Suggested Answers

VCE Chemistry 2016 Year 11 Trial Exam Unit 1

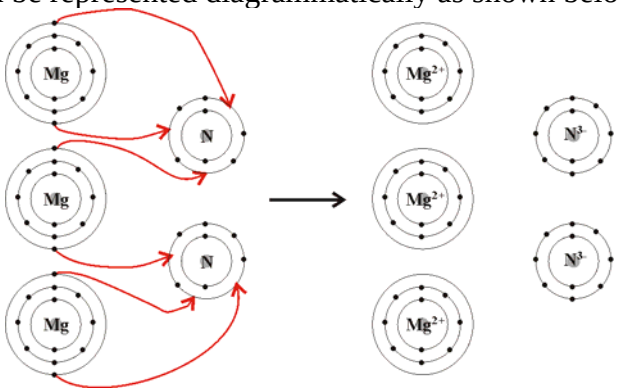
SECTION A – Multiple Choice Answers

(1 mark per question)

Q1 **B** Moving across a period in the Periodic Table, the nuclear charge increases. Therefore, the forces of attraction between the nucleus and the outer shell electrons increases and this results in a decrease in the atomic radii.

Q2 **D** The metallic bonding model describes the solid in terms of a lattice of positive ions where the valence electrons are delocalised (free to move about). Therefore, electrons can freely flow through a metal lattice when an electric field is applied.

Q3 **A** Referring to the *VCE Chemistry Data Book: Table 1 – The Periodic Table*, the atomic numbers for magnesium and nitrogen are 12 and 7 respectively. Therefore, the ground state electronic configurations of magnesium and nitrogen are $1s^2 2s^2 2p^6 3s^2$ and $1s^2 2s^2 2p^3$ (or in shell configurations as 2,6,2 and 2,5) respectively.
When these two elements form a compound, each magnesium can donate two electrons and in doing so form a magnesium ion, Mg^{2+}, while each nitrogen can accept three electrons to form a nitride ion, N^{3-}.
This can be represented diagrammatically as shown below.



The formula for the compound formed, magnesium nitride, will therefore be Mg_3N_2.

Q4 **B**

Molar mass: $M(Na_2SO_3) = 2\times23.0 + 1\times32.1 + 3\times16.0 = 126.1$ g mol^{-1}
In one mole m(S) = 32.1 g
$\%(S) = m(S)/M(Na_2SO_3) \times (100/1)$
$\%(S) = (32.1/126.1)\times(100/1) = 25.46$ %
An alternative calculation layout that shows the calculation of the percentage by mass of each element in the compound.

	Number	*M_A*	*Mass in 1 mol*		*%*
Na	*2*	*23.0*	*46.0*	*(46.0/126.1)×(100/1)*	*36.48*
S	*1*	*32.1*	*32.1*	*(32.1/126.1)×(100/1)*	*25.46*
O	*3*	*16.0*	*48.0*	*(48.0/126.1)×(100/1)*	*38.07*
Molar Mass			*126.1*		

Q5 **D**

Molar Mass: $M(MgCl_2) = 24.3 + 2\times35.5 = 95.3$ g mol^{-1}
$n(MgCl_2) = m/M = 19.06 / 95.3 = 0.200$ mol
$N(MgCl_2) = n(MgCl_2)\times N_A = 0.200 \times 6.02\times10^{23} = 1.204\times10^{23}$ particles
Since each $MgCl_2$ contains one Mg^{2+} and two Cl^- ions
$N(Mg^{2+}) = 1.204\times10^{23}$ Mg^{2+} ions
$N(Cl^-) = 2 \times 1.204\times10^{23} = 2.408\times10^{23}$ Cl^- ions
$N(ions) = 1.204\times10^{23} + 2.408\times10^{23} = 3.612\times10^{23}$ ions

Q6 **C**

The metallic elements that are magnetic are; iron, cobalt and nickel. These three elements are members of the first transition metal series in the Periodic Table.
While all metals will conduct electricity, the transition group metal elements in general tend to be better conductors.
Most transition group metal elements tend to have higher densities than those in the main group.
Main group metal elements tend to have a low to medium hardness and are generally ductile.

