AS 90932
Demonstrate understanding of aspects of carbon chemistry

ALCOHOLS AND FUELS

METHANOL (2013)
(a) Draw the structural formula of methanol.
(b) (i) Identify the type of bonding within a molecule of methanol.
   (ii) Give a reason for your choice.
(c) Compare & contrast the complete combustion of methanol to the incomplete combustion of octane.
   In your answer:
   • compare and contrast the combustion reactions of both fuels
   • compare and contrast the impacts of the combustion products of both fuels on human health
     or the environment
   • write a balanced symbol equation for the complete combustion of methanol.

FUELS (2011)
(a) Draw the structural formulae for butane and methanol. Both butane and methanol can be used as fuels.
(b) A sample of butane burns in air with a yellow flame, while a sample of methanol burns in air with an almost invisible flame.
   Compare and contrast the combustion of these two fuels.
(c) Write a balanced symbol equation for the combustion of methanol, which burns with an almost invisible flame.
(d) Combustion of fuels can have negative effects on both human health and the environment.
   Identify and explain TWO negative effects of the combustion of fuels on both human health and the environment.
   Your answer should include:
   • ONE negative effect on human health, and
   • ONE negative effect on the environment.

PROPERTIES OF HYDROCARBONS (2012)

Boiling points of straight chain alkanes

![Boiling points graph](image-url)
(a) Name and draw the structural formulae of the alkanes with 3 and 7 carbon atoms.
(b) Identify and explain the trend of boiling points for the alkanes shown in the graph above.
(c) In October 2011 a ship, the *Rena*, grounded on a reef near Tauranga Harbour, causing oil to be spilled into the ocean.
   It was observed that the oil formed a layer on top of the water, and that it lasted for a long time.
   Give an explanation for both observations by referring to the properties of oil.

**DISTILLATION AND CRACKING**

**FRACTIONAL DISTILLATION (2013)**
Crude oil is fractionally distilled in tall towers, like the ones shown below, to obtain useful products.
(a) Explain why crude oil must be fractionally distilled before it can be used.
(b) Name TWO of the fractions obtained from the fractional distillation tower, and describe ONE use for each.
(c) Explain why fractional distillation is carried out in towers.
   You will need to refer to the chemical structure and physical properties of the hydrocarbons that make up crude oil, and the way the fractional distillation tower operates.

**FRACTIONAL DISTILLATION (2011)**

Give a detailed account of the fractional distillation of crude oil.
In your answer you should:
- describe the composition of crude oil
- explain how the process of fractional distillation is carried out
- link the process of fractional distillation to the physical properties and chemical structure of hydrocarbons.
Crude oil is made up of different fractions. Some of these fractions contain large chain hydrocarbons that may not be useful as fuels. Cracking is the process used to produce smaller, more useful hydrocarbons. Give a detailed account of the process of cracking. In your answer you should:

- describe the process of cracking, stating the conditions required
- explain why the large chain fractions may not be useful as fuels
- by using hexane as an example, identify the products that would form in cracking, and explain why they form by referring to their chemical structures
- give ONE use for each of the products that form.

POLYMER QUESTIONS

POLYPROPENE (2013)

(a) Draw THREE repeating units to show the polymer that propene forms.
(b) Explain why alkenes can be used to make polymers, but alkanes cannot.
(c) Polypropene (propylene) has many uses that are linked to its chemical and physical properties. Name TWO uses of polypropene. Link each use to TWO physical and / or chemical properties of polypropene.

POLYMERS (2012)

This is a section of the polymer polyethene (polythene):

(a) Name and draw the monomer used to form polyethene.
(b) This monomer burns with a smoky flame in a limited oxygen supply. Identify and explain TWO negative effects on human health of the products of this combustion reaction.
(c) Polyethene is available in both a low density (LDPE) and high density (HDPE) form. Some properties of LDPE and HDPE are given in the table below.

<table>
<thead>
<tr>
<th>polymer</th>
<th>Mass</th>
<th>Solubility in water</th>
<th>Chemical resistance</th>
<th>Flexibility</th>
<th>Polymer chain packing</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE (low density polyethene)</td>
<td>light</td>
<td>insoluble</td>
<td>high</td>
<td>more flexible</td>
<td>chains packed loosely together</td>
</tr>
<tr>
<td>HDPE (high density polyethene)</td>
<td>light</td>
<td>insoluble</td>
<td>high</td>
<td>less flexible</td>
<td>chains packed closely together</td>
</tr>
</tbody>
</table>
Explain why LDPE is used to make plastic food wrap and HDPE is used to make plastic drink bottles, by analysing the properties provided in the table above.

