Mark Scheme (Results)

January 2021

Pearson Edexcel International Advanced Subsidiary Level
In Chemistry (WCH11)
Paper 1: Structure, Bonding and Introduction to Organic Chemistry

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

January 2021
Publications Code WCH11_01_2101_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Section A

Question number	Answer	Mark
1	**The only correct answer is B** (C_3H_8) ***A*** *is incorrect because the empirical formula is* CH_2 ***C*** *is incorrect because the empirical formula is* C_2H_5 ***D*** *is incorrect because the empirical formula is* CH_2	1

Question number	Answer	Mark
2	**The only correct answer is C** (BH_3) ***A*** *is incorrect because there are* 1.51×10^{23} *atoms* ***B*** *is incorrect because there are* 4.52×10^{23} *atoms* ***D*** *is incorrect because there are* 7.53×10^{23} *atoms*	1

Question number	Answer	Mark
3	**The only correct answer is A** (0.1 g dm^{-3} HCl) ***B*** *is incorrect because HCl has a higher concentration of chloride ions* ***C*** *is incorrect because HCl has a higher concentration of chloride ions* ***D*** *is incorrect because HCl has a higher concentration of chloride ions*	1

Question number	Answer	Mark
4	**The only correct answer is D** ($CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$) ***A*** *is incorrect because there are no waste products* ***B*** *is incorrect because H_2 has a lower M_r than Na_2CO_3* ***C*** *is incorrect because the combined M_r of H_2O and CO_2 is lower than Na_2CO_3*	**1**

Question number	Answer	Mark
5	**The only correct answer is B** ($^{124}_{50}\mathrm{Sn}$) ***A*** *is incorrect because $^{115}_{49}\mathrm{In}$ has 66 neutrons* ***C*** *is incorrect because $^{123}_{51}\mathrm{Sb}$ has 72neutrons* ***D*** *is incorrect because $^{124}_{52}\mathrm{Te}$ has 72neutrons*	**1**

Question number	Answer	Mark
6	**The only correct answer is B** ($1s^2 2s^2 2p^6 3s^2 3p^6$) ***A*** *is incorrect because this is the electronic configuration of an s-block element* ***C*** *is incorrect because this could not be the electronic configuration of the ion of a p-block element* ***D*** *is incorrect because this could not be the electronic configuration of the ion of a Period 3 element*	**1**

Question number	Answer	Mark
7	**The only correct answer is C** (carbon) ***A*** *is incorrect because Al is in Period 3* ***B*** *is incorrect because the element with the highest melting temperature is in Group 4* ***D*** *is incorrect because Si is in Period 3*	**1**

Question number	Answer	Mark
8	**The only correct answer is C** (Hg(l)) ***A*** *is incorrect because simple molecules do not conduct electricity* ***B*** *is incorrect because simple molecules do not conduct electricity* ***D*** *is incorrect because ionic compounds do not conduct electricity as solids*	**1**

Question number	Answer	Mark
9	**The only correct answer is A** (N^{3-}) ***B*** *is incorrect because F^- has more protons than N^{3-} so greater nuclear attraction on the outer electrons* ***C*** *is incorrect because Na^+ has more protons than N^{3-} so greater nuclear attraction on the outer electrons* ***D*** *is incorrect because Al^{3+} has more protons than N^{3-} so greater nuclear attraction on the outer electrons*	**1**

Question number	Answer	Mark
10	**The only correct answer is D** (Ca^{2+}) ***A*** *is incorrect because anions do not polarise cations* ***B*** *is incorrect because anions do not polarise cations* ***C*** *is incorrect because* K^+ *has a smaller charge and a greater ionic radius*	1

Question number	Answer	Mark
11	**The only correct answer is A** (C_{60} fullerene) ***B*** *is incorrect because the structure of diamond is formed by a giant lattice of carbon atoms* ***C*** *is incorrect because the structure of graphene is formed by a giant lattice of carbon atoms* ***D*** *is incorrect because the structure of graphite is formed by a giant lattice of carbon atoms*	1

