MARKSCHEME

November 2005

CHEMISTRY

Higher Level

Paper 2

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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) time for reactant concentration to halve / *OWTTE*; ***[1]***
Accept "time for mass to halve".

(b) 1000 s;
1000 s;
Accept 900-1100 s. ***[2]***

(c) first order;
constant half-life;
rate = k[A]; ***[3]***
Allow ECF for rate expression from stated order.

(d) $k = \dfrac{\text{rate}}{[\text{D}]^2[\text{E}]} \,/\, \dfrac{3.75\times10^{-5}}{(1.35\times10^{-2})^3}$;
= 15.2;
Accept answer in range 15.2 to 15.3.

$\text{mol}^{-2}\ \text{dm}^6\ \text{min}^{-1}$; ***[3]***

2. (a) (i) ionization, acceleration, deflection/separation; ***[2]***
*Award **[1]** for all three names and **[1]** for correct order.*
*Award **[1]** for two names in correct order.*

(ii) ionization: sample bombarded with high-energy or high-speed electrons/*OWTTE*;
acceleration: electric field/oppositely charged plates;
deflection: (electro)magnet/magnetic field; ***[3]***

(b) (i) average or (weighted) mean of masses of all isotopes of an element;
relative to (one atom of) ^{12}C; ***[2]***
Both marks available from a suitable expression.

(ii) $A_r = (70\times0.2260)+(72\times0.2545)+(74\times0.3673)+(76\times0.1522)$;
= 72.89; ***[2]***
No other final answer acceptable.
*Award **[2]** for correct final answer.*

(c) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$ / $[\text{Ar}]4s^2 3d^{10} 4p^2$; ***[1]***
Do not penalize for interchanging $4s^2$ *and* $3d^{10}$.

(d) (i) (4)p; ***[1]***

(ii) $\text{Ge}^+(g) \rightarrow \text{Ge}^{2+}(g) + e^-$; ***[1]***
Do not penalize for $e^-(g)$.
Accept loss of electron on LHS.

(iii) 5th electron removed from energy level closer to nucleus/5th electron removed from 3rd energy level and 4th electron from 4th energy level/*OWTTE*;
attraction by nucleus or protons greater (for electrons closer to nucleus)/*OWTTE*; ***[2]***

3. (a) sulfur is (simple) molecular;
(contains) covalent bonds/no delocalized electrons/all (outer) electrons used in bonding;
aluminium contains positive ions and delocalized electrons;
(delocalized) electrons move (when voltage applied or current flows); ***[4]***

(b) silicon dioxide is macromolecular/giant covalent;
many/strong covalent bonds must be broken; ***[2]***
*Award max **[1]** if no mention of covalent.*
Do not accept weakened instead of broken.

(c) (i) van der Waals' forces (between molecules);
Accept London or dispersion forces or temporary dipole-dipole attractions.
(these forces are) weak/easily overcome; ***[2]***

(ii) $SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$; ***[1]***
Ignore state symbols, accept $SiO_2.2H_2O$ or H_4SiO_4 as product.

4. (a) $CH_3CH(OH)CH_2CH_3$;
Accept more detailed formula.

butan-2-ol;
Accept 2-butanol.
ECF for correct name of another C_4 alcohol.

contains a chiral/asymmetric carbon atom/four different groups around one carbon atom;
(plane of) plane-polarized light rotated in opposite directions; ***[4]***

(b) $CH_2CHCH_2CH_3/CH_3CHCHCH_3$;
but-1-ene/but-2-ene;
Accept 1-butene or 2-butene, name must match formula.

dehydration/elimination;
bromine (water) decolorized; ***[4]***

SECTION B

5. (a) the enthalpy / energy / heat change for the formation of one mole of a compound / substance from its elements;
in their standard states / under standard conditions / at 298 K and 1 atm;
$\frac{1}{2}H_2(g) + \frac{1}{2}N_2(g) + 1\frac{1}{2}O_2(g) \rightarrow HNO_3(l)$; ***[4]***
*Award **[1]** for correctly balanced equation, **[1]** for all state symbols correct.*
Do not award equation mark if $2HNO_3$ *formed.*

(b) $\Delta H_r = \sum \Delta H_f^\ominus$ (products) $- \sum \Delta H_f^\ominus$ (reactants) / suitable cycle;
$= 3(-394) + 2(-286) - 185$;
*Award **[1]** for correct coefficients of CO_2 and H_2O values , **[1]** for correct value for C_3H_4 from Data Booklet.*

