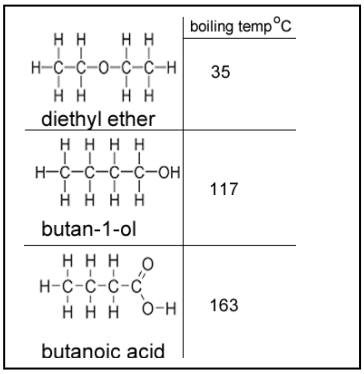
Lesson 6 Trends of organic molecules

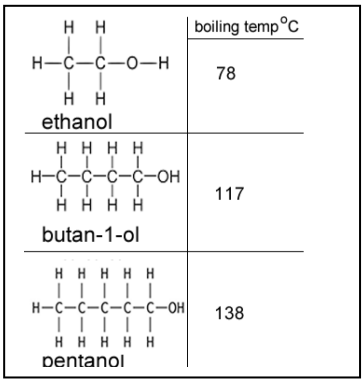
Click to revise trends
Firstly a few definitions.
Viscosity – is the liquid's resistance to flow
Flash point - is the lowest temperature at which a liquid's vapour can form an ignitable mixture in air

Viscosity, flash point, boiling and melting points are all influenced by the type of intermolecular forces acting between molecules and the strength of these forces. The relative strength of the three intermolecular forces is Hydrogen bonding > dipole-dipole > Van der Waals dispersion forces and depends on the functional groups present on the molecule.
Let's take a look at the trends in melting temperature.

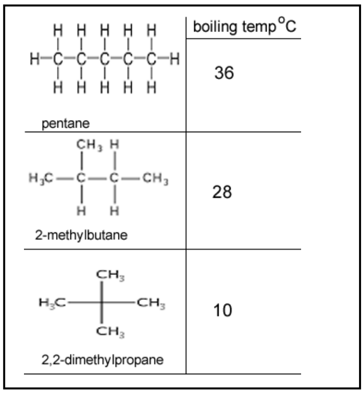
1. Boiling temperatures increase as the number of carbons is increased.
2. Branching decreases boiling temperatures.
3. The more polar the functional groups the greater the melting temperature.



Starting with the functional groups present consider the two molecules shown below. Both diethyl ether and butan-1-ol have identical molecular weights and yet the boiling temperature of diethyl ether is 35°C while the boiling temperature of butan-1-ol is 117°C.
Butan-1-ol exhibits hydrogen bonding as it's predominant intermolecular force while the dominant intermolecular force in diethyl ether is the weaker dipole-dipole bonding.
Consider the impact of the more polar carboxy (COOH) group on butanoic acid, which exhibits both dipole-dipole and hydrogen bonding, it cause the boiling temperature to jump significantly.

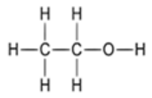
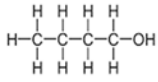
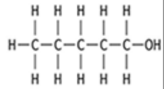


As the number of carbons increases in the molecule so does the boiling temperature. Consider the alcohols shown on the right. They all have hydrogen bonding, due to the hydroxyl (OH) functional group and yet as the carbon chain grows so does the melting temperature. The difference here is the Van der Waals dispersion forces, which are proportional to the length of the chain, or size of molecule. As the size of the molecule increases so do these, relatively weak, forces of attraction.



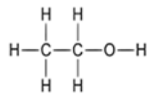
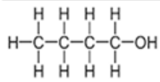
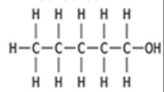
Now consider the impact of branching on the boiling temperature. As you can see from the molecules shown on the right, the greater the branching the lower the temperature. The molecules shown on the right rely on Van der Waals dispersion forces as the main force of attraction between the molecules. These forces are weak and act over small distances, the inability of the molecules to pack close together, due to branching, reduces the attraction of the Van der Waals dispersion forces, Refer to the link above for a detailed explanation.

Trends in flash point follow those of boiling temperature.
Consider the alcohols shown on the right. As the intermolecular forces of attraction increase so does the flash point of each molecule.

	flash point °C
 ethanol	17
 butan-1-ol	35
 pentanol	49

Viscosity is again related to the strength of intermolecular bonding and the relative strength of Van der Waals forces, dipole-dipole and hydrogen bonding acting between molecules. This in turn is related to how molecules pack together. Branching, therefore, reduces the impact of the intermolecular forces to attract molecules and reduces the viscosity of relatively smaller molecules, while an increase in the length of the linear molecules significantly increases the Van der Waals forces of attraction and allow for tangling amongst molecules, hence an increase in viscosity.