Question number	Answer	Mark
12	**The only correct answer is A** (HF) ***B*** *is incorrect because there is a relatively small difference in electronegativity between oxygen and fluorine* ***C*** *is incorrect because* BF_3 *is a non-polar molecule* ***D*** *is incorrect because* CF_4 *is a non-polar molecule*	1

Question number	Answer	Mark
13	**The only correct answer is B** (corrosive) ***A*** *is incorrect because this is a precaution and not a hazard* ***C*** *is incorrect because this is a precaution and not a hazard* ***D*** *is incorrect because this is not the symbol for oxidising*	**1**

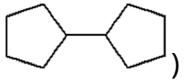
Question number	Answer	Mark
14	**The only correct answer is C** (3,4,6-trimethyloctane) ***A*** *is incorrect because the longest chain of carbon atoms is not seven* ***B*** *is incorrect because the longest chain of carbon atoms is not seven* ***D*** *is incorrect because the sum of the locant numbers is not the lowest*	**1**

Question number	Answer	Mark
15	**The only correct answer is A** (burn to produce greenhouse gases) ***B*** *is incorrect because they are not all carbon neutral* ***C*** *is incorrect because they are not all sustainable* ***D*** *is incorrect because they do not all biodegrade rapidly*	**1**

Question number	Answer	Mark
16(a)	**The only correct answer is D** ($C_5H_{10} + Br_2 \rightarrow C_5H_9Br + HBr$) ***A*** *is incorrect because C_5H_8 is the formula of cyclopentene and the reaction is not addition* ***B*** *is incorrect because the reaction is not addition and this product is not formed* ***C*** *is incorrect because these products are not formed*	**1**

Question number	Answer	Mark
16(b)	**The only correct answer is A** (only the initiation step involves homolytic bond fission) ***B*** *is incorrect because not all of the bromine is converted to radicals in the initiation step* ***C*** *is incorrect because many more propagation than termination reactions occur* ***D*** *is incorrect because additional substitution products are likely to form*	**1**

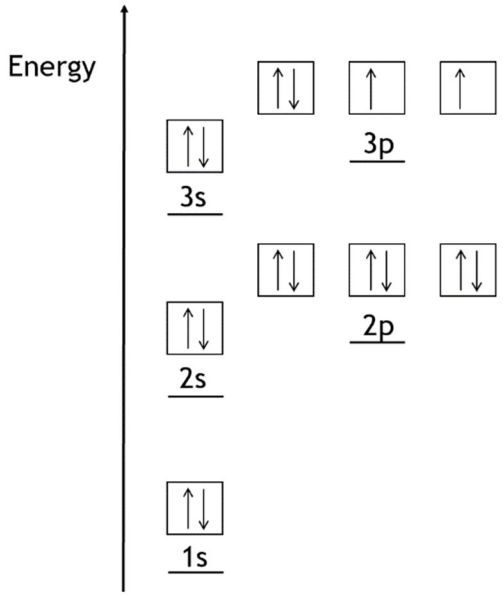
Question number	Answer	Mark
16(c)	**The only correct answer is D** ($H^{\bullet}$) ***A*** *is incorrect because $C_5H_9^{\bullet}$ radicals form in propagation reactions* ***B*** *is incorrect because $Br^{\bullet}$ radicals form in propagation reactions* ***C*** *is incorrect because $C_5H_8Br^{\bullet}$ radicals may form in secondary propagation reactions*	**1**

Question number	Answer	Mark
16(d)	**The only correct answer is C** () ***A*** *is incorrect because the molecule does not contain 10 carbon atoms* ***B*** *is incorrect because the molecule does not contain 10 carbon atoms* ***D*** *is incorrect because the molecule does not contain 18 hydrogen atoms*	**1**

Question number	Answer	Mark
17	**The only correct answer is B** (exporting polymer waste) ***A*** *is incorrect because biodegradable polymers are broken down by microorganisms* ***C*** *is incorrect because this removes harmful pollution* ***D*** *is incorrect because this saves energy and conserves non-renewable resources*	**1**

