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**CHEMISTRY**

**9701/21**

Paper 2 AS Structured Questions

**October/November 2017**

MARK SCHEME

Maximum Mark: 60

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**Published**

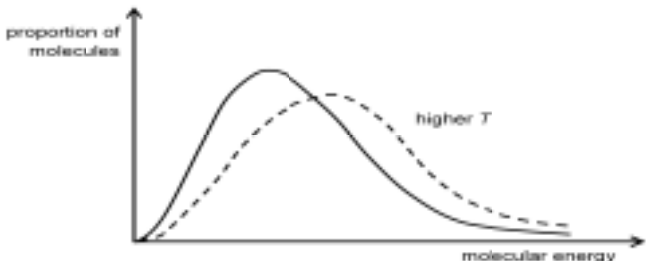
This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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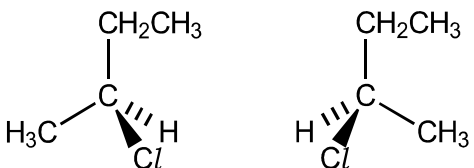
| Question | Answer                                                                                                                                                                                                        | Marks |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1(a)(i)  | energy needed / required to break a mole of (covalent) bonds                                                                                                                                                  | 1     |
|          | (All) in the gaseous state                                                                                                                                                                                    | 1     |
| 1(a)(ii) | $-92 = \{944 + 3(436)\} - 6E(\text{N-H})$                                                                                                                                                                     | 1     |
|          | $E(\text{N-H}) = (+)390.7 / 390.67 / 391$                                                                                                                                                                     | 1     |
| 1(b)(i)  | general shape of the curve and peak are displaced to right of original line and starts at origin                                                                                                              | 1     |
|          | the peak is lower and curve crosses once only finishing <b>above</b> original line                                                                                                                            | 1     |
|          |                                                                                                                              |       |
| 1(b)(ii) | rate increases AND explanation in terms of collisions                                                                                                                                                         | 1     |
|          | (at higher T) area above $E_a$ is greater<br>OR<br>(at higher T) more molecules with $E \geq E_a$                                                                                                             | 1     |
|          | higher frequency of successful collisions<br>OR<br>more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time | 1     |

| Question  | Answer                                                                                                                                                          | Marks |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1(b)(iii) | reduces yield (of ammonia).                                                                                                                                     | 1     |
|           | (increasing $T$ ) shifts equilibrium (reaction) to the left / in the reverse direction / towards $N_2$ and $H_2$ / towards reactants / in endothermic direction | 1     |
|           | to oppose the change OR oppose the increase in temperature OR to absorb the (additional) heat / energy OR decrease the temperature                              | 1     |
| 1(c)(i)   | $N_2 = 0.850$ (mol)                                                                                                                                             | 1     |
|           | $H_2 = 2.55$ (mol)                                                                                                                                              | 1     |
| 1(c)(ii)  | $n_{\text{TOTAL}} = 3.7$ mol                                                                                                                                    | 1     |
|           | mol fraction of $NH_3 = 0.3 / 3.7$                                                                                                                              | 1     |
|           | $p_{NH_3} = 2 \times 10^7 \times (0.3 / 3.7) = 1.62 \times 10^6$                                                                                                | 1     |
| 1(d)(i)   | $K_p = \frac{p_{NH_3}^2}{p_{N_2} \times p_{H_2}^3}$                                                                                                             | 1     |
| 1(d)(ii)  | $K_p = 1.(00) \times 10^{-16}$                                                                                                                                  | 1     |
|           | $Pa^{-2}$                                                                                                                                                       | 1     |
| 1(d)(iii) | (yield of ammonia) increases                                                                                                                                    | 1     |
|           | (value of $K_p$ ) stays the same                                                                                                                                | 1     |

