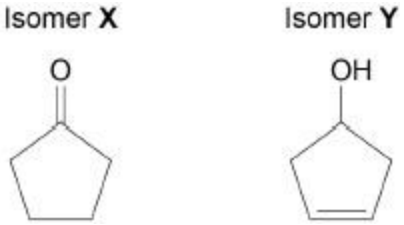
Q12.

Isomers **X** and **Y** have the molecular formula C_5H_8O



(a) Give the IUPAC name for isomer **X**.

_____

(1)

(b) Explain how and why isomers **X** and **Y** can be distinguished by comparing **each** of their

- boiling points
- ^{13}C NMR spectra
- infrared spectra.

Use data from Tables **A** and **C** in the Data Booklet in your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 7 marks)

Q13.

This question is about compounds containing fluorine.

(a) Draw the shape of a molecule of krypton difluoride (KrF_2).
Include in your answer any lone pairs of electrons that influence the shape.
Name the shape produced by the atoms in a KrF_2 molecule and suggest a bond angle.

Name of shape _____

Bond angle _____

(3)

(b) There are two lone pairs of electrons on the oxygen atom in a molecule of oxygen difluoride (OF_2).

Explain how the lone pairs of electrons on the oxygen atom influence the bond angle in oxygen difluoride.

_____

_____

_____

_____

_____

_____

_____

(2)

(c) Silicon tetrafluoride (SiF_4) is a tetrahedral molecule.

Deduce the type of intermolecular forces in SiF_4
Explain how this type of intermolecular force arises and why no other type of intermolecular force exists in a sample of SiF_4

Intermolecular forces in SiF_4 _____

Explanation _____

_____

_____

_____

_____

_____

_____

_____

_____

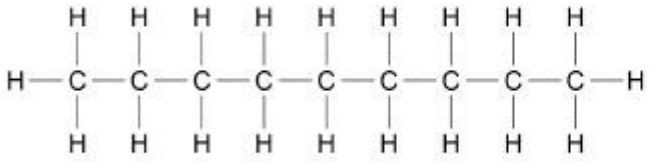
(3)

(Total 8 marks)

Q14.

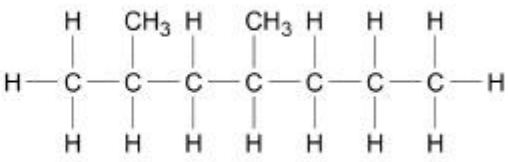
The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula C_9H_{20}
They are found in crude oil and can be separated by fractional distillation.
Both can be used in fuels or cracked to form other products.

nonane



boiling point 151 °C

2,4-dimethylheptane



boiling point 134 °C

(a) State the general formula of an alkane containing n carbon atoms.
Deduce an expression for the relative molecular mass (M_r) of an alkane in terms of n.

General formula _____

Expression _____

(2)

(b) Explain why nonane has a higher boiling point than 2,4-dimethylheptane.

(2)

(c) Give an equation for the complete combustion of nonane.

(1)

(d) Nonane is often found in fuel for jet engines. Combustion in jet engines produces pollutants including nitrogen monoxide (NO).

Explain how this nitrogen monoxide is formed.

(2)

(e) Nonane can be cracked to form large quantities of propene.

Name the type of cracking used.

(1)

(f) The main use of propene, formed from cracking, is to make poly(propene).

Draw the repeating unit of poly(propene).

(1)

(Total 9 marks)

Q15.

Which compound has the highest boiling point?

A butanal ⬭

B butan-2-ol ⬭

C but-2-ene ⬭

D 1-fluorobutane ⬭

(Total 1 mark)

Q16.

The oxidation of propan-1-ol can form propanal and propanoic acid.
The boiling points of these compounds are shown in the table.

Compound	Boiling point / °C
propan-1-ol	97
propanal	49
propanoic acid	141

In a preparation of propanal, propan-1-ol is added dropwise to the oxidising agent and the aldehyde is separated from the reaction mixture by distillation.

(a) Explain, with reference to intermolecular forces, why distillation allows propanal to be separated from the other organic compounds in this reaction mixture.

(3)

(b) Give **two** ways of maximising the yield of propanal obtained by distillation of the reaction mixture.

1. _____

_____

_____

_____

_____

_____

2. _____

_____

_____

_____

_____

_____

(2)

(c) Describe how you would carry out a simple test-tube reaction to confirm that the sample of propanal obtained by distillation does **not** contain any propanoic acid.

