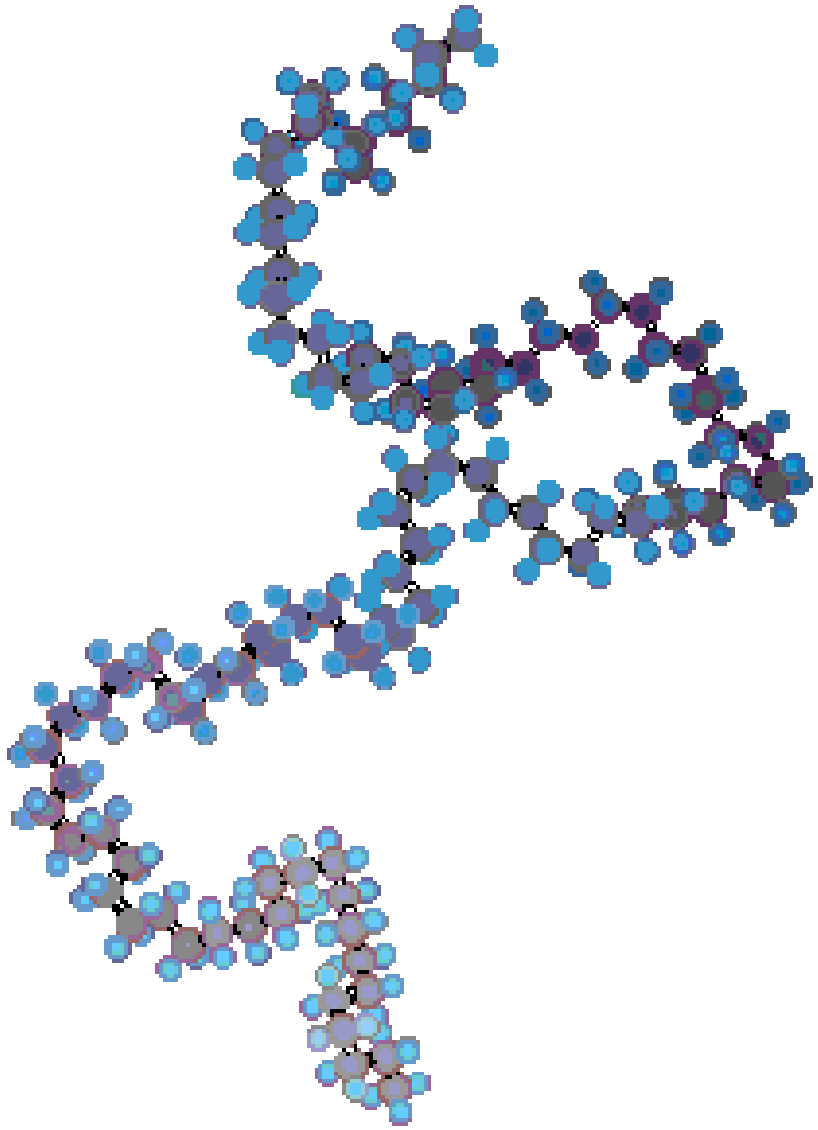
Polymer Science and Engineering

"I am inclined to think that the development of polymerization is perhaps the biggest thing that chemistry has done, where it has had the biggest effect on everyday life"

—Lord Todd,1980

Ethylene $CH_2=CH_2$ → (Magic ?) Polyethylene $[-CH_2-CH_2-]_n$



A Useful Classification

USE	NATURAL	SYNTHETIC
Fibers	Wool, Silk, Cellulose	Nylon, PET, Lycra®
Elastomers	Natural Rubber, Elastin	SBR, Silicones, Polybutadiene
Plastics	Gutta Percha, DNA, Polypeptides	Polyethylene, Polypropylene, Polystyrene
Composites	Wood, Bone, Teeth	Polyester/Glass, Carbon Fiber/Epoxy Formica
Adhesives	Barnacles!	Elmer's "Glue-All" Super-Glue
Paints	Shellac	Acrylics

Historical Background

NATURAL POLYMERS	- used throughout recorded history
SYNTHETIC POLYMERS	- initially chemically modified natural polymers
RUBBERS OR ELASTOMERS	- unique materials, both natural and synthetic

Historical Background

1845	SCHOENBEIM	- nitration reactions
1848	MENARD	- collodion films ;nitrated cellulose
1862	PARKES	- "Parkesine" ; added camphor (and other stuff) - *plasticizers*
1870's	HYATT	- billiard balls !!
1884	CHARDONNET	- extrusion
1890's	CROSS, BEVAN, & BEADLE	- regenerated cellulose rayon,cellophane
1905	BAEKELAND	- Bakelite, the first *thermoset*
1920	STAUDINGER	- the macromolecular hypothesis
> 1920	NEW *THERMOPLASTICS*	- (more on these later)

Natural Polymers

NATURAL POLYMERS - - used throughout recorded history

A natural fiber on the hoof

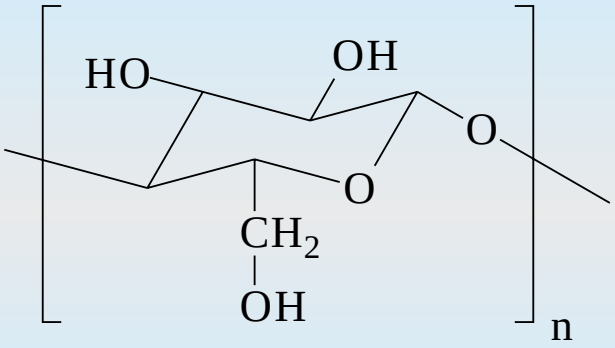
Silk

Better hope your garden never looks like this

Cotton

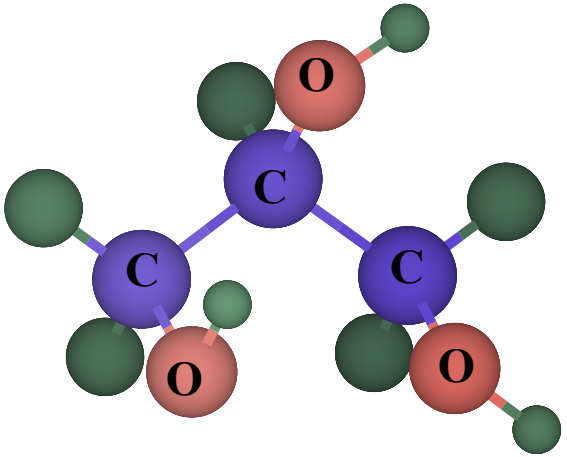
Nitrated Cellulose

Schoenbeim



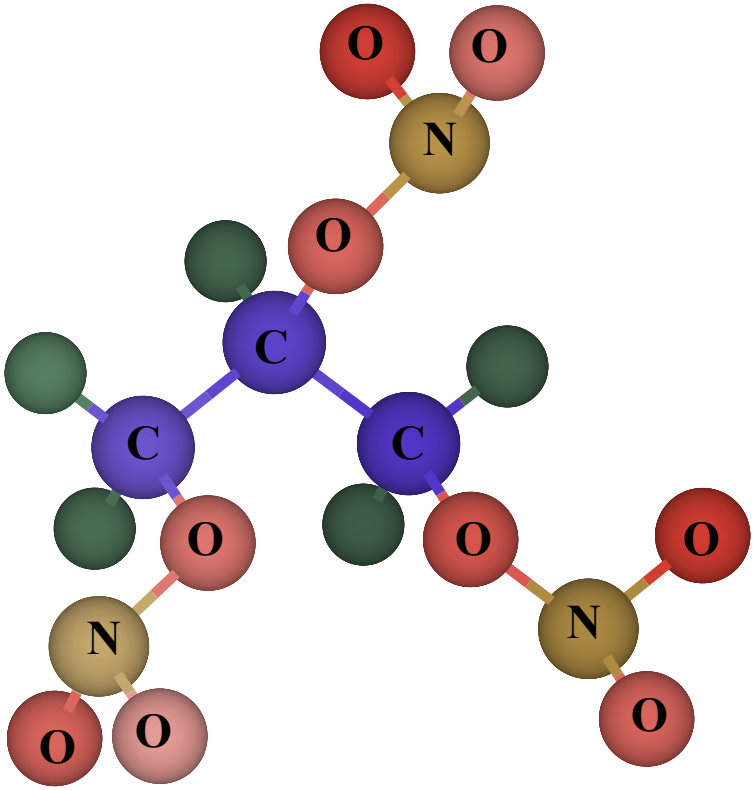
Cellulose

Explosive Stuff!



