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

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UNIVERSITY of CAMBRIDGE
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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 $= -\log_{10}[H^+]$ = **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]

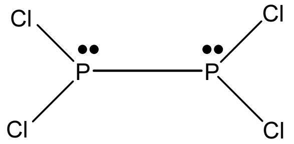
[Total: 12 max 11]

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 Cl = 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 with H attached to P

[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) $NO_2 + 2CO \rightarrow ½ N_2 + 2CO_2$ ***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) $NO + ½ O_2 \rightarrow NO_2$ [1]

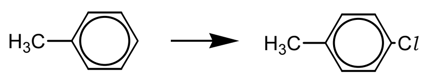
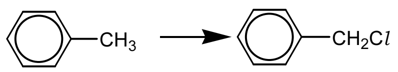
(iii) $K_p = (p_{NO}.p_{SO_3})/(p_{NO2}.p_{SO_2})$ [1]
units: dimensionless/none (don't accept just a blank!) [1]

(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]

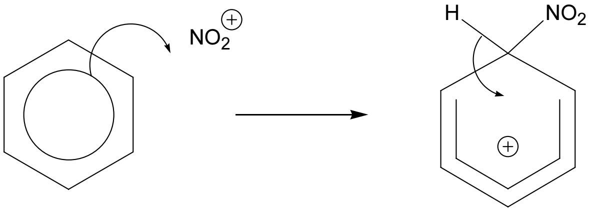
[Total: 11]

5 **(a)**

transformation	**reagent + conditions**
$C_2H_4 \rightarrow C_2H_5Cl$	**HCl, no light or catalyst**
$C_2H_5OH \rightarrow C_2H_5Cl$	**conc HCl + ZnCl$_2$ *or* SOCl$_2$ *or* PCl$_5$ *or* PCl$_3$ and heat**
$C_2H_6 \rightarrow C_2H_5Cl$	**Cl$_2$ + light**
$C_2H_4 \rightarrow C_2H_4Cl_2$	**Cl$_2$, no light or catalyst**
$CH_3CO_2H \rightarrow CH_3COCl$	**SOCl$_2$ *or* PCl$_5$ *or* PCl$_3$ and heat**
	**Cl$_2$ + AlCl$_3$**
	**Cl$_2$ + 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.)

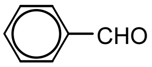
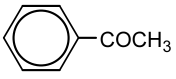
[Total: 12]

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

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

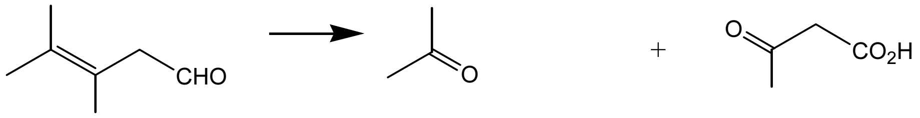
(iii) Pale yellow ppt. ***or*** antiseptic smell [1]

(iv)

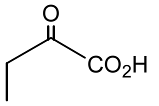
compound	result
CH_3OH	×
CH_3CH_2OH	✓
CH_3CHO	✓
CH_3CO_2H	×
 CHO	×
 $COCH_3$	✓

●✓●✓●✓ [3]

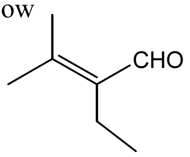
(b) (allow displayed, skeletal ***or*** structural formulae)



D **E** **F**

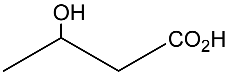
(**no mark** for )

for **D** allow

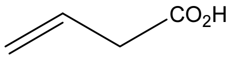


(**D** + **E** + **F**): 3 × [1]

