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General Certificate of Education

Chemistry 1421

CHEM2 Chemistry in Action

Mark Scheme

2010 examination - January series

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
1	a	i	Reducing agent ***OR*** Reduce(s) (WO_3 / tungsten oxide) ***OR*** electron donor ***OR*** to remove <u>oxygen</u> (from WO_3 / tungsten oxide or to form water);	1	
1	a	ii	$WO_3 + \mathbf{3}H_2 \longrightarrow W + \mathbf{3}H_2O$	1	Or multiples
1	a	iii	*One from* H_2 is • explosive • flammable or inflammable • easily ignited	1	Ignore reference to pressure or temperature
1	b	i	Addition ***OR*** (catalytic) hydrogenation ***OR*** Reduction	1	Ignore “electrophilic” Penalise “nucleophilic addition”
1	b	ii	Geometric(al) ***OR*** cis/trans OR E Z OR E/Z	1	
1	c	i	(If any factor is changed which affects an equilibrium), the position of <u>equilibrium</u> will <u>shift / move / change/ respond / act</u> so as <u>to oppose the change</u>. ***OR*** (When a system/reaction in equilibrium is disturbed), the <u>equilibrium</u> <u>shifts / moves</u> in a direction which tends <u>to reduce the disturbance</u>	1	A variety of wording will be seen here and the key part is the last phrase and must refer to <u>movement of the equilibrium</u>. **QoL**

1	c	ii	**M1 – Statement of number of moles / molecules** There are <u>more moles / molecules</u> (of gas) on the left / of reactants ***OR*** <u>fewer moles / molecules</u> (of gas) on the right./ products ***OR*** there are <u>4 moles / molecules</u> (of gas) on the left <u>and 2 moles / molecules</u> on the right. **M2 – Explanation of response / movement in <u>terms of pressure</u>** <u>Increase in pressure is opposed</u> (or words to that effect) ***OR*** <u>pressure is lowered</u> by a shift in the equilibrium (from left) <u>to right</u> / favours forward reaction.	2	Ignore ”volumes” for M1 Mark independently
1	d		$\sum$ B(reactants) – $\sum$ B(products) = ΔH (**M1**) ***OR*** <u>Sum</u> of bonds broken – <u>Sum</u> of bonds formed = ΔH (**M1**) B(H–H) +½B(O=O) – 2B(O–H) = – 242 (**M1**) B(H–H) = – 242 – ½(+496) + 2(+463) (this scores **M1** and **M2**) B(H–H) = (+)**<u>436</u>** (kJ mol^{-1}) (**M3**) Award 1 mark for – 436 Candidates may use a cycle and gain full marks.	3	M1 could stand alone <u>Award full marks for correct answer</u>. Ignore units. Two marks can score with an arithmetic error in the working.

Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	a		Heat (energy) change at constant pressure	1	Ignore references to standard conditions, but credit specified pressure.
2	b		The enthalpy change / heat (energy) change (at constant pressure) in a reaction is independent of the route / path taken (and depends only on the initial and final states)	1	
2	c		ΔH + 963 = –75 – 432 OR ΔH + 963 = – 507 (**M1**) ΔH = –75 – 432 – 963 (**M1** and **M2**) ΔH = **–1470** (kJ mol^{-1}) Award 1 mark for + 1470	3	Award full marks for correct answer Ignore units. Ignore numbers on the cycle **M1** and **M2** can score for an arithmetic error

Q	Part	Sub Part	Marking Guidance	Mark	Comments
3	a		NaBr ONLY	1	Penalise incorrect case or additional formulae. Ignore names
3	b		NaF ONLY	1	Penalise incorrect case or additional formulae. Ignore names
3	c		ONLY one from either NaF ***OR*** NaCl	1	Penalise incorrect case or additional formulae. Ignore names
3	d		NaI ONLY	1	Penalise incorrect case or additional formulae. Ignore names

