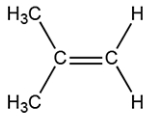
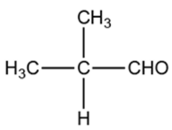
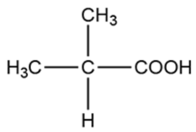
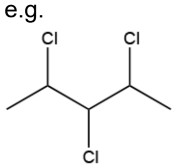
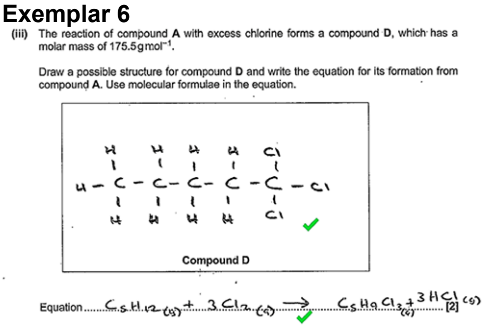
Mark scheme – Basic Concept of Organic Chemistry

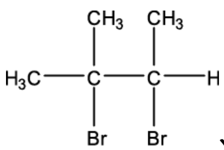
Question			Answer/Indicative content	Marks	Guidance
1		i	 **F** ✓  **G** ✓  **H** ✓	**3**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** mixture of the above (as long as unambiguous) **IGNORE** molecular formula **ALLOW** CH_3– **ALLOW** 1 mark for **G AND H** combined is structures are correct but in wrong boxes **<u>Examiner's Comments</u>** Part (i) discriminated extremely well and rewarded the well-prepared candidate. Compound F proved to be the most difficult option, with a large variety of responses, many appearing to be guesses. Candidates were much more successful with compounds **G** and **H**, although these were sometimes shown in reverse order. A significant number of candidates drew structures containing C=C or C=O bonds in which the carbon atom had five bonds. Candidates should check drawing of organic structures carefully to ensure that all carbon atoms have four bonds. There were some good responses for part (ii), with many clearly shown and correct systematic names.
		ii	2-methylpropan−1−ol ✓ *Both numbers required*	**1**	**IGNORE** absence of hyphen or use of dots or commas as separators **DO NOT ALLOW** 2−methylprop−1−ol **OR** 2−methpropan−1−ol **OR** 2−methypropan−1−ol
			Total	**4**	
2	a		**Structural isomers:** *1 mark* Different structural formulae AND same molecular formula ✓	**5**	For 'structural': **ALLOW** different structure **OR** different displayed/ skeletal formula **DO NOT ALLOW** any reference to spatial/space/3D

			Common molecular formula: *1 mark* C_5H_{12} for all 3 hydrocarbons ✓ **Boiling point and branching:** *1 mark* Boiling point decreases with more branching **OR** more methyl/alkyl groups/side chains **OR** shorter carbon chain ✓ **Branching and London forces:** *1 mark* *Could be seen anywhere within response* More branching gives less (surface) contact **AND** fewer/weaker London forces ✓ **Energy and intermolecular forces:** *1 mark* Less energy to break London forces/ intermolecular forces/intermolecular bonds/ ✓		Same formula is **not** sufficient (no 'molecular') Different arrangement of atoms is **not** sufficient (no 'structure'/'structural') **ALLOW** 5 carbons and 12 hydrogens **ALLOW** for 2 marks: Different structural formulae **AND** same molecular formula ✓ of C_5H_{12} ✓ **Comparisons** needed throughout **ORA** throughout **ALLOW** comparison between any alcohols, e.g. **A** is least branched and has highest b pt **C** is most branched and has lowest b pt **ALLOW** induced dipole(−dipole) interactions **IGNORE** van der Waals'/vdw forces **ALLOW** SA for surface area **ALLOW** 'harder to overcome intermolecular forces **ALLOW** more energy to separate the molecules **IGNORE** just 'bonds' ***intermolecular/London forces*** *required* **<u>Examiner's Comments</u>** This question discriminated well and resulted in a full range of marks. Most candidates were aware that structural isomers have different structural formulae but the same molecular formulae. It was common though for candidates to refer to different arrangements of atoms in space, clearly confusing with stereoisomerism. The best candidates used the structures (as in the question) to show that the common molecular formula was C5H12. Candidates were expected to link the amount of surface contact between molecules with induced dipole–dipole forces or London forces. 'Contact' or the name of the intermolecular forces was often omitted. Finally, candidates were expected to link the amount of branching to the strength of the intermolecular forces and the energy

