The Chemical Revolution
Not so-useful Chemistry
Useful to Know

The Chemical Revolution
Lavoisier, Davy and Faraday

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

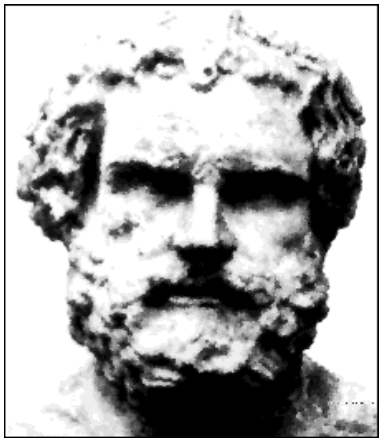
The Greek Philosopher Democritus

- 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



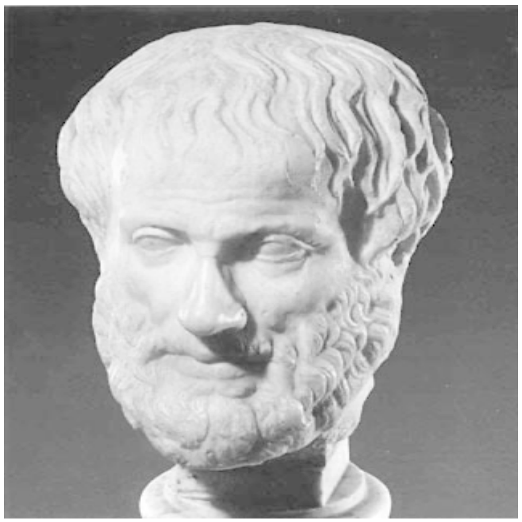
Democritus

- 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.

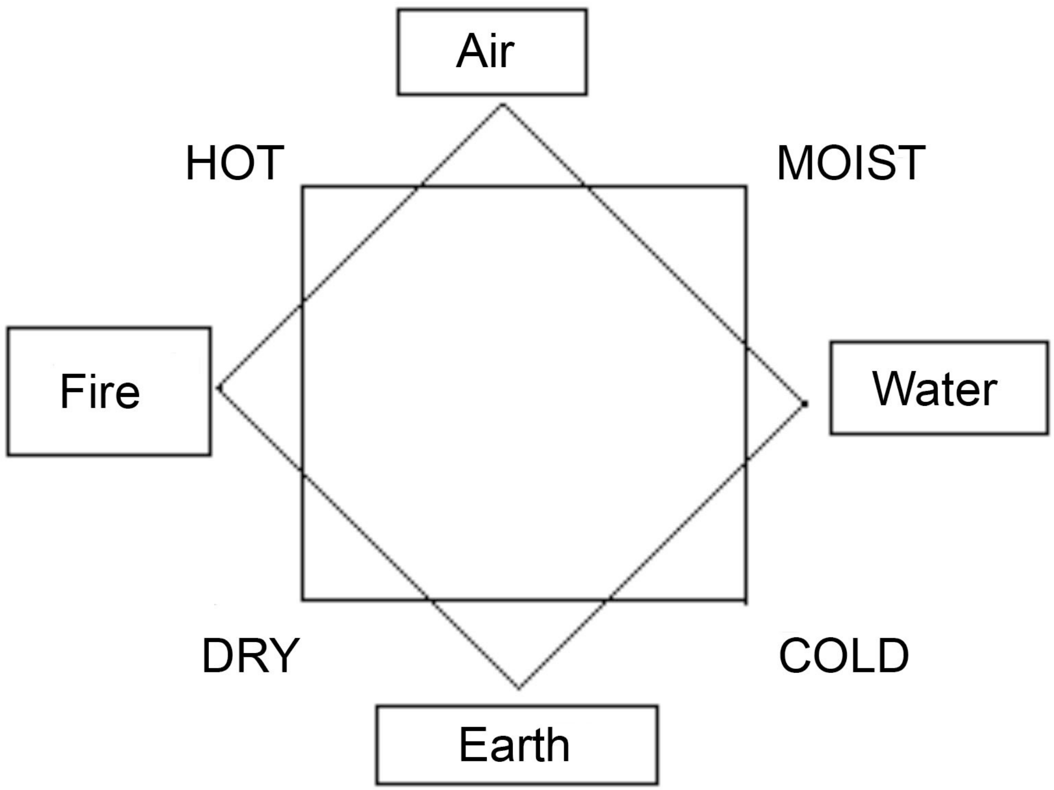
The Greek Philosopher Aristotle



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**.

The four elements of ancient times (Greek)



- All matter is made up of these four elements
- The above four elements are transmutable

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.

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

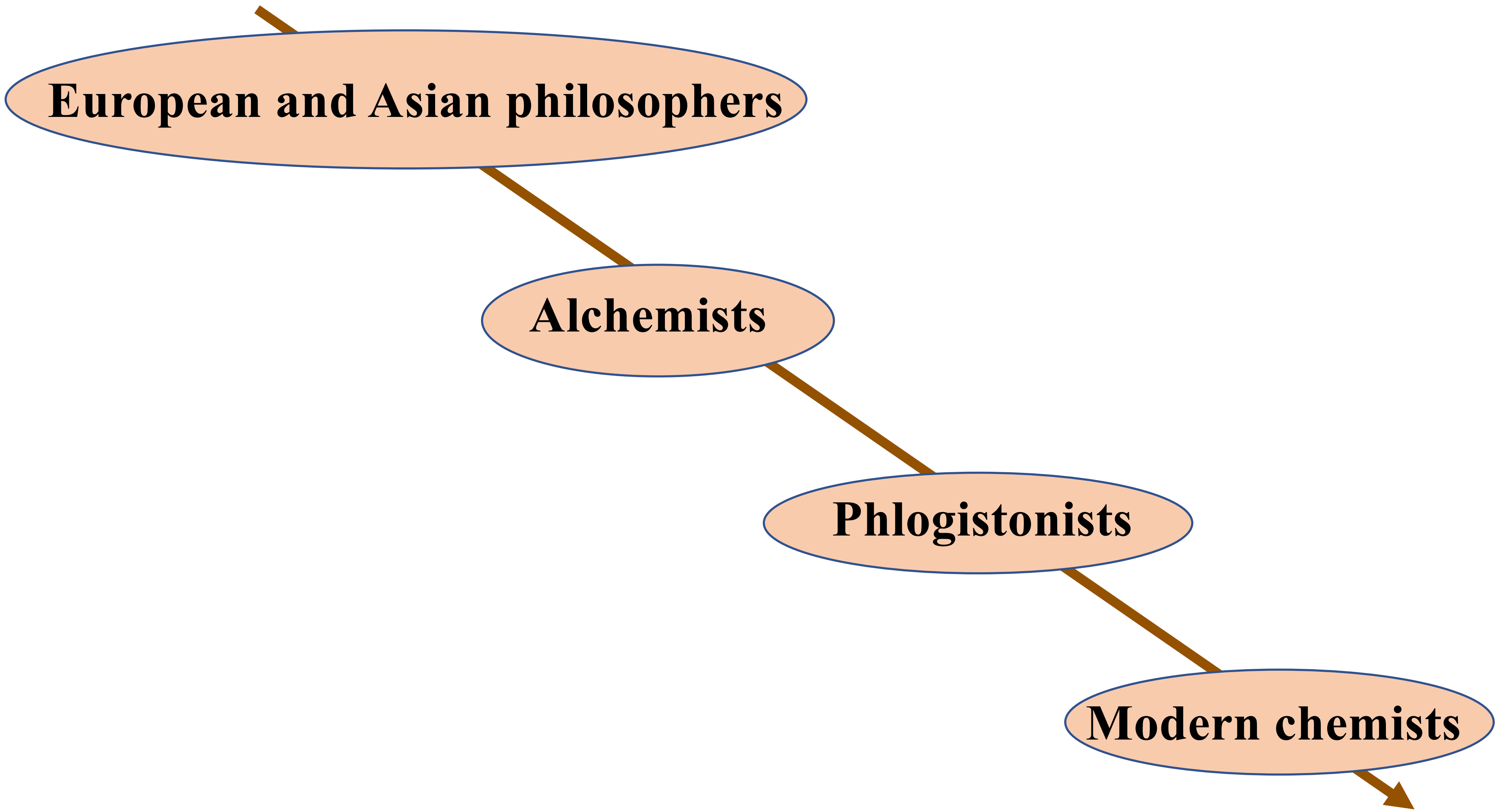
The Seven Planetary Metals

☉	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
Egyptian: Abu Mus-Hayyan	
8^{th} century AD	Elements + sulfur + mercury
European: Paracelsus, Swiss	
16^{th} century AD	Elements + {sulfur + mercury+salt}

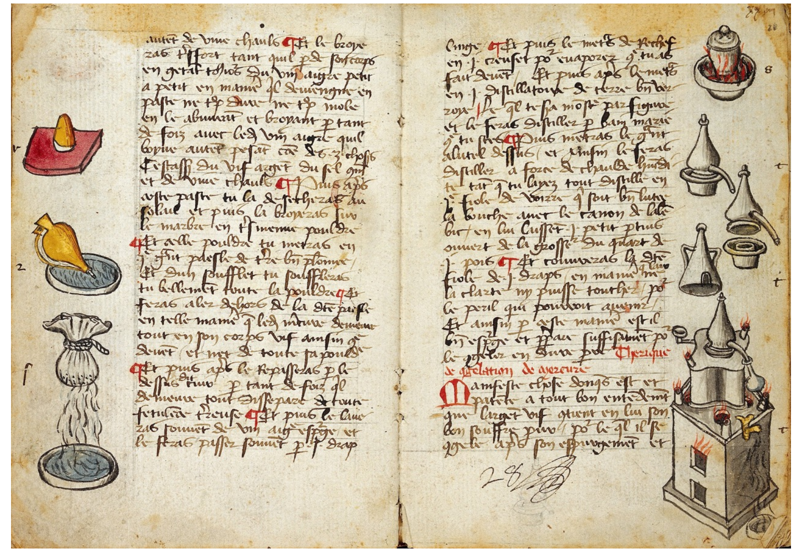
Alchemists laid the groundwork for many chemical processes, such as the refining of ores, the production of gunpowder, the manufacture of glass and ceramics, leather tanning, and the production of inks, dyes, and paints. Alchemists also made the first attempts at organizing and classifying substances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

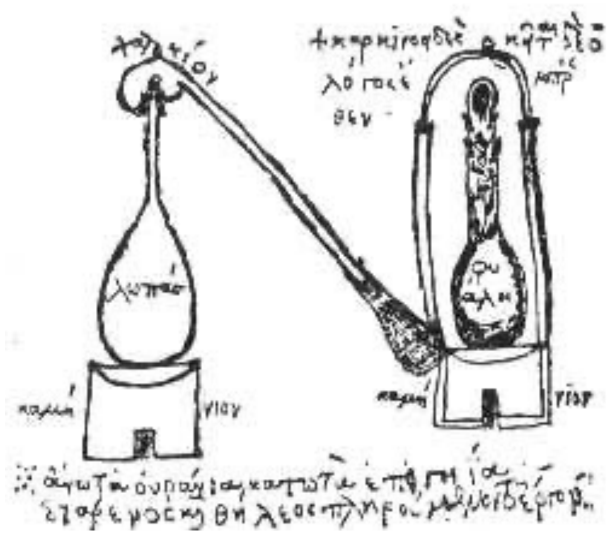
Alchemists
300 BC to 17th century
Arabian origin but was prevalent world over

- **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

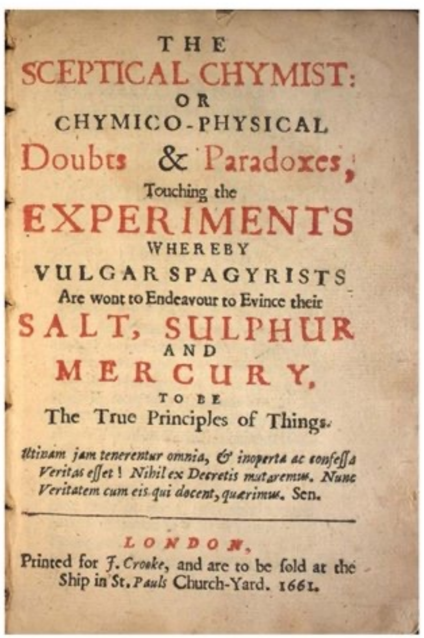




Beginnings of Phlogistonists

Johann Joachim **Becher** 1635 – 1682	Replaced Greek and Paracelsus (a Swiss alchemist) element (4+3) with two, Seven elements became two: earth and water, air used only as a mixer. Replaced fire with three types of earth, one being fatty **flammable earth**.
Georg Ernst **Stahl** 1659-1734	Kept the proposals of Becher except changed the name of flammable earth to **phlogiston**.

Robert Boyle (1627–1691)



THE
SCEPTICAL CHYMIST:
OR
CHYMICO-PHYSICAL
Doubts & Paradoxes,
Touching the
EXPERIMENTS
WHEREBY
VULGAR SPAGYRISTS
Are wont to Endeavour to Evince their
SALT, SULPHUR
AND
MERCURY,
TO BE
The True Principles of Things.

Utinam jam tenerentur omnia, & inoperta ac confessa Veritas esset! Nihil ex Decretis mutaremus. Nunc Veritatem cum eis qui docent, quaerimus. Sen.

LONDON,
Printed for J. Crooke, and are to be sold at the Ship in St. Pauls Church-Yard. 1661.

Robert Boyle: Away from four element theory

- The Greek concept of elements was popular for almost 2200 years.
- Rejected the Aristotelian elements: earth, water, air, and fire.
- In 1661 Boyle noted that **it was impossible to combine the four Greek elements to form any substance and it was equally impossible to extract these elements from a substance.**
- Boyle defined elements as simple substances that could not be decomposed into other substances.

