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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Chemistry 5421

CHM3 Introduction to Organic Chemistry

Mark Scheme

2007 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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Dr Michael Cresswell Director General

SECTION A

Question 1

(a) (i) At the bottom OR lower levels 1

(ii) At the top OR higher levels 1

(b) (i) To break (strong C-C) bonds QoL
OR homolytic fission 1
(ignore free-radical substitution)
(ignore overcoming Van der Waals forces as additional information)

(ii) C_nH_{2n} only(1)

(iii) $C_{13}H_{28} \longrightarrow C_6H_{14} + 2C_2H_4 + C_3H_6$
M1 correct alkene formulae 1
M2 balanced equation 1
(accept ethene formula written as CH_2CH_2, $CH_2{=}CH_2$, $H_2C{=}CH_2$ and similar for propene, but penalise M1 if either is incorrect e.g. $CH_2{\cdot}CH_2$)
(accept $CH_3(CH_2)_4CH_3$ for hexane)
(ignore conditions)

(iv) Correct structure of repeating unit 1
(ignore brackets)
(ignore "n")
(be lenient on vertical C-C bond in the structure)

Total 7

Question 2

(a) (i) $C_5H_{12} + 8O_2 \longrightarrow 5CO_2 + 6H_2O$ 1

(ii) Carbon OR C OR soot(y deposits) 1
(penalise "coke" OR "charcoal")

(iii) Petrol(eum)/Fuel/hydrocarbon mixture/(alkane) fraction has sulphur
(-containing impurities which burn) 1

(iv) (Causes) acid rain or wtte 1
OR toxic OR corrosive OR irritant
(penalise formation of acid/H_2SO_3/H_2SO_4 alone)
(penalise "harmful" alone)

(b) (i) The addition of water/H_2O QoL 1

(ii) $C_2H_4 + H_2O \longrightarrow CH_3CH_2OH$ 1
(accept ethene formula written as CH_2CH_2, $CH_2{=}CH_2$, $H_2C{=}CH_2$)
(accept ethanol formula written as C_2H_5OH in every case)
(penalise C_2H_6O once only)
(ignore H_3PO_4/H_2SO_4 on both sides of equation)

(iii) $C_6H_{12}O_6 \longrightarrow 2CH_3CH_2OH + 2CO_2$ 1

(possible RE for ethanol formula)

(iv) $CH_3CH_2OH + 2O_2 \longrightarrow 2CO + 3H_2O$ 1
(possible RE for ethanol formula)

Total 8

Question 3

(a) *Isomer 1* but-1-ene 1
Isomer 2 (2-)methylpropene 1
(credit "methylprop-1-ene")
(penalise methylpropanene and methylprop-2-ene)

(b) (i) M1 Compounds with the same structural formula 1
M2 but different arrangements of atoms/bonds/groups in space OR different spatial arrangements/orientations of atoms/bonds/groups 1
(ignore "same M_r, same molecular formula, same empirical formula, same displayed formula, but penalise M1 if any of these is stated to be different)

(ii) Isomer 3 and isomer 4 1
(credit correct names OR formulas)

(c) Isomer 2 1
(credit correct name OR formula)

(d) Electrophilic addition 1
(both words required)

M1 curly arrow from C=C bond towards/alongside the side of H atom on $H\text{-}OSO_2OH$ OR $H\text{-}OSO_3H$ 1
(penalise M1 if arrow to H_2SO_4 OR to formal charge on H of H-O bond)
(ignore partial charges on H and O of H_2SO_4, but penalise if these are incorrect on the H atom being attacked)
(credit M1 and M2 if correct curly arrow to H^+ provided the anion is present)
M2 curly arrow from H-O bond towards/alongside the side of the O atom on $H\text{-}OSO_2OH$ 1
(credit the arrow even if there are partial or formal charges on H and O, but the structure of H_2SO_4 is correct)
M3 correct structure of the carbocation 1
(penalise use of 'sticks' in this structure)
M4 curly arrow from lone pair on an individual oxygen atom of (correct formula for) hydrogensulphate ion towards/alongside C atom bearing the positive charge. 1
(insist that the anion has the correct formula with a lone pair of electrons and a negative charge.)
(Award a maximum of 3 marks for use of wrong alkene)