| Question  | Answer                                                                                                                                                                                                                                                                                                                                                                  | Marks |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2(a)(i)   | due to increasing nuclear attraction (for electrons)                                                                                                                                                                                                                                                                                                                    | 1     |
|           | due to increasing nuclear charge / atomic / proton number AND similar shielding / same (outer/number of) shell / energy level                                                                                                                                                                                                                                           | 1     |
| 2(a)(ii)  | Cross shown on first vertical line from the y-axis (Group 0 / Ne) is clearly higher than all shown                                                                                                                                                                                                                                                                      | 1     |
|           | Cross shown on second vertical line from the y-axis (Group 1 / Na) lower than all shown                                                                                                                                                                                                                                                                                 | 1     |
| 2(a)(iii) | Al (the outer / valence) electron (which is lost) is in (3)p sub-shell (Mg is in (3)s subshell)<br>OR<br>Al (the outer / valence) electron (which is lost) is in higher energy sub-shell <span style="float: right;">ora</span>                                                                                                                                         | 1     |
|           | (electron to be removed) is more shielded / experiences greater screening effect <span style="float: right;">ora</span>                                                                                                                                                                                                                                                 | 1     |
|           | S has a pair of electrons in (a) (3)p <u>orbital</u> / (a 3)p <u>orbital</u> is full <b>ora</b>                                                                                                                                                                                                                                                                         | 1     |
|           | electron pair repulsion                                                                                                                                                                                                                                                                                                                                                 | 1     |
| 2(b)(i)   | (L=) $\text{MgCl}_2$ / magnesium chloride                                                                                                                                                                                                                                                                                                                               | 1     |
|           | Any two from<br>(giant) ionic (with strong attractions)<br>$\text{Mg}^{2+}(\text{aq})$ / $\text{Mg}(\text{H}_2\text{O})_6^{2+}(\text{aq})$ is neutral / undergoes (partial) hydrolysis<br>$\text{Mg}(\text{OH})_2$ is the white precipitate / solid / insoluble / partially soluble<br>$\text{MgCl}_2 + 2\text{NaOH} \rightarrow \text{Mg}(\text{OH})_2 + 2\text{NaCl}$ | 2     |
| 2(b)(ii)  | (M=) $\text{SiCl}_4$ / silicon chloride                                                                                                                                                                                                                                                                                                                                 | 1     |
|           | Any two from<br>(simple) molecular / simple covalent<br>hydrolysis possible due to available d orbitals<br>forms $\text{HCl}(\text{aq})$ / hydrochloric acid / solution and / or $\text{HCl}$ gas / fumes<br>white solid is (hydrated) $\text{SiO}_2$<br>$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$                                   | 2     |

| Question | Answer                                                                                                                                                                      |                                                                                                                                                                        |                                                       | Marks |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------|
| 3(a)     | reaction                                                                                                                                                                    | reagent(s) and conditions                                                                                                                                              | reaction type(s)                                      | 6     |
|          | 1                                                                                                                                                                           | aqueous / aq / dilute NaOH / KOH<br>OR water                                                                                                                           | substitution<br>OR hydrolysis                         |       |
|          | 2                                                                                                                                                                           | alcoholic / ethanolic NaOH / KOH                                                                                                                                       | elimination                                           |       |
|          | 3                                                                                                                                                                           | NaCN / KCN in ethanol / alcohol                                                                                                                                        | substitution                                          |       |
|          | 4                                                                                                                                                                           | aqueous / dilute H <sub>2</sub> SO <sub>4</sub> / H <sup>+</sup> (aq)                                                                                                  | hydrolysis OR substitution<br>OR addition-elimination |       |
|          | 5                                                                                                                                                                           | acidified / H <sup>+</sup> (with) K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> / Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup><br>(and distil) NOT reflux              | oxidation OR elimination                              |       |
|          | 6                                                                                                                                                                           | acidified / H <sup>+</sup> K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> / Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup><br>Fehling's / Tollens' / Benedict's (reagent) | oxidation                                             |       |
| 3(b)     | <p>M1 lone pair on O of <sup>-</sup>OH AND curly arrow from lone pair to C(—Br)<br/>M2 correct dipole on C<sup>δ+</sup>—Br<sup>δ-</sup> AND curly arrow from bond to Br</p> |                                                                                                                                                                        |                                                       | 2     |

