AMOUNT OF SUBSTANCE QUESTION

Q5. When a sample of liquid, **X,** of mass 0.406 g was vaporised, the vapour was found to occupy a volume of 2.34×10^{-4} m^3 at a pressure of 110 kPa and a temperature of 473 K.

(a) Give the name of the equation $pV = nRT$.

(1)

(b) Use the equation $pV = nRT$ to calculate the number of moles of **X** in the sample and hence deduce the relative molecular mass of **X.**
(The gas constant R = 8.31 J K^{-1} mol^{-1})

*Moles of **X*** .....

*Relative molecular mass of **X*** .....

(4)

(c) Compound **X,** which contains carbon, hydrogen and oxygen only, has 38.7% carbon and 9.68% hydrogen by mass. Calculate the empirical formula of **X**.

.....

(3)

(d) Using your answers to parts (b) and (c) above, deduce the molecular formula of **X**.

.....

(1)
(Total 9 marks)

Q6. (a) Calculate the concentration, in mol dm^{-3}, of the solution formed when 19.6 g of hydrogen chloride, HCl, are dissolved in water and the volume made up to 250 cm^3.

.....

(3)

(b) The carbonate of metal **M** has the formula M_2CO_3. The equation for the reaction of this carbonate with hydrochloric acid is given below.

$M_2CO_3 + 2HCl \rightarrow 2MCl + CO_2 + H_2O$

A sample of M_2CO_3, of mass 0.394 g, required the addition of 21.7 cm^3 of a 0.263 mol dm^{-3} solution of hydrochloric acid for complete reaction.

(i) Calculate the number of moles of hydrochloric acid used.

(ii) Calculate the number of moles of M_2CO_3 in 0.394 g.

(iii) Calculate the relative molecular mass of M_2CO_3

(iv) Deduce the relative atomic mass of **M** and hence suggest its identity.

*Relative atomic mass of **M*** .....

*Identity of **M*** .....

(Total 9 marks)

AMOUNT OF SUBSTANCE QUESTION

Q20. Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

.....

(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas .....

Total moles of gas .....

(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

Moles of nitroglycerine .....

.....

Mass of nitroglycerine .....

(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

(The gas constant R = 8.31 J $K^{-1}mol^{-1}$)

Ideal gas equation .....

Pressure .....**(4)(Total 11 marks)**

BONDING QUESTION

Q3. (a) Both HF and HCl are molecules having a polar covalent bond. Their boiling points are 293 K and 188 K respectively.

(i) State which property of the atoms involved causes a bond to be polar.

(ii) Explain, in terms of the intermolecular forces present in each compound, why HF has a higher boiling point than HCl.

(4)

(b) When aluminium chloride reacts with chloride ions, as shown by the equation below, a co-ordinate bond is formed.

$$AlCl_3 + Cl^- \rightarrow AlCl_4^-$$

Explain how this co-ordinate bond is formed.

(2)

(c) Draw the shape of the PCl_5 molecule and of the PCl_4^+ ion. State the value(s) of the bond angles.

PCl_5 PCl_4^+

Bond angle(s) ..... *Bond angle(s)* .....

(4)
(Total 10 marks)

Q4. (a) (i) Complete the electronic configuration of aluminium.

$1s^2$ .....

(ii) State the block in the Periodic Table to which aluminium belongs.

.....

(2)

(b) Describe the bonding in metals.

(2)

(c) Explain why the melting point of magnesium is higher than that of sodium.

(3)

(d) Explain how metals conduct electricity.

(2)
(Total 9 marks)

Q5. (a) Iodine and graphite crystals both contain covalent bonds and yet the physical properties of their crystals are very different.
For iodine and graphite, state and explain the differences in their melting points and in their electrical conductivities.