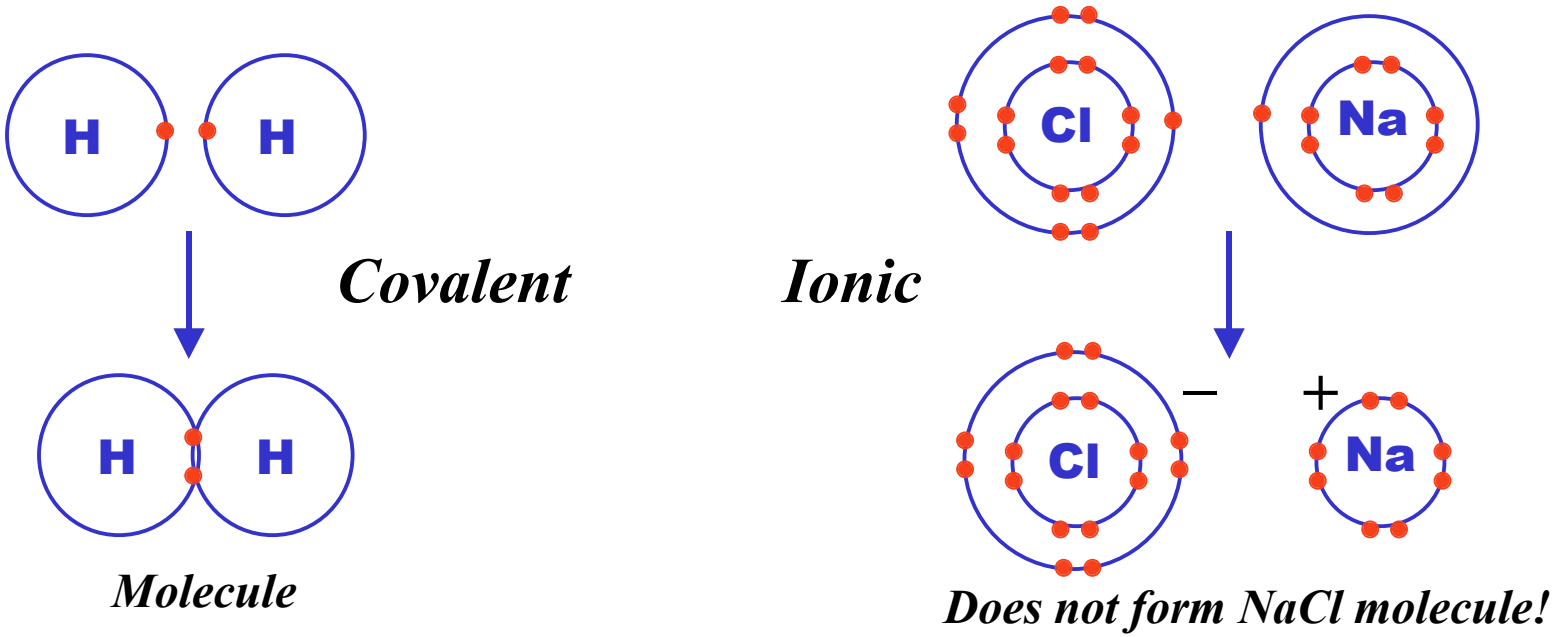
Glycerol

$CH_2OH–CHOH–CH_2OH$

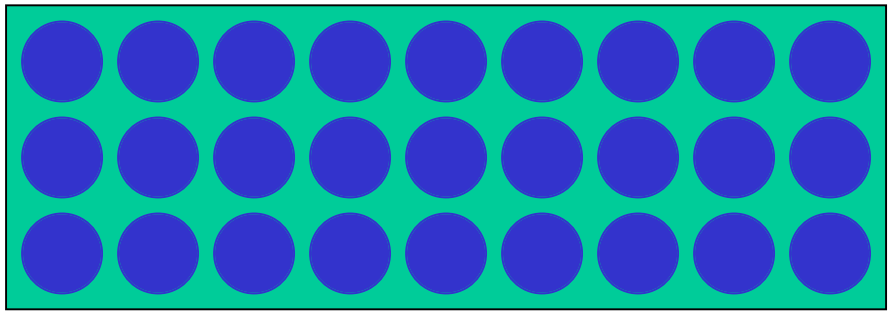


Nitroglycerin

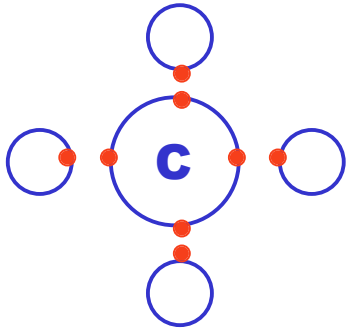
Some Basic Chemistry: Atoms and Bonding

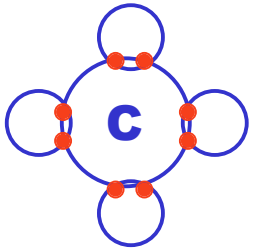


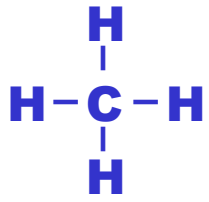
Metallic



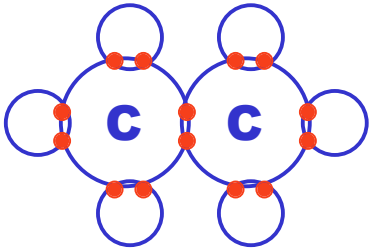
Some Basic Chemistry: Single and Double Bonds

