UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
GCE Advanced Level

MARK SCHEME for the May/June 2011 question paper

for the guidance of teachers

9701 CHEMISTRY

9701/41 Paper 4 (A2 Structured Questions), maximum raw mark 100

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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1 **(a)** N≡N triple bond is (very) strong
or the N_2 molecule has no polarity [1]

(b) $3Mg(s) \rightarrow 3Mg^{2+}(g)$ $\Delta H_1 = 3 \times 148 + 3 \times 2186 = 7002$
$N_2(g) \rightarrow 2N^{3-}(g)$ $\Delta H_2 = 994 + 2 \times 2148 = 5290$

LE = $-\Delta H_1 - \Delta H_2 - 461$ = **–12,753** (kJ mol^{-1}) (–[1] for each error) [3]

(c) **(i)** $Li_3N + 3H_2O \rightarrow NH_3 + 3LiOH$ (balanced equation) [1]

(ii) advantage: no high pressure/temperature/catalyst needed/standard conditions used [1]

disadvantage: Li is expensive
or Li would need to be recycled/removed
or LiOH by-product is corrosive/strongly basic
or this would be a batch, rather than continuous process [1]

(d) **(i)** Li_3N: 100 × 14/35 = 40% N [1]
urea: 100 × 28/60 = 47% N [1]

(ii) amide [1]

(iii) $NH_2CONH_2 + H_2O \rightarrow 2NH_3 + CO_2$
or $\rightarrow NH_2CO_2H + NH_3$
or $NH_2CONH_2 + 2H_2O \rightarrow 2NH_3 + H_2CO_3$ [1]

(iv) The LiOH would be strongly alkaline
or would increase the pH of the soil
or would 'burn' the crops/reduce plant growth/stunt plants
or would contaminate the environment [1]

[Total: 12]

2 **(a)** **(i)** One that can go in either direction. [1]

(ii) both forward & reverse reactions are going on at the same time, but the concentrations of all species do not change (owtte)
or rate of forward = rate of backward reaction [1]

(b) **(i)** $K_c = [H^+][OH^-]/[H_2O]$ [1]

(ii) $K_w = [H^+][OH^-]$ [1]
rearrangement of equation in **(i)** gives $K_c[H_2O] = [H^+][OH^-]$ & $K_w = K_c[H_2O]$ (owtte)
or the $[H_2O]$ is contained within K_w [1]

(iii) K_w will be higher in hot water **because** reaction is endothermic [1]

(c) **(i)** $[OH^-] = 5 \times 10^{-2}$; $[H^+] = (1 \times 10^{-14})/ 5 \times 10^{-2} = \mathbf{2 \times 10^{-13}}$ [1]
pH $= -\log_{10}[H^+] = \mathbf{12.7}$ (correct ans = [2]) ecf [1]

(ii) $[NH_4^+] = [OH^-]$ (= x) [1]
$x^2 = 1.8 \times 10^{-5} \times 0.05 \Rightarrow x$ (= $[OH^-]$) = $\mathbf{9.49 \times 10^{-4}}$ (mol dm^{-3}) (correct ans = [2]) [1]

(iii) $[H^+] = K_w/[OH^-] = (1 \times 10^{-14})/ 9.49 \times 10^{-4} = \mathbf{1.05 \times 10^{-11}}$(mol dm^{-3}) ecf [1]

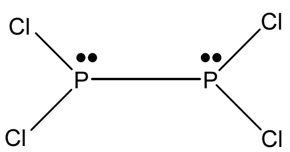
(iv) pH = **11.0** ecf [1]

[Total: 12 max 11]

3 **(a)** (+)1; (+)2; (+)3; (+)4 [1]
O.N. corresponds to the no. of electrons in outer/valence shell/lost [1]

(b) PCl_5 fizzes or white/misty fumes or heat evolved [1]
$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ *or* $PCl_5 + 3H_2O \rightarrow HPO_3 + 5HCl$
(allow partial hydrolysis: $PCl_5 + H_2O \rightarrow POCl_3 + 2HCl$) [1]

(c) **(i)** P = 30.4/31 = 0.98 C*l* = 69.6/35.5 = 1.96 [1]
Thus E.F = $\mathbf{PCl_2}$ [1]
$M_r(PCl_2) = 102$, so $2 \times PCl_2 = 204 \approx 200$, so M.F. = $\mathbf{P_2Cl_4}$ [1]