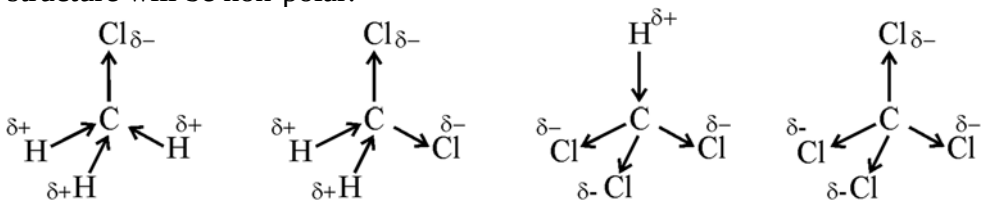
Q7 **A**

Nanoparticles are more chemically reactive than bulk materials because they have a significantly larger surface area for a given amount of material where reactions may occur.

Q8 **C**

The ion has a -2 charge therefore the ion contains two more electrons than there are protons in the nucleus.
Number of protons = 18 – 2 = 16 protons
Atomic number (Z) = 16, therefore sulfur, S.
Mass number (A) = number of protons + number of neutrons
A = 16 + 18 = 34
$^{34}_{16}S$

Q9 **D** In each of the molecules the C-Cl bond will be polarised due to the difference in the electronegativity between the carbon and chlorine (2.5 and 3.0 respectively). This results in an uneven electron distribution in the bond between the two atoms and results in the chlorine having a small negative (δ-) charge.
The difference in the electronegativity between carbon and hydrogen will also induce a polarising of the C-H with the hydrogen developing a small positive (δ+) charge.
The overall polar nature of the molecule is the combination of the individual bonds and the structure of the molecule.
In chloromethane, dichloromethane and trichloromethane, the structure will yield an overall dipolar molecule.
In tetrachloromethane, while the individual bonds are polar, the overall structure will be non-polar.



Q10 **A** The C_{60} structure has each carbon atom covalently bonded to three adjacent carbon atoms in alternating hexagonal and pentagonal rings joined to give an overall ball-type structure.
Because the material is made up from discrete C_{60} molecules, its melting point is low. *In the case of diamond and graphite, because the bonding extends throughout a very large lattice, the melting points are high.*

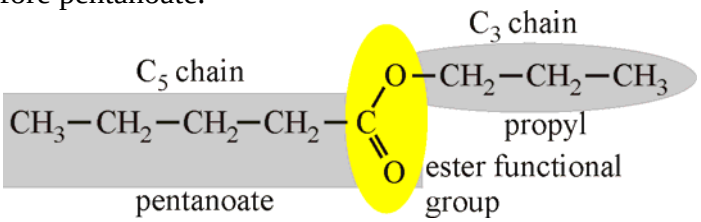
Q11 **B** From the systematic name of the compound, but-2-yne, the structure can be established.
but-2-yne: Four carbon atom chain.
but-2-**yne**: Contains a carbon-carbon triple bond (alkyne).
but-**2**-yne: Carbon-carbon triple bond is between second and third carbon atoms in the chain. In this case in the middle.

$$CH_3 - C \equiv C - CH_3$$

Q12 **A** In a thermosetting polymer there is cross-linking between the polymer strands that results in a rigid structure. The cross-linking involves covalent bonds between the polymer chains.
Thermosetting polymers will as a result not melt when heated.
When there is no cross-inking between the polymer strands, the material is a thermoplastic and it will melt when heated. Varying the degree of branching on the polymer strand, the arrangement of attached groups and/or the types of weak interactions between the polymer strands will alter the properties of the material.

Q13 **C**

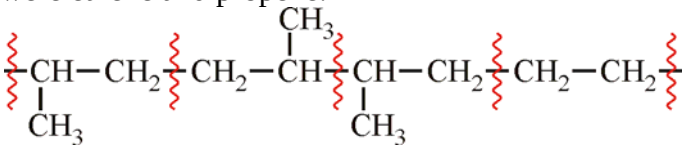
The compound contains an ester functional group, -COO-.
The carbon chain attached to the oxygen contains three carbons joined by single carbon-carbon bonds. This is a propyl group.
There are five carbons in the remaining chain joined by single carbon-carbon bonds, pentan-. This chain contains the carbon of the ester functional group, therefore pentanoate.



This ester would be synthesised by the reaction of propanol and pentanoic acid in the presence of a catalyst.

Q14 **D**

Addition polymers are synthesised from alkenes, where the addition reaction occurs at the carbons in the carbon-carbon double bonds.
Dividing the structure into two carbon unit segments identifies the monomers that the polymer was formed from.
In this case, there are two different types of segment in the structure, one containing two carbons and the other three carbons. Therefore, the monomers were ethene and propene.



