Student Booklet

C5.1 Carbon Chemistry

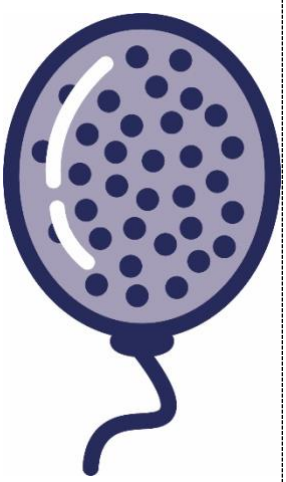
Combined Science

Science
Mastery

ArkCurriculum+

The Big Idea

Carbon Chemistry



What is crude oil actually made from? Why is so useful? How can we separate it and use it for different things? How is crude oil related to petrol and other fuels?

Organic chemistry is the study of the structure and properties of compounds that contain carbon. One of the biggest sources of carbon compounds is crude oil, which can be separated into many different compounds called hydrocarbons. Humans use these hydrocarbons for many different purposes.

This is the **sixth** unit we are studying as part of the big idea: **Structure Determines Properties.**

In this unit we will learn about what crude oil is and how it can be separated into different useful products. We will learn about different groups of hydrocarbons that can be obtained by fractional distillation of crude oil and the properties of these compounds and the different reactions they are involved in. We will also look at how some of these products can be made into useful polymers.

Chemistry students will also look at other groups of compounds, including alkenes, alcohols and carboxylic acids and reactions involving these compounds.

We will develop our skills in this unit by practising drawing models of covalent bonding in molecules. We will also revisit distillation as a method of separating a mixture based on the boiling points of the substances in it.

TASKS:

What subject will this unit focus on? BIOLOGY CHEMISTRY PHYSICS

(Circle the correct subject)

There are lots of keywords underlined above. List these into the two columns:

Words I know	Words I haven't seen before

To answer before the unit:

1. What are you most excited to learn about in this topic?

   _____

   _____

   _____

2. What do you already know about this topic?

   _____

   _____

   _____

3. Why do you think it's important to learn that structure determines properties?

   _____

   _____

4. What knowledge from previous science lessons might help us?

   _____

   _____

   _____

5. What questions do you have about this topic?

   _____

   _____

To answer at the end of the unit:

1. Tick off any words in the 'words I haven't seen before' column that you are now confident with. Circle any you still need more practice to use.

2. What have you most enjoyed about this unit?

   _____

   _____

   _____

3. What more would you like to learn about bonding as part of the big idea: 'Structure Determines Properties'?

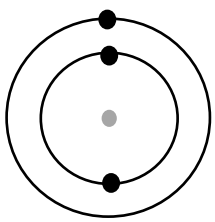
   _____

   _____

Pre-Test

1. The atomic structure of elements relates to their position on the Periodic Table.

   In which group of the Periodic Table would you find the element represented by this electronic configuration? [1]

   Tick (✓) **one** box.

   A. Group 2 ☐

   B. Group 3 ☐

   C. Group 1 ☐

2. Which is the correct definition of a compound?

   Tick (✓) **one** box. [1]

   A. Two or more elements mixed together ☐

   B. Two or more elements chemically bonded together ☐

   C. A group of non-metal atoms bonded together ☐

3. Which is the correct definition of a molecule?

   Tick (✓) **one** box. [1]

   A. A group of metals atoms bonded together ☐

   B. A group of metal and non-metal atoms bonded together ☐

   C. A group of non-metal atoms bonded together ☐

4. Which type of bonding would be found in a molecule of oxygen?

Tick (✓) **one** box. [1]

A. Covalent ☐

B. Ionic ☐

C. There would be no bonding ☐

5. Which type of bonding would be found in sodium chloride?

Tick (✓) **one** box. [1]

A. Covalent ☐

B. Ionic ☐

C. Metallic ☐

6. Which statement is true of covalent substances?

Tick (✓) **one** box. [1]

A. They contain non-metal atoms ☐

B. They contain metal atoms ☐

C. They contain metal and non-metal atoms ☐

7. What type of atoms make up both diamond and graphite?

Tick (✓) **one** boxes. [1]

A. oxygen ☐

B. hydrogen ☐

C. carbon ☐

D. copper ☐

8. Choose the correct electronic configuration of a carbon atom.
The atomic number of carbon is 6. [1]

Tick (✓) **one** box.

A. 2,4 ☐

B. 2,2,2 ☐

C. 2,8 ☐

9. Choose the best explanation for why noble gases are unreactive. [1]

Tick (✓) **one** box.

A. They all have 8 electrons in their outer shell ☐

B. They have a stable electron arrangement ☐

C. They are neutral because they have equal numbers of protons and electrons ☐

10. Define 'polymer'.
Tick (✓) **one** box. [1]

A. A polymer is a type of plastic ☐

B. A polymer is a long chain molecule made up of many units ☐

C. A polymer is a type of plastic that melts when heated ☐

End of Unit Pre-Test. Turn over to see the answers. Give yourself a mark out of 10.

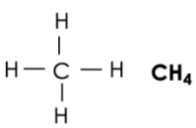
Qu	Answer	Marks
1	C	1
2	B	1
3	C	1
4	A	1
5	B	1
6	A	1
7	C	1
8	A	1
9	B	1
10	B	1

Knowledge Organiser

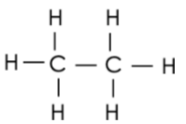
Crude Oil and Hydrocarbons

1. Crude oil is a **finite** resource found in **rocks**.
2. Crude oil is the remains of an ancient **biomass** consisting mainly of **plankton** that was buried in mud.
3. Crude oil is a mixture of a very large number of compounds. Most of the compounds in crude oil are hydrocarbons.
4. **Hydrocarbons** are molecules made up of **hydrogen** and **carbon** atoms only.
5. Most of the hydrocarbons in crude oil are hydrocarbons called **alkanes**.
6. The general formula for the homologous series of alkanes is C_nH2_{n+2}
7. The first four members of the alkanes are methane, ethane, propane and butane.
8. Many useful materials on which modern life depends are produced by the **petrochemical industry**, such as solvents, lubricants, polymers, detergents.
9. The vast array of natural and synthetic carbon compounds occur due to the ability of carbon atoms to form families of similar compounds.

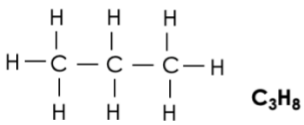
Methane Monkeys



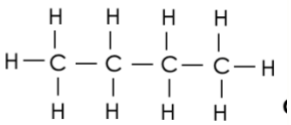
Ethane Eat

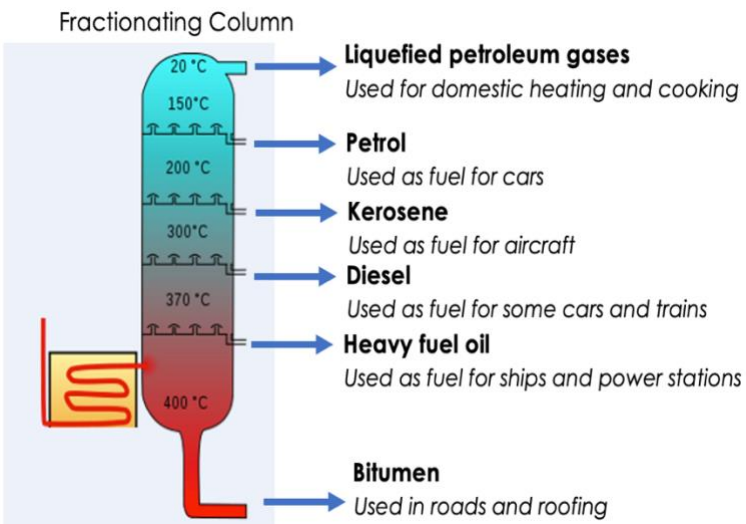


Propane Peanut



Butane Butter





Fractional Distillation

10. The many hydrocarbons in crude oil may be separated into **fractions**, each of which contains molecules with a **similar number of carbon atoms**, by fractional distillation.
11. The fractions can be processed to produce fuels and feedstock for the petrochemical industry.
12. Many of the fuels on which we depend for our modern lifestyle, such as **petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases**, are produced from crude oil.
13. During fractional distillation, a **fractionating column** is used. This column has **condensers** at varying heights.
14. A fractionating column is **hot** at the **bottom** and **cooler** at the **top**
15. Substances with **high boiling points condense** at the **bottom** and those with **low boiling points condense** at the **top**
16. During fractional distillation, crude oil is **evaporated**. Its **vapours condense at different temperatures** in the fractionating column.
17. Each fraction produced during fractional distillation has a similar number of carbons (or size of hydrocarbons)