_____

_____

_____

_____

_____

_____

(2)

(d) A student carried out an experiment to determine the enthalpy of combustion of ethanol. Combustion of 457 mg of ethanol increased the temperature of 150 g of water from 25.1 °C to 40.2 °C

Calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of ethanol in this experiment.
Give your answer to the appropriate number of significant figures.

(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

Enthalpy of combustion _____ kJ mol^{-1}

(3)

(e) A mixture of isomeric alkenes is produced when pentan-2-ol is dehydrated in the presence of hot concentrated sulfuric acid. Pent-1-ene is one of the isomers produced.

Name and outline a mechanism for the reaction producing pent-1-ene.

Name of mechanism _____

Mechanism

(4)

(f) A pair of stereoisomers is also formed in the reaction in **part (e)**.

Name the less polar stereoisomer formed.
Explain how this type of stereoisomerism arises.

Name _____

Explanation _____

_____

_____

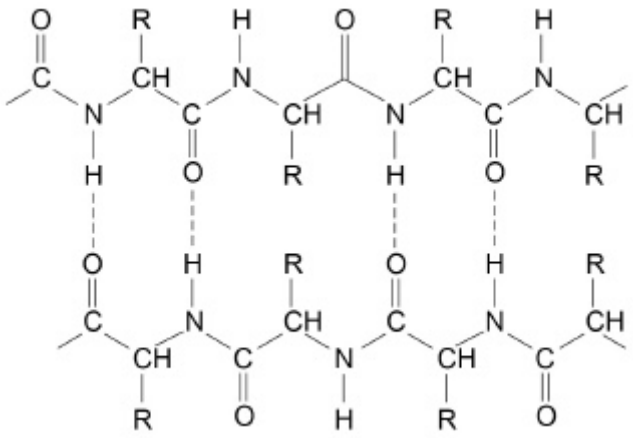
_____

(2)

(Total 16 marks)

Q17.

Use the Data Booklet to help you answer this question about amino acids.
The diagram shows parts of two polypeptide chains in a beta-pleated sheet of a protein.



(a) The polypeptide chains are held together by hydrogen bonding as shown in the diagram.

Explain how these hydrogen bonds form.

_____

_____

_____

_____

_____

(2)

(b) A different type of bond can form between two polypeptide chains when the chains each contain the amino acid cysteine.

Complete the structure to show the bond that forms between the side chains of two cysteine molecules.

(1)

(c) The type of bond in **part (b)** between two polypeptide chains influences the three-dimensional structure of the protein.

Name this type of protein structure.

_____

(1)

(d) Draw the structure of the zwitterion of a dipeptide formed by alanine and serine.

(2)

(Total 6 marks)

Q18.

This question is about intermolecular forces.

(a) Give the meaning of the term electronegativity.

_____

_____

_____

(1)

(b) Explain how permanent dipole-dipole forces arise between hydrogen chloride molecules.

_____

_____

_____

_____

_____

_____

(2)

(c) Complete the table by naming the shape of each molecule.

Place a tick (✓) in the final column if the molecule has a permanent dipole.

Molecule	Name of shape	Tick (✓) if molecule has a permanent dipole
SiH_4		
PH_3		
$BeCl_2$		
CH_3Cl		

(4)

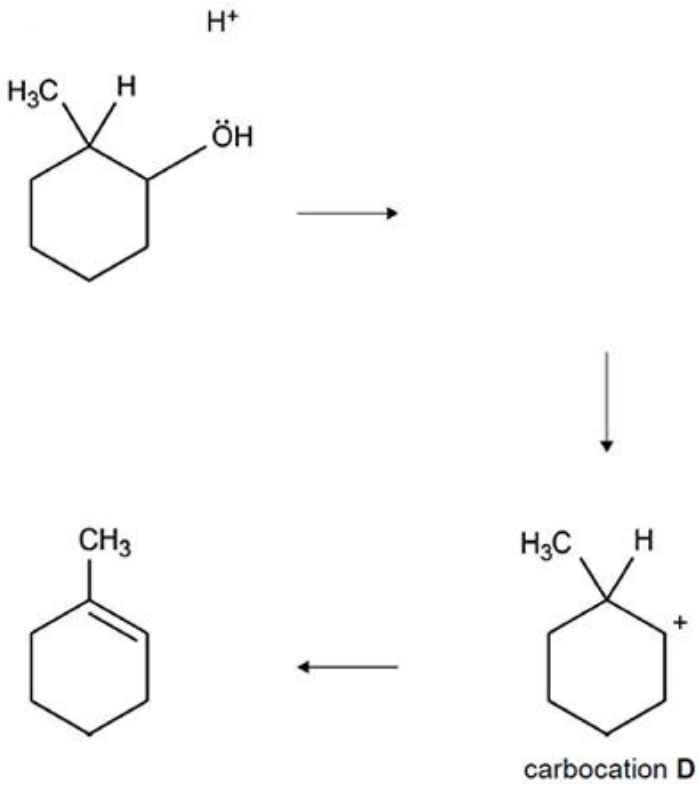
(Total 7 marks)

