MARKSCHEME

November 2006

CHEMISTRY

Higher Level

Paper 2

15 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) (i)

C	N	H
$\frac{62.0}{12.01}$/5.16	$\frac{24.1}{14.01}$/1.72	$\frac{13.9}{1.01}$/13.8

*Award **[2]** for above.*
No penalty for use of whole number atomic masses.
If atomic numbers used then only mark for % of H can be awarded.
*If H % and calculation missing, award **[1]**, and last mark cannot be scored.*
If H % calculation incorrect apply ECF.

C_3NH_8; ***[3]***

*Correct empirical formula scores **[3]**.*

(ii) the average mass of a <u>molecule</u>;
compared to $1/12$ of (the mass of) one atom of ^{12}C / compared to C–12 taken as 12;

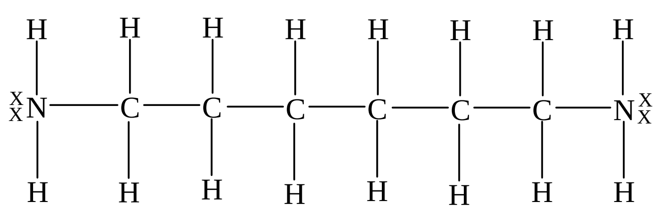
OR

$$\frac{\text{average mass of a molecule}}{\text{mass of } 1/12 \text{ of one atom of } ^{12}C}$$ ***[2]***

*Award **[2]** for the equation above.*

(iii) $C_6N_2H_{16}$; ***[1]***

(b) (i)



[1]

Accept dots or | (dash) instead of xx for lone pairs.
Accept condensed and branched structures provided that two terminal NH_2 groups are shown.
Do not accept answer without lone pairs.

(ii) 107°;
Accept answer in range 105 to 108^o.
lone pair (of electrons) on N repels the (three) bonding pairs (more than they repel each other); ***[2]***
Do not accept lone pair decreases the bond angle or lone pair repels atomes.

2. (a) enthalpy/energy change for the formation of 1 mol of a compound from its elements;
Do not accept ***heat*** *needed to form 1 mol…*
in their standard states / under standard conditions / at 298 K and 1 atm; ***[2]***

(b) greater value / more negative value;
energy given out when steam condenses/turns to water; ***[2]***

(c) $\Delta H^{\ominus} = \sum \Delta H_f^{\ominus}$ (products) $- \sum \Delta H_f^{\ominus}$ (reactants) / suitable cycle;
$= (-28 - 242) - (-201 - 46)$;
$= -23$ kJ / kJ mol^{-1}; ***[3]***
Units needed for 3rd mark.
Correct final answer scores ***[3]****.*
23 or +23 kJ / kJ mol^{-1} *scores* ***[2]****.*
If –239 used instead of –201 for CH_3OH*, award* ***[2]*** *for +15 kJ.*

(d) (i) moles of CH_3OH $(= 2000\times10^3 \div 32.05) = 6.24\times10^4$ (mol) and
moles of NH_3 $(= 2000\times10^3 \div 17.04) = 1.17\times10^5$ (mol);
Accept answers using whole-number A_r *values.*
Accept answers that do not include $\times10^3$.
methanol is limiting reactant; ***[2]***

(ii) M_r of methylamine = 31.07 / 31;
mass $(= 2000\times31.07 \div 32.05) = 1940$ (kg); ***[2]***
Accept answer in range 1930 to 1940.
Units not needed for mark, but penalise incorrect units and answers in g.
Correct final answer scores ***[2]****.*

3. (a) mixing/joining together/combining/merging of atomic orbitals to form molecular orbitals/new orbitals/orbitals of equal energy; ***[1]***
Accept specific example such as mixing of s and p orbitals.

(b) sp;
Do not award mark if sp^2 *or* sp^3 *is also stated.*
one sigma and two pi (bonds); ***[2]***

(c) (σ bond formed by) end-on/axial overlap;
electrons/electron density between the two (carbon) atoms / *OWTTE*;
(π bond formed by) sideways/parallel overlap;
electrons/electron density above and below σ bond / *OWTTE*; ***[4]***
Marks can be scored from a suitable diagram.
Do not award 2nd *and 4*th *marks if electrons are not mentioned.*

4. (a) (i) $C_4H_{10} + Br_2 \rightarrow C_4H_9Br + HBr$;
$CH_3CH_2CH_2CH_2Br$ / $CH_3CHBrCH_2CH_3$; ***[2]***
Accept more detailed formula.

