Textbooks and Chemical Order
From Lavoisier to Mendeleev

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Matter unit

Overarching questions:
Is the stuff of the world unchanging or transmutable?
How have the institutions of science evolved?

I. Enlightenment and Revolution

II. Priestley, Lavoisier, and Airs

III. Atoms, Elements, and Order

The Age of Enlightenment

Urbanization


Public Sphere

W. Hogarth, An Election Entertainment, 1755

Middle Class

J. Zoffany, British middle-class men, 1796

Print Culture

The London Magazine: For APRIL 1755

Or, GENTLEMAN's Monthly Intelligence. For JULY 1755...
Enlightenment Characteristics

Inspired by natural philosophy

Faith in reason and principles

Suspicion of authority or tradition
Encyclopedic Aspirations

Knowledge as an end in itself; expand education

Classifying ambition: universal, systematic, and complete
French Revolution

“Ancien Régime”: steep and rigid social structure. Three “orders”—nobles, clergy, and commoners. Privileges by birthright (or purchase); little social mobility.

Summer 1789: commoners in Paris stormed the Bastille; peasants in the countryside attacked feudal manors. That August, the National Assembly adopted the “Declaration of the Rights of Man and Citizen.”
Revolutionary Institutions

During the early years of the Revolution, the new government established several new educational institutions, including the École Polytechnique and the École Normale Superieure. These elite institutions focused on science and engineering, as properly “enlightened” topics around which to train new generations.
“The Terror”

By 1793, chaos reigned. France was fighting wars against Prussia and Austria, and internal factions divided the country. The Legislature appointed a 12-person “Committee on Public Safety,” which quickly imposed martial law.

Between September 1793 and July 1794, tens of thousands of people were charged with “treason” and sent to the guillotine.
Joseph Priestley (1733 – 1804) was barred from Oxbridge because of his religious beliefs. He was educated in Dissenting Academies outside London, with their mix of abstract theory and practical application. His work was principally supported by new institutions like the Lunar Society of Birmingham, rather than the Royal Society.

A master experimentalist and writer, Priestley discovered more new gases than any of his contemporaries.
Phlogiston

\[
\text{wood + common air} \rightarrow \text{ash + phlogisticated air}
\]

Common air can only absorb so much phlogiston before it becomes saturated. Thus the flame of a burning candle placed in a sealed jar will go out. The air that remains inside the container (“phlogisticated air”) will support neither combustion nor respiration (poor mouse).

Immediate public health applications: test the “goodness” of air in prisons, mines, hospitals, and schools.
Dephlogisticated Air

Priestley found that when he heated mercury in ordinary air, it formed a red precipitate. Upon heating the precipitate, a new kind of air was released that could revive asphyxiated mice. Flames burned brighter in the new air as well. Priestley called it “vital air” or “dephlogisticated air”: the new air was able to absorb even more phlogiston than common air.

In 1774, Priestley traveled to Paris and told the Lavoisiers about his experiments.
Antoine-Laurent Lavoisier (1743 – 1794) was born into an aristocratic family. He was elected at an early age to the Académie Royale des Sciences, and also served as a royal tax collector.

His wife trained herself to assist in the laboratory. She also learned English to be able to read and correspond with English chemists like Priestley. And she drew detailed illustrations to accompany Lavoisier’s publications.
Mass Balance

Inspired by advances in physics, Lavoisier sought precision and quantification. He carefully weighed reactants before and after combustion to ensure that total mass was conserved. When he re-did Priestley’s experiment with mercury, he found that the precipitate weighed more than the original sample. How could that be, if combustion involved the release of phlogiston?

Priestley was skeptical in part because Lavoisier’s apparatus was too elaborate. Few others could afford comparable equipment or replicate the results.
Priority Dispute

Lavoisier continued to experiment with the special air. By the late 1770s, he found that the acids of sulfur, carbon, nitrogen, and phosphorus all contained “eminently respirable air.” He concluded that all acids must come from that air, so he named it “oxygen” (acid-generating).

