

Major Chemicals and Plastics We Use Every Day

F803

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Outline of the 4 Lectures

- When and how did modern chemistry evolve?
- Major discoveries and milestones along the way.
- How did widely used and familiar materials arise?
- What are the benefits and problems resulting from them?

2008 US Chemicals Production

- Total sales \$689 billion
- At \$174 billion, 10% of US exports,
- But imports were \$176 billion,
- Employs 850,000 people,
- The US produces 19% of the chemicals in the world, more than any other country.

American Chemistry Council, June 2009.

Topics

1. History of chemistry, and significant discoveries in the 19th century. Nitrogen fertiliser.
2. Plastics and rubber
3. Silicones
4. Chlorine containing chemicals and polymers.

What is included in the study of Chemistry?

1. The science that deals with the composition and properties of substances
2. Chemical properties, reactions, phenomena, etc.

Webster

Ancient History

- Aristotle: Matter consists of 4 ingredients, earth, air, fire and water.
- Difficulty explaining combustion; additional component Phlogiston was hypothesised around 1720-1730.

Phlogiston: Substance supposed by 18th century chemists to exist in all combustible bodies, and to be released in combustion.

Oxford dictionary

Alchemy

A form of chemistry and speculative philosophy practiced in the Middle Ages and the Renaissance and concerned principally with discovering methods for transmuting baser metals into gold and with finding a universal solvent and an elixir of life.

Webster

Newton, Sir Isaac (1642-1727), “mathematician and physicist, one of the foremost scientific intellects of all time.” Said to have spent more than 50% of his working life seeking a process for converting base metals into gold.

Chemical Processes BCE

- Smelting of ores to make metals, eg copper, tin and iron.
- Making soap from oil or fat and wood ash.
- Fermentation to make wine.
- Oxidation of wine to vinegar.
- (Later) Destructive distillation of pine resin to make turpentine.

The New Chemistry

Antoine Lavoisier, a Frenchman, published 3 papers in the 1780's:

1. Reflexions sur le phlogistique (mid 1780's)
2. Methode de Nomenclature Chimique (1787)
3. Traite Elementaire de Chemie (1789)

Reflexions sur le Phlogistique

Lavoisier showed that:

- combustion was the material combining with air, nothing was lost or gained in combustion,
- that organic materials all produced carbon dioxide and water,
- Phlogiston did not exist.

This was done by burning materials in a metal boat floating in mercury and covered with a glass bell jar.

Methode de Nomenclature Chimique

- “Earth” (rock samples) produced ash when burned.
- From this ash he could obtain metals,
- These he called “elements”
- ie. This turned Aristotlean thinking on its head.

Traite Elementaire de Chemie

- Lavoisier's publications were not just hypothesis, they were based on years of experimentation.
- In Traite Elementaire de Chemie he listed elements he had been unable to break down further: oxygen, nitrogen, hydrogen, carbon, sulphur, phosphorus, and 16 metals, 33 in all.

Lavoisier

1788 - elected a foreign member of the Royal Society.

Lavoisier

1794 - Lavoisier guillotined.

“It took them only an instant to cut off that head but it is unlikely that a hundred years will suffice to reproduce a similar one”.

Dalton

1800-1805

- Atoms of each element have a unique weight and combine in fixed ratios.
- Search for a theoretical understanding of how atoms combine to form matter.
- Tremendous appeal – chemistry as a quantitative science.

Humphry Davy

1807

- Popular speaker and demonstrator.
- Believed electricity would break down materials into their constituent elements.
- Discovered sodium and potassium, followed by calcium, magnesium, strontium, boron and barium.
- There were now 36 known elements.

Identifying Natural Materials

- Tartaric acid from grapes, citric acid from lemons, lactic acid from sour milk, glycerine from animal fat, etc (Scheele 1770's)
- Analysis of rocks to identify metals (Smithson)
- Cholesterol from animal fat (1815)
- Morphine from opium (1805)
- Quinine and strychnine from cinchona bark (1820)

Gas from Coal

- Pyrolysis of coal at $\sim 1000^{\circ}\text{C}$
coal \rightarrow gas + oily liquid + coke.
- First commercial gas works was built 1812
- First gas lights on Westminster Bridge, New Year's Eve 1813
- 1850's, every medium sized town had a gas works to provide for street lighting.