(ii) 

(ignore lone pairs on Cl) [1]

(iii) O.N. = (+)2 [1]

(iv) $(HO)_2P\text{-}P(OH)_2$ *or* H(HO)P(=O)-P(=O)(OH)H ecf from structure in **(ii)** [1]
Allow HO-P-OH or HO-P=O
|
H

[Total: 10]

4 (a) $N_2 + 2O_2 \rightarrow 2NO_2$ (*or* via NO) *or* $2NO + O_2 \rightarrow 2NO_2$ [1]

(b) (i) catalytic converter **and** passing the exhaust gases over a catalyst/Pt/Rh [1]

(ii) $NO_2 + 2CO \rightarrow \frac{1}{2} N_2 + 2CO_2$ ***or*** similar [1]
Allow $2NO_2 + CH_4 \rightarrow CO_2 + N_2 + 2H_2O$

(c) No, it wouldn't be reduced. Because the reaction in **(a)** does not presuppose a particular fuel (owtte) [1]
Allow formed from N_2 and O_2 in air during combustion

(d) (i) SO_3 produces acid rain [1]

(ii) $NO + \frac{1}{2} O_2 \rightarrow NO_2$ [1]

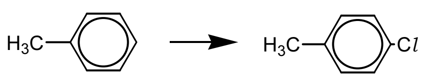
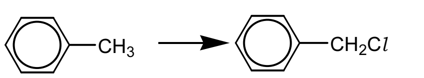
(iii) $K_p = (p_{NO}.p_{SO_3})/(p_{NO_2}.p_{SO_2})$ [1]
units: dimensionless/none (don't accept just a blank!) [1]

(iv) $K_p = 99.8^2/0.2^2 =$ $\mathbf{2.5 \times 10^5}$ [1]

(v) It will shift to the right (owtte) [1]
because the reaction is exothermic. NOT just Le Chatelier argument [1]

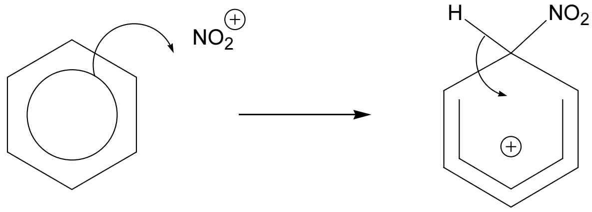
[Total: 11]

5 (a)

transformation	reagent + conditions
$C_2H_4 \rightarrow C_2H_5Cl$	**HC*l*, no light or catalyst**
$C_2H_5OH \rightarrow C_2H_5Cl$	**conc HC*l* + ZnC*l*$_2$ *or* SOC*l*$_2$ *or* PC*l*$_5$ *or* PC*l*$_3$ and heat**
$C_2H_6 \rightarrow C_2H_5Cl$	**C*l*$_2$ + light**
$C_2H_4 \rightarrow C_2H_4Cl_2$	**C*l*$_2$, no light or catalyst**
$CH_3CO_2H \rightarrow CH_3COCl$	**SOC*l*$_2$ *or* PC*l*$_5$ *or* PC*l*$_3$ and heat**
	**C*l*$_2$ + A*l*C*l*$_3$**
	**C*l*$_2$ + light or heat**

[6]

(b) **(i)** production of NO_2^+: $2H_2SO_4 + HNO_3 \rightarrow 2HSO_4^- + H_3O^+ + NO_2^+$ [1]
(accept $H_2SO_4 + HNO_3 \rightarrow HSO_4^- + H_2O + NO_2^+$)



curly arrow from ring to NO_2^+ **and** from C-H bond to ring [1]
correct intermediate, including charge in the right place
Note charge area must be more than half ring [1]

(ii) **C** is $C_6H_5CO_2H$ [1]

(iii) step 1: reagent is hot acidified or alkaline $KMnO_4$ [1]
step 2: reagent is Br_2 + $FeBr_3$/$AlCl_3$ etc. (H_2O or light negates) [1]

(If **C** is given as 3-bromotoluene, then allow the last [2] marks if steps 1 and 2 are reversed.)