| Question  | Answer                                                                                                                                                                                                                                                                                     | Marks |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3(c)(i)   | (different molecules) with same molecular formula / same numbers of atoms of (each type) of element                                                                                                                                                                                        | 1     |
|           | different structural formulae / displayed formulae                                                                                                                                                                                                                                         | 1     |
|           | chain / skeletal                                                                                                                                                                                                                                                                           | 2     |
|           | functional group                                                                                                                                                                                                                                                                           |       |
|           | position(al) / regioisomerism                                                                                                                                                                                                                                                              |       |
|           | two types correct = 1 mark, all three correct = 2 marks                                                                                                                                                                                                                                    |       |
| 3(c)(ii)  | S <sub>N</sub> / nucleophilic substitution                                                                                                                                                                                                                                                 | 1     |
|           | ((CH <sub>3</sub> ) <sub>3</sub> CBr / tertiary halogenoalkane) forms a stable (carbo)cation / stable intermediate (as charge density on cation is reduced)<br>OR<br>(in) 1-bromobutane / primary halogenoalkane there is no (stable) (carbo)cation / intermediate formed                  | 1     |
|           | (because) there are (3 /more) alkyl / methyl groups AND (+) I / (greater) inductive effect<br>OR<br>(because) there is only one / fewer alkyl / methyl group(s) (compared to reaction with 2-bromo-2-methyl propane / tertiary halogenoalkane) AND limited (+) I / (less) inductive effect | 1     |
| 3(d)(i)   | (different molecules) with the same (molecular and) structural formula /                                                                                                                                                                                                                   | 1     |
|           | with different arrangements of <u>atoms</u> in space / spatial arrangement of <u>atoms</u>                                                                                                                                                                                                 | 1     |
| 3(d)(ii)  | mirror images are super(im)posable / no chiral carbon / no chiral centre / it is achiral                                                                                                                                                                                                   | 1     |
|           | (one) C of double bond has identical groups / H (atoms) (attached)<br>OR<br>(one) end of double bond has identical groups / 2 H (atoms) (attached)                                                                                                                                         | 1     |
| 3(d)(iii) | <b>X</b> = 2-chlorobutane                                                                                                                                                                                                                                                                  | 1     |
|           | <b>Y</b> = 1-chlorobutane                                                                                                                                                                                                                                                                  | 1     |

| Question | Answer                                                                                                                                                                                                                                                 | Marks |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3(d)(iv) | optical (isomerism)                                                                                                                                                                                                                                    | 1     |
| 3(d)(v)  | one acceptable 3D structure of 2-chlorobutane                                                                                                                                                                                                          | 1     |
|          | <p>the 2nd optical isomer EITHER drawn as a mirror image of the first<br/>OR<br/>the same bond pattern is shown but two of the groups swap positions.</p> <div></div> | 1     |