Gas from Coal

- 122 chemicals identified in the oily liquid
- Companies separated, purified and sold the individual chemicals
- Important source of chemicals since then.
- Coke (impure carbon) is still necessary for steelmaking.

Organic and Inorganic Chemistry

- Analysis of materials from living things showed C, H, sometimes O and N, usually not much else.
- Rocks gave a huge variety of elements.
- Came to be regarded as 2 sciences

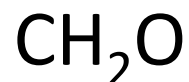
Organic Chemistry

Inorganic Chemistry

Liebig

Refined Lavoisier's combustion method so that it was quantitative and the ratios of the elements could be measured.

Many organic materials (eg sugar, starch, wood, cotton, flour, paper) analysed as having this ratio:



Water is H_2O

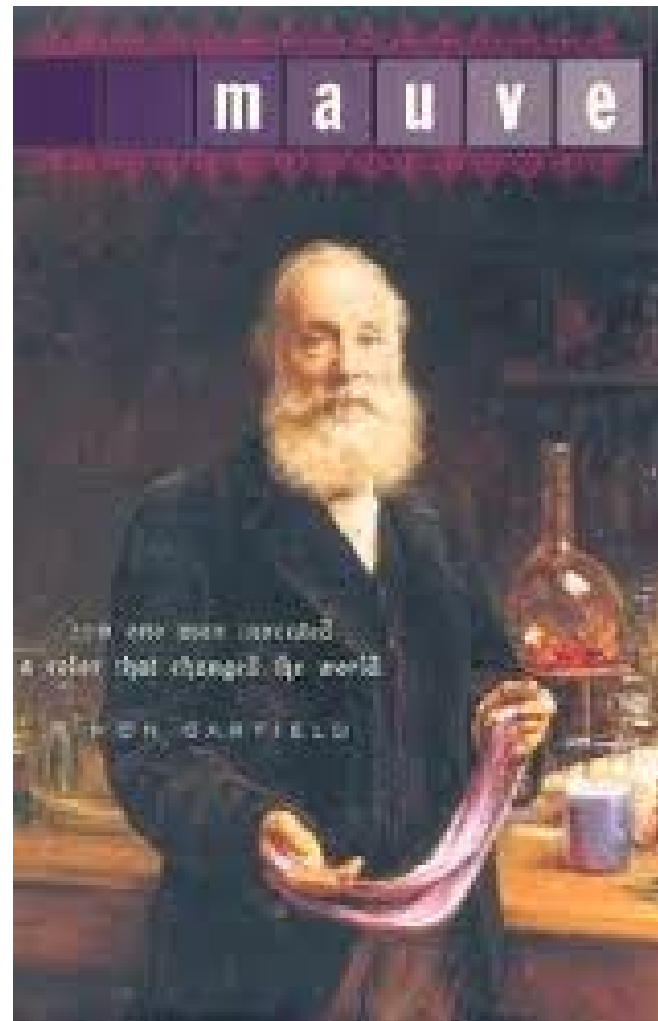
Are all these materials carbon combined with water in some way? **Carbohydrates**

1856 – Invention of Mauve Dye

An antique dress, made 4 years after the introduction of mauve dye



Sir William Henry Perkin

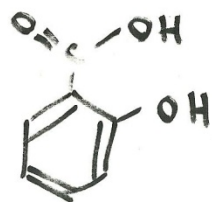


Impact

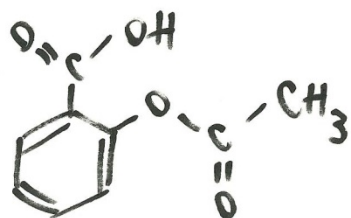
- Chemistry could produce new materials unknown in the natural world
- Profitable materials that customers wanted to buy.
- Beginning of the synthetic organic chemicals industry.
- Prof. Hofmann, and chemists in France and Germany soon became prominent inventing new dyes.