Q19.

Alcohols undergo dehydration in the presence of concentrated phosphoric acid, via a carbocation intermediate, to form alkenes.

(a) Complete the mechanism for the conversion of 2-methylcyclohexanol into 1-methylcyclohexene via carbocation **D** by drawing

- the structure of the missing intermediate
- all necessary curly arrows.

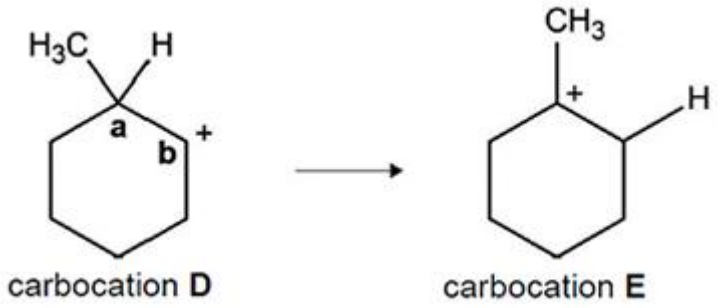


(4)

(b) Draw the structure of a different cyclic alkene formed from carbocation **D**.

(1)

(c) Carbocation **D** can undergo a type of reaction called a rearrangement to form carbocation **E**. In this reaction, a hydrogen atom and its bonding pair of electrons move from carbon **a** to carbon **b** as shown in the diagram below.



Use your knowledge of carbocations to explain why this rearrangement takes place.

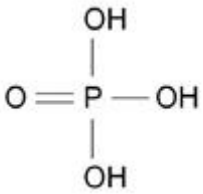
(2)

(d) As a result of the rearrangement in part (c), a third alkene is formed in this reaction.

Draw the structure of this third alkene.

(1)

(e) Cyclohexene is prepared by the dehydration of cyclohexanol using concentrated phosphoric acid as a catalyst. The structure of concentrated phosphoric acid is shown.



Identify the factors that influence the boiling points of each of the compounds in this reaction mixture. State how and explain why cyclohexene can be separated from the reaction mixture.

(6)

(Total 14 marks)

Mark Scheme

Q12.

(a) Cyclopentanone

Allow cyclopentan -1-one but no other numbers

Ignore spaces, commas and hyphens

1

(b)

This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.	
Level 3 **5-6 marks**	**All stages are covered and each stage is generally correct and virtually complete.** Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.
Level 2 **3-4 marks**	**All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete.** Answer shows some attempt at structure Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms
Level 1 **1-2 marks**	**Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete.** Answer includes isolated statements and these are presented in a logical order. Answer may contain valid points which are not clearly linked. Errors in the use of technical terms.
0 marks	Insufficient correct chemistry to gain a mark.

Indicative Chemistry content

Stage 1: boiling points
1a) **Y** has a higher bp
1b) **Y** has H-bonds between molecules and **X** has dip-dip imf
1c) More energy required to overcome H-bonds

Mention of covalent bond breaking loses 1c

Stage 2: ^{13}C NMR
2a) Both have 3 peaks/absorptions in their ^{13}C NMR
2b) **X** has peaks at 20-50 **OR** 190-220ppm
2c) **Y** has peaks at 50-90 **OR** 90-150ppm

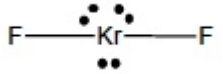
(Ignore peaks at 5-40ppm - present in both)

Stage 3: ir
3a) **X** has a peak (for C=O) at 1680-1750 cm^{-1}
3b) **Y** has peak (for O−H) at 3230-3550 cm^{-1}
OR peak (for C=C) at 1620-1680 cm^{-1}
3c) They would have different fingerprint regions (below 1500 cm^{-1})

6

[7]

Q13.