(d) Explain why polyethene is a non-biodegradable substance.

MAKING POLYMERS (2011)
Propene is used to make the polymer polypropene.
(a) Draw diagrams to show the chemical structure of both propene and polypropene.
(b) Outline in full the chemical reaction that occurs between propene molecules to form the polymer polypropene.
(c) Polypropene has many uses that are related to its properties.
   Describe TWO uses of polypropene and link these uses to named physical and chemical properties of polypropene.

ALKANES AND ALCOHOLS
ETHANE AND ETHANOL (2013)
(a) Draw the chemical structures for ethane and for ethanol.
(b) Analyse the differences between ethane and ethanol by considering the similarities and differences of their chemical structures and their physical properties.
   In your answer include, for both ethane and ethanol:
   • their state at room temperature
   • their relative melting and boiling points
   • their solubility in water.
(c) Fermentation is one method that can be used to produce ethanol.
   Elaborate on how fermentation is used to produce ethanol.
   In your answer include:
   • an explanation of the materials used and the products obtained
   • the conditions required for fermentation to occur
   • a balanced symbol equation.

ETHANOL (2012)
Ethanol can be produced by the fermentation of glucose.
(a) Draw the structural formula of ethanol.
(b) Outline the fermentation process that produces ethanol from glucose (C₆H₁₂O₆).
   Include the conditions required for this process to occur, and a balanced symbol equation.
(c) Ethanol burns in air with an almost invisible flame.
   State the type of combustion reaction ethanol undergoes and name the products formed.
   Write a balanced symbol equation for the reaction of ethanol burning in air.
(d) Identify and evaluate ONE effect that a product of the complete combustion reaction for ethanol would have on the environment.
Hexane and ethanol are organic compounds, which are liquid at room temperature. Using only water and a Bunsen burner, explain one chemical AND one physical test that could be used to identify hexane and ethanol.

Your answer must include:

- a description of each test
- the observations that would be made for each test for BOTH compounds
- an explanation of the chemical and physical properties of BOTH compounds that allow identification with your tests.
METHANOL (2013)

It is covalent bonding as it is made up of non-metal atoms C, H and O. Non-metal atoms share electrons to achieve full valence shells.

\[ 2\text{CH}_3\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 4\text{H}_2\text{O} \]

Methanol burns completely in plentiful oxygen with a blue / invisible / hot flame. Complete combustion produces CO\(_2\) and H\(_2\)O vapour, which are significant greenhouse gases. CO\(_2\) and H\(_2\)O vapour enhance the greenhouse effect which leads to increased trapping of infra-red radiation in the atmosphere. This leads to climate change and issues around global warming. The ocean absorbs CO\(_2\) released and this affects seawater chemistry. This can impact on marine food webs at all levels, including a food supply for humans.

Octane burns in limited O\(_2\) with an orange / sooty / cooler flame and soot (C) & CO may be produced as the combustion is incomplete. Carbon is an irritant when inhaled, is a carcinogen, and causes visible pollution. CO is a poisonous gas which, if inhaled will replace the oxygen transporting around the body and ultimately may kill the person.

FUELS (2011)

Butane is undergoing incomplete combustion as shown by the yellow flame. Incomplete combustion means there is not enough oxygen (insufficient percentage) present in the air for all of the carbon atoms in butane to turn into carbon dioxide. Some or all of it turns into carbon monoxide or carbon particles (soot). The hydrogen atoms react with oxygen to form water.

Methanol is undergoing complete combustion as shown by the almost invisible flame. This means there is sufficient oxygen present and all the carbon atoms react with oxygen to form carbon dioxide. The hydrogen atoms here also react with oxygen to form water.

Energy is released. Complete combustion is a more efficient producer of energy than incomplete combustion.

\[ 2\text{CH}_3\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 4\text{H}_2\text{O}(g) \]

(Candidates are not required to write states in equations.)

Carbon particles / particulates produced can affect the lungs if breathed in, and can cause respiratory problems including asthma and even lung cancer. (They can also get into the arteries and clog them, leading to heart disease.)

Carbon particles / particulates can scatter solar radiation. Large amounts of carbon can act as a blanket, blocking solar radiation, reducing efficiency of photosynthesis.

CO is a dangerous gas as it acts like a poison by combining with haemoglobin in the blood. CO forms a stable compound with haemoglobin, preventing oxygen from being carried to the parts of the body that need it. The person dies by suffocation.