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 18^{th} 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

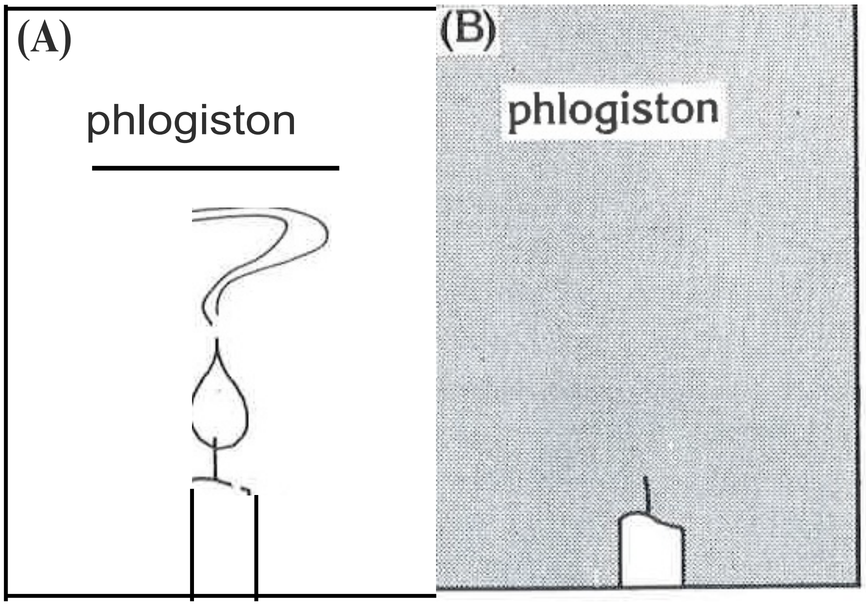
- All combustible substances contain phlogiston.
- Non-combustible substances do not contain *phlogiston*.
- The more phlogiston a substance contains, the better and more completely it burns.
- When wood burns there is a decrease in weight.
- Release of phlogiston results in weight loss.

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*.
- Combustion is impossible in a vacuum.
- Explanation: There was no air present to carry off the phlogiston.

Phlogiston Theory explained why things stopped burning

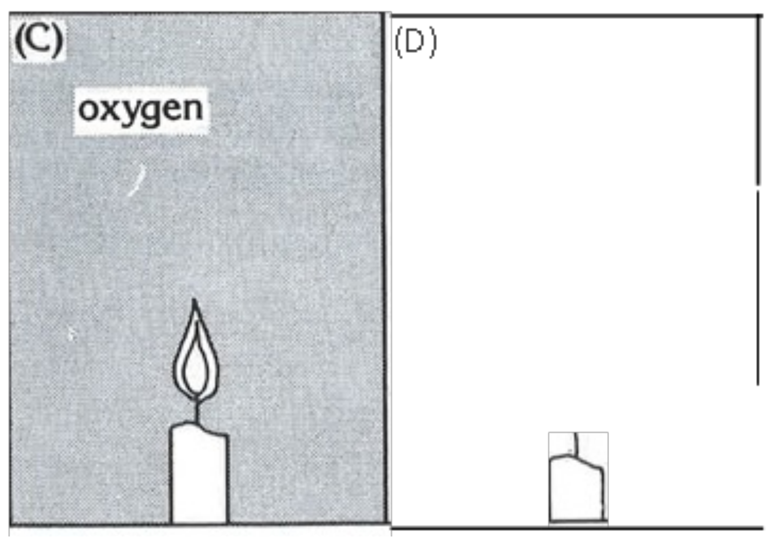
Phlogiston theory of burning. (A) When an object burns, it gives off a substance called phlogiston. (B) When the space surrounding the burning object is filled with phlogiston, the object will no longer be able to burn.



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.



Metal to metal calx
(instead of wood burning, metal rusting)

Phlogiston theory:

Metal ⟶ **Calx** + **Phlogiston**

Lavoisier theory:

Metal + **Oxygen** ⟶ **Calx**

A calx is what we call the metal oxide today.

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.

Levity is an ancient idea

- Levity, or inherent lightness, is an idea found in 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

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

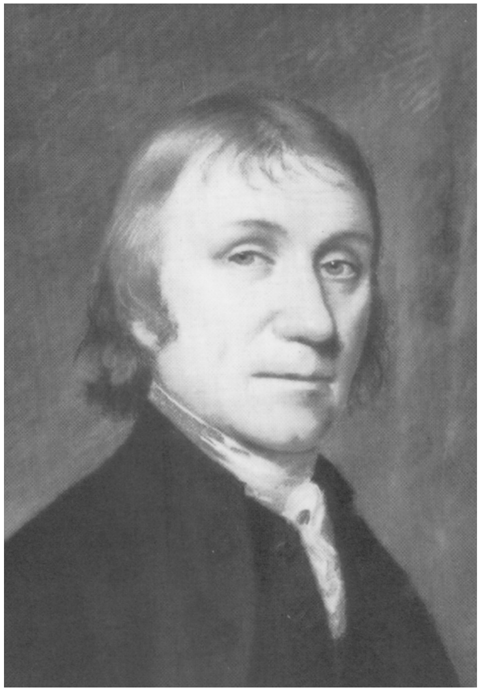
If calx is reheated in an oven filled with charcoal the calx turned back into the original metal.

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

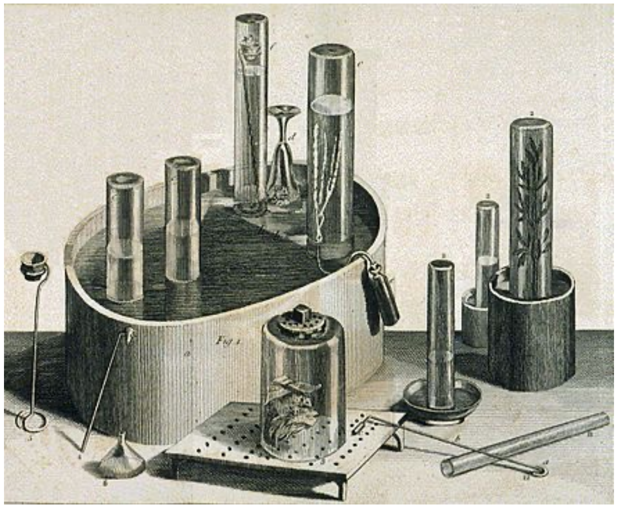
Charcoal absorbs the released oxygen and reacts to form carbon dioxide

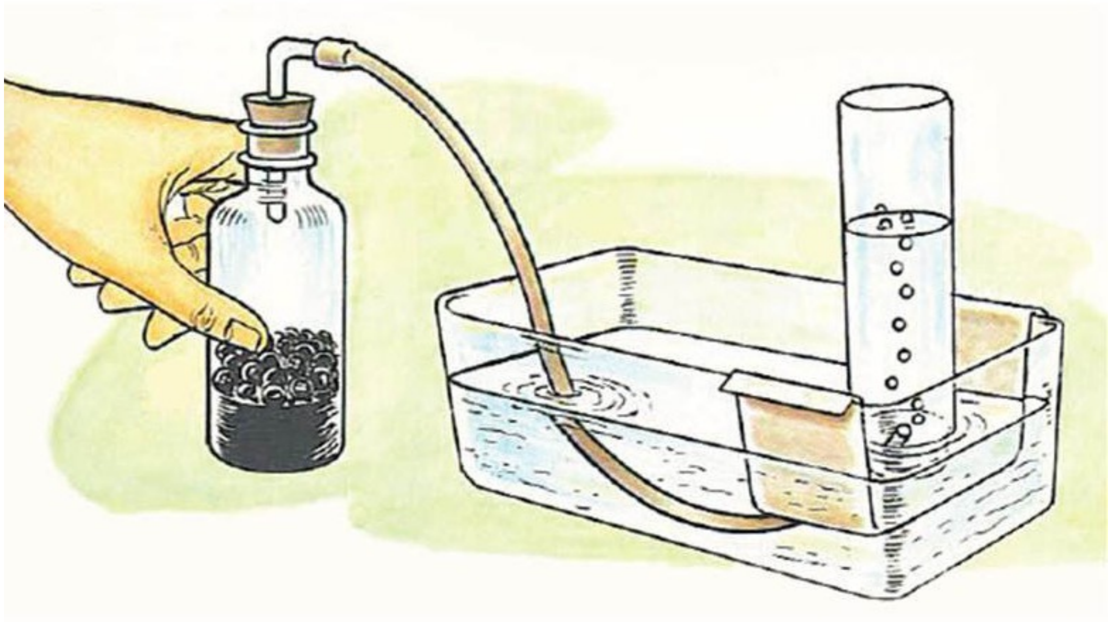
Dephlogisticated air

- 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.



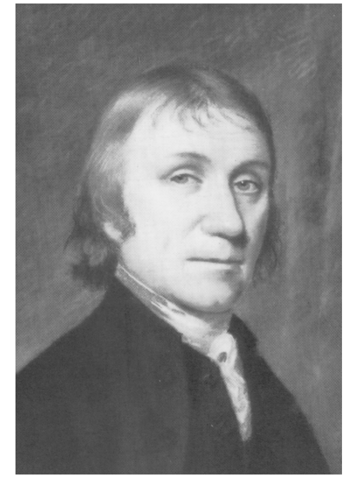
Joseph Priestley

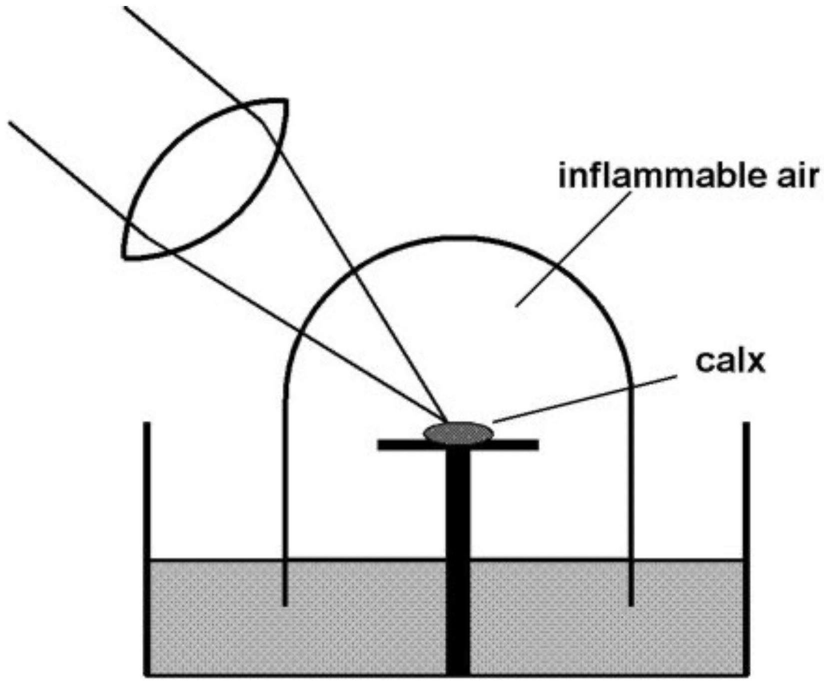




Dephlogisticated air

Mercury calx + Phlogiston → Mercury
Air





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.*"

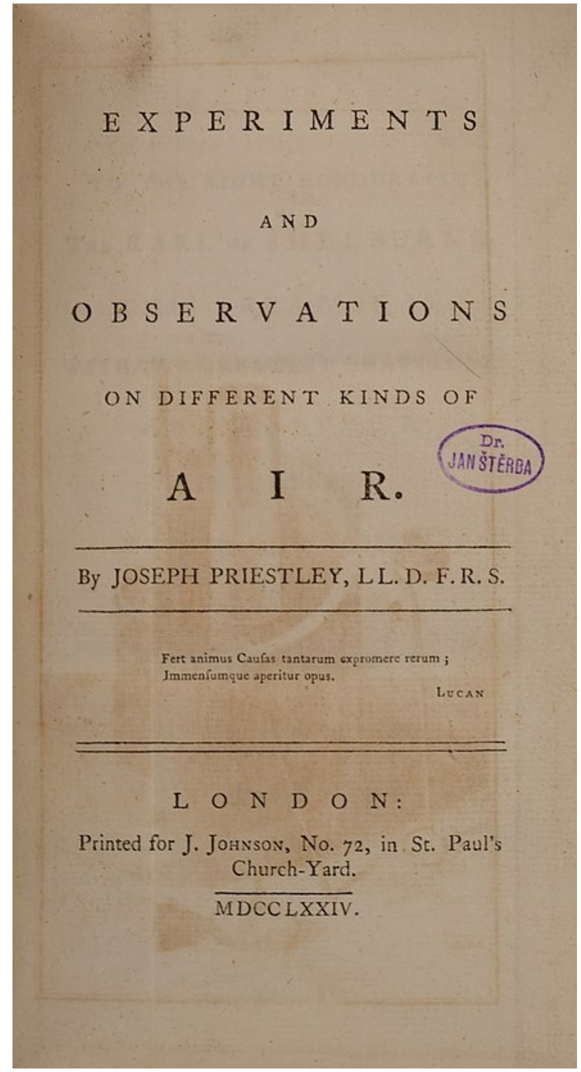
Dephlogisticated air

- 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.