(a) 

Allow diagram with 2 bonds and 3 lone pairs

1

Linear

1

180°

1

(b) Lone pairs repel more than bond pairs

1

Allow idea of reducing bond angle

bond angle will be lower (than regular tetrahedral angle) / bond angle of 103-106°

1

(c) Van der Waals forces

Allow London forces, dispersion forces, induced dipole-dipole
Apply List for M1.
Allow M2 if vdW mentioned in M1, otherwise CE=0

1

(Uneven distribution of electrons in) one molecule induces dipole in neighbouring/another/nearby molecule

1

symmetrical molecule / dipoles cancel

OR

no hydrogens bonded to F (N or O), therefore no hydrogen bonding

1

[8]

Q14.

(a) **M1** C_nH_{2n+2}

1

M2 14.0*n* + 2.0 or 14n + 2

or 2(7.0n + 1.0) or 2.0(7n + 1) or 2(7n + 1)

1

(b) **M1** nonane has stronger / greater / more <u>van der Waals' forces between molecules</u>

or converse arguments for 2,4-dimethylbutane having lower boiling point

question refers to nonane if not expressly stated by candidate

intermolecular forces = forces between molecules

***M1** ignore abbreviations vdW and/or imf*

1

M2 nonane molecules pack closer together / more (surface) contact

***M2** ignore reference to surface area alone*

CE=0 reference to breaking (covalent) bonds / breaking chain

1

(c) $C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$

allow multiples; ignore any state symbols; correct structures rather than formulae are fine

1

(d) **M1** nitrogen and oxygen from air react

***M1** must be at least one reference to air and no reference to nitrogen/oxygen coming from the fuel*

1

M2 at high temperature

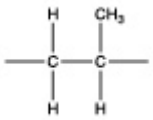
ignore reference to pressure, heat, hot, incomplete combustion

if temperature is stated, must be over 1000°C

1

(e) thermal (cracking)

1

(f) 

allow any correct structural representation

ignore any n or brackets

1

[9]

Q15.

B

[1]

Q16.

(a) Aldehyde/propanal has <u>dipole-dipole</u> forces (between molecules)

If any 'covalent bonds broken' CE=0 for clip.

Ignore Van der Waal forces

M1

Alcohol/propan-1-ol AND Carboxylic acid/ propanoic acid have hydrogen bonding (between molecules).

Ignore reference to energy

M2

The forces between the molecules in aldehyde are weaker (than those in alcohol and acid so it will evaporate first.)

M3 only awarded following correct M1 OR M2

Allow converse for M3

M3

(b) Keep the temperature of the reaction mixture below the boiling point of propan-1-ol/below 97 °C

Allow temperature in range 49-96 inclusive

Allow description of cooling the vessel

M1

Cool the distillate / collecting vessel

Ignore reference to oxidising agents

Penalise lid / sealed container

M2

(c) Add named carbonate/hydrogencarbonate OR magnesium to a sample of the distillate.

Incorrect chemical CE=0

Allow formula (mark on for incorrect formula)

Allow blue litmus or correct named indicator

M1

Effervescence/fizz/bubbles would confirm presence of acid or converse

Blue litmus turns red confirms acid present or converse

Allow gas/CO_2 produced which turns lime water cloudy OR gas/H_2 produced which burns with a squeaky pop

M2

(d) (Temperature difference = 15.1 °C)

If ΔT wrong – AE mark on otherwise can only award M2

If use 457 in M1, can only score M2

q = 150 × 4.18 × 15.1 or 9467.7 J or 9.4677kJ

M1

amount ethanol burned = 0.457/46.0 = 9.93×10^{-3} mol

If use 457 in M2 can score 2 for - 0.953 kJ mol-1

M2

Heat change per mole = (M1/1000)/M2 = 952.99 kJ mol-1

ΔH = – 953 kJ mol^{-1} must be 3sfs and must be negative

(allow range -953 to -954)

BEWARE if they miss conversion to kJ and also miss conversion to g, they get answer = - 953 which scores 1

