Achievement Standard 90932

Demonstrate understanding of aspects of carbon chemistry

CHEMISTRY

1.3

Externally assessed 4 credits

Hydrocarbons

Covalent bonds

Non-metal elements – those with 4, 5, 6 or 7 **valence** electrons – can achieve a stable electron arrangement by sharing electrons in their outer energy levels (valence electrons) with another non-metal atom. The attraction between the shared electrons and the nuclei of the two atoms is known as a **covalent bond** between two atoms.

The element carbon can form long chains of carbon atoms, with covalent bonds between the atoms.

- The C–C covalent bonds are very strong.
- Carbon-containing compounds are the basis of **organic chemistry**.
- The simplest organic compounds are **hydrocarbons** – compounds made up only of hydrogen and carbon.

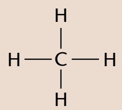
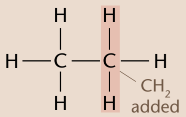
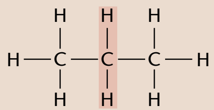
Carbon-containing compounds can be represented by either:

- a **molecular formula** – indicates the number and type of atoms in a molecule
- a **structural formula** – indicates the arrangement of atoms in a molecule, showing the covalent bonds between atoms.

Alkanes

The **alkanes** are a family of hydrocarbons with the general formula, C_nH_{2n+2} (*n* can be any number 1, 2, 3, 4, …, etc.).

Systematic naming of alkanes

Name	Molecular formula	Structural formula	Melting point (°C)	Boiling point (°C)	Physical state at 20 °C	Occurrence and uses
methane	CH_4		–182	–164	gas	natural gas fuel (CNG); source of hydrogen for ammonia production
ethane	C_2H_6		–183	–88	gas	natural gas; fuel (CNG)
propane	C_3H_8		–190	–42	gas	natural gas and petroleum; fuel (LPG)

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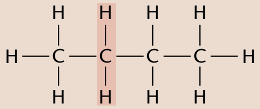
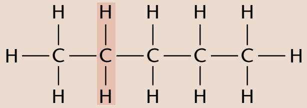
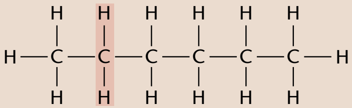
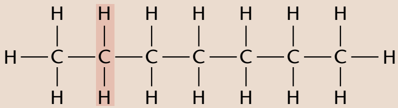
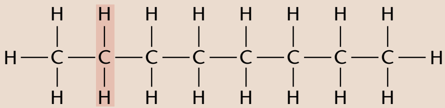
Name	Molecular formula	Structural formula	Melting point (°C)	Boiling point (°C)	Physical state at 20 °C	Occurrence and uses
butane	C_4H_{10}		–139	0	gas	natural gas and petroleum; fuel (LPG)
pentane	C_5H_{12}		–130	36	liquid	petroleum; fuel (petrol)
hexane	C_6H_{14}		–95	69	liquid	petroleum; fuel (petrol)
heptane	C_7H_{16}		–91	98	liquid	petroleum; fuel (petrol)
octane	C_8H_{18}		–57	126	liquid	petroleum; fuel (petrol)

Physical state of alkanes

As the number of atoms and length of the carbon chain of an alkane increases, the mass of the molecule increases. More energy is required to separate the molecules of larger mass, so melting points and boiling points increase as the mass of the molecule increases.

As the number of carbon atoms in the molecule increases, the state at room temperature (20 °C) changes from gas to liquid to solid.

At room temperature (20 °C), the smallest alkane molecules are gases (e.g. methane, ethane, propane and butane), larger molecules are liquids (e.g. pentane, hexane, heptane and octane) and the largest molecules (e.g. those with more than 20 carbon atoms) are solids.

Sources of alkanes

Alkanes occur naturally in fossil fuels, e.g.:

- natural gas – is mainly methane but also contains ethane
- petroleum (crude oil) – is a mixture of hydrocarbons (with up to 30 carbon atoms in the molecule), which are gases, liquids and solids.

Separating the petroleum mixture for use

- **Fractional distillation** is used – a process of separation based on the different condensation (or boiling) temperatures of molecules with different sizes.
- Distillation separates the hydrocarbons into useful **fractions** (i.e. groups of alkanes with similar-sized molecules), such as petrol, diesel, kerosene, jet fuel, etc.