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

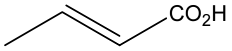


G

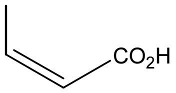


H

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

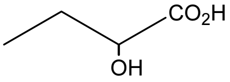


J



K

allow for **G**



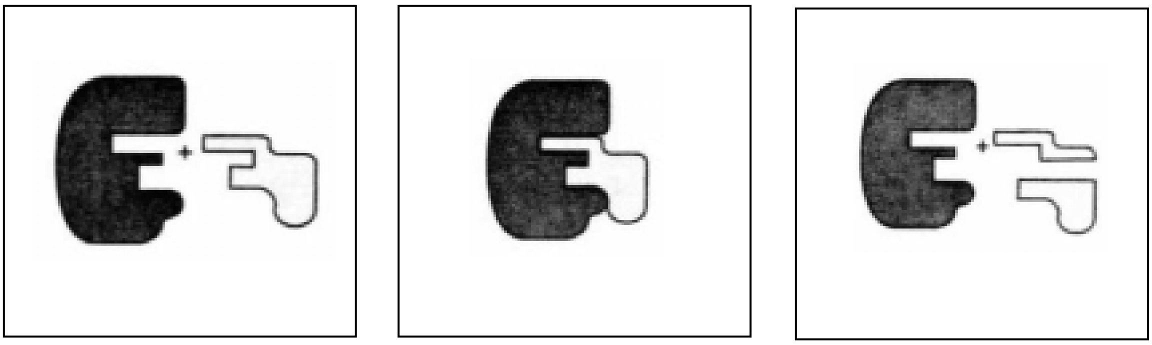
(N.B. letters **H**, **J**, **K** can be swapped around) (**G** + **H** + **J** + **K**): 4 × [1]

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]

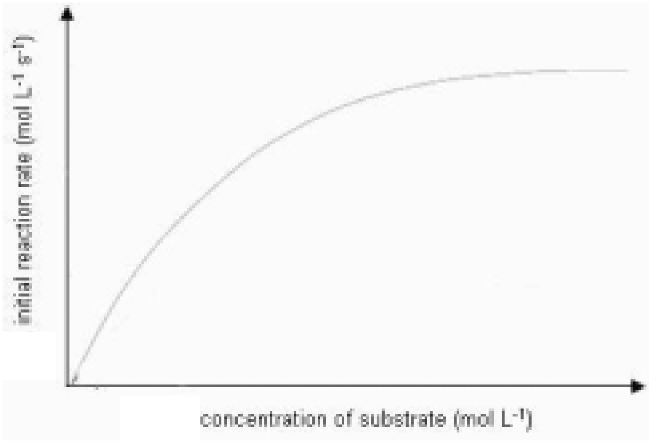
(c) a competitive inhibitor combines with the enzyme's active site (so preventing the substrate from binding) [1]

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]

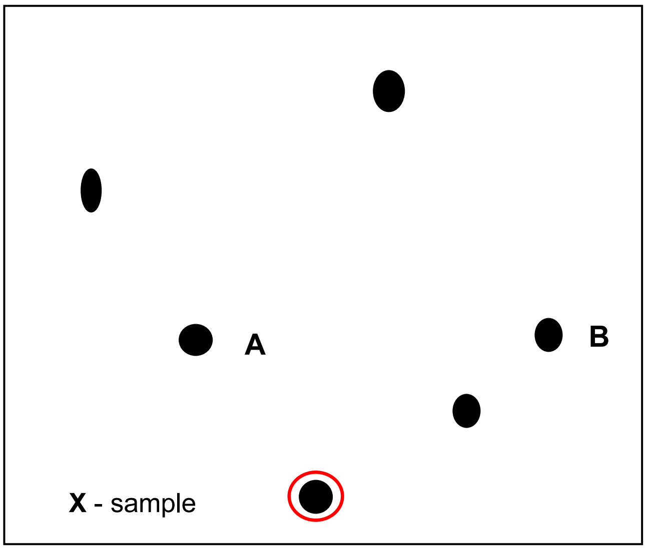
(ii) Inhibitor reduces the number of enzymes with 'working' active sites (owtte) [1]

[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) $\frac{M}{M+1} \quad \frac{100}{1.1} \times \frac{9}{n} \quad \frac{100}{0.3} \quad 1.1 \times n$

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

(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]

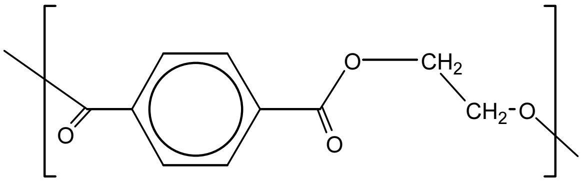
(b) Any TWO from:

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]