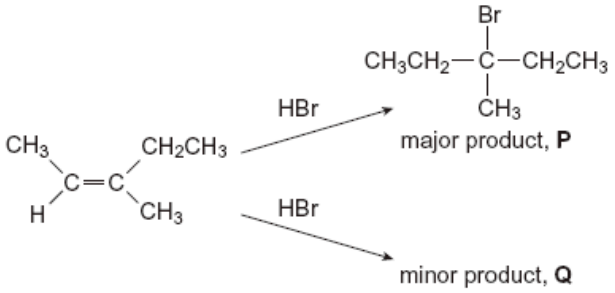
(9)

(b) Draw the shape of the $BeCl_2$ molecule and explain why it has this shape.
State and explain the effect that an isolated Be^{2+} ion would have on an isolated Cl^- ion and explain how this effect would lead to the formation of a covalent bond.
Give one chemical property of $Be(OH)_2$ which is atypical of the chemistry of Group II hydroxides.

(6)
(Total 15 marks)

ANALYTICAL CHEMISTRY

Q4. The alkene (Z)-3-methylpent-2-ene reacts with hydrogen bromide as shown below.



(a) (i) Name the major product **P**.

(1)

(ii) Name the mechanism for these reactions.

(1)

(iii) Draw the displayed formula for the minor product **Q** and state the type of structural isomerism shown by **P** and **Q**.

Displayed formula for **Q** Type of structural isomerism

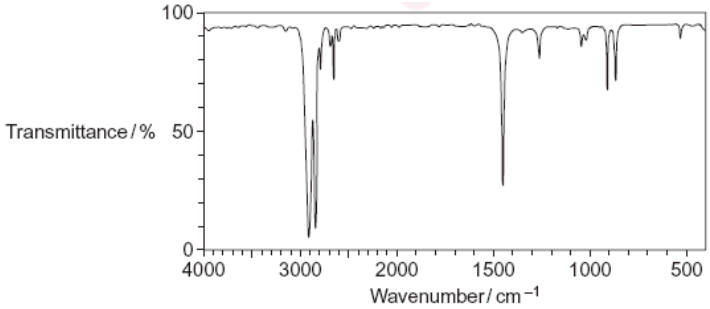
(2)

(iv) Draw the structure of the (E)-stereoisomer of 3-methylpent-2-ene.

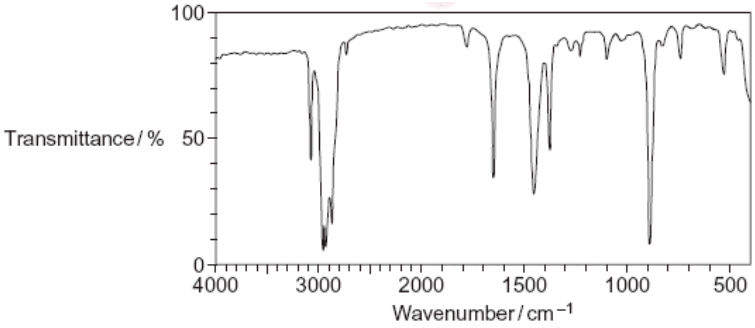
(1)

(b) The infrared spectra of two compounds **R** and **S** are shown below. **R** and **S** have the molecular formula C_6H_{12} and are structural isomers of 3-methylpent-2-ene. **R** is an unsaturated hydrocarbon and **S** is a saturated hydrocarbon.

Spectrum **1**



Spectrum **2**



(i) Identify the infrared Spectrum **1** or **2** that represents compound **R**.
Use information from the infrared spectra to give **one** reason for your answer.
You may find it helpful to refer to **Table 1** on the Data Sheet.

R is represented by Spectrum .....Reason .

(2)

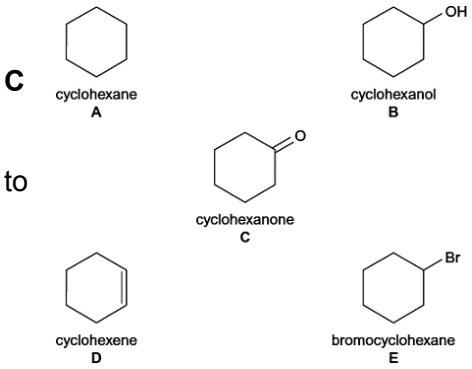
(ii) State the type of structural isomerism shown by **R** and **S**.

