Part 5 - Polymerization Reactions

- **Polymer** – a large molecule made by linking together many smaller molecules

  - Found naturally (protein, carbohydrates) and man made (teflon, styrofoam, PVC, polyester)

- **Monomer** – small molecules that are linked together to make a polymer

- **Polymerization** – formation of polymers from the reaction of monomer sub-units

Polymers can be made by one of two polymerization reactions:

- Addition polymerization – addition reactions are used to link monomer units

  - What must be present in order for a addition reaction to take place?

- Condensation polymerization – monomers are linked together by the removal of parts of the **functional group** on each monomer

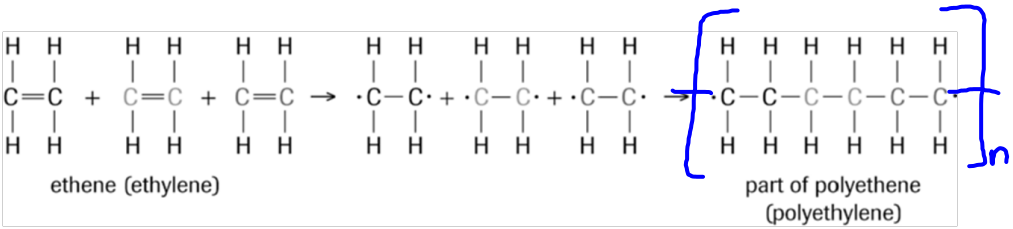
  - A small molecule is also produced, in addition to the polymer

Addition Polymers – pgs 445-448

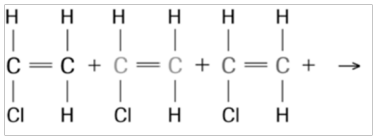
- Monomers containing a double or triple bond are joined using an ***addition*** reaction

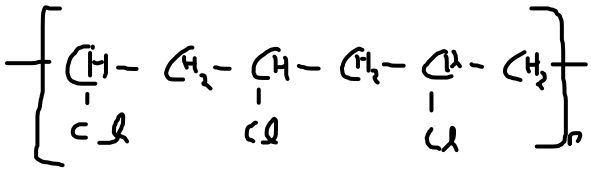
- Monomers join together at the carbons where the bond is broken

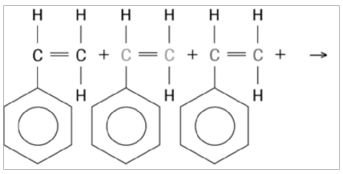
- The polymer is the only product produced



Examples:





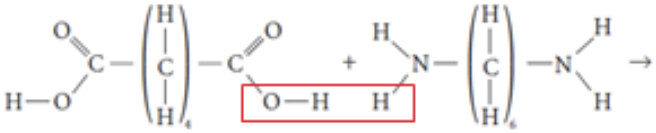


Teflon video

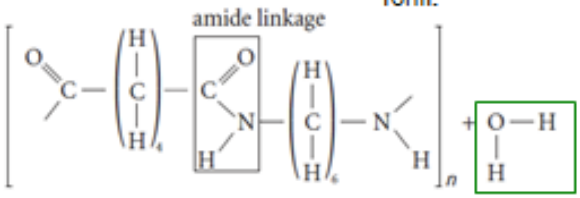
http://ed.ted.com/lessons/why-doesn-t-anything-stick-to-teflon-ashwini-bharathula

Condensation Polymerization

- Monomers combine to form a polymer and a bi-product. Each time a bond forms between monomers, small molecules, such as water, ammonia, or HCl are "condensed" out.
- The polymerization of nylon:

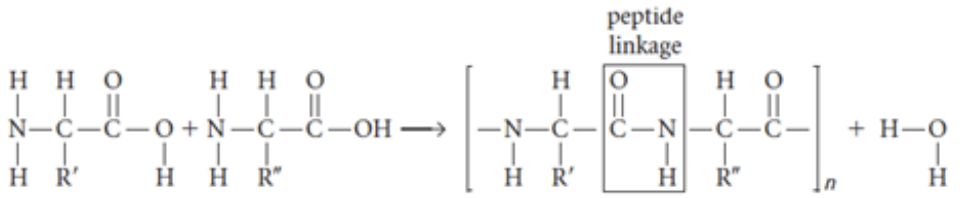


- For condensation polymerization to occur, monomers must be **bifunctional**, meaning they have at least two functional groups.
- If they only had one functional group, then only one bond would form.