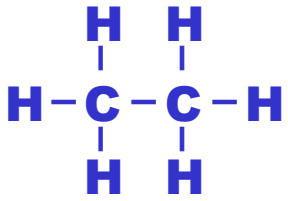




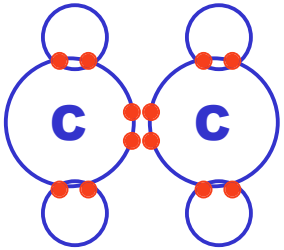


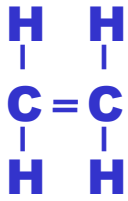
CH_4





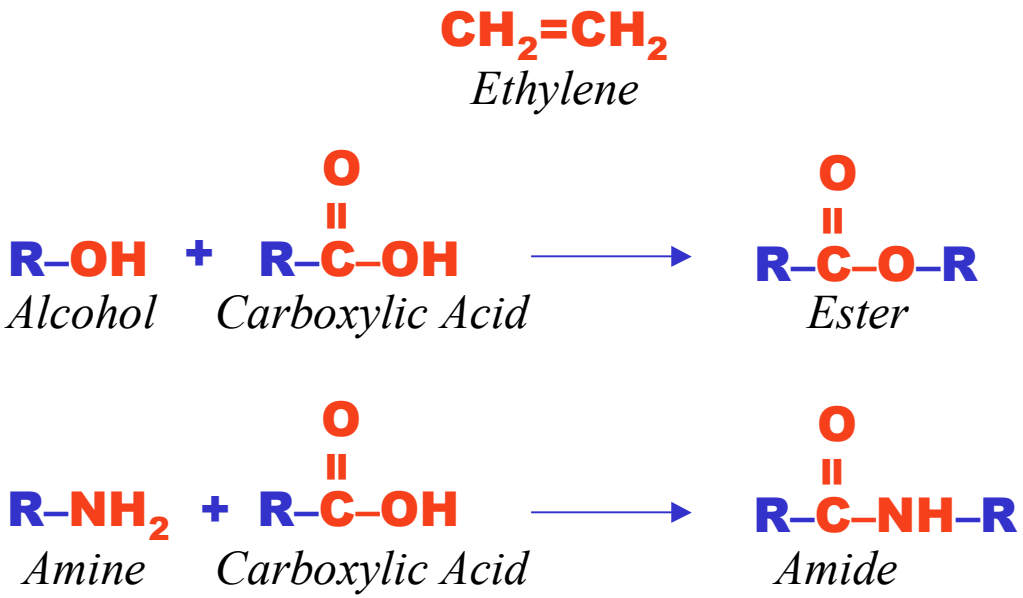
C_2H_6





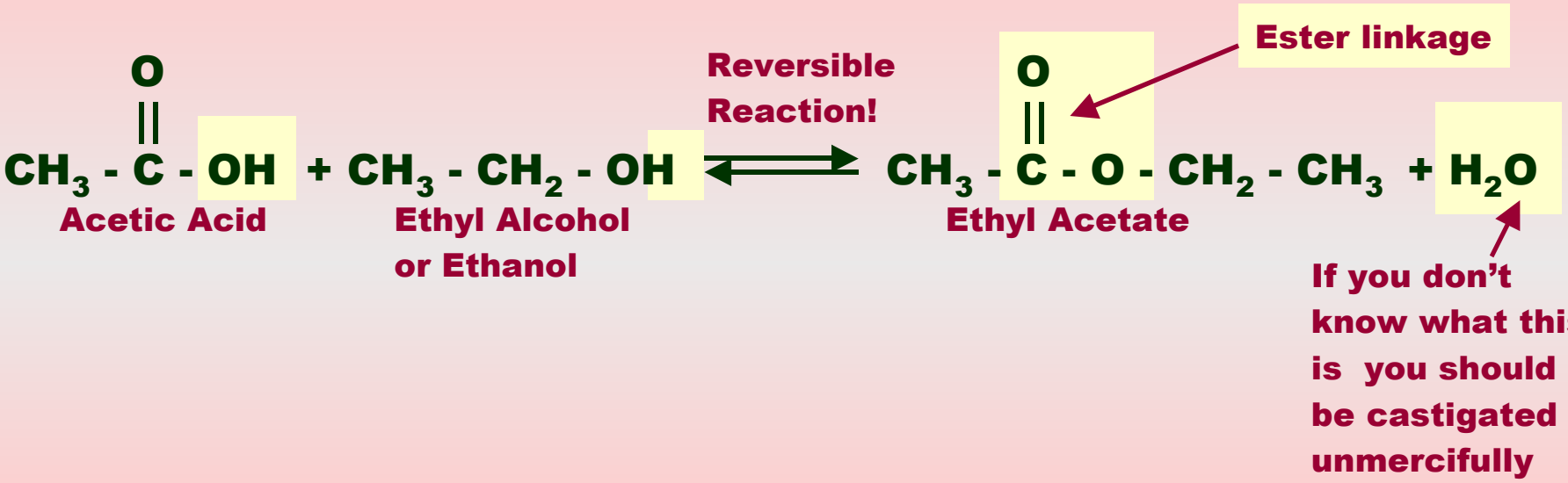
C_2H_4

Some Basic Chemistry: Functional Groups

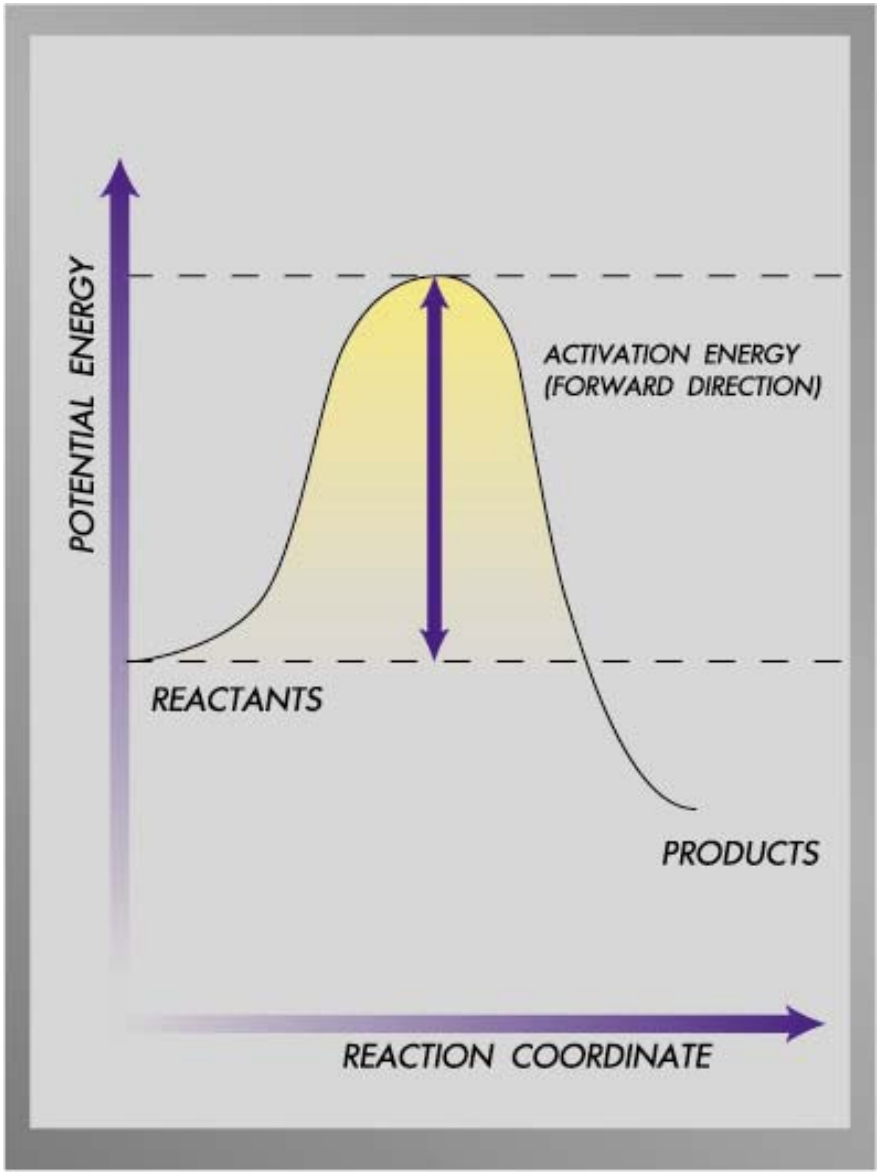


Functional Groups are small groups of atoms held together in a specific arrangement by covalent bonds. They are responsible for the principle chemical properties of the molecule in which they are found.