+953 can score M1 and M2

Allow -950 or -960 for rounding to 2sf

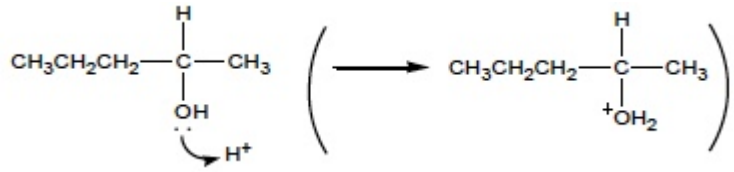
M3

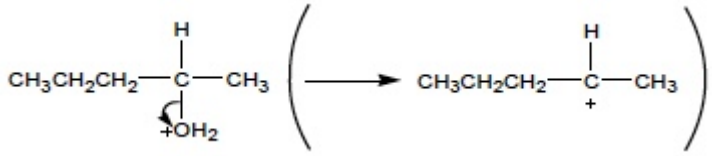
(e) Elimination

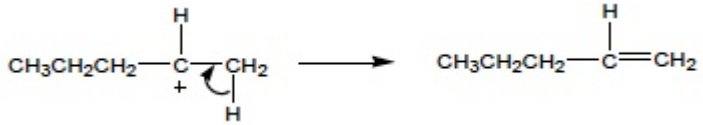
Penalise base elimination

M1

Mechanism : Either (E1)



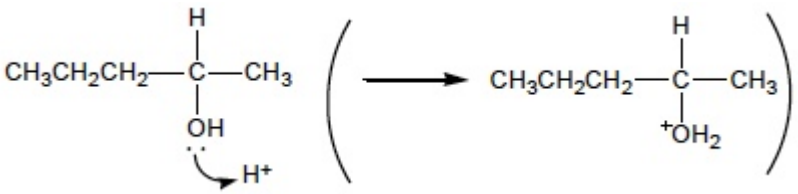




M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing loss of H^+
From correct carbocation (E1)
wrong alcohol used / alkene formed loses M4

3

OR (E2)



M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing simultaneous loss of H^+

wrong alcohol used / alkene formed loses M4

3

(f) *E*-pent-2-ene

Allow trans

M1

C=C bond cannot <u>rotate</u> **and**

Each carbon in the double bond has (2) different groups attached.

Allow (two) different groups on each/either side of the double bond.

M2

[16]

Q17.

(a) electron deficient H

Allow H delta plus / slightly positive

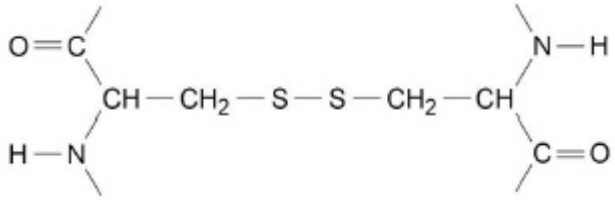
M1

(Which attracts) lone pair/electron pair on O

Penalise lone pair/electron pair donation

M2

(b)



Penalise dashed/dotted S—S

Ignore extra additions to structures

1

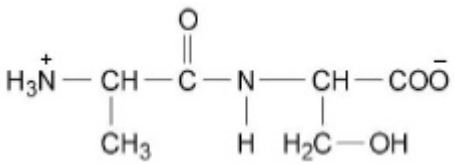
(c) Tertiary or Quaternary

Allow 3° or 4°

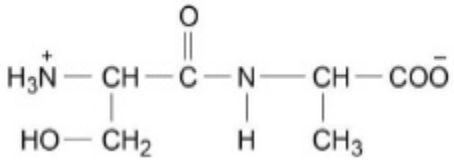
do not penalise minor error in spelling e.g. Quarternary

1

(d)



OR



Incorrect peptide bond CE=0

M1 for correct dipeptide

M2 for correct charges

Ignore additional dipeptide in working

Allow –CONH— or –COHN—

1
1

[6]

Q18.

(a) Power of an atom to attract a pair of electrons in a covalent bond.