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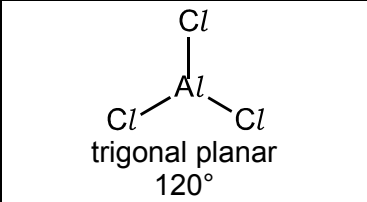
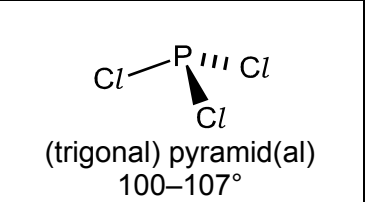
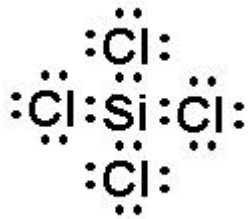
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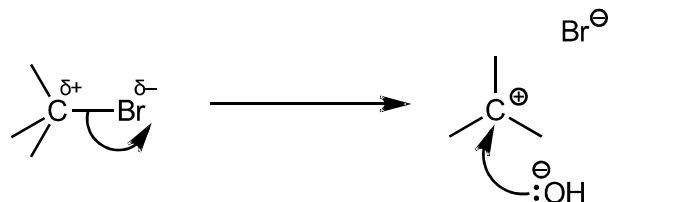
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| Question  | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Marks    |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1(a)      | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>trigonal planar<br/>120°</p> </div> <div style="text-align: center;">  <p>(trigonal) pyramid(al)<br/>100–107°</p> </div> </div> <p>3 marking points for each box: diagram, name and shape.<br/>for each box:<br/>all three correct = 2 marks<br/>two correct = 1 mark</p> | <b>4</b> |
| 1(b)(i)   | SiCl <sub>4</sub> simple / molecular <b>AND</b> Van der Waals' / id-id forces / London / dispersion forces / IMFs                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>1</b> |
|           | NaCl ionic <b>OR</b> giant                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>1</b> |
|           | bonding (in NaCl) stronger (than forces in SiCl <sub>4</sub> ) owtte                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>1</b> |
| 1(b)(ii)  | SiCl <sub>4</sub> has more electrons ORA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>1</b> |
|           | stronger Van der Waals' / id-id forces / London / dispersion forces / IMFs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>1</b> |
| 1(b)(iii) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>1</b> |

| Question  | Answer                                                                                                                | Marks |
|-----------|-----------------------------------------------------------------------------------------------------------------------|-------|
| 2(a)      | -444                                                                                                                  | 1     |
| 2(b)(i)   | (higher rate / rate increases) due to higher frequency of successful collisions                                       | 1     |
|           | more molecules / particles with $E \geq E_a$                                                                          | 1     |
| 2(b)(ii)  | (percentage decomposition of $\text{PCl}_5$ ) increases                                                               | 1     |
|           | (forward) reaction is endothermic                                                                                     | 1     |
| 2(c)      | <u>rates</u> of forward and reverse / backward reactions are equal                                                    | 1     |
|           | closed / sealed system/container                                                                                      | 1     |
| 2(d)(i)   | $n_{\text{TOTAL}} = 1.20 + 0.80 + 0.80$ OR $2.80 \text{ (mol)}$<br><b>OR</b> mole fraction = $1.20 / 2.80$ OR $0.429$ | 1     |
|           | $p\text{PCl}_5 = 1 \times 10^5 \times (1.20 / 2.80) = 4.29 \times 10^4 \text{ (Pa)}$                                  | 1     |
| 2(d)(ii)  | $K_p = \frac{p\text{PCl}_3 \times p\text{Cl}_2}{p\text{PCl}_5}$                                                       | 1     |
| 2(d)(iii) | $1.91 \times 10^4$                                                                                                    | 1     |
|           | Pa                                                                                                                    | 1     |

