Scientific Discovery

Coming up with new ideas

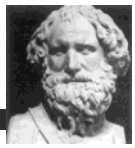
What is science?

- A set of confident statements about the world.
- Two aspects of creating science:
  - Scientific Discovery
    - Making the statements, expressed as hypotheses.
  - Scientific Method
    - Establishing the confidence; the testing of the hypotheses.

Scientific Discovery

- The intuitive process leading to the formulation of hypotheses.
  - May be a conscious or an unconscious process.
  - Some famous examples follow.

The Crown Problem



- Archimedes
  - Syracuse, about 250 B.C.
  - King Hieron II had a crown made for himself.
- Hieron's problem that he put to Archimedes:
  - Was the crown solid gold or had it been alloyed with copper or silver?
  - The goldsmith had been given a fixed amount of gold out of which to fashion the crown.

What Archimedes knew:

- Gold is far heavier than either silver or copper.
  - E.g. gold has weighs 19.3 g/cc.
  - Copper weighs 8.92 g/cc.
- Volume of the crown:
  - A crown of solid gold would have the same volume (take up the same amount of space) as the original amount of gold.
  - An alloyed crown would have a greater volume.

Measuring the volume of the crown

- Euclid's mathematics provided the means to measure the volume of an object with a nice regular shape, e.g. rectangular, conical, spherical, etc.
- The crown has an entirely irregular shape.
- The volume of the crown could be measured if it were hammered back into the form of a rectangular brick. – Destroying the crown!

Eureka!

- Archimedes went to the baths.
- There it occurred to him that when he lowers his body into the bath, it pushes out of the way a volume of water equal to the volume of Archimedes' body.
- If the crown were lowered into water, it too would push out a volume of water equal to the volume of the crown.
- The volume of the water can be measured.

The flash of insight

- Eureka means "I have found it."
- What Archimedes found was the solution to the one piece of the problem that had evaded him.
- The case for involuntary thought.
- The necessity for a prepared mind.

Kekulé's Dream

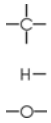
- Friedrich August Kekulé
  - Early days of organic chemistry.
  - Question of interest:
    - What was the structure of organic molecules?
    - Organic molecules are more complex than inorganic.
    - Two molecules can have the same formula, but totally different properties.

Valence

- A concept formulated in 1852.
- Meaning: the combining numbers of one atom with another.
- Kekulé worked out a system of valences.

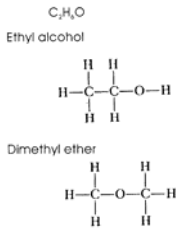
Kekulé's schematic representation of chemical structure

- Atoms were represented by their chemical symbol, usually one or two letters.
- Valences were represented by lines drawn from atom to atom.
- Examples:
  - Carbon had a valence of 4:
  - Hydrogen had a valence of 1:
  - Oxygen had a valence of 2:



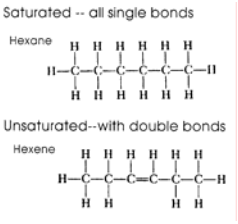
Schematic structures

- Typically a straight line forming the core of the molecule with Hydrogen molecules as spikes off the main line.
- Two organic compounds with the same formula, but different chemical properties.



Hydrocarbons

- Compounds of special interest were those made of Hydrogen and Carbon only—hydrocarbons.
- Saturated versus unsaturated bonds.



Kekulé's problem: Benzene

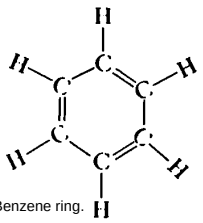
- Formula: C_6H_6
  - Equal number of carbon and hydrogen atoms
- Very stable compound
  - Should be saturated: all single bonds
- Impossible

Kekulé has a dream

- Asleep before a fire, or on a bus, dozing (different versions of the story).
- He dreams a snake swallows it own tail.
- Leads him to think of the straight line bending into a circle.

Eureka, again…

- The ring structure of Carbon atoms provides a stability of its own.
- The compound is stable despite three double bonds.
- Such rings are the class of aromatic compounds.



A Benzene ring.

The patterns of scientific discovery

- The prepared mind:
  - Archimedes and Kekulé knew all the relevant facts needed to solve their problems.
- A preconception blocked the way to thinking of the solutions.
  - Archimedes: That the volume of the crown needed to be measured directly.,
  - Kekulé: That stability required all single bonds and that chemical structures were in straight lines.
- A distraction allowed unconscious processes to think along unconventional lines, but the prepared mind could seize on the implications immediately.