TOTAL FOR SECTION A = 20 MARKS

Section B

Question Number	Answer	Additional guidance	Mark
18(a)	A completed diagram showing: • correctly labelled subshells (1) • correctly filled boxes/orbitals (1)	Allow p subshell labelled as orbitals eg $2p_x$, $2p_y$, $2p_z$ Ignore specified number of electrons, even if incorrect eg $3p^5$ Allow paired 3p electrons in any 3p orbital Allow unpaired 3p electrons as spin down Allow half-headed arrows Do not award vertical lines for arrows Do not award paired electrons with parallel spin <u>Example of completed diagram:</u>  	**2**

Question Number	Answer	Additional guidance	Mark
18(b)	• species and balancing (1) • correct state symbols (1)	Example of equation: $S(g) \rightarrow S^+(g) + e^{(-)}$ or $S(g) - e^{(-)} \rightarrow S^+(g)$ Do not award multiples **M2 dependent on S/S_8 on one side of equation and charged $S^+/S_8^+/S^-/S_8^-$ on the other (does not need to be balanced)** Ignore (g) state symbol on electron $S(g) + e^{(-)} \rightarrow S^+(g) + 2e^{(-)}$ scores (1)	**2**

Question Number	Answer	Additional guidance	Mark
18(c)	An explanation that makes reference to the following points: • outermost electrons in same subshell / (quantum) shell (1) • Cl contains the greatest number of protons / more protons than S (1) • repulsion between (paired) electrons in (3)p orbital in S (1)	Accept similar/same (electron) shielding Allow same number of shells Allow correct reference to full or partial electronic configurations for two/three elements Do not award incorrect electronic configurations Accept Cl has the greatest nuclear charge Ignore Cl has the greatest nuclear attraction Ignore Cl has the greatest atomic number Do not award just Cl has the greatest charge Do not award S has the smallest nuclear charge Allow Cl has the smallest atomic radius / smaller atomic radius than S Do not award S had the greatest atomic radius Do not award same/similar atomic radius Do not award outer electron same/similar distance from nucleus Do not award ionic/molecular radius There must be a mention of **p** (orbital) Allow subshell for orbital Do not award shell for orbital Allow spin-spin repulsion in p orbital/subshell Allow correct reference to stable half-full p subshell: eg stable half-full p subshell in P eg removing electron from S gives stable half-full p subshell Do not award reference to bonding electrons	**3**

Question Number	Answer	Additional guidance	Mark
18(d)(i)	• (atoms with the) same number of protons (1) • (and) different number of neutrons (1)	Penalise use of species/particles/molecules for atoms once only Allow same atomic number Allow amount for number Ignore atoms of the same element Ignore electrons Ignore different mass number Do not award different number of electrons	**2**

Question Number	Answer	Additional guidance	Mark
18(d)(ii)	• Expression for relative atomic mass (1) • Calculation and answer to two decimal places (1)	Example of calculation: (A_r =) $\frac{32 \times 94.88 + 33 \times 0.83 + 34 \times 4.27 + 36 \times 0.02}{100}$ (A_r =) 32.09 TE on transcription errors only (ie no TE on incorrect expression) Ignore units of amu / g / g mol^{-1} Do not award any other unit 32.09 scores (2) provided there is evidence of all four isotopes having been used in the calculation 32.09 with no working scores (1) 32.10 with no working scores (0) 33.75 scores (0)	**2**

Question Number	Answer	Additional guidance	Mark
18(e)(i)	• $\frac{256}{32}$ = 8 (atoms)	Allow working shown on mass spectrum Ignore calculations involving the Avogadro constant, even if incorrect Do not award just 8 (with no working)	**1**

Question Number	Answer	Additional guidance	Mark
18(e)(ii)	An answer that makes reference to the following points: • (species containing) two sulfur atoms (1) • (ion with) 1+ charge (1)	Penalise isotopes other than ^{32}S once only eg S_2 / S—S Allow SS / S,S Ignore incorrect charge, including negative charge **M2 dependent on an ion containing sulfur only** S_2^+ / $[S—S]^+$ / SS^+ / S,S^+ scores (2) S_4^{2+} / $[S_2—S_2]^{2+}$ / $S_2S_2^{2+}$ / $S_2^+S_2^+$ / S_2^+,S_2^+ scores (1)	**2**

(Total for Question 18 = 14 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>19(a)</td><td>A completed table showing:

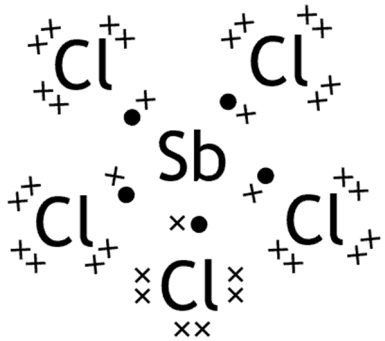
• correct number of bond pairs and lone pairs (1)

• correct Cl–N–Cl bond angle (1)

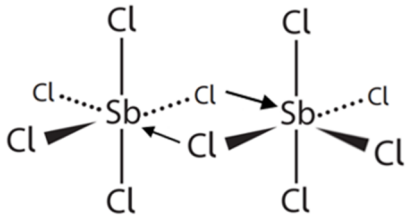
• correct name of shape (1)</td><td>Mark all points independently

<table><tr><td>Number of bond pairs around N atom</td><td><u>3</u></td></tr><tr><td>Number of lone pairs around N atom</td><td><u>1</u></td></tr><tr><td>Cl–N–Cl bond angle</td><td><u>107</u>$^{(o)}$
Allow 106$^{(o)}$ – 108$^{(o)}$</td></tr><tr><td>Name of shape of molecule</td><td>(Trigonal) <u>pyramidal</u>
Allow pyramid
Ignore tetrahedral
Do not award bipyramidal</td></tr></table></td><td>3</td></tr>
</table>

Question Number	Answer	Additional guidance	Mark
19(b)(i)	An explanation that makes reference to the following points: • strong(er) (electrostatic) attraction between ions (in PCl_5) (1) • (than) weak intermolecular forces (in $SbCl_5$) (1)	**Mark M1 and M2 independently** Ignore reference to solid/liquid Allow strong ionic bonds / strong ionic lattice Allow strong attraction between positive and negative charges Allow strong attraction between cations and anions / PCl_4^+ and PCl_6^- Ignore just PCl_5 is (giant) ionic Do not award reference to PCl_5 molecules/ intermolecular forces Do not award reference to breaking of covalent bonds Accept just London/van der Waals/dispersion/ temporary-induced dipole/instantaneous-induced dipole forces Ignore just $SbCl_5$ is (simple) molecular Do not award reference to breaking of covalent/ionic bonds Ionic bonding is stronger than intermolecular forces scores (2)	**2**

Question Number	Answer	Additional guidance	Mark
19(b)(ii)	Dot-and-cross diagram showing the following: • central Sb with five bond pairs and no lone pairs (1) • five Cl atoms each with one bond pair and three lone pairs (1)	**Mark M1 and M2 independently** Example of dot-and-cross diagram:  TE on M1 for three or four Cl atoms Allow any combination of crosses and dots Allow circles to indicate outer shells Ignore inner shells Ignore lines showing the covalent bonds	**2**

Question Number	Answer	Additional guidance	Mark
19(c)(i)	• suitable description of a dative covalent bond	For credit to be awarded, it must be clear that: i) a pair of / two electrons are involved ii) these electrons are shared/bonding iii) these electrons come from the same atom eg shared electrons in which both electrons come from the same atom eg lone pair/full orbital from one atom overlaps with empty orbital of another Allow element for atom Allow just both electrons in the bond come from the same element Allow one element donates/gives/shares both electrons to the bond Allow one atom shares both electrons Do not award just one atom donates/gives both electrons (or any reference to ions being formed) Do not award ion/molecule/species for atom	**1**

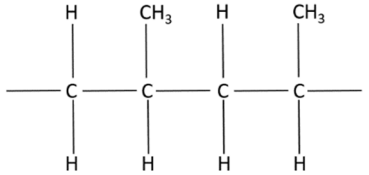
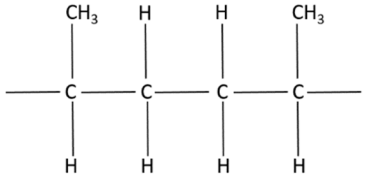
Question Number	Answer	Additional guidance	Mark
19(c)(ii)	• two correct dative covalent bonds shown as arrows	 Ignore lone pairs shown on Cl Do not award dative bonds from any other Cl atoms	1