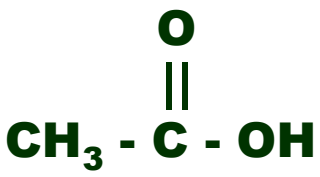
Condensation Reactions



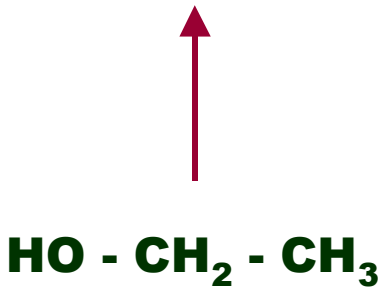
Why do Molecules React ?



Acetic Acid

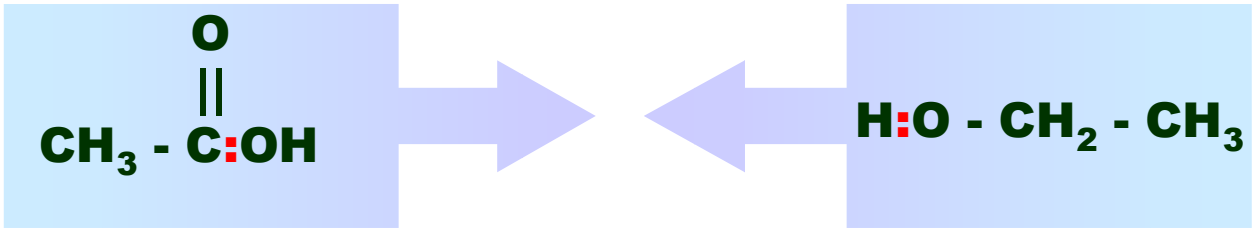


kersplat!



Ethyl Alcohol
or Ethanol

Why do Molecules React ?

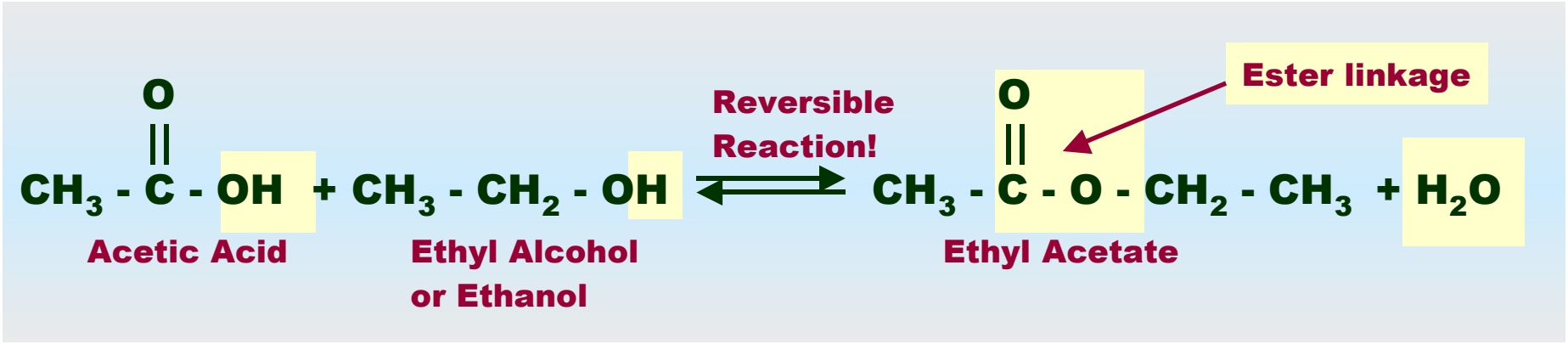


$$HO\cdot + \cdot H \longrightarrow HO{:}H \sim H_2O$$

$$CH_3 - \overset{\overset{O}{\|}}{C}\cdot + \cdot O - CH_2 - CH_3 \longrightarrow CH_3 - \overset{\overset{O}{\|}}{C}{:}O - CH_2 - CH_3$$

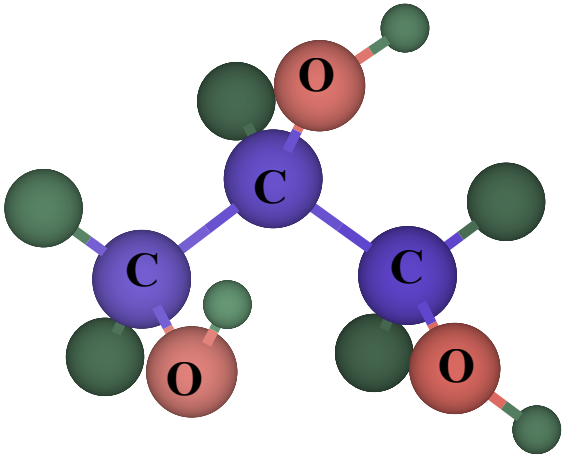
This isn't what really happens, but shows you how the valency electrons get rearranged

Making a Polymer



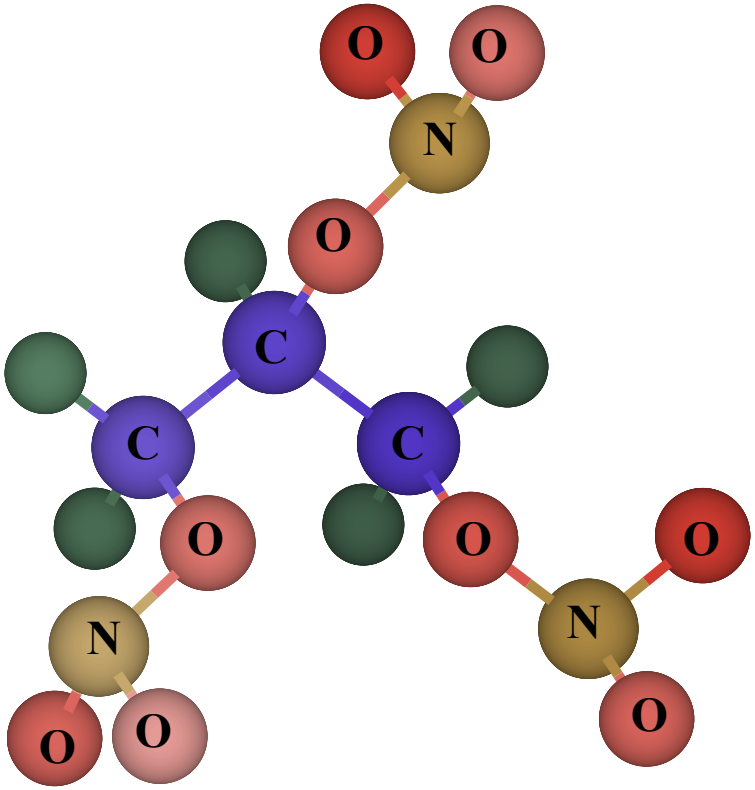
If we heat acetic acid and ethanol up to just over 100^{0}C, to get the reaction going and drive off water, why don't we form polymer?

Explosive Stuff!