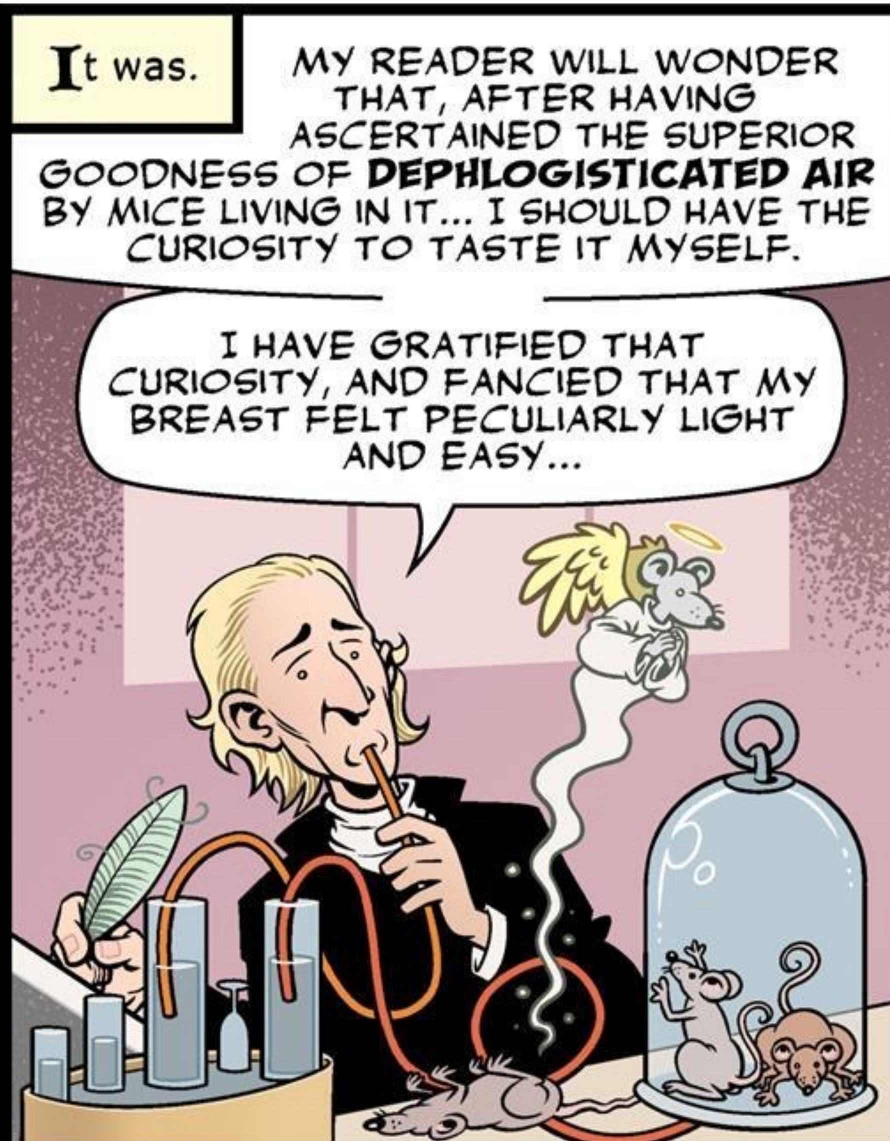
- Hence, the air that remained was deficient in phlogiston. He called it "dephlogisticated air".

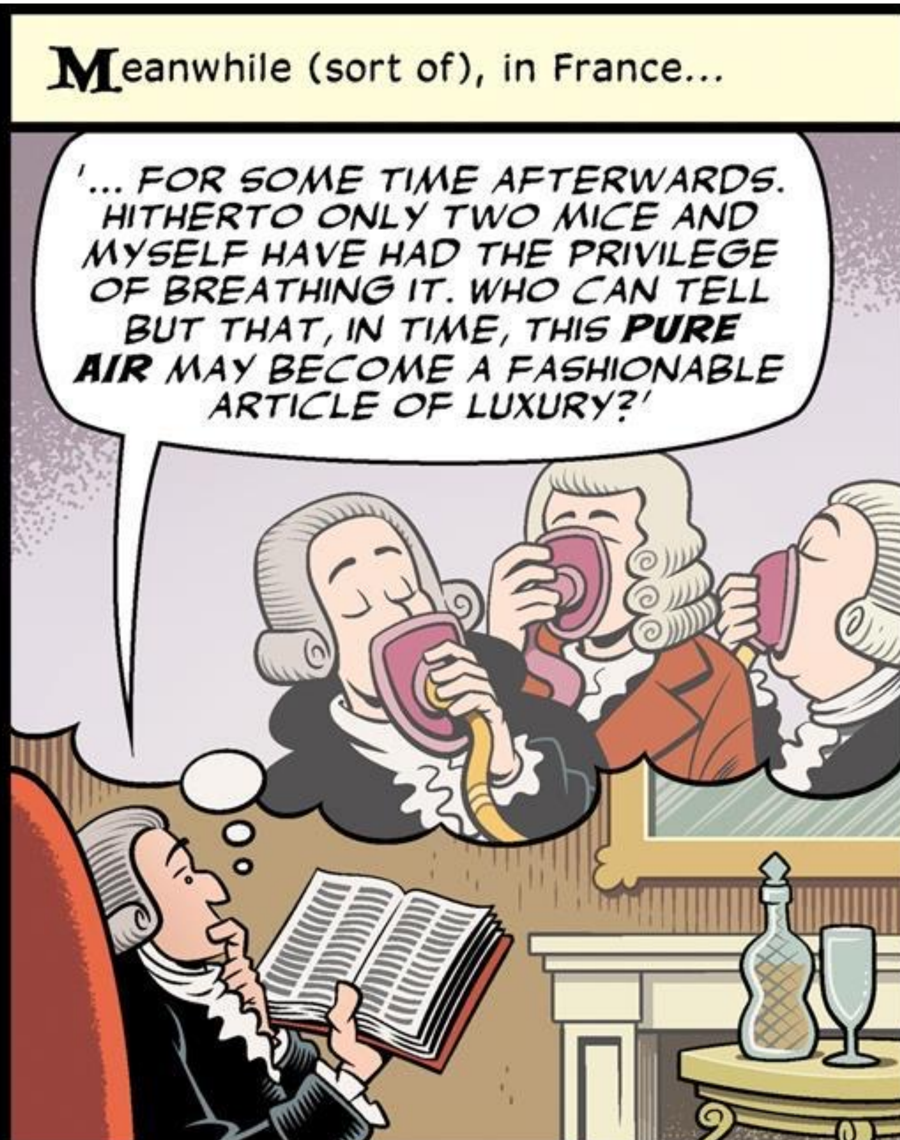
- Earlier charcoal was used instead of air as a source of phlogiston.

