N14/4/CHEMI/HP2/ENG/TZ0/XX/M

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MARKSCHEME

November 2014

CHEMISTRY

Higher Level

Paper 2

16 pages

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]**.

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 underlined 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) river (water); ***[1]***

(b) $\left(\frac{0.1}{5.1}\times 100 =\right) 2\%$; ***[1]***

(c) recognition that values differ by 2 pH units / calculation of **both** $[H^+]$ values;
(ratio =)$1:100 / \frac{1}{100} / 10^{-2} / 0.01$; ***[2]***
*Award **[2]** for correct final answer.*
*Award **[1 max]** for 100:1/100/10^2.*

(d) $pOH = (14.0 - 4.4 =) 9.6$ / $[H^+] = 4\times 10^{-5}\,(\text{mol dm}^{-3})$;
Accept $[H^+] = 3.98\times 10^{-5}\,(mol\,dm^{-3})$.
$[OH^-] = 3\times 10^{-10}\,(\text{mol dm}^{-3})$; ***[2]***
Accept $2.51\times 10^{-10}\,(mol\,dm^{-3})$.
*Award **[2]** for correct final answer.*

(e) $CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+ / CO_2 + 2H_2O \rightleftharpoons HCO_3^- + H_3O^+ / CO_2 + H_2O \rightleftharpoons H_2CO_3$; ***[1]***
Do not penalize missing reversible arrow.
Do not accept equations with the carbonate ion as a product.

2. (a) (bonds broken) C=C and O–H / $612 + 464 / 1076$;
(bonds formed) C–C and C–H and C–O / $347 + 413 + 358 / 1118$;

OR

(bonds broken) C=C and two O–H and four C–H / $612 + 4(413) + 2(464) / 3192$;
(bonds formed) C–C and five C–H and C–O and O–H / $347 + 5(413) + 358 + 464$ / 3234;

Ignore signs (+ and –) in M1 and M2. These two marks are awarded for recognizing the correct bonds.

enthalpy change = –42 (kJ); ***[3]***
Correct sign is necessary for awarding M3.
*Award **[3]** for the correct final answer.*
Do not penalize candidates using the former Data Booklet bond energy values (348, 412 and 463) (final answer will then be -45(kJ)).

(b) (i) heat/enthalpy change when 1 mol of a compound/substance is formed;
from its elements in their standard states/at $100\,\text{kPa}/10^5\,\text{Pa}$; ***[2]***

Allow $1.01\times10^5\,Pa/101\,kPa/1\,atm$ *as an alternative to 100 kPa/*10^5 *Pa.*
Allow under standard conditions or standard ambient temperature and pressure as an alternative to 100 kPa/10^5 *Pa.*
Allow "energy needed/absorbed" as an alternative to "heat/enthalpy change".
Temperature is not required in definition, allow if quoted (eg, 298K / 25 $^\circ C$*).*

(ii) $(-235)-(52-242)$ / $\Delta H = \Sigma\Delta H_f^\ominus(\text{products}) - \Sigma\Delta H_f^\ominus(\text{reactants})$;
$-45\,(\text{kJ})$; ***[2]***
*Award **[2]** for the correct final answer.*
*Award **[1]** for +45 or 45.*

(c) value in (b)(ii) (is more accurate) as values used in (a) are average values / value in (b)(ii) (is more accurate) as exact bond enthalpy depends on the surroundings of the bond / *OWTTE*; ***[1]***

(d) negative **and** fewer number of moles/molecules (of gas); ***[1]***

3. (a) $87\,(^\circ\text{C})$; ***[1]***
Accept boiling points in the range $86-88\,^\circ C$.

(b) similar shape above current curve / steeper than current curve; ***[1]***
Do not penalize if curves meet at 0 °C.

(c) (i) (intensity of) colour of vapour is constant; ***[1]***
Accept volume/level of liquid is constant.
Allow pressure is constant.

(ii) more (molecules in the) vapour / fewer molecules in the liquid at new equilibrium / *OWTTE*;
molecules have more energy/move faster/collide more frequently at the new temperature / *OWTTE*;
rates of evaporation and condensation are higher at the new temperature;
in both flasks the rates of evaporation and condensation are equal; ***[2 max]***

Accept converse points for the flask at lower temperature for M1, M2 and M3.