Q	Part	Sub Part	Marking Guidance	Mark	Comments
4	a		Antacid ***OR*** to neutralise acidity ***OR*** eases indigestion	1	Credit suitable reference to indigestion or to laxative or to relief of constipation
4	b		**M1** Decrease in T decreases the energy of the particles / ions / H^+ / molecules **M2 (also scores M1)** Decrease in the number of / less particles / ions / H^+ / molecules with $E \geq E_{Act}$ or $E \geq$ minimum energy to react **M3** Few(er) / Less effective / productive / successful collisions	3	In **M1** and **M2,** credit "atoms" but ignore "calcium carbonate", ignore "calcium", ignore any ion formula except H^+ **QoL**
4	c	i	Strontium has a higher melting point than barium, because **Correct reference to size of cations/proximity of electrons** **M1** (For Sr) delocalised electrons closer to cations / positive ions / atoms / nucleus ***OR*** cations / positive ions / atoms are smaller ***OR*** cation / positive ion / atom or it has fewer (electron) shells / levels **Relative strength of metallic bonding** **M2** (Sr) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons ***OR*** stronger metallic bonding (assume argument refers to Sr but accept converse argument for Ba)	2	Ignore general Group 2 statements Penalise M1 if Sr or Ba is said to have more or less delocalised electrons Ignore reference to shielding **CE = 0** for reference to molecules or intermolecular forces or covalent bonds Ignore "Van der Waals forces (between atoms)" but penalise if "between molecules"
4	c	ii	$Sr + \mathbf{2}H_2O \longrightarrow Sr(OH)_2 + H_2$	1	Or multiples
4	d	i	$\mathbf{2}Mg + TiCl_4 \longrightarrow \mathbf{2}MgCl_2 + Ti$	1	Or multiples

4	d	ii	It or $MgSO_4$ is soluble OR forms a solution (and is washed away) OR dissolves	1	Credit reference to $MgSO_4$ being the most soluble Group 2 sulfate. Ignore “disappears”

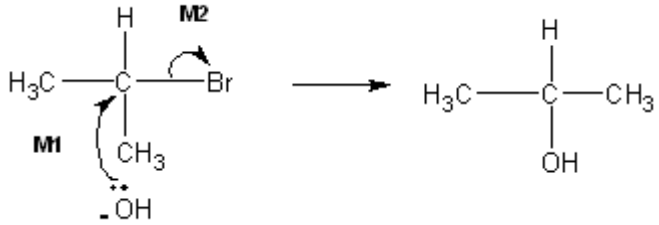
Q	Part	Sub Part	Marking Guidance	Mark	*Comments*
5	a	i	Oxidation ***OR*** Oxidised ONLY	1	
5	a	ii	Any one from • to provide / overcome activation energy • to provide the minimum energy to make the reaction go / start	1	NOT simply to increase the (initial) reaction rate.
5	a	iii	The reaction is exothermic OR releases heat (energy)	1	
5	a	iv	**M1** Catalysts provide an alternative route / pathway OR an alternative mechanism ***OR*** (in this case) surface adsorption occurs (or a description of adsorption) **M2** Lowers the activation energy ***OR*** of lower activation energy	2	Ignore reference to “surface” alone
5	b		**M1** The (forward) reaction is exothermic OR the (forward) reaction releases heat ***OR*** The reverse reaction is endothermic or absorbs heat **M2** – Direction of change N.B. **M2** depends on correct **M1** At lower temperatures, • the equilibrium yield of NO2 is greater • more NO2 is formed • equilibrium shifts (left) to right • (equilibrium) favours the forward reaction (***OR*** converse for higher temperatures)	2	

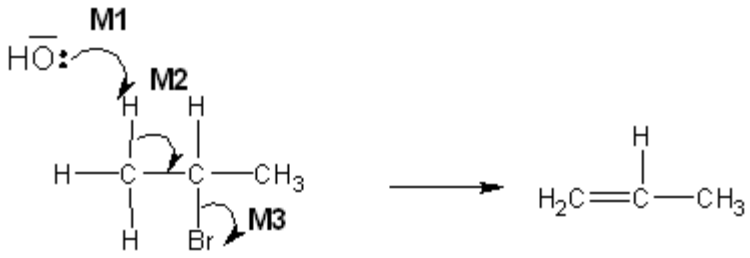
5	c		NO_2 (+) 4 $NO3^-$ (+) 5 HNO_2 (+) 3	3	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	a		Functional group (isomerism)	1	
6	b		**M1** Tollens' (reagent) *(Credit ammoniacal silver nitrate OR a description of making Tollens')* *(Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)* **M2** silver mirror OR black solid/precipitate *(NOT silver precipitate)* **M3 (**stays) colourless or no change or no reaction **M1** Fehling's (solution) or Benedict's solution *(Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark on to M2 and M3)* **M2** Red solid/precipitate *(Credit orange or brown solid)* **M3 (**stays) blue or no change or no reaction Mark on from an incomplete / incorrect attempt at the correct reagent, penalising M1	3	No reagent, CE=0 Allow the following alternatives **M1** (acidified) potassium dichromate(VI) (solution) **M2** (turns) green **M3** (stays) orange / no change OR **M1** (acidified) potassium manganate(VII) (solution) **M2** (turns) colourless **M3** (stays) purple / no change For M3 Ignore "nothing (happens)" Ignore "no observation"
6	c		(Both have) C=O ***OR*** a carbonyl (group)	1	
6	d	i	(Free-) radical substitution ONLY	1	Penalise "(free) radical mechanism"

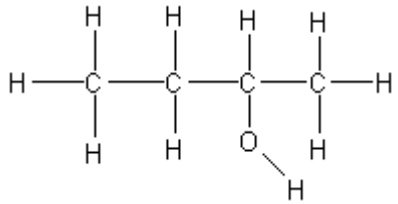
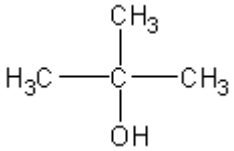
6	d	ii	**Initiation** $Cl_2 \longrightarrow 2Cl\bullet$ **First propagation** $Cl\bullet + CH_3CH_2CH_3 \longrightarrow \bullet CH_2CH_2CH_3 + HCl$ OR C_3H_8 **Second propagation** $Cl_2 + \bullet CH_2CH_2CH_3 \longrightarrow CH_3CH_2CH_2Cl + Cl\bullet$ ***OR*** C_3H_7Cl **Termination (must make C_6H_{14})** $2 \bullet CH_2CH_2CH_3 \longrightarrow C_6H_{14}$ or $CH_3CH_2CH_2CH_2CH_2CH_3$	4	Penalise absence of dot once only. Penalise incorrect position of dot on propyl radical once only. Penalise $C_3H_7\bullet$ once only Accept $CH_3CH_2CH_2\bullet$ with the radical dot above / below / to the side of the last carbon. Use of the secondary free radical might gain 3 of the four marks

6	e		M_r = 44.06352 (for propane) M_r = 43.98982 (for carbon dioxide) **M1** a correct value for both of these M_r values. **M2** a statement or idea that two peaks appear (in the mass spectrum) ***OR*** two molecular ions are seen (in the mass spectrum).	2	Mark independently

Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	a	i	Nucleophilic substitution  **M1** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom. **M2** must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently. Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.	1 2	Penalise M1 if covalent KOH is used Penalise M2 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks" Ignore product
7	a	ii	2-bromopropane ONLY	1	
7	a	iii	Polar C–Br ***OR*** polar carbon–bromine bond ***OR*** dipole on C–Br ***OR*** δ+ (δ–) C atom of carbon–bromine bond is δ+ / electron deficient ***OR*** C—Br (Credit carbon–halogen bond as an alternative to carbon–bromine bond)	1	It must be clear that the discussion is about the carbon atom of the C–Br bond. NOT just reference to a polar molecule. Ignore X for halogen

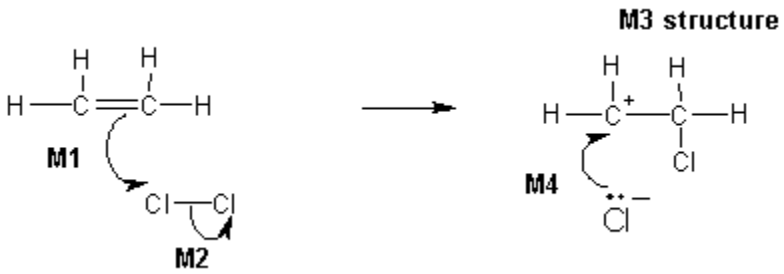
7	b		Elimination  **M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom **M2** must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1 **M3** is independent. Award full marks for an E1 mechanism in which M2 is on the correct carbocation.	1 3	Credit "base elimination" but NOT "nucleophilic elimination" No other prefix. Mechanism Penalise M1 if covalent KOH Penalise M3 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 2 marks **for the mechanism** for wrong reactant and/or "sticks" Ignore product
7	c		*Any one condition from this list to favour elimination;* • alcohol(ic) / ethanol(ic) (solvent) • high concentration of KOH / alkali / hydroxide OR concentrated KOH / hydroxide • high temperature or hot or heat under reflux or T = 78 to 100°C	1	Apply the list principle Ignore "aqueous" Ignore "excess"
7	d	i	Addition (polymerisation) ONLY	1	Penalise "additional"
7	d	ii	But-2-ene ONLY (hyphens not essential)	1	Ignore references to cis and trans or E/Z Ignore butene

Q	Part	Sub Part	Marking Guidance	Mark	Comments
8	a	i	**2**$CuFeS_2$ + **2**SiO_2 + **4**O_2 ⟶ Cu_2S + **2**$FeSiO_3$ + **3**SO_2	1	
8	a	ii	Acid rain ***OR*** an effect either from acid rain or from an acidic gas in the atmosphere	1	
8	a	iii	SO_2 could be used to make H_2SO_4 ***OR*** to make gypsum / plaster or $CaSO_4$ (xH_2O)	1	
8	b		Cu_2S + **2**O_2 ⟶ **2**CuO + SO_2	1	Or multiples Ignore state symbols
8	c		**2**CuO + C ⟶ **2**Cu + CO_2 ***OR*** CuO + C ⟶ Cu + CO	1	Or multiples Ignore state symbols
8	d	i	*Any one from the following two ONLY* • (Scrap) iron is cheap • Low energy requirement	1	Apply the list principle Not “less energy”
8	d	ii	Fe + Cu^{2+} ⟶ Fe^{2+} + Cu	1	Or multiples Ignore state symbols

Q	Part	Sub Part	Marking Guidance	Mark	Comments
9	a		**M1** Displayed formula for butan-2-ol  **M2** Alcohol **X** is  **M3** Alcohol **Y** is named (2)-methylpropan-1-ol ONLY	3	M1 displayed formula must have all bonds drawn out, including the O—H but ignore angles Penalise "sticks" M2 structure must be clearly identifiable as 2-methylpropan-2-ol and may be drawn in a variety of ways. M3 must be correct name, but ignore structures
9	b		**M1** The infrared spectrum shows an absorption / peak in the range 3230 to 3550 (cm^{-1})(which supports the idea that an alcohol is present) **M2** Reference to the 'fingerprint region' or below 1500 (cm^{-1}) **M3** Match with or same as known sample / database spectra ***OR*** alternatively **M2** Run infrared spectra (of the alcohols) **M3** Find which one matches or is the same as this spectrum.	3	In M1, allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption. Check the spectrum to see if alcohol OH is labelled and credit.

9	c		**M1** balanced equation $C_6H_{12}O_6 \longrightarrow CH_3CH_2CH_2CH_2OH + \mathbf{2}CO_2 + H_2O$ or C_4H_9OH **M2** *Any one from* • <u>excess/adequate/sufficient/ correct amount of /enough/plenty / a good supply</u> of oxygen or air • good mixing of the fuel and air/oxygen **M3** $CH_3CH_2CH_2CH_2OH + \mathbf{6}O_2 \longrightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$ or C_4H_9OH **M4** A biofuel is a fuel produced <u>from</u> (renewable) <u>biological (re)source(s)</u> ***OR*** (renewable) <u></u>(re)source(s) <u>from</u> (a specified) <u>plant(s) /fruit(s) /tree(s)</u>	4	Or multiples for M1 and M3 In M1 and M3 penalise use of $C_4H_{10}O$ or butan-2-ol once only For M2, do <u>not</u> accept simply "oxygen" or "air" alone Ignore reference to "temperature" In M4 Ignore references to "carbon neutral" Ignore "sugar" and "glucose"
9	d		**M1** butan-1-ol is a <u>primary or 1°</u> (alcohol) **M2** <u>Displayed formula</u> (ONLY) for butanal $CH_3CH_2CH_2CHO$ **M3** <u>Displayed formula</u> (ONLY) for butanoic acid $CH_3CH_2CH_2COOH$ **M4** Oxidation (oxidised) OR Redox **M5** <u>orange to green</u>	5	M2 and M3 displayed formula must have all bonds drawn out including the O—H but ignore angles. If butanal and butanoic acid formulae are <u>both</u> correctly given but not displayed, credit one mark out of two. Both colours required for M5 Ignore states

Q	Part	Sub Part	Marking Guidance	Mark	Comments
10	a		**M1** Cl_2 (provides the pale green colour) **M2** NaOH reacts with the acid(s) / the HCl / the HClO / H^+ **M3** **requires a correct answer in M2** Equilibrium shifts (from left) to right OR wtte	3	M1 requires the formula Ignore "reacts with the products" Ignore "reacts with chloride ion" Ignore "reacts with chlorine"
10	b		**M1** A reducing agent is an electron donor OR (readily) loses / gives away electrons **M2** $Cl_2 + \mathbf{2}e^- \longrightarrow \mathbf{2}Cl^-$ For M3 and M4, **i**odide ions are stronger reducing agents than chloride ions, because **M3** **Relative size of ions / atomic radius / ionic radius** Iodide ions are larger / have more (electron) shells / levels than chloride ions (or converse for chloride ion) OR electron(s) to be lost/outer shell/level is further from the nucleus (or converse for chloride ion) OR greater / more shielding **M4** **Strength of attraction for electron(s) being lost** Electron(s) lost from an iodide ion is less strongly held by the nucleus compared with that lost from a chloride ion (assume argument refers to iodide ions but accept converse argument for chloride ions)	4	Penalise M1 if "electron pair donor" Ignore state symbols in M2 Accept no charge on the electron Credit the electrons being lost on the RHS M3 and M4 must be comparative and should refer to electrons. For M3 insist on "iodide ions"

10	c		**M1** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$ **M2** <u>silver chloride</u> ONLY **M3** The solid / precipitate would dissolve ***OR*** is soluble ***OR*** (It) forms a (colourless) solution	3	Or multiples <u>M2 requires a name</u> Mark M3 independently Ignore "disappears"
10	d		<u>Electrophilic addition</u> *Mechanism:*  **M1**must show an arrow from the double bond towards one of the Cl atoms on a Cl–Cl molecule. **M2** must show the breaking of the Cl–Cl bond. **M3** is for the structure of the carbocation with Cl substituent. **M4** must show an arrow from the lone pair of electrons on a negatively charged chloride ion towards the positively charged carbon atom.	1 4	M2 Penalise partial charges if wrong way around, otherwise ignore Max 3 marks **<u>for the mechanism</u>** for wrong reactant and/or "sticks" (wrong reactant could be HBr or Br_2 or incorrect alkene)

General principles applied to marking CHEM2 papers by CMI+ for January 2010

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly as part of the "Quality of Language" (QoL) marking.

D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify whole reagents **will be penalised**. The command word "Identify", allows the candidate to choose to use either the name or the formula in their answer. In some circumstances, the list principle may apply when both are used.

For example

potassium cyanide rather than cyanide ion **or** KCN rather than CN^-

sodium hydroxide rather than hydroxide ion **or** NaOH rather than OH^-

F. Marking calculations, such as those involving enthalpy changes

In general

- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will score **only one mark**.

All other values **gain no credit** except

- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

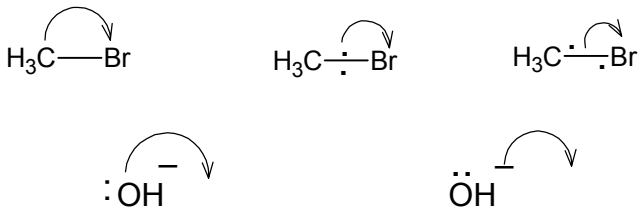
G. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.

Each of the following representations **should not gain credit** and will be penalised **once only** within a clip.



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

I. Organic structures

In general

- Displayed formulae must show all of the bonds in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C-H-O, they should be penalised **on every occasion**.
- Some latitude should be given to the representation of C-C bonds in structures, given that CH_3— is considered to be interchangeable with H_3C— even though the latter would be preferred.
- Poor presentation of vertical C — CH_3 bonds or C — OH bonds or C — NH_2 bonds should **not** gain credit. The limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
- The use of 'sticks' in structures should **not** gain credit. The occasions that this applies will be indicated in the mark scheme.

- Some examples of formulae for specific compounds which should **not** gain credit are given here

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions may be made in the context of balancing equations

Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol
2-hydroxybutane — all should be **butan-2-ol**
butane-2-ol
2-butanol

2-methpropan-2-ol — should be **2-methylpropan-2-ol**

2-methylbutan-3-ol — should be **3-methylbutan-2-ol**

3-methylpentan — all should be **3-methylpentane**
3-mythylpentane
3-methypentane

propanitrile — should be **propanenitrile**

aminethane — should be **ethylamine** (although aminoethane can gain credit)

2-methyl-3-bromobutane — all should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane
3-methyl-2-bromobutane

2-methylbut-3-ene — should be **3-methylbut-1-ene**

difluorodichloromethane — should be **dichlorodifluoromethane**