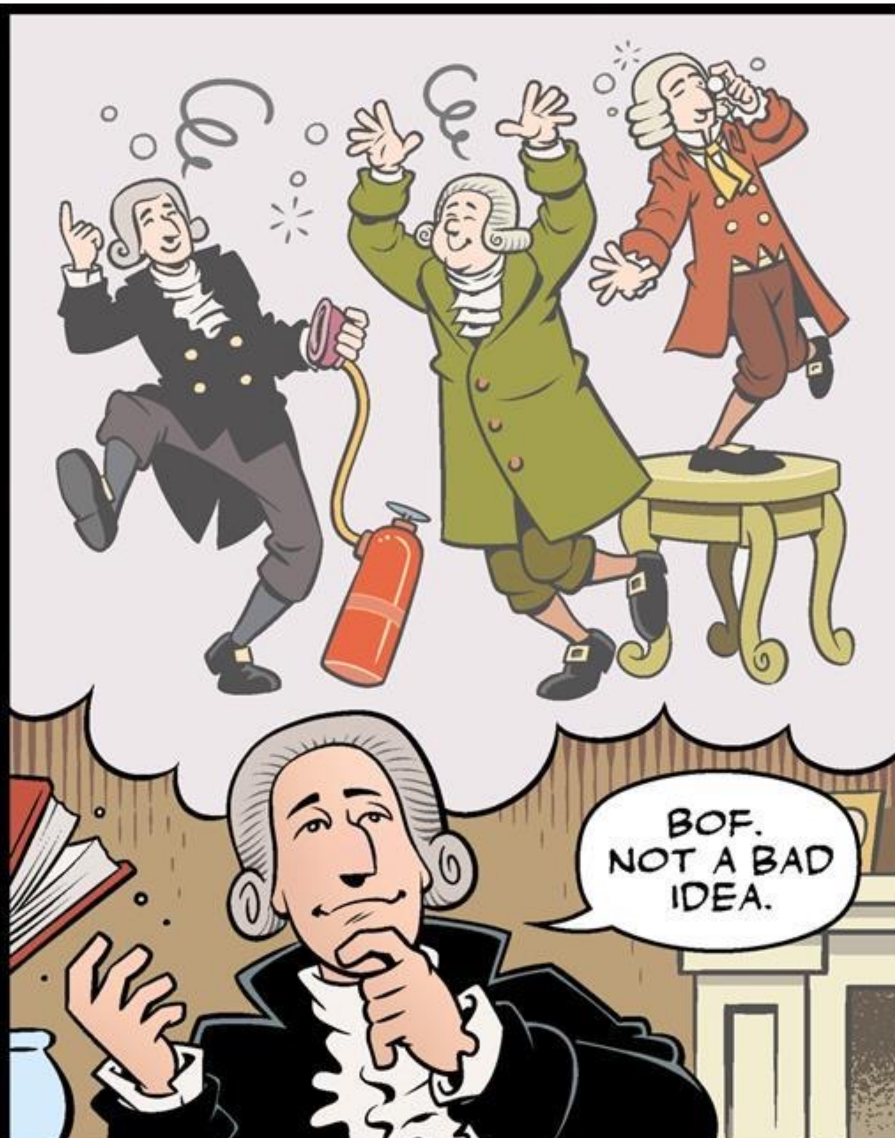


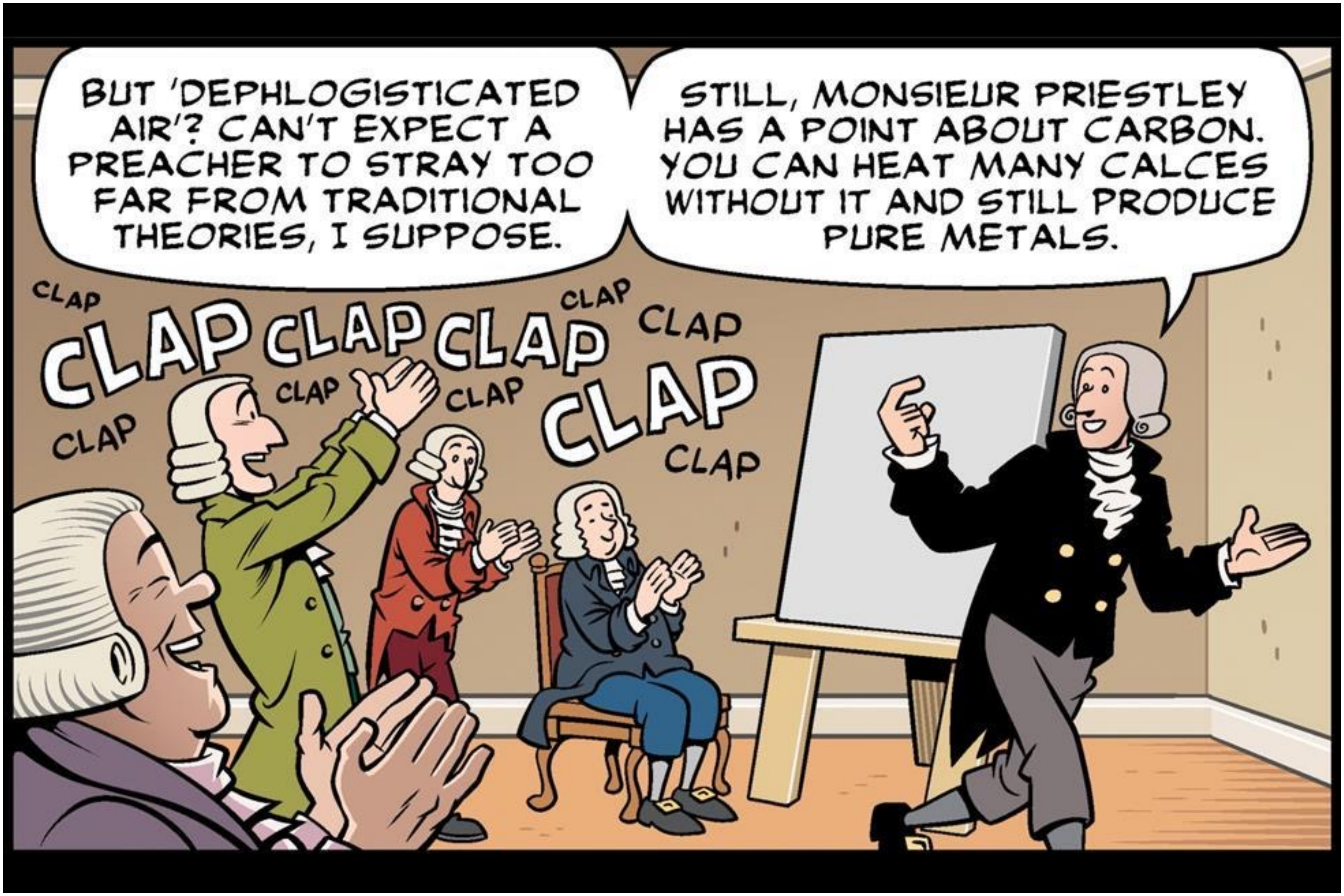
Dephlogisticated air

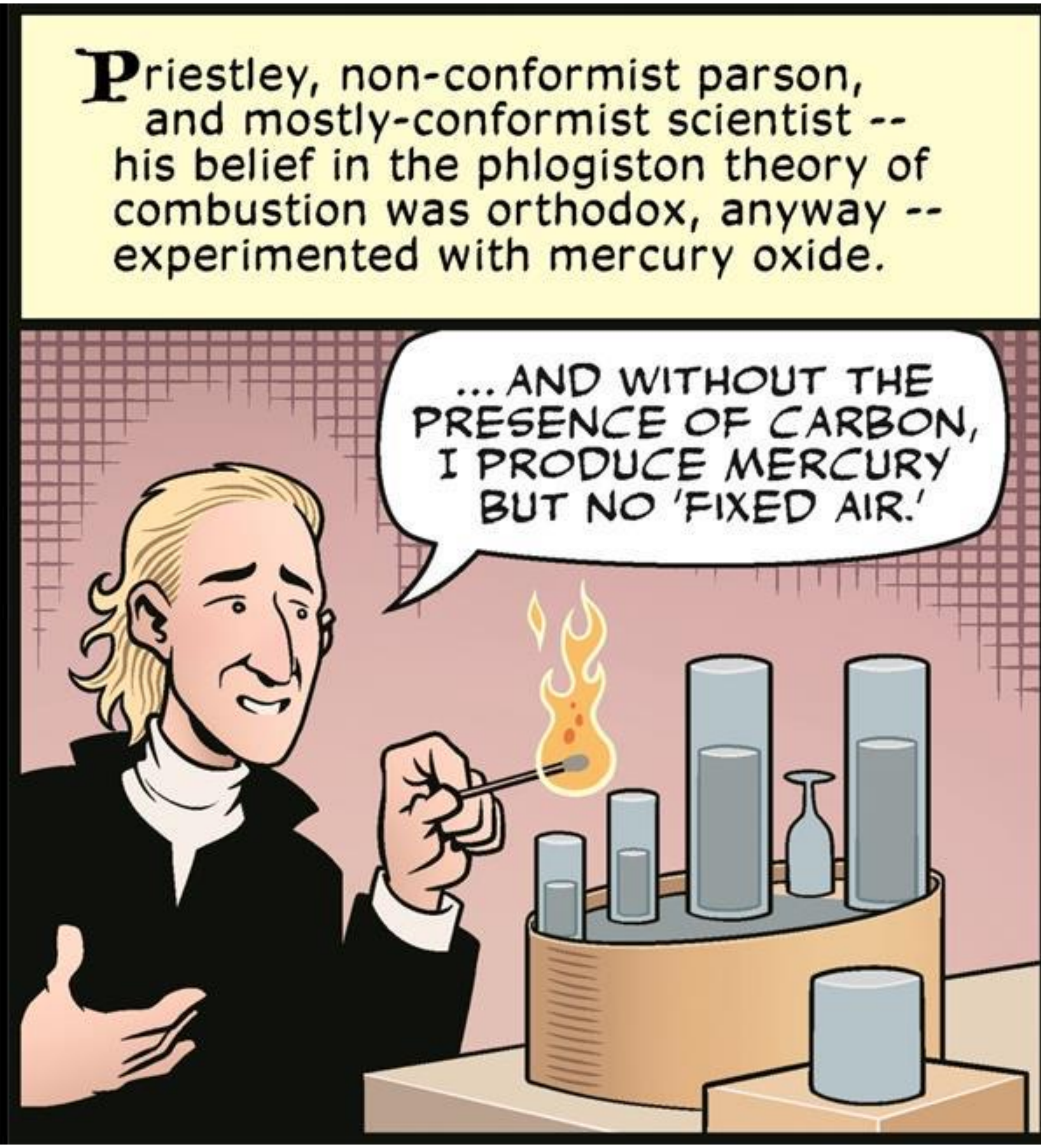
- Experimenting with his new air, Priestley found that:
  - A candle burned brighter in it.
  - A mouse put in a closed flask of the air lived longer than one in a flask with ordinary air.
  - He tried breathing it himself, and it made him feel great.

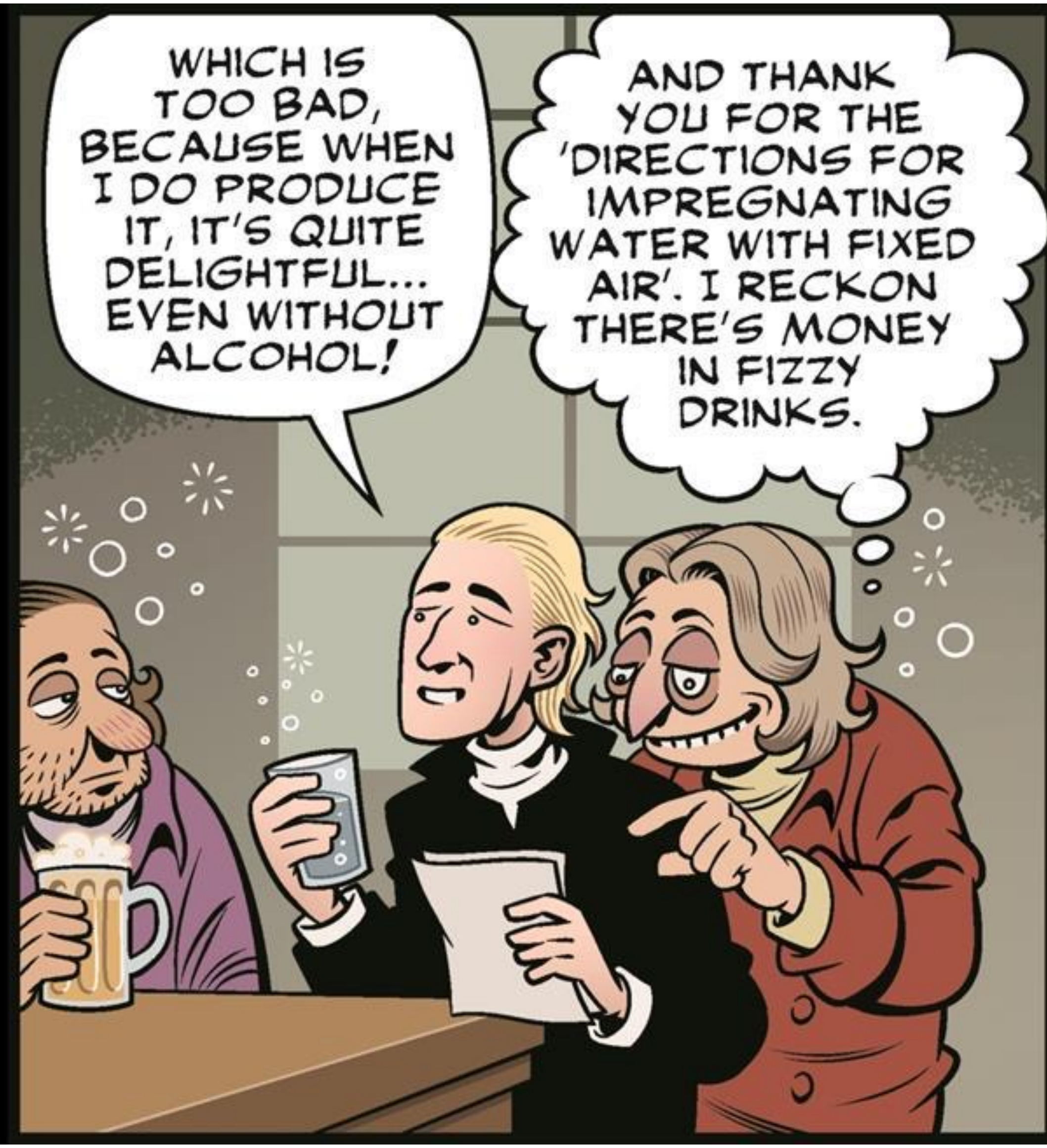

It was.
MY READER WILL WONDER THAT, AFTER HAVING ASCERTAINED THE SUPERIOR GOODNESS OF **DEPHLOGISTICATED AIR** BY MICE LIVING IN IT... I SHOULD HAVE THE CURIOSITY TO TASTE IT MYSELF.
I HAVE GRATIFIED THAT CURIOSITY, AND FANCIED THAT MY BREAST FELT PECULIARLY LIGHT AND EASY...

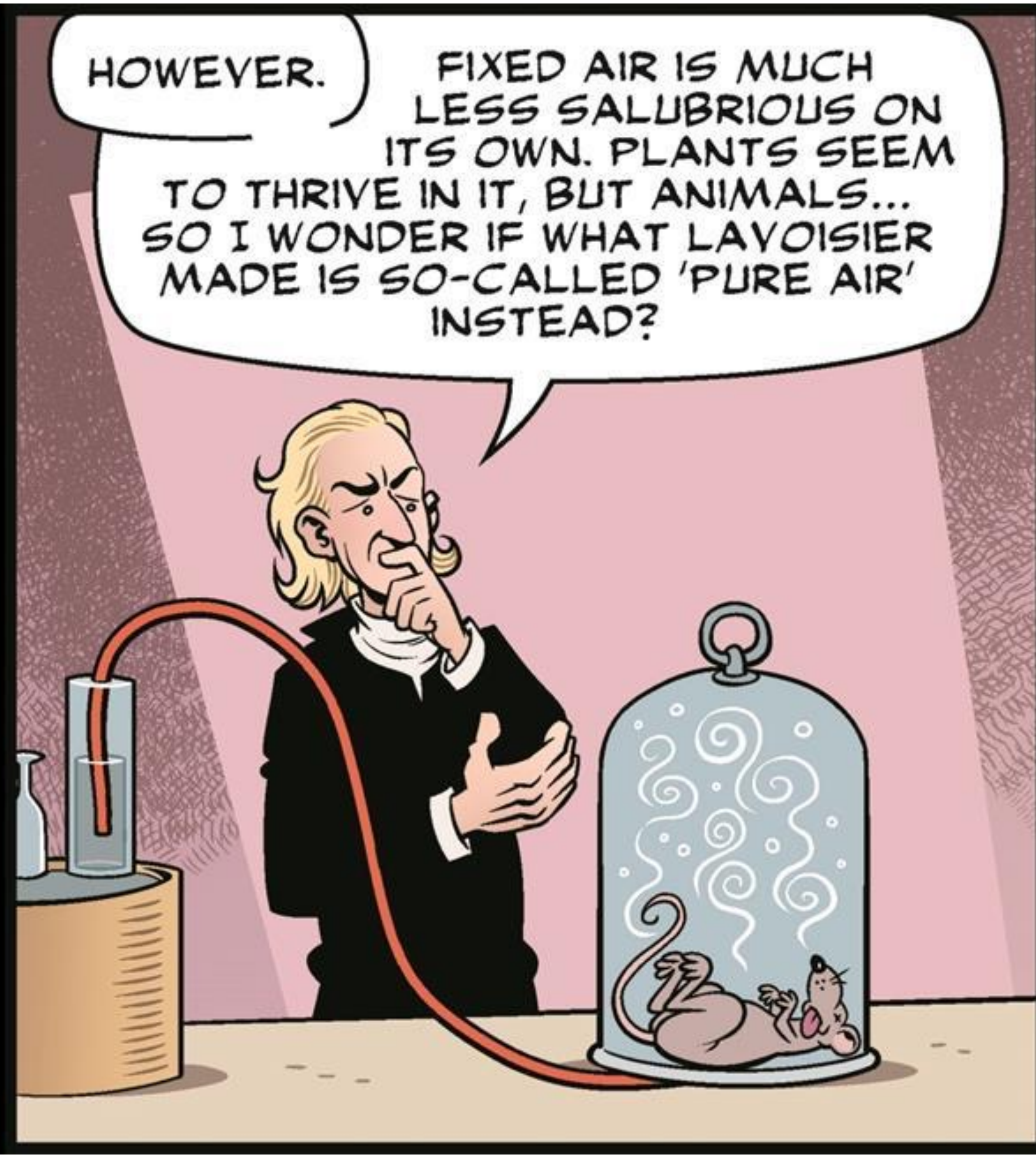

Meanwhile (sort of), in France...
'... FOR SOME TIME AFTERWARDS. HITHERTO ONLY TWO MICE AND MYSELF HAVE HAD THE PRIVILEGE OF BREATHING IT. WHO CAN TELL BUT THAT, IN TIME, THIS PURE AIR MAY BECOME A FASHIONABLE ARTICLE OF LUXURY?'


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


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

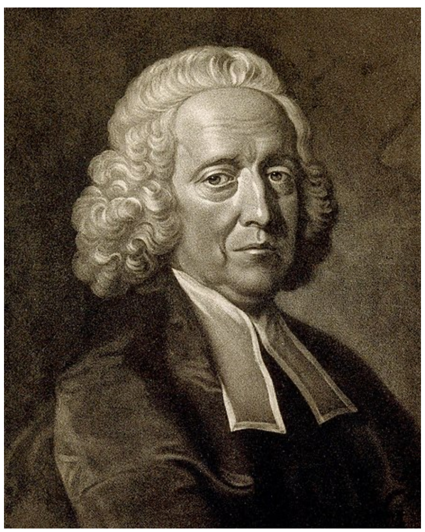
In order to communicate to it the peculiar Spirit and Virtues of
Pyrmont Water,
And other Mineral Waters of a similar Nature,

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

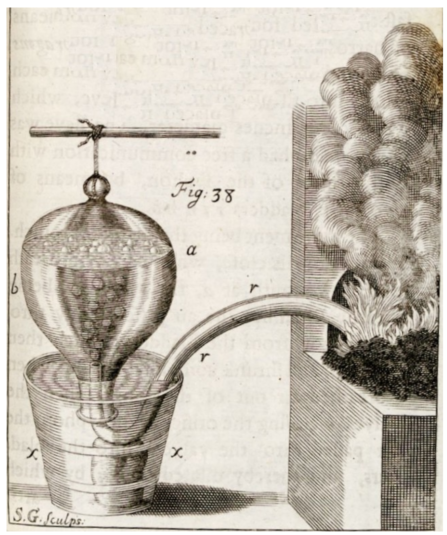
LONDON:
Printed for J. Johnson, No. 72, in St. Pauls Church-Yard, 1772.
[Price ONE SHILLING.]

