IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

MARKSCHEME

May 2005

CHEMISTRY

Higher Level

Paper 2

16 pages

Subject Details: Chemistry HL Paper 2 Markscheme

General

- Each marking point has a separate line and the end is signified by means of a semicolon (;).
- Alternative answers are separated by a slash (/) – this means that either answer is acceptable.
- Words underlined are essential for the mark.
- Material in brackets (…) is not needed for the mark.
- The order in which candidates score marks does not matter (unless stated otherwise).
- The use of ***OWTTE*** in a markscheme (the abbreviation for "or words to that effect") means that if a candidate's answer contains words different to those in the markscheme, but which can be interpreted as having the same meaning, then the mark should be awarded.
- Please remember that many candidates are writing in a second language, and that effective communication is more important than grammatical accuracy.
- In some cases there may be more acceptable ways of scoring marks than the total mark for the question part. In these cases, tick each correct point, and if the total number of ticks is greater than the maximum possible total then write the maximum total followed by **MAX**.
- In some questions an answer to a question part has to be used in later parts. If an error is made in the first part then it should be penalized. However, if the incorrect answer is used correctly in later parts then "follow through" marks can be scored. Show this by writing **ECF** (error carried forward). This situation often occurs in calculations but may do so in other questions.
- Units for quantities should always be given where appropriate. In some cases a mark is available in the markscheme for writing the correct unit. In other cases the markscheme may state that units are to be ignored. Where this is not the case, penalize the omission of units, or the use of incorrect units, once only in the paper, and show this by writing **–1(U)** at the first point at which it occurs.
- Do not penalize candidates for using too many significant figures in answers to calculations, unless the question specifically states the number of significant figures required. If a candidate gives an answer to fewer significant figures than the answer shown in the markscheme, penalize this once only in the paper, and show this by writing **–1(SF)** at the first point at which this occurs.
- If a question specifically asks for the name of a substance, do not award a mark for a correct formula; similarly, if the formula is specifically asked for, do not award a mark for a correct name.
- If a question asks for an equation for a reaction, a balanced symbol equation is usually expected. Do not award a mark for a word equation or an unbalanced equation unless the question specifically asks for this. In some cases, where more complicated equations are to be written, more than one mark may be available for an equation – in these cases follow the instructions in the mark scheme.
- Ignore missing or incorrect state symbols in an equation unless these are specifically asked for in the question.
- Mark positively. Give candidates credit for what they have got correct, rather than penalizing them for what they have got wrong.
- If candidates answer a question correctly, but by using a method different from that shown in the markscheme, then award marks; if in doubt consult your Team Leader

SECTION A

1. (a) $C_6H_5OH + 7O_2 \rightarrow 6CO_2 + 3H_2O$; ***[1]***

Ignore state symbols.

(b) $\Delta H_r^{\ominus} = \Sigma \Delta H_f^{\ominus}$ products $- \Sigma \Delta H_f^{\ominus}$ reactants ;

$-3050 = \left(6(-394) + 3(-286) - (\Delta H_f^{\ominus} \text{ phenol} + O)\right)$;

$\Delta H_f^{\ominus}$ phenol $= -172$ kJ mol^{-1} ; ***[3]***

*Award **[3]** for correct final answer.*
Apply –1(U) if appropriate.
*Award **[2 max]** for $\Delta H_f^{\ominus}$ phenol $= +172$ kJ mol^{-1}.*

(c) appropriate conversion of units;

$\Delta G = -172 - 298(-0.385)$;

$= -57.3$ kJ mol^{-1} / $-57\,300$ J mol^{-1} ; ***[3]***

*Award **[3]** for correct final answer.*
Accept answers in range –57.0 to –57.3 kJ mol^{-1}. Accept 3 s.f. only.
Allow ECF from (b).
Apply –1(U) if appropriate.

(d) spontaneous;
since ΔG is negative; ***[2]***
Allow ECF from (c).

