IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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M06/4/CHEMI/HP2/ENG/TZ0/XX/M+

# 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) $(\Delta H^{\ominus} = \sum \Delta H_{f\ products}^{\ominus} - \sum \Delta H_{f\ reactants}^{\ominus})$

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

$\Delta H^{\ominus}_c = -3773 / -3.8 \times 10^3$ (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) $(\Delta G^{\ominus}_c = \Delta H^{\ominus}_c - T\Delta S^{\ominus}_c) = -3800 - (298 \times 0.188)$;

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

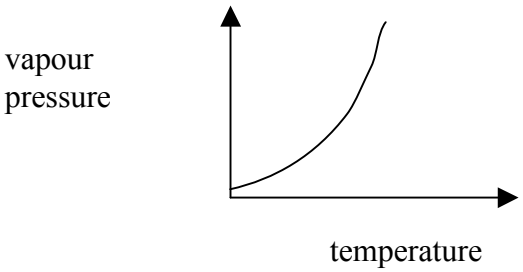
(f) $n(SO_2)_{\text{at equilibrium}} = 1.50 - 0.50 = 1.00$ mol;
$n(O_2)_{\text{at equilibrium}} = 2.00 - 0.250 = 1.75$ mol;

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

$K_c = (0.333)^2 \div 1.17 \times (0.667)^2$;
$= 0.213 \text{ dm}^3 \text{ mol}^{-1} / 0.214 \text{ dm}^3 \text{ mol}^{-1}$; ***[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]***

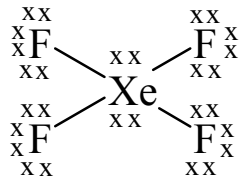
(ii)



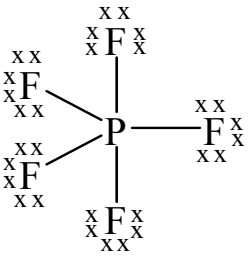

;

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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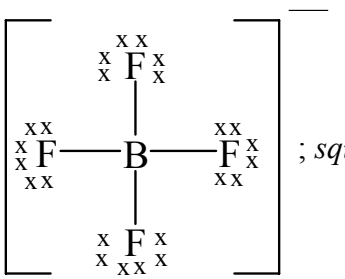


; *square brackets and charge required for the mark.*

*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]***

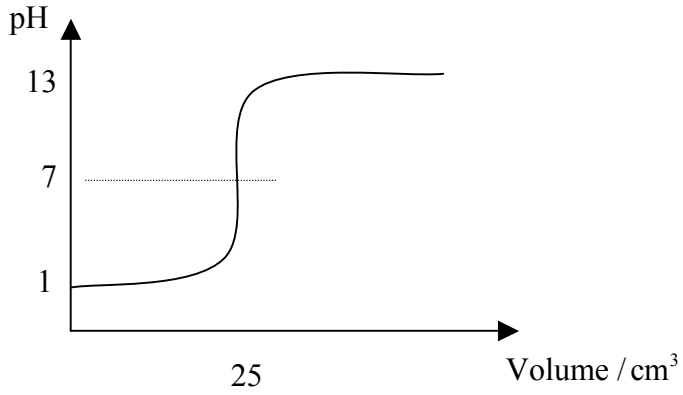
(ii) $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e$;
(even though) valence electrons in the same shell/main energy level / $Mg^{2+}$ has noble gas configuration;
Mg has greater nuclear/core charge/more protons; ***[3]***

(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 pair acceptor;

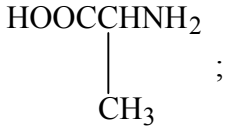
*Brønsted-Lowry acid*
Any suitable equation;

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]***

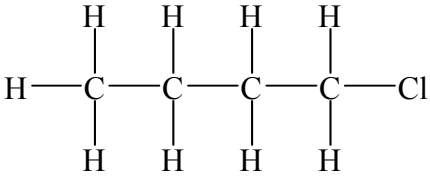
(ii) *physical properties*
ethanoic acid has a higher boiling point / ester has a lower boiling point;
ethanoic acid has vinegar smell, ester has sweet/fruit smell;
*Must specify one smell.*
ethanoic acid is more soluble in water than methyl ethanoate / methyl ethanoate is more soluble in non-polar solvents 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.*

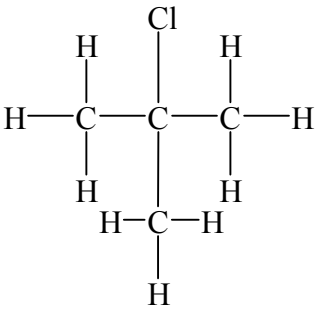
(iii) *ethanoic acid*
3:1;
*methyl ethanoate*
1:1; ***[2]***
*Allow 3:3.*

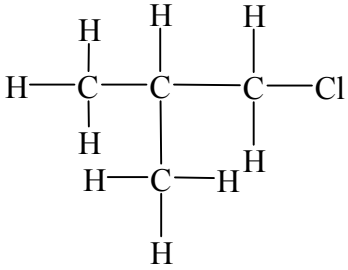
(e) (i) 2 – chlorobutane is the optical isomer;
has a chiral carbon/asymmetric carbon atom / 4 different groups around central atom; ***[2]***

(ii) pass plane polarized light through (two separate) samples;
each sample will rotate the polarized light in the opposite 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.*