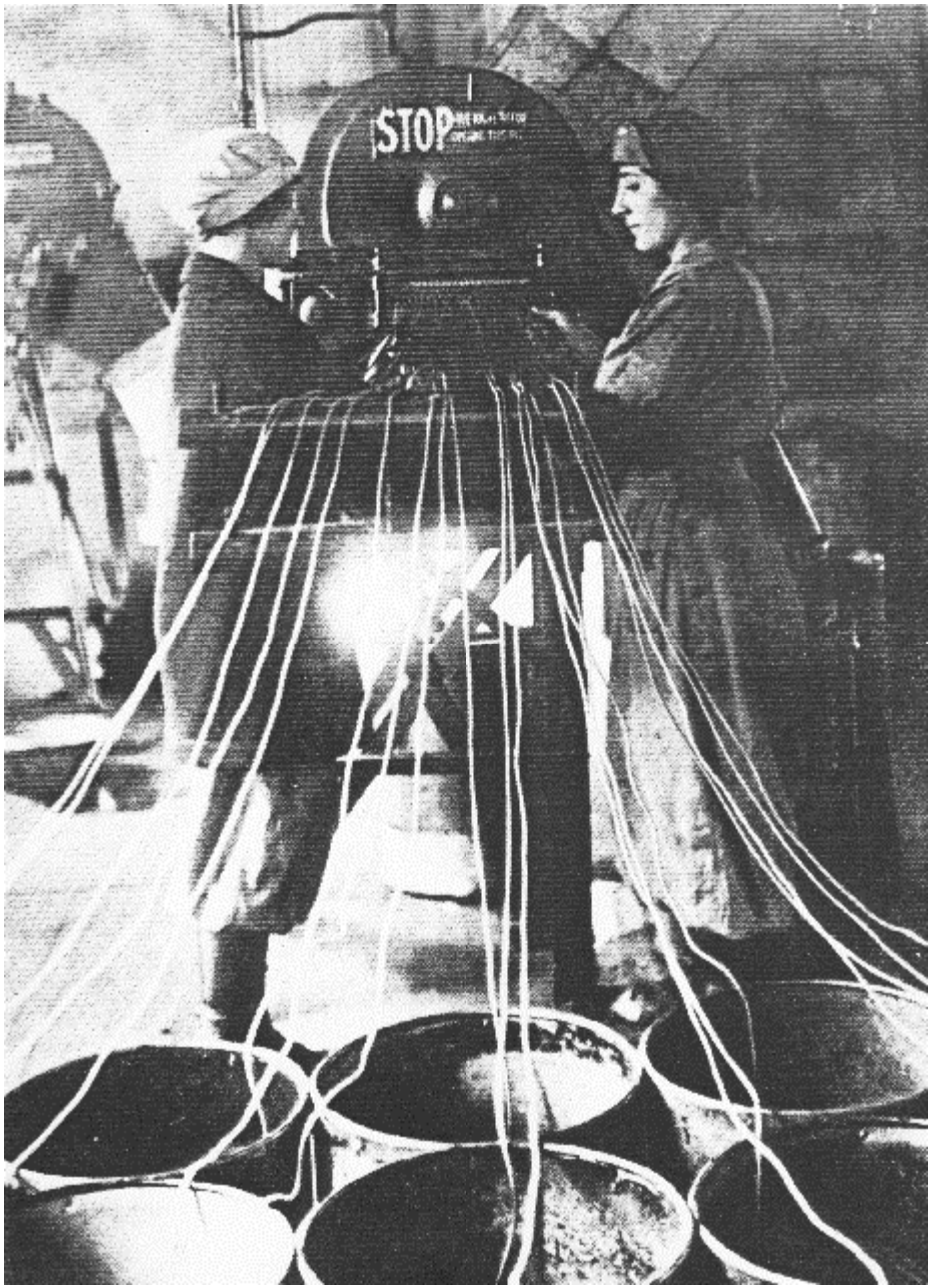
Glycerol

$CH_2OH–CHOH–CH_2OH$



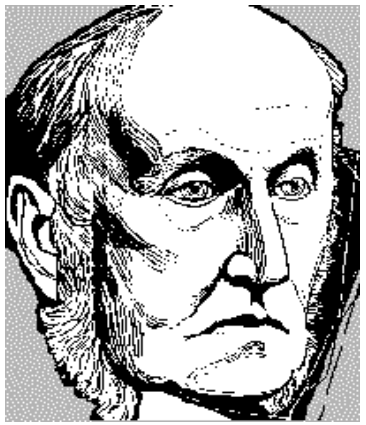
Nitroglycerin

Guncotton and Collodion

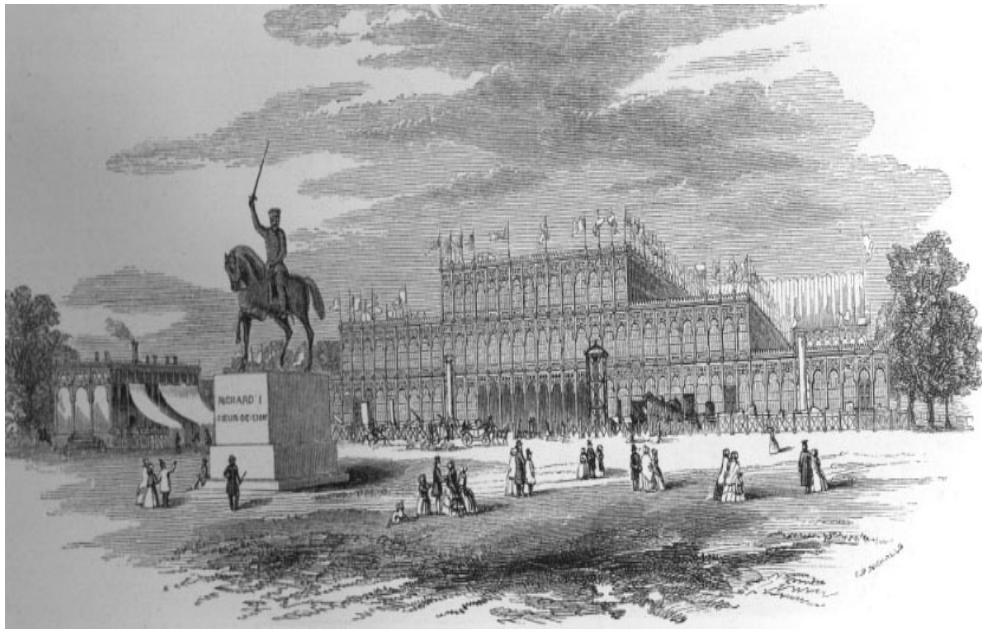


Guncotton and Collodion

Parkes and Parkesine

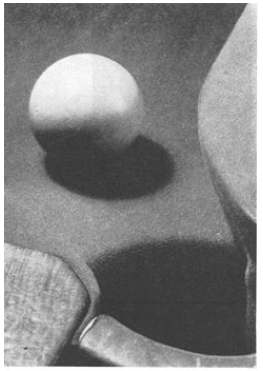


He wasn't this miserable.



