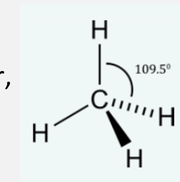
ALKANES

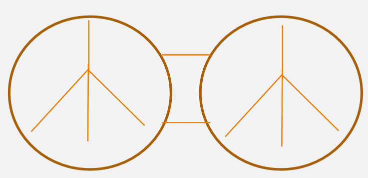
C_nH_{2n+2}

Alkanes

- **Alkanes** have the general formula C_nH_{2n+2}. They are ***saturated*** compounds (i.e. no C=C / C≡C bonds). The first four members of the alkanes are gases at room temperature (CH_4, CH_3CH_3, ...), and the remaining are liquids up to around a 30 carbon-chain length were they are waxy solids.
- Carbon atoms have four electrons in their outer shell. Therefore, each carbon atom can form four covalent bonds
- Alkanes are not polar and only weak London forces of attraction occur, as carbon and hydrogen have similar electronegativities.

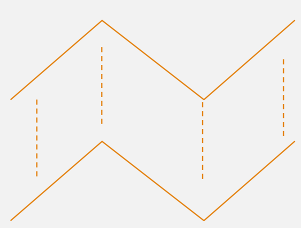


- ***Straight chain vs. Branched Chain Alkanes***
- Boiling point of alkanes increases with chain length, as there is a greater surface area and number of electrons for stronger London forces.
- ***Branched*** alkanes have ***lower boiling points than their straight-chained*** isomers as there are fewer points of contact between adjacent molecules – they don't pack so well together



2,2-dimethylpropane (2 molecules interacting, small surface area interaction compared to straight chain alkanes. Fewer points of contact

VS



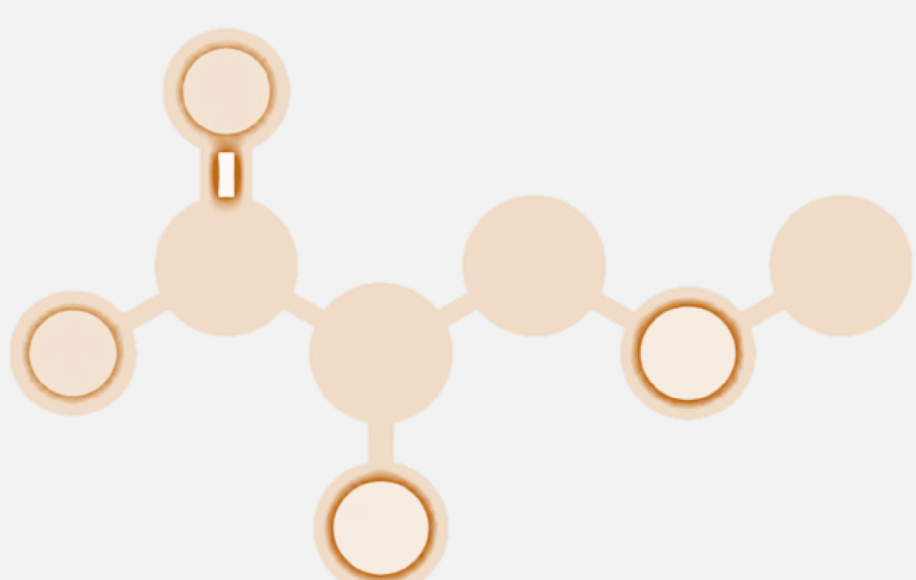
Butane surface interaction much greater higher boiling point