(1)

(iii) Name **one** possible compound which could be **S**. **(1)**

(Total 9 marks)

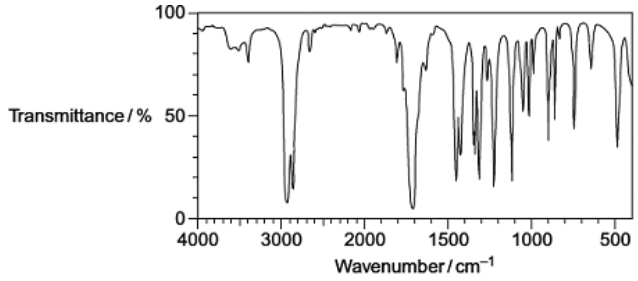
Q11. Consider the five cyclic compounds, **A**, **B**, **C**, **D** and **E**



(a) The infrared spectra of compounds **A**, **B**, and **D** are shown below.

Write the correct letter, **A**, **B**, **C** or **D**, in the box next each spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

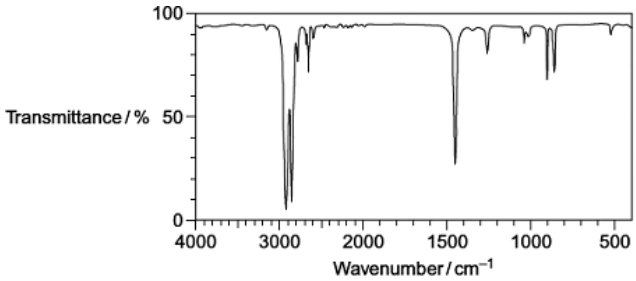
(i)



☐

(1)

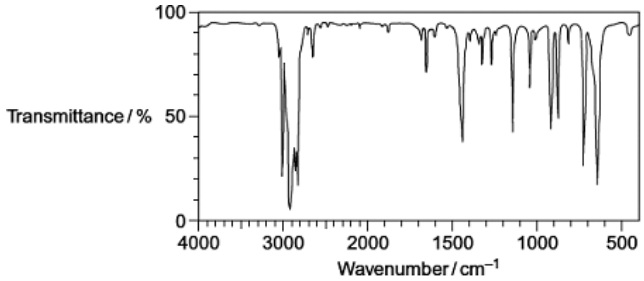
(ii)



☐

(1)

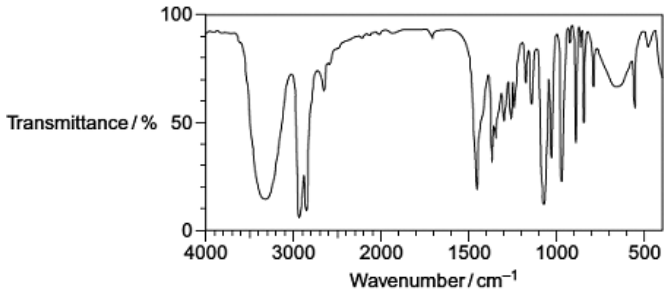
(iii)



☐

(1)

(iv)