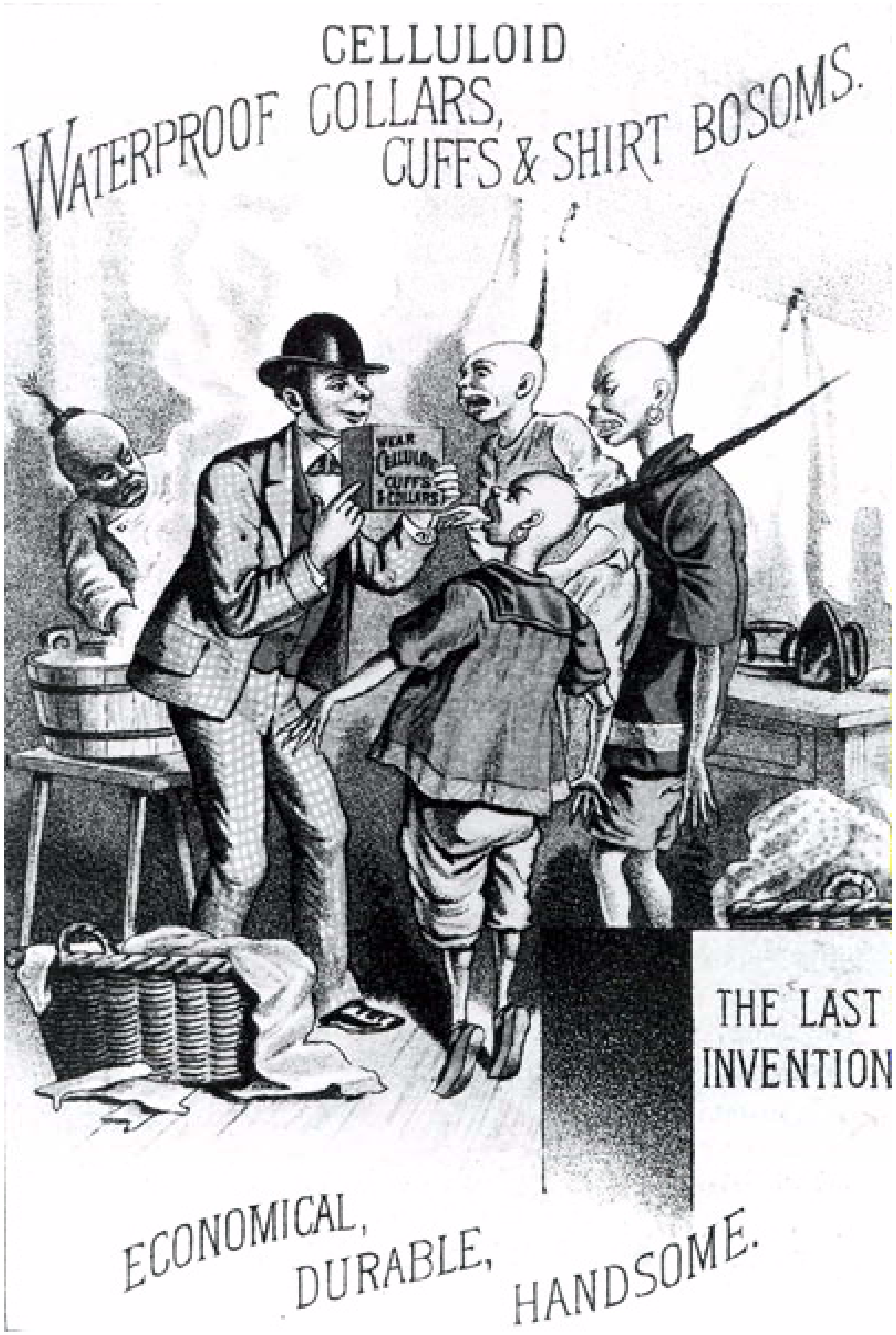
The Crystal Palace

Hyatt and the Elephants



Celluloid

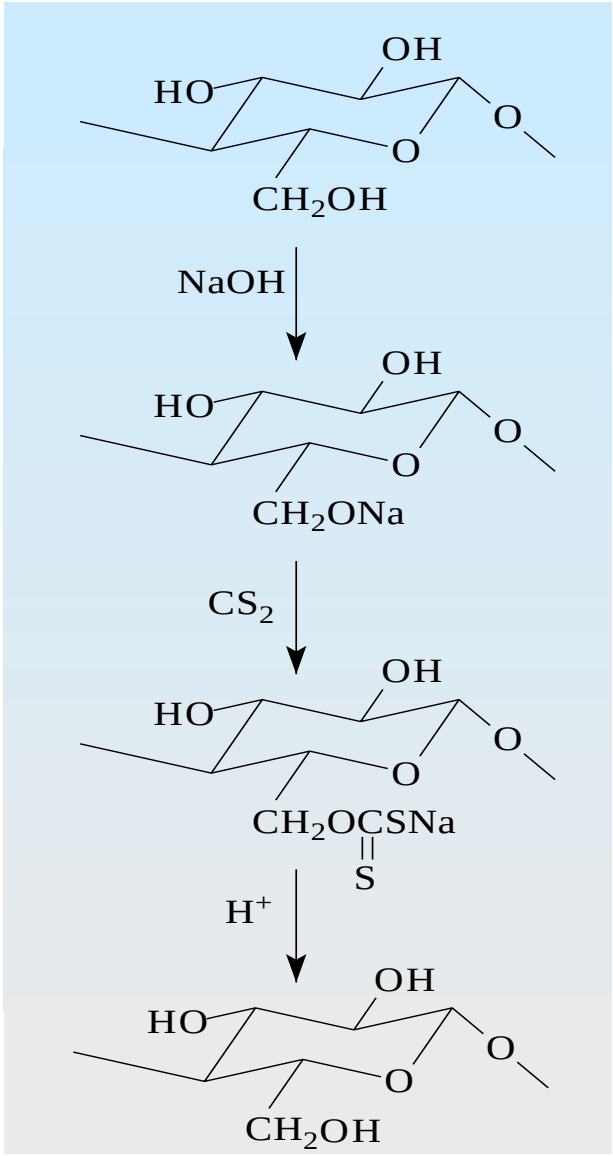
What a sales pitch



Chardonnet and Mother-in-Law Silk

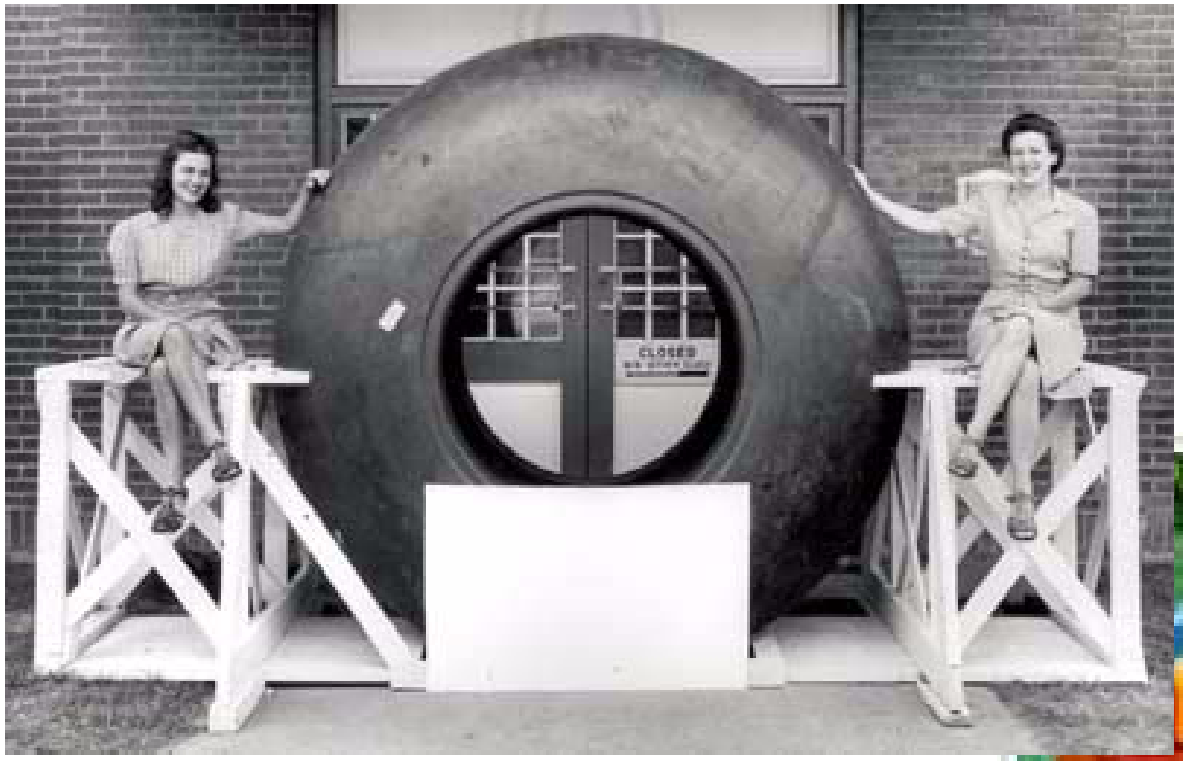
Regenerated Cellulose

Cellophane and Rayon



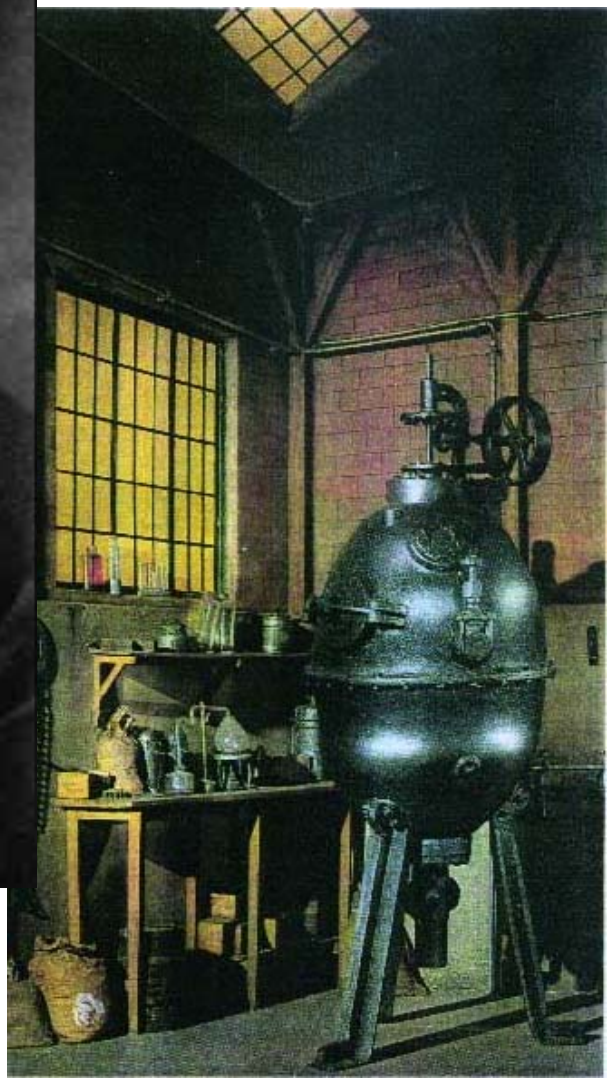
More Cellophane

Rayon



Baekeland and Bakelite

The first true synthetic plastic



Bakelite - Material of a Thousand Uses

Clear Bakelite items

Clock made of a phenolic resin and celluloid

A Bakelite telephone

A Bakelite camera

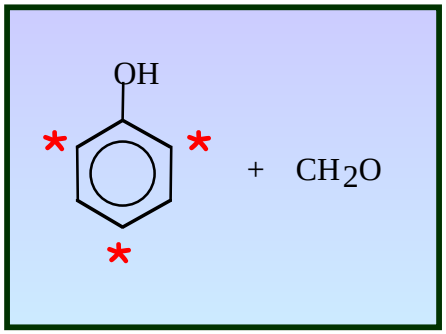