(ii) homolytic;
(free) radical / Br•; ***[2]***

(b) (i) $C_4H_8 + Br_2 \rightarrow C_4H_8Br_2$;
Equation scores ***[1]***.
$CH_3CHBrCHBrCH_3$; ***[2]***
Accept more detailed formula.

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

(c) -360 (kJ mol^{-1}) ;
benzene more stable than structure with (three) double bonds / benzene contains delocalized electrons; ***[2]***
Do not accept delocalized bonds.

5. (a) 12 protons and 13 neutrons and 11 electrons; ***[1]***

(b) electric field / oppositely charged plates / potential difference / *OWTTE*; ***[1]***

(c) $^{25}Mg^{+}$;
greater *m*/*z* value / less highly charged ions need stronger fields to deflect them / *OWTTE*; ***[2]***
Do not accept greater mass with no reference to charge, or greater mass and smaller charge.

SECTION B

6. (a) (i) $MgCl_2$ and $SiCl_4$;
$MgCl_2$ solid and $SiCl_4$ liquid; ***[2]***

(ii) $MgCl_2$ (conducts electricity) when molten/dissolved in water;
$SiCl_4$ does not conduct (under any conditions); ***[2]***

(iii) $MgCl_2$ pH value in range 5.0 to 6.9 / <u>just</u> under 7;
$SiCl_4$ pH value in range 0 to 3;
$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl / SiO_2.2H_2O + 4HCl$; ***[3]***
Do not accept $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$.

(b) (i) Ni^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ / $[Ar]3d^8$; ***[1]***

(ii) species with lone pair of electrons used to bond with the ion;
co-ordinate bond / dative (covalent) bond; ***[2]***

(iii) +2;
+2; ***[2]***
Accept 2+ but not 2 or II.

(iv) d orbitals / sub-levels (in complexes) split (into two sets at different energy levels);

energy difference corresponds to frequency/wavelength of (part of) visible light;
part of visible spectrum absorbed by electrons;
when they move between energy levels; ***[3 max]***
OWTTE for all of the above.
*Award **[1]** each for any two of the last three.*

(v) iron;
$N_2 + 3H_2 \rightleftharpoons 2NH_3$; ***[2]***
No penalty for $\rightarrow$.

(c) (i) (metal ions at) 1 mol dm^{-3} concentration;
25 °C / 298 K; ***[2]***
Do not accept 1 atm pressure.

(ii) $Ni^{2+} + 2e^{-} \rightarrow Ni$;
$Pb \rightarrow Pb^{2+} + 2e^{-}$; ***[2]***
No penalty for using e instead of e^{-}.
No penalty for $\rightleftharpoons$ *instead of* $\rightarrow$.

(iii) 0.15 V;
$10Cl^{-} + 2MnO_4^{-} + 16H^{+} \rightarrow 5Cl_2 + 2Mn^{2+} + 8H_2O$; ***[3]***
Ignore state symbols.
Correct reactants and products = ***[1]***
Correct balancing = ***[1]***

(iv) not sufficiently good oxidizing agent / cell potential would have negative $E^{\ominus}$ value; ***[1]***

7. (a) (i) $CH_3CH_2OCH_2CH_3$;
it is the only one without hydrogen bonding / it has only dipole-dipole attractions; ***[2]***
Do not award mark for statement about absence of double bonds.
Do not accept "has only van der Waals' forces" alone.

(ii) $T(=70+273)=343\,K$;
$V=nRT \div P / V=0.0200\times 8.31\times 343\div 1.10\times 10^5$;
$=5.18\times 10^{-4}\,m^3 / 0.518\,dm^3 / 518\,cm^3$; ***[3]***
Correct final answer with unit scores ***[3]****.*
Apply ECF for incorrect value of temperature.

(iii) C–O; ***[1]***

(iv) $COOH^+$;
$OCH_2CH_3^+$;
$CH_2CH_2OH^+$; ***[3]***
Penalize once for missing charge.