(e) reaction becomes less spontaneous;
ΔG becomes less negative / more positive; ***[2]***
Accept a suitable calculation.
Allow ECF from (c).

2. (a) mole ratio $C : H = \frac{85.6}{12.01} : \frac{14.4}{1.01} = 7.13 : 14.3$;
No penalty for using integer atomic masses.

empirical formula is $\underline{CH_2}$; ***[2]***

(b) (i) number of moles of gas $n = \frac{PV}{RT} = \frac{1.01 \times 10^2 \text{kPa } (.399 \text{ dm}^3)}{8.314 \frac{\text{J}}{\text{mol K}} (273 \text{ K})} = 0.178 \text{ mol}$;

$$\frac{\text{mass}}{\text{mol}} = \frac{1.00\text{g}}{.017 \text{ mol}} = 56.3 \text{ (g mol}^{-1}\text{)};$$ ***[2]***

OR

molar mass is the $\frac{\text{mass of the molar volume}}{22.4 \text{ dm}^3}$ at STP;

$= \frac{1.00 \times 22.4}{0.399} = 56.1 \text{ (g mol}^{-1}\text{)}$;

Accept answers in range 56.0 to 56.3.
Accept two, three or four significant figures.
*Award **[2]** for correct final answer*.

(ii) C_4H_8; ***[1]***
No ECF.

(c) carbon monoxide / carbon is produced;
CO is toxic / poisonous / forms carboxyhemoglobin / interferes with oxygen transport in the body;
carbon (soot) is harmful to the respiratory system; ***[2 max]***
*Award **[1]** each for any two*.

3. (a) the <u>particles/molecules</u> of ammonia gas are in rapid/random/constant motion; and will diffuse/spread out / *OWTTE*; ***[2]***

(b) less time;
(the particles/molecules of ammonia gas will have) greater velocity/greater kinetic energy/greater rate of diffusion/move faster; ***[2]***
Do not accept "greater energy". Answer must indicate increased movement.

4. (a) rate $= k[N_2O_5] / k[N_2O_5]^1$; ***[1]***

(b) (i) Rate $\times [N_2O_5]$
One molecule of $[N_2O_5]$; ***[1]***

(ii) Rate $\times [N_2O_5]\,[NO_3]$
But NO_3 comes from N_2O_5 in first step
So:Rate $\times [N_2O_5]^2$ ***[2]***

(c) the time taken for the concentration/amount (of N_2O_5) to decrease to half its original value / *OWTTE*; ***[1]***

(d) it is constant / does not depend on concentration (of reactant); ***[1]***

5. (a) $CH_3CH_2CH_2CH_2C1$;
l-chlorobutane, primary;
Do not accept chlorobutane.

$CH_3CH_2CHClCH_3$;
2-chlorobutane, secondary;
Do not accept chlorobutane.

$(CH_3)_3CCl$;
2-chloro-2-methylpropane, tertiary;

$(CH_3)_2CHCH_2C1$;
1-chloro-2-methylpropane, primary; ***[8]***

*Award **[1]** each for structural formulas. Accept more detailed formulas.*
Penalize missing H atoms once only.

*For names and classifications, award **[4]** for all 8 correct, **[3]** for 6 or 7 correct, **[2]** for 4 or 5 correct, **[1]** for 2 or 3 correct.*
Penalize incorrect punctuation, e.g. commas for hyphens, only once (*i.e. one of the 8 points above*).
*Also, allow the optical isomer of 2-chlorobutane instead of **one** of the above.*

(b) alcohol(s); ***[1]***

(c) (i) tertiary;
unimolecular/first order nucleophilic substitution; ***[2]***

(ii) $RCl \rightarrow R^+ + Cl^-$; ***[1]***
Allow use of tertiary representation.