A Bakelite radio

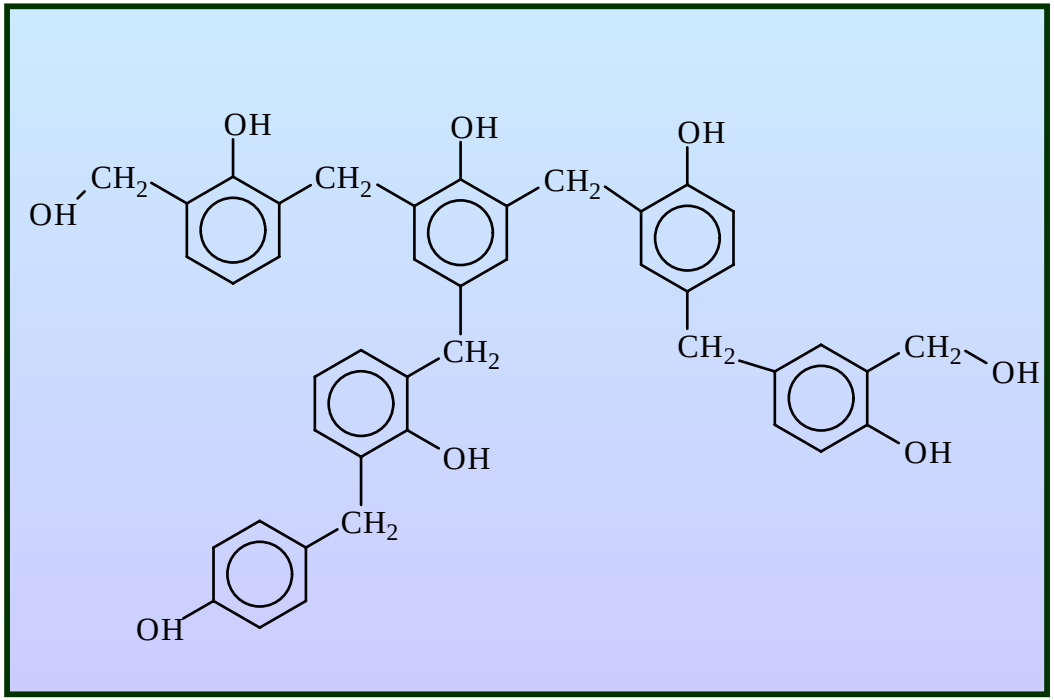
A Bakelite microphone


UPON arriving home you find a letter from an old friend inviting you to accompany him on a trip into the North Woods. You stroll into your den to look over your fishing rods and rifles; again you encounter this material, for the reel on the rod and the butt plates on the guns are formed of it.
Returning to the drawing room you join your wife for an evening's radio concert. Should you examine closely you will discover that the radio apparatus is made almost entirely of it.
BAKELITE
Condensite
The Material of a Thousand Uses

