M99/420/H(2)M

INTERNATIONAL BACCALAUREATE
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MARKSCHEME

May 1999

CHEMISTRY

Higher Level

Paper 2

16 pages

SECTION A

1. (a) $4C(s) + 4H_2(g) + O_2(g) \rightarrow C_3H_7COOH(l)$ *[1 mark]*

Notes: Insist on correct state symbols
In (b), (c), and (d), omission of super and subscripts is **not** penalised.

(b) $\Delta H^\circ_{f(\text{rxn})} = \sum \Delta H^\circ_{f(\text{products})} - \sum \Delta H^\circ_{f(\text{reactants})}$ *[1 mark]*

Note: Give ***[1 mark]*** if subsequent working is correct.

$$-2183.5 \text{ kJ} = \left[4(-393.5 \text{ kJ mol}^{-1}) + 4(-285.9 \text{ kJ mol}^{-1})\right] - \left[1(\Delta H^\circ_{f(\text{butanoic acid})}) + 5(0.0 \text{ kJ mol}^{-1})\right]$$ *[1 mark]*

Note: Give ***[1 mark]*** for correct substitution.

$$-2183.5 \text{ kJ} = \left[(-1574 \text{ kJ}) + (-1143.6 \text{ kJ})\right] - \left[1(\Delta H^\circ_f) + 0.0 \text{ kJ}\right]$$

$$-2183.5 \text{ kJ} = \left[(-2717.6 \text{ kJ})\right] - \left[1(\Delta H^\circ_f)\right]$$

$$\Delta H^\circ_f = 2183.5 \text{ kJ} - 2717.6 \text{ kJ}$$

$\Delta H^\circ_f = -534.1$ kJ or kJ mol^{-1} *[1 mark]*

Note: Relate (b) to equation in (a) even if (a) is wrong max ***[3 marks]***.

(c) $\Delta S^\circ_{f(\text{butanoic acid})} = \Delta S^\circ_{(\text{butanoic acid})} - \left[4S^\circ_{(C)} + 4S^\circ_{(H_2)} + S^\circ_{(O)}\right]$ *[1 mark]*

$= 226.3 \text{ J mol}^{-1} \text{ K}^{-1} - \left[4(5.7) + 4(130.6) + 1(205.0)\right] \text{ J mol}^{-1} \text{ K}^{-1}$ *[1 mark]*

$= -523.9 \text{ J mol}^{-1} \text{ K}^{-1}$ **OR** $-0.5239 \text{ kJ mol}^{-1} \text{ K}^{-1}$ *[1 mark]*

Note: Relate (c) to equation in (a), even if (a) is wrong

(d) $\Delta G^\circ_f = \Delta H^\circ_f - T\Delta S^\circ_f$ (may be assumed if answer correct) *[1 mark]*

$= -534.1 \text{ kJ} - (298 \text{ K})(-0.5239 \text{ kJ K}^{-1})$

$= -378.0$ kJ or kJ mol^{-1} *[1 mark]*

Note: Answers to (b), (c) and (d) must be consistent with (a)

(e) It is spontaneous since ΔG is negative **Need all for *[1 mark]***

[Consequently, if in (d) ΔG is given as positive, then reaction is **not** spontaneous]

Total [10 marks]

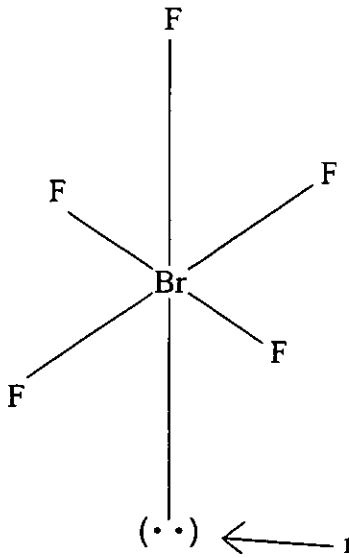
2. (a) (i) A solid (liquid not acceptable and high M_r not acceptable) *[1 mark]*
Relatively large van der Waal's / intermolecular forces / H-bonding *[1 mark]*
Note: Must have some discussion of bonding forces

(ii) The large number of C–C and C–H bonds / the long non-polar chain outweighs the polar OH. *[1 mark]*
[1 mark]

*Allow **[1 mark]** for simply stating non-polar molecular*

(b) BF_3 has only three pairs of electrons about the central B atom. *[1 mark]*
NF_3 has four pairs of electrons about the central N atom. *[1 mark]*
or explanation in terms of sp^2/sp^3

(c) Square pyramid *[1 mark]*



OR '(based on) octahedral' with suitable diagram: lone pairs must be there.