CO\(_2\) is one of the greenhouse gases. It contributes to the greenhouse effect because it causes heat energy to be radiated back to earth and subsequently global warming occurs.
**PROPERTIES OF HYDROCARBONS (2012)**

As the number of carbon atoms in alkanes increases, the boiling point increases. As the mass of the molecules increases, more energy is needed to separate molecules / particles to change state. This factor causes the boiling points to rise.

(Note: as the size of the molecule increases so does the strength of the intermolecular forces between the molecules. This means more energy is required to overcome the intermolecular forces to allow a change in state. Candidates may use intermolecular forces in their answer correctly, though this aspect is outside of the scope of the standard.)

Oil floats on top of the water because it is insoluble in water (immiscible), so will not dissolve in it. Because the water molecules are more attracted to each other than they are to oil molecules, a layer of oil forms on top of the water.

The oil remains for a long time because it is insoluble in water, so the water cannot disperse it. It is also a saturated / unreactive molecule so difficult to remove with other chemicals.

**FRACTIONAL DISTILLATION (2013)**

Crude oil consists of a mixture of hydrocarbon molecules of different sizes which need to be distilled in order to separate into useful fractions, since the fractions have different uses.

Fractions include: LPG (propane / butane) gas for heating and cooking; or octane / petrol and diesel for transport. Kerosene is another fuel and bitumen is used in roads.

A tower is used because the crude oil is heated and the hot particles rise. Hydrocarbons of different molecular masses have different boiling points. Larger molecules have higher boiling points. When the heated crude oil vapour enters the tower, the larger, heavier hydrocarbons with the higher boiling points condense into liquids lower down in the tower, while the smaller, lighter hydrocarbons with the lower boiling points rise up the tower and condense back into a liquid at the lower temperatures near the top of the tower. The smallest hydrocarbons (C1 – C4) remain gases at room temperature, and exit from the top of the tower.

The temperature at which a specific hydrocarbon condenses is related to its molecular mass, particularly the number of carbon atoms. The lower / higher its molecular mass is the lower / higher the temperature at which it will condense. This determines whereabouts on the tower the particular fraction is collected.

**FRACTIONAL DISTILLATION (2011)**

Crude oil consists of a mixture of hydrocarbon molecules of different sizes. Crude oil is heated and turned into a vapour to enter the fractionating tower. Hydrocarbons of different molecular masses have different boiling points. Larger molecules have higher boiling points. When the heated crude oil vapour enters the tower, the larger, heavier hydrocarbons with the higher boiling points condense into liquids lower down in the tower, while the smaller, lighter hydrocarbons with the lower boiling points rise up the tower and condense back into a liquid at the lower temperatures near the top of the tower. The smallest hydrocarbons (C1 – C4) remain gases at room temperature.
The temperature at which a specific hydrocarbon condenses is related to its molecular mass, particularly the number of carbon atoms. The lower / higher its molecular mass is, the lower / higher the temperature at which it will condense. (This determines where on the tower the particular fraction is collected.)

**CRACKING (2012)**

Cracking is a thermal decomposition reaction using heat and / or a catalyst to vaporise a larger alkane and break its bonds to produce a smaller alkane and an alkene. Long chained hydrocarbons don’t flow as well, and are difficult to ignite (because bigger molecules don’t vaporise as easily), so they are less efficient fuels than shorter chained hydrocarbons.

An alkane and an alkene are produced. Since the number of carbon and hydrogen atoms does not change, 2 alkanes cannot be made (as there would be 2 H atoms short).

*Eg hexane*

\[
\text{C}_6\text{H}_{14} \xrightarrow{\text{cracking}} \text{C}_4\text{H}_{10} + \text{C}_2\text{H}_4
\]

**EITHER**

Uses:

Butane is used as a fuel in lighters, propellant in aerosol cans and is (mixed with propane and) used to make LPG.

Ethene is used to make ethanol and in polymerisation reactions to make polyethene.

OR

\[
\text{C}_6\text{H}_{14} \xrightarrow{\text{cracking}} \text{C}_5\text{H}_8 + \text{C}_3\text{H}_6
\]

Uses:

Propane is (mixed with butane and) used to make LPG.

Propene is used in polymerisation reactions to make polypropene.

**POLYPROPENE (2013)**

Alkenes have a (reactive) double covalent bond between two carbon atoms. (Under high temperatures, high pressure and catalytic conditions) the double bond can be broken, resulting in a single covalent bond and a spare single bond that can covalently bond to the next monomer to form a long chain polymer.

\[
\text{C} = \text{C} \rightarrow \text{C} - \text{C} - \text{C}
\]

Alkanes have only single covalent bonds between carbon atoms, which are unreactive (in these conditions), so do not form polymers.
Valid uses linked to properties such as:

- low chemical reactivity (e.g. with air, water and living organisms). (But susceptible to UV degradation)
- high tensile strength / strong
- insolubility in water / does not absorb moisture
- ability to be moulded or extruded into a wide range of shapes with moderate heating due to high melting point (about 160°C)
- insulator
- low density / lightweight and floats
- recyclable.

