M13/4/CHEMI/HP2/ENG/TZ2/XX/M



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MARKSCHEME

May 2013

CHEMISTRY

Higher Level

Paper 2

24 pages

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-2-

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Subject Details: Chemistry HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer ALL questions in Section A [40 marks] and TWO questions in Section B [2 x 25 marks]. Maximum total = [90 marks].

- 3 -

- 1. A markscheme often has more marking points than the total allows. This is intentional.
- 2. Each marking point has a separate line and the end is shown by means of a semicolon (;).
- **3.** An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.
- 4. Words in brackets () in the markscheme are not necessary to gain the mark.
- 5. Words that are <u>underlined</u> are essential for the mark.
- 6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.
- 7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by *OWTTE* (or words to that effect).
- 8. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
- 9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.
- **10.** Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.
- 11. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the markscheme. Similarly if the formula is specifically asked for, unless directed otherwise in the markscheme, do not award a mark for a correct name.
- **12.** 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 directed otherwise in the markscheme.
- **13.** Ignore missing or incorrect state symbols in an equation unless directed otherwise in the markscheme.

SECTION A

1.	(a)	for h <i>Allo</i> u	emoglobin / myoglobin / transport of oxygen / enzyme / catalase / catalyst; w heme instead of hemoglobin.	[1]
	(b)	systematic (error); Do not accept parallax.		
	(c)	close Allov rand value	eness of agreement of a set of measurements to each other / OWTTE; w reproducibility/consistency of measurement / measurements with small om errors/total amount of random errors/standard deviation / a more precise e contains more significant figures / OWTTE.	[1]
	(d)	pota: botto	ssium permanganate has a very dark/deep (purple) colour so cannot read om of meniscus / <i>OWTTE</i> ;	[1]
	(e)	(i)	gain (of electrons);	[1]
		(ii)	VII / +7; Do not accept 7 or 7+.	[1]
	(f)	(i)	volume = $16.80 (\text{cm}^3) / 18.00 - 1.20 (\text{cm}^3)$; amount $\left(= \frac{16.80 \times 5.00 \times 10^{-3}}{1000} \right) = 8.40 \times 10^{-5} (\text{mol})$; Award [2] for correct final answer.	[2]
		(ii)	$(8.40 \times 10^{-5} \times 5 \times 10) = 4.20 \times 10^{-3} \text{ (mol per 250 cm}^3);$	[1]
		(iii)	$(55.85 \times 4.20 \times 10^{-3}) = 0.235$ (g); Do not penalize if 56 g mol ⁻¹ is used for atomic mass of iron.	[1]
		(iv)	$\left(\frac{0.235 \times 100}{1.65}\right) = 14.2\%;$ No ECF if answer >100 %.	[1]
	(g)	(i)	Chemical formula: MnO ₂ ; Name: manganese(IV) oxide; Allow manganese dioxide. No ECF if formula is incorrect.	[2]
		(ii)	$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g) / H_2O_2(aq) \rightarrow H_2O(l) + \frac{1}{2}O_2(g);$ Ignore state symbols.	[1]
		(iii)	add more (sulphuric) acid/H ₂ SO ₄ / ensure enough (sulphuric) acid/H ₂ SO ₄ is present / <i>OWTTE</i> ; <i>Award</i> [0] <i>if reference made to HCl or HNO</i> ₃ .	[1]

M13/4/CHEMI/HP2/ENG/TZ2/XX/M

[3]

- (h) (i) NO₃⁻ and Cl⁻ anions may also react with KMnO₄ / HNO₃ is an oxidizing agent / (HCl will not work as) Cl⁻ reacts with MnO₄⁻ (to form Cl₂) / HCl oxidized / OWTTE;
 For HCl, allow correctly balanced chemical equation: 2MnO₄⁻ + 10Cl⁻ + 16H⁺ → 2Mn²⁺ + 5Cl₂ + 8H₂O Accept NO₃⁻ and Cl⁻ may react with KMnO₄/Fe²⁺.
 - (ii) $CaCO_{3}(s) + H_{2}SO_{4}(aq) \rightarrow CaSO_{4}(s) + H_{2}O(l) + CO_{2}(g)$ correct chemical equation; correct state symbols; [2] Allow $CaSO_{4}(aq)$ instead of $CaSO_{4}(s)$. M2 can only be scored if M1 is correct. Award [1max] if $H_{2}CO_{3}(aq)$ is given instead of $H_{2}O(l) + CO_{2}(g)$.
- 2. (a) <u>minimum</u> energy needed (by reactants/colliding particles) to react/start/initiate a reaction / for a successful collision;
 [1]