All air are not the same

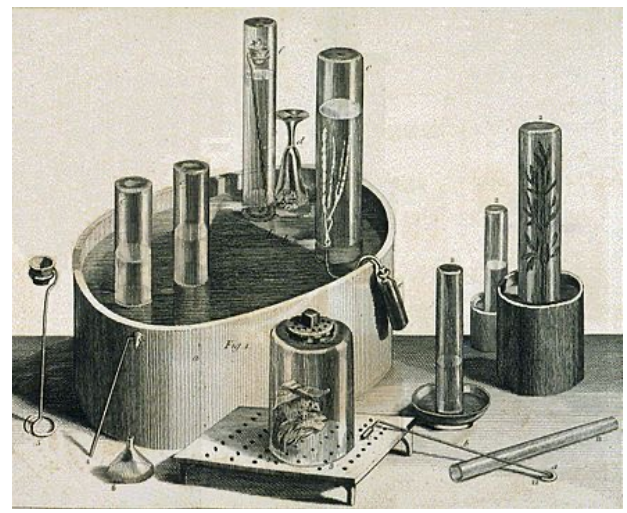
Parallel to phlogiston theory, another concept entered chemistry about the same time: the notion of "air" and that "air" is not just one thing, but that there are different kinds of air (many many air?)"



Stephen Hales
(1677 –1761)



Hales's

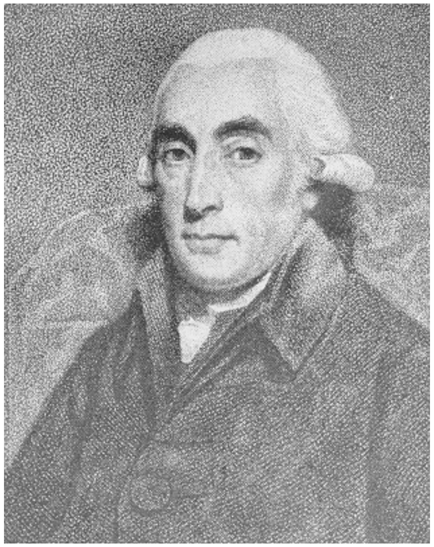


Priestly's

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.

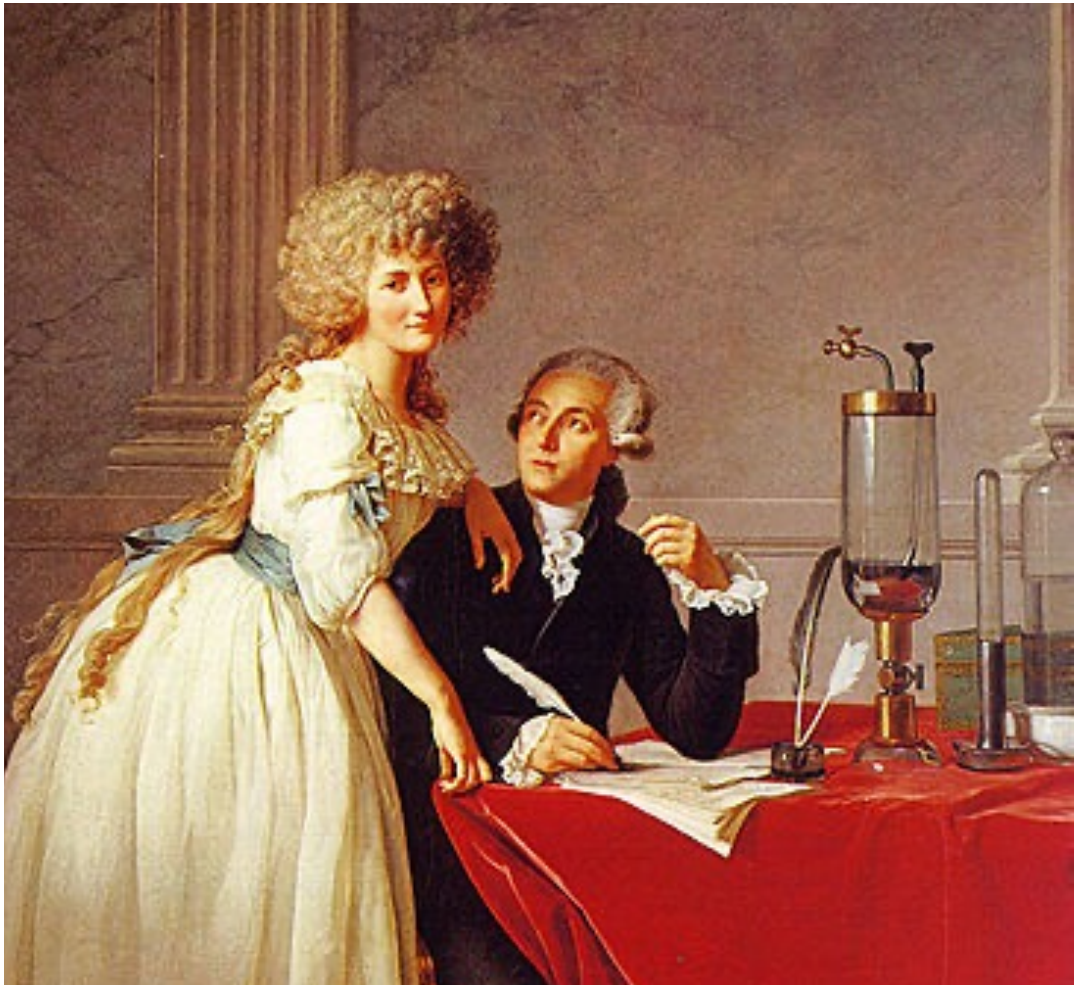
Lavoisier saw the opportunity

- 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.

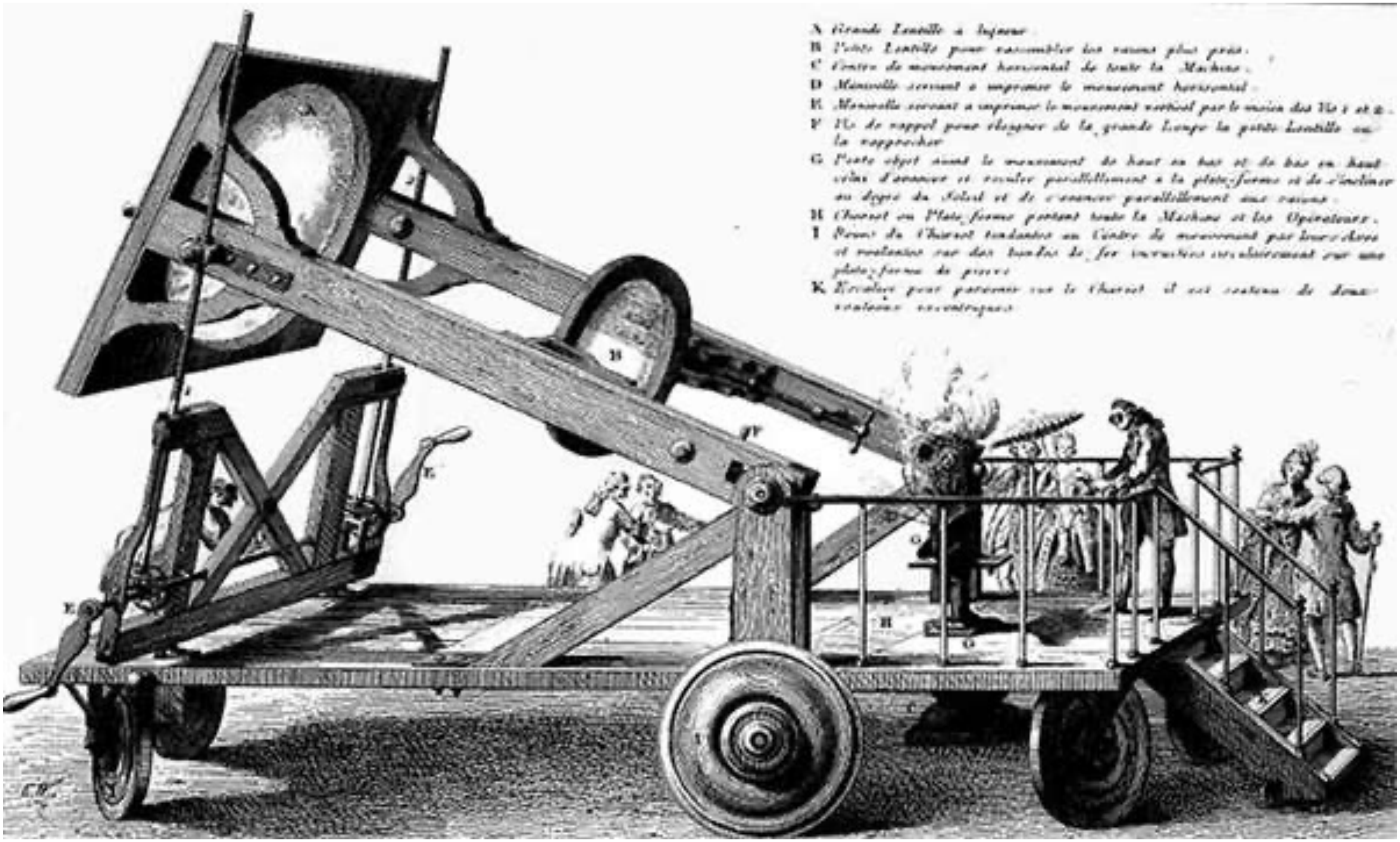
Madam Lavoisier



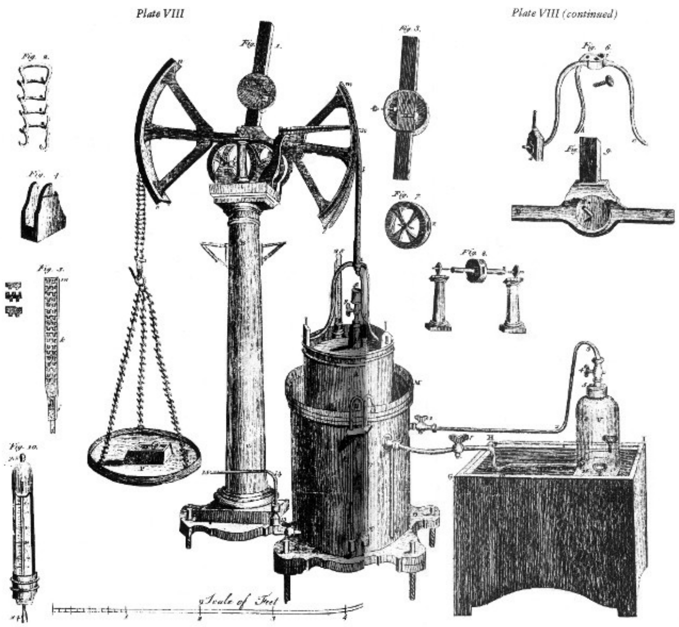
Marie-Anne would translate these English papers into French for her husband to be able to understand them

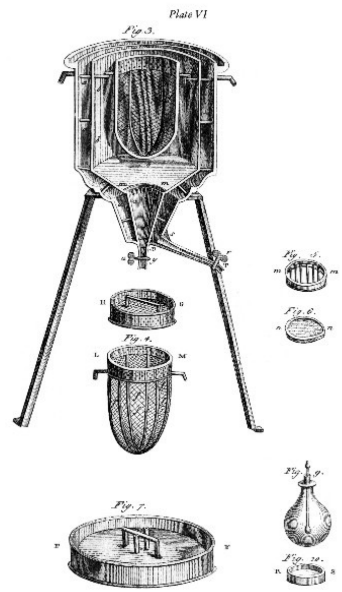
She also translated her husband's work from French into English so he could share his ideas.

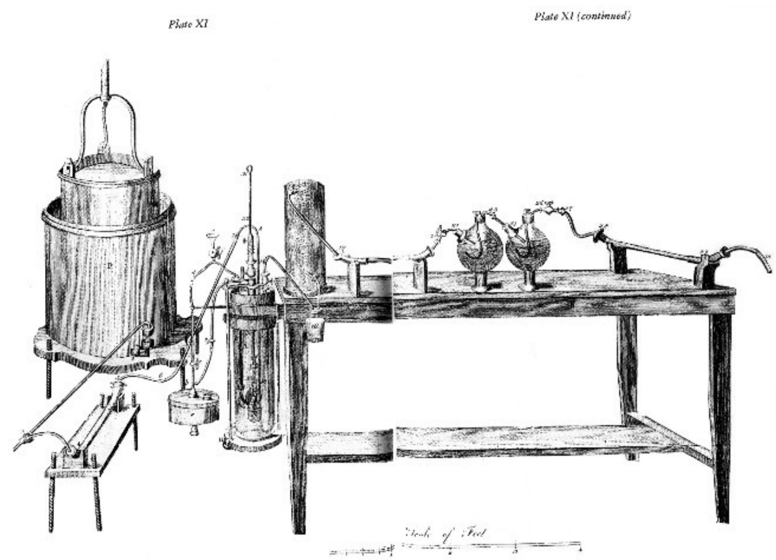
Her sketching skills were used to produce engravings of the apparatus and methods he used.