SECTION B

6. (a) $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$;

Accept correct equation with NH_4OH instead of NH_3.

mol $H_2SO_4 = 0.0201 \times 0.150$;

$2NH_3 = H_2SO_4$ / mol $NH_3 = 6.03 \times 10^{-3}$;

$[NH_3] = 0.241$ (mol dm^{-3}); ***[4]***

Apply –1(SF) if appropriate.

*Award **[3]** for the correct final answer for the concentration calculation.*

(b) bromocresol green;

reaction of weak base and strong acid / *OWTTE*;

pH range of bromocresol green is 3.8 to 5.4 /occurs at pH < 7; ***[3]***

(c) $K_b = 10^{-4.75} = 1.78 \times 10^{-5}$;

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$ / $[OH^-] = \sqrt{K_b[NH_3]}$;

$[OH^-] = \sqrt{1.78 \times 10^{-5} \times 0.121}$;

pOH = 2.83; ***[4]***

*Award **[4]** for the correct final answer.*

Allow ECF, for example any correct conversion of $[OH^-]$ to pOH.

(d) (i) a solution which resists change in pH / changes pH very slightly / keeps pH constant / *OWTTE*;

when <u>small</u> amounts of acid or base are added;

weak acid and its salt / weak acid and its conjugate base; ***[3]***

(ii) mol $NH_3 = 0.0050$ and mol $HCl = 0.0025$;

$[NH_4^+] = [NH_3]$;

$[OH^-] = K_b = 1.78 \times 10^{-5}$;

(pOH = 4.75 so) pH = 9.25 *(allow 9.2 to 9.3)*; ***[4]***

*Award **[4]** for correct final answer.*

Accept other valid methods such as Henderson-Hasselbach equation.

(e) (i) proton donor / *OWTTE*;
suitable equation; ***[2]***

(ii) electron <u>pair</u> acceptor / *OWTTE*;
suitable equation; ***[2]***

(iii) two species whose formulas differ by H^+ / *OWTTE*;
suitable equation;
both acid-base pairs correctly identified; ***[3]***

Examples of suitable equations:

$$\underset{\text{base1}}{NH_3} + \underset{\text{acid2}}{H_2O} \rightarrow \underset{\text{acid1}}{NH_4^+} + \underset{\text{base2}}{OH^-}$$

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

$Cu^{2+} + 4NH_3 \rightarrow Cu(NH_3)_4^{2+}$

$NH_2^- + H_2O \rightarrow NH_3 + OH^-$

$O^{2-} + H_2O \rightarrow 2OH^-$

Each equation must use at least one of the species in the question.
Each equation must be balanced.

7. (a) (i) $W^{3+}Y^{3-}$; ***[2]***

*Award **[1]** for formula and **[1]** for charges.*
*Accept WY, charges W: 3+ Y: 3– for **[2]**.*

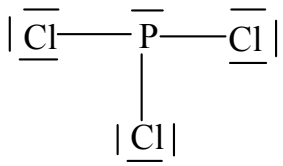
(ii) XZ_2 ; ***[1]***

Accept XZ.
Answers must be in terms of X and Z.

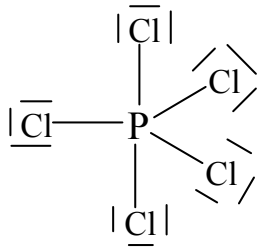
(b) find number of electron pairs/charge centres in (valence shell of) central atom;
electron pairs/charge centres (in valence shell) of central atom repel each other;
to positions of minimum energy/repulsion / maximum stability;
pairs forming a double or triple bond act as a single change centre;
non-bonding pairs repel more than bonding pairs / *OWTTE*; ***[3 max]***
Do not accept repulsion between bonds or atoms.
*Award **[1]** for any three points.*