$= -1939$ or -1940 kJ; ***[4]***
Ignore units.
*Award **[4]** for correct final answer.*
*Award **[3]** for +1939 or –1569.*

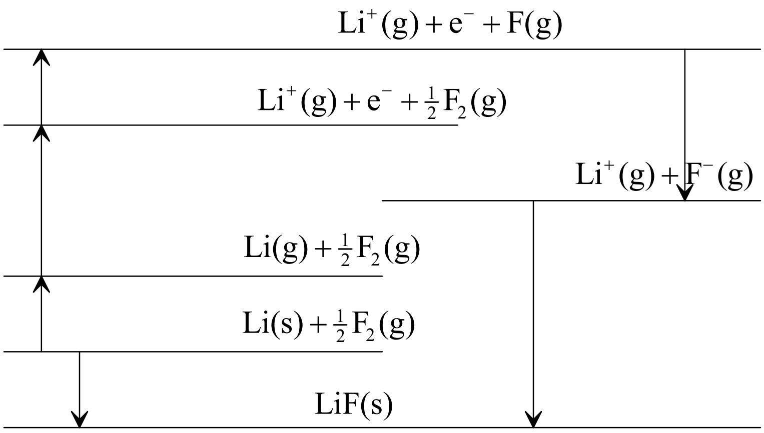
(c) negative;
decrease in disorder / increase in order;
5 mol of <u>gas</u> $\rightarrow$ 3 mol of <u>gas</u> / reduction in number of gas moles; ***[3]***
*Award **[1]** for answer of close to zero based on use of $H_2O(g)$.*

(d) $\Delta S = \sum S^\ominus$ (products) $- \sum S^\ominus$ (reactants) / suitable cycle;
$= 270 - 248 - 2 \times 131$;
$= -240$ (J K^{-1}); ***[3]***
Units not needed for mark, but penalize incorrect units.

*Award **[3]** for correct final answer.*

(e) $\Delta G^\ominus = -287 - (298 \times -0.240)$;
*Award **[1]** for correct substitution of values and **[1]** for conversion of units.*
$= -215$ kJ; ***[3]***
Units needed for mark.
Apply ECF from –360 kJ *or incorrect answer from (d).*

(f)



[6]

*Award **[6]** for completely correct cycle, with endothermic processes in any order. Deduct **[1]** for each line in which species symbol and/or state symbol is incorrect or missing.*
Penalize missing electrons once only.

(g) bonding in AgF more ionic than in AgI / bonding in AgI more covalent than in AgF;
Accept AgF is ionic and AgI is covalent.
values closer / in better agreement in AgF / big(ger) difference in values for AgI / *OWTTE*; ***[2]***

6. (a) (i) no effect;
equal gas moles on each side; ***[2]***

(ii) shift to right;
forward reaction absorbs heat/endothermic/*OWTTE*; ***[2]***

(iii) no effect;
catalyst speeds up both forward and reverse reactions equally; ***[2]***

(b) $K_c = \frac{[H_2][I_2]}{[HI]^2}$; ***[1]***
Ignore state symbols.

(c) (i) *experiment 1* $[HI] = 0.04 \text{ (mol dm}^{-3})$;
$[I_2] = 0.01 \text{ (mol dm}^{-3})$;
$K_c = \frac{(0.01)^2}{(0.04)^2} = 6.25 \times 10^{-2}$;
ECF from above values.

experiment 2 $[H_2] = 0.02 \text{ (mol dm}^{-3})$;
$[I_2] = 0.02 \text{ (mol dm}^{-3})$;
$K_c = \frac{0.02^2}{0.04^2} = 0.25$; ***[6]***
ECF from above values.

(ii) experiment 2 (at higher temperature);
higher K_c value/equilibrium shifted to right; ***[2]***

(d) *Brønsted-Lowry acid*
proton donor/*OWTTE*;
CH_3COOH and H_3O^+;

Lewis base
electron pair donor/*OWTTE*;
H_2O and CH_3COO^-; ***[4]***

(e) bromophenol blue is blue **and** phenol red is yellow;
pH of 4.8 is above range of bromophenol blue/bromphenol blue shows its alkaline colour/*OWTTE*;
pH of 4.8 is below range of phenol red/phenol red shows its acidic colour/*OWTTE*; ***[3]***

(f) $K_a = \dfrac{[CH_3COO^-][H^+]}{[CH_3COOH]}$/rearrangement for $[H^+]$;

$[H^+] = \dfrac{1.74 \times 10^{-5} \times 0.0500}{0.100} = 8.70 \times 10^{-6}$ (mol dm^{-3});

pH ($= -\log[H^+]$) $= 5.06$; ***[3]***

OR

$pH = pK_a + \log \dfrac{[CH_3COO^-]}{[CH_3COOH]}$;

$pH = 4.76 + \log\left(\dfrac{0.10}{0.05}\right)$;

$pH = 5.06$;

Accept answer in range 5.0 to 5.1.