| Question  | Answer                                                                                                                                                                                                                                            | Marks    |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(a)      | (IE) <u>decreases / lower</u> because increasing <b>distance</b> of outer electron(s) from nucleus<br><b>OR</b> increasing distance of outer / valence shell from nucleus<br><b>OR</b> increased <b>shielding</b> / screening (from inner shells) | <b>1</b> |
|           | reduces nuclear <b>attraction</b> (for electrons)                                                                                                                                                                                                 | <b>1</b> |
| 3(b)(i)   | (Melting point) <u>increases / higher</u> because (molecules have an) increasing (number of) electrons                                                                                                                                            | <b>1</b> |
|           | increasing strength / number / amount of IMFs / Van der Waals' / id-id / London / dispersion (forces)                                                                                                                                             | <b>1</b> |
| 3(b)(ii)  | increased metallic / (cat)ionic radius / size<br><b>OR</b> decreasing (cat)ion charge-density                                                                                                                                                     | <b>1</b> |
|           | decreased attraction (of ions) for delocalised / outer electrons                                                                                                                                                                                  | <b>1</b> |
| 3(c)(i)   | reaction 1: $\text{HNO}_3$ or nitric(V) acid                                                                                                                                                                                                      | <b>1</b> |
|           | reaction 2: water / $\text{H}_2\text{O}$                                                                                                                                                                                                          | <b>1</b> |
| 3(c)(ii)  | barium oxide                                                                                                                                                                                                                                      | <b>1</b> |
|           | $2\text{Ba} + \text{O}_2 \rightarrow 2\text{BaO}$                                                                                                                                                                                                 | <b>1</b> |
| 3(c)(iii) | $\text{NO}_2$ / nitrogen dioxide / nitrogen(IV) oxide <b>AND</b> $\text{O}_2$ / oxygen                                                                                                                                                            | <b>1</b> |
|           | (red / yellow-)brown gas <b>OR</b> gas given off that relights glowing splint                                                                                                                                                                     | <b>1</b> |
| 3(c)(iv)  | <u>white</u> ppt / solid / suspension                                                                                                                                                                                                             | <b>1</b> |
|           | of $\text{BaSO}_4$ / barium sulfate <b>OR</b> $\text{Mg}(\text{OH})_2$ / magnesium hydroxide                                                                                                                                                      | <b>1</b> |
|           | $\text{BaSO}_4$ is insoluble <b>OR</b> $\text{Mg}(\text{OH})_2$ is insoluble / partially / slightly / sparingly soluble                                                                                                                           | <b>1</b> |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                               |                                      | Marks |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------|
| 4(a)     | 1                                                                                                                                                                                                                                                                                                                                                                         | <u>concentrated</u> $\text{H}_2\text{SO}_4$ / $\text{H}_3\text{PO}_4$ <b>AND</b> NaBr<br><b>OR</b> (red) P / $\text{Br}_2$<br><b>OR</b> HBr                                   | substitution                         | 5     |
|          | 2                                                                                                                                                                                                                                                                                                                                                                         | aqueous / dilute NaOH / KOH                                                                                                                                                   | hydrolysis<br><b>OR</b> substitution |       |
|          | 3                                                                                                                                                                                                                                                                                                                                                                         | <u>concentrated</u> $\text{H}_2\text{SO}_4$ / $\text{H}_3\text{PO}_4$<br><b>OR</b> $\text{Al}_2\text{O}_3$ / $\text{P}_4\text{O}_{10}$ / pumice / porous pot / $\text{SiO}_2$ | dehydration                          |       |
|          | 4                                                                                                                                                                                                                                                                                                                                                                         | (ethanolic) HBr                                                                                                                                                               | addition                             |       |
|          | 4 marks for column 1 (one per row)    1 mark for col 2                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                               |                                      |       |
| 4(b)     |  <p>M1<br/>correct dipole on <math>\delta^+\text{C}-\text{Br}^{\delta-}</math> <b>AND</b> curly arrow from C—Br bond to Br</p> <p>M2 correct intermediate with + charge</p> <p>M3 curly arrow from lone pair on <math>:\text{OH}^-</math> to <math>\text{C}^+</math> of carbocation</p> |                                                                                                                                                                               |                                      | 3     |

| Question  | Answer                                                                                                                                                                                                                                                                                                                                                                                         | Marks |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 4(c)(i)   | (different molecules) same molecular formula / same numbers of atoms of each (type of) element                                                                                                                                                                                                                                                                                                 | 1     |
|           | different structural formulae / displayed formulae                                                                                                                                                                                                                                                                                                                                             | 1     |
|           | chain / skeletal<br>functional group<br>position(al) / regioisomerism<br>two types correct = 1 mark, all three correct = 2 marks                                                                                                                                                                                                                                                               | 2     |
| 4(c)(ii)  | S <sub>N</sub> / nucleophilic substitution                                                                                                                                                                                                                                                                                                                                                     | 1     |
|           | no (stable) (carbo)cation / intermediate is formed                                                                                                                                                                                                                                                                                                                                             | 1     |
|           | only one alkyl group / fewer alkyl / methyl groups (compared to reaction 2) <b>AND</b> limited (+)I / inductive effect / less electron donating (effect)                                                                                                                                                                                                                                       | 1     |
| 4(d)(i)   | mirror images are super(im)posable<br><b>OR</b> not chiral / no chirality / no chiral/asymmetric carbon/centre / achiral                                                                                                                                                                                                                                                                       | 1     |
|           | one or both C/end of <b>double bond</b> has identical groups / 2 methyl groups / 2 H (atoms)                                                                                                                                                                                                                                                                                                   | 1     |
| 4(d)(ii)  | addition                                                                                                                                                                                                                                                                                                                                                                                       | 1     |
|           | $  \begin{array}{cc}  \text{H}_3\text{C} & \text{H} \\    &   \\  \text{---C} & \text{---C---} \\    &   \\  \text{H}_3\text{C} & \text{H}  \end{array}  $ marking points: <ul style="list-style-type: none"> <li>• correct number of tetravalent carbon atoms in backbone, with extension bonds</li> <li>• correct groups on backbone carbon atoms <b>and</b> only one repeat unit</li> </ul> | 2     |
| 4(d)(iii) | not/non- biodegradable / harmful combustion products                                                                                                                                                                                                                                                                                                                                           | 1     |