In the fractionating tower:

- The crude oil is heated to above the boiling point of the hydrocarbons; this means the hydrocarbons vaporise into a gas mixture.
- As the vapours pass up the tower, they are progressively cooled.

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Atoms with the maximum number of electrons in the outer energy level (full shell) are particularly stable. Having the maximum number of electrons makes the elements helium (2), neon (2,8) and argon (2,8,8) chemically unreactive. These elements are called the **inert** gases.

With the exception of atoms of the elements hydrogen, helium, lithium and beryllium, atoms of the first 20 elements are most stable when their outer energy level contains *eight* electrons – this is the octet rule. Hydrogen, helium, lithium and beryllium atoms have a stable electron arrangement with *two* (or *zero* for hydrogen) electrons in the outer energy level.

The loss, gain or sharing of electrons in order to reach a stable electron arrangement is the basis of all chemical reactivity.

The periodic table

The modern periodic table lists the elements in order of *increasing atomic number*.

- The table contains vertical columns, or **groups**, and horizontal rows, or **periods**.
- The electron arrangements show that elements in the *same group* have the *same number of electrons in the outer energy level*.

The section of the periodic table shown below includes:

- the symbols of the first 20 elements
- the atomic number for each element (located above the symbol)
- the electron arrangement of an atom of the element (below the symbol)
- the dashed line separating the **metals** from the **non-metals**.

Group number

Period numbers	1	2	13	14	15	16	17	18
I	1 **H** 1							2 **He** 2
II	3 **Li** 2,1	4 **Be** 2,2	5 **B** 2,3	6 **C** 2,4	7 **N** 2,5	8 **O** 2,6	6 **F** 2,7	10 **Ne** 2,8
III	11 **Na** 2,8,1	12 **Mg** 2,8,2	1 **Al** 2,8,3	1 **Si** 2,8,4	15 **P** 2,8,5	16 **S** 2,8,6	17 **Cl** 2,8,7	18 **Ar** 2,8,8
IV	19 **K** 2,8,8,1	20 **Ca** 2,8,8,2						

Trends in the periodic table

Trends (gradual changes) in the properties of elements are consistent with the location of each element in the periodic table.

Patterns of chemical behaviour fall into place within a group and across a period. Elements within a group have similar chemical properties because their atoms have similar electron arrangements.

With the exception of hydrogen (which is a non-metal), the **metals** are located at the left and bottom of the periodic table and **non-metals** are to the top and right.

- Across any row of the periodic table, there is a gradual change from metallic elements (on the left) to non-metallic elements (on the right).
- The reactivity of metals (the ability of their atoms to form **positive ions**) *increases* down a group.
- The reactivity of non-metals (the ability of their atoms to form **negative ions** or **covalent bonds**) *decreases* down a group.

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Questions: Atomic structure and the periodic table

Year 2018
Ans. p.118

Question One: Magnesium, sodium and sulfur

a. Why do magnesium ions and sulfide ions have different charges?

In your answer, you should include the electron arrangement for both ions, and relate the charges of the ions to the position of the atoms on the periodic table.

b. Sodium metal will react with cold water, while magnesium metal will react with steam.

Give observations for each reaction linked to the products of each reaction.

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Catalytic decomposition of hydrogen peroxide

Catalysts

A **catalyst** is a substance that increases the rate of a chemical reaction without being used up itself. A catalyst reduces the amount of energy needed for the reaction to proceed.

> ***Example***
>
> Without a catalyst, the decomposition of hydrogen peroxide at room temperature is very slow. A catalyst speeds up the reaction so that it can be observed at room temperature.
>
> Only a small amount of catalyst is needed because it does not get used up during the reaction.

Decomposition of hydrogen peroxide

Hydrogen peroxide, H_2O_2 (a colourless liquid), is stable if very pure.