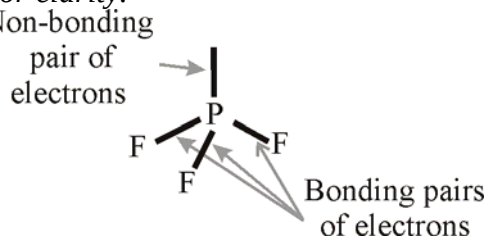
Q15 **B**

The properties of the substance reflect the bonding characteristics present.
The only type of bonding that matches all of the properties described is ionic bonding.
Metallic bonding would result in the substance being a good electrical and thermal conductor.
Covalent molecular bonding would result in the substance having a low melting point and being soft.
Covalent molecular lattice bonding would result in the substance having a very high melting point.

Q16 **B**

Fluorine (Z=9) and phosphorous (Z=15) have a ground-state shell electron configuration of 2, 7 and 2, 6, 5 respectively. Therefore, each fluorine will share one electron to form a single bond and have three non-bonding electron pairs. Phosphorous will share three electrons forming three covalent bonds and there will be a non-bonding electron pair.
The three fluorines will be bonded to the phosphorous. Therefore, together with the non-bonding electron pair, there will be four regions of electron density around the phosphorous. The least energetic arrangement for these will be in a tetrahedral structure when the non-bonding pair of electrons is included.
The structure of PF_3 is referred to as a trigonal pyramid and is similar to that for ammonia, NH_3.

The diagram below shows this structure with the non-bonding electron pair on the phosphorous. *The non-bonding pairs of electrons on the fluorines have been omitted for clarity.*



Q17 B The Bohr and later Schrödinger models deal with the arrangement of the electrons in shells and sub-shells. The Bohr model was able to explain the emission spectra of the hydrogen atom. Schrödinger's model extended this by the use of quantum mechanics.

Q18 C Determine the ratio of the ions
$N(ions) = 1.85\times10^{22}$ ions
$N(anions) = N(Y^{b-}) = 7.40\times10^{21}$ ions
$N(cations) = N(X^{a-}) = 1.85\times10^{22} - 7.40\times10^{21} = 1.11\times10^{22}$ ions
Determine the ratio of the ions by dividing by the smaller number
$N(X^{a-}) : N(Y^{b-}) = 1.11\times10^{22} : 7.40\times10^{21}$
$= 1.5 : 1$
Multiply both numbers by 2 to get whole number ratio
$= 3 : 2$
X_3Y_2

Q19 A As the name suggests, liquefied petroleum gas, lpg, contains compounds that are gases at room temperature and pressure, and will therefore have low molecular masses.
The main components of lpg are propane, C_3H_8, and butane, C_4H_{10}.
The boiling points of alkanes increases with their molecular mass, therefore those with at least six carbons tend to be liquids at room temperature, with those containing even larger numbers of carbons being solids.
C_6H_{14} (b.p.: 69 ºC) C_8H_{18} (b.p.: 126 ºC)
Lpg is mainly used as a fuel.
Alkenes and alkynes contain carbon-carbon double and triple bonds respectively, and are more useful as feedstocks in the chemical industry than as fuels.

Q20 B The functional group in $CH_3CH_2COOCH_2CH_3$ is -COO-. This is the ester functional group. This compound is ethyl propoanoate.
The functional group in $CH_3CH_2CH_2CH_2COOH$ is –COOH. This is the carboxylic acid functional group. This compound is pentanoic acid.
Because both compounds have the same molecular formula but different structures, these two compounds are structural isomers.
Because they have different functional groups, they belong to different compound families.

SECTION B – Short Answer (Answers)

Question 1 (8 marks)

a. **i.** The electronegativity of **beryllium would be less** than that for fluorine because the electronegativities of the elements increase moving across a period in the Periodic Table **(1 mark)**.
The electronegativity values for Be and F are 1.57 and 3.98 respectively. Fluorine is the element with the highest electronegativity in the Periodic Table.
The electronegativity is a measure of the electron attracting power of an element. Since both elements are in the second period of the Periodic Table, the second shell is the outer or valence shell. The effective nuclear charge is the nuclear charge minus the number of electrons in any inner shell/s. Beryllium has an effective nuclear charge of +2 compared with +7 for fluorine. Therefore, fluorine will be a more powerful electron attractor **(1 mark)**.