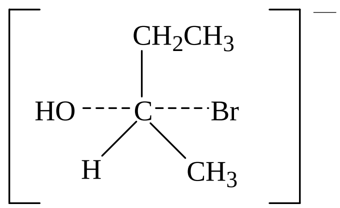
(b) propan-2-ol;
Accept 2-propanol.
oxidation / redox;
(potassium/sodium) dichromate(VI) / potassium manganate(VII);
Accept just dichromate, permanganate, $KMnO_4$, MnO_4^-, $K_2Cr_2O_7$, $Cr_2O_7^{2-}$.
(sulfuric) acid;
heat under <u>reflux</u>; ***[5]***

(c) (the molecule contains a) chiral/asymmetric carbon atom / carbon atom with four different groups;
polarized light passed through;
(plane of polarization) rotated in opposite/different directions; ***[3]***

(d) (i) but-2-ene / $CH_3CHCHCH_3$; ***[1]***
Accept 2-butene.

(ii) 3:2:2:1; ***[1]***
Accept numbers in any order.

(e) (i)



all five groups around C correct;
negative charge and dotted lines to OH and Br correct; **[2]**
Do not award 2nd mark if bond from OH (i.e. OH-----).

(ii) $CH_3CH_2CH(CH_3)Br \rightarrow CH_3CH_2CH(CH_3)^+ + Br^-$;
$CH_3CH_2CH(CH_3)^+ + OH^- \rightarrow CH_3CH_2CH(CH_3)OH$; **[2]**
Accept C_4H_9 instead of $CH_3CH_2CH(CH_3)$ throughout.

(f) decrease;
C–Cl bond stronger (than C–Br); **[2]**

8. (a) $K_c = \frac{[H_2]^3[CO]}{[CH_4][H_2O]}$; ***[1]***

(b) (i) shifts position of equilibrium to the right;
increases value of K_c; ***[2]***

(ii) shifts position of equilibrium to the left;
does not change value of K_c; ***[2]***

(c) (i) CO = 0.4 (mol);
$H_2O = 1.6$ (mol);
K_c $(= 1.6^2 \div 0.4 \times 1.6) = 4.0 / 4$; ***[3]***
Apply ECF from K_c expression.
Ignore units.

(ii) H_2 and CO_2 / products = 1.33 / 1.3 (mol);
CO and H_2O / reactants = 0.67 / 0.7 (mol); ***[2]***
Using $K_c = 9.0$, values for H_2 and CO_2 are 1.5 and values for CO and H_2O are 0.5.

(d) no effect on position of equilibrium;
forward and reverse reactions speeded up equally / affects the rate of reaction but not the extent of the reaction;
no effect on value of K_c;
no change in concentrations of reactants or products / K_c only changes if temperature alters; ***[4]***

(e) (i) pH = 2.8;
$[H^+] = 1.58 \times 10^{-3}$ (mol dm^{-3}); ***[2]***
Apply ECF from pH to $[H^+]$.

(ii) 28 (cm^3); ***[1]***

(iii) nNaOH / CH_3COOH $(= 0.100 \times 0.0280) = 2.80 \times 10^{-3}$ (mol);
ECF from value in (ii).
$[CH_3COOH]$ $(= 2.80 \times 10^{-3} \div 0.025) = 0.112$ (mol dm^{-3}); ***[2]***
ECF from n above.
*Correct final answer scores **[2]**.*

(iv) phenolphthalein / phenol red;
$HIn \rightleftharpoons H^+ + In^-$ **and** HIn and In^- have different colours;
in acid equilibrium shifts to left/to HIn / in alkali equilibrium shifts to right/to In^-; ***[3]***

(f) (i) $pK_a = pH$ at half-neutralization;
$[H^+] = 10^{-pH} / 10^{-4.76} = 1.74 \times 10^{-5}$ (mol dm^{-3}); ***[2]***

(ii) $CH_3COO^- + H^+ \rightarrow CH_3COOH$ / $CH_3COO^- + H_3O^+ \rightarrow CH_3COOH + H_2O$; ***[1]***

9. (a) (i) $2\text{ICl} + \text{H}_2 \rightarrow \text{I}_2 + 2\text{HCl}$; ***[1]***

(ii) *ICl order*
1;
because doubling [ICl] doubles rate (when $[\text{H}_2]$ constant);

H_2 order
2;
because halving $[\text{H}_2]$ quarters rate (when [ICl] constant);
or doubling $[\text{H}_2]$ quadruples rate (when [ICl] constant); ***[4]***

(iii) rate $= k[\text{ICl}][\text{H}_2]^2$; ***[1]***
ECF from (ii).