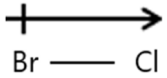
Question Number	Answer	Additional guidance	Mark
19(d)	An answer that makes reference to one of the following points: • no 2d orbitals **or** (nitrogen) cannot expand its octet **or** • (nitrogen is) too small (to bond to 5 atoms) **or** • repulsion between electron **pairs** would be too great	Accept reverse arguments Allow no d orbitals as only two (quantum) shells Allow no d orbitals (accessible) Allow (nitrogen) cannot have more than eight electrons in its outer shell Ignore just cannot expand its outer/valence shell Ignore just nitrogen obeys the octet rule Ignore just (nitrogen has a) very small/smallest atomic radius Ignore Cl atoms too large Ignore nitrogen has fewest/only two shells Ignore just repulsion between electron pairs Ignore repulsion between Cl atoms Ignore not enough room for 5 electron pairs	1

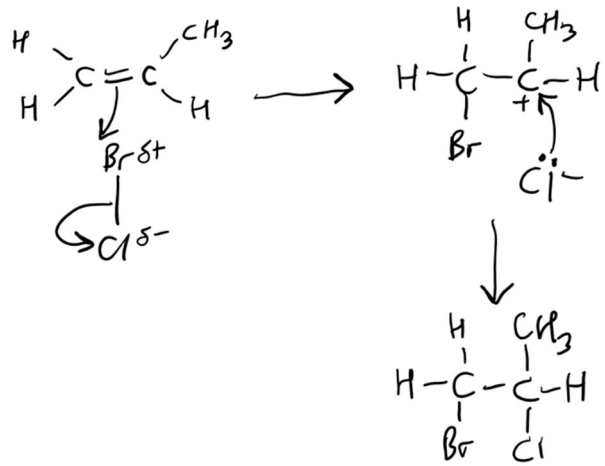
(Total for Question 19 = 10 marks)

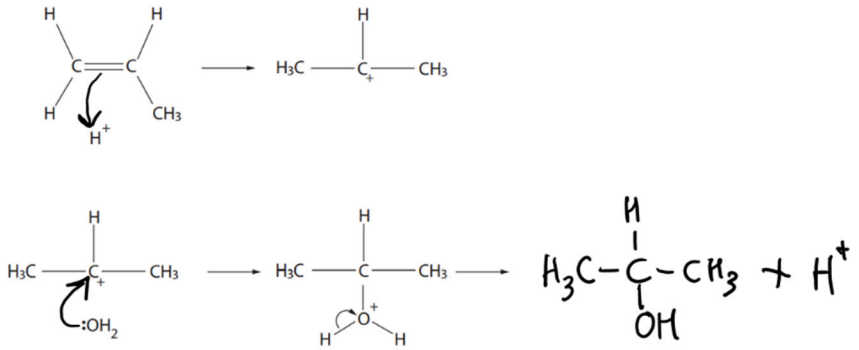
Question Number	Answer	Additional guidance	Mark
20(a)	• balanced equation with **1 mol** C_3H_6 and correct products (1) • state symbols (1)	Example of equation: $C_3H_6(g) + 3O_2(g) \rightarrow CO_2(g) + CO(g) + C(s) + 3H_2O(l)$ Allow structural, displayed or skeletal formulae Allow $H_2O(g)$ Do not award $H_2O(aq)$ M2 dependent on correct species for the incomplete combustion of any C_nH_{2n} / C_nH_{2n+2} hydrocarbon forming $CO_2(g)$, $CO(g)$, $C(s)$ and $H_2O(l)/(g)$ If no other mark awarded, a correctly balanced equation, with correct state symbols, for the incomplete combustion of propene scores (1) eg $C_3H_6(g) + 3O_2(g) \rightarrow 3CO(g) + 3H_2O(l)/(g)$ eg $2C_3H_6(g) + 7O_2(g) \rightarrow 2CO_2(g) + 4CO(g) + 6H_2O(l)/(g)$	**2**