ECF from $[H^+]$.

*Award **[3]** for correct final answer.*

7. (a) *at negative electrode (cathode)*

$Na^{+} + e^{-} \rightarrow Na$;

at positive electrode (anode)

$2Cl^{-} \rightarrow Cl_2 + 2e^{-}$;

If both equations correct but electrodes incorrect or not stated, then deduct ***[1]****.*

electrons flow through the external circuit or wires;

ions gain/lose electrons at electrodes/ions move to electrodes; ***[4]***

(b) 0.2 mol;

the $Na : Cl_2$ mol ratio is 2 : 1/correct reference to equations in (a); ***[2]***

(c) $0.1 \times \frac{1}{2} \times 5$;

= 0.25 mol; ***[2]***

(d) *negative electrode*

hydrogen / H_2;

$2H^{+} + 2e^{-} \rightarrow H_2 / 2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$;

positive electrode

oxygen/O_2;

$4OH^{-} \rightarrow 2H_2O + O_2 + 4e^{-} / 2H_2O \rightarrow O_2 + 4H^{+} + 4e^{-}$; ***[4]***

(e) (i) chlor<u>ine</u>/Cl_2 gains electrons and is reduced;

brom<u>ide</u> (ions)/Br^{-} loses electrons and is oxidized; ***[2]***

Award ***[1]*** *max if no mention of reduced and oxidized.*

(ii) *S in SO_2*

+4;

S in H_2SO_4

+6;

Award only ***[1]*** *for 4+ and 6+ or 4 and 6.*

SO_2 oxidized because oxidation number (of sulfur) increases; ***[3]***

(f) the potential/voltage difference between the element and its ions;
(and) a hydrogen electrode;
under standard conditions/ion concentration at 1 mol dm^{-3}/298 K/25 °C ;
(+)1.23 (V);
$E^{\ominus}$ value more positive or less negative than bromine/bromide system /
$E^{\ominus}$ value of combined half-cells is positive/*OWTTE*;

$2Br^- + \frac{1}{2}O_2 + 2H^+ \rightarrow Br_2 + H_2O$;
*Award **[1]** for all formulas correct, **[1]** for correct balancing.*
*Award **[1]** for correct equation reversed.*

$E^{\ominus}$ (= 1.23 – 1.09) = (+)0.14 (V); ***[8]***
Ignore state symbols.

8. (a) replacement of atom / group (in a molecule) / *OWTTE*;
Do not accept substitution.
by a species with a lone pair of electrons / species attracted to an electron-deficient carbon atom; ***[2]***

(b) correct structure of $(CH_3)_3CBr$;
curly arrow showing C—Br bond fission;
correct structure of $(CH_3)_3C^+$;
curly arrow showing attack by OH^- on correct C atom;
correct structure of $(CH_3)_3COH$; ***[4 max]***
*Award **[1]** each for any four.*

(c) correct structure of $CH_3CH_2CH_2CH_2Br$;
curly arrow showing C—Br bond fission;
correct structure of transition state showing charge and all bonds;
curly arrow showing attack by OH^- on correct C atom;
correct structure of $CH_3CH_2CH_2CH_2OH$; ***[4 max]***
*Award **[1]** each for any four.*

(d) *secondary*
$CH_3CHBrCH_2CH_3$;
2-bromobutane;
other primary
$(CH_3)_2CHCH_2Br$;
1-bromo-2-methylpropane; ***[4]***

(e) C_4H_9OH (has the higher boiling point) because of hydrogen bonding;
C_4H_9Br has weak intermolecular forces/van der Waals' forces; ***[2]***

(f) peaks at 136 and 138 due to (two) isotopes of bromine;
peak at 57 due to $C_4H_9^+$/loss of Br^-;
peak at 42 due to $C_3H_6^+$/(further) loss of CH_3;
tertiary isomer/correct structure of tertiary isomer; ***[4]***
*Penalize once **[-1]** for no charge.*

(g) secondary; ***[1]***

(h) $(CH_3)_3CH$; ***[1]***

(i) $C_4H_{10} + Br_2 \rightarrow C_4H_9Br + HBr$;
bond breaking in which each product takes one electron from the bond/*OWTTE*;
$Br\bullet$ / $C_4H_9\bullet$; ***[3]***