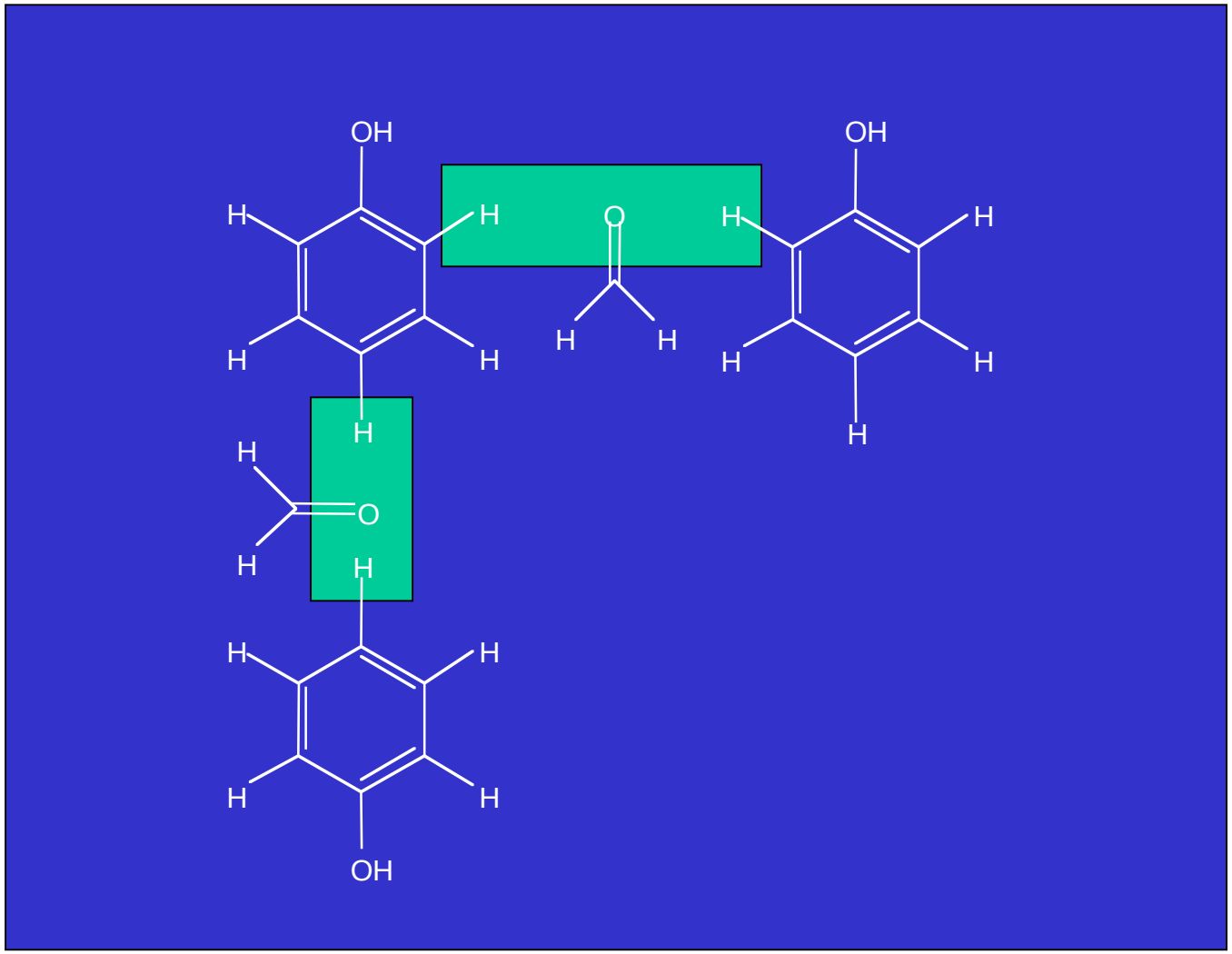
Network Formation

The hydrogens in the ortho and para positions to the OH group, which by convention are not usually shown but here are indicated by a *, can react with fomaldehyde to form (initially) oligomers.



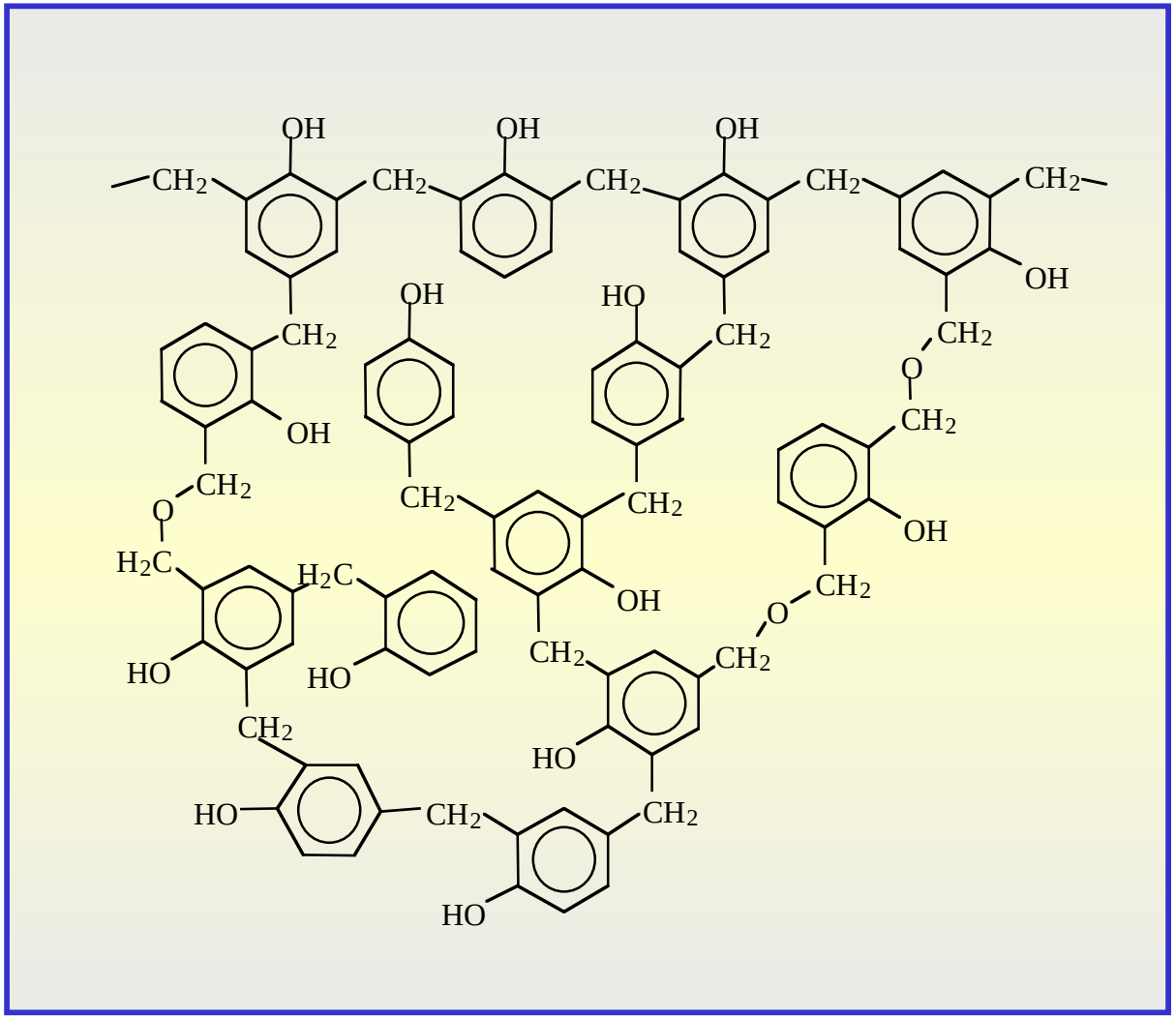


A Condensation Reaction!



Network Formation

Continued reaction builds up a densely cross-linked network. This is Bakelite, a *thermosetting* polymer. Once the reaction is complete, the material cannot be reheated and reformed. So, what do you think the definition of a *thermoplastic* is?



NEXT;
Staudinger and the Macromolecular Hypothesis