TAYLOR'S UNI. COLLEGE
CHEMISTRY (9701)
A Level

APPLICATION CHEMISTRY:
MATERIALS & DESIGN
(Part 2 – Polymers)

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(Yellow Room; Table 1)

Addition Polymerisation

SAQ 5. **(a)** *Draw the structure of poly(phenylethene).*

(b) *Write an equation to show the addition polymerisation of three poly(phenylethene) molecules.*

(c) *Circle a repeating unit in your diagram of poly(phenylethene).*

(d) *Explain why this polymerisation is called addition polymerisation.*

Addition Polymerisation

- Polymers made from **alkenes only** contain carbon and hydrogen atoms.
- The physical properties of polymers are determined by the **van der Waals' forces present in the polymer**.
- The properties of addition polymers can be modified in a number of ways.
- Addition polymers tend to **deform easily and once deformed do not return to their original shape**.
- Generally, the **longer the polymer chains, the stronger the van der Waals' forces**.

Addition Polymerisation

- Generally, **unbranched chains can pack together better than polymers with lots of side chains**.

- The **“soft” bags** are made from low density poly(ethene) (**LDPE**), which has **lots of side chains** and is **relatively weak and easy to deform**.

- The type of **bag that rustles** is made from **high density poly(ethene) which has fewer side chains**.

- **Presence of chlorine atoms** in poly(chloroethene) **results in permanent dipole interactions** between carbon and chlorine because of the polarity of the carbon-chlorine bond.

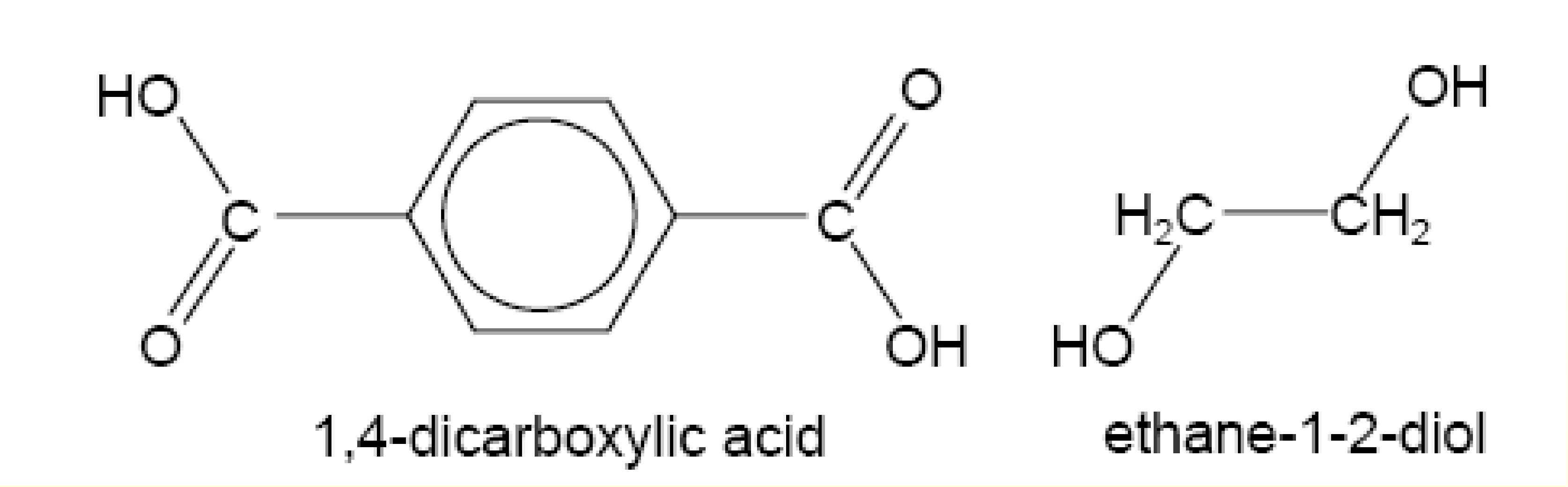
Condensation Polymerisation

- Usually requires **two different molecules that can react together to form** an **ester or amide bond** with the **elimination of a small molecule** such as water.

- Examples : **polyesters (**drink bottles, clothing and carpeting) and **polyamides , peptides and proteins**.