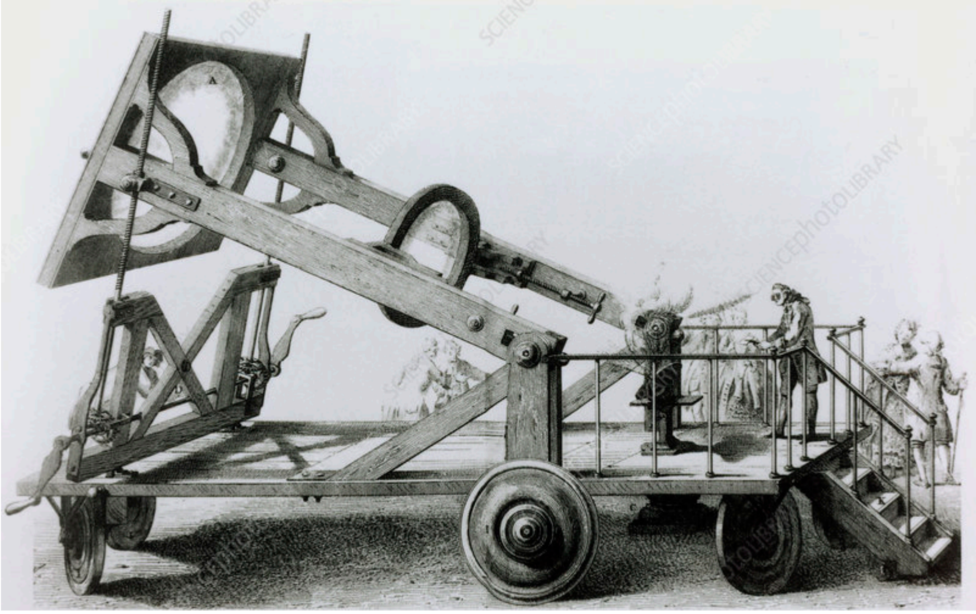

A Grande Lentille à liqueur.
B Petite Lentille pour rassembler les rayons plus près.
C Centre de mouvement horizontal de toute la Machine.
D Manivelle servant à imprimer le mouvement horizontal.
E Manivelle servant à imprimer le mouvement vertical par le moien des Vis 1 et 2.
F Vis de rappel pour éloigner 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

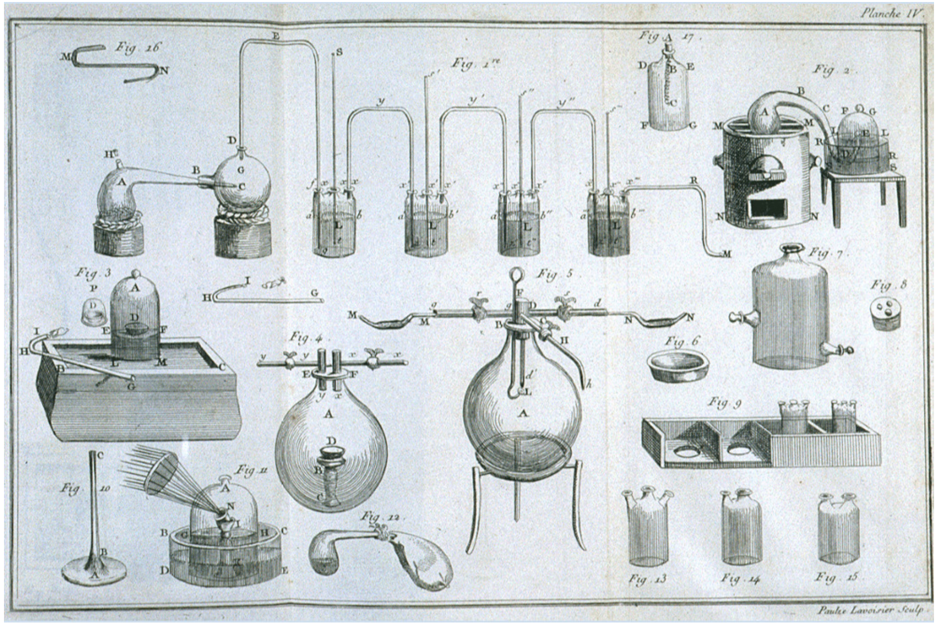
Home built laboratory equipments





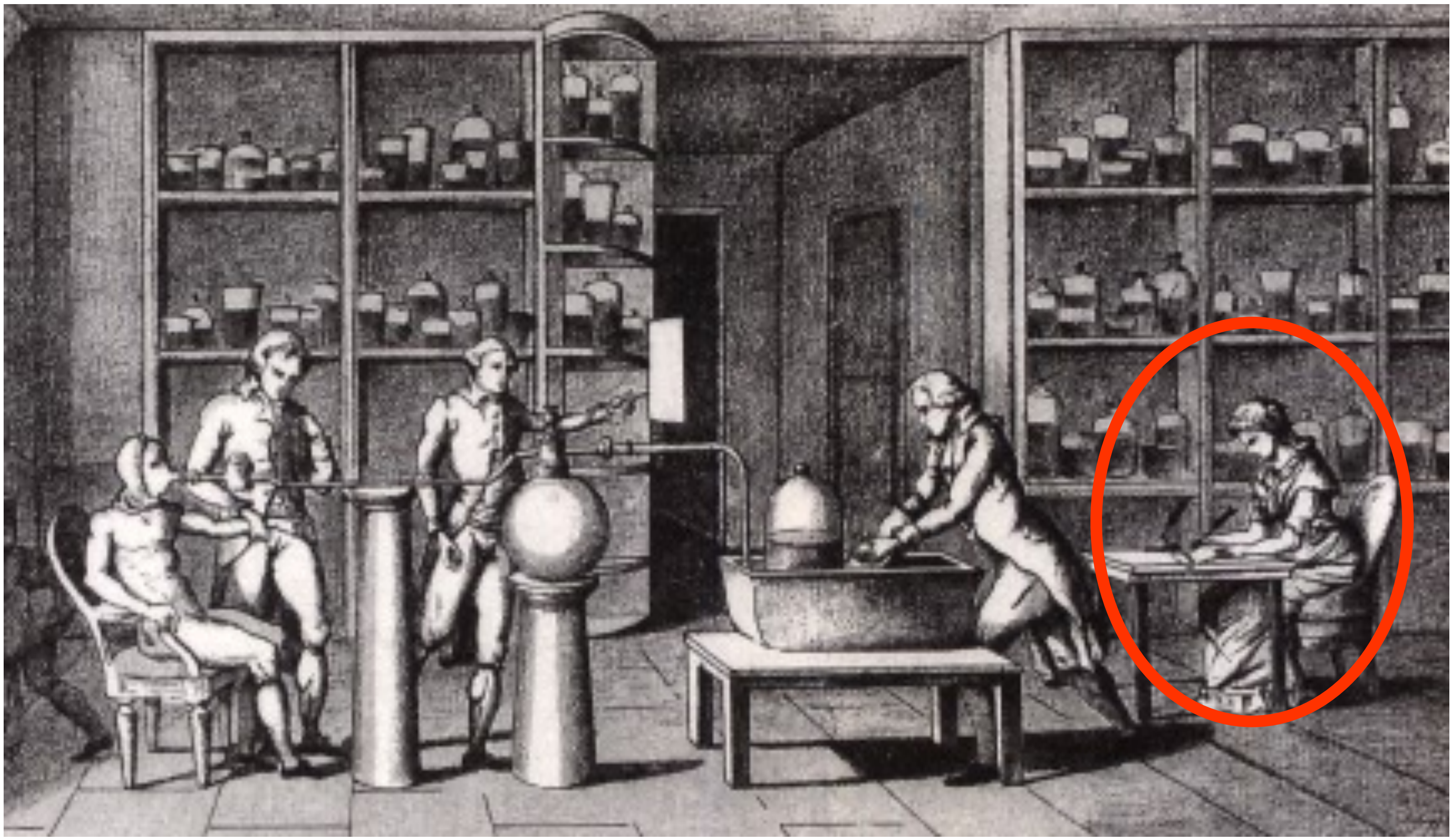






Married Marie-Anne in 1771

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

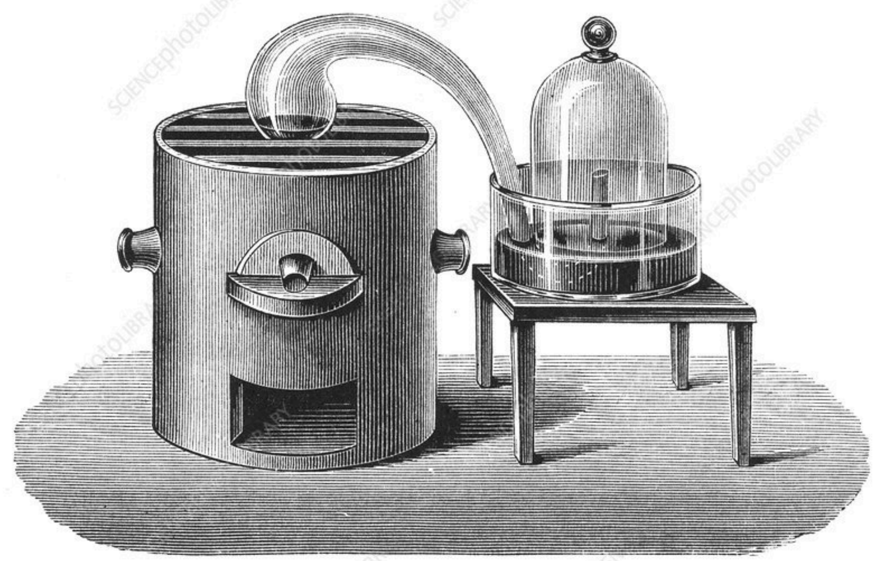


Lavoisier’s ideas

- 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.

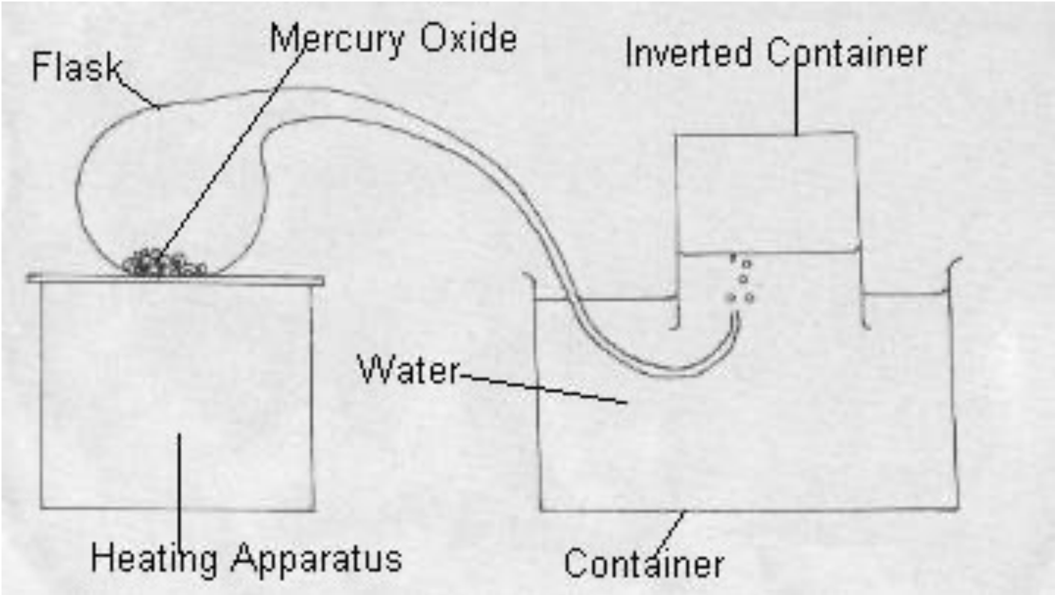
Lavoisier's classic experiment-1

- 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.

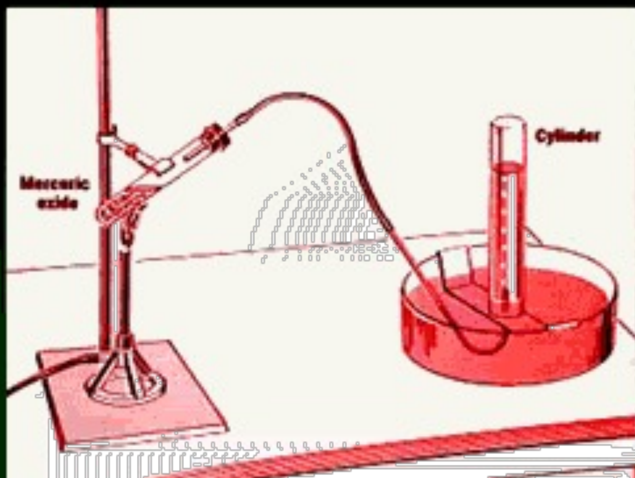
- He called that element “oxygen,” meaning “acid maker.”

- 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).

freed thinking from phlogiston theory

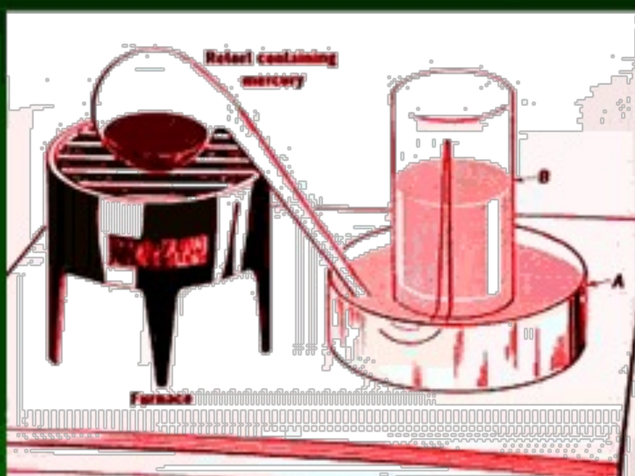


PRIESTLY'S DEPHLOGISTICATED AIR

Red mercury calx is heated and the effluent collected over water.