4. (a) $P_4O_{10}: \left(\frac{5.00}{283.88} =\right) 0.0176\,(\text{mol})$ **and** $H_2O: \left(\frac{1.50}{18.02} =\right) 0.0832\,(\text{mol})$;

H_2O is the limiting reactant **and** reason related to stoichiometry; ***[2]***

(b) $\frac{0.0832 \times 4}{6} / 0.0555(\text{mol})$;

$(0.0555 \times 98.00 =) 5.44\,\text{g}$; ***[2]***

The unit is needed for M2.
*Award **[2]** for correct final answer.*
Do not penalize slight numerical variations due to premature rounding.

(c) H_3PO_4 is the weaker acid **and** higher pK_a/lower K_a; ***[1]***

(d) $PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(g)$

correct products and balancing;
correct state symbols; ***[2]***
Accept (aq) for HCl or H^+ and Cl^- ions.
M2 can only be awarded if M1 correct.
Allow $PCl_5(s) + H_2O(l) \rightarrow POCl_3(g) + 2HCl(g)$.

5. (a) van der Waals'/vdW/London/dispersion (forces)/LDF / temporary/instantaneous/ induced dipoles; ***[1]***

(b) *Two of the following pairs:*

used as pencil (lead);
layers can flake off/slide off/break off/stick to paper / *OWTTE*;
M2 must contain concept of separation of layers, so do not award mark for phrases like "layers can slide over each other" on their own.

OR

used as carbon fibre / *OWTTE*;
bonding within layer is strong / layers are extensive / layers are strong;

OR

used as electrodes/conductor/in batteries;
has mobile/free/delocalized electrons (between layers) / electricity flows parallel to layers;

OR

used for thermal insulation;
vibrations are not easily passed between layers; ***[4 max]***

Accept other valid uses of graphite along with a suitable explanation.

6. (a) hydroxyl **and** carbonyl; ***[1]***

Accept alcohol as an alternative to hydroxyl and/or ketone as an alternative to carbonyl.
Allow hydroxy, but not hydroxide, as an alternative to hydroxyl.

(b) CH_2O; ***[1]***

(c) $C: \left(\frac{12.01}{30.03} \times 100 = \right) 39.99/40.0\%$

$H: \left(\frac{2.02}{30.03} \times 100 = \right) 6.73/6.7\%$

$O: \left(\frac{16.00}{30.03} \times 100 = \right) 53.28/53.3\%$;; ***[2]***

*Award **[2]** if all three are correct, and **[1]** if two are correct.*
Accept if the third value is obtained by subtracting the other two percentages from 100%.
Do not penalize if integer values of relative atomic masses are used.

7. (a) concentration of products is much higher than the concentration of reactants / reaction nearly/almost goes to completion / position of equilibrium lies very far to the right / *OWTTE*; ***[1]***

*Response must indicate the position of equilibrium is far to the right, but **not** complete conversion.*

(b) (hypothesis is not valid as) equilibrium already nearly goes to completion / *OWTTE*;
(hypothesis is not valid as increase in yield may not be worth) expense of using pure oxygen / *OWTTE*;

(hypothesis is valid as pure oxygen) increases the rate of (the forward) reaction / more SO_3 produced per day/hour;
(hypothesis is valid as pure oxygen) shifts equilibrium to the right/products/SO_3 / increases the equilibrium concentration of SO_3; ***[2 max]***

Award [1 max] if no reference to "hypothesis'.

SECTION B

8. (a) (i) $\left(\frac{(77.44\times 24)+(10.00\times 25)+(12.56\times 26)}{100}\right)$;

24.35; ***[2]***

*Award **[2]** for correct final answer.*
Two decimal places are required for M2.
Do not award any marks for 24.31 without showing method (as the value can be copied from the Data Booklet).

(ii) same atomic radii / 160 pm;
isotopes only differ by number of neutrons/size of nucleus / radius determined by electron shells and number of protons / *OWTTE*; ***[2]***
Accept neutrons do not affect distance of electrons / OWTTE.

(b) (i) decreasing repulsion between electrons / radius decreases as electrons are removed; ***[1]***
Accept increasing positive charge on ion attracts electrons more strongly.

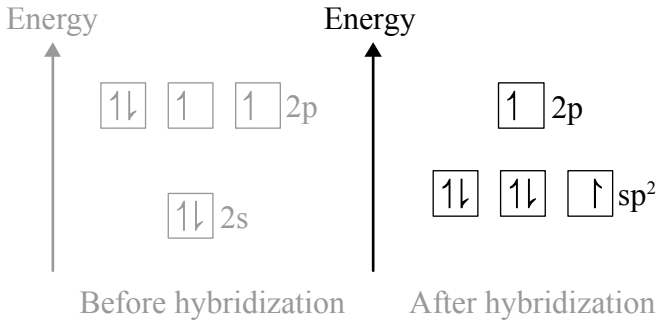
(ii) 10^{th} electron is in second energy level/shell while 11^{th} electron is in first energy level/shell / 10^{th} is removing electron from electronic arrangement 2,1 while 11^{th} ionization energy is removing electron from electronic arrangement 2;
11^{th} electron removed is much closer to the nucleus / 11^{th} electron removed from a (much) lower energy level/shell; ***[2]***
Accept opposite statement for 10^{th} electron.

(c) (i) magnesium (atom) gives two electrons to oxygen (atom) / oxygen (atom) takes two electrons from magnesium (atom) / magnesium (atom) loses two electrons **and** oxygen (atom) gains two electrons;
3-dimensional/3-D arrangement of ions / lattice of ions;
(electrostatic) attraction between oppositely charged ions/Mg^{2+} and O^{2-}; ***[2 max]***

(ii) electrostatic attraction between a pair of electrons and (positively charged) nuclei; ***[1]***
Accept a/two pairs of shared electrons.

(iii) difference in <u>electronegativity</u> is larger between Mg and O/smaller between C and O; ***[1]***
Accept reference to a numerical value of difference in electronegativity such as above and below 1.80.

(d) (i) C: sp hybridization;
O: sp^2 hybridization; ***[2]***
*Award **[1]** if the answer is sp without specifying C or O atoms.*

(ii) 

three sp^2 orbitals **and** one p-orbital at higher energy;
sp^2 orbitals contain: two, two and one electron **and** p-orbital contains one electron; ***[2]***
Do not allow ECF from (d)(i).

(iii) ability of atom/nucleus to attract bonding/shared pair of electrons / attraction of nucleus for bonding/shared pair of electrons / *OWTTE*; ***[1]***

(iv) (same number of shells but) increase in nuclear charge/atomic number/number of protons increases electronegativity / O has more protons than C;
Accept oxygen has a higher effective nuclear charge.
decrease in radius along the period increases electronegativity / O has smaller radius than C; ***[2]***

(e) (i) smooth curve through the data; ***[1]***
*Do not accept a curve that passes through **all** of the points or an answer that joins the points using lines.*

(ii) $p = 21\times10^5 / 2.1\times10^6\,(\text{Pa}) / 2.1\times10^3\,(\text{kPa})$ **and**
$V = 50\times10^{-6} / 5.0\times10^{-5}\,(\text{m}^3) / 5.0\times10^{-2}\,(\text{dm}^3)$;
$\left(n = \frac{pV}{RT} =\right) \frac{2.1\times10^6 \times 5.0\times10^{-5}}{8.31\times330}$;
$n = 0.038\,(\text{mol})$; ***[3]***
*Award **[3]** for correct final answer.*
For M3 apply ECF for correct computation of the equation the student has written, unless more than one mistake is made prior this point.

(f) (i) equilibrium between HIn and In^- / $HIn \rightleftharpoons In^- + H^+$;
the colours of HIn and In^- are different;
if added to acid, the equilibrium shifts to the left and the colour of HIn is seen / *OWTTE*;
if added to base/alkali, the equilibrium shifts to the right and the colour of In^- is seen / *OWTTE*; ***[2 max]***

(ii) phenolphthalein; ***[1]***
Accept phenol red.

9. (a)

Compound	Name
$CH_3CH_2CH(OH)CH_3$	butan-2-ol/2-butanol;
$CH_3CH_2COCH_3$	butanone; *Accept butan-2-one and 2-butanone.*
$CH_3CH_2CH_2OH$	propan-1-ol/1-propanol;
$CH_3CH_2CH_2CHO$	butanal;

[4]

(b) (i) same molecular formula but differ in arrangement of their atoms; ***[1]***
Allow "different structures/structural formulas" instead of "different arrangement of atoms".

(ii) (compounds) 2 and 4 / butanone and butanal; ***[1]***

(c) (i)

Compound	Organic Product
$CH_3CH_2CH(OH)CH_3$	butanone/$CH_3CH_2COCH_3$;
$CH_3CH_2COCH_3$	no reaction;
$CH_3CH_2CH_2OH$	propanoic acid/CH_3CH_2COOH;
$CH_3CH_2CH_2CHO$	butanoic acid/$CH_3CH_2CH_2COOH$;

[4]

(ii) orange to green; ***[1]***

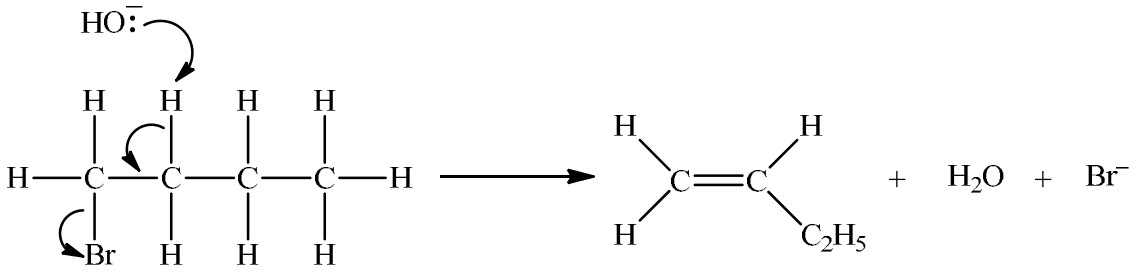
(d)

	Reagent	Product
Stage 1	CN^- / NaCN / KCN / HCN;	$CH_3CH_2CH_2CH_2CN$;
Stage 2	H_2 (with Ni/Pd/Pt catalyst) / $LiAlH_4$;	$CH_3CH_2CH_2CH_2CH_2NH_2$;

[4]

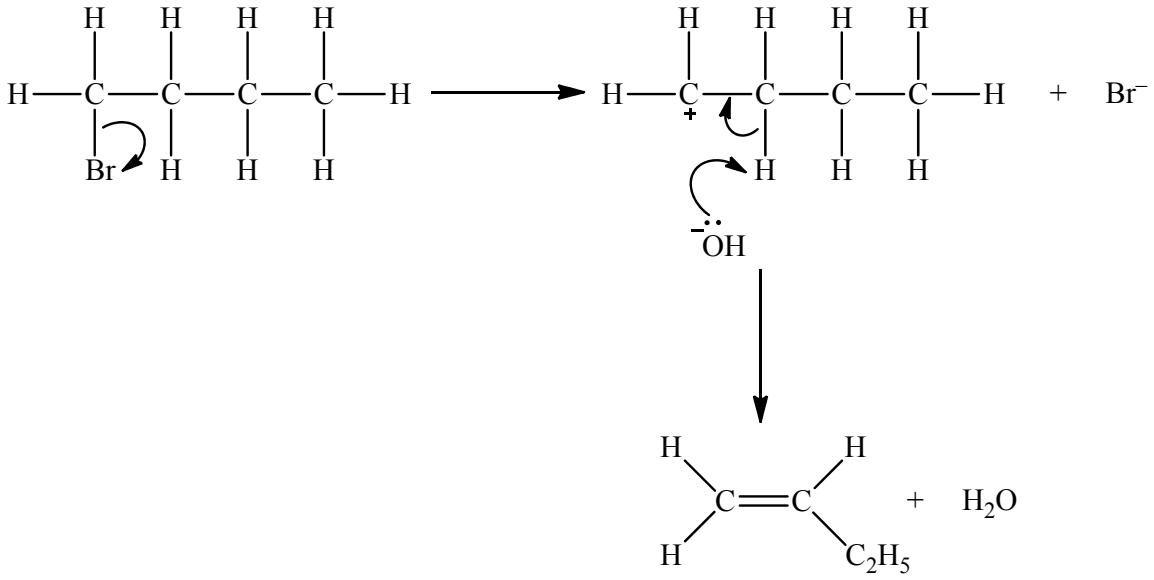
Accept formulas or names of reagents but only structural formulas (condensed or displayed) of products.
Penalize wrong bonding and/or missing hydrogens once only.
Accept other valid reduction reagents for Stage 2 such as hydrides.

(e)



curly arrow going from lone pair/negative charge on O in HO^- to H on β–C;
Do not allow curly arrow originating on H in HO^-.
Accept mechanism with an alkoxide ion (eg RO^- / ethoxide/$CH_3CH_2O^-$) rather than HO^- acting as the base.
curly arrow going from CH bond to form C=C bond;
curly arrow showing Br leaving;
formation of organic product $H_2C{=}CH(C_2H_5)$ **and** H_2O **and** Br^-;
Penalize missing hydrogens or incorrect bond linkages once only.

Allow E_1 mechanism:



curly arrow showing Br leaving;
representation of carbocation;
curly arrow going from lone pair on O in HO^- to H on C adjacent to C^+ **and** curly arrow going from CH bond to form C=C bond;
formation of organic product $H_2C{=}CH(C_2H_5)$ **and** H_2O **and** Br^- (somewhere in mechanism); ***[4]***

(f) (i) $CH_3CH_2CH_2CH_2COOCH_2CH_3$;
ester; ***[2]***

(ii) condensation / addition-elimination; ***[1]***
Accept esterification.

(g) a base is a proton acceptor;
weak means it is only partially ionized/dissociated (in solution/water);
$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$; ***[3]***
Reversible arrow is required for M3.

10. (a) (i) oxidation **and** (iron/Fe) loses electrons/increases in oxidation number/state; ***[1]***

(ii) $O_2(aq) + 4e^- + 2H_2O(l) \rightarrow 4OH^-(aq)$

$\boxed{0}$ $\boxed{I}$ $\boxed{-II}$ $\boxed{-II}$ $\boxed{I}$;; ***[2]***

*Award **[2]** for five correct.*
*Award **[1]** for four correct.*
Accept use of oxidation states (0, +1, –2, –2, +1) for oxidation numbers.
Penalize once for incorrect notation (eg, 2, 2–).

(iii) $O_2(aq) + 2H_2O(l) + 2Fe(s) \rightarrow 2Fe^{2+}(aq) + 4OH^-(aq)$; ***[1]***
Ignore state symbols.

(iv) Fe/iron; ***[1]***

(b) oxygen is non-polar;
needs to break strong hydrogen bonds/H–bonds between water molecules (to dissolve) / oxygen cannot form hydrogen bonds/H–bonds with water;
oxygen can only form (weak) van der Waals'/vdW/LDF/London/dispersion forces with water; ***[2 max]***

(c) groups indicate the number of electrons in the highest energy level/outer/valence shell;
periods indicate the number of (occupied) energy levels/shells (in the atom); ***[2]***

(d) V_2O_5 catalyses oxidation of SO_2 / V_2O_5 is a catalyst in the Contact Process;
Fe catalyses the reaction between N_2 and H_2 / Fe is a catalyst in the Haber Process;
Ni/Pd/Pt catalyses hydrogenation / manufacture of margarine / addition of hydrogen to C=C / conversion of alkenes to alkanes;
Pd/Pt is a catalyst in catalytic converters / Pd/Pt catalyzes reaction of NO_2 and CO/NO_2 and (unburnt) fuel/exhaust gases; ***[2 max]***
Accept other correct examples.
Accept formulas or names of substances.

(e) (i) $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) / 2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$; ***[1]***
$\rightleftharpoons$ *and state symbols are necessary for the mark.*

(ii) $K_W = [H^+][OH^-] / K_W = [H_3O^+][OH^-]$; ***[1]***

(iii) at higher temperatures ionization increases / at higher temperatures equilibrium shifts to right;
ionization is endothermic; ***[2]***
Do not allow ECF for M2.

(iv) $5.13 \times 10^{-13} = [H_3O^+]^2 / [H^+]^2 \ / [H_3O^+] / [H^+] = 7.16 \times 10^{-7}\ (\text{mol dm}^{-3})$;
$pH = 6.14/6.15$; ***[2]***
*Award **[2]** for correct final answer.*

(f) (i) chlorine/Cl_2 (is produced at the positive electrode/anode);
according to electrochemical series/ E° values/ease of oxidation OH^-/H_2O reacts/oxygen is released / *OWTTE* / at low chloride concentration OH^-/H_2O reacts/oxygen is released;
high concentration makes Cl^- oxidize/react in preference to OH^-/H_2O / *OWTTE*; ***[3]***

(ii) *Negative electrode (cathode):*
$2H^+(aq) + 2e^- \rightarrow H_2(g) / H^+(aq) + e^- \rightarrow \frac{1}{2}H_2(g) / 2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$;

Positive electrode (anode):
$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^- / Cl^-(aq) \rightarrow \frac{1}{2}Cl_2(g) + e^- / 2Cl^-(aq) - 2e^- \rightarrow Cl_2(g) /$
$Cl^-(aq) - e^- \rightarrow \frac{1}{2}Cl_2(g)$*;* ***[2]***
Ignore state symbols.

Accept e instead of e^-.
Award ***[1]*** *if half-equations are correct but placed at the wrong electrodes.*

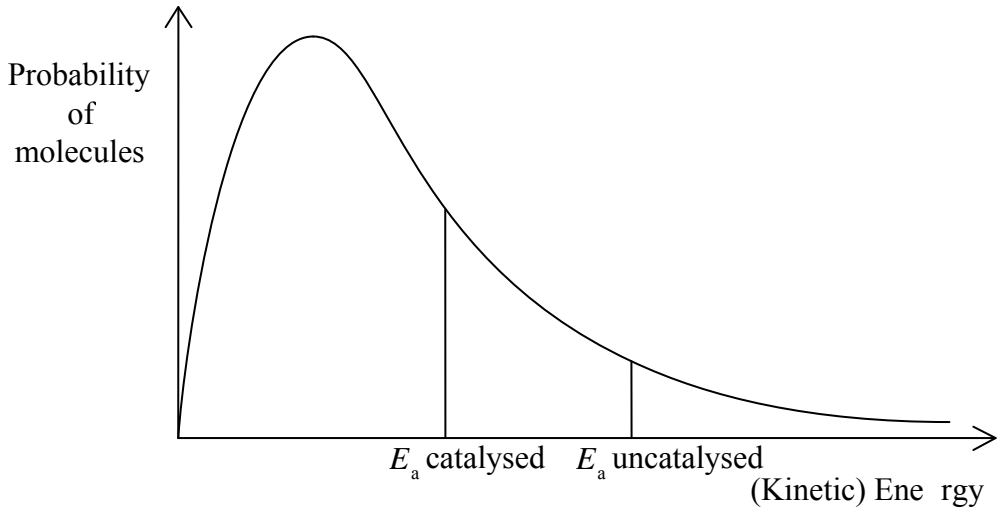
(g) bracelet/object to be electroplated is the cathode/negative electrode;
silver anode/positive electrode;
Accept Pt anode.
Electrolyte: liquid $Na[Ag(CN_2)]$/sodium dicyanoargentate/$[Ag(CN)_2]^-$/ solution of an appropriate silver salt; ***[3]***
Accept $AgNO_3$*/silver nitrate.*
All marks can be scored with a labelled diagram.

11. (a) (i) (draw a) tangent to the curve at origin/time = 0/start of reaction;
(calculate) the gradient/slope (of the tangent); ***[2]***

(ii) rate decreases (with time);
concentration/number of (reactant) molecules per unit volume decreases (with time);
Do not accept "number of molecules decreases" or "amount of reactant decreases".

collisions (between reactant molecules/reactant and catalyst) become less frequent; ***[3]***
Do not accept "fewer collisions" without reference to frequency (eg, no. collisions per second).

(b) *y-axis*: probability / fraction of molecules/particles / probability density
Allow "number of particles/molecules" on y-axis.
and
x-axis: (kinetic) energy;
Accept "speed/velocity" on x-axis.

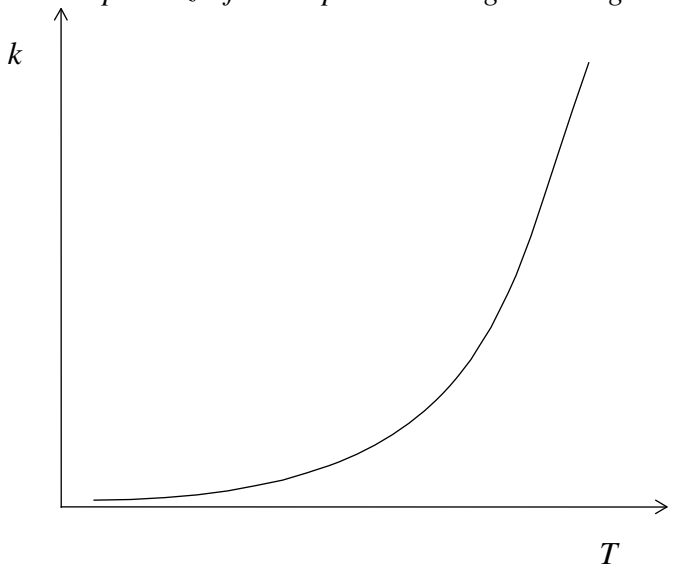


correct relative position of E_a catalysed and E_a uncatalysed;
more/greater proportion of molecules/collisions have the lower/required/catalysed E_a (and can react upon collision); ***[3]***
*M3 can be scored by stating **or** shading and annotating the graph.*
Accept "a greater number/proportion of successful collisions as catalyst reduces E_a".

(c) (i) reactant not involved in (or before) the slowest/rate-determining step/RDS;
reactant is in (large) excess; ***[1 max]***

(ii) $(\text{rate} =) k[\text{A}]$; ***[1]***
Accept rate $= k[A]^1[B]^0$.

(d) curve with a positive slope curving upwards; ***[1]***
Do not penalize if curve passes through the origin.



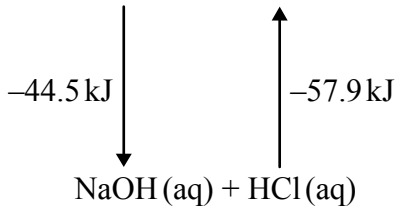
(e) (i) heat transferred/absorbed/released/enthalpy/potential energy change when 1 mol/molar amounts of reactant(s) react (to form products) */ OWTTE*;
under standard conditions / at a pressure 100 kPa/101.3 kPa/1 atm **and** temperature 298 K/25 °C ; ***[2]***
*Award **[2]** for difference between standard enthalpies of products and standard enthalpies of reactants / $H^{\ominus}$ (products) – $H^{\ominus}$ (reactants).*
*Award **[2]** for difference between standard enthalpies of formation of products and standard enthalpies of formation of reactants / $\Sigma\Delta H_f^{\ominus}$ (products) – $\Sigma\Delta H_f^{\ominus}$ (reactants).*

(ii) $(1.00 \times 0.0500 =) 0.0500\,(\text{mol})$;
$(0.0500 \times 57.9 =) 2.90\,(\text{kJ})$; ***[2]***
Ignore any negative sign.
*Award **[2]** for correct final answer.*
*Award **[1 max]** for 2900 J.*

(iii) $\left(\frac{2.50}{40.00} =\right) 0.0625\,(\text{mol NaOH})$;
$0.0500 \times 4.18 \times 13.3 = 2.78\,(\text{kJ}) / 50.0 \times 4.18 \times 13.3 = 2780\,(\text{J})$;
$\left(\frac{2.78}{0.0625}\right) = -44.5\,(\text{kJ mol}^{-1})$; ***[3]***
*Award **[3]** for correct final answer.*
Negative sign is necessary for M3.
Award M2 and M3 if 52.5 g is used to obtain an enthalpy change of –46.7 (kJ mol-1).

(iv) $-44.5 - 57.9$ / correct Hess's Law cycle (as below) / correct manipulation of equations;

$NaOH(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$



$-102.4\,kJ$; ***[2]***

*Award **[2]** for correct final answer.*

(f) (i) zinc (only) forms the ion Zn^{2+} / has the oxidation state +2;
Allow forms only one ion / has only one oxidation state.
has full d-subshell/orbitals / does not have a partially filled d-subshell/orbitals (needed to exhibit transition metal properties); ***[2]***

(ii) Fe^{2+}: $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^6$ /[Ar] $3d^6$ **and** Fe^{3+}: $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^5$ /[Ar] $3d^5$;
half-full sub-level/$3d^5$ has extra stability;
less repulsion between electrons / electrons singly occupy orbitals / electrons do not have to pair with other electrons; ***[3]***
Accept converse points for Fe^{2+}.