(e) (i) Correct structure of 2-methylpropan-2-ol and H_2SO_4 in the equation 1
(be lenient on the vertical bond in the alcohol, but penalise if C-H-O is clearly drawn)

(ii) (2-)methylpropan-2-ol 1

(f) (acid) catalyst 1 — 1
(ignore "homogeneous" and "heterogeneous"

Total 14

Question 4

(a) (i) 4[O] and $2H_2O$ — 1

(ii) OHC-CHO — 1
(insist on CHO groups drawn out)

(b) (i) *Reaction 1 is* electrophilic addition — 1
Reaction 2 is nucleophilic substitution — 1
(in both cases, both words are required)

(ii) *Compound X is* epoxyethane — 1
Reaction 4 is hydrolysis OR hydration OR (nucleophilic) addition — 1
(penalise "electrophilic" OR "free-radical addition")

(iii) M1 Formula for $H_2NCH_2CH_2NH_2$ — 1
M2 Balanced equation with $4NH_3$ and $2NH_4Br$ — 1
(accept $NH_2CH_2CH_2NH_2$ or $CH_2(NH_2)CH_2(NH_2)$ for M1 with or without brackets)
(accept $NH_4^+Br^-$)
(do not accept equations with HBr)
(award M2 if equation balanced with for example, $C_2H_8N_2$)

Total 8

Question 5

(a) (i) *Initiation* $F_2 \longrightarrow 2F\cdot$ — 1
(credit correct half arrows, but penalise double headed arrows)
(penalise FI once only)
(penalise the absence of dots once only)

First propagation $CH_3F + F\cdot \longrightarrow \cdot CH_2F + HF$ — 1
Second propagation $\cdot CH_2F + F_2 \longrightarrow CH_2F_2 + F\cdot$ — 1
(accept $CH_2F\cdot$)

(ii) $C_2H_6 + 5F_2 \longrightarrow CF_3CHF_2 + 5HF$ — 1
(penalise if any radicals appear in this equation)
(accept C_2F_5H in equation)

(b) (i) CCl_2F_2 OR CF_2Cl_2 OR structure drawn out — 1

(ii) M1 % F = 54.5 — 1

M2 mol C = 11.5/12.0 and mol Cl = 34.0/35.5 — 1
(mol F = 54.5/19.0)

M3 Ratio 0.958 : 0.958 : 2.87 OR 1 : 1 : 3 and $CClF_3$ — 1
(correct answer gains full credit)

(award a maximum of 2 marks for consistent use of atomic number rather than A_r, since this leads to approximately the correct answer)
(penalise M2 for incorrect Ar e.g. 35 for Cl)

Total 8

Question 6

(a) M1 A saturated alcohol contains only single bonds
OR no double bonds 1

M2 $H_2C{=}CHCH_2OH + H_2 \longrightarrow \underline{CH_3CH_2CH_2OH}$ 1
(accept C_3H_6O, C_3H_5OH and CH_2CHCH_2OH for prop-2-en-1-ol,)
(penalise molecular formulae and similar e.g. C_3H_8O, C_3H_7OH, for propan-1-ol,)

M3 propan-1-ol <u>only</u> 1

(b) M1 CH_3COCH_3 or drawn out 1

M2 Ketone 1
(ignore the actual name)

M3 CH_3CH_2CHO or drawn out 1

M4 Aldehyde 1
(ignore the actual name)
(award one mark only from M2 and M4 if the two classes are the wrong way)
(If other classes are referred to (e.g .alcohols) penalise any contradiction)

Total 7

Question 7

M1 NaOH OR KOH 1

M2 alcohol solvent OR (alcoholic) OR (ethanolic) 1
OR CH_3OH OR C_2H_5OH stated
(penalise M1 and M2 (CE=0) if acid is added OR wrong reagent OR no reagent)
(if hydroxide(ion)/base/ammonia penalise M1, but mark on)
(ignore all conditions)
(penalise "ethanoic" for M2 but award M1)

M3 Correct <u>structure</u> for 2-methylbut-1-ene 1
(be lenient on vertical bonds and credit structure if in a mechanism)

M4 Correct <u>structure</u> for 2-methylbut-2-ene 1
(be lenient on vertical bonds and credit structure if in a mechanism)

M5 Correct <u>name</u> for **either** <u>2-methylbut-1-ene</u> **or** (2-)<u>methylbut-2-ene</u> 1
(ignore additional correct name, but penalise M5 if one name correct and one name wrong)