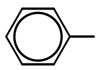
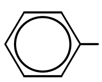
[Total: 12]

6 **(a)** **(i)** aqueous alkaline iodine ***or*** I_2 + OH^-(aq) allow NaClO + KI [1]

(ii) CH_3CO- ***or*** $CH_3CH(OH)$- [1]

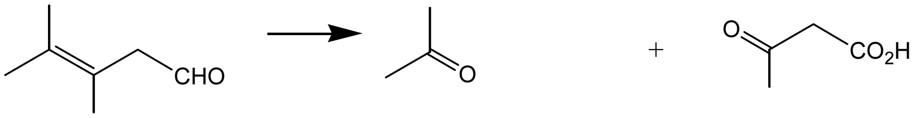
(iii) Pale yellow ppt. ***or*** antiseptic smell [1]

(iv)

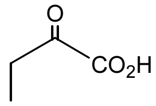
compound	result
CH_3OH	×
CH_3CH_2OH	✓
CH_3CHO	✓
CH_3CO_2H	×
CHO	×
$COCH_3$	✓

●✓●✓●✓ [3]

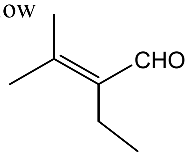
(b) (allow displayed, skeletal ***or*** structural formulae)



D **E** **F**

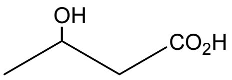
(**no mark** for )

for **D** allow

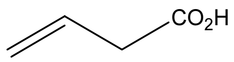


(**D** + **E** + **F**): 3 × [1]

(c) (allow displayed, skeletal ***and*** structural formulae)
Must be consistent with **F**

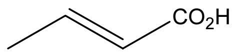


G

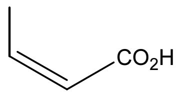


H

(only allow mark for **H** if **G** is the 3-OH acid)

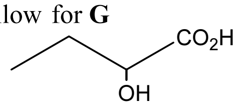


J



K

allow for **G**



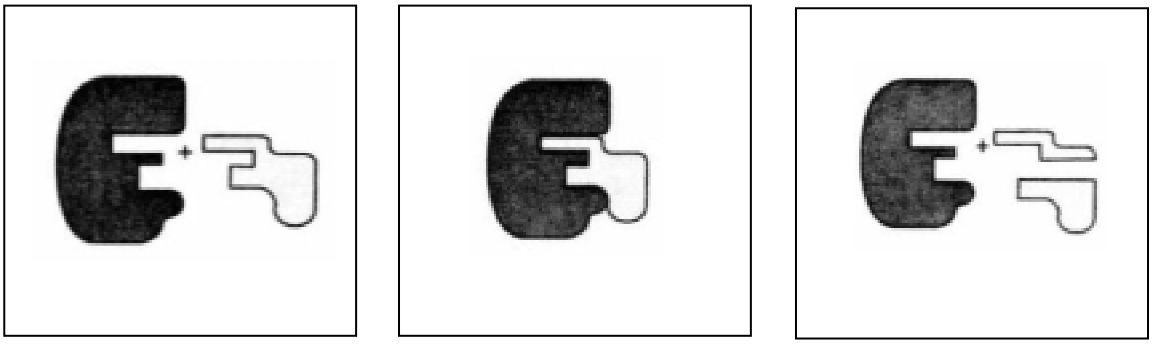
(N.B. letters **H**, **J**, **K** can be swapped around) (**G** + **H** + **J** + **K**): 4 × [1]

geometrical *or* cis-trans isomerism [1]

[Total: 14]

7 **(a)** The tertiary/3-dimensional structure/shape is held together by hydrogen/ionic/van der Waals bonds [1]
These break (relatively) easily/are weak/break at/above 45 °C [1]

(b) (*or* similar diagrams)



Enzyme + substrate Enzyme-substrate complex Enzyme + products 3 × [1]

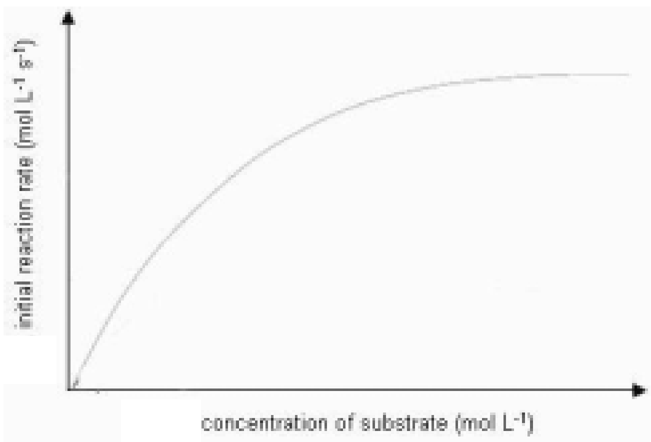
(c) a competitive inhibitor combines with the enzyme's active site (so preventing the substrate from binding) [1]

non-competitive inhibitor bonds with the enzyme away from the active site/at an allosteric site [1]

this changes the shape of the active site [1]