To Lavoisier, combustion arose when a burning substance combined with oxygen from the air—hence the weight gain. But why was heat released? “Caloric”: a fluid of pure heat, with no weight of its own.
Reform Nomenclature

Chemical nomenclature was a mess: substances were named for their composition, or the site they were found, or their discoverer, ... No order, no system.

Inspired by Condillac and the Encyclopédie, Lavoisier introduced a “rational order” based on analysis: start with the simplest substances that cannot be further broken down, and build up from there.
Reform Teaching

Lavoisier aimed to reform chemical training in the same way: students should begin with the simplest substances and proceed to complex ones. The new names meant that students no longer needed to re-do every experiment along the way.

The goal was to make it possible to train chemists in a year or two rather than via lifetime apprenticeships.
Ignoble Ends

Priestley’s home laboratory was attacked by an angry mob in 1791 because of his outspoken support of the French Revolution. He fled to the US in 1794.

C. J. Hullmandel, *Destruction of Joseph Priestley’s Home and Laboratory, 1791*

Lavoisier was arrested because of his work as a royal tax collector. He was tried, convicted, and executed by guillotine on the same day: 8 May 1794.

Lavoisier arrested in his laboratory, 1793
Dalton and Vapors

John Dalton (1766 – 1844) was a Quaker. Like Priestley, he was educated in Dissenting Academies; he was largely self-taught in natural philosophy.

Dalton was fascinated by the soggy climate of England’s Lake District. He studied vapor pressure.

Law of Partial Pressures, 1801: in a mixture of gases, each gas contributes pressure as if it were alone. The total vapor pressure is the sum of each partial pressure.
Chemical and Physical Atoms

Dalton explained his result by assuming that every substance consists of *atoms*. The atoms of a given substance are identical to each other, but different from those of other substances.

Dalton believed that atoms of different elements had different *weights*. The ratios by weight of constituents in chemical compounds arose from the different relative weights of the underlying atoms.
Atoms or Elements?

Lavoisier had assumed that any list of elements was *temporary*. An “element,” to him, meant a substance that chemists had *not yet* further reduced to simpler substances.

Dalton thought otherwise: the world is made of “solid, massy, hard, impenetrable, moveable Particles” or atoms. They were eternal and unchanging, and they corresponded uniquely to chemical elements.
Serfs and Substances

In 1861, the Russian Tsar emancipated the serfs throughout the Russian empire. The universities were flooded with new students. Dmitri Mendeleev (1834 – 1907), a young chemistry professor in St. Petersburg, began writing a new textbook.

Lavoisier had identified 33 elements. By Mendeleev’s day, 63 were known. He eschewed chemical theory and focused on laboratory techniques: how do chemists learn about simple substances?
Classify!

By late January 1869, Mendeleev had finished volume 1 of his textbook, having only treated 8 elements — that left 55 to go!

He latched on to atomic weight: it was numerical, not random, and it offered some system for plowing through the rest of the material.
Mendeleev left gaps in his table to be filled in: he *predicted* the weights and chemical properties of three new elements.

The discovery of those “missing” elements in the 1870s helped to establish Mendeleev’s reputation and that of his periodic table.

The discoveries also helped to solidify the association between *chemical elements* and *physical atoms.*
Politics, Pedagogy, and the Stuff of Matter

THE PRINCIPLES OF CHEMISTRY

BY

D. MENDELEEFF

PART THREE

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TRAITE ELEMENTAIRE DE CHIMIE,
PRESENTE DANS UN ORDRE NOUVEAU
ET D'APRES LES DECOUVERTES MODERNES;

Avec Figures:

Par M. Lavoisier, de l'Academie des
Sciences, de la Societe Royale de Medicine, des
Societes d'Agriculture de Paris & d'Orleans, de
la Societe Royale de Londres, de l'Institut de
Bologne, de la Societe Helvetique de Basle, de
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