Quiz 3 - Biofuels

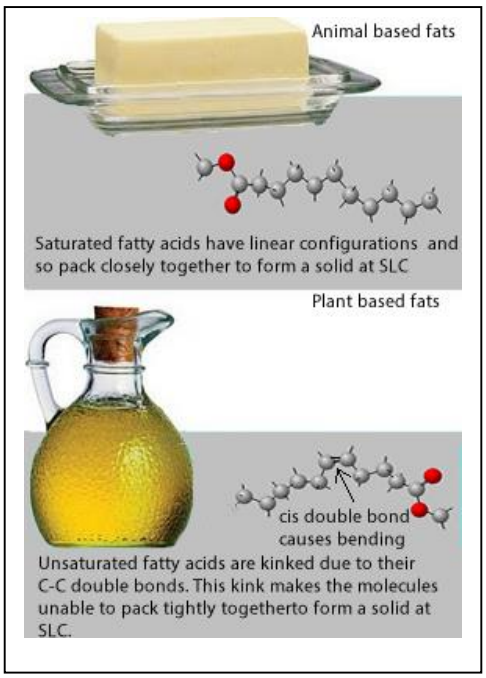
"Biofuel" is a fuel produced from renewable plant and animal biomass. Four distinct groups of biofuels exist:

- alcohols such as ethanol, which is produced from the fermentation of sugar.
- biodiesel made of plant oils
- biogas obtained from the decomposition of organic matter.
- organic matter that can be burnt to produce heat such as wood fibre or plant oils.

1) Palm tree oil is a precursor to the production of biodiesel and is heralded as a way of bringing economic prosperity to poor countries. Many people argue that fuels such as ethanol and biodiesel produced from corn and palm trees respectively are unsustainable. Suggest reason why?
- Clearing huge areas of land for the planting of corn or palm trees requires deforestation of land and the destruction of native habitats.
- Planting of crops for biofuel competes with land which can be used for the planting of food crops.
- Plantations used to grow resources for biofuels require a great deal of water and fertiliser as resources which can lead to severe degradation of local waterways.
- Biofuels are not completely carbon neutral. Their production requires the burning of fossil fuels that generates CO_2 emissions. Take ethanol, for example, in order to purify ethanol it must be distilled. Distillation requires a great deal of heat energy which is generally obtained from the burning of fossil fuels.

Fuels are now being synthesised from fatty acids derived from plants and animals to form biofuels that are quickly becoming common fuels for public transport.

Fatty acids derived from plants are usually unsaturated and exist as oils rather than solid fats as are some animal products.



2) A biofuel is formed from the esterification of methanol and one of three fatty acids, oleic ($C_{18}H_{34}O_2$), stearric ($C_{18}H_{36}O_2$), and linolenic ($C_{18}H_{30}O_2$), fatty acids.
   a) Classify each fatty acid as saturated, monounsaturated and polyunsaturated.
   Saturated = stearic
   mono-unsaturated = oleic
   Poly-unsaturated = linolenic
   Saturated fatty acids have the following general formula. $C_nH_{2n+1}COOH$.
   For every double bond we lose two hydrogens
   b) Which methyl ester exhibits the lowest viscosity at SLC? Explain your reasoning.
   Compounds with low viscosity flow freely through pipes. Those with a high viscosity, however, have molecules that are

attracted strongly to each other and hence cannot slide past each other with ease to flow freely. Since all three methyl esters exhibit dipole-dipole bonding, due to their ester functional group the difference the strength of intermolecular bonding will depend on the attraction generated by Van der Waals forces. This is further complicated by the presence of C-C double bonds which causes the molecules to kink. Van der Waals forces are very weak and act over small distances. Kinks in the molecule means that they cannot pack close to each other and hence the intermolecular bonds of molecules with similar molecular mass are weaker if the degree of saturation is greater. Click to see an animation that attempts to explain the difference in intermolecular bonding between saturated and unsaturated hydrocarbons.

c) Which methyl ester is best suited to cold climates? Explain your reasoning?
An ester that exhibits a high strength of intermolecular forces is most likely to solidify in the fuel lines at low temperatures. Or at the very least its high viscosity would make it hard to pump through the fuel lines at such low temperatures.

d) Which methyl ester has the highest flash point? Justify your answer.
The flash point of a volatile material is the lowest temperature at which vapours of the material will ignite, when given an ignition source. Once again this property is directly related to the strength of intermolecular bonding, where the molecules with the lowest intermolecular bonding exhibit low flash points. The highest flash point will be exhibited by

3) A scientist synthesised three alkyl esters using oleic acid, methanol, ethanol and butan-1-ol.
Each alkyl ester performed differently when it was tested for viscosity at SLC.

a) Place the three alkyl esters in order of lowest to highest viscosity. Justify your answer.
All three esters exhibit dipole-dipole bonding and dispersion forces (Van der Waals forces). They differ, however, in the strength of the dispersion forces exhibited between the molecules. Heavier molecules will exhibit stronger dispersion forces than lighter molecules, hence, the lighter molecule, the methyl ester, will have the lowest viscosity.

b) Cloud point refers to the temperature below which diesel or biodiesels starts to solidify to form a cloudy appearance. Which alkyl ester has the lowest cloud point and why is this an important consideration when choosing a fuel for a cold environment?
It is important for a fuel to remain as a free flowing liquid at low temperatures and not solidify in fuel lines. Once again it is a case of the molecule with the lowest strength intermolecular forces of attraction. The methyl ester is most likely to remain a liquid at low temperatures.