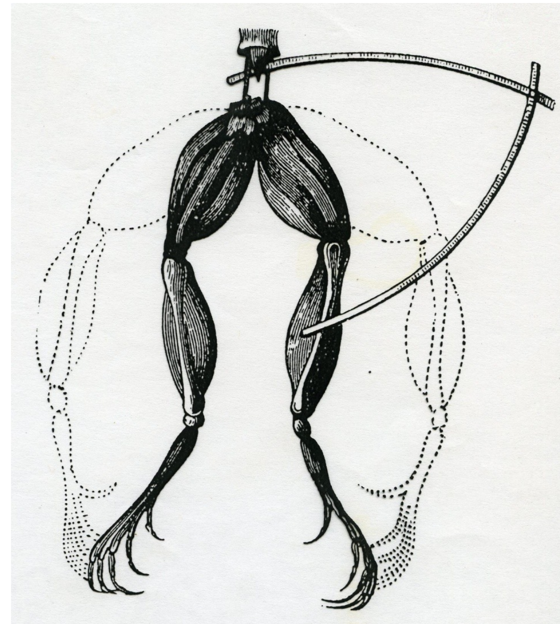


Alessandro Volta's Response (ca.1800)

Alessandro Volta realized that most of the unusual electrical behavior observed by Galvani involved two different types of metals, such as the iron of a scalpel and the brass of a hook. This led him to suggest that the animal tissue was not necessary; any moist material between different metals would produce electricity. Instead of "animal electricity," Volta believed in "metallic electricity."

Volta believed the brass hooks on which the legs hung were reacting chemically with an iron stand to create an **electric current**.

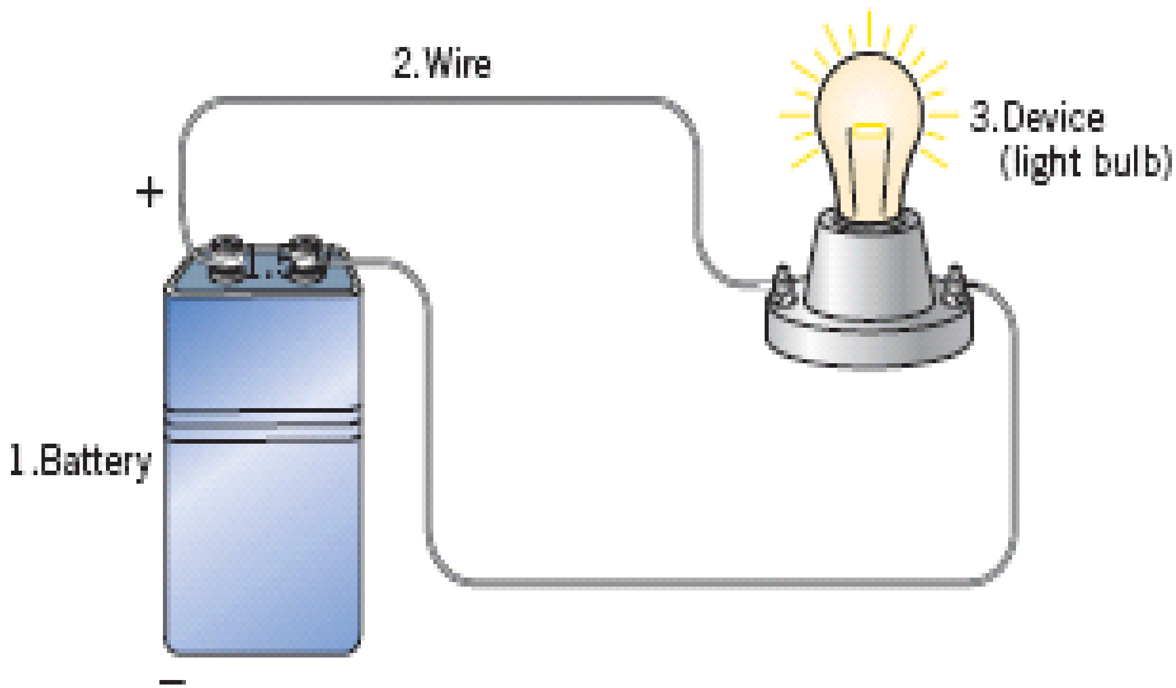
Volta made the first battery in 1800.

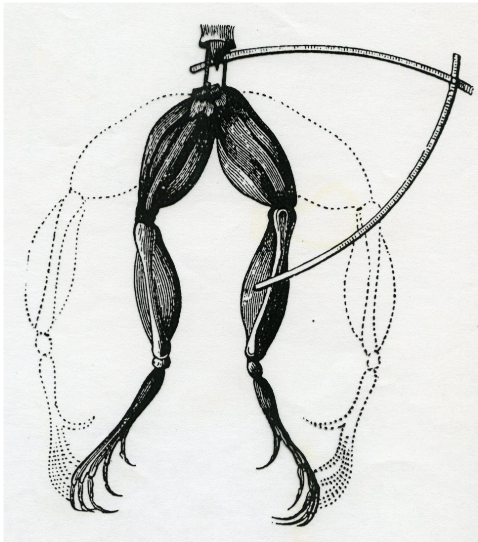


Alessandro Volta
1745-1827

Three Parts of an Electric Circuits

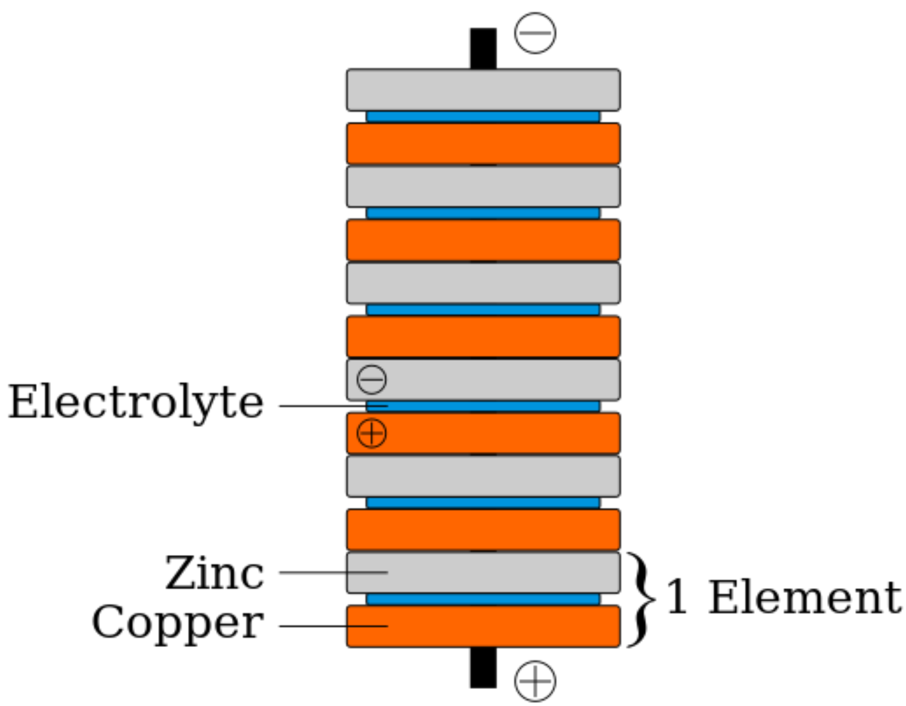
1. Source of electrical energy
2. Closed path
3. Device to use electrical energy





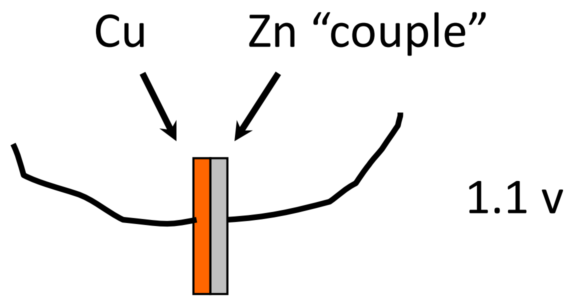
Volta's pile (1800)

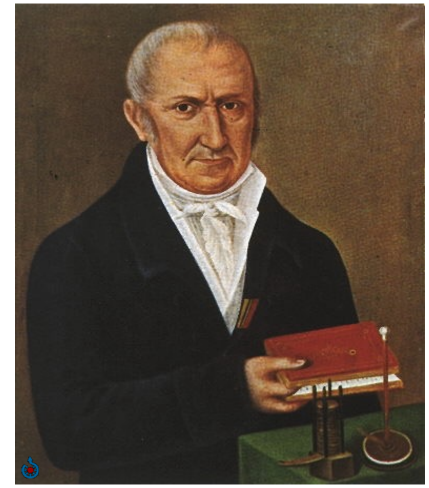
The voltaic pile, invented by Alessandro Volta in 1800, was **the first device to provide a steady supply of electricity**.