 Allow energy difference between reactants and transition state.
 [1]
 - (b) *k* increases with *T*; [1] Do not accept *k* proportional to *T* or statement of Arrhenius equation from Data booklet.

(c) slope/gradient/
$$m = \frac{-E_a}{R} / -6.20 \times 10^3$$
;
Allow range of m from -5.96×10^3 to -6.44×10^3 .
Award M1 for $m = \frac{-E_a}{R}$ even if gradient is out of range.

 $E_{\rm a} = (6.20 \times 10^3 \times 8.31) = 51.5 \,\rm kJ \, mol^{-1} / 5.15 \times 10^4 \,\rm J \, mol^{-1}$

*E*_a value correct; units correct; *Award* [3] for correct final answer. Allow range of E_a from 49.5 to 53.5 kJ mol⁻¹/4.95×10⁴ to 5.35×10^4 J mol⁻¹. Answer must be given correct to three significant figures. M3 can be scored independently.

- **3.** (a) ester; Do not accept just carbonyl. Allow carboxylato (ligand)/carboxylate (ligand) but not carboxyl/carboxy.
 - (b) dative (covalent) / coordinate; Do not allow just covalent or co-dative.

y

y

(c)

(i)

symmetrical s orbital representation; Do not penalize if axes are not labelled for s orbital. x, y, z can be located in any direction.



x-axis must be labelled for p_x orbital. Do not accept if p_y and p_z are also drawn as question asks for orbital not sub-level.

(d) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 4d^6$;[1]Order of 4s and 3d levels can be interchanged.
Do not accept other notation such as subscripts.[1]



Allow full arrows instead of half-arrows in orbital diagram. Sub-levels must be labelled for mark. [1]

[1]

[1]

[1]

[4]

FT TT

-7-

4.

(a) (i)

$$(K_{\rm c} =) \frac{[{\rm HI}]^2}{[{\rm H}_2][{\rm I}_2]} / \frac{[{\rm HI}]}{[{\rm H}_2]^{\frac{1}{2}}[{\rm I}_2]^{\frac{1}{2}}};$$

Do not award mark if brackets are omitted or incorrect.

(ii) Η, $+I_2$ $\rightarrow 2 HI$ $(7.50 \times 10^{-3} - x)$ $(7.50 \times 10^{-3} - x)$ 2x/ $(1.50 \times 10^{-2} - x)$ $(1.50 \times 10^{-2} - x)$ 2x/ $[H_2]_{initial} - x$ $[I_2]_{initial} - x$ 2x; Accept $[H_2]_{initial} = [I_2]_{initial} = 7.50 \times 10^{-3} (mol \, dm^{-3})$ for M1.

$$53 = \frac{(2x)^2}{(7.50 \times 10^{-3} - x)^2} / \sqrt{53} = \frac{(2x)}{(7.50 \times 10^{-3} - x)};$$

Accept
$$53 = \frac{(2x)^2}{(1.50 \times 10^{-2} - x)^2} / \sqrt{53} = \frac{(2x)}{(1.50 \times 10^{-2} - x)}.$$

$$[H_2] = 1.62 \times 10^{-3} (\text{mol dm}^{-3}) \text{ and } [I_2] = 1.62 \times 10^{-3} (\text{mol dm}^{-3});$$

 $[HI] = 1.18 \times 10^{-2};$
Award [4] for correct final answer for values given in M3 and M4.
Award [2 max] for $[H_2] = [I_2] = 7.50 \times 10^{-3} (\text{mol dm}^{-3})$ and
 $[HI] = 5.46 \times 10^{-2} \text{ mol dm}^{-3}.$