Question Number	Answer	Additional guidance	Mark
20(b)	• both solutions decolourise / turn colourless (1) • from purple with (potassium) manganate((VII))/$KMnO_4$/MnO_4^- **and** from orange with (aqueous) bromine/Br_2 (1)	Ignore any reference to breaking of the C=C bond / type of reaction Ignore any reference to layers / effervescence Ignore any reference to reaction products / formation of solids Ignore turn clear / change colour Allow pink for purple or any combination of purple/pink Allow yellow or brown for orange or any combination of orange/yellow/brown Do not award any mention of red (eg red-brown) If neither M1 nor M2 awarded, either of the following scores (1): (potassium) manganate((VII))/$KMnO_4$/MnO_4^- decolourises from purple/pink or bromine decolourises from orange/yellow/brown	**2**

Question Number	Answer	Additional guidance	Mark
20(c)	• poly(propene) structure containing two repeat units with extension bonds	Example of diagram:  Accept CH_3 groups on same or opposite sides Allow head-to-head and tail-to-tail configurations eg  Allow displayed, structural, skeletal formulae or any combination of these Ignore connectivity of vertical C–CH_3 bond Ignore brackets and 'n'	**1**

Question Number	Answer	Additional guidance	Mark
20(d)(i)	• correct dipole	Example of correct diagram: δ+ δ– Br —— Cl Allow correct indication of net dipole moment:  Br —— Cl Ignore horizontal arrow from Br to Cl, on or above the bond Ignore bond pair electrons on diagram Ignore lone pairs on Br/Cl Ignore electron density map Ignore double-headed curly arrow from bond to Cl Do not award full charges	**1**

Question Number	Answer	Additional guidance	Mark
20(d)(ii)	A mechanism showing: • curly arrow from C=C bond to (δ+)halogen **and** curly arrow from Br–Cl bond to (δ–)halogen or just beyond (1) • secondary carbocation (1) • curly arrow from lone pair on halide ion to $C^{(+)}$ **and** correct product (1)	Example of mechanism:  Allow displayed, structural, skeletal formulae or any combination of these Penalise incorrect propene structure once only Penalise half-headed curly arrows once only Allow primary carbocation for mechanism involving ethene only Allow curly arrow from lone pair to positive charge Do not award δ– on halide ion	**3**

Question Number	Answer	Additional guidance	Mark
20(e)	A mechanism showing: • curly arrow from C=C bond to H^+ (1) • curly arrow from lone pair on water to C^+ (1) • correct structure for propan-2-ol **and** H^+ (catalyst regenerated) (1)	Example of correct mechanism:  Do not award any additional curly arrows from/to/on propene/H^+ Allow curly arrow from lone pair to positive charge Do not award any additional curly arrows shown in this step Allow any combination of displayed/structural/skeletal formulae Ignore atom connectivity except displayed C–H–O Ignore any additional curly arrows added to the central intermediate	**3**

(Total for Question 20 = 12 marks)

Question Number	Answer	Additional guidance	Mark
21(a)	Any **two** from the following: • chemically stable / inert / does not (easily) oxidise (1) • colourless (1) • odourless (1) • non-toxic / non-irritant (1) • hydrophobic / immiscible with water (1) • hypoallergenic (1)	Ignore any reference to: carbon chain length intermolecular forces melting/boiling temperature flammability/volatility liquid/moisturising/softening/lubricating/hydrating spreads easily/absorbed easily natural/in human skin cheap Allow unreactive / not very reactive / long shelf life / durable / does not breakdown (easily) Ignore just stable Ignore transparent/clear Allow not harmful / non-hazardous / non-corrosive Ignore safe Allow insoluble Ignore oily	**2**

Question Number	Answer	Additional guidance	Mark
21(b)	• $C_{30}H_{62}$	Accept $H_{62}C_{30}$	**1**

Question Number	Answer	Additional guidance	Mark
21(c)(i)	• nickel	Accept palladium or platinum Allow correct symbol	**1**

Question Number	Answer	Additional guidance	Mark
21(c)(ii)	• 0.00001 / (1 ×) 10^{-5} (g)	Example of calculation: mass = $\frac{50}{10^6}$ × 0.2 = 0.00001 (g) Do not award incorrect unit Accept 10 μg / 0.01 mg Allow answer as fraction eg $\frac{1}{10^5}$ (g) Ignore SF Correct answer with no working scores (1)	**1**

