Physical Properties of Alkanes

The common physical properties that we will focus on are:

- Melting point
- Boiling point
- Solubility

However, any inferences drawn on these may also extend to other properties such as density.

Generally, there is a smooth change in physical properties (melting and boiling point) among the homologous series of alkanes (C_nH_{2n+2}) attributed to the van der Waals forces that exist in these molecules.

As the number of carbon and hydrogen atoms increase, the additive effects of these weak intermolecular forces become significant, as evidenced by the increase in boiling and melting points from methane to decane and beyond.

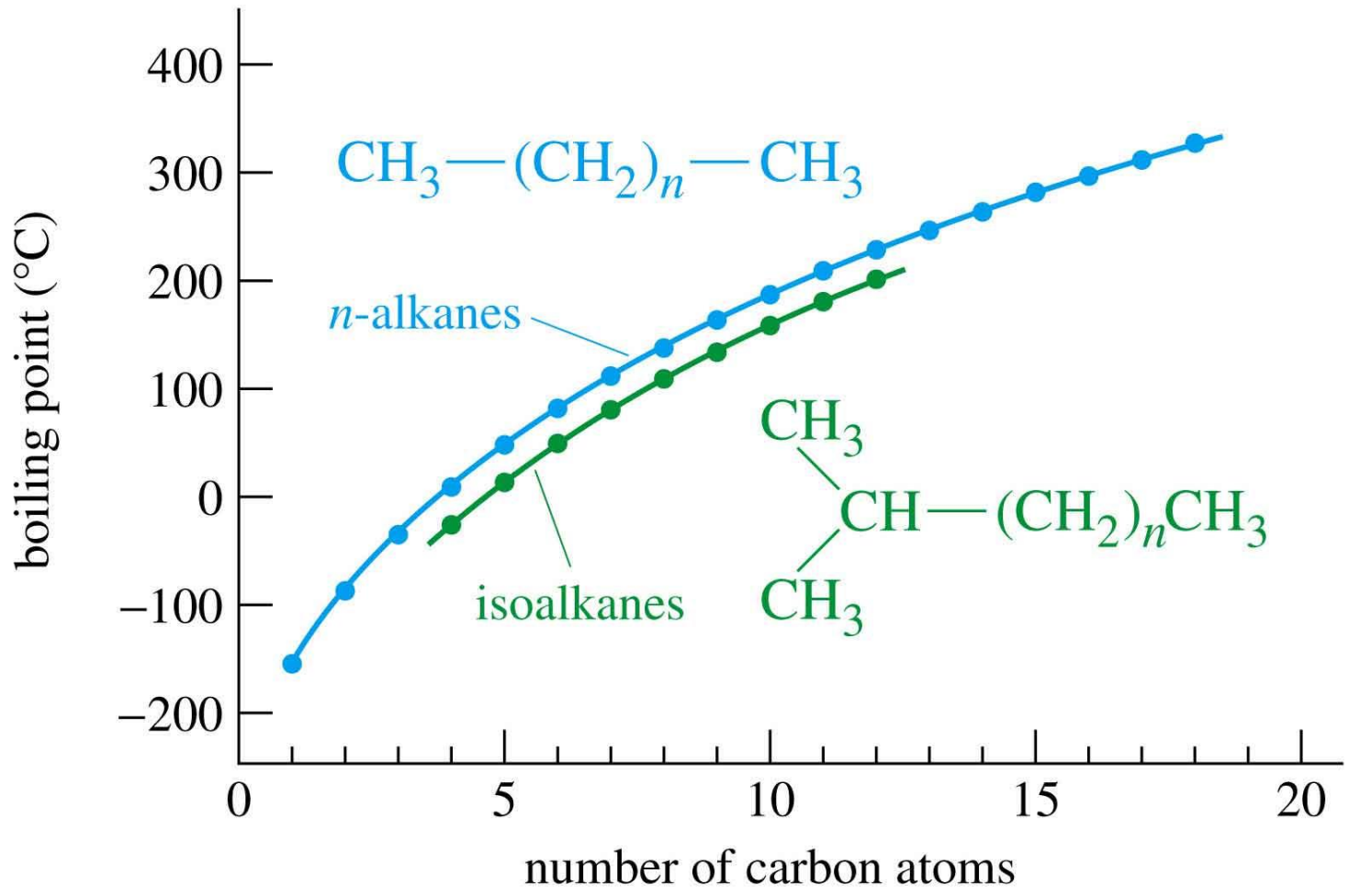
Boiling Points of Alkanes

The boiling points below are illustrative of this homology.

# of Carbons	Name of Alkane	Boiling Point (°C)
1	Methane	-162
2	Ethane	-89
3	Propane	-42
4	Butane	-0.5
5	Pentane	36
6	Hexane	69
7	Heptane	98
8	Octane	126
9	Nonane	151
10	Decane	174

The boiling points of hexane and heptane are 69°C and 98°C, respectively, a difference of 29°C for one CH_2 unit. We would expect the boiling point of octane to be 98°C + 29°C = 127°C, which is close to the actual boiling point of 126°C.

Graph of Boiling Points of Alkanes



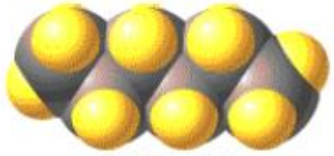
For boiling point, as n increases, each additional CH_2 group contributes a fairly constant increase in boiling point.

Boiling Points of Alkanes
(Exceptions)

For branched isomeric alkanes, there is too much variation in structure for regularities to be apparent.

Refer to the boiling points of the isomeric pentanes below.

n-Pentane



n-pentane

b.p. 36.1°C

2-Methylbutane

2-methylbutane

b.p. 28°C

2,2-Dimethylpropane

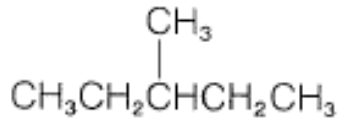
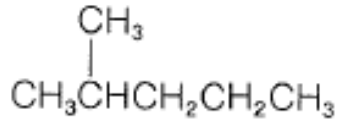
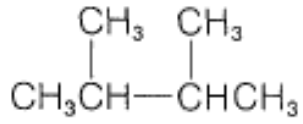
2,2-dimethylpropane

b.p. 9.5°C

Note that volatility appears to increase with increased branching that reduces the surface interactions.

Boiling Points of Alkanes
(Exceptions)

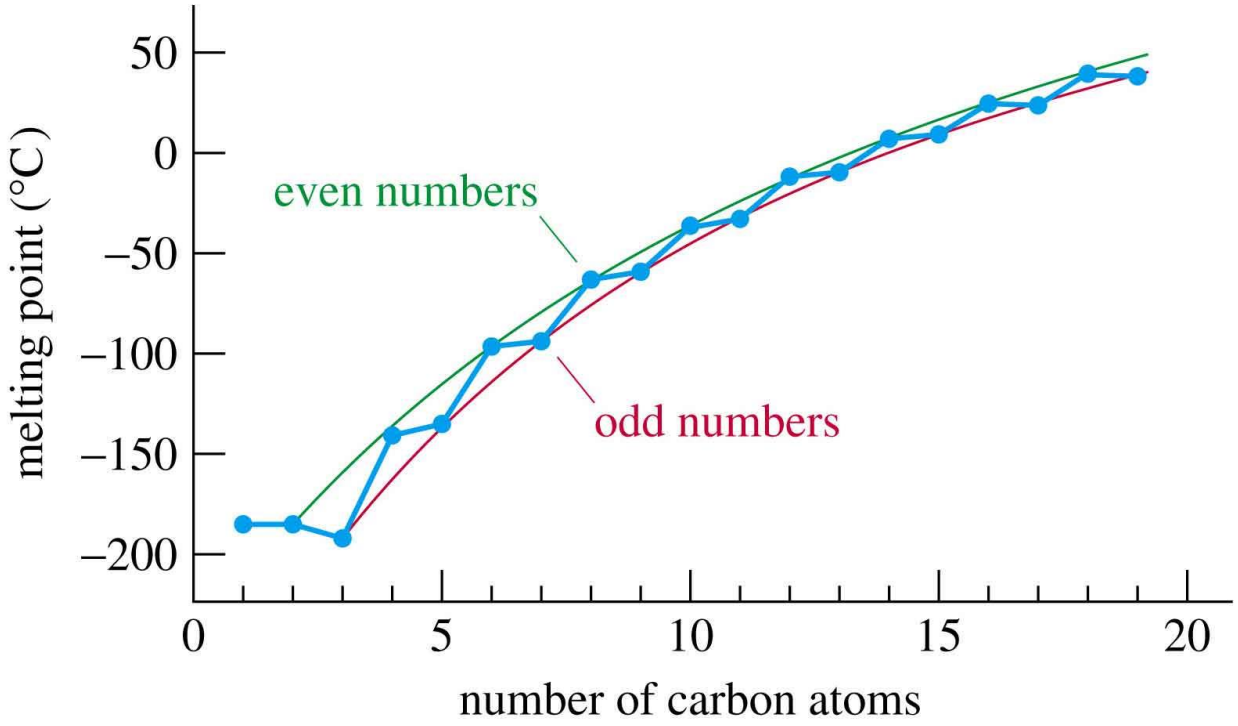
Observe the same variability among isomeric hexanes below.

Isomer	Structure	Bp, °C
hexane	$CH_3(CH_2)_4CH_3$	68.7
3-methylpentane		63.3
2-methylpentane		60.3
2,3-dimethylbutane		58.0

Straight chain alkanes have a higher boiling point than branched alkanes due to the greater surface area in contact and therefore greater van der Waals interactions.

Melting Points of Alkanes

Among the homologous series of alkanes (C_nH_{2n+2}), the melting points also increase but not as smoothly as boiling points.



For melting point, as n increases, there appears to be a progressive increase among odd numbered and among the even numbered alkanes.

Solubility of Alkanes

- Since alkanes are hydrocarbons and there is no significant differences in electronegativity between carbon and hydrogen, they are nonpolar.
- Being nonpolar, alkanes dissolve in nonpolar solvents because the van der Waals interactions between nonpolar alkane molecules and nonpolar solvent molecules are similar to the alkane-alkane and nonpolar solvent-nonpolar solvent molecule interactions.
- Alkanes are thus soluble in nonpolar solvents (i.e. other alkanes) and insoluble in polar solvents (water).
- The liquid alkanes are therefore good solvents for nonpolar covalent compounds.

Occurrence of Alkanes

Highlights

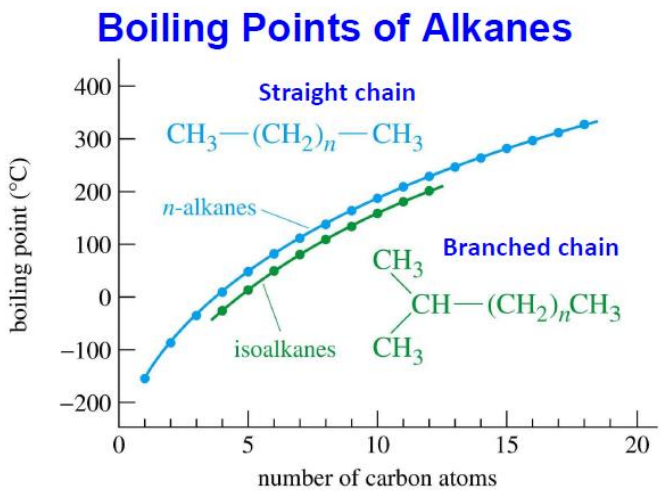
- The most important source of alkanes is natural gas and fossil oil.
- Natural gas contains primarily methane and ethane alongside some propane and butane.
- Methane is also present in biogas produced by methanogenic bacteria acting on decaying animal and vegetable matter.

- Fossil oil is a mixture of liquid alkanes and other hydrocarbons.

Oil Refining

The Rationale

- Crude oil, being a mixture of liquid alkanes, must undergo several separation processes into components that can be used as fuels.
- This separation process is called oil refining.
- The separation into its component alkanes takes advantage of their differences in boiling points.
- Recall that the boiling points of alkanes change gradually with molecular weight.