Condensation Polymerisation

- ***Terylene***
- Monomers : **ethane-1-2-diol and 1,4-benzenedicarboxylic acid**



Condensation Polymerisation

SAQ 6. *(a)* *Write an equation to show the formation of* ***one*** *repeating unit of the polyester chain.*

(b) *The amino acid alanine has the following structure – $H_2NCH(CH_3)CO_2H$.*

Draw the structure of the tripeptide formed by three molecules of alanine

(d) *How many water molecules are lost in this condensation reaction to form the tripeptide?*

SAQ 7. *Cellulose is the polymer responsible for the strength of fibres such as cotton. Cellulose is a linear polymer of sugars with many –OH groups. Suggest, in terms of bonding, why cellulose is so strong.*

Spider Silk

- Based on weight, spider silk is **five times stronger than steel** of the same diameter.

- More recently, it has been suggested that a strand of spider silk as thick as a pencil would stop a jumbo jet in flight!

- Spider silk is a protein that is in the same protein group as hair, nails and ligaments.

Spider Silk

- The Golden Orb-Weaving spider produces a **dragline silk** (a dragline connects a spider to its web) that is the **strongest form of spider silk**.

- The **protein in dragline silk is called fibroin**.

- Fibroin has a molecular mass of 200 000 – 300 000 and consists of **42% glycine** and **25% alanine**, with the **remainder coming from just seven other amino acids**.

Spider Silk

- The **alanine** molecules occur in polyalanine regions, where **between 4 and 9 alanine molecules are linked in a block**.

- The **elasticity of spider silk comes from regions that are rich in glycine**. In these regions a **sequence of five amino acids is repeated**.

- After each sequence a **180° turn occurs producing a spiral**.

- **Ordinary silk**, produced by silk moths has a **β-pleated sheet structure**, held together by hydrogen bonds