M6, M7 and M8 are for the elimination mechanism using **either one** of 2-methylbut-1-ene **or** 2-methylbut-2-ene only
(ignore any further attempts at a mechanism)

M6 curly arrow from lone pair of electrons on oxygen of hydroxide ion 1
(insist on a lone pair of electrons on the oxygen atom and a negative charge, but only credit this mark if the attack is to a correct H atom)

M7 curly arrow from the middle of the C-H bond to the middle of the C-C bond. 1
(only credit this mark if the arrow originates from the correct C-H bond and if an attempt has been made at M1)

M8 curly arrow from the middle of the C-Br bond towards/alongside the Br atom. 1
(credit M3 independently unless the bond breaking is contradicted by an additional arrow)
(penalise curly arrow if the C-Br has a formal positive charge)
(credit full marks for an E1 mechanism, with M2 awarded for a correct curly arrow on the correct carbocation)
(award a maximum of two marks for either an incorrect haloalkane or an incorrect organic product)
(maximum 2 marks for use of 'sticks' for the haloalkane, unless RE from elsewhere in the paper, when credit can be given)

Total 8

General principles applied to marking CHM3/W papers
(updated January 2007)

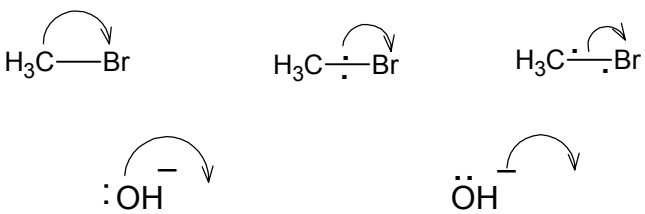
It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Errors which should be penalised

The following illustrate errors which ordinarily should be **penalised once only** per script. On the second occasion that the **same error** is repeated for the same bond or species, the mark should be awarded and the tick annotated **RE** (repeat error).

A. Mechanisms

1. Curly arrows should originate either from a lone pair of electrons or from a bond. Each of the three C-Br bond breaking representations shown below should be **penalised once** per script. The two representations of the movement of a pair of electrons from a hydroxide ion shown below (or similar from e.g. a bromide ion) should be penalised on **every** occasion.



2. The absence of a radical dot in a free radical substitution should be **penalised once** per script.

3. Incorrect positioning of the radical dot may be penalised, but if this occurs, it will be only once per script
   e.g. $\bullet CH_2F$ NOT $CH_2F\bullet$

4. The use of double-headed arrows or the incorrect use of half-headed arrows in a free-radical mechanism will be **penalised once** only per script. In general, there is no expectation for candidates to use half –headed arrows.

B. Structures

1. Bonds should be drawn clearly between the relevant atoms. By way of illustration, each of the following representations will usually be penalised once per script.

(accept up to the mid-point)

If candidates show the alcohol functional group as C-H-O, this may be penalised on every occasion.

Some latitude may 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-C bonds may be penalised.

2. Formulae for specific compounds which will be **penalised**.

CH_3COH	for	ethanal
CH_2OCH_2 or CH_2CH_2O	for	epoxyethane
CH_3CH_2HO $OHCH_2CH_3$ C_2H_6O	for	ethanol
CH_2CH_2 $CH_2.CH_2$ $CH_2:CH_2$	for	ethane

(N.B. Occasional exceptions may be made in the context of balancing equations)

3. The use of 'sticks' in structures should be **penalised once** per script. This will also apply to structures in mechanisms.

C. Names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should be **penalised once** per script. Some illustrations are given here. *(N.B. specific exceptions may be made at individual standardising meetings)*

but-2-ol 2-hydroxybutane butane-2-ol 2-butanol	all should be butan-**2-ol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan 3-mythylpentane	both should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane may gain credit)

D. 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.

cyanide (ion) should be e.g. potassium cyanide

hydroxide (ion) should be e.g. sodium hydroxide

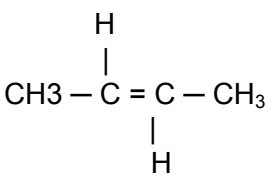
Some general guidance on organic structures

Each of the following **should be given 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, $CH_3CH(OH)CH_3$

CH_2OHCH_2OH for ethane-1,2-diol



for *trans* but-2-ene