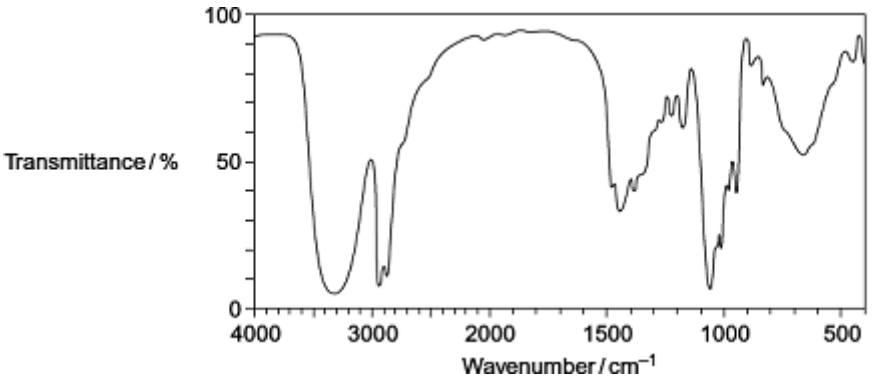
☐

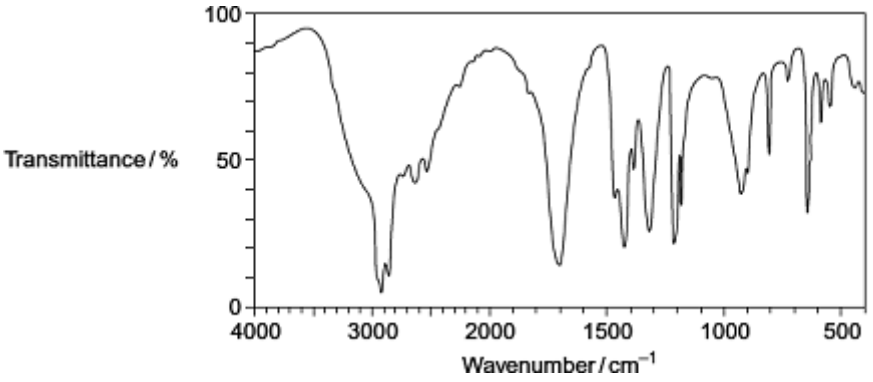
(1)

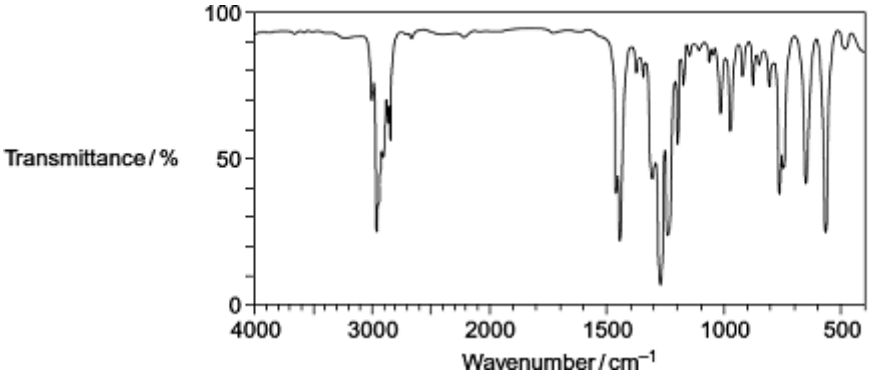
Q13 (ii) The infrared spectra shown are those of three compounds.

Compound **A** 1,4-dibromobutaneCompound **B** butane-1,4-diol
Compound **C** butanedioic acid

Identify the compound responsible for each spectrum by writing the correct letter, **A**, **B** or **C**, in the box next to each spectrum.
You may find it helpful to refer to **Table 1** on the Data Sheet.







(3)

AMOUNT OF SUBSTANCE (A)

M5. (a) Ideal gas equation law **(1)**

1

(b) *Moles of **X***: $n = \frac{PV}{RT}$ **(1)** $= \frac{110000 \times 2.34 \times 10^{-4}}{8.31 \times 473}$ $= 6.55 \times 10^{-3}$ **(1)**

If write $n = \frac{RT}{PV}$ *zero here, but can score* M_r

*Relative molecular mass of **X***: $M_r = \frac{m}{n}$ **(1)**= 62 **(1)**

4

(c) % oxygen = 51.6 **(2)**

C =38.7 / 12 H = 9.68 / 1 O = 57.6**(2)** / 16 **(1)**

= 3.23 = 9.68 = 3.23

1 : 3: 1 ∴ CH_3O **(1)**

3

(d) ($\frac{62}{31}$ × CH_3O) = $C_2H_6O_2$ **(1)**

1

[9]

M6. (a) Moles HCl = $\frac{\text{mass}}{M_r}$ = $\frac{19.6}{36.5}$ **(1)** (= 0.537)

Concentration = $\frac{0.537}{0.25}$ **(1)** = 2.15 (mol dm^{-3}) **(1)**

$\frac{mass}{M_r}$

3

(b) (i) $\frac{21.7}{1000} \times 0.263$ = 5.7**(1)** × 10^{-3} (mol) **(1)**

(ii) $\frac{5.71 \times 10^{-3}}{2}$ = 2.85×10^{-3} (mol) **(1)**

(iii) $\frac{0.394}{2.85 \times 10^{-3}}$ = 138 **(1)**

(iv) *Relative atomic mass of **M***: 138 - 60 = 78 **(1)**

$\frac{78}{2}$ **= 39 (1)**

***Identify of M*: Potassium or K or K^+ (1)**

Conseq

If 78 = M_r then M = selenium

6

[9]