Spider Silk

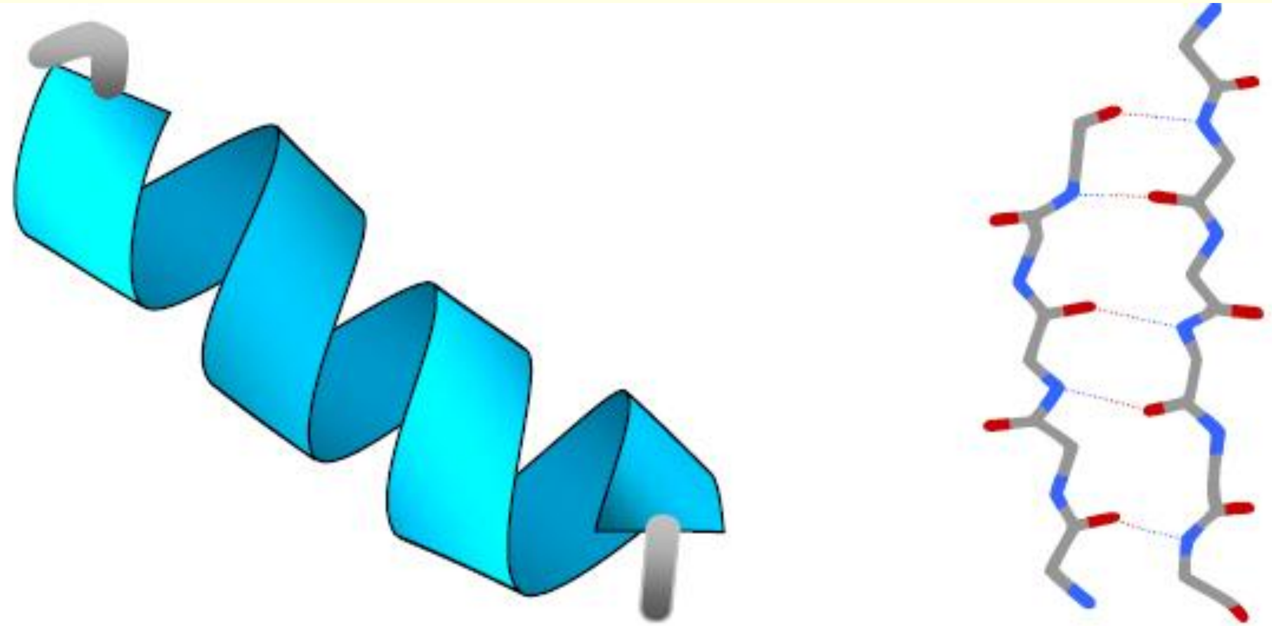


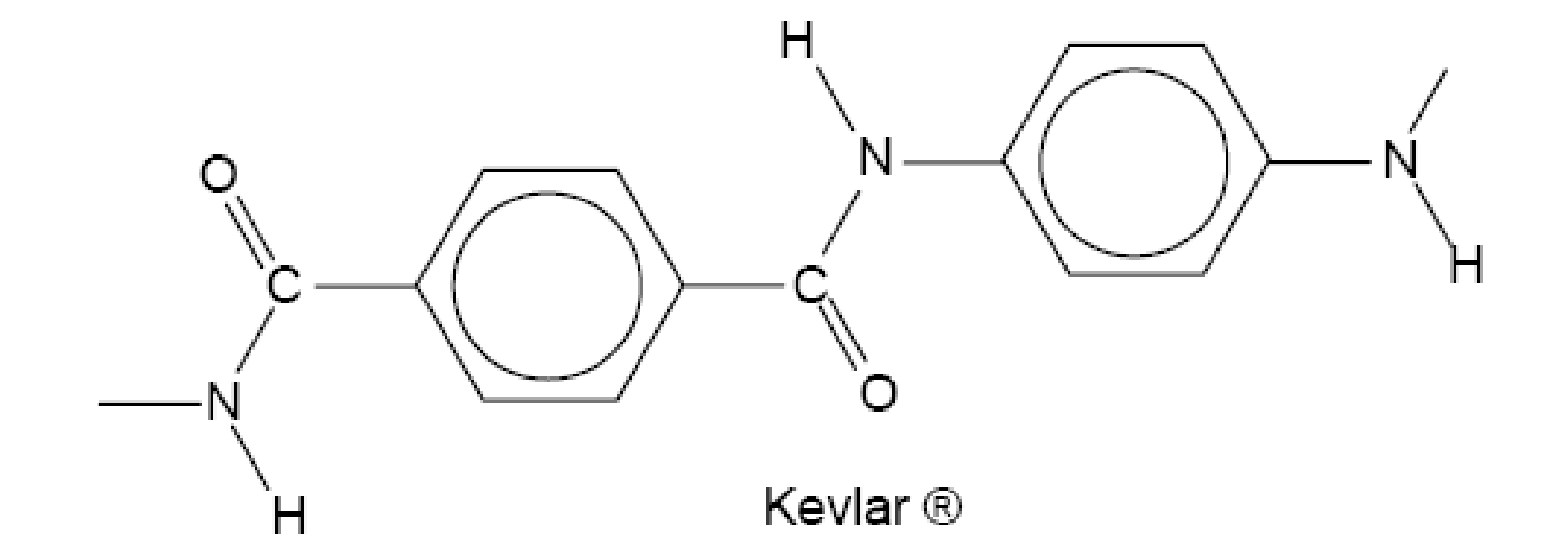
Figure 3.5 – the spiral structure of spider silk and the β-pleated sheet structure of ordinary silk

Spider Silk

- The **most elastic spider silk** is ‘**capture silk**’ that has about **43 repeats and can extend to 200% of its length**.

- Kevlar® is used for bulletproof vests; **re-enforcing Kevlar® with spider silk would make these vests even stronger**.

Spider Silk



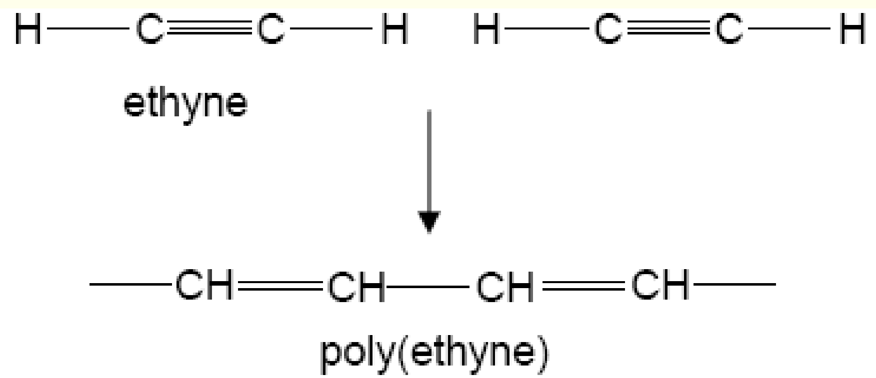
Plastics That Conduct Electricity Or Emit Light

- Conducting polymers were discovered by accident by a Japanese student.

- **Polymerisation of ethyne (acetylene) produces poly(ethyne) by addition polymerisation**.

- This material **has alternating single and double bonds**. Poly(ethyne) **has two forms, cis and trans**.

