**Assessment Schedule – 2019**

**Chemistry: Demonstrate understanding of bonding, structure, properties and energy changes (91164)**

**Evidence Statement**

<table>
<thead>
<tr>
<th>Q</th>
<th>Evidence</th>
<th>Achievement</th>
<th>Merit</th>
<th>Excellence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ONE (a)</strong></td>
<td>Na(s) (sodium)</td>
<td><strong>Solid</strong> metal / metallic</td>
<td><strong>Type of particle</strong> atoms / cations (or metal nuclei) in sea of delocalised electrons</td>
<td><strong>Attractive forces between particles</strong> metallic bond</td>
</tr>
<tr>
<td></td>
<td>NaI(s) (sodium iodide)</td>
<td><strong>Solid</strong> ionic</td>
<td><strong>Type of particle</strong> ions</td>
<td><strong>Attractive forces between particles</strong> ionic bond / electrostatic attraction between (oppositely charged) ions</td>
</tr>
<tr>
<td></td>
<td>I(s) (iodine)</td>
<td><strong>Solid</strong> (covalent) molecular</td>
<td><strong>Type of particle</strong> molecules</td>
<td><strong>Attractive forces between particles</strong> (weak) intermolecular (forces)</td>
</tr>
<tr>
<td><strong>(b)</strong></td>
<td>Sodium is a metallic solid made up of atoms in 3D lattice held together by non-directional metallic bonds (or cations non-directionally electrostatically attracted to a surrounding sea of electrons). When a force (or pressure) is applied, the atoms / layers can move without breaking / disrupting these non-directional bonds; thus the structure can change shape. Sodium is not malleable because if pressure is applied to an ionic lattice, it forces ions with the same charge next to each other; they repel each other and break the structure.</td>
<td><strong>Achievement</strong> Two rows or two columns correct.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NaI is made up of alternating positive ions / Na$^+$ ions, and negative ions / I$^-$ ions, ionically bonded in a 3D lattice. NaI is not malleable because if pressure is applied to an ionic lattice, it forces ions with the same charge next to each other; they repel each other and break the structure.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Achievement</strong> Describes structure of sodium. OR Recognises metallic bonding as non-directional.</td>
<td>Describes malleability and Links this to non-directional metallic bonding of sodium.</td>
<td></td>
<td><strong>Describes brittleness of sodium iodide and links it to directionl ionic bonding / repulsion of like charged ions.</strong></td>
</tr>
</tbody>
</table>
(c) Iodine is a non-polar (covalent) molecular substance made up of I\textsubscript{2} molecules held together by weak intermolecular forces. Iodine is soluble in cyclohexane, but does not easily dissolve in water. For iodine in water, the iodine-water attractions are not strong enough to overcome both the iodine-iodine / solute-solute and the strong water-water / solvent-solvent attractions. For iodine in cyclohexane, the iodine-cyclohexane attractions are strong enough to overcome iodine-iodine / solute-solute and cyclohexane-cyclohexane / solvent-solvent attractions because all attractive forces are similar (nonpolar).

- Recognises I\textsubscript{2} as a non-polar molecule.
- Identifies iodine as (more) soluble in cyclohexane and insoluble/less soluble in water.
- Links attractions (or lack of) of water OR cyclohexane for non-polar iodine to solubility.
- Comprehensively explains iodine’s solubility in cyclohexane and insolubility (low solubility) in water linking polarity, strength of attraction and overcoming / not overcoming existing bonding within the solvent or solid.

(d) The melting of ice is endothermic, as (intermolecular) bonds are being broken as water changes from solid to liquid. This requires energy to be absorbed from the surroundings/the drink. This causes the temperature of the drink to decrease.

- Identifies the melting of ice is endothermic / absorbs or requires energy / breaks bonds.
- Links bond breaking to energy being absorbed from the surroundings / drink / environment.
- Full explanation that links to the cooling of the drink.