Reaction with Halogens

- Alkanes react with the halogens, specifically chlorine and bromine, in the presence of UV light to form haloalkanes.
- The reaction takes place in three stages: **initiation, propagation and termination**. This reaction is a **free radical substitution** with the steps:
- Overall Reaction: $CH_4 + Cl_2 \rightarrow CH_3Cl$
- ***Initiation***: The formation of free radicals (an uncharged species with an unpaired electron that is used to form a covalent bond). Light energy splits a chlorine molecule into chlorine radicals (homolytic fission):
  $Cl_2 \rightarrow 2Cl•$.
- ***Propagation***: Chlorine radicals are very reactive – when they collide with a methane molecule with sufficient energy, a hydrogen atom is removed to form a methyl radical: CH_4 + Cl• + → HCl + •CH_3.
  Cl_2 + •CH3 + → CH_3Cl + Cl•. (Methyl radicals are also very reactive).
- *(Using any halogenoalkane or alkane as a starting material e.g. CH_2Cl_2 the* ***orange radicals, HCl and Cl_2*** *will always be produced. Try this yourself).*
- ***Termination*** — free radicals are removed.
  This isn't likely to happen, as the concentration of the free radicals is so low.
  Examples of these chain-breaking reactions are:
  •CH_3 + •CH_3 → CH_3CH_3,
  Cl• + •CH_3 → CH_3Cl
  Cl• + Cl• → Cl_2

Cracking

- Cracking converts longer chain hydrocarbons to more economically valuable shorter chain hydrocarbons
- Cracking involves breaking C-C bonds in alkanes
- In thermal cracking, alkanes are heated to high temperatures under high pressures. C-C bonds break homolytically and free radicals are formed. These react to form shorter chain hydrocarbons including at least one alkene. It produces a high proportion of alkenes.
- This is useful as both the products are much more useful that the reactant. This method is used mainly to produce motor fuels (branched & cycloalkanes) and aromatic compounds.
- The conditions for this reaction include heating the alkene at low temperatures and passing it over an Al_2O_3 (aluminium oxide) catalyst .
- For example: $\mathbf{C_5H_{12} \rightarrow C_2H_4 + C_3H_8}$



Fractional Distillation

- Crude oil is a fossil fuel formed from the breakdown of plant and animal remains.
- Fractional distillation will separate crude oil into different fractions . A fraction is a group of hydrocarbons that have a similar boiling point.
- The crude oil is vaporised in a furnace and passed into the bottom of a fractionating column. The crude oil is vaporised in a furnace and passed into the bottom of a fractionating column.
- Small molecules condense at the top at lower temperatures and longer hydrocarbons condense at the bottom at higher temperatures.

Combustion

- Alkanes can be used as a fuel source.
- **In complete combustion:** The alkane burns with a clean blue flame. ***Water vapour*** and ***carbon dioxide*** are formed (greenhouse gases). E.g.
  $$C_3H_8\,(g) + 5O_2\,(g) \rightarrow 3CO_2\,(g) + 4H_2O\,(g)$$
- **In incomplete combustion:**
  The alkane burns with a **dirty yellow flame**. It can produce **carbon, carbon monoxide and unburned hydrocarbons** as products.
  $$CH_4\,(g) + O_2\,(g) \rightarrow C\,(s) + 2H_2O\,(g)$$
  $$CH_4\,(g) + 1.5O_2\,(g) \rightarrow CO\,(g) + 2H_2O\,(g)$$
- **Sulphur containing alkenes:**
  Produce sulphur dioxide during combustion that dissolves in rainwater to cause acid rain**. *Sulphur dioxide can be removed*** from flue gases using ***calcium oxide*** or ***calcium carbonate***.
  $$CaO\,(s) + 2H_2O\,(l) + SO_2\,(g) \rightarrow CaSO_3\,(s) + 2H_2O\,(l)$$
  $$CaCO_3\,(s) + 2H_2O\,(l) + SO_2\,(g) \rightarrow CaSO_3\,(s) + 2H_2O\,(l) + CO_2\,(g)$$
- **Nitrogen containing alkanes:**
- Combusting nitrogen-containing alkanes will form nitrogen oxides, which contribute to acid rain and photochemical smog.
- Catalytic converters can remove gaseous pollutants from internal combustion engines by using precious metals spread over a mesh to form less harmful products such as **N_2, CO_2, and H_2O**