| Question | Answer                  | Marks |
|----------|-------------------------|-------|
| 4(e)     | 2-bromo-2-methylpropane | 1     |
|          | 1-bromo-2-methylpropane | 1     |

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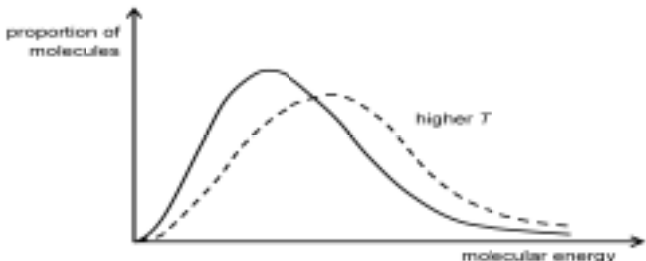
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| Question | Answer                                                                                                                                                                                                        | Marks |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1(a)(i)  | energy needed / required to break a mole of (covalent) bonds                                                                                                                                                  | 1     |
|          | (All) in the gaseous state                                                                                                                                                                                    | 1     |
| 1(a)(ii) | $-92 = \{944 + 3(436)\} - 6E(\text{N-H})$                                                                                                                                                                     | 1     |
|          | $E(\text{N-H}) = (+)390.7 / 390.67 / 391$                                                                                                                                                                     | 1     |
| 1(b)(i)  | general shape of the curve and peak are displaced to right of original line and starts at origin                                                                                                              | 1     |
|          | the peak is lower and curve crosses once only finishing <b>above</b> original line                                                                                                                            | 1     |
|          |                                                                                                                              |       |
| 1(b)(ii) | rate increases AND explanation in terms of collisions                                                                                                                                                         | 1     |
|          | (at higher T) area above $E_a$ is greater<br>OR<br>(at higher T) more molecules with $E \geq E_a$                                                                                                             | 1     |
|          | higher frequency of successful collisions<br>OR<br>more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time | 1     |

| Question  | Answer                                                                                                                                                          | Marks |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1(b)(iii) | reduces yield (of ammonia).                                                                                                                                     | 1     |
|           | (increasing $T$ ) shifts equilibrium (reaction) to the left / in the reverse direction / towards $N_2$ and $H_2$ / towards reactants / in endothermic direction | 1     |
|           | to oppose the change OR oppose the increase in temperature OR to absorb the (additional) heat / energy OR decrease the temperature                              | 1     |
| 1(c)(i)   | $N_2 = 0.850$ (mol)                                                                                                                                             | 1     |
|           | $H_2 = 2.55$ (mol)                                                                                                                                              | 1     |
| 1(c)(ii)  | $n_{\text{TOTAL}} = 3.7$ mol                                                                                                                                    | 1     |
|           | mol fraction of $NH_3 = 0.3 / 3.7$                                                                                                                              | 1     |
|           | $p_{NH_3} = 2 \times 10^7 \times (0.3 / 3.7) = 1.62 \times 10^6$                                                                                                | 1     |
| 1(d)(i)   | $K_p = \frac{p_{NH_3}^2}{p_{N_2} \times p_{H_2}^3}$                                                                                                             | 1     |
| 1(d)(ii)  | $K_p = 1.(00) \times 10^{-16}$                                                                                                                                  | 1     |
|           | $Pa^{-2}$                                                                                                                                                       | 1     |
| 1(d)(iii) | (yield of ammonia) increases                                                                                                                                    | 1     |
|           | (value of $K_p$ ) stays the same                                                                                                                                | 1     |

| Question  | Answer                                                                                                                                                                                                                                                                                                                                                                  | Marks |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2(a)(i)   | due to increasing nuclear attraction (for electrons)                                                                                                                                                                                                                                                                                                                    | 1     |
|           | due to increasing nuclear charge / atomic / proton number AND similar shielding / same (outer/number of) shell / energy level                                                                                                                                                                                                                                           | 1     |
| 2(a)(ii)  | Cross shown on first vertical line from the y-axis (Group 0 / Ne) is clearly higher than all shown                                                                                                                                                                                                                                                                      | 1     |
|           | Cross shown on second vertical line from the y-axis (Group 1 / Na) lower than all shown                                                                                                                                                                                                                                                                                 | 1     |
| 2(a)(iii) | Al (the outer / valence) electron (which is lost) is in (3)p sub-shell (Mg is in (3)s subshell)<br>OR<br>Al (the outer / valence) electron (which is lost) is in higher energy sub-shell ora                                                                                                                                                                            | 1     |
|           | (electron to be removed) is more shielded / experiences greater screening effect ora                                                                                                                                                                                                                                                                                    | 1     |
|           | S has a pair of electrons in (a) (3)p <u>orbital</u> / (a 3)p <u>orbital</u> is full ora                                                                                                                                                                                                                                                                                | 1     |
|           | electron pair repulsion                                                                                                                                                                                                                                                                                                                                                 | 1     |
| 2(b)(i)   | (L=) $\text{MgCl}_2$ / magnesium chloride                                                                                                                                                                                                                                                                                                                               | 1     |
|           | Any two from<br>(giant) ionic (with strong attractions)<br>$\text{Mg}^{2+}(\text{aq})$ / $\text{Mg}(\text{H}_2\text{O})_6^{2+}(\text{aq})$ is neutral / undergoes (partial) hydrolysis<br>$\text{Mg}(\text{OH})_2$ is the white precipitate / solid / insoluble / partially soluble<br>$\text{MgCl}_2 + 2\text{NaOH} \rightarrow \text{Mg}(\text{OH})_2 + 2\text{NaCl}$ | 2     |
| 2(b)(ii)  | (M=) $\text{SiCl}_4$ / silicon chloride                                                                                                                                                                                                                                                                                                                                 | 1     |
|           | Any two from<br>(simple) molecular / simple covalent<br>hydrolysis possible due to available d orbitals<br>forms $\text{HCl}(\text{aq})$ / hydrochloric acid / solution and / or $\text{HCl}$ gas / fumes<br>white solid is (hydrated) $\text{SiO}_2$<br>$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$                                   | 2     |

| Question | Answer                                                                                                                                                                      |                                                                                                                                                                        |                                                       | Marks |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------|
| 3(a)     | reaction                                                                                                                                                                    | reagent(s) and conditions                                                                                                                                              | reaction type(s)                                      | 6     |
|          | 1                                                                                                                                                                           | aqueous / aq / dilute NaOH / KOH<br>OR water                                                                                                                           | substitution<br>OR hydrolysis                         |       |
|          | 2                                                                                                                                                                           | alcoholic / ethanolic NaOH / KOH                                                                                                                                       | elimination                                           |       |
|          | 3                                                                                                                                                                           | NaCN / KCN in ethanol / alcohol                                                                                                                                        | substitution                                          |       |
|          | 4                                                                                                                                                                           | aqueous / dilute H <sub>2</sub> SO <sub>4</sub> / H <sup>+</sup> (aq)                                                                                                  | hydrolysis OR substitution<br>OR addition-elimination |       |
|          | 5                                                                                                                                                                           | acidified / H <sup>+</sup> (with) K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> / Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup><br>(and distil) NOT reflux              | oxidation OR elimination                              |       |
|          | 6                                                                                                                                                                           | acidified / H <sup>+</sup> K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> / Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup><br>Fehling's / Tollens' / Benedict's (reagent) | oxidation                                             |       |
| 3(b)     | <p>M1 lone pair on O of <sup>-</sup>OH AND curly arrow from lone pair to C(—Br)<br/>M2 correct dipole on C<sup>δ+</sup>—Br<sup>δ-</sup> AND curly arrow from bond to Br</p> |                                                                                                                                                                        |                                                       | 2     |

| Question  | Answer                                                                                                                                                                                                                                                                                     | Marks |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3(c)(i)   | (different molecules) with same molecular formula / same numbers of atoms of (each type) of element                                                                                                                                                                                        | 1     |
|           | different structural formulae / displayed formulae                                                                                                                                                                                                                                         | 1     |
|           | chain / skeletal                                                                                                                                                                                                                                                                           | 2     |
|           | functional group                                                                                                                                                                                                                                                                           |       |
|           | position(al) / regioisomerism                                                                                                                                                                                                                                                              |       |
|           | two types correct = 1 mark, all three correct = 2 marks                                                                                                                                                                                                                                    |       |
| 3(c)(ii)  | S <sub>N</sub> / nucleophilic substitution                                                                                                                                                                                                                                                 | 1     |
|           | ((CH <sub>3</sub> ) <sub>3</sub> CBr / tertiary halogenoalkane) forms a stable (carbo)cation / stable intermediate (as charge density on cation is reduced)<br>OR<br>(in) 1-bromobutane / primary halogenoalkane there is no (stable) (carbo)cation / intermediate formed                  | 1     |
|           | (because) there are (3 /more) alkyl / methyl groups AND (+) I / (greater) inductive effect<br>OR<br>(because) there is only one / fewer alkyl / methyl group(s) (compared to reaction with 2-bromo-2-methyl propane / tertiary halogenoalkane) AND limited (+) I / (less) inductive effect | 1     |
| 3(d)(i)   | (different molecules) with the same (molecular and) structural formula /                                                                                                                                                                                                                   | 1     |
|           | with different arrangements of <u>atoms</u> in space / spatial arrangement of <u>atoms</u>                                                                                                                                                                                                 | 1     |
| 3(d)(ii)  | mirror images are super(im)posable / no chiral carbon / no chiral centre / it is achiral                                                                                                                                                                                                   | 1     |
|           | (one) C of double bond has identical groups / H (atoms) (attached)<br>OR<br>(one) end of double bond has identical groups / 2 H (atoms) (attached)                                                                                                                                         | 1     |
| 3(d)(iii) | <b>X</b> = 2-chlorobutane                                                                                                                                                                                                                                                                  | 1     |
|           | <b>Y</b> = 1-chlorobutane                                                                                                                                                                                                                                                                  | 1     |

| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks    |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(d)(iv) | optical (isomerism)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>1</b> |
| 3(d)(v)  | one acceptable 3D structure of 2-chlorobutane                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>1</b> |
|          | <p>the 2nd optical isomer EITHER drawn as a mirror image of the first<br/>OR<br/>the same bond pattern is shown but two of the groups swap positions.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <math display="block">  \begin{array}{c}  \text{CH}_2\text{CH}_3 \\    \\  \text{H}_3\text{C}-\text{C} \\  \diagup \quad \diagdown \\  \text{H} \quad \text{Cl}  \end{array}  </math> </div> <div style="text-align: center;"> <math display="block">  \begin{array}{c}  \text{CH}_2\text{CH}_3 \\    \\  \text{H}-\text{C} \\  \diagup \quad \diagdown \\  \text{Cl} \quad \text{CH}_3  \end{array}  </math> </div> </div> | <b>1</b> |