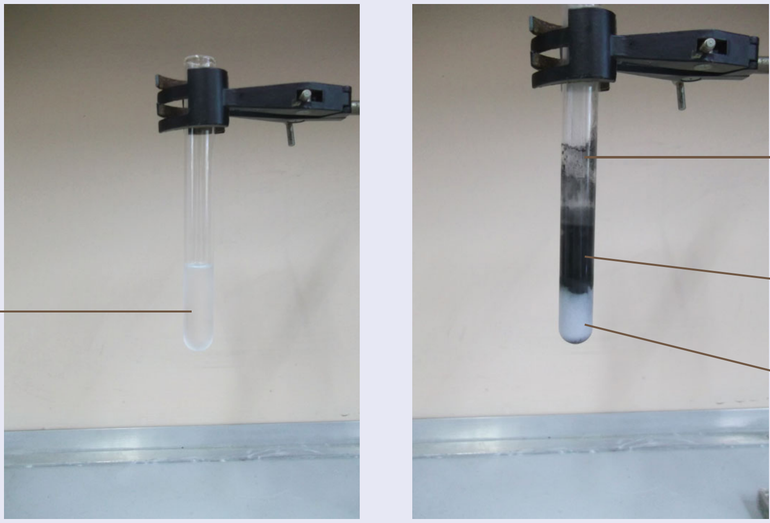
It decomposes rapidly to oxygen, O_2, and water, H_2O, at room temperature if a catalyst, such as manganese(IV) oxide, MnO_2, is present. Heat is given off during this reaction.

hydrogen peroxide → oxygen gas + water

$$2H_2O_2 \rightarrow O_2 + 2H_2O$$

The presence of oxygen gas can be detected by holding a glowing splint above the test-tube. The splint will burst into flame due to the presence of oxygen.

The rate of a catalysed reaction is very rapid at first. The rate levels off after a short time as all the reactant (hydrogen peroxide) is used up.



The rate of an uncatalysed reaction is much slower than a catalysed reaction. However, the volume of oxygen produced in an uncatalysed reaction will steadily increase over time until it reaches the same volume as the catalysed reaction when all the reactant is used up.

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Questions: Decomposition reactions

Year 2018 Ans. p.123

Question One: Different decompositions

a. Some chemical reactions are listed in the table below:

Reaction 1	Some manganese dioxide is added to hydrogen peroxide in a test tube.
Reaction 2	A sample of barium hydroxide is heated in a boiling tube.
Reaction 3	A sample of sodium hydrogen carbonate is heated in a boiling tube.

i. What types of chemical reactions are these?

ii. Explain your answer, with reference to **Reaction 2**.

iii. What would be observed during **Reaction 1**?

Link the observations to the species involved.

iv. Write a word and a balanced symbol equation for **Reaction 3**.

Word equation:

Balanced symbol equation:

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Achievement Standard 90944

Demonstrate understanding of aspects of acids and bases

SCIENCE

1.5

Externally assessed 4 credits

Periodic table and table of ions

A periodic table is given on page vii of this book.

Table of ions

You must know the *names* of the ions. Following is the table of ions that you will be given in the AS 90944 (Science 1.5) exam but with spaces for you to write the names of the ions.

Ans.p.128

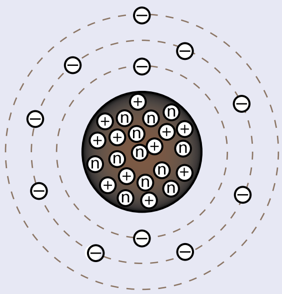
+1	+2	+3	–3	–2	–1
NH_4^+	Ca^{2+}	Al^{3+}		O^{2-}	OH^-
Na^+	Mg^{2+}	Fe^{3+}		S^{2-}	Cl^-
K^+	Cu^{2+}			CO_3^{2-}	NO_3^-
Ag^+	Pb^{2+}			SO_4^{2-}	HCO_3^-
H^+	Fe^{2+}				F^-
Li^+	Ba^{2+}				I^-
	Zn^{2+}				

Atomic structure

Elements are made up of only one type of atom. **Atoms** are made up of **protons** (positively charged), and **neutrons** (no charge) that form a central nucleus. The nucleus is surrounded by **electrons** (negatively charged) that orbit the nucleus in shells.

Atomic number = no. protons. **Mass number** = no. of protons + no. neutrons (electrons are so small their mass is negligible in contributing to the overall mass of an atom). Example: sodium, Na: atomic no. 11 (11 protons); mass no. 23 (11 protons + 12 neutrons)

The sodium atom



Na: 2,8,1

Atoms are neutral (have no overall charge) – the number of (positive) protons equals the number of (negative) electrons. Example: sodium, Na, atomic no. 11, has 11 protons and *also* 11 electrons.

Electrons orbit the nucleus in **energy levels** ('shells'). For the first 20 elements, first shell (closest to nucleus) holds maximum of 2 electrons; 2nd and 3rd shells hold up to 8 electrons; any remaining electrons are found in the 4th shell. The **electron arrangement** is a shorthand way to describe the number of electrons in each shell. Example: sodium (11 electrons: 2 electrons in 1st shell, 8 electrons in 2nd shell, 1 electron in 3rd shell) electron arrangement is written **Na: 2,8,1**

Atoms in the same group (column of the periodic table) have similar electron arrangements, i.e. they have the same number of electrons in their outer shell. As a result, elements in the same group react chemically in a similar way to each other.

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Ions form when atoms *gain or lose electrons* – becoming 'charged' particles (no longer neutral). Atoms react to attain a complete outer shell of electrons and become stable. For the first 20 elements …

- If outermost shell has < 4 electrons, atom tends to *lose* electrons, becoming a *positive ion* (now *more* protons than electrons). Examples: Na: 2,8,1 reacts to lose the one electron in its outermost shell becoming Na^+ ion with electron arrangement 2,8; magnesium, Mg: 2,8,2, loses two electrons from outermost shell becoming Mg^{2+}: 2,8
- If outermost shell has > 4 electrons, atom tends to *gain* more electrons, becoming a *negative ion* (now *fewer* protons than electrons). Examples: fluorine F: 2,7 reacts to gain one more electron in its outermost shell becoming an F^- ion with electron arrangement 2,8; oxygen, O: 2,6, gains two electrons in its outermost shell becoming O^{2-}: 2,8
- Atoms that already have a complete outermost shell are very stable and do not react in normal laboratory conditions (Group 18, inert gases – e.g. He, Ne).
- Hydrogen, H, has a first shell of just one electron. It reacts to lose its electron and form the H^+ ion, effectively becoming just a proton.

Metals, found on the left and middle of the periodic table, react by losing electrons to form positive ions. Group 1 metals (e.g. Li, Na, K) react to lose one electron; group 2 metals (e.g. Mg, Ca) react to lose two electrons.

Non-metals, found on the right side of the periodic table, react by gaining electrons to form negative ions; group 17 (e.g. F, Cl) all react to gain one electron. **Polyatomic ions** are made of more than one atom – e.g. ammonium, NH_4^+; hydroxide, OH^-; carbonate, CO_3^{2-}; sulfate, SO_4^{2}; nitrate, NO_3^-

Metals reacting with non-metals form **ionic compounds**. The attraction of unlike changes (+ metal ion and – non-metal ion) holds the ions together forming an **ionic bond**. Examples: sodium fluoride, NaF; magnesium oxide, MgO; copper chloride, $CuCl_2$

To write a formula for an ionic compound: (1) Select the required ions from the Table of Ions. (2) Put the positive ion first, negative ion second. (3) The total number of positive and negative charges must balance as the compound is overall neutrally charged. If the charges are not equal for the two ions, 'drop and swap' the *values* of the ions – the value of the charge becomes the subscript of the other ion. Examples follow.

Magnesium oxide: Mg forms Mg^{2+} ion, O forms O^{2-} ion. Values of charges the same (both 2), so formula MgO

Magnesium chloride: Values of charges (Mg^{2+} and Cl^-) different, so value of Mg ion (2) becomes subscript for Cl ($_2$) and the formula is $MgCl_2$. (Value of Cl^- ion is 1; no need to put a 1 either in front of the charge or as a subscript for Mg.)

Magnesium hydrogencarbonate: Hydrogencarbonate is the polyatomic ion HCO_3^-; *brackets* must be used before the subscript is included, i.e. $Mg(HCO_3)_2$

Write the formulae of the ionic compounds on the following table.

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Formulae of ionic compounds

Ans.p.128

Name	Formula	Name	Formula
sodium hydroxide		zinc oxide	
silver chloride		ammonium hydroxide	
calcium sulfide		ammonium carbonate	
copper chloride		iron(II) sulfate	
copper hydroxide		iron(III) sulfate	
barium hydroxide		aluminium hydroxide	
lead oxide		aluminium oxide	
lead nitrate		sodium hydrogencarbonate	
potassium oxide		magnesium hydrogencarbonate	

For all reactions, **word equations and balanced chemical equations** need to be written. To write a balanced chemical equation: (1) Write the chemical formula for each of the reactants and products using the ion table. (2) Count to see if there is the *same number of each kind of atom on both sides of the equation.* (3) If needed, put a whole number *in front of the compound.* For example, reaction of sodium hydroxide with sulfuric acid:

Word equation:	sodium hydroxide	+	sulfuric acid	→	sodium sulfate	+	water
Chemical equation:	NaOH	+	H_2SO_4	→	Na_2SO_4	+	H_2O
Balanced chemical equation:	2NaOH	+	H_2SO_4	→	Na_2SO_4	+	$2H_2O$

2 is needed in front of the NaOH in the reactants as there are two Na's in Na_2SO_4 in the products. 2NaOH gives two O and two H. Therefore, a **2** is also needed in front of H_2O in the products. Counting up the atoms shows the equation is now balanced:

	Na	O	H	S
Reactants	*two Na* (from 2NaOH)	*six O* (two from 2NaOH, four from H_2SO_4)	*four H* (two from 2NaOH and two from H_2SO_4)	*one S* (from SO_4)
Products	*two Na* (from Na_2SO_4)	*six O* (four from Na_2SO_4, two from H_2O)	*four H* (from $2H_2O$)	*one S* (from SO_4)

Science 1.5

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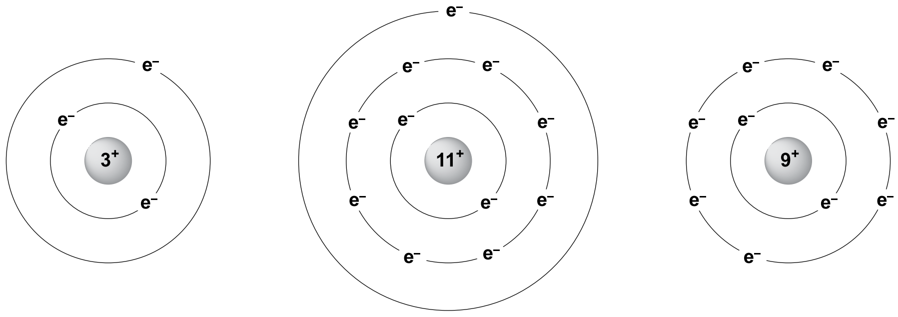
Questions: Atomic structure

Year 2018
Ans. p.128

Question One: Atoms and electrons

The diagrams show models of three different atoms:



Use the diagrams to answer parts **a.**, **b.**, and **c.**

a. Why are lithium and sodium in the same group (column) of the Periodic Table, but in different periods (rows)?

b. Sodium and fluorine form ions that both have the same electron arrangement.

How can sodium and fluoride ions have the same electron arrangement but different charges?

In your answer you should refer to the number of protons, charge, and electron arrangement of the two atoms and ions.

Science 1.5

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Answers and explanations

Assessment criteria

Achievement	Merit	Excellence
Demonstrate understanding will typically involve: • describing, identifying, naming, drawing, giving an account of, or defining aspects • using chemistry vocabulary, symbols and conventions, including names and formulae • completing word equations.	*Demonstrate in-depth understanding* will typically involve: • explaining aspects • using chemistry vocabulary, symbols and conventions, including names and formulae • writing word equations or completing given symbol equations.	*Demonstrate comprehensive understanding* will typically involve: • linking aspects when elaborating, justifying, relating, evaluating, comparing and contrasting, or analysing • using chemistry vocabulary, symbols and conventions consistently • writing balanced symbol equations.

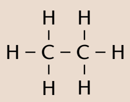
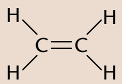
Achievement Standard 90932 (Chemistry 1.3): Demonstrate understanding of aspects of carbon chemistry

1.3 Hydrocarbons

Question One: Two carbon compounds

p. 6

a. i.

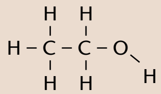
Ethane	Ethene
	

ii. The trend in the boiling points of both alkanes and alkenes is for an increasing boiling point as the number of carbons increase. Alkene molecules have slightly lower boiling points than equivalent alkane molecules.

In both alkanes and alkenes when the number of carbon atoms increase, the chain length and mass also increase. Longer chains have a greater amount of attractions occurring between molecules which requires more energy to overcome during the boiling process. A greater mass requires a greater kinetic energy to move and separate the molecules during boiling. So, as the number of carbon atoms increases, the energy required for boiling increases – thus the boiling points increase.

Alkenes have a C=C covalent double bond which is unable to rotate; whereas alkanes only have C–C covalent single bonds, which can rotate. The effect of this is that any bends in an alkene chain are locked in position and prevent the molecules packing together as closely as occurs in alkane molecules. This means less attractions between molecules are able to form, making the molecules easier to separate. Equivalent alkanes are able to rotate and remove bends in the chain – they can then pack closer together, allowing more attractions to form between molecules. In addition to this, alkanes have two more H atoms than equivalent alkenes, which also increases the amount of attractive forces between molecules. Thus, more energy is required to separate alkane molecules and they have slightly higher boiling points than equivalent alkenes.

b. i.

Ethanol


ii. A hydrocarbon can only be made up of hydrogen and carbon atoms. Ethanol has hydrogen, carbon and also *oxygen* atoms in the molecule, so it's *not* a hydrocarbon.

iii. Cracking of hexane involves strongly heating a long-chain alkane (such as hexane) over a silicate catalyst – this results in breaking the chain into smaller hydrocarbons, one of which will be a 2-carbon long ethene molecule. The ethene product can then be heated with dilute acid under pressure to react the molecule by adding water across the double bond to form ethanol.

Fermentation involves using yeast enzymes to process glucose into ethanol and carbon dioxide gas. Fermentation requires moderate temperatures of 25–40 °C and anaerobic conditions for the reaction to proceed.

Although both processes can be used to produce ethanol, they are different as fermentation requires milder conditions which allow the living yeast enzymes to survive – this makes ethanol in a single-step process. Whereas cracking to form ethene then converting the ethene to ethanol is a two-step process that uses harsher reaction conditions of high temperatures and then reaction with acid under heat and pressure.

Cracking of hexane:

$$CH_3CH_2CH_2CH_2CH_2CH_3 \rightarrow CH_3CH_2CH_2CH_3 + H_2C{=}CH_2$$

Ethanol by fermentation:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

(**A** – 3 of: both diagrams correct in **a. i.**, states an increasing trend with increasing number of carbons in **a. ii.**, identifies correct type of bonding in **a. i.**, correct diagram for **b. i.**, gives correct definition for hydrocarbons in **b. ii.**, correct description of cracking as breaking longer-chain alkanes into smaller molecules one of which will be ethene or fermentation as enzymes reacting with sugar/glucose in **b. iii.**;

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M – 2 of: correctly explains boiling point increase in terms of increasing amounts of attractions between molecules in **a. ii.**, explains that ethanol contains oxygen so can't be a hydrocarbon in **b. ii.**, either balanced equation correct in **b. iii.**;

E – **M** *and* the difference in equivalent alkane and alkene molecule boiling points fully linked to the structures for each in **a. ii.**, and both processes explained with differences in conditions linked to the reaction occurring and correct balanced equations in **b. iii.**)

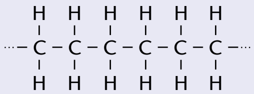
Question Two: Polymers and unknowns

p. 8

a. **i.** ethene

ii. The polymerisation reaction involves breaking one of the two bonds making up a reactive C=C double bond in the ethene and then forming a single bond to add onto an adjacent ethene, which then breaks one of the two bonds making up its C=C bond to form a single bond to add to the next adjacent ethene that is itself breaking its double bond. This process carries on for many ethene monomers to make up a long-chain polymer molecule of over 100 units long. The C=C double bond is stable, so this reaction requires the use of heat, pressure, and a catalyst to take place so as to provide the energy needed to break one of the C=C double bonds – otherwise the polymerisation reaction would not occur.

The structural formula of polyethene is:



Dashes (or 3 dots) are drawn at each end of a polymer segment to indicate that the chain continues in each direction.

b. Compound A: ethanol

Compound B: propane

Compound C: ethane

Of the three choices, ethane and propane are non-polar molecules which makes them insoluble due to their inability to form the attractions needed with polar water molecules during dissolving. The ethanol is the only choice that is polar due to the partially charged –OH group that is part of the molecule. This polarity enables ethanol to form the attractions needed with polar water molecules during dissolving, and so ethanol is soluble – which identifies it as compound A.

Of the remaining two compounds, ethane is made up of 2 carbons which would thus produce 2 molecules of CO_2 when combusted; propane is made up of 3 carbons, which would thus produce 3 molecules of CO_2 when combusted. Referring to the table, compound C forms 2 molecules of CO_2, so C is ethane; compound B forms 3 molecules of CO_2, so is propane.

You could also use the number of CO_2 molecules to identify propane first, and then solubility to distinguish between ethanol and ethane.