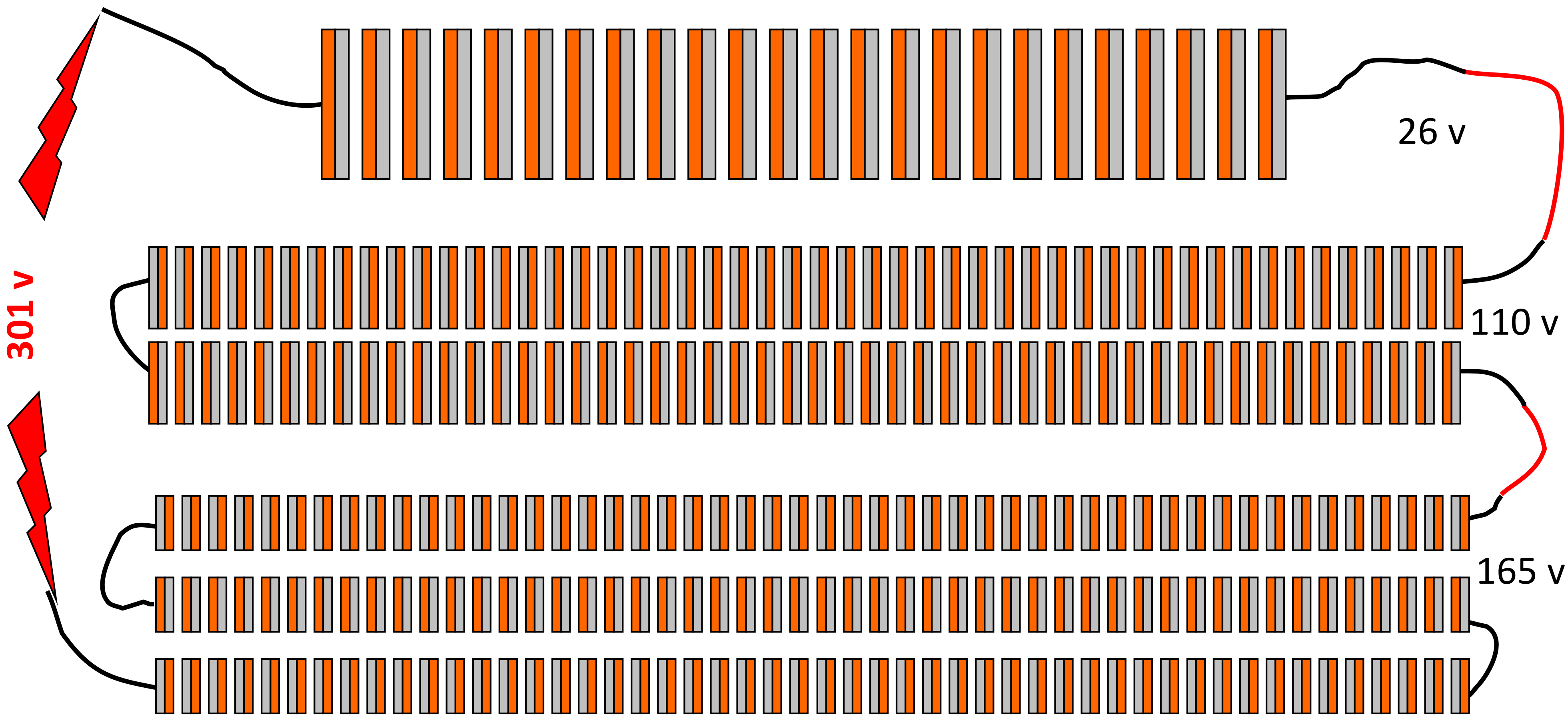


Volta's pile (1800)

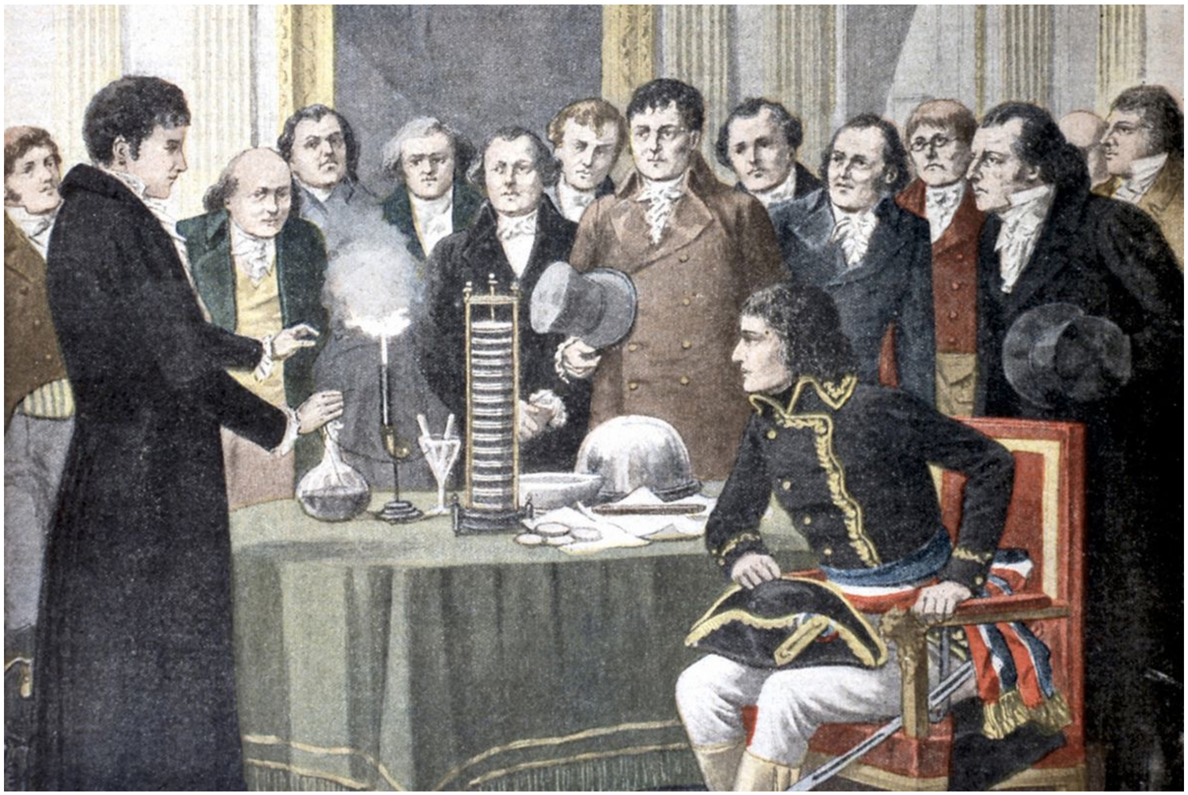
In 1800, Alessandro Volta (1745 – 1827, an Italian physicist) discovered that chemical reactions could be used to create positively charged anodes and negatively charged cathodes.







Volta's pile, the first battery



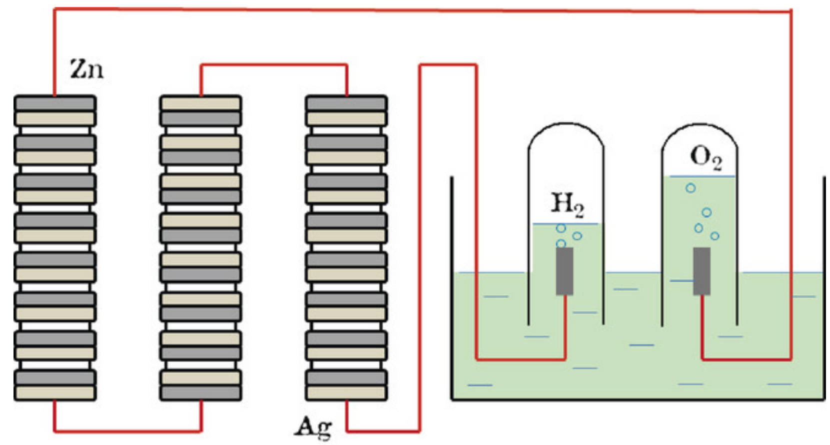
In 1800 A. Volta invented the voltaic pile, which was one of the first electric batteries. It was essentially a stack of alternating metal discs separated by brine-soaked material that helped make them more conductive.

Volta demonstrated his battery for the French leader Napolean and promptly earned a nice gold medal, -----

Humphry Davy built his own Voltaic pile and experimented

"…though there was a high intensity of action, the water of the solutions alone was affected, and hydrogen and oxygen disengaged with the production of much heat and violent effervescence."

(*electrolysis of water*)



⊖ cathode: $2 \times [2H_2O + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}]$

⊕ anode: $2H_2O \rightarrow O_{2(g)} + 4H^+_{(aq)} + 2e^-$

$$2H_2O \rightarrow O_{2(g)} + 2H_{2(g)}$$

Birth of electrochemistry

Davy's excitement on elemental discoveries

Davy used electricity to split up compounds to form elements

1807

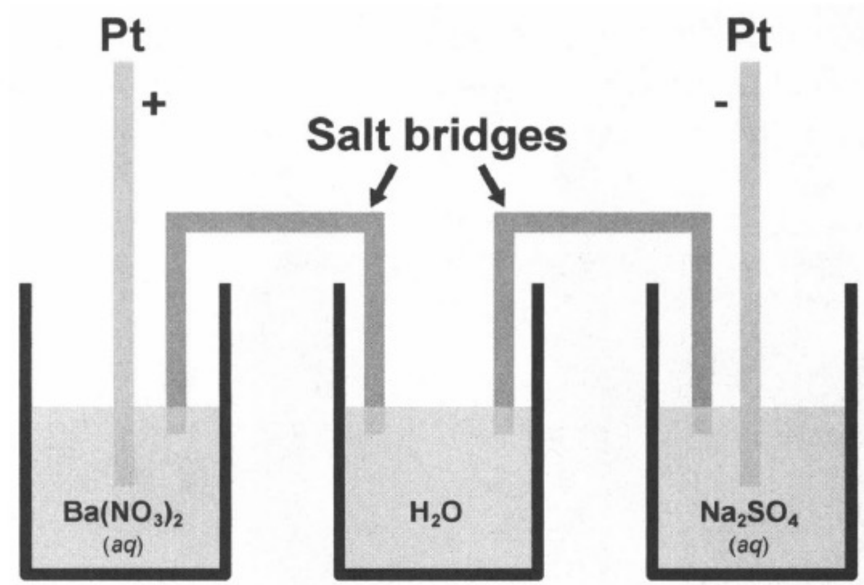
Na

Li	Be	**B**
Na	**Mg**	Al
K	**Ca**	Ga
Rb	Sr	In
Cs	**Ba**	Te

"... when he saw the minute globules of potassium burst through the crust of potash, and take fire as they entered the atmosphere, he could not contain his joy– he actually bounded about the room in ecstatic delight; and ... some little time was required for him to compose himself sufficiently to continue the experiment"

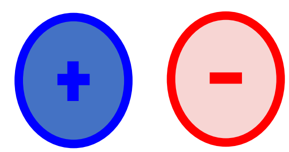
Edmund Davy, Cousin who watched the expt.

Davy's view of a chemical bond: The ions make a bond



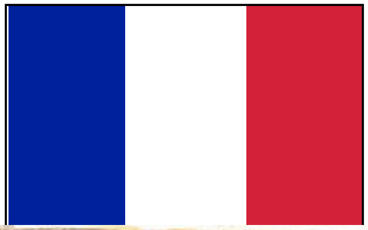
Using this set-up, Davy showed that a precipitate of $BaSO_4$ was formed in the middle compartment, thus proving that barium ions migrated towards the negative electrode and sulphate ions towards the positive one.

Davy's view of chemical bonding
Opposite charges attract



1807-8

Humphry Davy
Big Science
a
Roy



Napo

(*via* Ga

tes
tes
al

Davy Makes Science Fashionable

- The first preparation of nitrous oxide in a pure form; Davy was also the first to recognize its anesthetic properties.

- The isolation of metallic potassium, sodium, barium, strontium, calcium, magnesium, and boron.

