MARKSCHEME

May 2006

CHEMISTRY

Higher Level

Paper 2

17 pages

SECTION A

1. (a) $C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$; ***[1]***

(b) (i) $(\Delta H^{\ominus} = \sum \Delta H_f^{\ominus}{}_{\text{products}} - \sum \Delta H^{\ominus}{}_{\text{f reactants}})$

$\Delta H^{\ominus} = (6\times -394 + 6\times -242) - (-43)$;

$\Delta H^{\ominus}{}_c = -3773 / -3.8\times 10^3$ (kJ mol^{-1}); ***[2]***

Accept 2, 3 or 4 sf.

*Award **[1]** for* $+3773 / +3.8\times 10^3$ $(kJ\ mol^{-1})$.

Allow ECF from (a) only if coefficients used.

(ii) $\Delta S^{\ominus} = (S_p^{\ominus} - S_r^{\ominus}) = (6\times 189 + 6\times 214) - (385 + 9\times 205)$;

$\Delta S_c^{\ominus} = 188$ (J K^{-1} mol^{-1}); ***[2]***

Accept only 3sf.

*Award **[1]** for –188.*

Allow ECF from (a) only if coefficients used.

(c) $(\Delta G^{\ominus}{}_c = \Delta H^{\ominus}{}_c - \mathrm{T}\Delta S^{\ominus}{}_c) = -3800 - (298\times 0.188)$;

$= -3900\ kJ\ mol^{-1}$. ***[2]***

Accept –3800 to –3900.

Accept 2, 3 or 4 sf.

Allow ECF from (b).

Units needed for second mark.

(d) spontaneous and $\Delta G^{\ominus}$ negative; ***[1]***

Allow ECF from (c).

(e) $-1\times \Delta H_1$ / 676;

$1\times \Delta H_2$ / –394;

$2\times \Delta H_3$ / – 484;

$\Delta H_4 = -202$ (kJ mol^{-1}); ***[4]***

Accept alternative methods.

*Correct answers score **[4]**.*

*Award **[3]** for* $(+)202$ *or* $(+)40$ $(kJ / kJ\ mol^{-1})$.

2. (a) $A_r(\text{Tl}) = 203 \times 0.2952 + 205 \times 0.7048 \,/\, A_r(\text{Tl}) = 204.41$;
$A_r(\text{Br}) = 79 \times 0.5069 + 81 \times 0.4931 \,/\, A_r(\text{Br}) = 79.99$;
$M_r(\text{TlBr}_3) = 204.41 + 3 \times 79.99 = 444.38 \,/\, 444.37$; ***[3]***
*Correct answer scores **[3]**.*
Ignore units of g or g mol^{-1}.
Apply ECF to M_r from A_r values.

(b) M_r is an <u>average</u> value (because of the isotopes);
each HBr molecule has its own value depending on which isotopes (of H or Br) it contains/*OWTTE*; ***[2]***

(c) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$; ***[1]***
Do not accept noble gas shortcut. No subscripts.

(d) Mg^{2+}; ***[1]***

(e) Al^{3+}, O^{2-}, Ne, Na^{+}, F^{-}, N^{3-}; ***[2]***
*Award **[2]** for any three, **[1]** for any two.*

3. $n(Fe_2O_3) = 30 \times 10^3 \div 159.7 \,/\, n(Fe_2O_3) = 188$ mol;
$n(C) = 5.0 \times 10^3 \div 12.01 \,/\, n(C) = 416$ mol;
Fe_2O_3 is the limiting reagent or implicit in calculation;
$n(Fe) = 2 \times n(Fe_2O_3) = 2 \times 188 = 376$ mol;
$m(Fe) = 376 \times 55.85 = 21$ kg; ***[5]***
Accept 2sf or 3sf, otherwise use –1(SF).
*Correct final answers score **[5]**.*
Allow ECF.