← not necessary for 'square pyramid' answer *[1 mark]*

(d) one (sp) σ bond σ/π= 1 *[1 mark]*
and two π bonds *[1 mark]*

***Triple** bond for 1 compensatory mark*

$2\sigma, 1\pi = 1$
$1\sigma, 1\pi = 1$

if C_2H_4 ,"double" = 0
$1\sigma, 1\pi = 1$

Total [10 marks]

3. (a) $K_c = \dfrac{[NO_2]^2}{[N_2O_4]}$ insist on [ ] *[1 mark]*

(b) (i) $[NO_2]$ increases or yield increases *[1 mark]*
since $[N_2O_4]$ increases and K_c is constant *[1 mark]*
OR equilibrium moves to the right

(ii) $[NO_2]$ decreases or yield decreases *[1 mark]*
since increased pressure pushes equilibrium to the left *[1 mark]*
OR by Le Chatelier's Principle the smaller volume is favoured

(iii) $[NO_2]$ unchanged or yield unchanged *[1 mark]*
catalyst does not affect position of equilibrium *[1 mark]*
OR both forward and backward reaction rates affected equally

(c) (i) $N_2O_4 \rightleftharpoons 2NO_2$ *[1 mark]*
0.8 0.4

(ii) $\dfrac{(0.4)^2}{0.8} = 0.2 \ \text{mol dm}^{-3}$ *[2 marks]*
[1] [1]

Note: Carry forward error from (a) in both numerical answer and units
Error carried forward in (c) (ii), *e.g.* if $[NO_2]$ is given as 0.2 then $K_c = 0.05$

(d) K_c increased *[1 mark]*
since forward reaction is endothermic *[1 mark]*
OR equilibrium moves to right as temperature increases

Total [14 marks]

4. (a) 2 *[1 mark]*

(b) 1 *[1 mark]*

(c) Rate = $k[A]^2[B]$ [ ] must be used *[1 mark]*

(d) $0.5 = k(0.2)^2(0.2)$ $k = 62.5$ error carried forward from (c) *[1 mark]*

Total [4 marks]

5. (a) Step 1 since it is the slowest. (Explanation must be given.) *[1 mark]*

(b) Step 1 *[1 mark]*
Slowest step, therefore has a higher activation energy relative to Step 2. *[1 mark]*

(c) Rate = $k[NO_2][F_2]$ *mark consequentially on (a)* *[1 mark]*

Total [4 marks]

SECTION B

6. (a) s, p, d, f *[2 marks]*

1 error, for example s, p, f, d or p, s, d, f deduct ***1 mark***

p, s, f, d ***0 marks***

(b) $d = 5, f = 7, p = 3, s = 1$

4 correct *[2 marks]*
2 or 3 correct *[1 mark]*
1 correct *[0 marks]*

Any answer which suggests the above

(c) Any 2 from 3:

electrons move (to lower) energy levels/orbitals *[1 mark]*

emitting energy as they do so *[1 mark]*

excitation and/or promotion to higher energy level *[1 mark]*

(d) Fill **singly before doubling** *[1 mark]*

since two **electrons** in the same orbital will **repel**/Hund's rule/orbitals are degenerate *[1 mark]*

Ti $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$ or reversed or Ar $3d^2 4s^2$ *[1 mark]*

Note: Must be superscript: $1s^2$

(e) (i) Order must be correct:

Mass spectrometer. *[1 mark]*

A sample of naturally occurring **gallium vapour** *[1 mark]*

is injected into the evacuated ionising chamber where an **electron beam ionises a part of the sample** by knocking electrons from the neutral atoms or molecules. *[1 mark]*

Charged plates accelerate the positive ions towards the detector *[1 mark]*

and the **ions pass through a magnetic field** perpendicular to their path *[1 mark]*

where the charged **ions are separated (deflected) into different paths.** *[1 mark]*

The **detector detects the paths according to the masses of the particles.** *[1 mark]*

Accept labelled diagram and adequate explanation.

Any five points from the six given. ***[max 6 marks]***

(ii) Ga-69 31p 38n *[1 mark]*

Ga-71 31p 40n *[1 mark]*

$$\frac{(60 \times 69) + (40 \times 71)}{100}$$ *[1 mark]*

69.8 *[1 mark]*

continued...

Question 6 continued...

(f) (i) **removed from a positively charged ion**, $Be^+(g)$, whereas *[1 mark]*
the **first electron is removed from a neutral atom**, Be(g). *[1 mark]*

*1st electron is removed from a full sub-orbital; 2nd electron is removed from a singly occupied sub-orbital, gains **[1 mark]** only*

(ii) Electron from 3p in Al but
electron from 3s in Mg *[1 mark]*
which is of lower energy *[1 mark]*

(iii) Electron from 2(p) in B ('p' not essential)
Electron from 3(p) in Al ('p' not essential) *[1 mark]*

The latter is further from the nucleus / the former is nearer to the nucleus *[1 mark]*

Total [25 marks]

7. (a) (i) $NaHCO_3$: Brønsted–Lowry base because proton acceptor, *[1 mark]*
Lewis base because electron **pair** donor. *[1 mark]*
$CaCO_3$: Both *[1 mark]*

(ii) $HCO_3^- + H^+ \rightarrow H_2O + CO_2$ *[1 mark]*
OR $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

Note: If H_2CO_3, no mark given.

$Al(OH)_3 + 3H^+ \rightarrow Al^{3+} + 3H_2O$ *[2 marks]*
OR $Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$
OR $Al(OH)_3(H_2O)_3 + 3H^+ \rightarrow [Al(H_2O)_6]^{3+}$

Note: ***[1 mark]*** for correct species, ***[1 mark]*** for correct balance.

$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + H_2O + CO_2$ *[1 mark]*
$+2HCl \rightarrow CaCl_2$

Note: If H_2CO_3 **again**, do not penalise.

(iii) $n_{mol}NaHCO_3 = 1\text{ g} \times \frac{1\text{ mol}}{84\text{ g mol}^{-1}} = 0.012$ *[1 mark]*

$n_{mol}Al(OH)_3 = 1\text{ g} \times \frac{1\text{ mol}}{78\text{ g mol}^{-1}} = 0.013$ *[1 mark]*

$n_{mol}CaCO_3 = 1\text{ g} \times \frac{1\text{ mol}}{100\text{ g mol}^{-1}} = 0.010$ *[1 mark]*

$Al(OH)_3$ reacts with 3 mol of H^+ so it is more effective than $CaCO_3$ which reacts with 2 mol of H^+ which is more effective than $NaHCO_3$ which reacts with 1 mol of H^+ *[3 marks]*

OR $Al(OH)_3$ best *[1 mark]*
$CaCO_3$ *[1 mark]*
$NaHCO_3$ worst *[1 mark]*

a further ***[2 marks]*** if stoichiometry has been used to explain the rest of the order

Note: If order is wrong look for consequential marking

(iv) NaOH is a strong alkali *[1 mark]*
damages body tissues / corrosive to body *[1 mark]*
difficult to store

Note: Accept other answers on merit

continued...

Question 7 continued...

(b) (i) amphoteric/amphiprotic *[1 mark]*

(ii) $Zn(OH)_2 + 2H^+ \rightarrow Zn^{2+} + 2H_2O$ *equation 1, balanced 1* *[2 marks]*

$Zn(OH)_2 + 2OH^- \rightarrow Zn(OH)_4^{2-}$ (**OR** $ZnO_2^{2-} + 2H_2O$) *[2 marks]*

$Al(OH)_3$ / $Pb(OH)_2$ / $Sn(OH)_2$ / Al_2O_3 / $Cr(OH)_3$ / accept other suitable oxides/hydroxides (**not** H_2O) *[1 mark]*

(iii) Electron pair acceptor. *[1 mark]*

They have available / empty (*d*) orbitals. *[1 mark]*

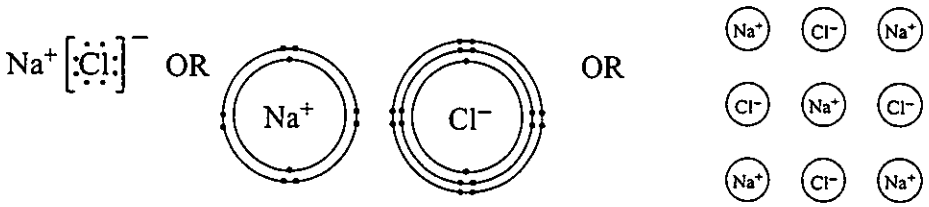
e.g. $Cu^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+}$ *[2 marks]*

choice of base (ligand) 1, formula of suitable complex 1 ***Total [25 marks]***

N.B. $[Cu(H_2O)_4]^{2+}$ or $[Cu(H_2O)_6]^{2+}$, both are acceptable

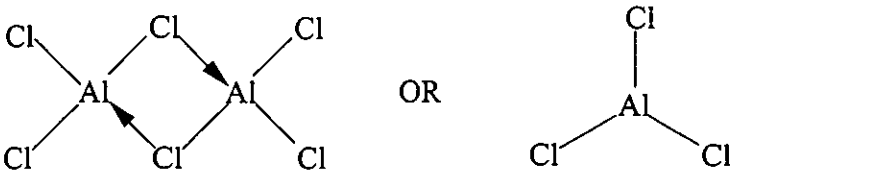
Note: Equation does not have to be balanced

8. (a) (i) NaCl – high melting and boiling points – giant structure/ionic *[1 mark]*
– strong attraction between ions *[1 mark]*



[1 mark]

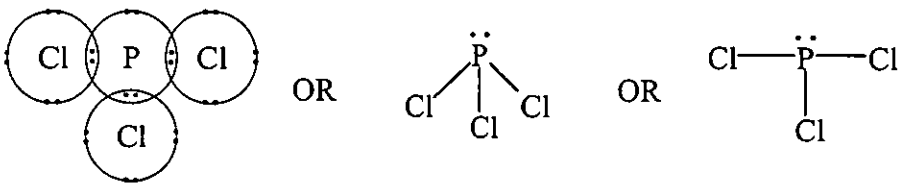
Al_2Cl_6 – low melting and boiling points – simple molecular/covalent *[1 mark]*
– associated or weak forces between individual molecules *[1 mark]*



[1 mark]

OR Lewis dot-cross diagram

PCl_3 – low melting and boiling points – simple molecular/covalent *[1 mark]*
– weak forces between individual molecules *[1 mark]*



[1 mark]

(ii) NaCl dissolves (do not accept dissociates) *[1 mark]*
$AlCl_3$ vigorous reaction /exothermic/fizzing/gas evolved *[1 mark]*
PCl_3 gives vigorous reaction/exothermic/fizzing/gas evolved *[1 mark]*
$AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$ *[1 mark]*
$PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$ *[1 mark]*

(b) (i) ionic, ionic, covalent, covalent *[4 marks]*

(ii) strong alkali OR high pH, weak alkali OR pH above 7, nothing OR 7, acid OR below 7 *[4 marks]*

$Na_2O + H_2O \rightarrow 2NaOH$ Give *[1 mark]* if product is correct *[1 mark]*
$MgO + H_2O \rightarrow Mg(OH)_2$ *[1 mark]*
$P_4O_6(P_2O_3) + 6H_2O(3H_2O) \rightarrow 4H_3PO_3(2H_3PO_3)$ *[1 mark]*
OR
$P_4O_{10}(P_2O_5) + 6H_2O(3H_2O) \rightarrow 4H_3PO_4(2H_3PO_4)$

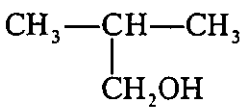
Total [25 marks]

9. (a) (i) $C_4H_{10}O = 74$ *[1 mark]*
Therefore molecular formula = $C_4H_{10}O$ *[1 mark]*

(ii) Removal of CH_3 / $C_3H_7O^+$ is present *[1 mark]*

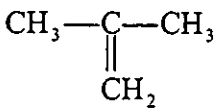
(iii) OH *[1 mark]*

(b) $CH_3CH_2CH_2CH_2OH$

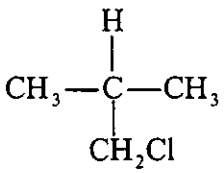


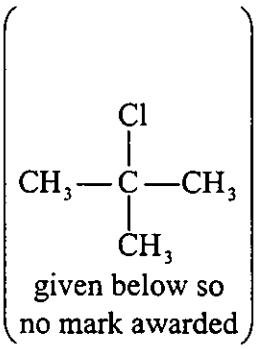
[2 marks]

(c) (i) C=C (or alkene) accept 'primary alcohol' or $-CH_2OH$ if candidate has misinterpreted the question *[1 mark]*

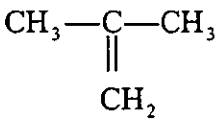
(ii) $CH_3CH_2CH{=}CH_2$  *[2 marks]*

(iii) $CH_3CH_2CH(Cl)CH_3$
$CH_3CH_2CH_2CH_2Cl$





[3 marks]

(d)  *[1 mark]*

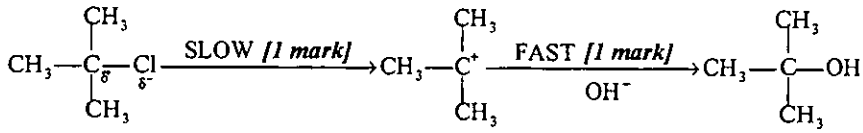
The phrasing of the question may lead candidates to offer more than one answer. Give credit for correct answer – ignore the rest.

continued...

Question 9 continued...

(e) (i) substitution *[1 mark]*
nucleophilic *[1 mark]*
1st order/unimolecular *[1 mark]*

(ii) Steric effects of CH_3 *[1 mark]*
CH_3 electron releasing *[1 mark]*
The $(CH_3)_3C^+$ ion is stable *[1 mark]*

(iii) 

polarity [1 mark] *[1 mark]* OH^- ion + product *[1 mark]* *[5 marks]*

Note: If candidate has given a lot of detail in (e)(i), carry forward credit to (e)(iii).

(f) A tertiary alcohol cannot be oxidised. *[1 mark]*

Total [25 marks]