ii. The first ionisation energy is the energy required to remove an electron from the outer shell of an atom **(1 mark)**.
Since both elements are in the same period, the second shell is the outer or valence shell for both. The electrons in the outer shell of fluorine are attracted by a +7 effective nuclear charge, whereas those in beryllium are attracted by a +2 effective nuclear charge. Consequentially more energy is required to remove an electron from the outer shell of a fluorine atom compared to that for a beryllium atom **(1 mark)**.

b. Magnesium and calcium are both in Group 2 of the Periodic Table.
When elements react it involves the rearrangement of the outer or valence shell electrons.

i. The chemical reactivity of Group 2 elements increases moving down the group because the reactions involve the loss of the outer or valence shell electrons. Magnesium is in the second period and calcium is in the third period of the Periodic Table. Therefore, calcium will more readily release the outer or valence shell electrons compared to magnesium, making it more reactive **(1 mark)**.

ii. Barium is in the sixth period of the Periodic Table, therefore it will be significantly more reactive than either calcium or magnesium. The students would most probably see a violent reaction between barium and water **(1 mark)**.

c. The order in which the sub-shells fill is: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, ...
The maximum number of electrons in s, p and d sub-shells are 2, 6 and 10 respectively

i. As: Z = 33 $\Rightarrow$ 33 electrons
$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$ (1 mark).

ii. Al: Z = 13: Al^{3+} ion $\Rightarrow$ 10 electrons
$1s^2 2s^2 2p^6$ (1 mark).

Question 2 (6 marks)

a. **i.** The carbon monoxide, CO, would react with the iron oxide to form carbon dioxide, CO_2. Both these compounds are gases at room temperature.
The chemical equation can be developed stepwise once the reactants and products are identified.

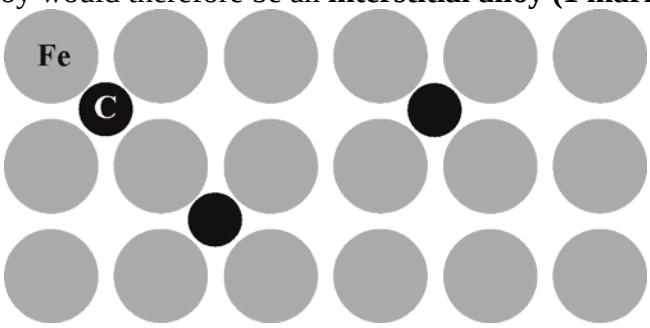
$$Fe_2O_3(s) + CO(g) \rightarrow Fe(l) + CO_2(g)$$

Each CO 'accepts' an O from the iron oxide

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$$ **(1 mark)**.

ii. The readily identifiable environmental impact would be the production of carbon dioxide.
Since the process produces carbon dioxide that would be released into the atmosphere, this would contribute to the enhanced greenhouse effect and global warming **(1 mark)**.
Other environmental impacts that could be considered include:
Production of the slag by-product.
Noise and dust pollution from the furnace.

iii. Since the atomic radius of the carbon atoms is smaller than that for iron, the carbon atoms would occupy the spaces between the iron atoms in the lattice. The alloy would therefore be an **interstitial alloy (1 mark)**.



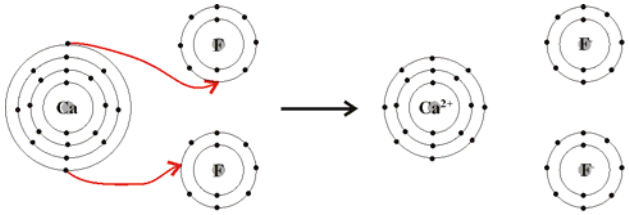
b. **i.** Quenching will result in the formation of **small crystals** in the solid **(1 mark)**. Because the solid contains many small crystals then there will be a large surface area where the crystals will be in contact with one another. This will make the **metal hard but brittle (1 mark)**.

ii. Annealing allows the formation of larger crystals and as a result, the metal will be **softer and more ductile** than a quenched sample **(1 mark)**.

Question 3 (7 marks)

a. In **molten sodium chloride**, the sodium, $Na^+(l)$, and chloride, $Cl^-(l)$, **ions are free to move about in the liquid**, whereas in the solid, the ions are in fixed positions within the lattice. The **free moving ions** can therefore **carry an electric current (1 mark)**.
In an aqueous solution, **the hydrated ions**, ions surrounded by water molecules (attracted to the ions by ion-dipolar interactions), **are free to move in the solution**.
Again it is these free moving ions that can carry an electric current **(1 mark)**.

b. Diagram should show formation of ions with electrons being transferred from the calcium to the fluorine.