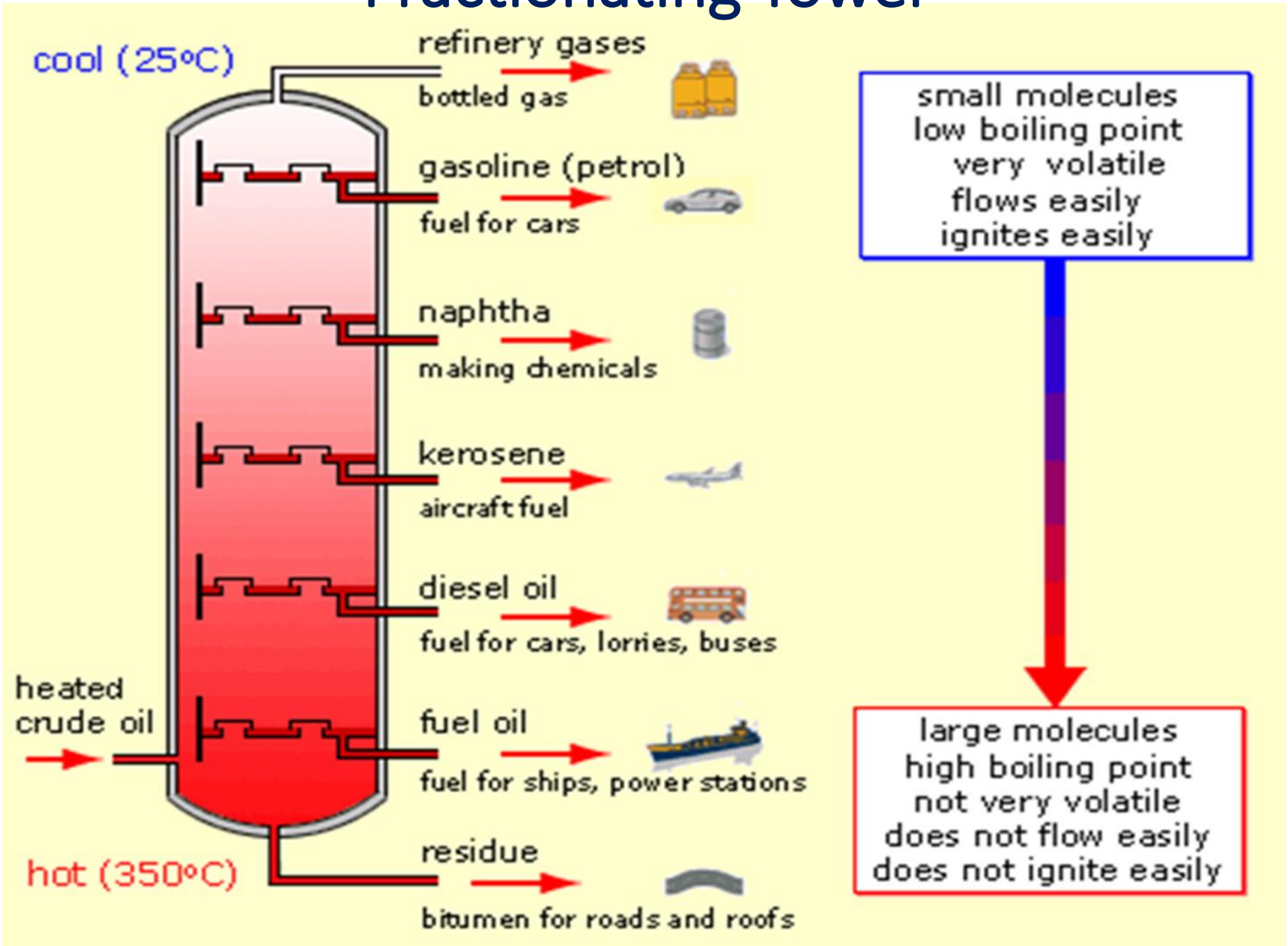
Oil Refining

Fractional Distillation

- Distillation is based on the fact that the vapour of a boiling mixture will be richer in the components that have lower boiling points.
- Thus, when this vapour is cooled and condensed, the condensate will contain the more volatile components. At the same time, the original mixture will contain more of the less volatile components.
- Oil refining by fractional distillation involves heating the crude oil to vapor then letting the vapor to condense at different levels of the distillation tower.
- When the fractions are collected at different levels of the tower, they attract different applications.
- See overleaf, the schematics of a typical distillation tower in a oil refinery.

Oil Refining

Fractionating Tower



Occurrence of Alkanes

Highlights

- Some pine trees produce exceptionally high amounts of *n*-heptane and burn readily during bush fires.
- The tsetse fly uses 2-methylheptadecane as a pheromone. It can detect it over long distances in locating a mate.
- The plant cuticle contains solid long-chain alkanes that protect the plant against water loss and leaching of important minerals by rain.



Uses of Alkanes

Highlights

Hydrocarbons (alkanes) are traditionally called paraffin's in recognition of their use as fuels and oils.

The applications of alkanes depend on the carbon chain,

- Alkanes upto 4 carbons (methane – butane) are mainly for heating and cooking purposes. Methane and ethane are the main components of natural gas.
- Propane and butane can be readily liquified at low pressure and are the chief components of liquified petroleum gas (LPG).

Uses of Alkanes

Highlights

- Pentane to octane are reasonably volatile liquids that are used as fuels in internal combustion engines. They are also good solvents for nonpolar substances.
- Nonane to hexadecane are used as kerosene and jet fuel.
- Alkanes from hexadecane are liquids of high viscosity and are commonly used as lubricating oil.
- Petroleum jelly, a semi-solid mixture of hydrocarbons (mainly higher than 25 carbons), is used as a skin protectant in cosmetic skin care.

Uses of Alkanes

Highlights

- Many solid alkanes find use as parafin wax in candles.
- Some synthetic polymers such as polyethene are chains containing hundreds of thousands of carbon atoms.