Also allow competitive inhibition can be overcome by increasing [substrate] ***or*** non-competitive inhibition cannot be removed by increasing [substrate] for the 3rd mark

(d) **(i)**



Line must be of similar shape to original but level out below original line [1]

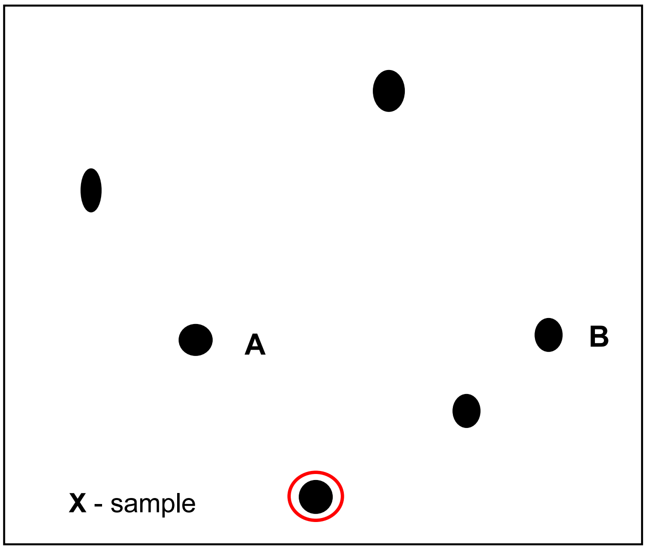
(ii) Inhibitor reduces the number of enzymes with 'working' active sites (owtte) [1]

[Total: 10]

8 **(a)** **partition** – separation due to the different solubilities of compounds in two solvents/phases [1]

adsorption – separation due to the different attractions between the compounds and the stationary phase, relative to their solubility in the solvent [1]
Note, if candidates do <u>not</u> refer to different solubilities and different attractions max 1

(b)



Ring: [1]
A + **B**: [1]

(c) **(i)** **X** is bromine – M and (M+2) peaks almost same height [1]

(ii) $\frac{M}{M+1} = \frac{100}{1.1} \times \frac{9}{n} = \frac{100}{0.3}$ 1.1 × n

Hence $n = \frac{100 \times 0.3}{1.1 \times 9} = 3.03$ $p = 3$

(answer + working) [1]

(If the mass peak is at 122 and the compound contains Br and 3 C atoms then Q = (122 – 79 – 36)) thus **Q = 7** ecf from **(ii)** [1]

(The compound is C_3H_7Br)

(iii) *(R is at m/e 43),* hence $\mathbf{C_3H_7^+}$ [1]

(d) Any **two** from H_2, H_2O, CO, C_2H_4, C_2H_2, CH_4 2 × [1]

[Total: 10]

9 **(a)** **(i)** One [1]

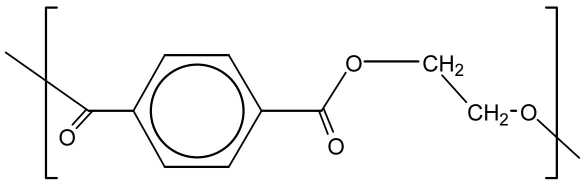
(ii) Any alkene (***or*** allow a cyclic amide, as in caprolactam) [1]

(b) Any TWO from:
addition needs unsaturated/double bonds/alkene
condensation eliminates a small molecule
condensation needs a molecule other than a hydrocarbon
empirical formula of addition polymer is the same as that of its monomer
condensation needs two different functional groups

(**NOT** – "condensation needs two different monomers") 2 × [1]

(c) **(i)** Water [1]

(ii)



Correct 'ester' bond [1]
'sticks' to rest of molecule [1]
Note : candidates need only show 'brackets' if more than one repeat unit shown

(iii) Polyesters [1]

(d) Monomers in *Terylene* have to alternate in order to condense out water (owtte) [1]

Alkenes can link in any order (and still form a polyalkene) (***or*** diagram showing this) [1]

[Total: 10]