4. (a) (i) (a species that) gains electrons (from another species) / causes electron loss; ***[1]***

(ii) changes by 3;
reduced because its oxidation number decreased $/ +6 \rightarrow +3 \,/\, 6+ \rightarrow 3+$ / it has gained electrons; ***[2]***

(b) (i) $C_6H_8O_6 \rightarrow C_6H_6O_6 + 2H^+ + 2e$; ***[1]***

(ii) $C_6H_8O_6 + 2Fe^{3+} \rightarrow C_6H_6O_6 + 2H^+ + 2Fe^{2+}$; ***[1]***

5. (a) same <u>general</u> formula;
successive members differ by CH_2;
Do not allow elements or just "they".
similar chemical properties;
Allow same/constant.
gradual change in physical properties;
Do not allow change periodically.
same functional group; ***[2 max]***
*Award **[1]** each for any two.*

(b) add bromine (water);
alkanes – no change / stays or turns brown;
Allow red-brown or any combination of brown, orange or yellow.
alkenes – bromine (water) decolorizes;
Do not allow clear or discoloured.

or

add (acidified) $KMnO_4$;
alkanes – no change;
alkenes – MnO_4^- decolorizes / brown / black; ***[3]***
Do not accept addition of H_2 or HBr.

(c)

butan-1-ol:	butanal; butanoic acid;
butan-2-ol:	butanone;
2 methylpropan-2-ol:	no oxidation; ***[4]***

Also accept correct structures. Where both name and structure given structure must be correct and name largely correct.

SECTION B

6. (a) $K / K_c = [SO_3]^2 \div [SO_2]^2[O_2]$; ***[1]***
Exactly as written.
Accept correct K_p expression.

(b) (i) vanadium(V) oxide / (di)vanadium pentaoxide / V_2O_5 /Pt; ***[1]***
Allow just vanadium oxide but not incorrect formula.

(ii) catalyst does not affect the value of K_c;
forward and reverse rate increase equally/by the same factor;
catalyst increases the rate of the reaction;
(by providing an alternative path for the reaction with) lower activation energy; ***[4]***

(c) more energetic collisions / more molecules have energy greater than activation energy;
more frequent collisions; ***[2]***
Do not accept more collisions without reference to time.

(d) (i) shifts equilibrium position to the products/right;
to the side with least gas molecules or moles / lower volume of gas; ***[2]***

(ii) shifts equilibrium position to the products/right;
to compensate for loss of SO_3 / produce more SO_3; ***[2]***

(e) exothermic;
K_c decreases with increasing temperature / back reaction favoured / heat used up / *OWTTE*; ***[2]***

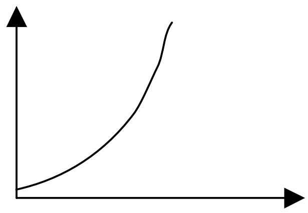
(f) $n(SO_2)_{\text{at equilibrium}} = 1.50 - 0.50 = 1.00$ mol;
$n(O_2)_{\text{at equilibrium}} = 2.00 - 0.250 = 1.75$ mol;

$[SO_2] = 1.00 \div 1.50 = 0.667 \text{ mol dm}^{-3}$, $[O_2] = 1.75 \div 1.50 = 1.17 \text{ mol dm}^{-3}$
$[SO_3] = 0.500 \div 1.50 = 0.333 \text{ mol dm}^{-3}$;

$K_c = (0.333)^2 \div 1.17 \times (0.667)^2$;
$= 0.213 \text{ dm}^3 \text{ mol}^{-1} / 0.214 \text{ dm}^3 \text{ mol}^{-1}$; ***[5]***
Allow ECF.
*If 0.202 dm^3 mol^{-1} is given award **[4]**, this is obtained by premature rounding.*
*Award **[5]** for correct answer with units.*

(g) (i) the greater the strength of the intermolecular forces the greater the enthalpy of vaporization/*OWTTE*;
pentane has only van der Waals' forces between molecules;
propanoic acid has H-bonding (as well as van der Waals' forces); ***[3]***

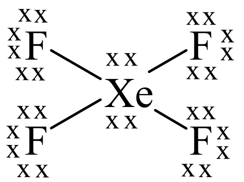
(ii)



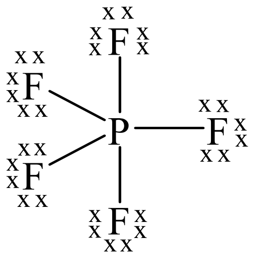
;

1st mark: graph goes upwards with T;
2nd mark: curve as shown;
as temperature increases (more) molecules have enough energy to overcome intermolecular / attractive forces; ***[3]***

7. (a)



; lone pairs on Xe required for the mark.