The gas supports combustion better than air. Preistly theorizes he has removed the phlogiston from air, increasing its capacity to absorb phlogiston and support combustion.

Experiment is QUALITATIVE



LAVIOSIER'S OXYGEN

Mercury is heated until a red calx forms. The volume of air in the cylinder decreases as the water rises. When calx stops forming heating is stopped.

Mercury plus calx has gained exactly the same weight as the cylinder has lost. Remaining air does not support combustion.

Calx is now heated as in Preistly's experiment. Air given off weighed the same as the weight lost previously and supported combustion.

Experiment is QUANTITATIVE

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 - - -.”

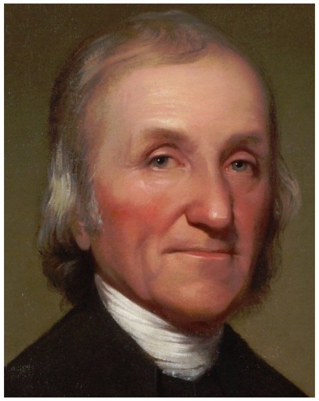
Lavoisier

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?

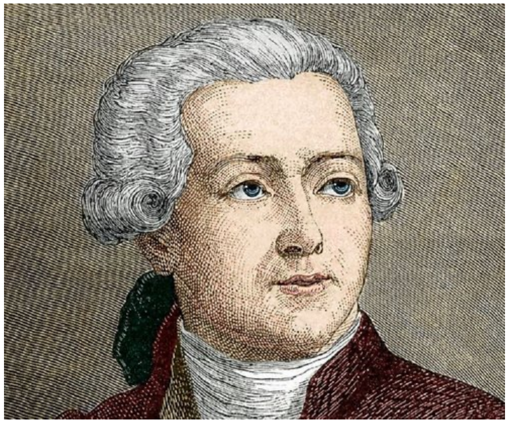


Joseph Priestley
1733 – 1804

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

Carl Scheele
1742 - 1786

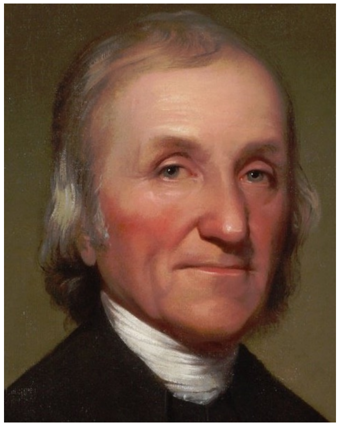
Swedish chemist **Scheele**, identified it **several years before** Priestley (1770-1773). Unfortunately, his scientific report sat in a printer's office for two years and got published in **1777**.



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?

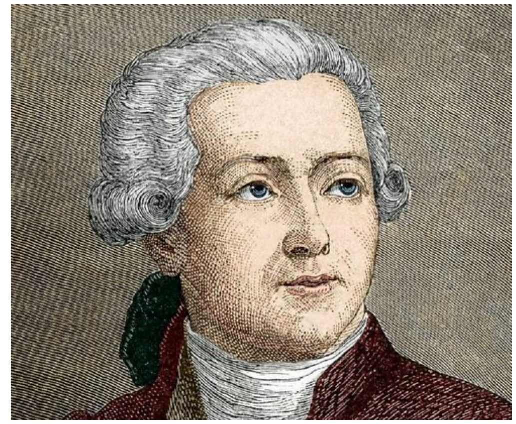


Joseph Priestley
1733 – 1804

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.

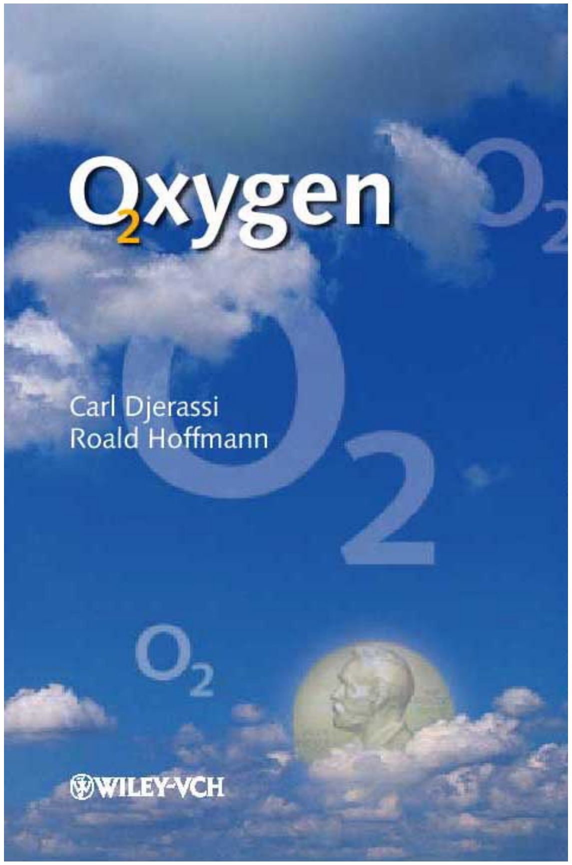


Antoine Lavoisier
1743—1794

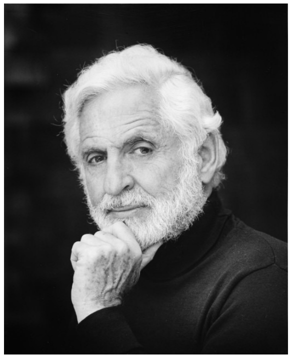
Brilliant economist, great and meticulous scientist. Mind was flexible to discard old ideas. Lacked professional integrity.

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.



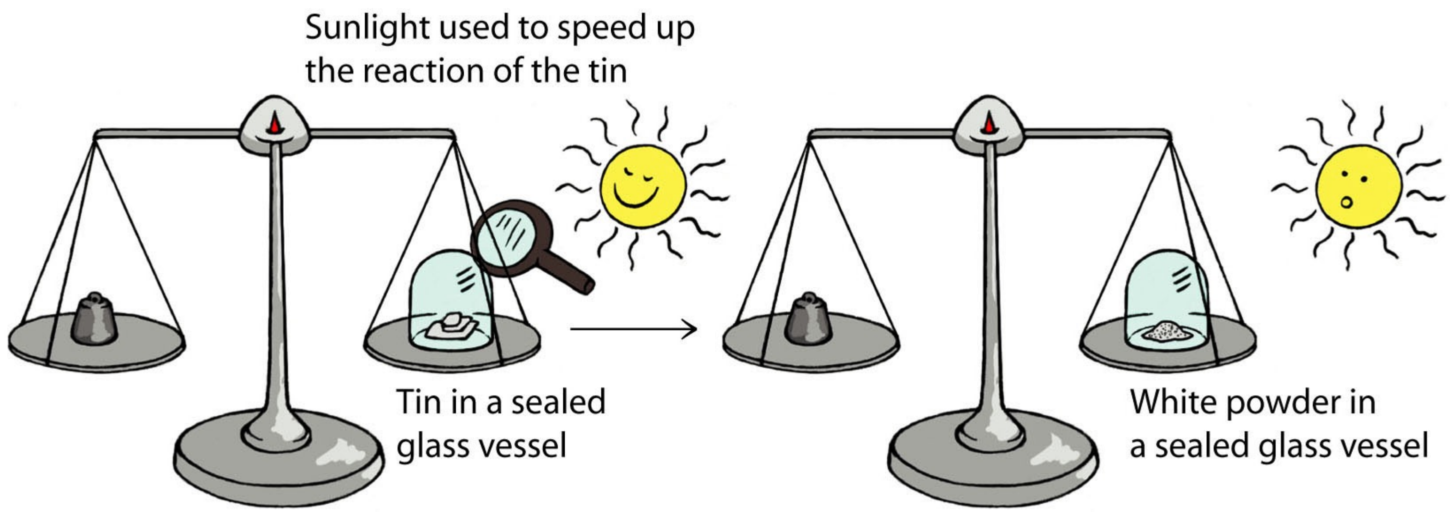
Scheele's work was carried out years before but remained unpublished until 1777. Scheele and Priestley fit their discovery into an entirely wrong logical framework—the phlogiston theory—that Lavoisier is about to demolish. How does Lavoisier deal with the Priestley and Scheele discoveries? Does he give 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

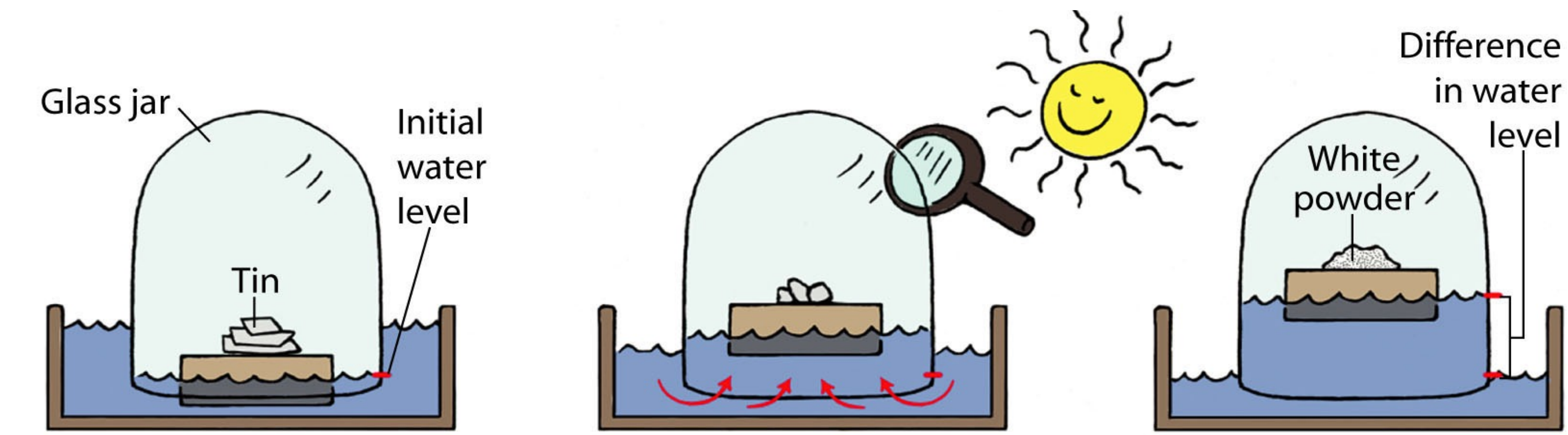
(Reactants) (Products)

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

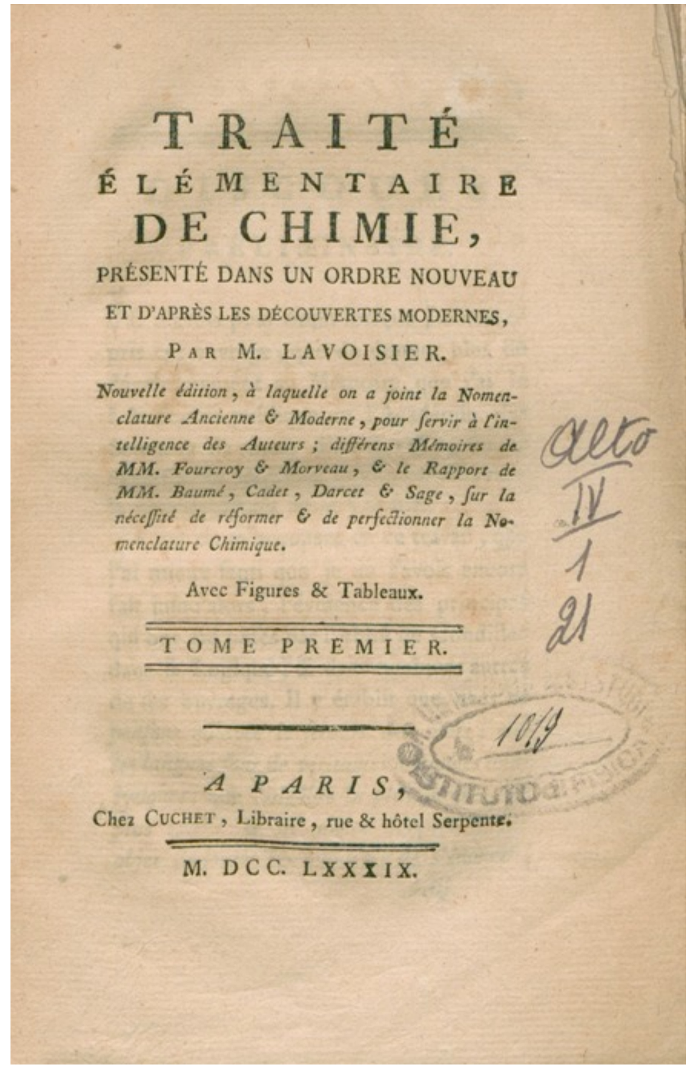
Law of the indestructibility of matter
applied to chemical change

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
DE CHIMIE,
PRÉSENTÉ DANS UN ORDRE NOUVEAU
ET D'APRÈS LES DÉCOUVERTES MODERNES,
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.