(1 mark)

$Ca^{2+} + 2F^- \rightarrow CaF_2$ **(1 mark)**

2,8,8 2,8

c. A polyatomic ion is an ion that **consists of two or more tightly bound atoms** that form an ion with an overall charge on the group of atoms. Polyatomic ions can have either a positive or negative charge.
Examples include (but are not limited to): ammonium, NH_4^+; hydroxide, OH^-; carbonate, CO_3^{2-}; sulfate, SO_4^{2-}; nitrate, NO_3^-; phosphate, PO_4^{3-};
[Mark allocation: Must have example of an appropriate ion together with the explanation: (1 mark)]

d. **i.** Copper(II) Sulfate pentahydrate
Copper(II) = Cu^{2+}
Sulfate = SO_4^{2-}
Pentahydrate = $5H_2O$
$CuSO_4 \cdot 5H_2O$ (1 mark).

ii. In hydrates, the water of crystallisation is weakly bonded to the ions through ion-dipole interactions. When a sample of the hydrate is heated, the solid will decompose and the water of crystallisation will be released into the atmosphere **(1 mark)**. *The colour of the solid will change from blue to white when this dehydration occurs.*

$CuSO_4 \cdot 5H_2O(s) \rightarrow CuSO_4(s) + 5H_2O(g)$

Question 4 (6 marks)

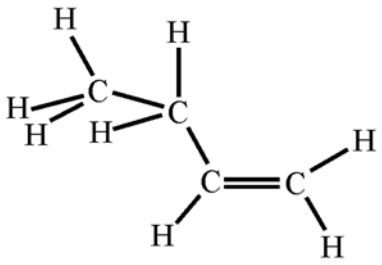
a. The relative atomic mass is the weighted average of the isotopic masses.
The relative abundance for the lighter isotope will be 100 – 39.9 = 60.1 % **(1 mark)**.
A_r = 68.93 × (60.1/100) + 70.93 × (39.9/100) = **69.7 (1 mark)**.

b. Referring to the *VCE Chemistry Data Book: Table 1*.
$M(Na_2CO_3 \cdot 10H_2O)$ = 2×23.0 + 12.0 + 13×16 + 20×1.0
$M(Na_2CO_3 \cdot 10H_2O)$ = **286 g mol^{-1} (1 mark)**.

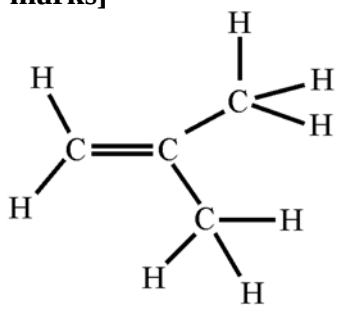
c. m(compound) = 9.572 g
m(Cr) = 6.549 g
m(O) = 9.572 – 6.549 = 3.023 g
Determine the molar ratio
n(Cr) : n(O) = m(Cr)/M(Cr) : m(O)/M(O)
= 6.549/52.0 : 3.023/16.0
= 0.126 : 0.189 **(1 mark)** (divide the larger value by the smaller)\
= 0.126/0.126 : 0.189/0.126
= 1 : 1.5 **(1 mark)** (convert to whole number ratio)
= 2 : 3
Cr_2O_3 (1 mark)

Question 5 (7 marks)

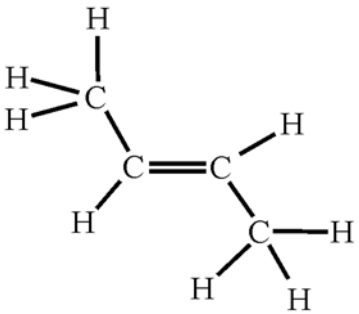
a. An alkene contains a carbon-carbon double bond.
The molecular formula for the alkene will be C_4H_8.
There are three possible structural isomers for a C_4 alkene.
but-1-ene
but-2-ene
2-methylpropene
The diagram below shows two stereoisomers for but-2-ene. Stereoisomers are not part of the Unit 1 VCE course.
[1 mark for a correct structure. 1 mark for the correct systematic name for the structure drawn. Total mark allocation = 4 marks]



but-1-ene

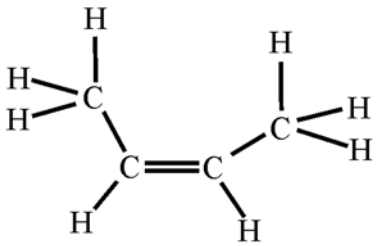


2-methylpropene



trans (E) stereoisomer

but-2-ene



cis (Z) stereoisomer

b. **i.** Determine the mole ratio of the elements.

n(C) : n(O) : n(H) = 54.5/12.0 : 9.1/1.0 : 36.4/16.0

= 4.54 : 9.1 : 2.275 **(1 mark)**

(divide all values by the smallest value)

= 2 : 4 : 1

C_2H_4O (1 mark)

ii. The molecular formula is a whole number multiple of the empirical formula.

$M(C_2H_4O) = 2\times12.0 + 4\times1.0 + 16.0 = 44.0$ g mol^{-1}

$M((C_2H_4O)_x) = 44.0\times x = 88.0$

$x = 88.0/44.0 = 2$

$(C_2H_4O)_2$ = **$C_4H_8O_2$ (1 mark)**

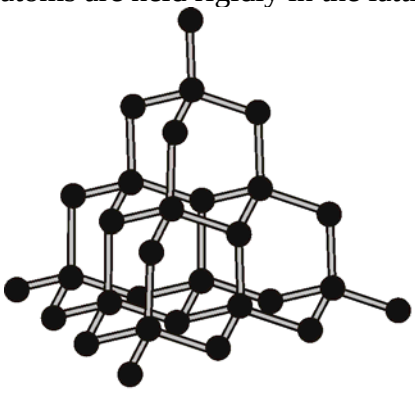
Question 6 (6 marks)

a. **i.** In the structure of diamond, each carbon atom is covalently bonded to four adjacent carbon atoms in a three-dimensional lattice. In this case, all four valence electrons are involved in the bonding. There are no free or mobile electrons, therefore diamond is a non-conductor of electricity.

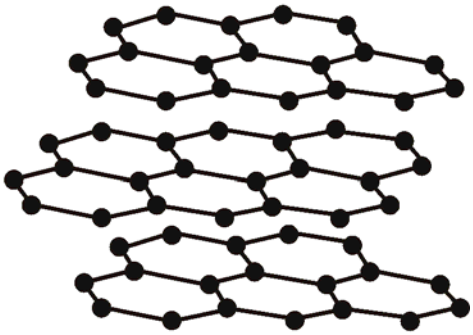
The structure of graphite has each carbon atom covalently bonded to three other adjacent carbon atoms in a two-dimensional sheet-type structure. The fourth valance electron from each carbon atom is delocalised, and therefore mobile, within the layer.

The delocalisation of the electrons allows an electron current to flow through a layer of graphite **(1 mark)**.

ii. Because of the layer structure for graphite, the various layers can slide over each other making it soft. The covalent bonding throughout the three-dimensional lattice in graphite results in the material being hard as the atoms are held rigidly in the lattice by covalent bonds **(1 mark)**.

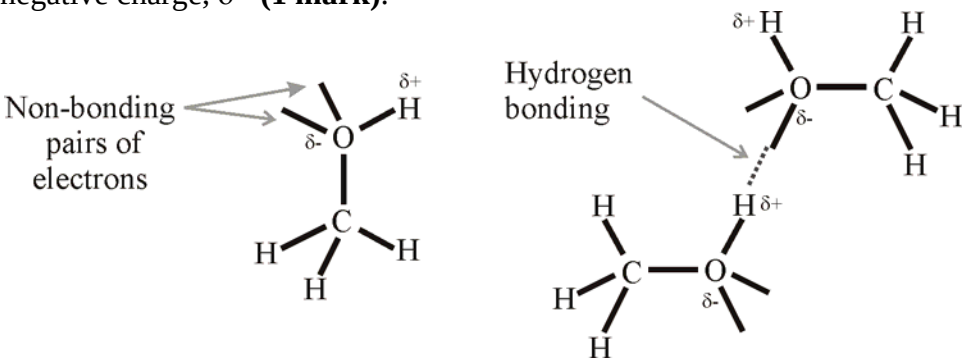


Diamond



Graphite

b. **i.** The central carbon will have three single carbon-hydrogen covalent bonds and a single carbon-oxygen covalent bond. In addition to being covalently bonded to the carbon, the oxygen will form a single oxygen-hydrogen bond. Oxygen will also have two non-bonding electron pairs.
There will be four regions of electron density around the carbon and oxygen, as a result of the electron repulsion these will both have tetrahedral arrangements.
Because of the differences in the electronegativities of carbon, hydrogen and oxygen, all of the bonds will be polarised with the oxygen developing a small negative charge, δ- **(1 mark)**.



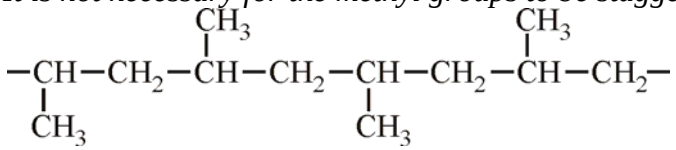
ii. As with any species there will be weak **dispersion forces** between the methanol molecules. In the case of methanol, these will be the weakest intermolecular forces.
Because the methanol molecules are polar then there will be **dipole-dipole interactions** between the molecules.
Since hydrogen and oxygen are involved in the dipole then the strongest intermolecular interaction will be **hydrogen bonding**.
[Mark Allocation: All three correct: 2 marks. Two correct: 1 mark]

iii. Because methanol is polar and has a small hydrocarbon chain attached to the polar O-H bond then methanol would be expected to be soluble in water **(1 mark)**.
The methanol molecules will form hydrogen bonds with the water molecules similar to those that they form with each other.
Methanol is completely miscible (mixes completely) with water, so aqueous solutions over the entire concentration can be prepared.

Question 7 (5 marks)

a. The diagram must show the correct repeating units and bonds at both ends to signify extension of the molecule **(2 marks)**.

It is not necessary for the methyl groups to be staggered or on one side only.



b. **i.** Possible answers include: **(1 mark)**

Increasing the length of the polymer molecule chain will increase the strength of the material as the longer chains tend to tangle more easily and therefore more energy will be required to get the chains to slide over each other. Increasing the chain length will increase the melting point of the material because of the higher molecular mass.

ii. In polymeric materials that are highly crystalline, the polymer chains are arranged in regular order, requiring larger forces to deform the material **(1 mark)**.

iii. Plasticisers are **small molecular compounds** that are added to polymeric materials. These materials are located between the polymer chains **making it easier for them to slide over one another**. This results in a **softer material (1 mark)**.

Question 8 (5 marks)

a. The products of complete combustion are carbon dioxide and water.

The chemical equations can be derived using a systematic stepwise procedure.

Octane – Alkane, single carbon-carbon bonds, with eight carbons:

General formula: C_nH_{2n+2} : n = 8 therefore C_8H_{18}

$$C_8H_{18}(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$$

Balance carbons

$$C_8H_{18}(l) + O_2(g) \rightarrow 8CO_2(g) + H_2O(l)$$

Balance hydrogens

$$C_8H_{18}(l) + O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$$

Balance oxygens

$$C_8H_{18}(l) + \tfrac{25}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$$ **(1 mark)**

The equation can be left as this or the coefficients can all be multiplied by 2.

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

Ethanol – Alkanol with two carbons and the alcohol functional group, -OH: C_2H_5OH or C_2H_6O or CH_3CH_2OH.

$$C_2H_5OH(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$$

Using the same steps as for octane.

$$C_2H_5OH(l) + O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$$

$$C_2H_5OH(l) + O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$ **(1 mark)**

b. **i.** All alkenes are hydrocarbons that contain at least **one carbon-carbon double bond (1 mark)**.
Ethene: $CH_2=CH_2$. But-1,3-diene: $CH_2=CH-CH=CH_2$.

ii. Propene: Hydrocarbon with three carbons and one carbon-carbon double bond.
(*States not critical. If semi-structures are shown then chlorines must be on the correct carbons.*)
The product is 1,2-dichloropropane.

$$CH_3-CH=CH_2(g)+Cl_2(g) \rightarrow CH_3-CHCl-CH_2Cl(l)$$ **(1 mark)**

or

$$CH_3CHCH_2(g)+Cl_2(g) \rightarrow CH_3CHClCH_2Cl(l)$$

$$C_3H_6(g)+Cl_2(g) \rightarrow C_3H_6Cl_2(l)$$

iii. The chlorines are added to the molecule, across the carbon-carbon double bond, therefore this is **an addition reaction process (1 mark)**.

End of Suggested Answers