18. Some properties of hydrocarbons depend on the size of their molecules, including boiling point, viscosity and flammability. These properties influence how hydrocarbons are used as fuels.
19. **Boiling point, viscosity and flammability** change with **increasing molecular size.**

Combustion of Hydrocarbons

20. The combustion of hydrocarbon fuels **releases energy**.
21. During combustion, the carbon and hydrogen in the fuels are oxidised.
22. The complete combustion of a hydrocarbon produces carbon dioxide and water.
23. The general word equation that describes the complete combustion of an alkane is:

alkane + oxygen → carbon dioxide + water

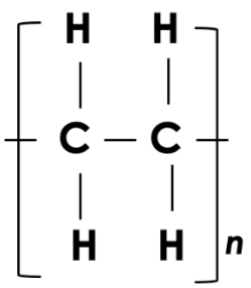
24. Complete combustion reactions of alkanes can be represented by balanced symbol equations, for example:
    $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$
25. Incomplete combustion can occur if there is not enough oxygen. In this case, carbon, carbon monoxide is produced.

Cracking

26. Hydrocarbons can be bro**ken down (cracked)** to produce **smaller**, **more useful** molecules.
27. Cracking can be done by various methods including **catalytic cracking** and **steam cracking**.
28. The products of cracking include **alkanes** and another type of hydrocarbon called **alkenes**.
29. **Alkenes** are more reactive than alkanes and **react with bromine water**, which is used as a test for alkenes.
30. If **alkenes** are present, the bromine water will turn from **orange** to **colourless**.
31. Alkenes are used to produce polymers and as starting materials for the production of many other chemicals.
32. There is a **high demand for fuels** with **small molecules** and so some of the products of cracking are useful as fuels.

Polymers

33. **Polymers** have very large molecules. The atoms in the polymer molecules are linked to other atoms by **strong covalent bonds**.
34. Polymers can be represented in the form:



where n is a large number

35. The intermolecular forces between polymer molecules are relatively strong and so these substances are solids at room temperature.
36. The properties of polymers depend on what monomers they are made from and the conditions under which they are made. For example, low density (LD) and high density (HD) poly(ethene) are produced from ethene.
37. **Thermosoftening polymers** melt when they are heated.
38. **Thermosetting polymers** do not melt when they are heated.

Glossary

Alkane	A hydrocarbon molecule with the general formula C_nH_{2n+2}. *Methane, ethane and propane are all **alkanes**.*
Alkene	A hydrocarbon molecule with the general formula C_nH_{2n}. ***Alkenes** contain a carbon-carbon double bond.*
Amino acid	A naturally occurring monomer that contains two different functional groups. ***Amino acids** can be joined together to make polypeptides and proteins.*
Catalyst	A substance that speeds up a chemical reaction without being used up. *Ethanol can be made from ethene, but this requires a **catalyst**.*
Combustion	A reaction where a substance burns in oxygen. ***Combustion** of alkanes produces carbon dioxide and water.*
Covalent bonding	The type of bonding found between non-metals, where electrons are shared to provide full outer shells. ***Covalent bonding** is found in both covalent molecules and giant covalent structures.*
Cracking	The process by which longer hydrocarbon chains are broken down into shorter hydrocarbons. ***Cracking** produces an alkane and an alkene.*
Crude oil	A finite resource found in rocks made from the ancient biomass of plankton. ***Crude oil** is a non-renewable resource that is used to provide fuels and make plastics.*

Fractional distillation	The process by which crude oil is separated into groups of similar compounds based on their boiling points. *During **fractional distillation**, crude oil is evaporated and fractions condense at different temperatures.*
Functional group	An atom or group of atoms that is responsible for the chemical properties of a compound. *Alcohols, alkenes and carboxylic acids all contain a **functional group**.*
Homologous series	A group of compounds that have similar chemical properties and the same general formula. *The alkanes are a **homologous series** that all have the general formula C_nH_{2n+2}.*
Hydration	A process which adds water. *Alcohols can be made from alkenes by **hydration**.*
Hydrocarbon	A molecule that contains carbon and hydrogen atoms only. *Alkenes and alkanes are **hydrocarbons**.*
Intermolecular forces	Attractive forces that hold molecules of a substance together. *Covalent molecules have low melting and boiling points because little energy is required to overcome the **intermolecular forces**.*
Molecule	A small group of non-metal atoms chemically joined together *There are millions of **molecules** of water in a swimming pool.*
Monomer	A repeating subunit used to make a polymer. *Glucose is the **monomer** that makes up starch (a polymer).*
Physical property	A property of a substance that can be observed at any time *A **physical property** of iron is that it is hard.*

Polymer	A substance made up of repeating subunits (monomers). *Plastic is a **polymer**.*
Saturated	A compound that contains only carbon-carbon single bonds. *Alkanes are **saturated** as they contain only single bonds between carbon atoms.*
Thermosetting	Polymers that do not melt when they are heated. *A **thermosetting** plastic's shape cannot be changed.*
Thermosoftening	Polymers that melt when they are heated. *The shape of a **thermosetting** plastic can be changed when it is heated.*
Unsaturated	A compound that contains one or more carbon-carbon double (or triple) bonds. *Alkenes are **unsaturated** as they contain a double bond between carbon atoms.*
Viscosity	A measure of a substance's resistance to flow or how easy it is to pour. *Water has a low **viscosity**, so is not very viscous, but honey has a high viscosity and is very viscous.*

Prior Knowledge Review

Do Now

1. State the chemical symbol for carbon.
2. Carbon has an atomic number of 6. State its electron configuration.
3. State the type of bonding found in water.
4. Give an example of a giant covalent network.
5. Define a compound.

Drill:

1. State the chemical formula for carbon dioxide.
2. Name the type of bonding found in carbon dioxide.
3. Draw a dot and cross diagram to show the bonding in a molecule of carbon dioxide.

Read Now:

Covalent bonding takes place between non-metal atoms, where they share electrons to achieve a full outer shell and stable electron arrangement. Some covalent structures are molecules, which are small groups of non-metal atoms held together by strong covalent bonds. Some molecules can actually be very large, including one of the largest naturally-occurring molecules: DNA. Covalent bonding can also be found in giant covalent structures, such as diamond and graphite, which involve huge numbers of atoms covalently bonded to other atoms.

1. Identify the type of elements between which covalent bonds are formed.
2. Explain why atoms make bonds.
3. Explain what is meant by a stable electron arrangement.
4. Define a molecule.
5. Give an example of a giant covalent structure.

Covalent bonding

What type of elements form covalent bonds? _____

What happens to the electrons in a covalent bond? _____

How many electrons are in one covalent bond? _____

Draw a dot and cross diagrssm for a molecule of

a) hydrogen

b) Chlorine

c) Hydrogen bromide (HBr)

The structure of simple covalent substances

What simple covalent substances consist of? _____

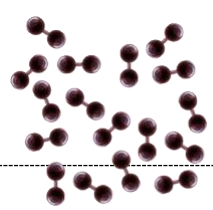
What holds the atoms together?_____

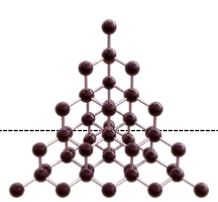
What holds the molecules together? _____

Give three names of simple covalent substances

Properties of covalent substances

Name the two types of covalent substances. Label the diagrams with the name of each.