Aspirin

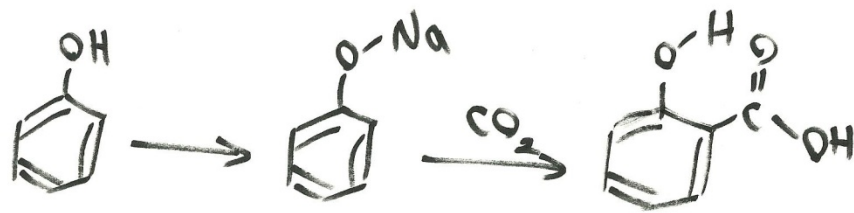
- Hippocrates ~400 BCE knew that powdered willow bark provided pain relief
- 1829 the active ingredient (Salicin) was extracted, but it was bitter and damaging to the stomach
- 1853 a French chemist made a “buffered” analogue by reacting salicylic acid with acetic acid, and neutralising.
- 1859 New manufacturing process from phenol.
- 1899 Hoffmann (of Bayer) rediscovered the 1853 work and treated his arthritic father with good results.
- Patented in 1900 and sold as a powder by Bayer.



Salicylic acid

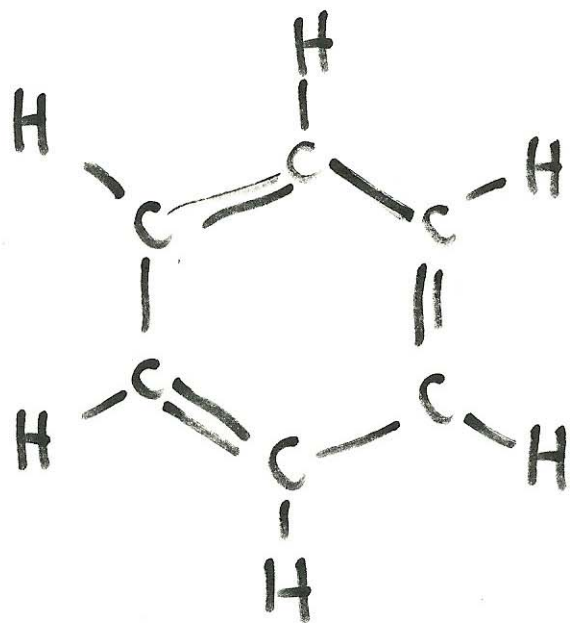


Aspirin



1859 Process.

Benzene Ring



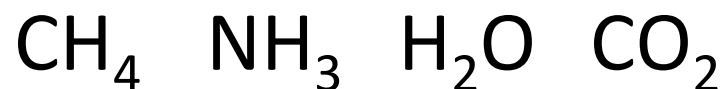
Short hand.

The Periodic Table

- In 1830 there were 53 known elements
- From this time chemists tried to classify them and search for some order
- Mendeleev (1869) and Meyer (1870) published their Periodic Tables
- Elements were listed in order by their weight, and elements with similar properties put in columns.

Valency

- How many chemical bonds does each element form with its near neighbors? Important in assessing similar properties in elements, eg



Carbon 4

Nitrogen 3

Oxygen 2

Hydrogen 1

The Periodic Table

- Discovery of the table created some order out of chaos. It illustrated the scope and range of the elements
- Empty boxes in the table suggested undiscovered elements.
- The table predicted the approximate weight and properties of the missing elements. This validated the theory as the unknown elements were discovered.

Chemical knowledge about 1900

- There were 92 elements, 2 of which had never been found on earth.
- Their weights and properties were well known.
- Test methods were precise and accurate.
- There was a good understanding of the underlying science
- Many chemical reactions had been discovered, needed chemicals could be made as required.

The Periodic Table

- Today the Table contains 118 elements.
- 94 have been found naturally on earth, but 4 are extremely rare.
- The other 24 are not natural and were made in nuclear reactors
- 81 are stable, the rest are radioactive and degrade over time.