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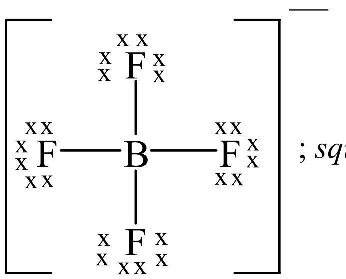


; *square brackets and charge required for the mark.*

Accept any combination of dots, crosses and lines. ***[3]***
Penalise missing fluorine lone pairs once only.

(b) *XeF_4*
Square planar and 90°;
PF_5
trigonal bipyramid and 90° and 120°;
BF_4^-
Tetrahedral and 109.5°/109 °; ***[3]***
Allow clear suitable diagrams instead of name.
No ECF from (a).

(c) hybridization: mixing / merging of atomic orbitals;
N_2 – sp;
N_2H_2 – sp^2;
N_2H_4 – sp^3; ***[4]***

(d) σ bonds (result from the) overlapping of orbitals end to end / along inter-nuclear axis;
π bonds (result from the) overlapping of parallel/sideways p orbitals;
(single bonds) σ bonds only;
(double bonds) have a σ bond and a π bond; ***[4]***
Suitable clear and labelled diagrams acceptable for all marks.

(e) (i) electron removed from higher energy level / further from nucleus / greater atomic radius;
increased repulsion by extra inner shell electrons / increased shielding effect; ***[2]***

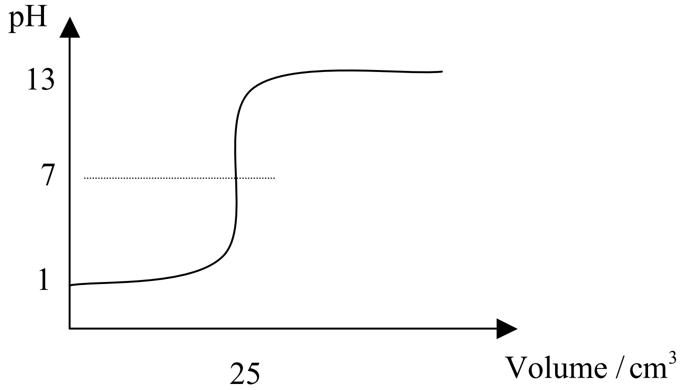
(ii) $Mg^{2+}\underline{(g)} \rightarrow Mg^{3+}\underline{(g)} + e$;
(even though) valence electrons in the same shell/main energy level / Mg^{2+} has noble gas configuration;
Mg has greater nuclear/core charge/more protons; ***[3]***

(f) (i) Mg has twice/more delocalized electrons as Na;
the ionic charge is twice as big/greater in Mg than Na;
sodium ion is larger than magnesium ion;
attraction of ions and electrons is less in sodium/greater in magnesium; ***[3 max]***
Correct discussion of charge density gains 2nd and 3rd mark.
Award ***[1]*** *each for any three.*

(ii) SO_2 has (weak) intermolecular/van der Waals' force/dipole – dipole;
MgO has (strong) ionic bonds;
Ionic bonding is stronger than intermolecular attraction (OWTTE); ***[3]***

8. (a) (i) $pH = -\log[H^+]$; ***[1]***

(ii) curve should include the following:
starting pH = 1;
equivalence point: 25.0 cm^3 of NaOH;
pH at equivalence point = 7;
pH to finish = 12 –13;



[4]

*Penalise **[1]** if profile incorrect.*

(iii) $K_a = 10^{-4.76} / 1.74 \times 10^{-5}$;

$K_a = [H^+]^2 \div [CH_3COOH] / 1.74 \times 10^{-5} = \frac{[H^+]^2}{0.100}$;

$[H^+] = 1.32 \times 10^{-3}$ $(mol\,dm^{-3})$;
starting pH = 2.88;
Accept 3sf.
*Award **[4]** for correct pH.*
Allow ECF.
pH at equivalence point: 8 – 9; ***[5]***

(b) (i) HIn is a weak acid;
$HIn \rightleftharpoons H^+ + In^-$ and two colours indicated;

In acid <u>equilibrium</u> moves left or vice versa; ***[3]***

(ii) phenolphthalein / phenol red / bromothymol blue;
colour change of indicator occurs within the range of pH at equivalence point / on vertical part of graph; ***[2]***

(c) (i) specific examples of weak base and its salt / specific strong acid and weak base; ***[1]***
Name of structure acceptable.
e.g. NH_3 and NH_4Cl.