A: _____ B _____

For each statement write A or B or both or neither

1. Low melting and boiling point
2. May conduct electricity
3. Liquid or gas at room temperature
4. Do not conduct electricity
5. Solid at room temperature
7. High melting and boiling point

Drill

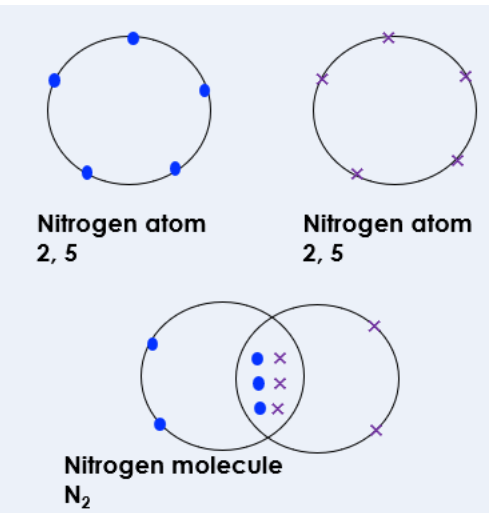
1. What type of elements are bonded during covalent bonding?
2. What happens during covalent bonding?
3. How is a single covalent bond represented?
4. How is a double covalent bond represented?
5. What is a double covalent bond?
6. What is the formula for methane?
7. State one example of a simple covalent substance.
8. What state of matter are simple covalent substances at room temperature?
9. Are covalent bonds weak or strong?
10. Name the forces that act between molecules in a simple covalent substance.
11. Explain the electrical conductivity of water.

I: Drawing covalent bonding diagrams

Use dot-and-cross diagrams to show the covalent bonding in a nitrogen molecule, N_2

Steps to Success

1. Draw the electronic configuration of the reacting atoms using dots for one type of atom and crosses for the other. Only draw the valance shell.
2. Count how many electrons each atom will need to share in order to get a full valance shell.
3. Draw the atoms overlapping with any shared electrons in the middle



We: Drawing covalent bonding diagrams

Use dot-and-cross diagrams to show the covalent bonding in an oxygen molecule, O_2

You: Drawing covalent bonding diagrams

Use dot-and-cross diagrams to show the covalent bonding in an ammonia molecule, NH_3

Exit Ticket

1. Which answer correctly defines covalent bonding?

- ❑ A. Covalent bonding occurs where two or more non-metal atoms share pairs of electrons in order to achieve a stable electronic configuration
- ❑ B. Covalent bonding occurs where two or more metal atoms share pairs of electrons in order to achieve a stable electronic configuration
- ❑ C. Covalent bonding occurs where electrons are transferred from one atom to another in order to achieve a stable electronic configuration

2. How many pairs of electrons are shared, and how many covalent bonds are shown in this diagram?

- ❑ A. 4 pairs of electrons are shared, and there are two single covalent bonds
- ❑ B. 2 pairs of electrons are shared, and there are two double covalent bonds
- ❑ C. 4 pairs of electrons are shared, and there are two double covalent bonds

3. Why doesn't pure water conduct electricity?

- ❑ A. It isn't a solid
- ❑ B. Pure water does conduct electricity
- ❑ C. It does not contain any free electrons

Crude Oil and Hydrocarbons

Do Now

1. State the type of elements that form covalent bonds.
2. Describe what happens to electrons when a covalent bond is formed.
3. Define a compound.
4. Define a molecule.
5. Calculate the relative formula mass of methane (CH_4). C=12, H=1

Drill:

Here are some common chemical formulae: CO_2, H_2O, O_2, NaCl, $Ca(OH)_2$.

1. Identify which of these formulae represent elements.
2. Identify which of these formulae represent compounds.
3. Identify which of these formulae would form molecules.

Read Now:

Crude oil is one of the most important energy sources in the world and is used in many aspects of everyday life, from fuel and heating, to petrochemicals, tarmac for roads and plastics. Crude oil is a fossil fuel found deep underground rocks, so it is a finite or non-renewable resource. It is made of the remains of ancient biomass that lived and died millions of years ago. It is mainly from plankton, which was buried under many layers of mud. Crude oil itself is a mixture of different compounds called hydrocarbons. Crude oil is a very valuable resource, sometimes described as 'liquid gold' because it is so valuable. 5 countries are responsible for nearly half the global production of crude oil: the USA, Saudi Arabia, Russia, Iran and Canada.

1. State how crude oil is used in everyday life.
2. Describe where crude oil is found.
3. Describe what crude oil is made from.
4. Explain whether crude oil is a renewable or non-renewable resource.

5. Name the countries that are the largest producers of crude oil.

Crude Oil and Hydrocarbons

Give two uses of crude oil

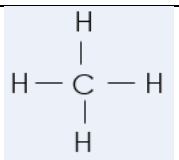
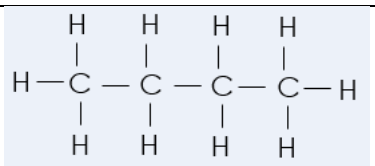
_____

What type of resource is it? _____

Is crude oil an element, compound or mixture?_____

Define hydrocarbon

Complete the table below

Name of alkane	**Formula**	**Displayed formula**
Methane		
	C_2H_6	
propane		
		

Drill

1. Describe where crude oil is found.
2. Describe what crude oil is made from.
3. Explain why crude oil is a mixture.
4. Define a hydrocarbon.
5. State the general formula of the alkanes.
6. Name the alkane with 1 carbon.
7. Name the alkane with 4 carbons.
8. Draw the displayed formula for the alkane with 3 carbons

I: Alkane Formulae

We can use the general formula of alkanes to determine how many atoms are in a given molecule.

What is the general formula of the alkanes?

How many hydrogen atoms would there be in an alkane with 5 carbons?

How many carbon atoms would there be in an alkane with 14 hydrogens?

We do: Alkane Formulae

How many hydrogen atoms would there be in an alkane with 8 carbons?

How many carbon atoms would there be in an alkane with 22 hydrogens?

You do: Alkane Formulae

How many hydrogen atoms would there be in an alkane with 12 carbons?

How many carbon atoms would there be in an alkane with 38 hydrogens?

Exit Ticket

1. Which alkane is this?
    - ❑ A. Ethane
    - ❑ B. Propane
    - ❑ C. Butane
2. An alkane has 15 carbons. How many hydrogen atoms would it have?
    - ❑ A. 30
    - ❑ B. 32
    - ❑ C. 34
3. What is crude oil?
    - ❑ A. A finite resource formed from ancient plankton biomass
    - ❑ B. A finite resource formed from rocks
    - ❑ C. A finite resource containing compounds of carbon and water

Fractional Distillation

Do Now

1. Define a hydrocarbon.
2. Name the alkane that contains four carbon atoms.
3. State the general formula of the alkanes.
4. Describe what happens when a covalent bond is formed.
5. Explain why covalent molecules have relatively low boiling points.

Alkane	Melting point (°C)	Boiling point (°C)
Methane	-182	-164
Ethane	-183	-89
Propane	-190	-42
Butane	-138	-1

Drill:

The melting and boiling points of some of the alkanes are given in the table.

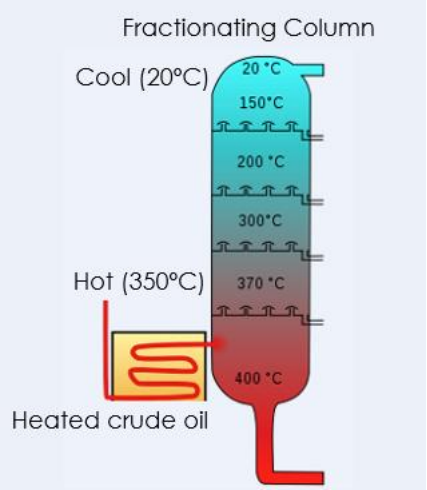
1. Identify which state of matter these alkanes would be at room temperature (20 °C).
2. Identify which state of matter these alkanes would be at -50°C.

Read Now:

Distillation is a method used to separate a mixture into the different compounds or elements within it based on their boiling points. For example, salt can be separated from sea water by distillation, as when it is heated the water will boil before the salt. The water vapour is then collected into a condenser where it cools down to form a pure liquid. Fractional distillation uses heating to separate the mixture of crude oil into its 'fractions', which are groups of different chemical compounds. Each of these fractions contains hydrocarbons of different lengths which are used for different functions. The shortest hydrocarbon molecules are used as gas fuels, while the longer hydrocarbon molecules are used for heavy fuel oil or bitumen for making tar for roads.

1. State the physical property that distillation uses to separate mixtures.
2. Describe what happens during distillation.
3. Explain why crude oil is a mixture.
4. Explain what is meant by a 'fraction' of crude oil.
5. Give a use of the shorter hydrocarbon chains.