Condensation Polymerization

- Condensation polymerization also produces natural polymers, called **proteins**.
- Amino acids (monomers) polymerize to make peptides (short chains of amino acids) or proteins (long chains of amino acids)



glycine + alanine → a dipeptide + water

Comparison of Addition and Condensation Polymerization

Addition

- Needs a double or triple bond in the monomer
- Produces only one product, the polymer

Condensation

- Needs bifunctional monomers (have two functional groups)
- Produces two products: the polymer and the biproduct (water, ammonia or HCl)

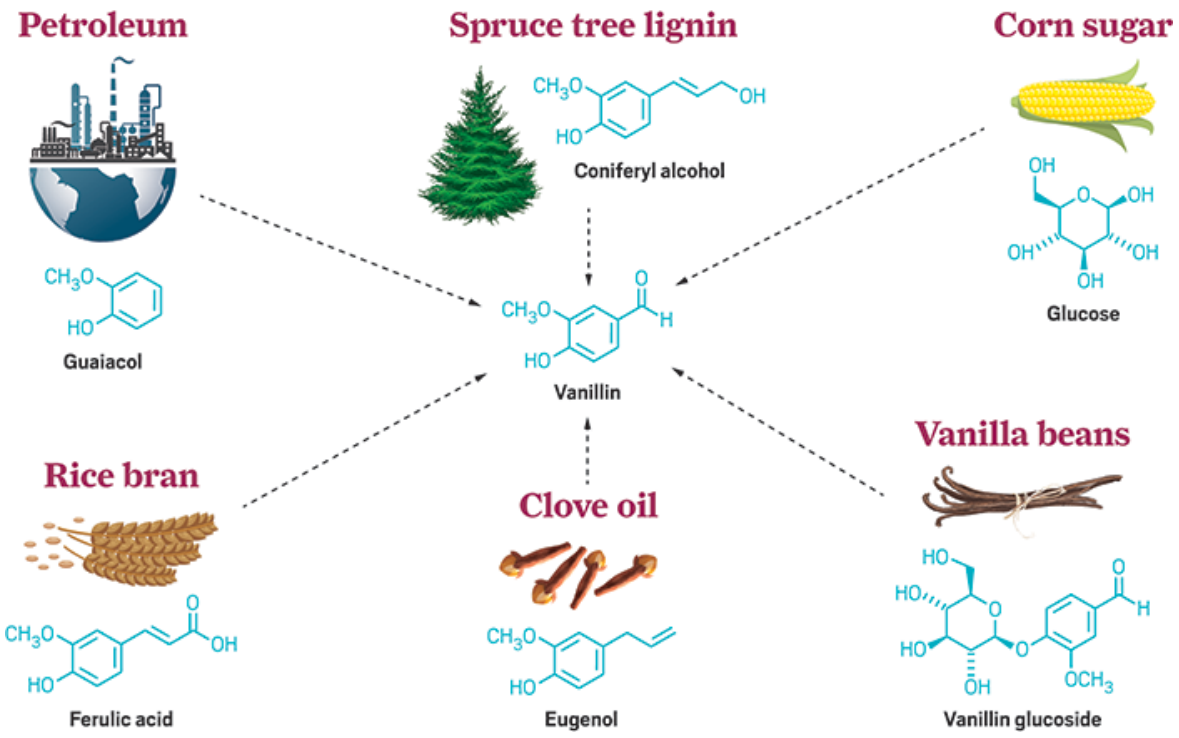
Polyester

- When a carboxylic acid reacts with an alcohol in an esterification reaction, a water molecule is eliminated and a single ester molecule is formed.
- This esterification reaction can be repeated so many esters are joined in a long chain… a **polyester**
  - This is created using a dicarboxylic acid (an acid with a carboxyl group at each end) and a diol (an alcohol with a hydroxyl group at each end)
  - The ester linkages are formed end to end between alternating acid and alcohol molecules

If we were to depict the acid with the symbol Δ — Δ , the alcohol with o — o, and the ester linkage with oΔ, we could represent the polymerization reaction like this:

Δ — Δ + o — o + Δ — Δ + o — o → — Δ — ΔO — oΔ — ΔO — o — + water

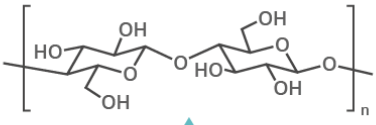
polyester


Petroleum
Guaiacol
Spruce tree lignin
Coniferyl alcohol
Corn sugar
Glucose
Vanillin
Rice bran
Ferulic acid
Clove oil
Eugenol
Vanilla beans
Vanillin glucoside

THE CHEMISTRY OF PAPER AND POLYMER BANKNOTES

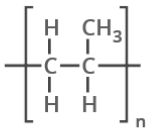
The UK recently began its introduction of polymer bank notes. Here we look at the chemistry used in bank notes and their security features.

THE SUBSTRATES



CELLULOSE

Most paper banknotes are actually not made from paper, but from around 80% cotton paper. Cotton is made up of the natural polymer cellulose – so in a way, paper banknotes are actually polymer banknotes too!



POLYPROPYLENE

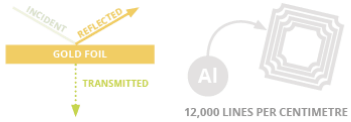
Transparent material, but later made opaque with white ink.

Newer polymer notes are usually made from biaxially oriented polypropylene (BOPP). 'Biaxially oriented' refers to the manner in which it is stretched during production, increasing its strength and transparency. White pigment, inks, and varnish are later applied to the notes.

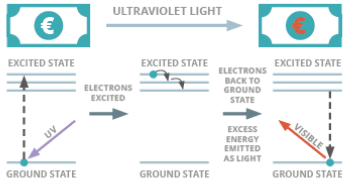
POLYMER BENEFITS

SECURE	Harder to counterfeit than paper banknotes – more security features.
CLEANER	Waterproof and do not get dirty easily, unlike paper banknotes.
DURABLE	Estimated to last 2.5 times longer on average than paper banknotes.
GREENER	Unlike paper banknotes, polymer notes can be recycled after use.

SECURITY MEASURES



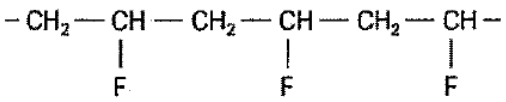
OVDs (Optically Variable Devices) are parts of the note that change their appearance when something external to the note changes, such as the angle it's being viewed at. Thin films of gold appear green in transmitted light, but gold in reflected light. Thin patterned lines coated with aluminium can also provide various colours.

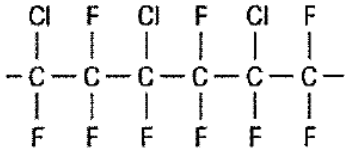


Anti-counterfeiting compounds that fluoresce when placed under ultraviolet light are also a common security device. Euro notes use compounds of lanthanide elements to accomplish this, including those of Europium.

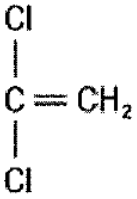
Practice Sheet 8
Polymerization

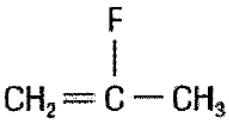
1. Name and draw the monomers that would make the following polymers

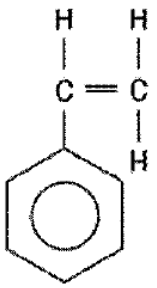




2. Name the following monomer and draw the polymer that it would make in a polymerization reaction





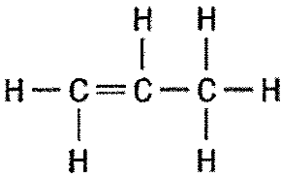


Practice Sheet 9
Organic Reactions

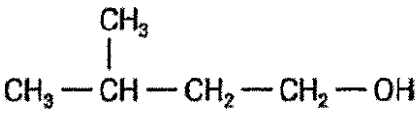
2. For each of the compounds below answer questions a-c

a. Identify a reaction type that could be used to **produce** each molecule.
b. Draw the condensed chemical structures in a balanced equation for the production of each molecule.
c. Below each of your equations in question b, write the name of the reactants and products developed in your answer.

Molecule 1



Molecule 2



Molecule 3