(ii) pH changes very little / most acid neutralized by base;
equation from (i); ***[2]***
Any other suitable example.
e.g. $NH_3 + H^+ \rightarrow NH_4^+$ / $NH_4OH + H^+ \rightarrow NH_4^+ + H_2O$.

(d) *Brønsted-Lowry acid*
a proton donor;

Lewis acid
electron <u>pair</u> acceptor;

Brønsted-Lowry acid
Any suitable equation;

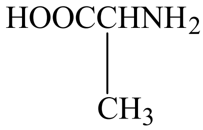
Lewis acid – BF_3 / $AlCl_3$/transition metal ions that form complex ion with ligands;

For example
$BF_3 + NH_3 \rightarrow BF_3NH_3$ / $Cu^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+}$ / $AlCl_3 + Cl^- \rightarrow AlCl_4^-$; ***[5]***
Or any suitable equation.

(e) acidic;
$[Al(H_2O)_6]^{3+}$ is (weak) acid due to the formation of H^+ /
$[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H^+$; ***[2]***

9. (a) (i) CH_2CH_2; **[1]**

(ii) **[1]**



;

Allow appropriate acyl chloride.

(iii) $H_2N(CH_2)_6NH_2$;
$HOOC(CH_2)_4COOH$; **[2]**
Allow correct alternative.
Accept correct names as alternatives.
If correct structure and incorrect name given, award the mark.
Penalise $COOH-C$ once only.

(b) (addition polymers) contain $C=C$ / $C\equiv C$;
(condensation polymers) contain two reactive/functional groups; **[2]**

(c) $HCOOCH_3$;
methyl methanoate; **[2]**
Accept other correct alternative.

(d) (i) methanol / methyl alcohol;
heat and acid catalyst/ H^+;
$CH_3OH + CH_3COOH \rightarrow CH_3COOCH_3 + H_2O$; **[3]**

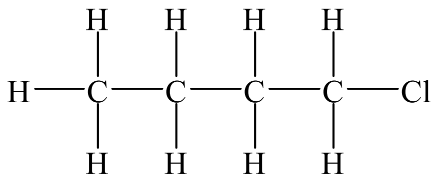
(ii) *physical properties*
ethanoic acid has a higher boiling point / ester has a lower boiling point;
ethanoic acid has vinegar smell, ester has sweet/fruit smell;
Must specify one smell.
ethanoic acid is more soluble in water than methyl ethanoate / methyl ethanoate is more soluble in non-polar solvents than ethanoic acid;
ethanoic acid (in water) has a pH < 7, ester (in water) has a pH $=7$; **[2 max]**
*Award **[1]** each for any two.*

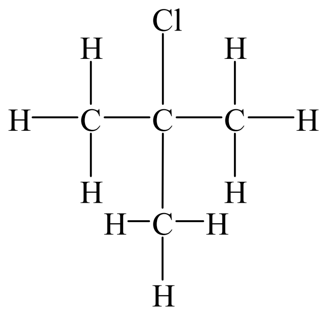
(iii) *ethanoic acid*
3:1;
methyl ethanoate
1:1; **[2]**
Allow 3:3.

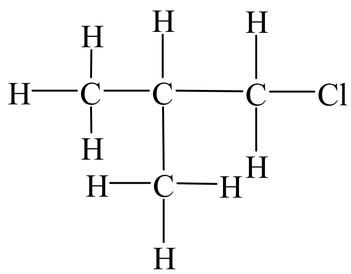
(e) (i) 2 – chlorobutane is the optical isomer;
has a chiral carbon/asymmetric carbon atom / 4 different groups around central atom; ***[2]***

(ii) pass plane polarized light through (two separate) samples;
each sample will rotate the polarized light in the <u>opposite</u> direction; ***[2]***

(iii) ***[2]***







*Award **[2]** marks for 3 and **[1]** mark for 2 structures.*
Penalise missing H atoms once only.

(iv) 1-chlorobutane / 1-chloro–2–methylpropane; ***[1]***
Accept structures.

(v) *mechanism*

curly arrow from O of ^-OH joined to C, and from C–Cl bond to Cl;
transition state structure with partial bonds to OH and Cl and a negative charge;
product: $CH_3CH_2CH_2CH_2OH$ / $CH_3CH(CH_3)CH_2OH$; ***[3]***

e.g.