Fractional Distillation



Fill in the key words in the method

Crude oil is h_____and v_____

The column is h_____ at the bottoma and c_____ at the t_____.

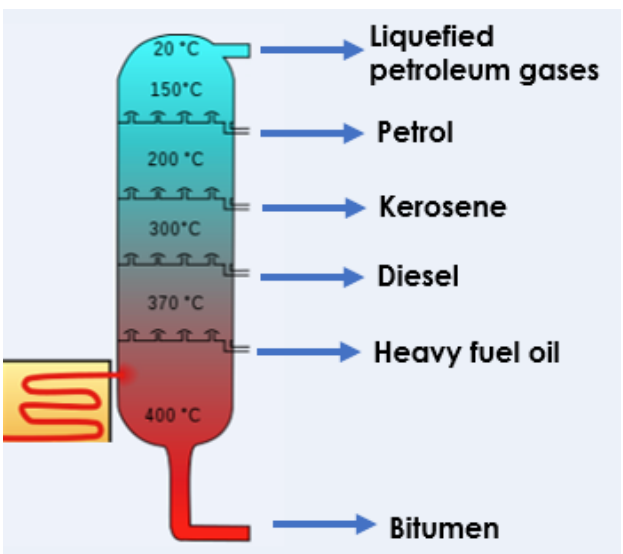
The smaller molecules have _____ boiling points, so they rise to the _____ of the column wheras larger molecules have a _____ boiling point so styay at the bottom.

As the mixture rises it c_____ and c_____.

The vapours will consense at different t_____ because the hydrocarbons have different b_____ p_____.

Give a use of each fraction

Label the column to show where larger molecules will be and where smaller moelcules will be



Drill

1. Explain why crude oil is a mixture.
2. Name the piece of equipment used to separate crude oil into fractions.
3. State the physical property that fractions are separated based on.
4. Name the fraction with the smallest molecules.
5. Name the fraction with the largest molecules.
6. Give two fractions that are used as fuels for transport.
7. Describe the relationship between size of molecules and boiling point.
8. Explain the relationship between size of molecules and boiling point.

Describe: ***to recall facts, events or processes in an accurate way***

We: Describe how volatility changes with increasing molecule size in fractions of crude oil.

_____

_____

_____

You: Describe how boiling point changes with increasing molecule size in fractions of crude oil.

_____

_____

_____

Exit Ticket

1. How does fractional distillation separate crude oil into fractions?
    - ❑ A. Each fraction has a different viscosity
    - ❑ B. Each fraction has a different melting point
    - ❑ C. Each fraction has a different boiling point
2. Which fraction is used for producing material for roads?
    - ❑ A. Liquefied gases
    - ❑ B. Petrol
    - ❑ C. Bitumen
3. Which best explains the pattern in boiling points of the alkanes?
    - ❑ A. As the alkanes get longer, boiling points increase because there are more atoms
    - ❑ B. As the alkanes get longer, boiling points decrease because they are more likely to be liquid
    - ❑ C. As the alkanes get longer, boiling points increase because the intermolecular forces increase

Combustion of Hydrocarbons

Do Now:

1. Name the process used to separate crude oil.
2. Explain how this process separates crude oil.
3. Describe the pattern of viscosity as hydrocarbon chains get longer.
4. Name the alkane that contains two carbon atoms.
5. Explain the difference between an exothermic and an endothermic reaction.

Drill:

1. Name the compound with the formula CH_4.
2. Calculate the relatie formula mass of propane. C=12, H=1
3. Calculate the percentage by mass of carbon in ethane.

Read Now:

Many of the hydrocarbons in crude oil are used as fuels. A fuel is any substance that is burned to release energy. Combustion is the chemical reaction that takes place when a substance burns in air, so when hydrocarbons are burned, these are combustion reactions. These reactions are useful as they are highly exothermic, which means they transfer a large amount of energy to the surroundings. The main advantage of burning hydrocarbons is this release of energy, although there are also disadvantages. Combustion of hydrocarbons produces carbon dioxide as a product, which contributes to global warming. Scientists and companies are developing new fuels that are less harmful to the environment, but humans are still dependent on crude oil as a fuel source for heating homes, gas for cooking and fuel for cars and other modes of transport.

1. Explain what is meant by a fuel.
2. Explain what is meant by a combustion reaction.
3. Explain why combustion of hydrocarbons is a useful chemical reaction.
4. Give a disadvantage of burning hydrocarbons.
5. Describe two uses of hydrocarbons for humans.

Complete Combustion

Alkane + oxygen → _____ _____ + water

This reaction is e_____

Incomplete Combustion

Incomplete combustion occus where there is a limited supply of _____

Incomplete combustion produces water, c_____ m_____ and c_____

The toxic product of incomplete combustion is _____

Incomplete combustion is _____ exothermic than complete combustion

IIf sulfur is present you may also get _____ produced.

$$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$$

Balancing combustion equations

Always balance C, then H then O!

$$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$$

Number of atoms	Element	Number of atoms
	C	
	H	
	O	

Drill

1. Name the substance that hydrocarbons react with during combustion.
2. State the two products of combustion of hydrocarbons.
3. Identify which product is linked to global warming.
4. Explain the difference between complete and incomplete combustion.
5. Describe how sulfur dioxide is formed.
6. State the environmental problem associated with sulfur dioxide.
7. Explain which fractions of crude oil can be burned most easily.

I: Combustion Reactions

What is the chemical formula for methane?

Methane burns in air.

Draw the displayed formula for methane.

Write a word equation for the combustion of methane.

Write a symbol equation for the combustion of methane.

Balance the symbol equation.

We: Combustion Reactions

What is the chemical formula for propane?

propane burns in air.

Draw the displayed formula for propane.

Write a word equation for the combustion of propane.

Write a symbol equation for the combustion of propane.

Balance the symbol equation.

You: Combustion Reactions

Pentane (C_5H_{12}) burns in air.

Draw the displayed formula for pentane.

Write a word equation for the combustion of pentane.

Write a symbol equation for the combustion of pentane.

Balance the symbol equation.

Exit Ticket

1. Which is the correct general equation for the combustion of alkanes?
    - ❑ A. Alkane + water → oxygen + carbon dioxide
    - ❑ B. Alkane + oxygen → water + carbon dioxide
    - ❑ C. Alkane + air → water + carbon dioxide
2. Which is an advantage of burning hydrocarbons?
    - ❑ A. It releases lots of energy
    - ❑ B. It releases carbon dioxide
    - ❑ C. It releases water
3. When does incomplete combustion take place?
    - ❑ A. If there is not enough oxygen
    - ❑ B. If there is not enough alkane
    - ❑ C. If there is not the same amount of alkane and oxygen

Cracking

Do Now

1. State the general equation for the combustion of alkanes.
2. Describe when incomplete combustion takes place.
3. Name the alkane with the chemical formula C_2H_6
4. Describe what short chain hydrocarbons are used for.
5. Draw the structural formula for methane.

Drill:

1. Determine how many hydrogen atoms would be in an alkane with 14 carbon atoms.
2. Determine how many hydrogen atoms would be in an alkane with 60 carbon atoms.
3. Determine how many carbon atoms would be in an alkane with 104 hydrogen atoms.

Read Now:

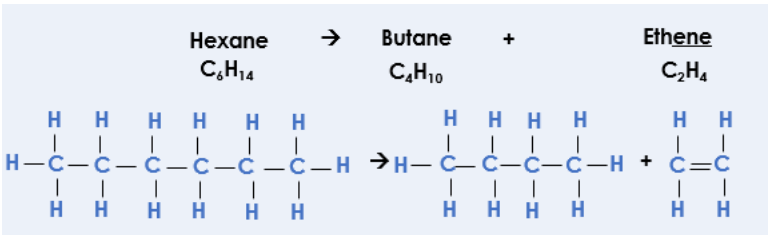
According to a survey from 2022, there are about 1.45 billion cars in the world. That means that over 17 % of the human population has a car, but the cars are not spread evenly as some cars have many more cars than others. Many of these cars have petrol engines, which burn petrol as the fuel. Petrol contains relatively short chain hydrocarbons, such as octane (C_8H_{18}). As there is such high demand for these shorter hydrocarbons, some larger hydrocarbons can be broken down in chemical reactions to form these shorter chains. This type of chemical reaction is called cracking, and produces a shorter chain hydrocarbon as well as another type of hydrocarbon called an alkene. Alkenes are also useful for many different things, including making plastics.