(**A** – 3 of: **a. i.** correct, identifying that ethene has a C=C in **a. ii.**, identifies reaction conditions in **a. ii.** stating that the polymer is made of ethenes joined together in **a. ii.**, all correct in **b.**, correctly identifying the solubility of the unknowns in **a. ii.**;

M – 2 of: explaining the addition reaction process in terms of breaking one of the C=C bonds and forming a new bond with adjacent ethenes in **a. ii.**, explains reaction conditions in **a. ii.**, correctly explaining either solubility or number of CO_2 molecules produced for identifying two of the unknowns in **a. ii.**;

E – **M** *and* reaction conditions and why they are required linked to the polymerisation of ethene reaction and correct structure in **a. ii.**, and the explanation of the identification of all three compounds linking to the relevant properties of the molecule and the information from the table in **a. ii.**)

Question Three: Crude oil processing

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a. **i.** Crude oil is a mixture of different carbon compounds, each of which have different uses. Fractional distillation separates the mixture into each usable fraction/component.

ii. Smaller hydrocarbons have very low boiling points due to weak forces between molecules. As the crude oil vapour mixture moves up the tower it cools and each fraction condenses out of the gas mixture. However, the smaller hydrocarbons remain as vapour, even at the coolest top of the tower, and so are collect from the top in the gas state.

b. $C_{10}H_{22} \rightarrow C_5H_{12} + C_3H_6 + C_2H_4$

Cracking produces at least one alkane and at least one alkene.

Ethene, C_2H_4, is nearly always an alkene product from cracking; it is made up of 2 C atoms and 4 H atoms.

The other product given is pentane, C_5H_{12}; it is made up of 5 C atoms and 12 H atoms.

Decane is $C_{10}H_{22}$; it is made up of 10 C atoms and 22 H atoms.

Now, ethene, C_2H_4, and pentane, C_5H_{12}, represent a total of 2 + 5 = 7 C atoms and 4 + 12 = 16 H atoms.

This means 10 – 7 = 3 C atoms and 22 – 16 = 8 H atoms need to be accounted for. Since there is only one more product, it must have the formula C_3H_6 (propene).

c. Fractional distillation is a physical process used for separation of a mixture, there are no changes to the properties of the products or new compounds being created. Fractional distillation utilises the physical property of different boiling points of the molecules in the mixture.

Cracking is a chemical reaction that involves heating a large, long-chain hydrocarbon over a silica catalyst such that the long-chain hydrocarbon breaks down to produce smaller molecules; these new compounds – at least one alkane and at least one alkene – have lower boiling points and different chemical properties to the reactant molecule.

(**A** – 3 of: states crude oil is a mixture in **a. i.**, identifies the smaller hydrocarbons are in gas state at the top in **a. ii.**, has the correct formula for the pentane product in **b.**, describes fractional distillation as separating a mixture in **c.**, describes cracking as breaking off a small molecule in **c.**; **M** – 3 of: explains separation needed for different uses in **a. i.**, links the gas state of smaller hydrocarbons to low b.p. in **a. ii.**, equation correct in **b.**, fully explains the process of fractional distillation or cracking in **c.**; **E** – **M** with: explanation of how smaller hydrocarbons have been separated and remain a gas linked to low b.p. in **a. ii.**, and correct comparison of both fractional distillation and cracking linking the relevant properties to the changes that have occurred for each process in **c.**)

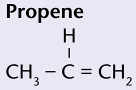
Question Four: Propane and propene

p. 11

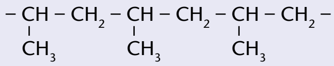
a. **Propane**

$CH_3 - CH_2 - CH_3$

Propene



b.



Use dashes (or 3 dots) at each end of the diagram to show that the molecule continues.

c. Propene is a bigger molecule with a larger mass than ethene. This means a greater amount of attractive forces can occur between adjacent propene molecules compared with ethene molecules, and these greater attractive forces in propene require more energy to separate the molecules during boiling of the substance. Hence, propene has a higher b.p. than ethene.

d. Polymers form from the addition reaction between propene monomer molecules. This can occur because propene has a C=C double bond. One of these bonds can be broken while the other bond keeps the molecule still joined; this then allows the C atom at the end of the molecule to form a new bond with the C atom on an adjacent molecule that has similarly had its double bond broken – this repeats in a recurring way so that the long molecule keeps breaking the double bonds at its ends to form a long-chain polymer.

Propane only contains single C–C bonds which cannot be broken without breaking the molecule itself – this means the C atoms within the propane are not able to form more bonds with adjacent molecules so cannot make a polymer.

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