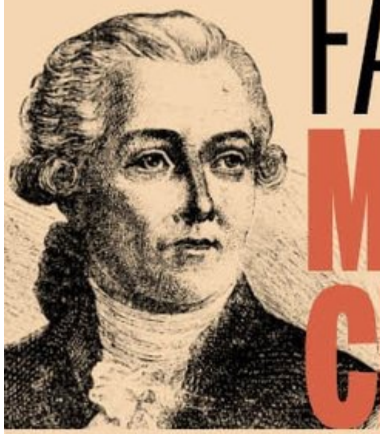
Antoine Lavoisier
1789

Chemistry

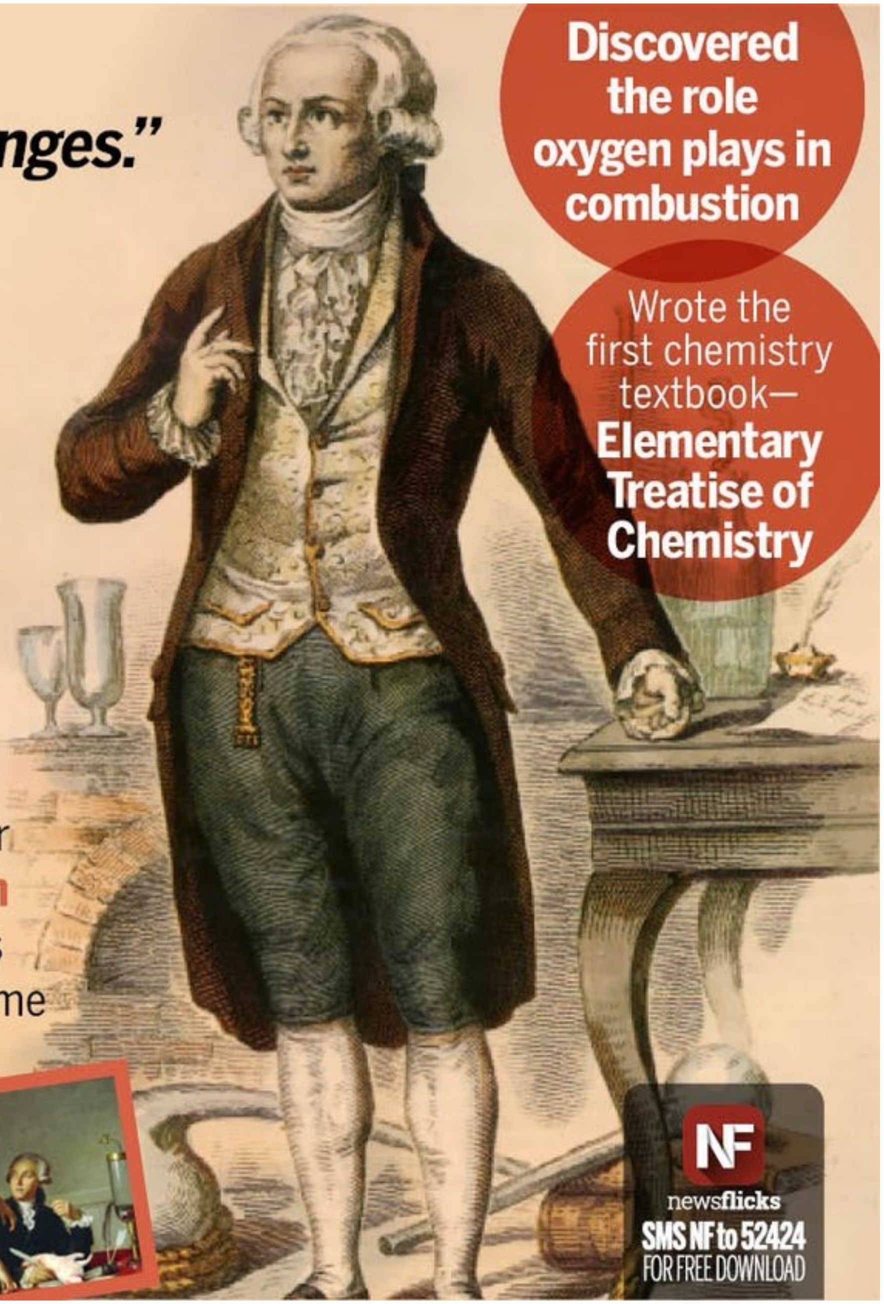
Robert Boyle (1627–1691)	Antoine-Laurent Lavoisier (1743–1794)
• Irish chemist, 1600s • Father of modern chemistry • First to define *element* • *The Sceptical Chemist*, 1661, described matter as cluster of tiny particles (now called atoms) • Changes in matter occurred when clusters rearranged • Boyle's law - temperature, volume, pressure affect gases	• French chemist, 1700s • Father of modern chemistry • Developed methods for precise measurements • Discovered law of Conservation of Mass, proved matter could not be created, destroyed • Recognized, named oxygen, introduced metric system • invented first periodic table

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

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



FATHER OF MODERN CHEMISTRY



Discovered the role oxygen plays in combustion

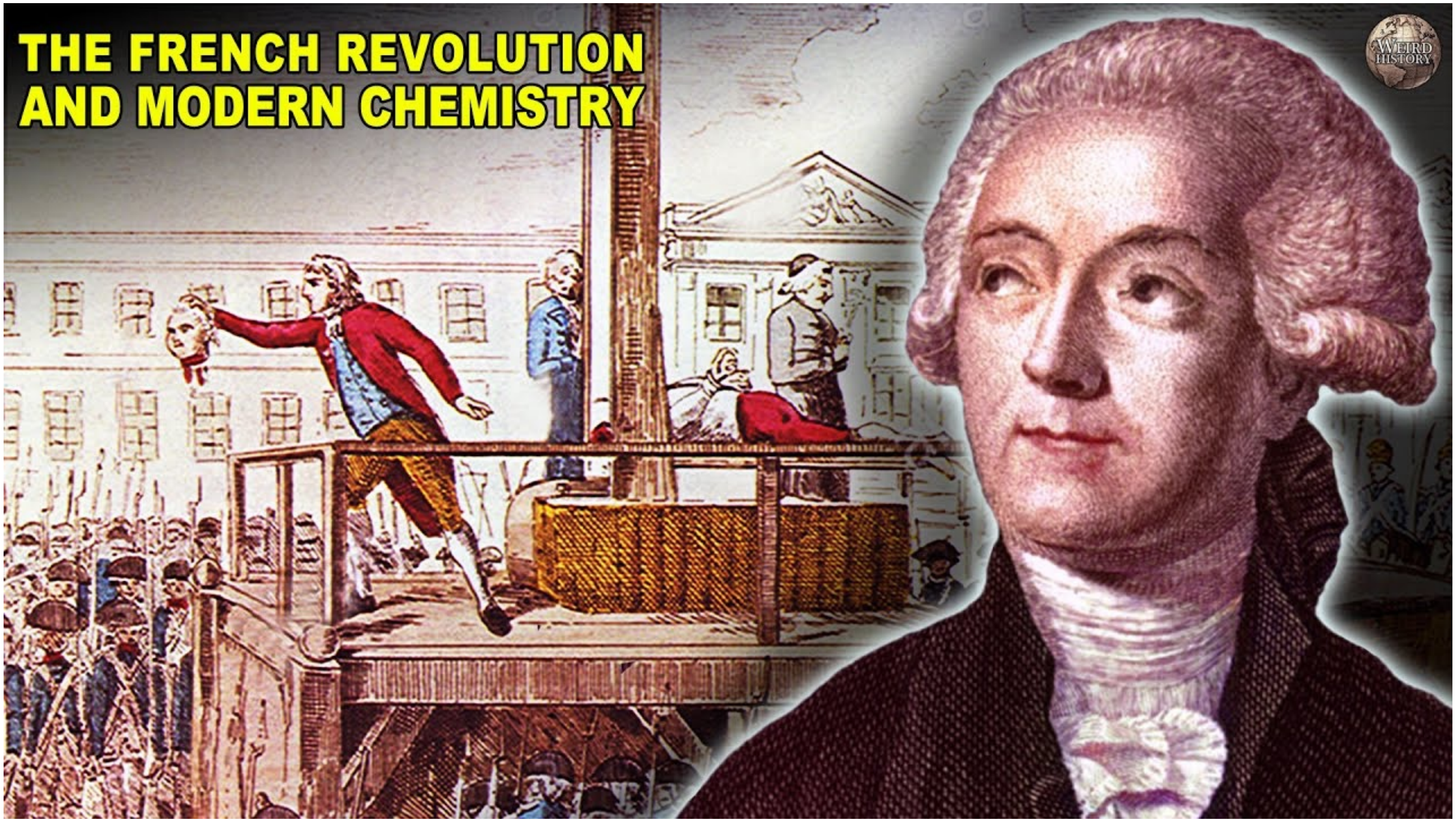
Wrote the first chemistry textbook—**Elementary Treatise of Chemistry**

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

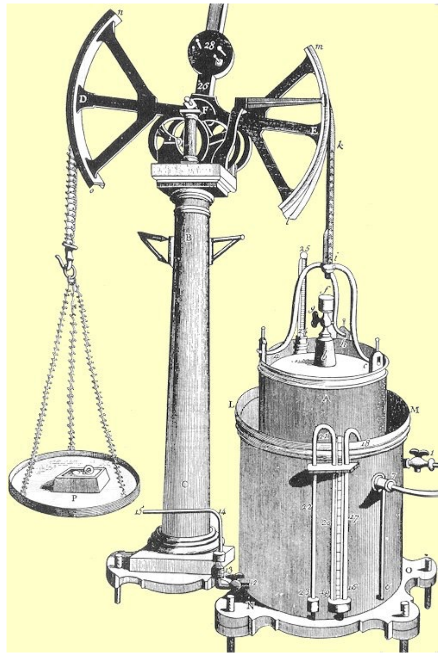
Despite his eminence and his services to science and France, he came under attack as a former farmer-general of taxes and was guillotined in 1794 (51 yrs old).

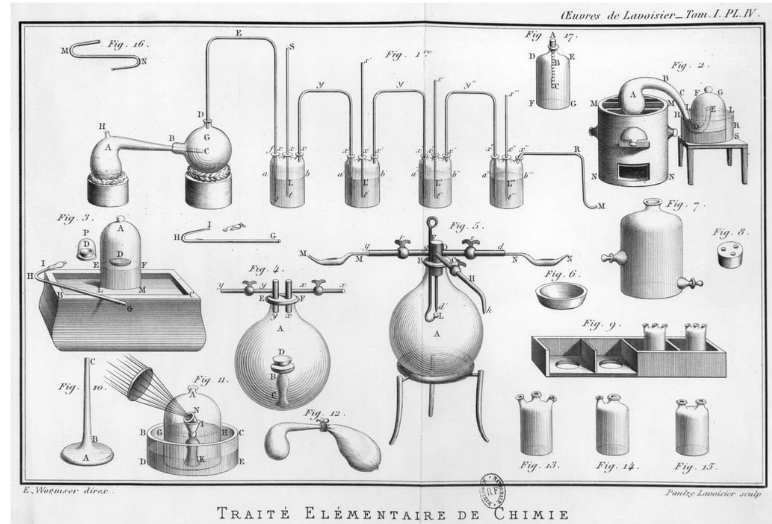


"*It took them only an instant to cut off that head, and a hundred years may not produce another like it*."

Joseph-Louis Lagrange

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?*

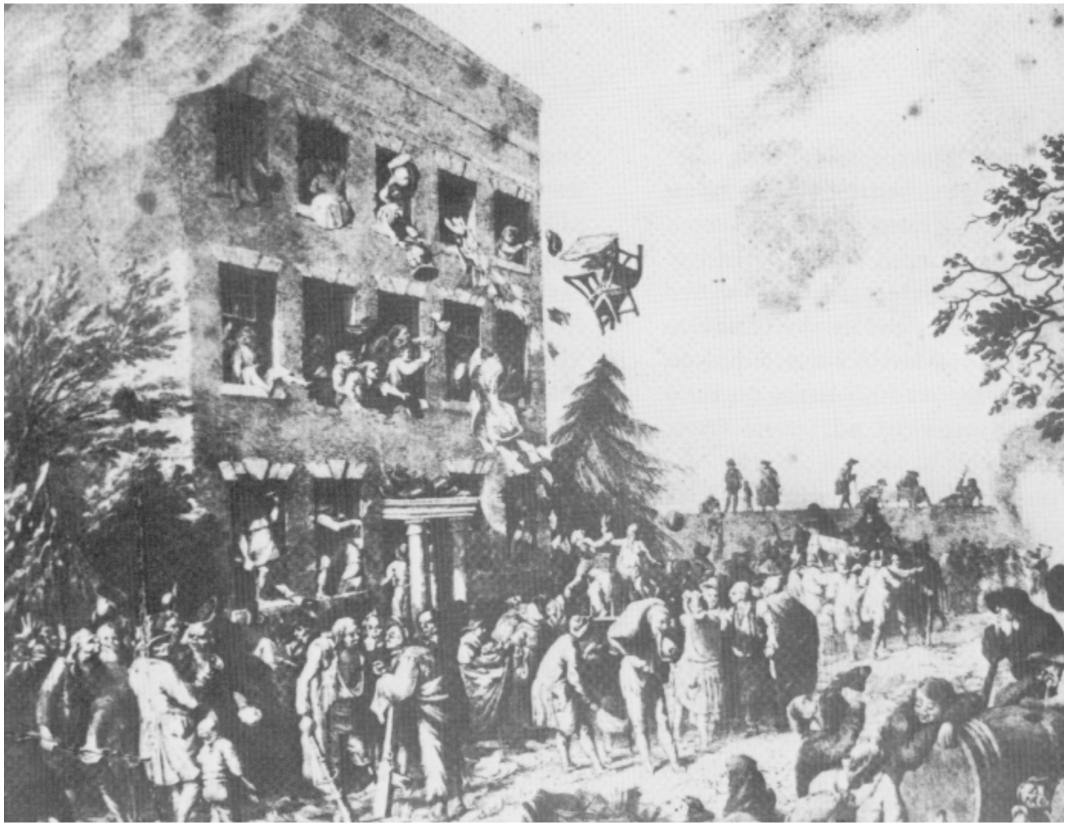
Antoine Lavoisier – Sad Ending

(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

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