Plastics That Conduct Electricity Or Emit Light



SAQ 10. *Draw sections of poly(ethyne) containing three ethyne units to show the cis and the trans isomers.*

Plastics That Conduct Electricity Or Emit Light

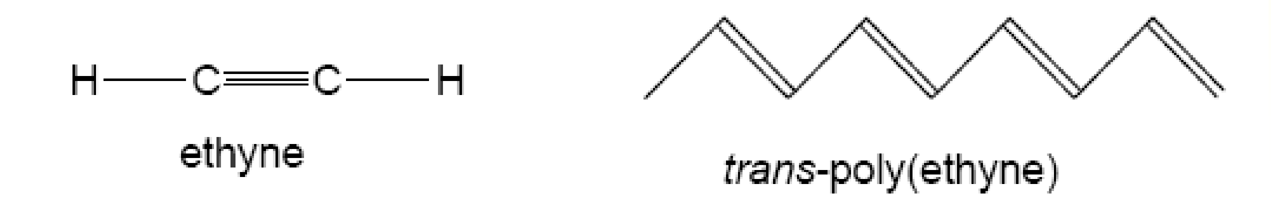
- The two isomers have different colours,
  - ***trans*-poly(ethyne)** is **blue or silver coloured**;
  - ***cis*-poly(ethyne)** is **red or copper coloured**.

- Molecules that have alternating single and double bonds have "**conjugated systems**".

- The realisation that ***trans*-poly(ethyne) had conjugated π bonds led to the discovery that this polymer could conduct electricity**!

Plastics That Conduct Electricity Or Emit Light

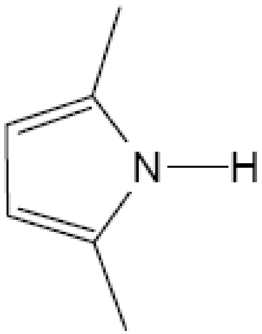
- The conjugated system in ***trans*-poly(ethyne)** is shown below.



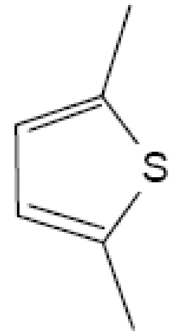
- Other conducting polymers include compounds such as poly(pyrrole) and poly(thiophene).

- conducting polymers are **semi-conductors**

Plastics That Conduct Electricity Or Emit Light

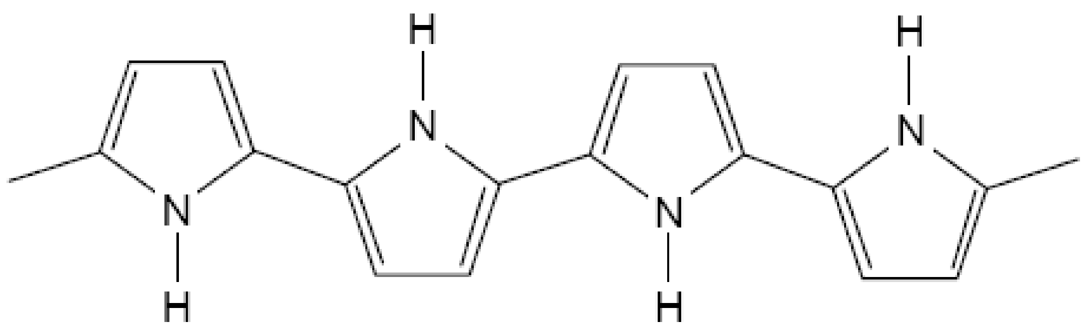


poly(pyrrole) monomer



poly(thiophene) monomer

Polypyrrole has the structure below.



Plastics That Conduct Electricity Or Emit Light

- For these polymers to conduct, they **need to be ‘doped’,** meaning that **some electrons are removed** (by oxidation) **or introduced** (by reduction) leaving ‘holes’ allowing the electrons (or the ‘holes’) to flow.

- Another use is ‘Smart’ windows that have been developed to reduce glare from sunlight.

- The windows are **coated with a conductive polymer in contact with a layer of black particles**.

- **When current is passed through** the polymer, these **molecules particles align and let light through**.

- When the **current is stopped**, they **become disordered** and **block light**.

The traffic lights are changing

- Traditionally, traffic lights have been lit with a single bulb that shines through coloured glass.
- **OLED**s - **organic light emitting diodes**.
- If one of the OLEDs fail, there are still plenty left, so you will be able to cross on the green.

The traffic lights are changing

- OLED displays are appearing in a number of applications. For example Kodak have designed a **camera with an OLED screen** instead of a liquid crystal display screen.

- OLED advantages
  - it can be **viewed even in sunlight as light is being emitted**.
  - **wider viewing angle**.