<table>
<thead>
<tr>
<th>NO</th>
<th>N1</th>
<th>N2</th>
<th>A3</th>
<th>A4</th>
<th>M5</th>
<th>M6</th>
<th>E7</th>
<th>E8</th>
</tr>
</thead>
<tbody>
<tr>
<td>No response; no relevant evidence.</td>
<td>1a</td>
<td>2a</td>
<td>3a</td>
<td>4a</td>
<td>2m</td>
<td>3m</td>
<td>2e with up to one minor error/omission</td>
<td>3e with up to one minor error/omission</td>
</tr>
</tbody>
</table>
### Q (a)(i)

<table>
<thead>
<tr>
<th>Molecule</th>
<th>CH₄</th>
<th>NCl₃</th>
<th>OF₂</th>
</tr>
</thead>
</table>
| Lewis Structure | \[
\begin{array}{c}
\text{H} \\
\text{H} - \text{C} - \text{H} \\
\text{H} \\
\end{array}
\] | \[
\begin{array}{c}
\text{:Cl} \\
\text{N} - \text{Cl} : \\
\text{:Cl} \\
\end{array}
\] | \[
\begin{array}{c}
\text{O} \\
\text{F} \\
\text{F} \\
\end{array}
\] |
| Name of Shape | tetrahedral | trigonal pyramidal | bent / v-shaped / angular |

Bond angle is determined by the number of electron density regions around the central atom, which are arranged into a position to minimise repulsion by having maximum separation.

All molecules have 4 electron density regions / areas of negative charge around the central atom which arrange with maximum separation into a tetrahedral shape / geometry with a bond angle of (approx.) 109.5° / 109°.

In CH₄ all of the electron pairs are bonded, and so the shape of the molecule is also tetrahedral.

In NCl₃ three of the electron pairs are bonded and one is non-bonding. The observed shape of the molecule is trigonal pyramidal.

In OF₂, due to the presence of two non-bonding pairs of electrons / regions (or two bonding regions) on the central atom, OF₂ has an observed shape that is bent / v-shaped / angular.

### Evidence

- Identifies the 4 regions of negative charge for each molecule.
- Links number of areas of negative charge (including bonding / nonbonding) around the central atom to the shape of TWO molecules using minimise repulsion / maximum separation.
- Identifies bonded atoms have different electronegativity (values).
- Links bond polarity to electronegativity differences between bonded atoms for all bonds in one molecule.

### Achievement

- Two Lewis structures correct. OR Two shapes correct.
- Identifies the 4 regions of negative charge for each molecule.
- Recognises that electrons density regions are arranged in a position of maximum separation / minimal repulsion.
- Two shapes correct.
- Links four regions on the central atom for two or more molecules to a bond angle of 109.5° using minimise repulsion / maximum separation.

### Merit

- Links bond polarity to electronegativity differences between bonded atoms for all bonds in one molecule.

### Excellence

- Justifies the shape of all molecules by referring to all factors that influence shape and bond angle.

### Q (b)(i)

CHCl₃ is polar.

NH₃ is polar.

In CHCl₃, there are two types of bond, C–H and C–Cl, each polar, due to the difference in electronegativity between C and H and C and Cl atoms. These dipoles have different polarities / sizes as H and Cl have different electronegativities. (Despite the tetrahedral arrangement appearing symmetrical) the different (sized) bond dipoles do not cancel each other out, so CHCl₃ is polar.

In NH₃, the three N–H bonds are polar, i.e. have a dipole, due to the difference in electronegativity between N and H atoms. These (equally sized) dipoles are arranged in a non-symmetrical trigonal pyramidal shape, resulting in the bond dipoles not cancelling each other out, so NH₃ is polar.

- Identifies polarity of both molecules.
- Identifies bonded atoms have different electronegativity (values).
- Identifies polarity of both molecules by referring to differences in electronegativity, dipoles, and non-symmetrical arrangement of NH₃ dipoles.