- Davy was the first to argue that if electricity could be generated by chemical action then, conversely, electricity could decompose compounds into their fundamental elements (birth of electrochemistry)

- The realization that chemical forces were, fundamentally, electrical in nature (birth of the Nature of a chemical bond)

Forgotten Davy lamp

- Enormous coal mine explosions in England during 1800s.
- Each miner carried a wax candle stub on his helmet or in his hand.
- The open flame ignited the gases (methane) killing a large number of miners every year.
- The miners approach Davy at the Royal Institute

Davy's life holds some lessons for ethics and science today

August 3rd, 1815.

SIR,

I had the honour of receiving the letter which you addressed to me in London at this place, and I am much obliged to you for calling my attention to so important a subject.

It will give me great satisfaction if my chemical knowledge can be of any use in an inquiry so interesting to humanity, and I beg you will assure the Committee of my readiness to co-operate with them in any experiments or investigations on the subject.

I shall be here ten days longer, and on my return south will visit any place you will be kind enough to point out to me where I may be able to acquire information on the subject of the coal-gas.

Your obedient, humble servant,
H. DAVY.

Chief Mining Engineer John Buddle Approaches Davy at the behest of miners

‘After a great deal of conversation with Sir Humphry Davy, and he making himself perfectly acquainted with the nature of our mines and what was wanted,------ he said “ **Do not despair, I think I can do something for you in a very short time**”.’

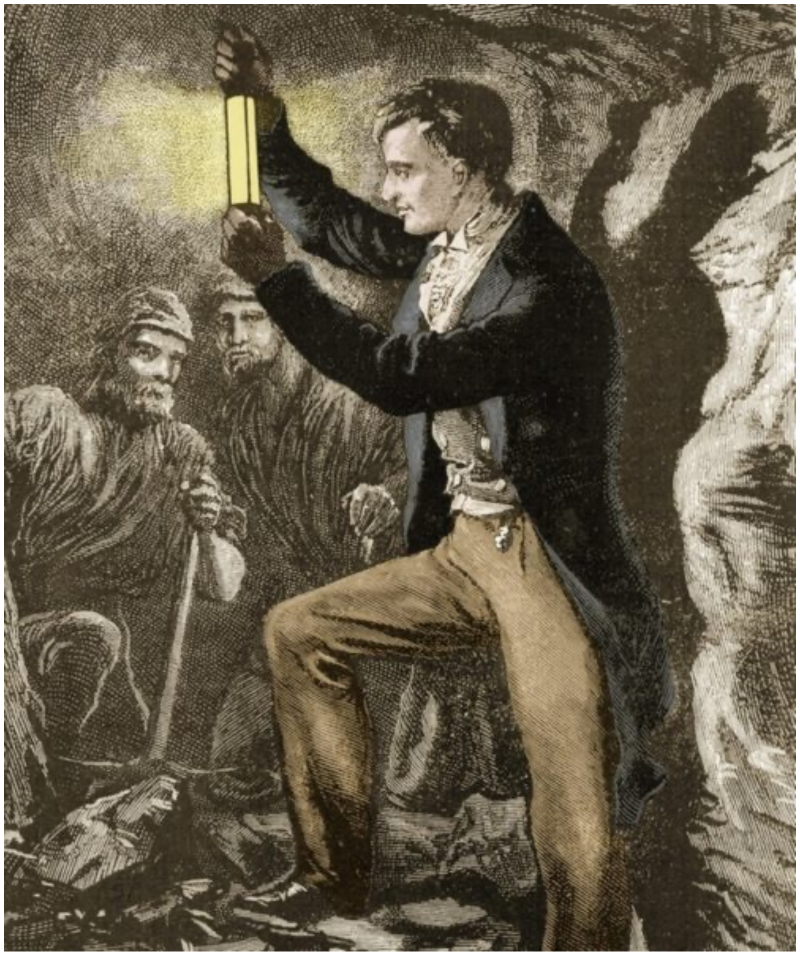
John Buddle
1773-1843

Invention of Davy lamp

- Studied the problem for three weeks in Durham, visiting mines and talking to miners;
- Went back to the lab for three months.
- Built a working prototype lamp what would be known as the Davy Lamp.
- Returned to the mines. He spent hours underground, teaching safety techniques, refining the design.

Invention of miner’s lamp, Davy Lamp

Training miners with Davy Lamp



John Buddle: "We have at last subdued this monster".

Davy lamp is still popular world over

In September 1816 ‘*we, the undersigned miners at the Whitehaven Collieries' thanked Davy for his 'invaluable discovery of the safe lamps, which are to us life preservers*'.

Priority Dispute: Davy lamp

Buddle urged Davy to take out a patent, pointing out that he could not only make his fortune but control the quality of the lamps issued to miners. Davy consistently refused, although he knew his colleague Wollaston had made a fortune with a patent on processing platinum. Yet Davy was hugely proud of his achievement and was never modest about it.

Davy's high-minded claims produced a bitter priority dispute. In the spring of 1816 the engineer at the Killingworth mine, just north of Newcastle, George Stephenson, challenged Davy's precedence, and accused him of plagiarising of his own 'Geordie Lamp'.

Priority Dispute: Iodine

Priority dispute on the discovery of iodine with the gifted young chemist Joseph Gay-Lussac. Gay-Lu sac, Davy's exact contemporary.

Two not-so-well-known chemists, N. Clément and C. B. Desormes had reported that a strange new substance had been discovered in seaweed. Gay-Lussac was assigned to review their experiments and repeat them to make sure the results were correct. Six days before the announcement of the results by Gay-Lussac, Ampère, Clément, and Desormes paid a visit to Davy and showed him the sample. Davy immediately isolated and identified the element as iodine.

Gay-Lussac's short paper was actually presented and published first, on 12 December. Davy, taken by surprise, presented his to the Academie on 13 December, but antedated it to 11 December, and had it published as such in the Journal de Physique. He claimed, perhaps justly, that he had previously shared his key ideas with Gay-Lussac.

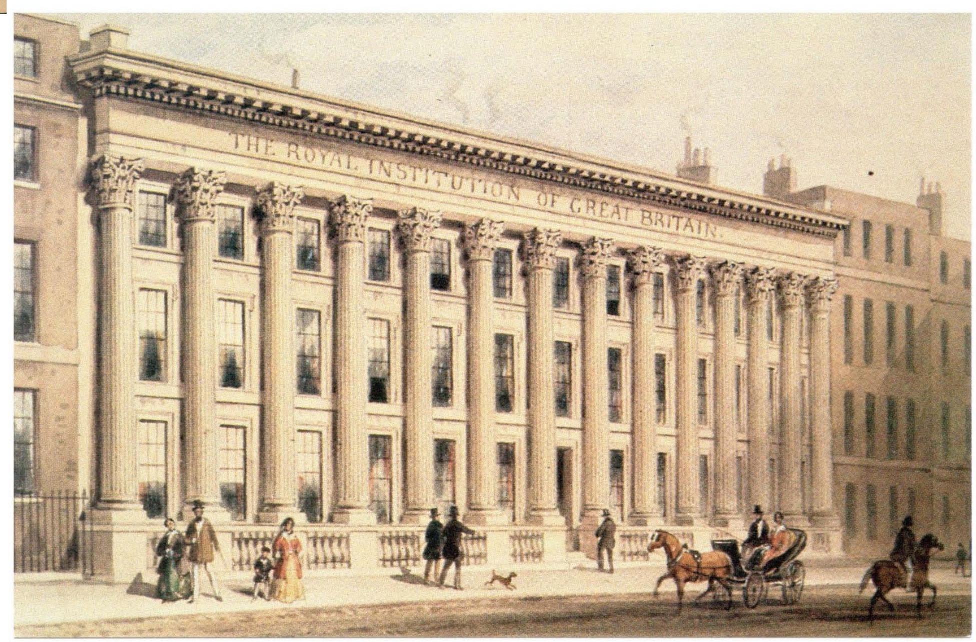
Davy's surprising sharpness in a 'priority' controversy was noticed by Faraday.

ChemMatters, December 2006, p. 18

The Age of Wonder: Communication with the public

Outstanding Lecturer & Performer

The first one-way street in the world



Davy's advice on giving on lectures

"I was made to write out the first lecture entirely, and Davy took me into the lecture hall the evening before I was to talk and made me read it all out while Davy sat in the furthest corner and listened; and then Davy read the lecture while I listened. Next day I read it to an audience of about 150 to 200 people and they gave me a very generous plaudit at the conclusion."

John Dalton on his first lecture at Royal Institution in 1803

Davy trusted the experiments more than his brain

"One good experiment is worth more than the ingenuity of a brain like Newton's."

Recipe for Research
"Observation, Experiment and Analogy"

- Observe to formulate a problem
- Experiment to gain an understanding
- Compare the results with known to generate a hypothesis

Readings

http://mysteryofmatter.net/Davy.html

https://www.rigb.org/whats-on

***The Age of Wonder*, R. Holmes, 2008, Ch 6 and 8**

Sir Humphry Davy: Boundless Chemist, Physicist, Poet and Man of Action, JM. Thomas, PP. Edwards, and VL. Kuznetsov, *ChemPhysChem*, **2008**, *9*, 59

Sir Humphry Davy: natural philosopher, inventor, discoverer, poet, man of action. JM. Thomas, *Proc. Am. Phil. Soc*. **2013**, *157*, 143.

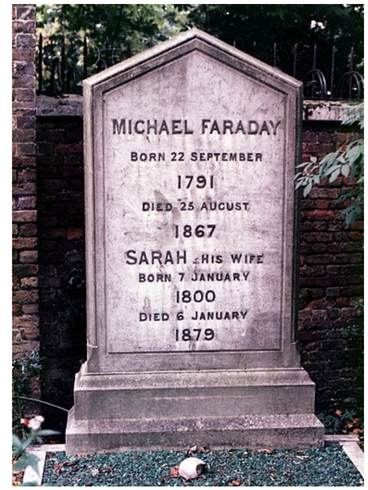
Sir Humphry Davy and the coal miners of the world: a commentary on Davy (1816) 'An account of an invention for giving light in explosive mixtures of fire-damp in coal mines', JM Thomas, *Phil. Trans. R. Soc*. A **2014**, *373*: 20140288.

Humphry Davy: Chemistry's First Showman

Humphry Davy
1778-1829

- **Nitrous oxide**
- **Elements Na, K, Cl, Br, I, etc.**
- **Basis of electrochemistry**
- **Davy lamp**
- **Lead the Royal Society**
- **Connected science to society**
- **Encouraged and mentored Faraday**

The Greatest Discovery of Davy: Michael Faraday



The Electric Life of Michael Faraday, A. Hirshfield, 2006

Faraday, Maxwell, and the Electromagnetic Field: How Two Men Revolutionized Physics, N. Forbes and B. Mahon, 2014.