1. State how many cars there are in the world.
2. Name an alkane found in petrol.
3. Explain why there is high demand for petrol.
4. Describe what happens in a cracking reaction.
5. Name the other type of product from a cracking reaction.

Cracking

_____ molecules are in high demand as they are used as _____

Cracking is _____



Cracking produces both alkanes and _____. These are different to alkanes because they have at lease one _____. We say alkenes are u_____

To test for alkenes we can use _____ water.
If an alkene is present, it will turn from _____ to _____
The two types of cracking are _____ and _____

Drill

1. Explain the difference between supply and demand.
2. Describe what happens during cracking.
3. Name the two types of product produced through cracking.
4. Give two reasons why cracking is useful.
5. Describe what happens when bromine water is added to alkanes.
6. Describe what happens when bromine water is added to alkenes.
7. Explain why alkenes are described as unsaturated.
8. Name two different methods of cracking.
9. Describe the conditions needed for catalytic cracking.
10. Describe the conditions needed for steam cracking.

I: Determining the products of cracking

Dodecane ($C_{12}H_{26}$) is cracked to produce octane (C_8H_{18}). **$C_{12}H_{26} \rightarrow C_8H_{18}$ +** _____

What is the chemical formula for the other product formed? Write it on the lane
*What homologous group does the other product belong to?*_____
Explain how you could tell the difference between the two products once they were separated.

_____
_____
_____

*Explain why it is useful to crack dodecane***.**

_____
_____

We: Determining the products of cracking

Dodecane ($C_{12}H_{26}$) is cracked to produce heptane (C_7H_{16}). **$C_{12}H_{26} \rightarrow C_7H_{16}$ +** _____

What is the chemical formula for the other product formed? Write it on the lane
*What homologous group does the other product belong to?*_____
Explain how you could tell the difference between the two products once they were separated.

_____
_____
_____

*Explain why it is useful to crack dodecane***.**

_____
_____

You: Determining the products of cracking

Octane (C_8H_{18}) is cracked to produce hexane (C_6H_{14}).

$C_8H_{18} \rightarrow C_6H_{14}$ + _____

What is the chemical formula for the other product formed? Write it on the lane
*What homologous group does the other product belong to?*_____
Explain how you could tell the difference between the two products once they were separated.

_____
_____
_____

*Explain why it is useful to crack dodecane***.**

_____
_____

Mark it: Looking at a student exam answer

1. Read the question and the student's answer carefully.

2. Use the mark scheme to award the student a number of marks and annotate their answer with suggestions to improve.

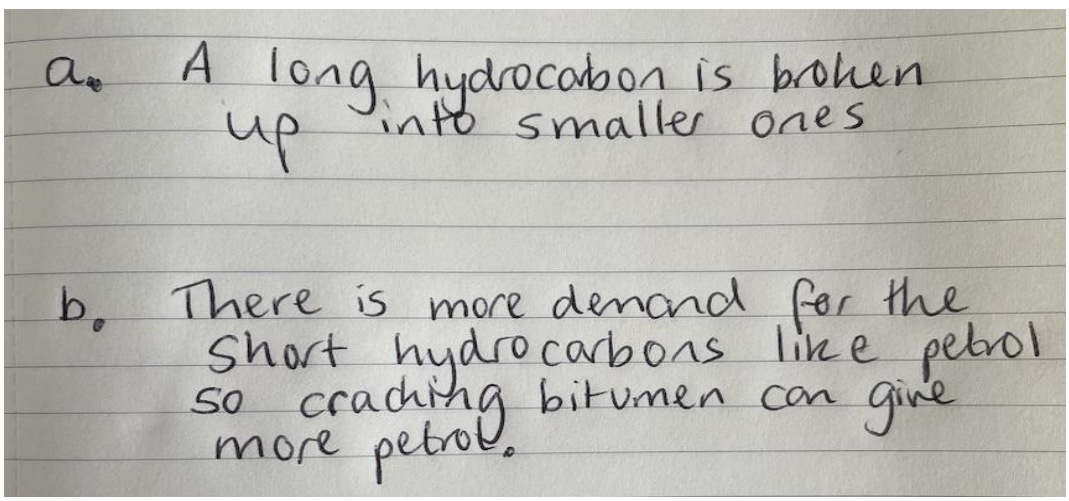
Stretch: Rewrite the answer to show how it should be done!

Question: The table below gives some information about some of the fractions in crude oil.

Fraction	**Length of hydrocarbons (number of carbon atoms)**	**% in crude oil**	**% demand**
Gas	1-4	3	14
Petrol	5-8	7	26
Kerosene	9-15	12	18
Diesel	16-24	24	20
Bitumen	>25	54	22

a. The quantity of each fraction can be changed by cracking.
Describe what happens when a hydrocarbon is cracked and the conditions required **(4)**
b. Use information from the table to explain why cracking is useful. **(3)**

Student answer:



Marks awarded= _____

Mark scheme:

a.

Point	**Mark**
Long/large hydrocarbon chains are broken down	1
Into shorter chain hydrocarbons (alkanes)	1
And alkenes	1
A high temperature or catalyst is required	1

b.

Point	Mark
There is higher demand than supply of short chains (from crude oil)	1
So cracking can increase the supply of short chain hydrocarbons	1
Named example, e.g. only 7% of crude oil is petrol but it is over a quarter of the demand, so producing more petrol through cracking can meet this demand	1

Exit Ticket

1. Which explains why cracking is useful?
    - ❑ A. It increases demand for shorter hydrocarbon chains
    - ❑ B. It increases supply of shorter hydrocarbon chains
    - ❑ C. It separates crude oil into different useful fractions
2. What is the formula of the other product of this cracking reaction?

$C_{10}H_{22} \rightarrow C_8H_{18}$ + _____

- ❑ A. C_2H_4
- ❑ B. C_2H_6
- ❑ C. $C_{18}H_{40}$

3. What is the difference between alkanes and alkenes?
    - ❑ A. Alkanes have a C=C double bond
    - ❑ B. Alkenes have a C=C double bond
    - ❑ C. Alkenes contain more hydrogen atoms

Polymers

Do Now:

1. Define a hydrocarbon.
2. Name the type of bonding found in hydrocarbons.
3. State the general formula of the alkanes.
4. Describe how fractional distillation is used to separate crude oil.
5. Explain the difference between reusing and recycling.

Drill:

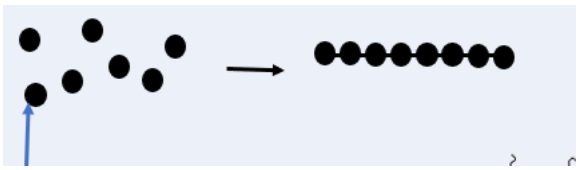
1. Describe the structure of diamond.
2. Describe the structure of graphite.
3. Explain why graphite conducts electricity but diamond does not.

Read Now:

The word polymer comes from Greek and means 'many parts'. A polymer is a very long molecule made up of many units. Polymers can be naturally occurring or synthetic (man-made) and we use many examples in our daily lives. One of the most important naturally occurring polymers is DNA, which is found in the nuclei of all our cells. Other naturally occurring polymers are proteins and starch. These naturally occurring polymers make up an important part of our diet, but they must be digested into small soluble products before being absorbed into our blood stream. Products made from synthetic polymers are all around us, including plastic products, silicone products, nylon and polyester clothing.

1. Define a polymer.
2. Define synthetic.
3. Give three examples of naturally occurring polymers.
4. Explain why naturally occurring polymers found in foods must be digested.
5. Give an example of a synthetic polymer.

Poly**mer**

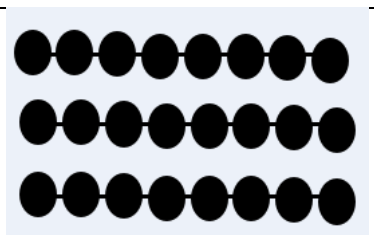
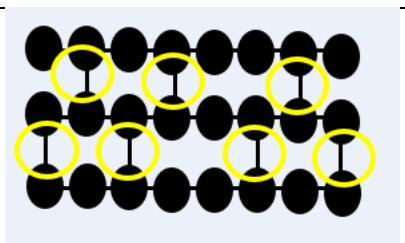


Properties of polymers

The properties of a polymer depend on two things:

- the -_____it is made from
- the _____ that the polymer is made in

Complete the table for thermosetting sand thermosoftening plastics

		
Type of polymer		
What happens when heated?		
Are there intermolecular forces between the polymer chains?		
Are there crosslinks (covalnt bonds) between the chains when heated?		
Are they suitable for recycling?		