- Links bond polarity to electronegativity differences between bonded atoms for all bonds in one molecule.
- Uses lack of symmetry for NH₃ OR differing bond dipoles for CHCl₃ to link molecule polarity to dipoles not cancelling in one molecule.
### (c) Bond breaking
\[
\begin{align*}
2 \times C \rightarrow C &= 348 \times 2 = 696 \\
8 \times C \rightarrow H &= 413 \times 8 = 3304 \\
5 \times O = O &= 495 \times 5 = 2475 \\
\text{Total} &= 6475 \\
\end{align*}
\]

### Bond making
\[
\begin{align*}
8 \times O \rightarrow H &= 463 \times 8 = 3704 \\
6 \times C = O &= 6x \\
\Delta H &= \Sigma \text{Bond energies (bonds broken)} - \Sigma \text{Bond energies (bonds formed)} \\
6475 - 3704 - 6x &= -2056 \text{ kJ mol}^{-1} \\
6x &= 2056 + 6475 - 3704 = 4827 \\
x &= 805 \text{ kJ mol}^{-1}
\end{align*}
\]

- Correctly calculates total bonds broken. OR Correctly identifies bonds made in a formula.
- Correct process with minor error / omission.
- Correct answer with unit.

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<td>1a</td>
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<tr>
<td>THREE (a)(i) (ii)</td>
<td>Exothermic as ( \Delta H ) is negative. To be able to conduct electricity, there needs to be mobile/free moving charged particles. Graphite, ( C(s) ), is an extended covalent network solid. Each carbon atom is covalently bonded to 3 other carbon atoms in hexagonal layers. This leaves one delocalised electron per carbon atom that is mobile and able to carry a charge, so graphite conducts electricity. Carbon dioxide is a covalent molecule. The molecules are held together by weak intermolecular forces, so it is a gas at room temperature. There are no free moving ions or electrons in their structure. Therefore, it can’t conduct electricity.</td>
<td>• Correct term with reason in (i). accept energy/heat is lost OR ( \Delta H )/enthalpy change is negative. • Recognises mobile charged particles needed for conductivity. OR Identifies graphite is a covalent network made of atoms and ( \text{CO}_2(g) ) consists of molecules. • Links 2D network/layered covalent network structure of graphite to free moving electrons which conduct electricity OR molecules of ( \text{CO}_2 ) to being uncharged / not having a free moving charged particle and therefore not conducting electricity.</td>
<td>• Links 2D network/layered covalent network structure of graphite to free moving electrons which conduct electricity OR molecules of ( \text{CO}_2 ) to being uncharged / not having a free moving charged particle.</td>
<td>• Justifies the conductivity of graphite and carbon dioxide in terms of structure and bonding providing / not providing free moving charged particles.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(b)(i) (ii) ( n(\text{O}_2(g)) = \frac{1804.5}{1203} = 1.5 \text{ moles} ) ( m = n \times M = 1.5 \times 32 = 48.0 \text{ g} ) ( n = \frac{m}{M} = \frac{100}{40.3} = 2.48 ) Energy = ( \Delta_r H \times n = \frac{-1203}{2} \times 2.48 = -1492.5 \text{ kJ} / -1493 \text{ kJ} ) ( -1490 \text{ kJ} ) (3 sf) (either positive or negative values accepted)</td>
<td>• ONE step of calculation correct. • ONE step of calculation correct.</td>
<td>• Correct answer.</td>
<td>• Correct answer.</td>
<td>BOTH correct answers with units.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>
(c) \[
65000 \times 60 = 3900000 \text{ g}
\]
\[
n(\text{Al}) = \frac{3900000}{27} = 144444 \text{ moles}
\]
\[
\Delta_r H = \frac{144444}{4} \times 3350 = 121000000 \text{ kJ} = 1.21 \times 10^8 \text{ kJ} \text{(rounded to 3sf)}
\]
\[
\text{OR} \quad \frac{65000}{27} = 2407 \text{ moles}
\]
\[
\Delta_r H = \frac{2407}{4} \times 3350 = 2015862 \text{ kJ} \times 60
\]
\[
= 121000000 \text{ kJ} = 1.21 \times 10^8 \text{ kJ} \text{(rounded to 3sf)}
\]

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<td>3m</td>
<td>2e</td>
<td>3e</td>
</tr>
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</table>

Cut Scores

<table>
<thead>
<tr>
<th></th>
<th>Not Achieved</th>
<th>Achievement</th>
<th>Achievement with Merit</th>
<th>Achievement with Excellence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 – 7</td>
<td>8 – 13</td>
<td>14 – 18</td>
<td>19 – 24</td>
</tr>
</tbody>
</table>