AMOUNT OF SUBSTANCE (A)

M20. (a) (i) Avogadro's number/constant of molecules/particles/species / 6×10^{23}

[Not 'atoms'] **Or** same number of particles as (there are atoms) in 12.(00)g of ^{12}C

1

(ii) *Moles* $O_2 = \frac{0.350}{32}$ *(= 1.09 × 10⁻² mol)*

1

= 29 (× 1.09 × 10^{-2})

1

= 0.316 – 0.317 mol [answer to 3 + sf] **1**

(iii) Moles of nitroglycerine = 4 × 1.09 × 10^{-2} (= 0.0438 mol)

[Mark conseq on their moles of O_2]

1

M_r of nitroglycerine = 227 or number string

1

Moles of nitroglycerine = 227 × 0.0438 = 9.90 – 9.93(g)

[answer to 3+ sf]

(b) pV = nRT **or** $pV = \frac{mRT}{V}$ **or** $p = \frac{nRT}{V}$

1

$p = \frac{nRT}{V} = \frac{0.873 \times 8.31 \times 1100}{1.00 \times 10^{-3}}$

1

= 7980093 **or** 7980 **or** 7.98

1

units = Pa **or** kPa **or** MPa (as appropriate)

1

[11]

BONDING ANSWERS

M3. (a) (i) Electronegativity (difference) or suitable description **(1)**

Accept F and Cl are highly electronegative
Not both atoms are highly electronegative

(ii) HF = hydrogen bonding **(1)**
HCl = (permanent) dipole-dipole bonding **or** even van de Waals' **(1)**
Hydrogen bonding stronger / is the strongest IMF **(1)**

Accept a statement that HF must have the stronger IMF, even if no IMFs identified

*The explanation **must** be based on **intermolecular** forces/attractions*

Note: if the explanation is clearly intramolecular = CE

4

(b) Electron pair **or** lone pair donated **(1)**

Do not accept 'donation of electrons'

From chloride ion to Al **or** $AlCl_3$ **(1)**

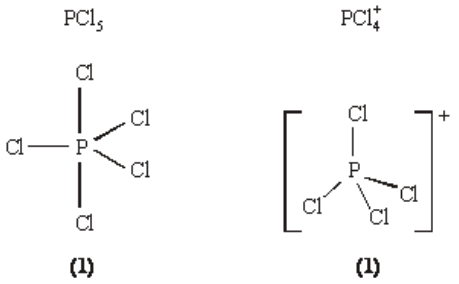
M1 can be earned by a general explanation of coordinate bonding, even if the electron pair is said to come from Al. The second mark, M2, is for this specific bond

Ignore missing charge

2

(c)

4



(1) (1)

PCl_5 shown as trigonal bipyramid [Look for: ONE solid linear Cl-P-Cl bond]

Bond Angle(s) 90° and 120° **(1)**

PCl_4^+ shown as tetrahedral NO solid linear Cl-P-Cl bonds]

Bond angle(s) 109 or 109.5° **(1)**

[10]

M4. (a) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ **(1)***Allow subscripted electron numbers*

(ii) p (block) **(1)** *Allow upper or lower case 's' and 'p' in (a)(i) and (a)(ii)*

2

(b) Lattice of metal / +ve ions/ cations / atoms **(1)***Not +ve nuclei/centres***.** *Accept regular array/close packed/tightly packed/uniformly arranged*
(Surrounded by) delocalised electrons **(1)** *Note: Description as a 'giant ionic lattice' = CE*

2

(c) Greater nuclear or ionic charge or more protons **(1)**

Smaller atoms / ions **(1)** *Accept greater charge density for either M1 or M2*

More delocalised electrons / e^- in sea of e^- / free e^- **(1)**

Stronger attraction between ions and delocalised / free electrons etc. **(1)**

Accept stronger 'electrostatic attraction' if phrase prescribed elsewhere
Ignore references to m/z values
If Mg or Na compared to Al, rather than to each other, then: ***Max 2***
*Treat description that is effectively one for Ionisation Energy as a '****contradiction****'*