(iv) $k = 5.00 \times 10^{-3} \div 0.100 \times 0.0500^2 = 20$;
$\text{mol}^{-2}\ \text{dm}^6\ \text{s}^{-1}$; ***[2]***
ECF from (iii).

(v) rate $= 20 \times 0.200 \times 0.100^2 = 4.00 \times 10^{-2}$ $(\text{mol dm}^{-3}\ \text{s}^{-1})$; ***[1]***
ECF from (iii).

(b) (i) $\text{P} + \text{Q} \rightarrow \text{PQ}$ and $\text{PQ} + \text{Q} \rightarrow \text{R}$;
1st step identified as rate-determining; ***[2]***
Accept other symbol such as X instead of PQ.

(ii) 2 / bimolecular; ***[1]***

(c) 4 minutes; ***[1]***

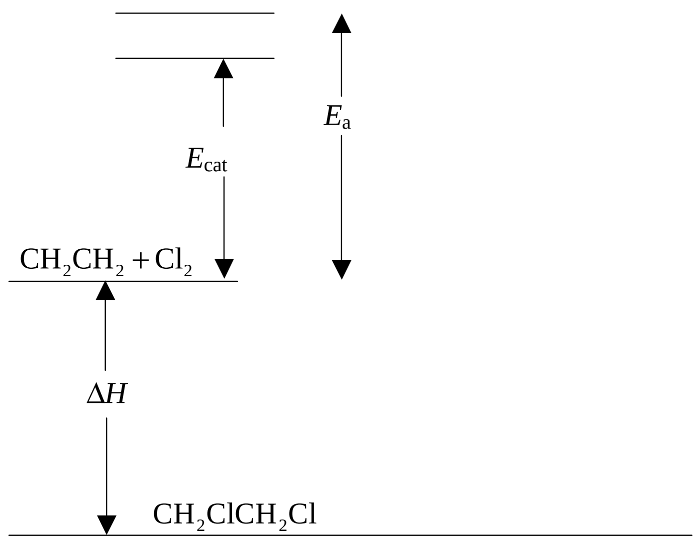
(d) (i) it relates to the geometric requirements of the reaction / orientation of reactants on collision / *OWTTE*; ***[1]***

(ii) minimum energy needed for reactants to react (on collision) / *OWTTE*; ***[1]***

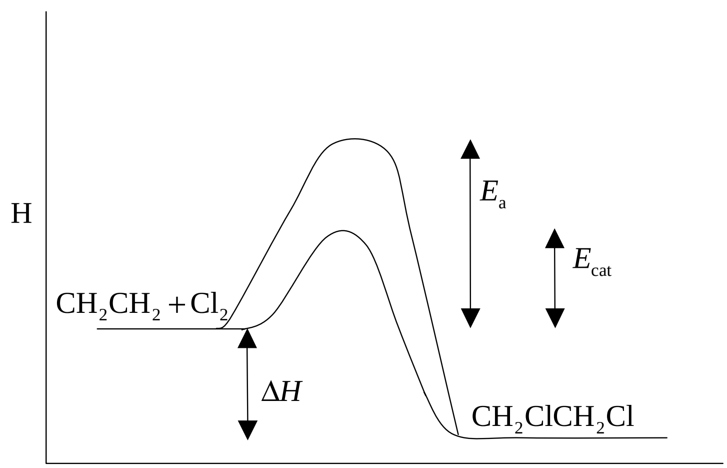
(iii) *k* measured at different values of temperature;
graph plotted of ln *k* against 1/*T*;
intercept on *y*-axis is ln *A*;
$A = e^{\text{intercept}}$;
measured slope of graph $= -E_a / \text{R}$;
$E_a = -\text{R} \times \text{gradient}$; ***[5 max]***
*Award **[1]** each for any five.*

(e) (i) homogeneous catalyst is in same phase as reactants and heterogeneous catalyst is in different phase from reactants; ***[1]***

(ii)



OR



reactants line higher than product line *(labels not needed)*;
ΔH label;
E_a label;
E_{cat} label; ***[4]***