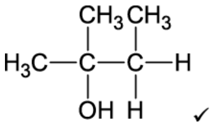
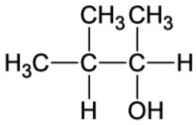
					needed to change state. Lower ability candidates often let themselves down by being unable to construct a well-reasoned response. There was often a gulf between the clear responses of able candidates and those of lower ability candidates.
	b	i	Radical substitution ✓	1	**ALLOW** Free radical substitution **<u>Examiner's Comments</u>** Most candidates identified this reaction as radical substitution.
		ii	<table><tr><th>A</th><th>B</th></tr><tr><td>3 ✓</td><td>2 ✓</td></tr></table>	2	**<u>Examiner's Comments</u>** Most candidates achieved at least one mark, particularly for isomer **A**. Successful candidates often drew structures of the isomers alongside the table to help with their response.
		iii	**Structure of D** Structure of a trichloro isomer of **A**, e.g.  ✓ **ALLOW** any trichloro isomer of A **CHECK** carefully **Equation** $C_5H_{12} + 3Cl_2 \rightarrow C_5H_9Cl_3 + 3HCl$ ✓ **Molecular formulae required** **NO ECF** from incorrect structure of **D**	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** molecular formula **ALLOW** multiples, e.g. $2C_5H_{12} + 6Cl_2 \rightarrow 2C_5H_9Cl_3 + 6HCl$ **<u>Examiner's Comments</u>** Many candidates correctly drew the structure of compound D but comparatively few were able to construct a correct equation. For this equation, candidates needed to apply their knowledge and understanding of monosubstitution of alkanes to substitution of three H atoms by three Cl atoms. This task proved to be one of the most difficult questions on this paper. The exemplar shows an excellent response. The candidate has drawn a trisubstituted structure that fits the molar mass of 175.5 g mol^{-1} and a

					correct equation for its formation. Many attempts at this equation showed H2 as the second product rather than HCl. **Exemplar 6** 
			Total	**10**	
3			Electron pair acceptor (1) I^{+} (1)	2	
			Total	**2**	
4			$C_nH_{2n}O_2$ **OR** $C_nH_{2n+1}COOH$ ✓	**1**	**Examiner's Comment:** The correct response; $C_nH_{2n}O_2$ or $C_nH_{2n+1}COOH$, was presented by a good proportion of candidates but many incorrect alternatives were seen.
			Total	**1**	
5	a	i	(series of compounds with the) same functional group **OR** same / similar chemical properties **OR** same / similar chemical reactions ✓ each **successive / subsequent** member differing by CH_2 ✓	2	**IGNORE** reference to physical properties **IGNORE** same general formula (*in question*) Differs by CH_2 is **not** sufficient (*no successive*) **DO NOT ALLOW** same empirical **OR** have the same molecular formula **Examiner's Comments** Many candidates were able to score both marks by specifying the same functional group and that each successive member varies by a CH_2 group. Some responses were imprecise and referred to just members differing by a CH_2 group.
		ii	$C_nH_{2n-1}Br$ ✓	1	**ALLOW $C_nH_{2n-1}X$ ONLY** if X is specified as Br (*question asks for bromide*)

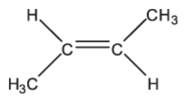
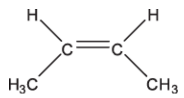
					Examiner's Comments The most able candidates were able to determine the general formula required. Many candidates came close and stated $C_nH_{2n-1}X$, but failed to specify that X was Br.
		iii	3-bromoprop(-1-)ene ✓	1	**ALLOW** 1-bromoprop-2-ene **Examiner's Comments** Candidates were asked to give the systematic name for ally bromide. Although a fair proportion stated 3-bromopropene, 1-bromoprop-2-ene was also a common response. Either of these was allowed by the mark scheme. A common incorrect response was 1-bromoprop-3-ene. Candidates should be aware that the lowest possible locant numbers should be used when naming compounds.
	b	i	Movement of an electron pair ✓	1	**ALLOW** movement of a lone pair **OR** movement of a bond **Examiner's Comments** Although the definition of a curly arrow was well known, many imprecise responses were seen. The most common was that a curly arrow represents the movement of electrons. Candidates should be aware that it is important to refer to an electron pair, when describing the meaning of a curly arrow.
		ii	Electron pair donor ✓	1	**ALLOW** can donate a lone pair **Examiner's Comments** Most candidates could state the correct definition. However, as with part (i) a significant number of candidates failed to specify 'electron pair' and stated that a nucleophile is an electron donor.
			Total	**6**	
6	a	i	(compounds or molecules having the) same molecular formula but different structural formulae ✓	1	**ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula for structure **DO NOT ALLOW** any reference to spatial / space Same formula is **not** sufficient (*no reference to molecular*) Different arrangement of atoms is **not**

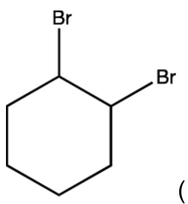
					sufficient (*no reference to structure / structural*) **Examiner's Comments** Most candidates were able to define structural isomers. Some responses were imprecise with candidates stating that isomers had 'different arrangements of atoms' rather than referring to different structural formulae.
		ii	2, 2, 3-trimethylbutane ✓	1	**ALLOW** trimethylbutane as the **ONLY** alternative response **Examiner's Comments** Many candidates found this question difficult and it was common to see incorrect names for compound **A**. These included incorrect use of locant numbers e.g. 2,3,3-trimethylbutane and inappropriate nomenclature e.g. 2,2-dimethyl-3-methylbutane. A small proportion of candidates named compound **A** as heptane.
	b		 ✓	1	**DO NOT ALLOW** molecular formulae **OR** structural formula **OR** displayed formula **OR** mixture of the above **Examiner's Comments** The majority of candidates were able to provide the skeletal formula of pentane.
			Total	**3**	
7	a		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **DO NOT ALLOW** molecular formula **ALLOW** dichloro or diiodo compound instead of the dibromo compound as the **only** alternatives. **Examiner's Comments** This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo

					compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).
	b		Reagent **A**: correct halogen✓ e.g. Br_2 / bromine	1	**ALLOW** Cl_2 if dichloro compound drawn **ALLOW** I_2 if diiodo compound drawn **IGNORE** state symbols Answer must match box from **(a)** to score **Examiner's Comments** This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).
	c	i	Steam **AND** acid catalyst ✓	1	**ALLOW** H^+ / named acid / H_2SO_4 / H_3PO_4 **ALLOW** $H_2O(g)$ **ALLOW** water only if a temperature of 100 °C or above is quoted. **IGNORE** any temperature given with steam **IGNORE** pressure **Examiner's Comments**

					One would expect the majority of candidates to do well in a question which required them to state the reagents and conditions required for the hydration of alkenes; however this was not the case. The most able candidates provided accurate responses which referred to both steam and the acid catalyst, which was often shown to be H_3PO_4. Other candidates stated only one of the two required responses and it was common to see the acid catalyst stated alongside a temperature and pressure but with no reference to steam. Some candidates stated the reagent as H_2O instead of steam and this was allowed if accompanied by a temperature of over 100 °C. Candidates should be encouraged to learn reagents and conditions required for organic reactions.
		ii	(compounds or molecules) having the same molecular formula but different structural formulae ✓	1	**ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula for structure Same formula is **not** sufficient Different arrangement of atoms is **not** sufficient **Examiner's Comments** The majority of candidates were able to explain the term structural isomers.
		iii	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** any vertical bond to OH **DO NOT ALLOW** OH− **Examiner's Comments** Many candidates found this question difficult and a large number of candidates showed structures of alcohols with the molecular formula $C_5H_{12}O$, but that could not be formed from 2- methylbut-2-ene. Examples of these incorrect responses included 2-methylbutan-1-ol, pentan-1- ol, pentan-2-ol and pentan-3-ol. Only the most able could show the structures of both alcohols produced by the hydration of 2-methlybut-2-ene. Candidates should be reminded to check

					that any structures they suggest are consistent with the context of the question.
		iv	Does not contain OH group(s) **OR** does not contain hydroxyl group(s) **OR** is not an alcohol ✓ Does not form hydrogen bonds with water ✓	2	**ALLOW ORA** throughout **DO NOT ALLOW** OH^- (ions) / hydroxide (ions) 'Does not form hydrogen bonds' is **not** sufficient **Examiner's Comments** The majority of candidates were able to recognise that the key to the solubility of the isomers in water is that they contain the OH group whereas 2-methylbut-2-ene does not. Most candidates scored the second mark by accurately explaining that the OH group could form hydrogen bonds with water.
			Total	**8**	
8	a	i	(series of compounds with the) same functional group **OR** same / similar chemical properties **OR** same / similar chemical reactions ✓ each **successive/subsequent** member differing by CH_2 ✓	2	**IGNORE** references to physical properties **IGNORE** has same general formula (in question) **DO NOT ALLOW** have the same empirical formula **OR** have the same molecular formula **Examiner's Comments** Many candidates were able to score both marks by specifying the same functional group and that each successive member varies by a CH_2 group. Some responses were imprecise and referred to just members differing by CH_2 group.
		ii	C_nH_{2n} ✓	1	**Examiner's Comments** Most candidates were able to state the general formula for the cycloalkanes.
		iii	More carbons (in ring) **OR** more (surface area of) contact **AND** **more van der Waals** forces	2	**Both answers need to be comparisons** **ALLOW** ORA throughout **ALLOW** has more electrons **OR** larger (carbon) ring **OR** higher molecular mass **IGNORE** bigger molecule **IGNORE** chain instead of ring **DO NOT ALLOW** 'more contact between atoms' **ALLOW** 'VDW' for van der Waals

			OR stronger van der Waals forces ✓ More energy needed to break the intermolecular forces ✓		‘More intermolecular forces’ is **not** sufficient **ALLOW** it is harder to overcome the intermolecular forces **ALLOW** intermolecular bonds / van der Waals bonds **ALLOW** more energy is needed to separate molecules **IGNORE** more energy is needed to break bonds **Examiner's Comments** This was a well answered question and many candidates could relate the difference in boiling point to the increase in points of contact and stronger van derWaals' forces. A significant number of candidates referred to the breaking of bonds rather than intermolecular forces.
	b	i	(Compounds with the) same structural formula but a different arrangement (of atoms) in space ✓	1	**ALLOW** different spatial arrangement of atoms. **DO NOT ALLOW** different displayed formula. **Examiner's Comments** Although many candidates were able to provide the correct definition, some responses did not state that stereoisomers have the same structural formula.
		ii	 ✓  ✓	2	**ALLOW** displayed **OR** skeletal formula **OR** mixture of the above. **ALLOW** structures in either order **IGNORE** molecular formula **IGNORE** structural formula **IGNORE** names **IGNORE** E/Z and cis / trans labels **ALLOW** 1 mark for a pair of E/Z isomers of an incorrect hydrocarbon structure with **four** C atoms e.g. C, or CH or CH_2 instead of CH_3 groups. **Examiner's Comments** This question required candidates to identify isomers of cyclobutane that would exhibit stereoisomerism and proved challenging for some. The more able candidates were able to provide two correct structures. A significant number of candidates suggested

					cyclic alkenes, which were not isomers of cyclobutane.
			Total	**8**	
9	a		Aliphatic = E, H, I, J (1) Alicyclic = E, H, J (1) Aromatic = F, G (1)	3	
	b		C_nH_{2n+1}	1	**do not allow** C_nH_{2n+} 1
	c	i	*Equation:* $C_6H_{12}O \rightarrow C_6H_{10} + H_2O$ (1) *Calculation:* **FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 32.7 (%) award 3 marks theoretical yield = 7.65 / 100 = 0.0765 (mol) (1) actual yield = 2.05 / 82 = 0.025 (mol) (1) % yield = (0.025 / 0.0765) × 100% = 32.7(%) (1)	4	**ignore** state symbols **allow** $C_6H_{11}OH$ for $C_6H_{12}O$ **If there is an alternative answer, check to see if there is any ECF credit possible using working below** % yield **must** be to 1 dp **allow** theoretical and actual yield calculated in mass theoretical yield = 0.0765 × 82 = 6.273 g % yield = (2.05 / 6.273) = 32.7(%) **allow ecf** from calculated actual and theoretical yields
		ii	bromine water is decolourised (1)  (1)	2	**allow** bromine water turns colourless **ignore** 'goes clear' **allow** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above
			Total	**10**	