(c) (i) *Award **[1]** for each correct Lewis structure.*

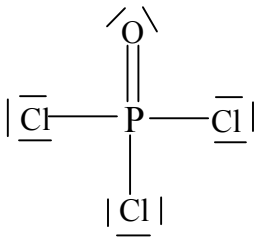
PCl_3



PCl_5

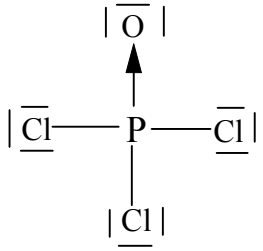


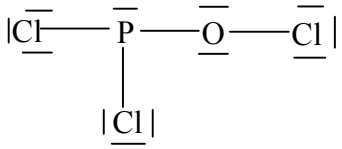
$POCl_3$



[3]

Accept use of dots or crosses to represent electron pairs.
*Subtract **[1]** if non-bonding pair on P in PCl_3 is missing.*
*Subtract **[1]** if non-bonding pair(s) on Cl or O are missing.*
Accept legitimate alternatives for $POCl_3$, e.g. see below.





(ii)

PCl_3	PCl_5	$POCl_3$
trigonal pyramid;	trigonal bipyramid;	tetrahedral;
Accept answers in range 100° to 108°;	90° **and** 120°;	*Accept answers in range* 100° to 112°; ***[6]***

Allow ECF if based on legitimate chemical structure.

(iii)

PCl_3	PCl_5	$POCl_3$
polar, polarities do not cancel / *OWTTE*;	non-polar, polarities cancel / *OWTTE*;	polar, polarities do not cancel / *OWTTE*; ***[3]***

*Award **[2]** for three polarities correct, **[1]** for two polarities correct, and **[1]** for correct reason(s).*
Accept argument based on dipole moments.
Allow ECF if based on legitimate chemical structure.

(d) (i) combining of atomic orbitals to form new orbitals / *OWTTE*; ***[1]***

(ii) σ : overlap of orbitals between nuclei / end-on overlap;

π : overlap above and below line joining nuclei / sideways overlap;

*Award **[1]** if candidate counts bonds (8 σ, 1 π), or describes all three types of bonds* (i.e. *C—H is σ, C—C is σ, C=C is σ and π*).

single bonds longer than double;
double bonds stronger than single;

C of CH_3 is sp^3;
other two C are sp^2; ***[6]***
Accept suitable diagrams.

8. (a) (i) ionization energy increases;
nuclear charge increases / electron is closer to the nucleus / atomic radius decreases; ***[2]***

(ii) Al is lower than expected;
S is lower than expected;
Al – electron removed is in p sub-level / at higher energy than in Mg;
S – electron removed is in an orbital that contains a second electron that repels it / change to half-filled p subshell; ***[4]***
*Award **[1]** if Al and S given without any extra detail.*

(b) (i) metallic bonding in Na and Mg;
more delocalized (*OWTTE*) electrons in Mg / Mg ion is smaller/more positive;
stronger attraction in Mg between positive ions and delocalized electrons; ***[3]***

(ii) Si is macromolecular / a giant molecule / *OWTTE*;
many (covalent) bonds to be broken; ***[2]***
A clear implication of covalent bonding must be made if both marks are to be awarded.

(iii) van der Waals' / weak intermolecular forces / London dispersion forces;
Cl_2 has more electrons / higher M_r than Ar; ***[2]***

(c) (i) NaCl conducts **and** $SiCl_4$ does not;
NaCl ionic **and** $SiCl_4$ covalent;
ions can move in liquid (in NaCl) / *OWTTE*; ***[3]***

(ii) NaCl pH = 7;
salt of strong acid and strong base / Na^+ and Cl^- not hydrolysed;
$SiCl_4$ pH = 0 to 3;
HCl is formed / strong acid formed; ***[4]***

(d) (i) +2 and +3 / Fe^{2+} and Fe^{3+};
both s electrons are lost giving Fe^{2+} **and** one more d electron is also lost to form Fe^{3+}; ***[2]***

(ii) presence of unpaired electrons;
the d orbitals are split into two energy levels;
electrons move between these energy levels;
electrons can absorb energy from light of visible wavelength / *OWTTE*; ***[3]***
*Award **[1]** each for any three.*