**POLYMERS (2012)**

Incomplete combustion produces C (soot) which can be inhaled and cause respiratory problems and damage the heart. Soot is a carcinogen. CO can also be produced which is a poisonous gas as it can replace oxygen’s position in red blood cells and cause death.

LDPE and HDPE are both light, insoluble in water and have high chemical resistance. These properties make both of them suitable for storing food or drinks, as they won’t react with the food or drinks, and they are light, making them easy to carry.

LDPE is more flexible with its polymer chains loosely packed together, so it is suitable for use as plastic food wrap, which needs to be flexible to wrap around any shaped food (or food on plates) to store it.

HDPE is less flexible with its chains tightly packed together, so it is suitable to use to make plastic bottles, which need to be rigid enough to support the liquid drink that is stored in them.

Polythene is non-biodegradable because the single bonded hydrocarbon (alkane) chains do not react (the strong covalent bonds between atoms need a lot of energy to be broken) thus it can’t be broken down by chemicals in the environment (or decomposer organisms).

**MAKING POLYMERS (2011)**

The chemical reaction requires heat, high pressure and a catalyst. Many small propene molecules are joined together to form long-chain molecules. The (covalent) double bond between each carbon atom in the propene molecule is broken and a single covalent bond formed between these carbon atoms and between carbon atoms of neighbouring molecules, forming long carbon chains which are the forms of the polypropene molecule.
Identified uses are linked to properties such as:

- Low chemical reactivity (e.g., with air, water, and living organisms).
- Insolubility in water.
- Ability to be moulded or extruded into a wide range of shapes with moderate heating.
- Insulator
- Good for ropes used in water, as low density and floats. (*not good for other rope applications as UV degrades it*)
- Recyclable, reshape and use for garden chairs, bins etc.

**ETHANE AND ETHANOL (2013)**

Ethane has a lower melting / boiling point than ethanol because it has weaker attractions between the molecules, so does not need as much energy to boil.

Ethane is a gas at room temperature. Ethanol is a liquid at room temperature

Ethane as a gas is not soluble in water, as there are no attractions between ethane and water.

Ethanol is an alcohol that is soluble in water because the (OH) part of ethanol is attracted to the water molecules.

Fermentation involves the conversion of a solution of sugar molecules (in water) into ethanol and carbon dioxide in warm, anaerobic conditions using yeast as a catalyst. Yeast is a living organism and requires warmth and moisture to carry out life processes. Yeast metabolises / converts the sugars to alcohol when it is starved of oxygen. The yeast dies when the alcohol levels become too high.

\[
C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2
\]

**ETHANOL (2012)**

(Accept appropriate condensed or stick structures.)

Fermentation involves the conversion of a solution of glucose molecules into ethanol and carbon dioxide in warm, anaerobic conditions using yeast as a catalyst.

\[
C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2 \text{ or } C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2
\]

Ethanol undergoes complete combustion (with sufficient oxygen) to produce carbon dioxide and water.

\[
C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O
\]

Complete combustion produces CO₂, which is a greenhouse gas. CO₂ contributes to the greenhouse effect, which leads to an increase in the amount of infra-red radiation trapped in the atmosphere.

An increase in the concentration of CO₂ on Earth is believed to lead to global warming and issues around climate change. Some of the issues include extreme weather events, melting of ice at the poles, and decreased biodiversity.

The greenhouse effect is responsible for the Earth’s average temperature and is one of the reasons life exists on this planet.

(Water vapour, H₂O gas, has also been shown to contribute to the greenhouse effect. When clouds are present in the atmosphere, more infra-red radiation is trapped.)
Properties of Carbon Compounds (2011)

Hexane has 6 carbons and is a bigger molecule, so it would be slightly harder to vaporise and therefore ignite and its size means it would likely burn with an orange flame producing soot.

Hexane forms 2 layers when mixed with water (immiscible / insoluble) because there are no attractive forces between the water and the hexane molecules to allow solubility.

Ethanol has only 2 carbons, so it is easy to ignite and will burn with an almost colourless flame.

Ethanol is soluble (miscible) in water because there are attractive molecules between ethanol and water.

Ethanol will boil before hexane as it has less mass and hence weaker attractive forces between the molecules.