3

(d) (Delocalised) electrons **(1)**

Move / flow in a given direction (idea of moving non-randomly)
or under the influence applied pd *QoL mark* **(1)***Allow 'flow through metal'*

2

M5. (a) I_2 sublimes when heated / has low melting point AND
graphite has (very) high melting point **(1)**

I_2 is (simple) molecular / I_2 / I-I **(1)**

Van der Waals forces / induced or temporary dipole-dipole / London forces **(1)**

Whch are weak or easily overcome (so low melting point) **(1)**

Graphite is macromolecular / giant covalent / giant molecular / giant atomic / **(1)**
Diagram

min 3 correctly fused rings – ignore diagram unless no description offered
CE = 0 if 'ionic' or 'metallic' loses M5, M6, M7

(Many) covalent bonds need to be broken **(1)***covalent may be inferred from structure*

Which takes much energy / bonds are strong **(1)**

Only graphite conducts **(1)***NOT just graphite is a better conductor***.** As it has delocalised / free / mobile electrons **(1)**

All e^- in iodine are used in bonding and lone pairs OR as it has no delocalised / free / mobile e^- **(1).** *M9 and M10 tied to correct statements about graphite = conductor and iodine = non-conductor*

Max 9

(b) Diagram Cl–Be–Cl (clearly linear) **(1)**

(Equal) repulsion between 2 bonding pairs / bonds **(1)**

Cl^- ion polarised by Be^{2+} / distorts e^- cloud (must be ions) /diag with correct charges **(1)**

Because of high charge density on Be^{2+} OR high charge / size ratio **(1)**
NOT just Be^{2+} is smaller. Treat higher m/z value as a contradiction

Electrons / electron cloud from Cl^- ion forms covalent bond (with Be) /
electrons in new bond are from Cl^- ion (wtte) **(1)***Accept a correct dot-and-cross diagram***.**
Penalise missing charges or ions once only for M3, M4 and M5

$Be(OH)_2$ is amphoteric / description / dissolves in base **(1)**
NOT Beryllium is amphoteric

6

[15]

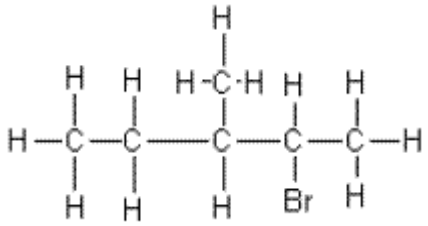
M4. (a) (i) **3**-bromo-**3**-methylpentane ONLY

Must be correct spelling but ignore hyphens and commas

1

(ii) Electrophilic addition (reaction) **1**

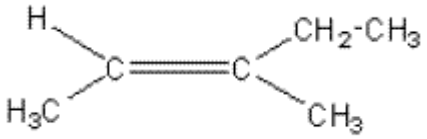
(iii) **M1** Displayed formula of 2-bromo-3-methylpentane



All the bonds must be drawn out but ignore bond angles

M2 Position(al) (isomerism) **2**

(iv) Structure of (E)-3-methylpent-2-ene



Accept C_2H_5 for ethyl **1**

(b) (i) **M1** R is represented by **Spectrum 2**

M2 Spectrum 2 shows an infrared absorption/spike/dip/ trough/peak with any value(s)/range within the range 1620 to 1680 (cm^{-1}) OR this range quoted/identified and this is due to C=C
OR this information could be a correctly labelled absorption on the spectrum

OR Spectrum 1 does not have an infrared absorption in range 1620 to 1680 (cm^{-1}) and does not contain C=C.

Award M1 if it is obvious that they are referring to the second spectrum (or the bottom one)

2

(ii) Functional group (isomerism)

1

(iii) Cyclohexane ***OR*** Methylcyclopentane etc.

1

[9]

Q11. i)C ii) A iii) D iv) B

Q13 ii) **M1** B **M2** C **M3** A