9. (a) the removal of hydrogen and oxygen in the (atomic) ratio 2 : 1 / removal of water from a compound / removal of H and OH from neighbouring carbon atoms / *OWTTE*;
Do not accept removal of water.
concentrated sulfuric acid / concentrated phosphoric acid / hot Al_2O_3 / hot ceramic; ***[2]***

(b) $CH_3CH_2CH_2OH$;
$CH_3CH(OH)CH_3$;
1-propanol/propan-1-ol **and** 2-propanol/propan-2-ol;
Names must match formulas.
CH_3CHCH_2;
propene;
Accept more detailed formulas. ***[5]***
*Award **[1]** mark for methoxyethane, structure and name.*

(c) (i) C_3H_6 three peaks;
relative areas 3:2:1;

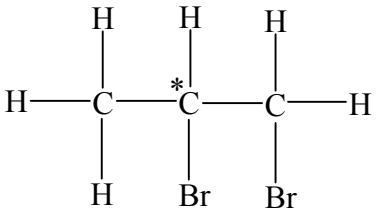
C_3H_7OH four peaks;
relative areas 3:2:2:1;

OR

propan-2-ol three peaks;
relative areas 6:1:1; ***[4]***
*If correct answer seen but no alcohol referred to award **[1]**.*
Ratio implies number of peaks, so this does not have to be stated separately.
Allow ECF from (b).

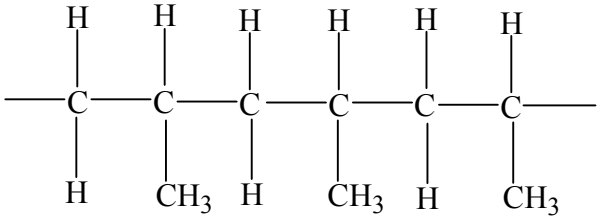
(ii) C_3H_7OH absorption at $3230-3550\,(cm^{-1})$ due to O—H /
at $1000-1300\,(cm^{-1})$ due to C—O;
C_3H_6 absorption at $1610-1680\,(cm^{-1})$ due to C═C; ***[2]***

(d) (i) $C_3H_6 + Br_2 \rightarrow C_3H_6Br_2$;
1,2-dibromopropane;
yellow/orange/brown/red colour of bromine disappears / bromine is decolorised; ***[3]***
Do not allow "goes clear".

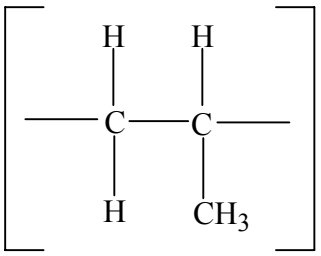
(ii)  / $CH_3C^*HBrCH_2Br$;

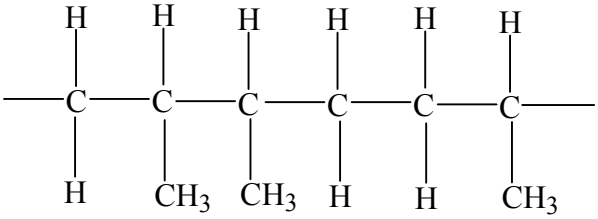
optical activity / enantiomeric forms of the structure / left and right handed forms of the structure / molecule and mirror image not superimposable; ***[2]***

(e) addition polymerization;

 ***[2]***

CH_3 groups can be above or below the horizontal.

Allow  3

Accept  *i.e. "head to head" addition.*

(f) <u>acidified</u> potassium dichromate / <u>acidified</u> sodium dichromate / <u>acidified</u> potassium manganate(VII); *(accept name or formula)*
CH_3CH_2CHO;
CH_3CH_2COOH;
aldehyde: distil product off as formed / limited amount of oxidizing agent / *OWTTE*;
acid: (heat under) reflux / excess oxidizing agent / more concentrated acid; ***[5]***