OR

if
$$K_{c} = \frac{[HI]}{[H_{2}]^{\frac{1}{2}}[I_{2}]^{\frac{1}{2}}}$$
 is given in (i).

$$\begin{split} &\frac{1}{2}H_2 & +\frac{1}{2}I_2 & \to HI \\ &(7.50 \times 10^{-3} - x) & (7.50 \times 10^{-3} - x) & 2x / \\ &(1.50 \times 10^{-2} - x) & (1.50 \times 10^{-2} - x) & 2x / \\ &[H_2]_{initial} - x & [I_2]_{initial} - x & 2x; \\ &Accept \ [H_2]_{initial} = [I_2]_{initial} = 7.50 \times 10^{-3} (mol \ dm^{-3}) \ for \ MI. \end{split}$$

$$53 = \frac{(2x)}{(7.50 \times 10^{-3} - x)};$$

Accept
$$53 = \frac{(2x)}{(1.50 \times 10^{-2} - x)}$$

 $[H_2] = 2.73 \times 10^{-4} \text{ mol dm}^{-3} \text{ and } [I_2] = 2.73 \times 10^{-4} \text{ mol dm}^{-3};$ $[HI] = 1.45 \times 10^{-2} \text{ mol dm}^{-3};$ Award [4] for correct final answer for values given in M3 and M4. Award [2 max] for $[H_2] = [I_2] = 7.50 \times 10^{-3} (mol \, dm^{-3})$ and $[HI] = 5.46 \times 10^{-2} \, mol \, dm^{-3}.$

- (b) van der Waals'/London/dispersion **and** dipole-dipole; *Allow abbreviations for van der Waals' as vdW or for London/dispersion as FDL.*
- (c) (i) (CH₃)₂NH;
 (intermolecular) attraction between hydrogen (atom) in O–H/N–H (polar) bond and (lone pair on) <u>electronegative</u> N/O / hydrogen between two very <u>electronegative</u> elements (nitrogen and oxygen) / OWTTE;
 Accept hydrogen bonded to nitrogen which is electronegative/has lone pair.

Do not allow ECF if M1 is incorrect.

(ii) representative drawing showing hydrogen bond between $(CH_3)_2NH$ and H_2O ;



Do not penalize if lone pair as part of hydrogen bond is not shown. Allow any representation of hydrogen bond (for example, dashed lines, dots etc.) which differs from full stick representation of the other covalent bonds in amine and water molecules. Allow full line if labelled as hydrogen bond. Lone pairs on oxygen not necessary. Award mark if two hydrogen bonds drawn between the molecules from the lone pair and the H on the N.

(iii) N-methylmethanamine / methylmethanamine / dimethylamine; Do not accept N–N dimethylamine. [1]

[1]

[2]

[1]

SECTION B

-9-

(a) (i) 2 mol (g) going to 3 mol (g)/increase in number of particles, therefore entropy increases/ΔS positive / OWTTE; [1] Accept if numbers of moles of gas are given below the equation.
(ii) (ΔS^Θ = [(2)(311.7) + (205.0)] - (2)(325.0) =)(+)178.4 (J K⁻¹ mol⁻¹); [1]
(iii) heat/enthalpy change/required/absorbed when 1 mol of a compound is formed from its elements in their standard states/at 100 kPa/10⁵ Pa/1 bar; [1]

Allow 1.01×10^5 Pa / 101 kPa / 1 atm. Allow under standard conditions or standard temperature and pressure. Temperatures not required in definition, allow if quoted (for example, 298 K/25 °C – most common) but pressure value must be correct if stated.

(iv)
$$(\Delta H^{\ominus} = [(2)(-288.1)] - [(2)(-542.2)]) =)(+)508.2 \text{ (kJ mol}^{-1});$$
 [1]

(v)
$$\left(\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} = (508.2) - (298) \left(\frac{178.4}{1000}\right) = \right) (+) 455.0 \, (\text{kJ mol}^{-1});$$
 [1]

(vi)
$$T > \left(\frac{\Delta H^{\odot}}{\Delta S^{\odot}} = \frac{508.2}{\left(\frac{178.4}{1000}\right)} = \right) 2849 \,(\text{K}) / 2576 \,(^{\circ}\text{C});$$
 [1]

Allow temperatures in the range 2848-2855 K. Accept T = 2849 (K). No ECF for temperatures T in the range 0-100 K.

5.

[3]



Lewis (electron dot) Structure	:O: P CI CI CI CI CI CI CI CI CI CI	Crosses or lines to represent in PCl ₃ but penalize missing O or Cl atoms.	
Shape	tetrahedral;	trigonal/triangular pyramidal; Do not allow tetrahedral. Do not allow just pyramidal.	
	Do not allow ECF from Lewis structures with incorrect number of negative charge centres. Only allow shapes based on legitimate structures below.		



allow any bond angle in the range 100° to less than 109° (experimental (ii) value is 100°);

due to four negative charge centres/four electron pairs/four electron domains (one of which is a lone pair)/tetrahedral arrangement of electron pairs/domains;

extra repulsion due to lone pair electrons / lone pairs occupy more space (than bonding pairs) so Cl-P-Cl bond angle decreases from 109.5° / OWTTE;

(iii) $PCl_3(l) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq);$ [1] Ignore state symbols. Do not accept $P(OH)_3$ for H_3PO_3 .

(c) (i)



Allow any combination of dots/crosses or lines to represent electron pairs. Do not penalise missing lone pairs on Cl if already penalised in (b)(i).

- (ii) trigonal/triangular bipyramidal; Do not allow ECF from Lewis structures with incorrect number of negative charge centres.
- (iii) 120° and $90^{\circ}/180^{\circ}$;

(iv)

Ignore other bond angles such as 240° and 360°. Apply list principle if some correct and incorrect angles given.

	Isomer 1	Isomer 2	Isomer 3
Structure	both Br's in axial positions, all Cl's in equatorial positions	both Br's in equatorial positions, two Cl's in axial positions, one Cl in equatorial position	one Br in equatorial position, one Br in axial position, one Cl in axial position and two Cl's in equatorial positions
Molecular polarity	non-polar	polar	polar

Award [1] for correct structure **and** molecular polarity. Award [1 max] for correct representations of all three isomers. Lone pairs not required.

Do not accept colour emitted.

(d) (i) species with lone/non-bonding pair (of electrons); which bonds to metal ion (in complex) / which forms dative (covalent)/coordinate bond to metal ion (in complex); [2]
(ii) unpaired electrons in d orbitals / d sub-level partially occupied; d orbitals split (into two sets of different energies); frequencies of (visible) light absorbed by electrons moving from lower to higher d levels; colour due to remaining frequencies / complementary colour transmitted; [3max] Allow wavelength as well as frequency.

[1]

[1]

[1]

[3]

- 11 -

[2]

[2]

[1]

[1]

[4]

6. (a)
$$[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{(1.00 \times 10^{-14})}{(3.98 \times 10^{-3})} = 2.51 \times 10^{-12} (\text{mol}\,\text{dm}^{-3});$$

 $pH(=-\log[H_3O^+] = -\log(2.51 \times 10^{-12})) = 11.6;$

OR

 $pOH = (-\log (5.98 \times 10^{-3}) =) 2.4;$ pH = (14.00 - 2.40) = 11.6;Award [2] for correct final answer. Allow correct use of H⁺ instead of H₃O⁺ throughout.

(b) (i) *Brønsted-Lowry theory:* proton/H⁺ donor;

Lewis theory: electron <u>pair</u> acceptor;

(ii) *Strong acid:* acid/electrolyte (assumed to be almost) completely/100% dissociated/ionized (in solution/water) / *OWTTE* **and** *Weak acid:* acid/electrolyte partially dissociated/ionized (in solution/water) / *OWTTE*;

Mixture	Buffer
HCOOH and KHCOO	Yes
HCl and excess NH ₃	Yes;

Award [1] for both "yes". Award [0] for any "no".

(ii)
$$K_{a} = \frac{[H_{3}O^{+}][X^{-}]}{[HX]} / [H_{3}O^{+}] = \frac{K_{a}[HX]}{[X^{-}]};$$

 $[H_{3}O^{+}] = \frac{1.40 \times 10^{-4} \times 1.55 \times 10^{-1}}{1.05 \times 10^{-1}};$
 $[H_{3}O^{+}] = 2.07 \times 10^{-4} \pmod{dm^{-3}};$
 $pH(= -\log(2.07 \times 10^{-4})) = 3.68;$

OR

$$pK_{a} = 3.854;$$

$$pH = pK_{a} + \log \frac{[X^{-}]}{[HX]} / pH = pK_{a} - \log \frac{[HX]}{[X^{-}]};$$

$$pH = 3.854 - 0.169;$$

$$pH = 3.68;$$

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

$$Allow correct use of H^{+} instead of H_{3}O^{+} throughout.$$

$$Allow acid for HX, conjugate base/salt for X^{-} throughout.$$

(d)	(i)	$\operatorname{HIn}(\operatorname{aq}) \rightleftharpoons \operatorname{H}^{+}(\operatorname{aq})$	$+ In^{-}(aq) /$	$\operatorname{HIn}(\operatorname{aq}) + \operatorname{H}_2\operatorname{O}(\operatorname{l}) \rightleftharpoons$	$\ln^{-}(aq) + H_{3}O^{+}(aq)$	
		Colour A	Colour B	Colour A	Colour B	
		Allow statement su conjugate base/In ⁻ (Equilibrium sign re Ignore state symbol Allow correspondin for example, BOH	ch as solution of (aq) and undisso (quired. (s. (aq) $\rightleftharpoons B^+(aq) +$	f weak acid with differe ciated acid/HIn(aq) / O an indicator as a weak b OH ⁻ (aq) etc.	ent colours for WTTE. base.	
		in acid/presence of in alkali/base/prese	H^+ equilibrium l nce of OH^- equi	ies to left (so colour A) librium lies to right (so	colour B);	
		colour changes/end	point when [H]	$\ln(aq)] \approx [\ln(aq)];$		[3 max]
	(ii)	phenolphthalein/phenolphthalei	enol red; colour in range	of pH at equivalence	point which is	[2]
		<i>M2 can be scorea i</i> <i>Accept it is a titrati</i>	naepenaently evo on of weak acid	en if indicator is incorre with a strong base for N	<i>12.</i>	
	(iii)	$n(\text{HCl}) \left(= \frac{(150 \times 5.5)}{(100)} \right)$	$\left(\frac{00 \times 10^{-1}}{000}\right) = 7.5$	0×10^{-2} (mol) and		
		$n(\text{NaOH}) \left(= \frac{(300 \times 10^{-3})}{10^{-3}} \right)$	$\left(\frac{(2.03\times10^{-1})}{(1000)}\right) = 0$	$5.09 \times 10^{-2} (mol);$		
		$n(\text{HCl})_{\text{remaining}} (= (7.$	$50-6.09) \times 10^{-2}$	$=1.41\times10^{-2}$ (mol);		
		$[HC1] = (1.41 \times 10^{-2})$)(1000) / (450) =	$3.13 \times 10^{-2} (\text{mol dm}^{-3});$		
		pH = 1.50;	<u> </u>			[4]
		Award [4] for corre	ect final answer.	2		

Award [3max] for $pH = -log(1.41 \times 10^{-2}) = 1.85$.

[4]

(e) (i) $FeCl_3$:

acidic;

Fe³⁺ ion attracts electrons in OH bonds of water ligands releasing H⁺ ions (due to high charge density) / *OWTTE*; Accept suitable equations such as $[Fe(H_2O)_6]^{3+} \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H^+$

- 14 -

/ $[Fe(H_2O)_6]^{3+} + H_2O \Longrightarrow [Fe(H_2O)_5(OH)]^{2+} + H_3O^+$ for M2. Accept equations indicating the formation of $[Fe(H_2O)_4(OH)_2]^+$, $[Fe(H_2O)_3(OH)_3]$, $[Fe(H_2O)_2(OH)_4]^-$. Do not penalize \rightarrow . M2 can only be awarded if M1 correct.

 $CH_3CH_2NH_3NO_3$: acidic; $CH_3CH_2NH_3^+$ is conjugate acid of weak base, $CH_3CH_2NH_2$ so acidic and NO_3^- is conjugate base of strong acid, HNO_3 , so pH-neutral / salt of a weak base and a strong acid / *OWTTE*; *M4 can only be awarded if M3 correct. Do not allow the salt produces a strong acid and weak base in solution.*

(ii) acidic;

 $K_{a}(NH_{4}^{+}) > K_{b}(F^{-}) / pK_{a}(NH_{4}^{+}) < pK_{b}(F^{-});$ (2) M2 can only be awarded if M1 correct but award [1max] for neutral as salt of weak acid and weak base.

[1]

[1]

[3]

[1]

- 7. (a) increase (in oxidation number);
 - (b) (i) $Cu(s) + 2NO_3^{-}(aq) + 4H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l) / Cu(s) + 2HNO_3(aq) + 2H^+(aq) \rightarrow Cu^{2+} + 2NO_2(g) + 2H_2O(l);$ correct reactants and products; fully balanced chemical equation; *Ignore state symbols. M1 can be scored if there are unbalanced electrons in equation. M2 can only be scored if M1 is correct. M2 can be scored if there are balanced electrons on both sides of equation.*

- 15 -

- (ii) Oxidizing agent: NO₃^{-/}nitrate/HNO₃/nitric acid **and** Reducing agent: Cu/ copper;
- (c) (i) Diagram showing gas, solution and solid electrode; *For example*,



1 mol dm⁻³ H⁺(aq) and Pt; Allow 1 mol L^{-1} or 1 M. Allow 1 mol dm⁻³ HCl(aq) or other source of 1 mol dm⁻³ H⁺(aq) ions.

100 kPa/10⁵ Pa/1 bar ($H_2(g)$ pressure) and 298 K / 25 °C; Ignore state symbols throughout. Allow 1.01×10^5 Pa/1 atm.

(ii) potential of reduction half-reaction under standard conditions measured relative to standard hydrogen electrode/SHE / potential under standard conditions relative to standard hydrogen electrode/SHE;
 Instead of standard conditions allow either solute concentration of 1 mol dm⁻³ or 100 kPa/10⁵ Pa/1 bar (pressure) for gases (allow 1 atm). Allow voltage/EMF instead of potential.

[2]

(iii) $\operatorname{Cu}^{2+}(\operatorname{aq}) + \operatorname{H}_{2}(\operatorname{g}) \rightarrow \operatorname{Cu}(\operatorname{s}) + 2\operatorname{H}^{+}(\operatorname{aq})$ reactants and products; fully balanced chemical equation, including state symbols; M2 cannot be scored if M1 is incorrect.

- 16 -

(d) Voltaic cell showing: (i)



Labelled positive electrode (cathode): Cu^{2+}/Cu and negative electrode (anode): $\operatorname{Sn}^{2+}/\operatorname{Sn}$;

Do not penalize if state symbols are not included (since given in question).

voltmeter and salt bridge; Voltmeter can be labelled or drawn as a circle with a V. Allow ammeter/A. Salt bridge can be labelled, represented with drawing connecting the two half-cells, labelled as potassium nitrate or using its chemical formula (for example, KNO₃) etc.

	correct direction of electron movement from Sn to Cu in external circuit;	[3]
(ii)	(+) 0.48 (V);	[1]
(i)	positive;	[1]
(ii)	provides ions (to carry current) / water poor conductor (of electricity); Do not accept electrons instead of ions.	[1]
(iii)	copper reacts so (nonreactive metal such as) Pt used; Accept Ag, Au or any named metal less reactive than copper as electrode. Do not accept Cu reacts with water or graphite as electrode.	[1]
(iv)	Positive electrode (anode): 2H ₂ O(l) \rightarrow O ₂ (g)+4H ⁺ (aq)+4e ⁻ / 4OH ⁻ (aq) \rightarrow O ₂ (g)+2H ₂ O(l)+4e ⁻ ;	
	Negative electrode (cathode): $H^+(aq) + e^- \rightarrow \frac{1}{2}H_2(g) / 4H^+(aq) + 4e^- \rightarrow 2H_2(g) / 2H^+(aq) + 2e^- \rightarrow H_2 / 2H^-(aq) / H^-(aq) / H^-(aq) / H^-(aq) / H^-(aq) + 0H^-$	[2]
	$2 \prod_{2} O(1) + 2 O(1) + 2 O(1) + 2 O(1) + $	[4]

Award [1 max] if M1 and M2 reversed.

(e)

[1]

Ignore state symbols. Allow e instead of e^- . Do not penalize use of equilibrium sign instead of \rightarrow . Accept a multiple of the equations.

(v) $2H_2O(l) \rightarrow 2H_2(g) + O_2(g) / H_2O(l) \rightarrow H_2(g) + \frac{1}{2}O_2(g);$ [1] State symbols required as asked for in question. Do not penalize use of equilibrium sign instead of \rightarrow . Do not accept any multiple of $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2(g) + O_2(g).$



electrolytic cell showing solid electrodes immersed in solution;positive electrode (anode) connected to positive terminal of battery andnegative electrode (cathode) to negative terminal;Allow graphite or metal given in e(iii) as electrodes.

(vii) bubbles /gas produced;Do not accept hydrogen is formed at cathode and oxygen formed at anode.

(f)
$$n(O_2) \left(= \left(\frac{100}{22.4 \times 1000}\right) \right) = 4.46 \times 10^{-3} \text{ (mol)};$$

 $m \left(= (4.46 \times 10^{-3} \times 2 \times 207.19) \right) = 1.85 \text{ (g)};$

OR

$$n(O_2) \left(= \frac{PV}{RT} \right) = 4.45 \times 10^{-3} (mol);$$

$$m \left(= 4.45 \times 10^{-3} \times 2 \times 207.19 \right) = 1.84 (g);$$
[2]

(a)	compounds with same structural formula but different arrangements of atoms in space; Award [1] if correct description of geometric and optical isomers given.	[1]
(b)	1 : sp^2 and 2 : sp^3 ;	[1]
(c)	amine; benzene ring; <i>Allow phenyl (group).</i> <i>Do not allow just benzene.</i>	
	alkene / chloroalkene; chloro; ether / phenyl ether; <i>Ethers not required as per guide but allow if given.</i>	[1 max]
(d)	(i) _H _H	



[2 max]

8.

(ii) *trans*-but-2-ene **and** *cis*-but-2-ene; *Allow trans 2-butene and cis 2-butene. Do not accept just 2-butene or 2-butene.*

> but-1-ene; Allow 1-butene.

(iii) Q: CH₃CHBrCH₂CH₃;
R: CH₃CH(OH)CH₂CH₃;
S: CH₃CHBrCHBrCH₃;
T: CH₃CH(OH)CH₂CH₃; *Condensed or full structural formulas may be given.*

– 19 –

[4]

[2]

(iv) Since secondary bromoalkane could be either $S_N 1$ and $S_N 2$ so allow $S_N 1$ or $S_N 2$ for M1 - M4.

-20 -



curly arrow showing Br leaving; Do not allow arrow originating from C to C–Br bond.

representation of secondary carbocation;

curly arrow going from lone pair/negative charge on O in HO⁻ to C⁺; *Do not allow arrow originating on H in OH*⁻.

formation of $CH_3CH(OH)CH_2CH_3$ and Br^- ; Allow formation of NaBr instead of Br^- .





curly arrow going from lone pair/negative charge on O in HO⁻ to C; *Do not allow curly arrow originating on H in OH*⁻.

curly arrow showing Br leaving;

Accept curly arrow either going from bond between C and Br to Br in 2-bromobutane or in the transition state. Do not allow arrow originating from C to C–Br bond.

[1]

[1]

[1]

representation of transition state showing negative charge, square brackets and partial bonds;

Do not penalize if HO and Br are not at 180° to each other. Do not award M3 if OH—C bond is represented.

formation of CH ₃ CH(OH)CH ₂ CH ₃ and Br ⁻ ;	[4]
Allow formation of NaBr instead of Br^{-} .	

- (v) H₃CCOCH₂CH₃;
 Condensed or full structural formula may be given.
- (vi) butan-2-one;
 Allow 2-butanone or butanone.
 Accept butan-2-one if (v) is incorrect but also apply ECF.

(e) (i) $m_{\rm C} : (1.755 \times 10^{-1} \times 12.01) / (44.01) = 4.790 \times 10^{-2} \text{g}$ and $m_{\rm H} : (7.187 \times 10^{-2} \times 2 \times 1.01) / (18.02) = 8.056 \times 10^{-3} \text{g};$ $m_{\rm O} : (6.234 \times 10^{-2} - 8.056 \times 10^{-3} - 4.790 \times 10^{-2}) = 6.384 \times 10^{-3} \text{g};$ $(n_{\rm C} = 3.988 \times 10^{-3} \text{ and } n_{\rm H} = 2 \times 3.988 \times 10^{-3} \text{ and } n_{\rm O} = 3.988 \times 10^{-3} \text{ hence}$ empirical formula =) $C_{10}H_{20}O$; $(M(C_{10}H_{20}O) = 156.30 \text{ (g mol}^{-1}), \text{ therefore molecular formula =}) C_{10}H_{20}O;$ OR

$$n_{\rm CO_2} = \left(\frac{1.755 \times 10^{-1}}{44.01}\right) = 3.988 \times 10^{-3} \text{ and } n_{\rm H_2O} = \left(\frac{7.187 \times 10^{-1}}{18.02}\right) = 3.988 \times 10^{-3} ;$$

$$m_{\rm O} : (6.234 \times 10^{-2} - 8.056 \times 10^{-3} - 4.790 \times 10^{-2}) = 6.384 \times 10^{-3} \text{ g} ;$$

$$(n_{\rm C} = 3.988 \times 10^{-3} \text{ and } n_{\rm H} = 2 \times 3.988 \times 10^{-3} \text{ and } n_{\rm O} = 3.988 \times 10^{-3} \text{ hence}$$

empirical formula =)C₁₀H₂₀O;

$$\left(M(C_{10}H_{20}O) = 156.30 \text{ (g mol}^{-1}), \text{ therefore molecular formula =}\right)C_{10}H_{20}O;$$

$$\left(M(C_{10}H_{20}O) = 156.30 \text{ (g mol}^{-1}), \text{ therefore molecular formula =}\right)C_{10}H_{20}O;$$

$$\left(M(C_{10}H_{20}O) = 156.30 \text{ (g mol}^{-1}), \text{ therefore molecular formula =}\right)C_{10}H_{20}O;$$

$$\left(M(C_{10}H_{20}O) = 156.30 \text{ (g mol}^{-1}), \text{ therefore molecular formula =}\right)C_{10}H_{20}O;$$

Allow alternative working to be used. Award [3 max] for $C_{10}H_{20}O$ if no working shown.

- (ii) chiral (carbon/centre/atom) / (tetrahedral) carbon surrounded by four different groups; [1]
 Accept chiral compound or chiral molecule.
- (iii) polarimeter **and** (enantiomers) rotate <u>plane</u> of polarized light in (equal and) opposite directions;

(iv) Physical properties:
identical except for rotation of plane polarized light;
Accept "identical" as different optical properties assessed in (iii).
Do not accept similar.
Chemical properties:
identical unless they interact with other optically active/chiral compounds/reagents/solvents / identical with achiral compounds/reagents
/solvents / OWTTE;
Allow different physiological effects/taste.