Solubility in water, however, is directly related to the degree of polarity of the molecule and the length of the hydrocarbon chain. The longer the hydrocarbon chain the less soluble in water a molecule is.

	solubility mol/100g
 ethanol	miscible
 butan-1-ol	0.11
 pentanol	0.03

1) List the following molecules in order of increasing solubility. Give an explanation
   a) i. pentanoic acid
      ii. ethanoic acid
      iii. hexanoic acid

   Hexanoic acid ($CH_3CH_2CH_2CH_2CH_2COOH$) < pentanoic acid($CH_3CH_2CH_2CH_2COOH$) < ethanoic acid(CH_3COOH)
   The hydrocarbon part of the molecule is bigger in hexanoic acid than ethanoic acid. Interaction with water molecules cannot take place in the section of the molecule composed of hydrocarbons.

   b) List the following molecules in order of increasing viscosity. Give an explanation

      i. 1,2,3-pentanetriol

      ii. 1-pentanol

      iii. 1,2-pentanediol

   1-pentanol <1,2-pentanediol < 1,2,3-pentanetriol. Viscosity is related to the ability of the molecule to resist flow, hence the greater the attraction between the molecules the greater the resistance. Three hydroxyl groups make for greater attraction due to hydrogen bonding than one hydroxyl group.

2) Consider the molecules shown below.

a) $CH_3CH_2CH_3$
b) CH_3CH_2OH
c) CH_3CHO
d) CH_3COCH_3

i. List the following molecules in order of increasing boiling point.

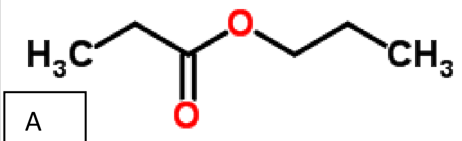
$CH_3CH_2CH_3 < CH_3CHO < CH_3COCH_3 < CH_3CH_2OH$
Boiling point is related to the strength of intermolecular bonding.
$CH_3CH_2CH_3$ has dispersion forces only.
CH_3CHO has dispersion forces and dipole-dipole bonding
CH_3COCH_3 slightly large molecule than ethanal with a larger surface area for greater interaction. Intermolecular bonding is composed of weak dispersion forces as well as dipole-dipole bonding.
CH_3CH_2OH has weak dispersion forces as well as hydrogen bonding.

ii. To what homologous group does each molecule belong to?

a)Alkane, b) alcohols, c) aldehydes, d) ketone

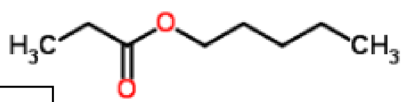
3) Consider the two molecules shown on the right.
a) Name each molecule.
A) propyl propanoate

B) Pentyl propanoate



A

b) Which has the highest boiling temp? Explain
B. Both molecules have the same functional group but B is a larger molecule than A. The strength of the weak dispersion forces depends on the size of the molecule, the bigger the molecule and greater the dispersion forces.

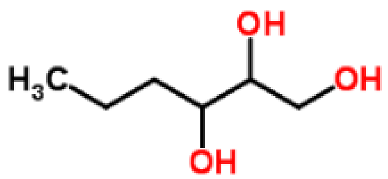


B

c) Which has the highest solubility in water? Explain
A.
Hydrocarbons are hydrophobic, hence, the longer the hydrocarbon chain in a molecule the less soluble it is in water. A has a longer hydrocarbon chain than B.

4) Consider the two molecules shown on the right.

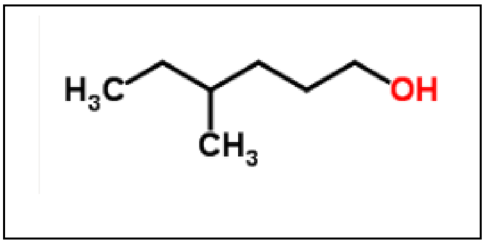
a) Name each molecule
1,2,3-hexanetriol or hexane-1,2,3-triol
4-methylhexan-1-ol. or 4-methyl-1-hexanol



b) Which has the highest boiling temp? Explain

hexan-1,2,3-triol.

It has more hydrogen bonding and is a linear molecule than 4-methyl-1-hexanol. Branching reduces the strength of the intermolecular forces of attraction.



c) Which has the highest solubility in water? Explain

hexan-1,2,3-triol. It has more hydroxyl groups (OH) so more places with which to interact with water molecules.