Drill

1. What is a polymer?
2. What kind of bonding occurs between monomers in a polymer?
3. What does the n represent in the general formula for a polymer?
4. Name the forces that act between the polymer molecules.
5. State whether these forces are weak or strong
6. Describe the state of polymers at room temperature
7. What determines the properties of polymers?
8. What happens to thermosetting polymers when heated?
9. What happens to thermosoftening polymers when heated?
10. Explain why these polymers behave differently when heated.

We: Explain: ***to use scientific understanding to make something clear or state the reason for something happening***

Many recyclable plastic bottles are made from thermosoftening polymers.

Explain how the properties of a thermosoftening polymer make them suitable for recycling.

You: Explain: ***to use scientific understanding to make something clear or state the reason for something happening***

Firefighters' helmets are made from thermosetting polymers.

Explain how the properties of a thermosetting polymer make them suitable for this purpose

Exit Ticket

1. How many carbon atoms will the polymer represented by this diagram have?
   - ❑ A. 20
   - ❑ B. 40
   - ❑ C. 80
2. What is between polymer molecules?
   - ❑ A. Covalent bonds
   - ❑ B. Intermolecular forces
   - ❑ C. Electrostatic attraction
3. What is the difference between thermosetting and thermosoftening polymers?
   - ❑ A. Thermosoftening polymers melt when heated
   - ❑ B. Thermosetting polymers melt when heated
   - ❑ C. Thermosoftening polymers contain crosslinks

Independent Practice

Prior Knowledge Review

Section A

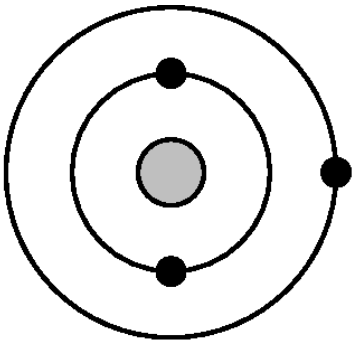
1. Choose the correct words from the box to complete the sentence.

You can use each work once, more than once or not at all.

elements	**metals**	**non-metals**	**ions**

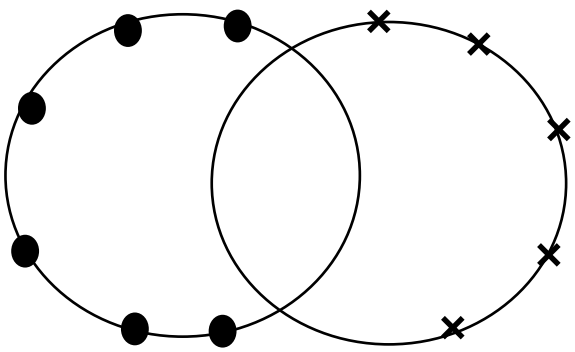
Covalent bonding occurs between _____ and _____.

2. Complete the electronic configuration diagram below to show 6 electrons on the outer shell.



3. Redraw the electronic configuration from question 2 above, but this time
    - Only draw the valance shell electrons
    - Draw the atom with a full outer shell

4. Complete the dot and cross diagram to show the bonding in a molecule of Chlorine gas, Cl_2.



Section B

5. Draw a dot-and-cross diagram to show the bonding in a molecule of water, H_2O.

6. Draw a dot-and-cross diagram to show the bonding in a molecule of methane, CH_4.

7. Draw a dot-and-cross diagram to show the bonding in a molecule of ammonia, NH_3.

Section C

8. Hydrochloric acid has the chemical formula HCl.

    a. Identify the type of bonding present in HCl.
    b. Draw a dot-and-cross diagram to show the bonding in HCl.
    c. Calculate the relative formula mass of hydrochloric acid.
    d. Calculate the percentage by mass of chlorine in HCl.
    e. Write a word equation to show what happens in the reaction between hydrochloric acid and sodium hydroxide.
    f. Write a balanced chemical equation for the reaction in Q5.
    g. Identify the type of bonding that would be present in each of the products of the reaction in Q5.

Crude Oil and Hydrocarbons

Section A

1. Choose the correct words from the box to complete the sentences.

compound	**mixture**	**hydrocarbons**	**mud**	**plankton**	**rocks**	**finite**	**infinite**

Crude oil is a _____ resource found deep underground. It is made from the biomass of ancient _____, which was buried under _____.

2. Choose the correct definition of a hydrocarbon.

   Tick (✓) **one** box.

   A. A compound made of hydrogen and carbon atoms ☐

   B. A compound made of water and carbon atoms ☐

   C. A mixture made of hydrogen and carbon atoms ☐

   D. A mixture made of water and carbon atoms ☐

3. State the general formula of the alkanes.

   _____

4. Choose the name of the alkane that contains three carbon atoms.

   Tick (✓) **one** box.

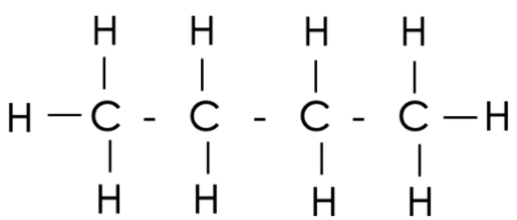
   A. Ethane ☐

   B. Propane ☐

   C. Butane ☐

5. Name the alkane shown by the structural formula below.

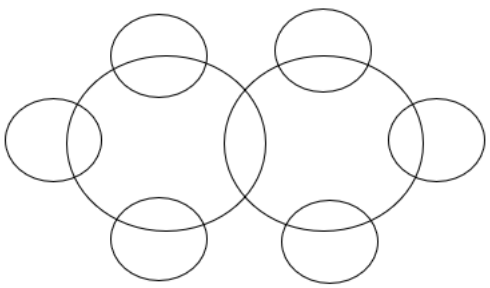
   _____



Section B

6. Methane and ethane are both alkanes.
   a. Draw the structural formulae for methane and ethane.

   b. Complete the dot and cross diagram to show the bonding in a molecule of ethane.



   c. Compare the structures of methane and ethane.

_____

_____

_____

_____

   d. The alkanes is a large family of compounds.
      Determine the chemical formula of an alkane with:
      i. 8 carbons

      _____

      ii. 24 carbons

      _____

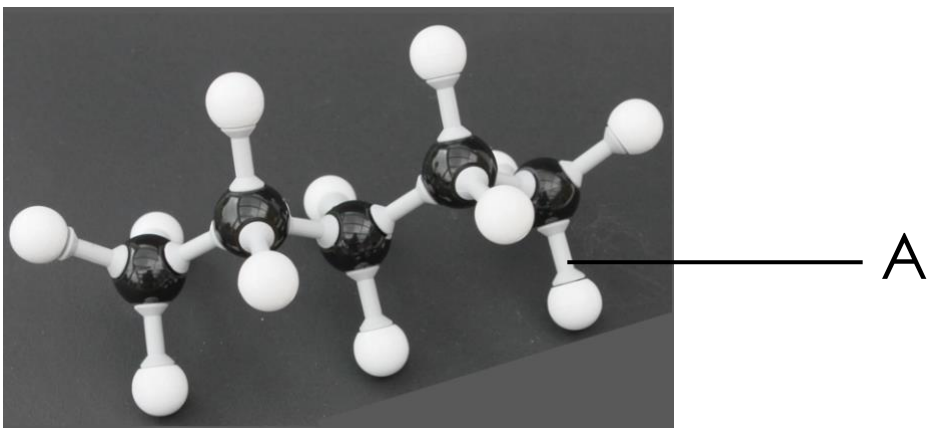
      iii. 36 hydrogens

      _____

iv. 20 hydrogens

_____

7. The image below shows a model of an alkane.



a. Determine the chemical formula of this alkane.

_____

b. Give an advantage of this model.

_____

_____

c. What is represented by the letter A?

_____

d. Explain why this alkane is a compound and a molecule.

Section C

8. Carbon has an atomic number of 6 and a mass number of 12.

    h. State the number of protons, neutrons and electrons in an atom of carbon.
    i. Draw the electronic configuration of a carbon atom.
    j. Explain why a carbon atom is neutral.
    k. Carbon's mass number is usually rounded to 12 but the relative atomic mass is actually 12.02. Explain why this is not a whole number.
    l. Compare the atomic structures of carbon-12 and carbon-14.

Fractional Distillation

Section A

1. Explain why crude oil is described as a mixture.

_____

_____

2. Choose the fraction of crude oil that has the lowest boiling point.

   Tick (✓) **one** box.

   A. Bitumen ☐

   B. Petrol ☐

   C. Liquefied petroleum gases ☐

3. Choose the option that correctly describes the pattern of viscosity in the fractions of crude oil.

   Tick (✓) **one** box.

   A. Viscosity increases as the size of molecules in a fraction increase ☐

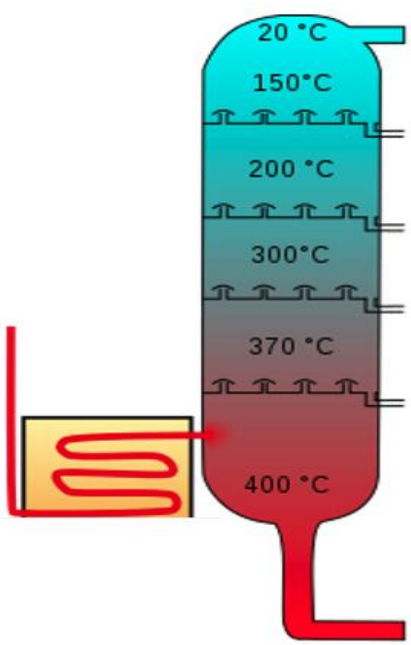
   B. Viscosity decreases as the size of molecules in a fraction increase ☐

   C. Viscosity increases as the size of molecules in a fraction decrease ☐

4. The image below shows a fractionating column.

   a. Add labels to the fractionating column to show where it is hottest and coolest.

   b. Add labels to the fractionating column to name each of the fractions collected at each condenser.



Section B

5. Fractional distillation is used to separate crude oil.
   a. Describe how fractional distillation separates crude oil.

_____

_____

_____

_____

   b. Describe the relationship between the size of molecules in a fraction and boiling point.

_____

_____

   c. Explain the relationship between the size of molecules in a fraction and boiling point.

_____

_____

_____

_____

6. The table below shows the boiling points of three alkanes.

Alkane	**Boiling point (°C)**
Pentane (C_5H_{12})	36
Decane ($C_{10}H_{22}$)	174
Pentadecane ($C_{15}H_{22}$)	271

a. What is an alkane?

_____

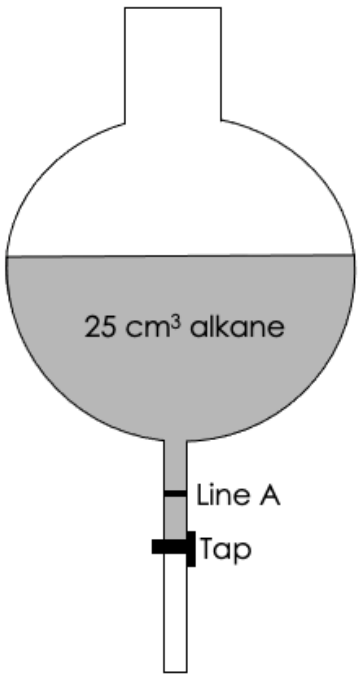
_____

b. What is the general formula for alkanes?

_____

c. Determine which state of matter pentane would be at room temperature (22 °C).

A student used the following experiment to investigate a property of these alkanes:



- Add 25 cm^3 of pentane to a separating flask (as shown)
- Start the timer as the tap is opened
- Record the time taken for the level of pentane to reach line A
- Repeat for decane and pentadecane

d. What property is the student investigating with this experiment?

_____

e. The student measured 5.2 seconds for pentane to reach line A.

Predict how the time taken for decane and pentadecane would compare.

Explain your answer.

_____

_____

_____

_____

Section C

7. Fractional distillation is used to separate crude oil into fractions, but there are many other uses of distillation.

   a. Describe how distillation is used in desalination.
   b. Give a disadvantage of using distillation for desalination.
   c. Give the name for water that is safe to drink.
   d. Explain the difference between water that is safe to drink and distilled water.
   e. Explain whether distilled water would conduct electricity.
   f. Draw a dot and cross diagram to show the bonding in water.
   g. Calculate the percentage by mass of oxygen in water.

Combustion of Hydrocarbons

Section A

1. Choose the correct definition of a hydrocarbon.
   Tick (✓) **one** box.

   D. A molecule that contains carbon and water atoms only ☐

   E. A molecule that contains carbon and hydrogen atoms only ☐

   F. A molecule that contains a mixture of carbon and hydrogen atoms ☐

2. Complete the chemical formula for propane.

   C__H___

3. Choose the substance that hydrocarbons react with during combustion.
   Tick (✓) **one** box.

   A. Air ☐

   B. Oxygen ☐

   C. Carbon dioxide ☐

4. Complete the general equation for the complete combustion of alkanes:

   Alkane + _____ → _____ _____ + _____

5. Describe what is needed for complete combustion of alkanes to take place.

   _____

   _____

Section B

6. Methane is a common hydrocarbon that is used as a domestic fuel.

   a. Write a balanced symbol equation for the complete combustion of methane.

   _____ + _____ → _____ + _____

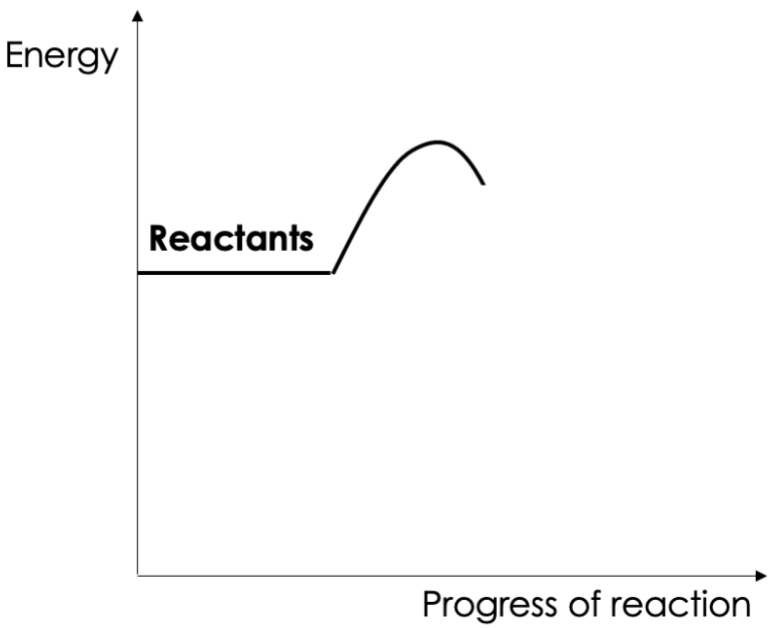
   b. Explain why the incomplete combustion of methane may be dangerous.

_____

_____

_____

   c. Complete the reaction profile for the combustion of methane.



   d. Explain your answer to question c.

_____

_____

_____

7. Petrol is used as a fuel in many cars. One of the compounds in petrol is octane (C_8H_{18}).

a. Complete the word equation for the reaction of octane that takes place in a car engine:

Octane + _____ → _____ + _____

b. Cars should use sulfur-free petrol. Explain why.

_____

_____

_____

c. Many scientists are concerned about one of the products of the complete combustion reaction of octane in car engines. Identify the product that is concerning scientists and explain why it is a concern.

_____

_____

_____

_____

The table below provides data on the composition of gases from the exhaust of a petrol engine.

Gas	Percentage
Nitrogen	67
Carbon dioxide	16
Carbon monoxide	1.5
Oxygen	0.5
Nitrogen oxides	0.15
Sulfur dioxide	0.02
Other gases	

d. Calculate the percentage of other gases present.

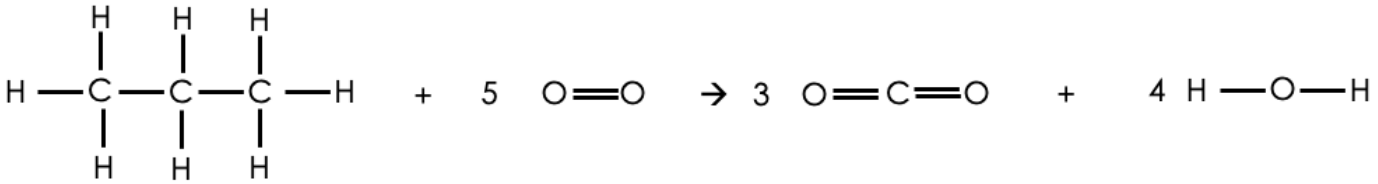
_____

e. Name the compound that makes up most of the other gases.

_____

Section C

8. Below shows the reaction between propane and oxygen. This reaction is exothermic as 2018 kJ/mol more energy is released when forming the bonds than is taken in to break the bonds in the reactants.



Bond	Bond Energy (kJ/mol)
C-H	413
O=O	498
C=O	799
O-H	464

a. Use the information given to calculate the C-C bond energy.
b. Calculate the mass of carbon dioxide that would be made when 100 g of propane burns in 600 g of oxygen.
Relative atomic masses:

Carbon = 12

Hydrogen = 1

Oxygen = 16

Cracking

Section A

1. Describe what happens when large hydrocarbon molecules are cracked.

_____

_____

2. Choose which of these is an alkene.

   Tick (✓) **one** box.

   A. Ethane ☐

   B. Ethene ☐

   C. Propane ☐

3. Give one difference between alkanes and alkenes.

_____

_____

4. What type of reaction is cracking?

   Tick (✓) **one** box.

   A. Combustion ☐

   B. Neutralisation ☐

   C. Decomposition ☐

5. The chemical equations below show some of the reactants and products of different cracking reactions.
   a. Determine the formula of the missing product in each case.

      i. $C_{10}H_{22} \rightarrow C_6H_{14}$ + _____

      ii. $C_6H_{14} \rightarrow C_2H_4$ + _____

      iii. $C_{14}H_{30} \rightarrow C_8H_{18}$ + _____

   b. Highlight all alkanes in one colour and all alkenes in another colour.

Section B

6. Crude oil is fractionally distilled. Fractions with larger molecules can then be cracked.

   Describe two differences between fractional distillation and cracking.

_____

_____

_____

_____

7. Decane ($C_{10}H_{22}$) is commonly cracked.

   a. Determine the formula of the other product formed when decane is cracked.

      $C_{10}H_{22} \rightarrow C_2H_4$ + _____

   b. Name the product with the formula C_2H_4.

_____

   c. C_2H_4 is an alkene. Explain how this could be tested.

_____

d. Give two conditions used for cracking decane.

8. The table below gives some information about fractions of crude oil.

Fraction	**Approximate % of crude oil**	**Approximate % of total demand**
LPG	4	6
Petrol	10	25
Kerosene	16	14
Diesel	20	20
Heavy fuel oil		18
	28	17

a. What does LPG stand for?

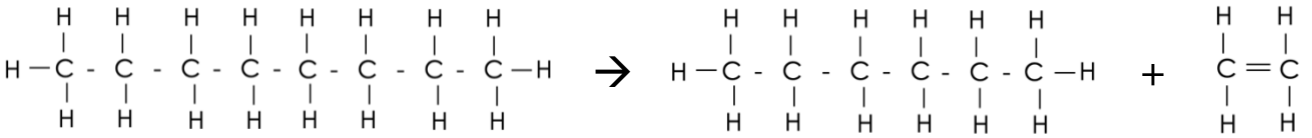
b. Complete the table by naming the missing fraction and calculating the approximate percentage of crude oil that is made up of heavy fuel oil.

c. Identify which of these fractions is the most flammable.

d. Use the information in the table to explain why it is useful to crack hydrocarbons.

9. The diagram below shows a chemical reaction.

Compound A Compound B Compound C



a. Compounds A, B and C are all what type of compound?

_____

b. What type of chemical reaction is shown by this diagram?

_____

c. Suggest one use for Compound B.

_____

d. Suggest one use for Compound C.

_____

Section C

10. Cracking is used to break long hydrocarbon chains into smaller hydrocarbon chains.
    a. Cracking takes place under high temperatures. Explain whether cracking is an exothermic or endothermic reaction.
    b. (HT) $C_{20}H_{42}$ can be cracked. The equation for the reaction is:

       $C_{20}H_{42} \rightarrow C_{16}H_{34} + 2\ C_2H_4$

       Calculate the mass of $C_{20}H_{42}$ needed to produce 40 kg of ethene.

       Relative atomic masses:
       C=12
       H=1

Polymers

Section A

1. What is the definition of a polymer?
   Tick (✓) **one** box.

   A. Repeating units that join together to make a long chain ☐

   B. Small molecules held together by intermolecular forces ☐

   C. A long molecule made up of many repeating units ☐

2. Give the name for repeating units that polymers are made from.

   _____

3. What polymer would be made from repeating units of ethene?

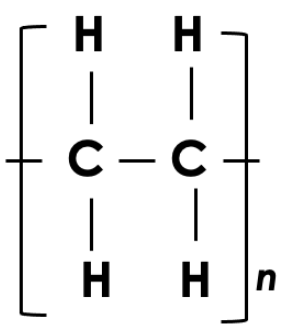
   Tick (✓) **one** box.

   A. poly(propene) ☐

   B. poly(ethene) ☐

   C. poly(ethane) ☐

4. Look at the diagram representing a polymer below.



   a. What does the single straight line in between the H and C represent?

   _____

   b. What does the 'n' represent?

   _____

Section B

5. What type of bonds are there in a polymer chain?

6. Describe the forces that occur <u>between</u> polymer chains.

7. What type of polymers melt when heated?

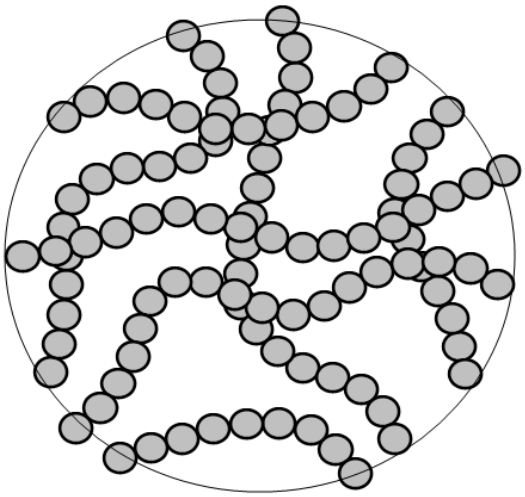
8. Draw the molecular formula for a polymer molecule with 50 carbon atoms.

9. Explain why thermosetting polymers are suitable as a material for a saucepan handle.

10. Thermosoftening polymers are used to make plastic bottles and food packing. Explain why thermosoftening polymers would not be suitable for storing hot food.

11. The diagrams below show models for the structures of a thermosetting polymer and a thermosoftening polymer.
Identify which is which and explain why.

A_____ **B**_____



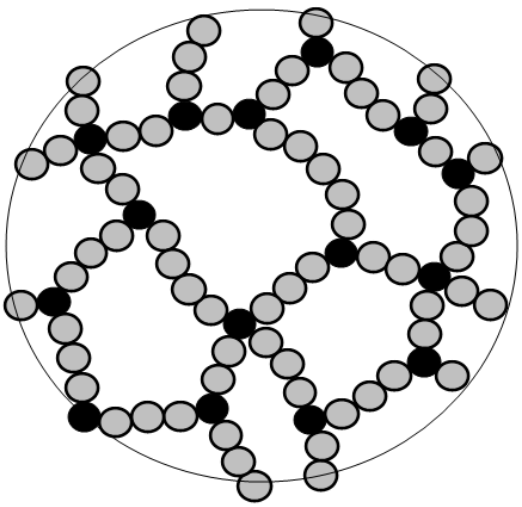


Image from Wikimedia

Section C

12. Carbon dioxide and diamond both contain carbon.

a. Describe the bonding in carbon dioxide.
b. Describe the bonding in diamond.
c. Explain why carbon dioxide is a gas at room temperature but diamond is a solid