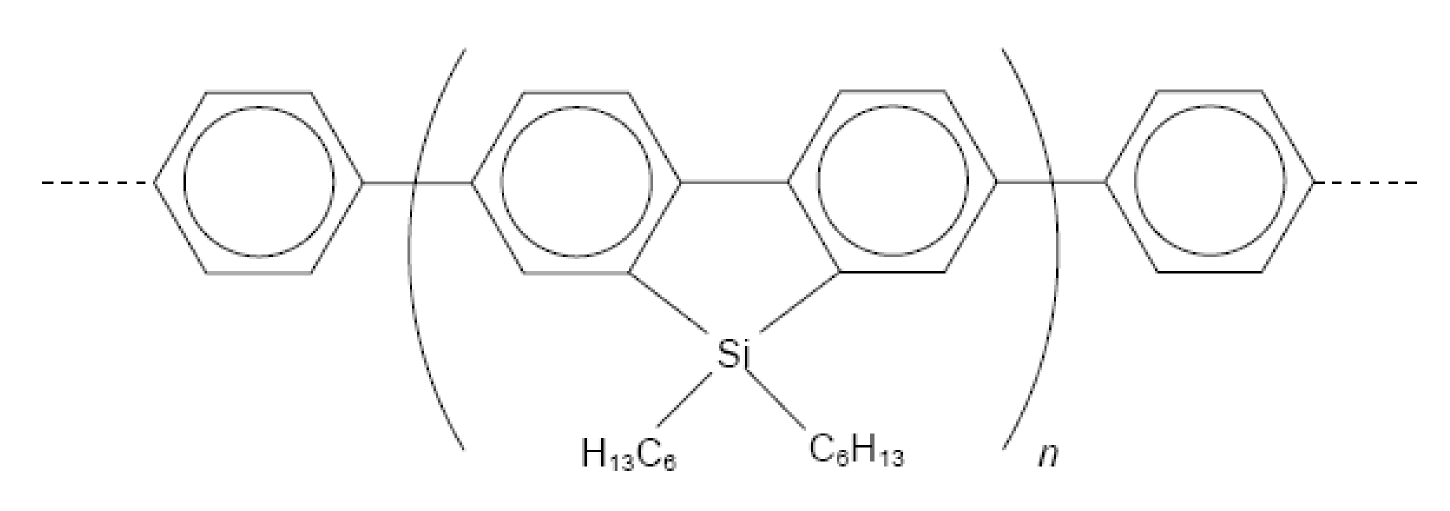
- However, current OLEDs, particularly the blue ones, have a shorter lifetime than liquid crystal displays.

The traffic lights are changing

Figure 3.7 – photo of screen on Kodak camera, courtesy of Jessops.

The traffic lights are changing

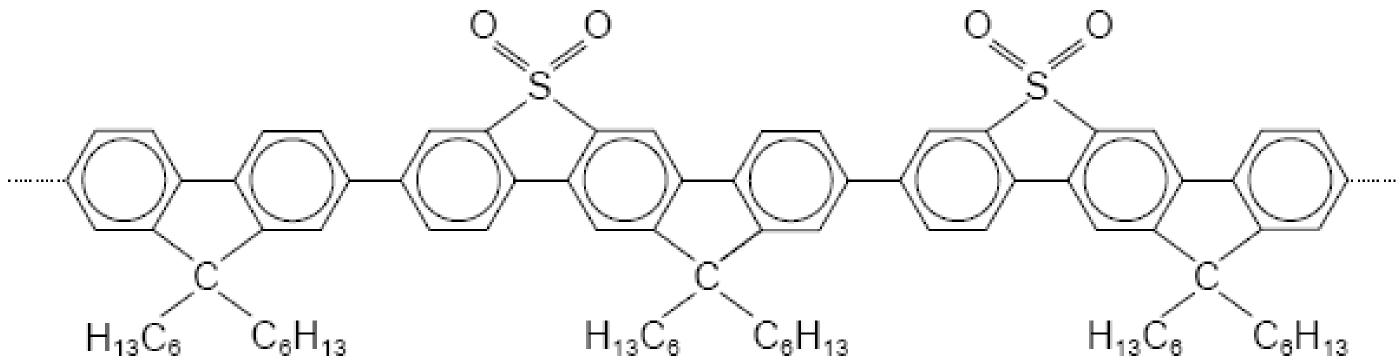
- Research published in 2005 has found blue-emitting materials that may overcome the problem of the shorter lifespan of blue pixels in OLEDS compared to the red and green-emitting pixels in OLED displays.
- A team from Cambridge in the UK **created the blue-emitting polymer**, shown below.



The traffic lights are changing

- A second independent team, working between the Donetsk University in the Ukraine and the University of Durham, UK has discovered a similar blue-emitting material.

- The structure of their polymer is shown below.



SAQ 12. *Identify the repeat unit in this polymer by drawing brackets and adding a label 'n' as in the first polymer above.*