Allow power of an atom to attract a bonding/shared pair of electrons

Allow power of an atom to withdraw electron density from a covalent bond

Not lone pair Not Element

1

(b) Difference in electronegativity leads to bond polarity

If chloride (ions) mentioned then CE = 0

1

(dipoles don't cancel therefore the molecule has an overall permanent dipole) and there is an attraction between $\partial+$ on one molecule and $\partial-$ on another

partial charges should be correct if shown and can score M2 from diagram

1

(c)

SiH_4	**Tetrahedral**		1 shape & no tick
PH_3	**Pyramidal (trigonal) Allow tetrahedral**	✓	1 shape & tick
$BeCl_2$	**Linear**		1 shape & no tick
CH_3Cl	**(Distorted)Tetrahedral**	✓	1 shape & tick

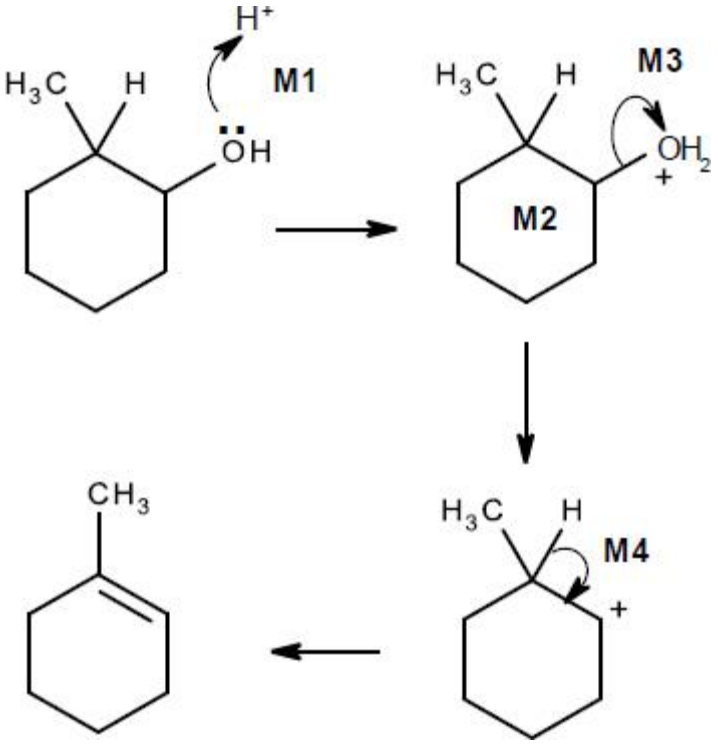
If shapes are drawn rather than named then penalise first mark gained

4

[7]

Q19.

(a)



M1 curly arrow from lone pair on O to H^+ **1**

M2 correct structure of intermediate with + on O **1**

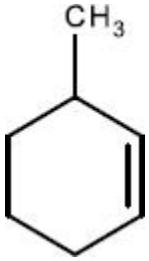
M3 curly arrow from C-O bond to O **1**

M4 curly arrow from correct C-H bond towards correct C-C <u>bond</u> **1**

*Ignore other species that are drawn, but penalise any curly arrows to/from other species for **M1/3/4** as relevant (but allow attack by an anion of phosphoric acid on the H that is lost in **M4** in addition to the arrow specified)*

*for **M2**, the O of the $^+OH_2$ group must be bonded to the ring*

(b)



Any correct structural representation **1**

(c) **M1** more stable (carbocation formed)

*For **M1** penalise more stable product* **1**

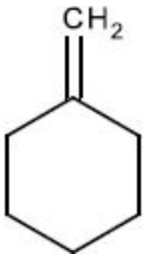
M2 changes from secondary to tertiary (carbocation)

*For **M2** allow explanation via inductive effect with more alkyl / C groups attached or inductive effect from methyl group as alternatives*

Allow 2^o or 2^y for secondary and 3^o or 3^y for tertiary

1

(d)



Any correct structural representation

1

(e) **M1** cyclohexene : van der Waals' forces (between molecules)

1

M2 cyclohexanol : hydrogen bonds (between molecules)

1

M3 phosphoric acid: hydrogen bonds (between molecules)

1

M4 idea that cyclohexene has weakest forces

1

M5 separated by (simple / fractional) distillation

1

M6 cyclohexene has lowest boiling point / boils off first

Extended response

Maximum of 5 marks for answers which do not refer to the van der Waals forces or hydrogen bonds being between molecules in some way

***M1** penalise reference to presence of other intermolecular forces*

***M1** allow vdW forces (on this occasion)*

***M1/2/3** penalise reference to breaking covalent bonds*

***M2 & M3** ignore reference to van der Waals and/or (permanent) dipole-dipole forces*

***M2** allow use of term H bonds (on this occasion)*

***M4** allow converse argument*

***M4 & M6** – allow correct comparison of cyclohexene forces and boiling point to one of the other two compounds if only one of cyclohexanol or phosphoric acid discussed*

[14]