Question Number	Answer	Additional guidance	Mark
21(c)(iii)	• conversion of temperature to K (1) • rearrangement of ideal gas equation (1) • evaluation to give moles of hydrogen (1) • evaluation of mole ratio **and** number of C=C bonds per molecule of squalene (1)	Example of calculation: T = 200 + 273 (= 473 K) $n = \frac{pV}{RT}$ or $n = \frac{4.0 \times 10^5 \times 500}{8.31 \times 473}$ $n(H_2) = 50882.429$ Ignore SF except 1 SF TE on temperature M3 dependent on correct use of ideal gas equation $n(H_2) : n$(squalene) 50882 : 8500 6 : 1 6 (× C=C bonds per molecule) TE on $n(H_2)$ provided $n(H_2)$ > than 8500 and answer is rounded to nearest integer 6 (× C=C bonds per molecule) with no working scores (1) 2 (× C=C bonds per molecule) from use of 24 dm^3 mol^{-1} as molar gas volume scores (2)	**4**

21(c)(iii) cont	**Alternative route to M2, M3 and M4** • rearrangement of ideal gas equation (1) • evaluation to give volume of squalene (1) • evaluation of volume ratio **and** number of C=C bonds per molecule of squalene (1)	Example of calculation: $V = \frac{nRT}{p}$ or $V = \frac{8500 \times 8.31 \times 473}{4.0 \times 10^5}$ V(squalene) = 83.52589 (m^3) Ignore SF except 1 SF TE on temperature M3 dependent on correct use of ideal gas equation $V(H_2)$: V(squalene) 500 : 83.52589 6 : 1 6 (× C=C bonds per molecule) TE on V(squalene) provided V(squalene) < 500 (m^3) and answer is rounded to nearest integer	

Question Number	Answer	Additional guidance	Mark
21(c)(iv)	• $C_{30}H_{50} + 6H_2 \rightarrow C_{30}H_{62}$	Ignore state symbols TE on (c)(iii) for any C_nH_{2n+2} product formula where $24 \leq n \leq 30$ If the number of C=C bonds is not stated in (c)(iii) then award (1) for an equation of the form: $C_nH_{2n-2y+2} + yH_2 \rightarrow C_nH_{2n+2}$ Where $24 \leq n \leq 30$ and $1 \leq y \leq 14$	**1**

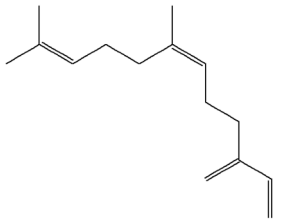
Question Number	Answer	Additional guidance	Mark
21(d)(i)	• (fractional) distillation	Ignore solvent extraction Ignore filtration as part of the separation process Do not award just filtration Do not award chromatography	**1**

Question Number	Answer	Additional guidance	Mark
21(d)(ii)	• calculation of mass of squalene in 2.8 million dm^3 **or** calculation of volume of squalene per shark (1) • calculation of number of sharks required (1)	Example of calculation: mass = $2.8 \times 10^9 \times 0.86 = 2.408 \times 10^9$ (g) **or** volume = $\frac{300}{0.86}$ = 348.8372 (cm^3) $\frac{2.408 \times 10^9}{300} = 8.0267 \times 10^6 = 8026666.667 / 8.0 \times 10^6$ TE on mass **or** $\frac{2.8 \times 10^9}{348.8372} = 8.0267 \times 10^6 = 8026666.667 / 8.0 \times 10^6$ TE on volume Ignore SF Penalise incorrect rounding once only Correct answer with no working scores (2)	**2**