Faraday Rediscovered, D. Gooding and F. A. J. L. James, 1985

Michael Faraday, L. Pearce Williams, 1964

The Beginning

- Born near London on Sep 22 1791, three siblings
- Father a blacksmith, mostly unemployed and unhealthy
- Mother from a family of farmers
- Deeply religious, Sandemanian sect of Christianity
- Educated in rudimentary reading, writing and arithmetic, age 5-13

The Beginning

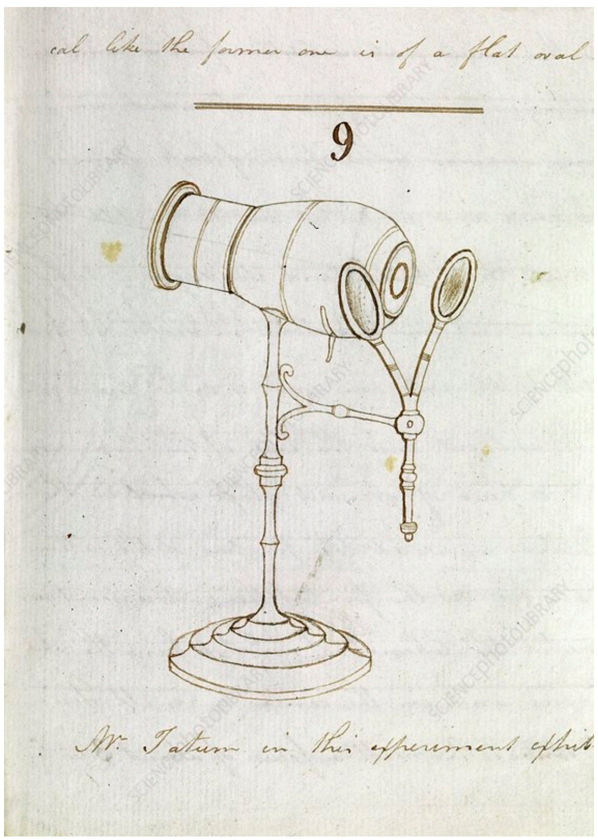
- To support the family took up a job at age 13 as an errand-boy for a local shopkeeper
- At the age of 18 he became an assistant to a book binder
- While he was a book binder a French roommate taught him to draw three dimensional drawings and French
- Took courses on elocution
- As a book binder he came across two important books

•*The Encyclopedia Britannica* – his source for electrical knowledge and much more

•*Conversations on Chemistry* – 600 pages of chemistry for ordinary people written by Jane Marcet based on Davy's lectures at the Royal Institution

John Tatum's lectures (1772-1858) exposed Faraday to science

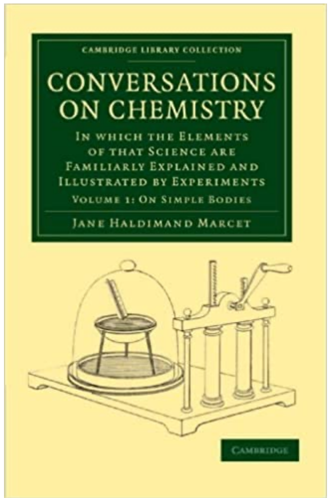
Tatum founded the City Philosophical Society in 1808 where Faraday and other scientists received inspiration.



Faraday, a bookbinder's apprentice at the time, attended around 13 lectures by silversmith John Tatum (1772-1858) between February 1810 and September 1811. The notes Faraday made from these lectures formed four volumes and 300 pages and helped him start his career in science.

Building Confidence

Jane Marcet, 1769-1858



The book that recorded Davy's lectures at RI

"When I questioned Mrs. Marcet's book (Conversations on Chemistry) by such little experiments as I could perform, and found it true----, I felt I got hold of an anchor of chemical knowledge---."

Michael Faraday

Getting Started

"My desire to escape from trade, which I thought vicious and selfish, and to enter into the service of Science, which I imagined made its pursuers amiable and liberal, induced me at last to take the bold and simple step of writing to Sir H. Davy, expressing my wishes, and a hope that if an opportunity came in his way he would favor my views; at the same time, I sent the notes I had taken of his lectures." (1812)

Based on the letter Faraday wrote about the experience later in life after Davy's death to J.A. Paris. (1829)

Davy's encouraging reply to Faraday

"Sir,– I am far from displeased with the proof you have given me of your confidence, and which displays great zeal, power of memory, and attention. I am obliged to go out of town and shall not be settled in town till the end of January; I will then see you at any time you wish. It would gratify me to be of any service to you; I wish it may be in my power.

I am, Sir, your obedient humble servant,
H. Davy."

Faraday was grateful to Davy till the end of his life
A revealing letter where Davy cautions

"At the same time that he thus gratified my desires as to scientific employment, *he still advised me not to give up the prospects I had before me, telling me that Science was a harsh mistress, and in a pecuniary point of view but poorly rewarding those who devoted themselves to her service.* He smiled at my notion of the superior moral feelings of philosophic men and said he would leave me to the experience of a few years to set me right on that matter."

A letter written to a friend by Faraday in 1829

Getting the foot in the hole, Apprentice as a chemist

Faraday's tough time with Lady Jane Davy

Lady Davy in front of guests ***ordered Faraday to take his meal in the kitchen with the servants*.**

Faraday to his hometown friend,

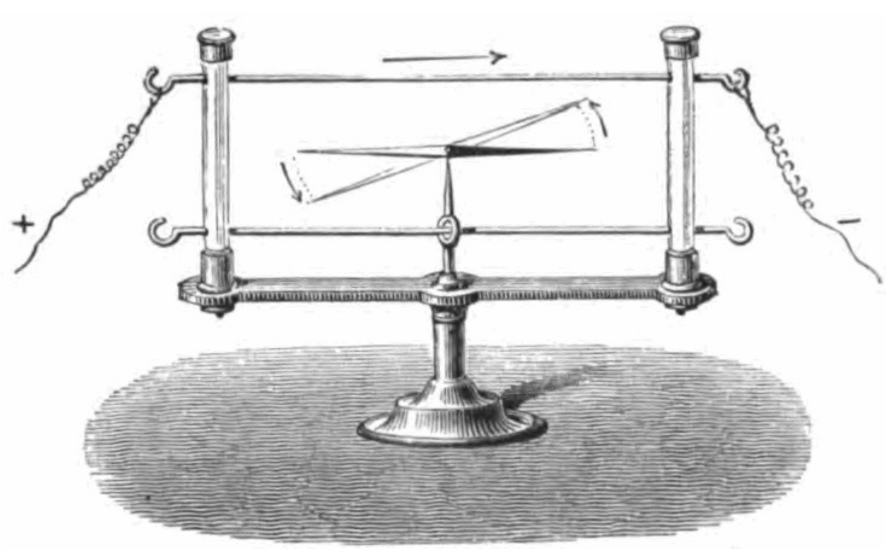
"Alas!, how ***foolish perhaps was I to leave home, to leave those whom I loved and who loved me*** ----. And what are the boasted advantage to be gained? Knowledge. ---- ***What a result is obtained from knowledge and how much must the virtuous human mind be humiliated*** --- Ah Ben, I am not sure that I have acted wisely in leaving a pure and certain enjoyment for such a pursuit."

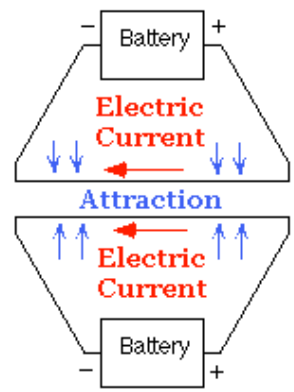
An unexpected turn in the life of MF

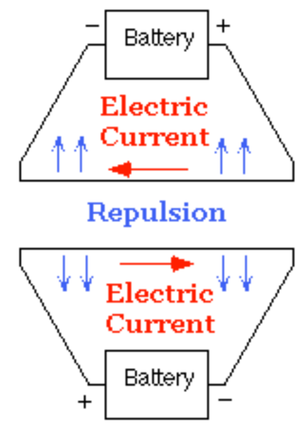
Early observations on the connection between magnetism and electricity

Hans Christian Ørsted, 1777-1851
First to establish a connection between electricity and magnetism

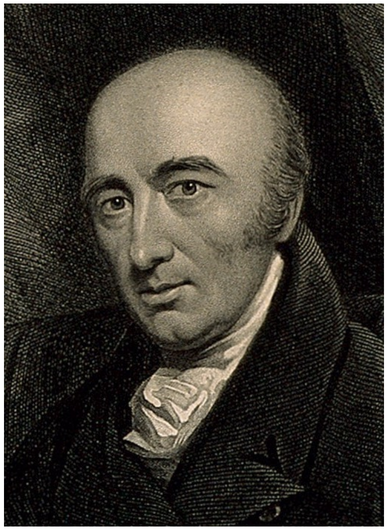
André-Marie Ampère
1775-1836



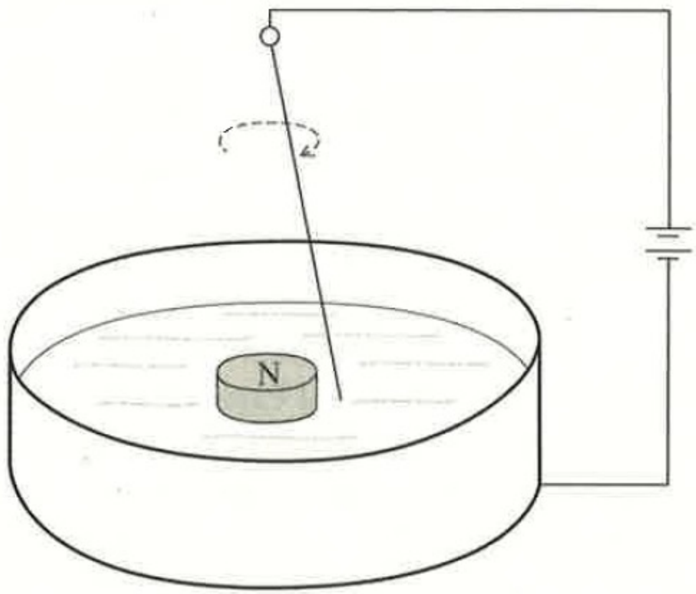




https://www.youtube.com/watch?v=qS361iadCPA



William Hyde Wollaston
1766 –1828



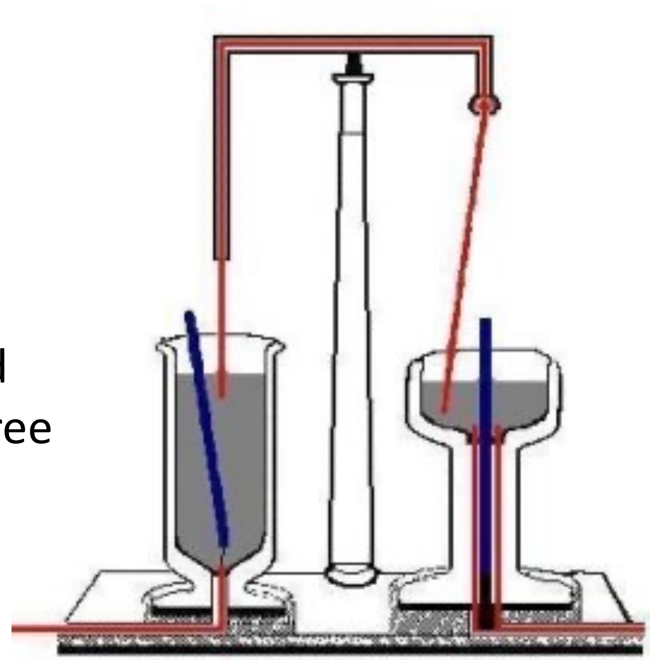
Humphry Davy
1778-1829

Davy was trying to re-create a famous electromagnetism experiment of Ørsted with fellow chemist William Wollaston, wondering why applying an electric current to a wire caused that wire to behave like a magnet. He could not make the experiment work.

He teasingly told Faraday to try his hand at it after he was done cleaning the lab. *Faraday figured it out, and the result was the* ***first induction motor****, which converts electrical current into continuous mechanical motion.*

World's First Electric Motor-1821

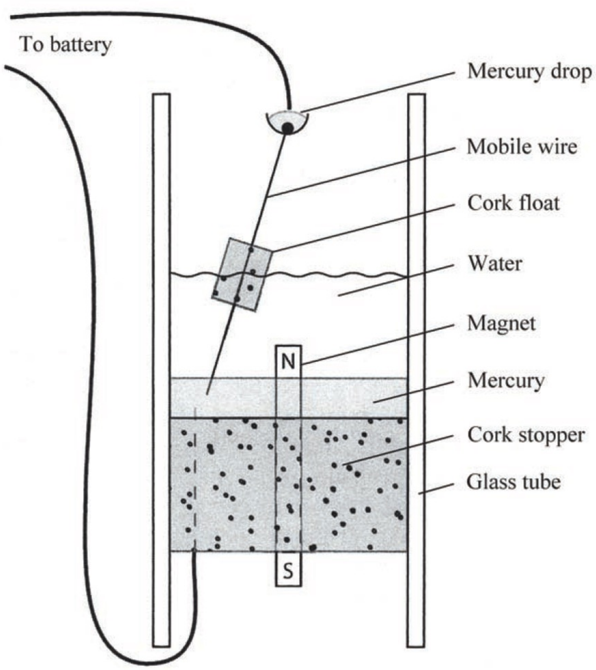
Electromagnetic rotation experiment of Faraday

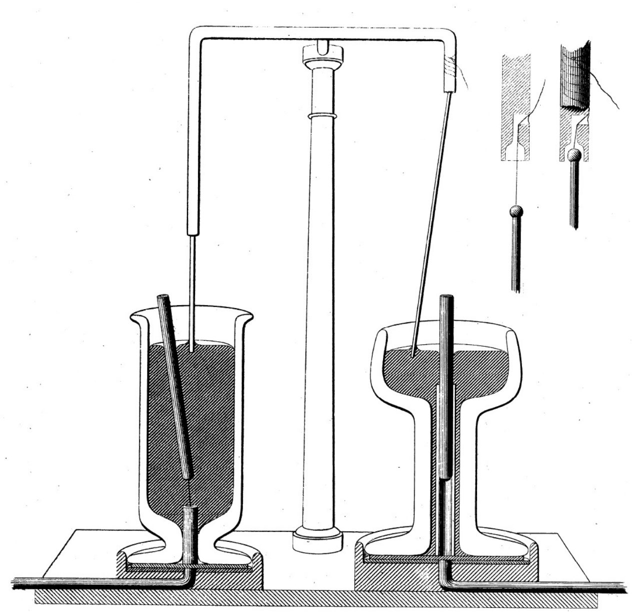


https://www.youtube.com/watch?v=EECRoYNaSxg

World's First Electric Motor-1821

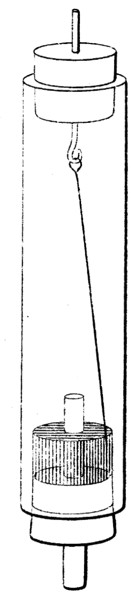
Electromagnetic rotation experiment of Faraday





Wire fixed
Magnet free

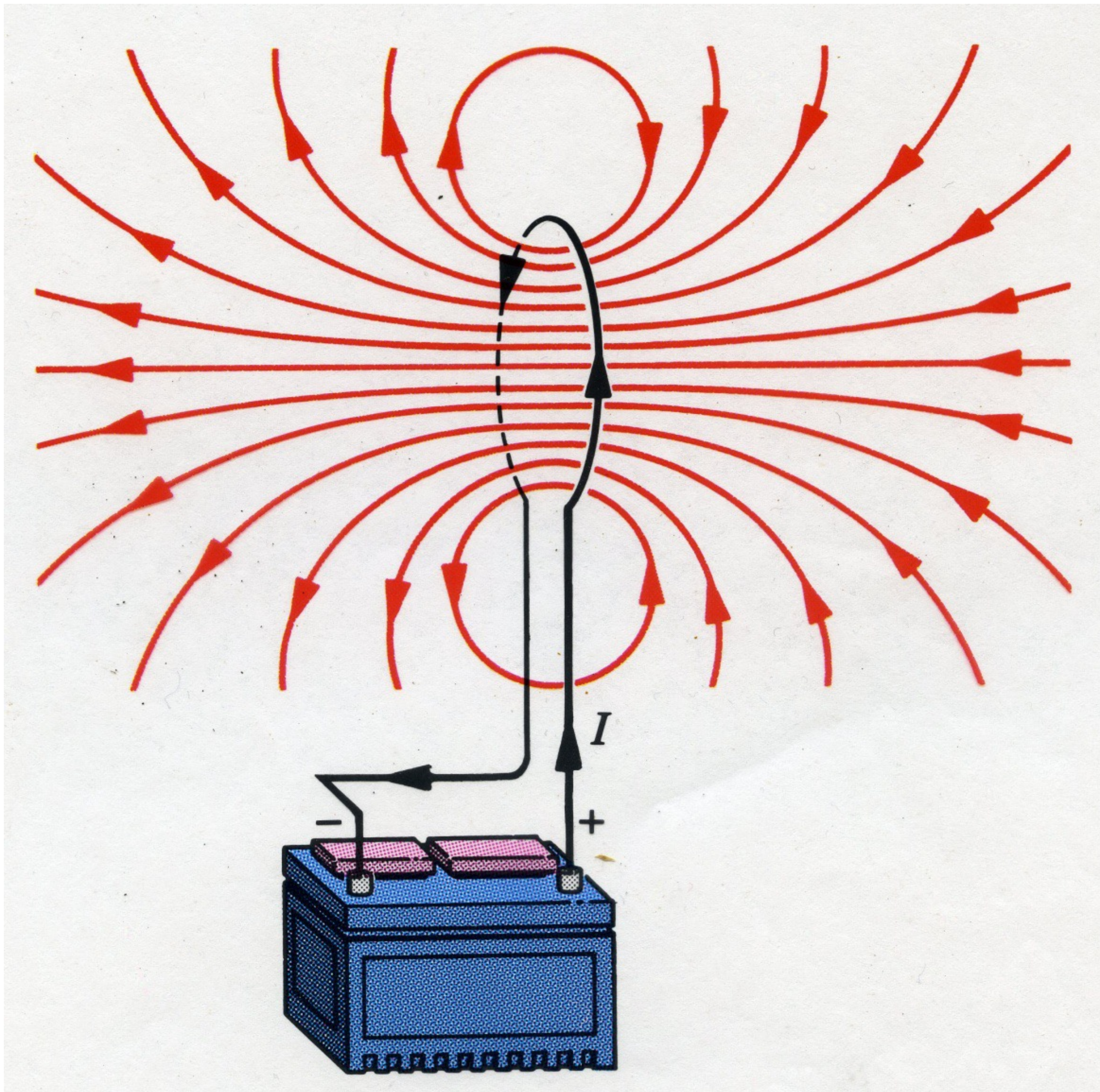
Magnet fixed
Wire free



Gift model

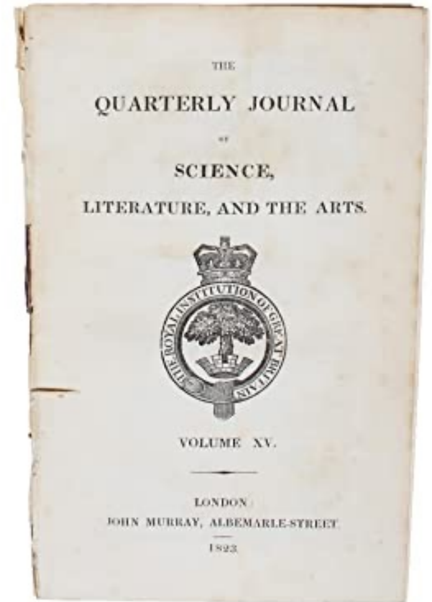
Exploratory Experiments, Ampere, Faraday and the Origins of Electrodynamics, F. Steinle & A.Levine, 2005

Magnetic Effects from Electricity



The publication that created excitement and problems

On Some New Electromagnetic Motions and the Theory of Electromagnetism M. Faraday, *Quarterly Journal of Science*, **1821-23 (three articles)**



(US$ 4,060.35)

Faraday published without acknowledging Davy and Wollaston.

Davy and Wollaston accused Faraday of plagiarizing their idea.

Public liked the little and pocket-sized motor that were gifted and sold.

But, Faraday was out of favor with the old guards of British scientific establishments. They were unsure of his knowledge to make such an important discovery.

Public and old guards were not aware that Faraday is the author of an authoritative review on electromagnetism published in Annals of Philosophy under a pseudo-name.

Mentor and mentee relationship was complex

Science is a human endeavor, driven by hopes, dreams and aspirations. They may be brilliant, even geniuses. But as human beings they may also be seriously flawed.

Michael Faraday
1791-1867

Sir Humphry Davy
1778-1829

Occasionally, science can take on personal, almost vindictive quality.

Faraday finds a trusted friend in Ampere

To Ampere, Faraday privately complained

"***I am compelled to say I have not found that kindness, candor and liberality at home*** which I have now on several occasions uniformly experienced from the Parisian men of Science ... ***Considering the very subordinate position I hold here and the little encouragement which circumstances hold out to me I have been more than once tempted to resign scientific pursuits altogether*** ... I struggle on in hopes of getting results at one time or another that shall by their novelty or interest raise me into a more liberal and active sphere."

Complex relationship between Davy and Faraday

Compliments

Davy to Faraday, "I think you are a better chemist than Donovan."

---- believe me there is ***no one more interested in your success & welfare than your sincere well wisher & friend,*** *H. Davy*."

Complex relationship

Davy tried to block his own protege from "rising to the light."

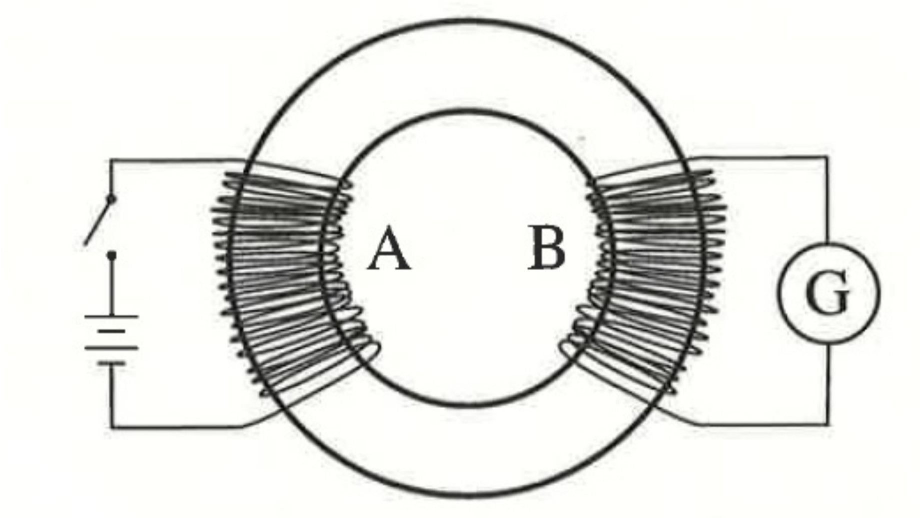
Faraday's nomination to the Royal Society was announced at ten successive Royal Society meetings and, at the eleventh, on January 8, 1824, secret ballots were cast. *Faraday was elected- with one dissenting vote by Davy.*

Recommended Faraday to be the Director of RI and assigned him on an uninteresting project on glass (1825-1831).

Humphry Davy dies in 1829.

Series of pioneering discoveries 1831-

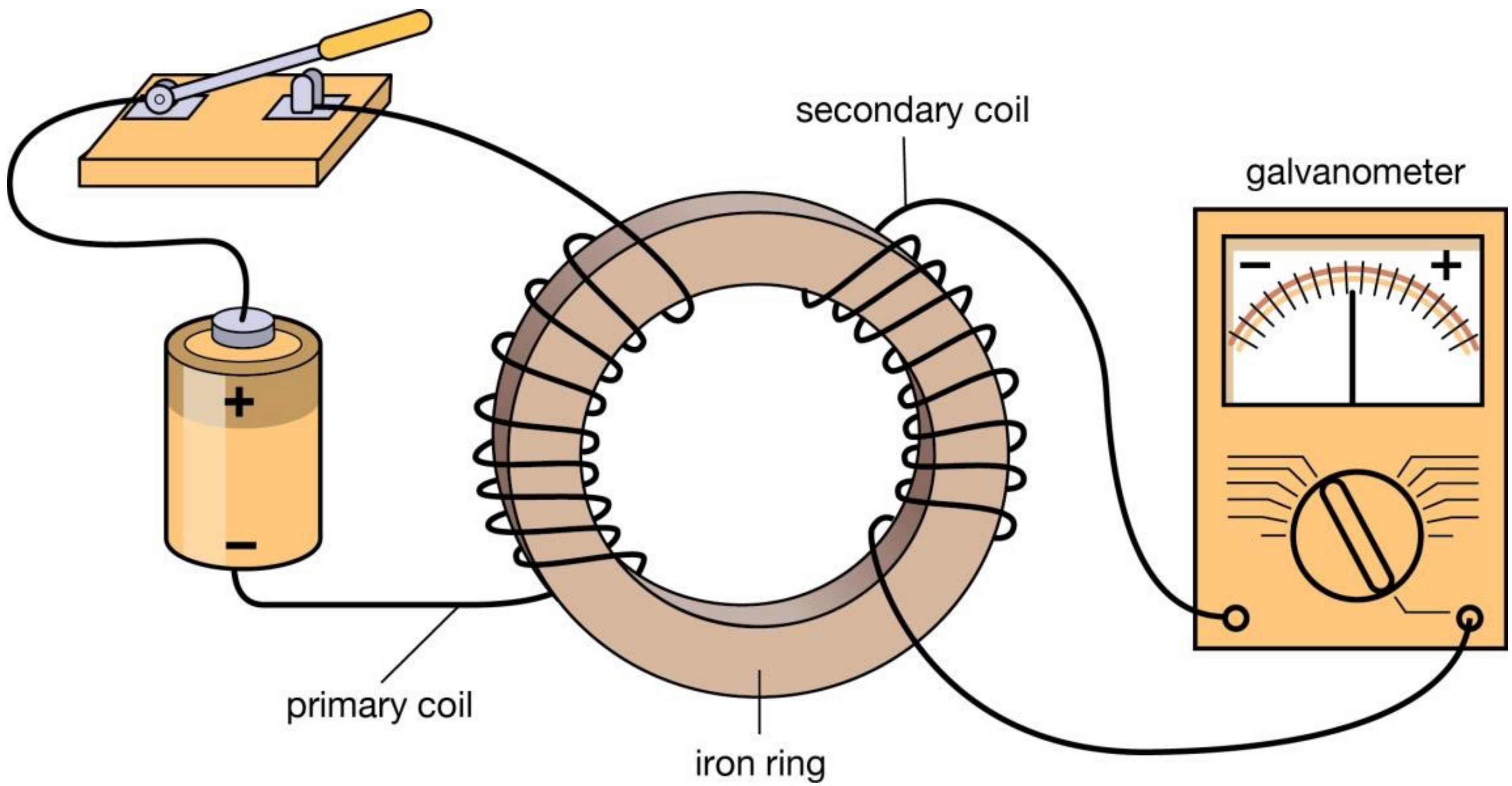
First Electromagnetic Induction



Electricity to Magnetism

Magnetism to Electricity

Transformer

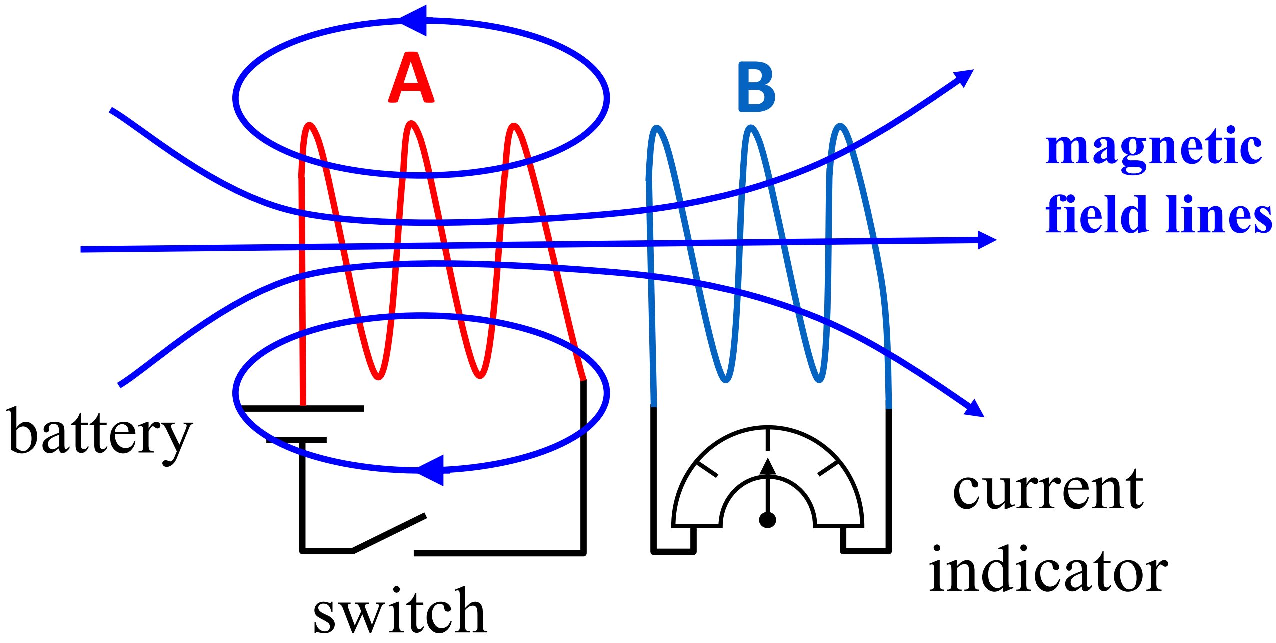


Twitches only when the switch goes on-off

Never publicize till you publish

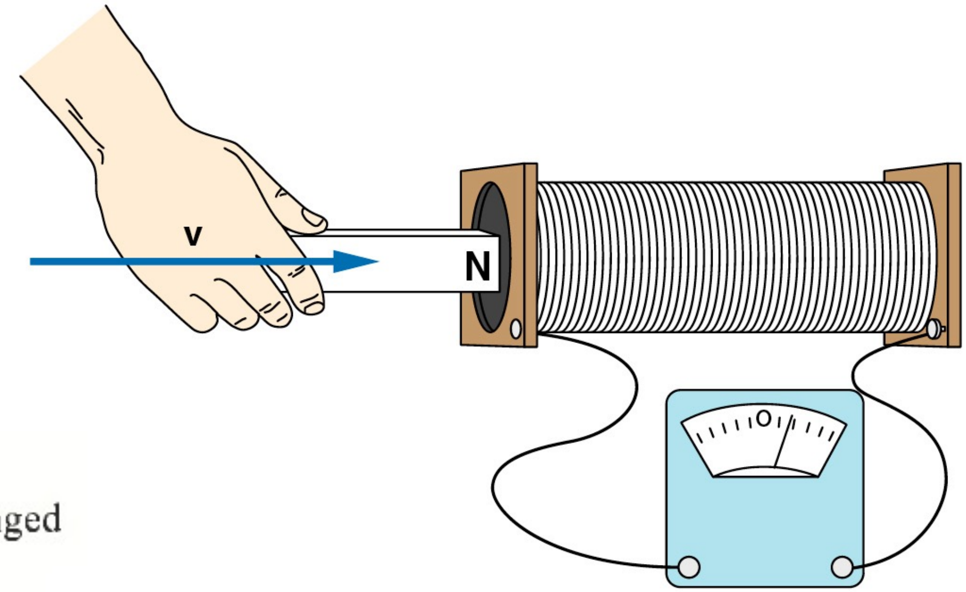
- Faraday presented the discovery to Royal Society on November 24, 1831
- Faraday informed French physicist J. N. P. Hachette
- J. N. P. Hachette passed on the information to Francois Arago
- Arago presented the work to Academy of Sciences on December 26, 1831
- Two Italian scientists came to know of this and published as their own on January 1832, with the date of November 1831.
- Faraday did not publish the work till early 1832
- Finally sorted out, French and Italian workers agreed that the original discovery was due to Faraday and apologized
- Faraday learnt the lesson: ‘never publicize till you publish’

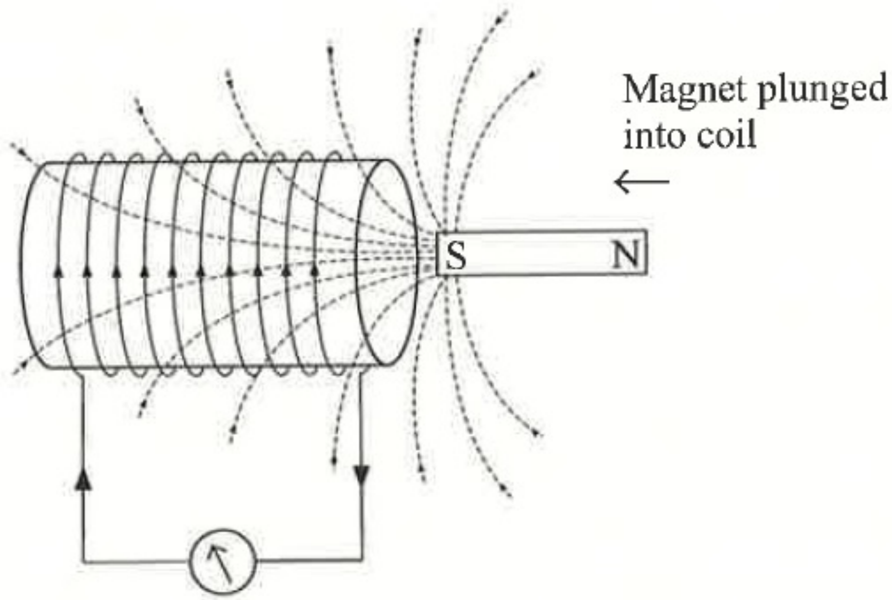
Induced currents



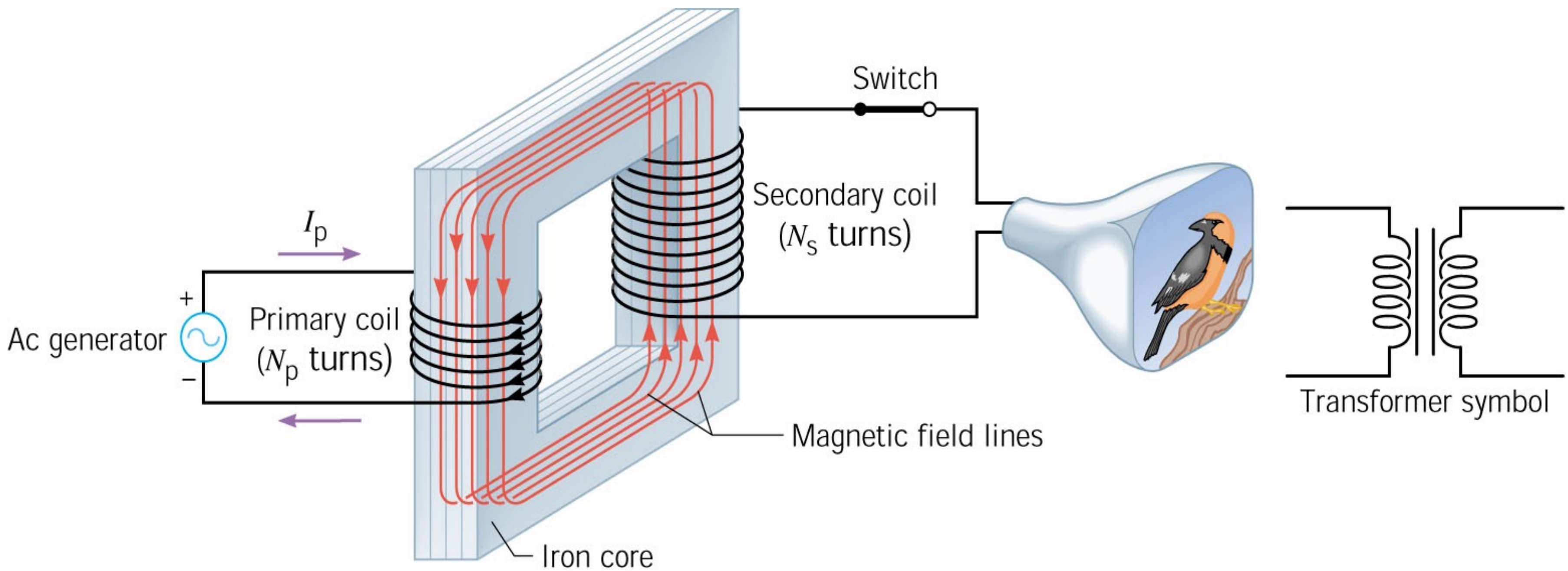
- When a current is turned on or off in coil A, a magnetic field is produced which also passes through coil B.
- A current then **briefly** appears in coil B
- The current in coil B is called an **induced current.**
- The current in B is only present when the current in A is turned on or off, that is, when the current in A is *changing*

A magnet moved in or out of a helical coil of wire produces an electric current in the coil.





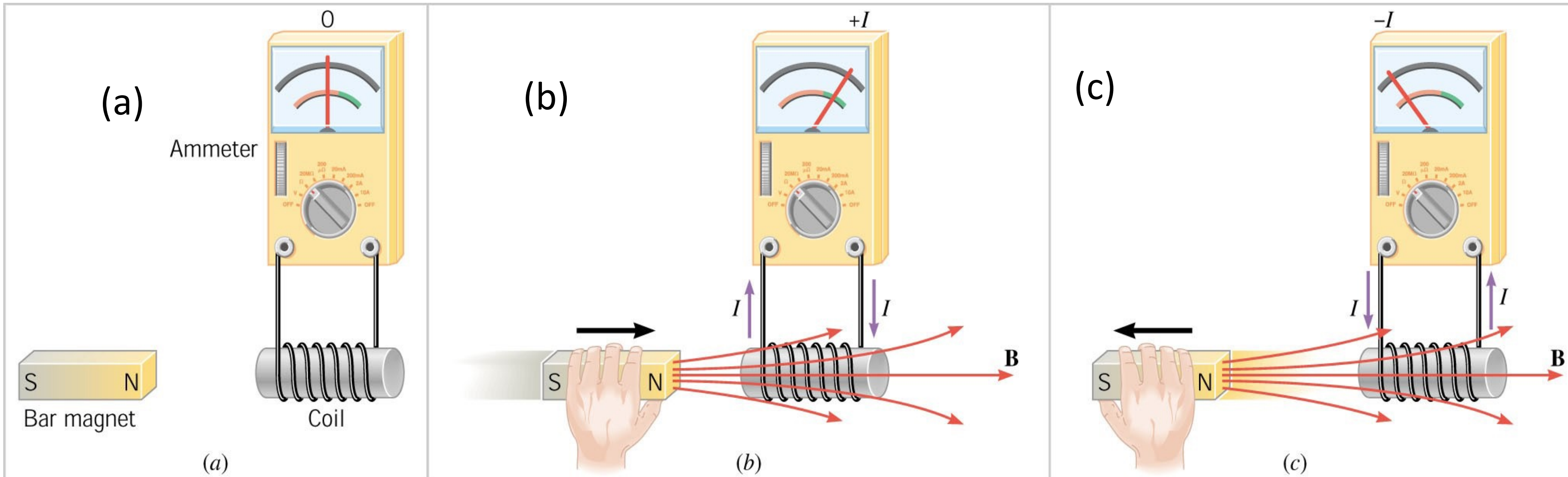
The transformer



The voltage on the secondary depends on the number of turns on the primary and secondary.

Step-up → the secondary has more turns than the primary
Step-down → the secondary has less turns than the primary

Induced currents

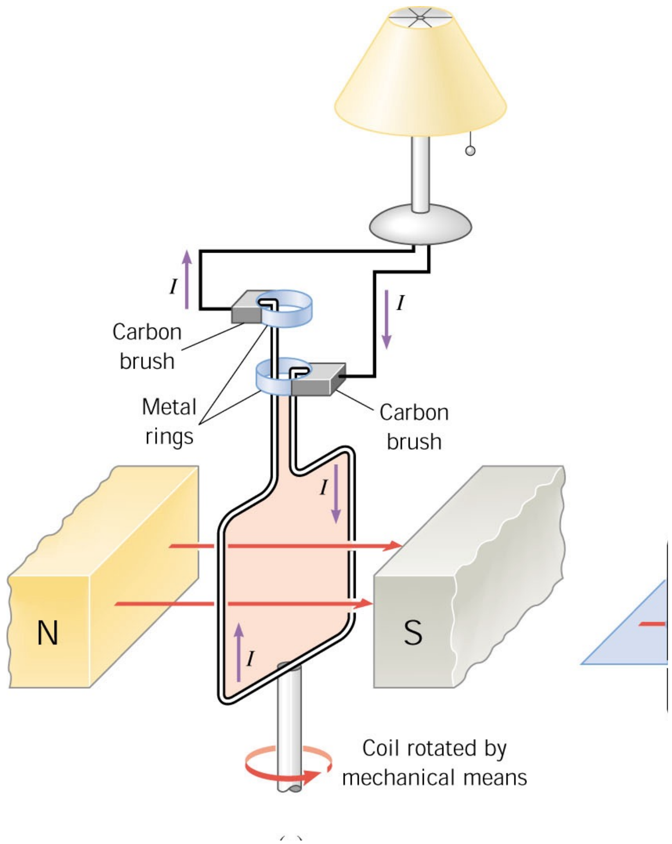


a) No current is induced if the magnet is stationary.

b) When the magnet is pushed toward the coil or pulled away from it an induced current appears in the coil.

c) The induced current only appears when the magnet is being moved

Electric Generators



When a coil is rotated in a magnetic field, an induced current appears in it. This is how electricity is generated. Some external source of energy is needed to rotate the turbine which turns the coil.

Faraday’s breakthroughs propelled our society to a new level of knowledge

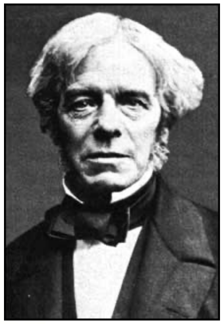
- We use motor in thousands of applications: disk drive, video machine, fan, pump, washing machine, refrigerator, air conditioner, aeroplane …
- We need generator to produce electricity
- We need transformer for long-range electricity delivery and in some devices
- Faraday’s inventions compose the frame of our electric world

Effect of Electricity and Magnetism on Light

When Faraday was nearly fifty-four years old, attempted, for the sixth time, to discover a connection between light and electricity. He repeated the experiments to vary the polarization of a beam of light by passing it through an electrolyte transmitting a current. Then he tried passing the beam through powerful electrostatic tension by electrical machines but was unable to observe any effect.

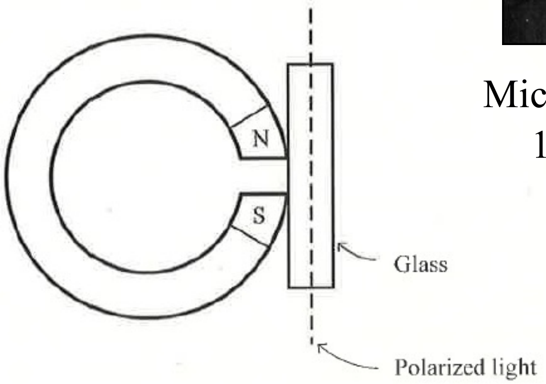
After a fortnight, he tried the effect of powerful magnetic fields. He laid a piece of heavy glass across the poles of the electro-magnet and passed a beam of polarized light through it longitudinally. He found that the polarization of the beam had been affected; "thus magnetic force and light were proved to have relations to each other."

Light is an electromagnetic wave

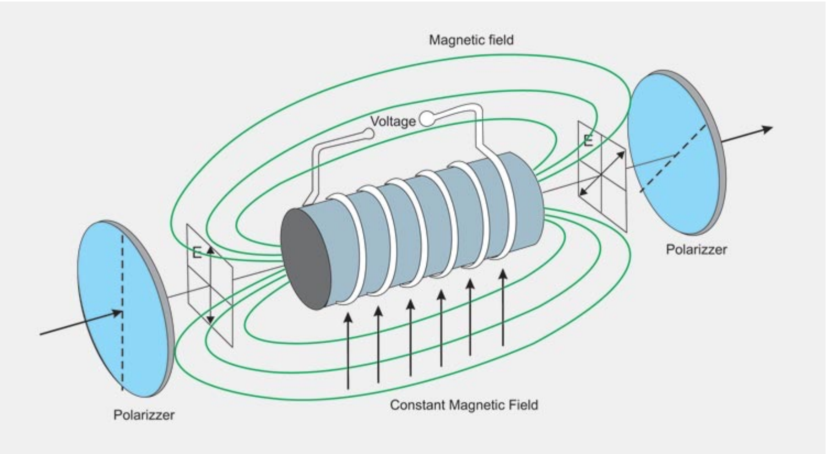


Michael Faraday
1791-1867

Faraday Effect: Magnetic field rotates plane polarized light



In 1845, Michael Faraday discovered that the plane of polarization of linearly polarized light is rotated when the light rays travel along the magnetic field direction in the presence of a transparent dielectric, an effect now known as Faraday rotation

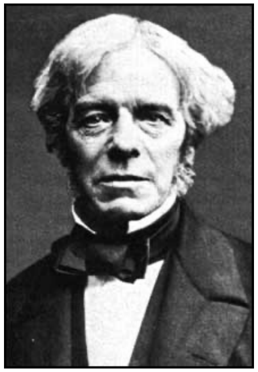


What is light?

A link between magnetism, electricity and light established

To Ampere, Nov 1845

"I happen to have discovered a direct relation between magnetism and light, also electricity and light---and the field it opens is so large & I think rich that I naturally wish to look at it first"

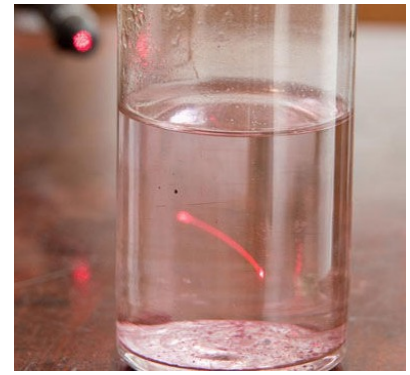


Michael Faraday
1791-1867

Nanoscience

Stained glass vessels of ancient times, BC

Faraday's gold colloidal solution on display at RI, 1856



Faraday-Tyndall effect

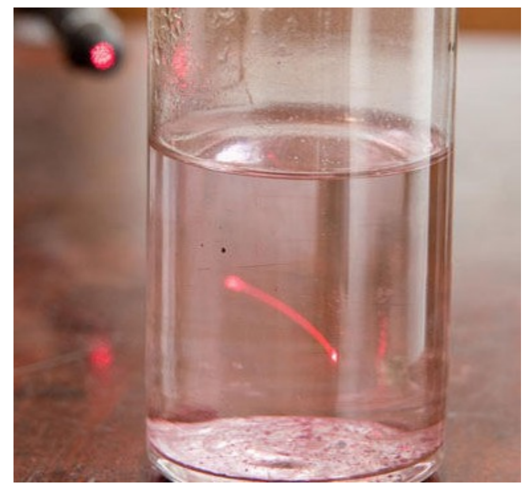
150 years old gold nanoparticles of Faraday on display at RI

Beginnings of Nanoscience

Gold chloride + Phosphorous = Gold nanoparticle

"No dissolved gold, only diffused gold"

Faraday realized that this cone effect was made because the fluid contained suspended gold particles that were too small to see with the scientific apparatus of the time but which scattered the light to the side (*Faraday-Tyndall effect*).



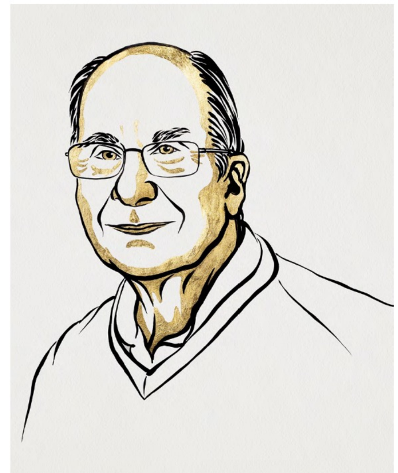
Faraday-Tyndall effect

Faraday is the father of modern nanoscience and nanotechnology.

2023 chemistry laureates

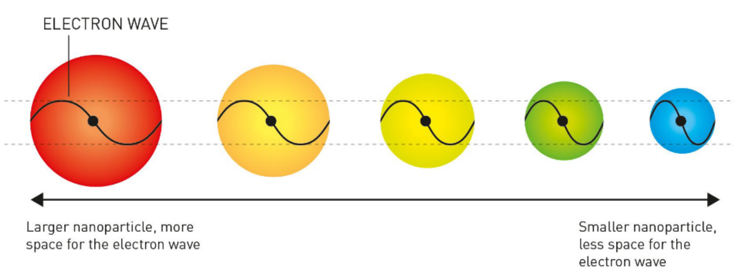
"for the discovery and synthesis of quantum dots"

Moungi G. Bawendi
Born: 1961, France



Louis E. Brus
Born: 1943, USA

Aleksey Yekimov
Born: 1945, former USSR



When particles are only a few nanometres in diameter, the space available for electrons is very limited. That affects the optical attributes of the particle.

Faraday's age, health and laboratory safety issues caught up with him

1866, Mrs. Faraday: "Don't you remember those beautiful gold experiments that you made?"

Faraday: "Oh yes, beautiful gold, beautiful gold"

8-25-1867, Faraday died while sitting in his chair at the age of 75

"Tyndal, I must remain plain Michael Faraday to the last"

Discoveries with no mathematical equations

Electromagnetic induction ------Electrical engineering

Transformer and dynamo ------ Industrial revolution

Theory of electricity and magnetism: not liquids but fields

Magneto-optical effect or Faraday effect;

Provided a common thread between electricity, magnetism and light

Electromagnetic theory of light

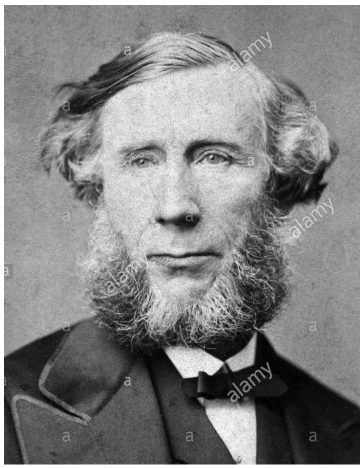
Interaction between electrical & magnetic forces and molecules

Dielectrics, para-magnetism and dia-magnetism

Theory of electrolysis	**Electrochemistry**
Discovery of benzene	**Dye industry**
Gold nanoparticles	**Nanoscience**

https://www.youtube.com/watch?v=Wyh7E_FzxgY

Similar yet dissimilar



John Tyndall
1820-1893

"Brothers in intellect, Davy and Faraday, however, could never have become brothers in feeling; their characters were too unlike. Davy loved the pomp and circumstance of fame; Faraday the inner consciousness that he had fairly won renown. They were both proud men. But with Davy pride projected itself into the outer world; while with Faraday it became a steadying and dignifying inward force."

"A father is not always wise enough to see that his son has ceased to be a boy, and estrangement on this account is not rare; nor was Davy wise enough to discern that Faraday had passed the mere assistant stage and become a discoverer."

Listen to the pioneers

Davy's pure scientific method:

Observation, Experiment, Analogy

Secret of **Faraday**'s success as a scientific investigator

Work, Finish, Publish.

If I could live my life over again I would study mathematics; it is a great mistake not to do so, but it is too late now (**Faraday** 1857)

The Aristotelian tradition and medieval alchemy eventually gave rise to modern chemistry