Question Number	Answer	Additional guidance	Mark
21(d)(iii)	**Method 1** • calculation of mass of corn starch required (1) • calculation of required land area in hectares (1) • conversion of land area from hectares to km^2 (1) **Method 2** • conversion of land area from hectares to km^2 (1) • calculation of required land area in km^2 to produce 2500 tonnes of corn starch (1) • calculation of required land area in km^2 to produce 2500 tonnes of squalene (1)	Ignore SF and do not penalise correct premature rounding Penalise incorrect rounding once only Penalise incorrect units in final answer only mass = $\frac{2500}{23} \times 100 = 10869.57$ (tonnes) Allow conversion of mass of corn starch to kg / g land area = $10869.57 \times 0.093 = 1010.87$ (hectares) land area = $1010.87 \times 0.01 = 10.1087 = 10$ (km^2) $0.093 \times 0.01 = 0.00093 / 9.3 \times 10^{-4}$ (km^2) land area = $0.00093 \times 2500 = 2.325$ km^2 Allow conversion of mass of corn starch to kg / g land area = $\frac{2.325}{23} \times 100 = 10.1087 = 10$ (km^2)	**3**

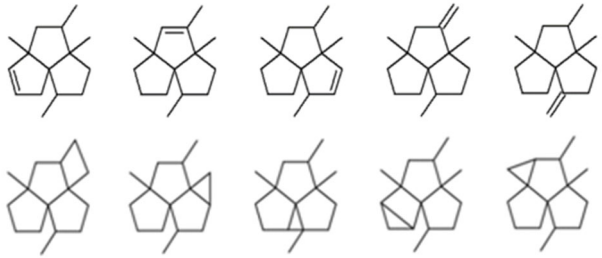
21(d)(iii) cont	**Method 3** • calculation of required land area in hectares to produce 2500 tonnes of corn starch (1) • calculation of required land area in hectares to produce 2500 tonnes of squalene (1) • conversion of land area from hectares to km^2 (1)	land area = 2500 × 0.093 = 232.5 (hectares) Allow conversion of mass of corn starch to kg / g land area = $\frac{232.5}{23}$ × 100 = 1010.87 (hectares) land area = 1010.87 × 0.01 = 10.1087 = 10 (km^2) If no other mark awarded, 1 tonne corn starch yields 230 kg squalane scores (1)	

Question Number	Answer	Additional guidance	Mark
21(e)(i)	An explanation that makes reference to the following points: • restricted rotation about/around C=C (1) • (only) central C=C has two different groups attached to each carbon of the C=C (1)	**Mark M1 and M2 independently** Accept pi-bond for C=C Allow just double bond for C=C Allow limited/no rotation about/around C=C Allow C=C restricts rotation Allow C=C cannot rotate Ignore just restricted rotation Do not award molecule cannot rotate Accept C=C from 6th carbon/6-ene for central C=C Allow (only) central C=C has four different groups Allow indication of central C=C on diagram Do not award if any other C=C bond identified as *E*/*Z*	**2**

Question Number	Answer	Additional guidance	Mark
21(e)(ii)	• skeletal formula of *Z*-isomer (1) • (*Z* isomer has highest) priority groups on same side (of C=C) (1)	**Mark M1 and M2 independently** Examples of correct structure:  or  Ignore bond lengths and bond angles Ignore labelling of C=C bonds as *E*/*Z* Ignore any other type of formula Allow lowest priority groups on same side Allow identification of (highest) priority groups on diagram Allow ranking for priority Ignore preference for priority Ignore reference to mass/size of groups Allow top/bottom for same Ignore any reference to cis/trans	**2**

Question Number	Answer	Additional guidance	Mark
21(f)(i)	• (compounds with the) same molecular formula (1) • different structural formula (1)	**Mark M1 and M2 independently** Ignore just same formula Ignore compounds with the same atoms Do not award same molecule Do not award same general formula Allow just different structure Allow different position of the C=C/double bonds Allow different displayed/skeletal formulae Ignore different arrangement of atoms (in space)	2

Question Number	Answer	Additional guidance	Mark
21(f)(ii)	• four / 4	Ignore *E*/*Z*	1

Question Number	Answer	Additional guidance	Mark
21(f)(iii)	• valid structure containing **one** C=C bond or • valid structure containing **one** bridging carbon-carbon bond	Examples of valid structure:  Ignore bond lengths and bond angles	1

(Total for Question 21 = 24 marks)
TOTAL FOR SECTION B = 60 MARKS
TOTAL FOR PAPER = 80 MARKS

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom