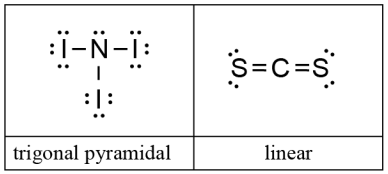
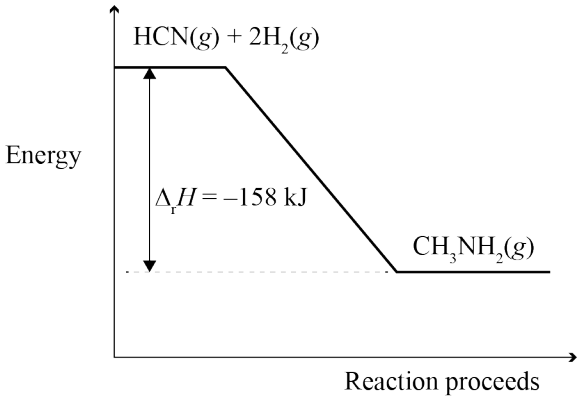
Assessment Schedule – 2024

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

Evidence

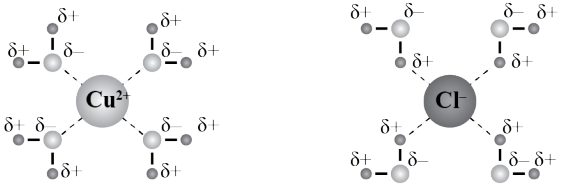
Q	Evidence	Achievement	Merit	Excellence
ONE (a)	 trigonal pyramidal | linear	• Two Lewis structures OR two shapes.		
(b)	There are four regions of electron density around the central Si atom in SiH_4. These repel to maximum separation, resulting in minimum repulsion with bond angles of 109.5°. All regions are bonded; therefore both the arrangement and the final shape are tetrahedral. By comparison, HNO only has three regions of electron density around the central N atom. These repel to maximum separation, resulting in minimal repulsion and a trigonal planar arrangement with bond angles of 120°. Of these three regions, two are bonded and one has a lone pair of electrons; therefore the final shape of the molecule is bent. The final shape is different to the arrangement for HNO due to the presence of lone pairs around the central atom.	• Identifies the correct number of bonding and lone pairs / non-bonding regions for one molecule. OR Recognises electron density regions are arranged in positions of maximum separation / minimum repulsion. OR States correct bond angles for one molecule.	• Links total number of areas of electron density around the central atom to arrangement / parent geometry and bond angle for ONE molecule using repulsion theory.	• Explains bond angles and shapes of BOTH molecules by referring to regions of electron density, repulsion theory and bonding AND non-bonding electron areas / lone pairs.

(c)i (ii)	Both molecules are polar. Both molecules contain polar bonds due to a difference in electronegativity of the atoms involved in the bond. H_2S has two polar bonds and two lone pairs. Therefore, the molecule is bent, but the dipoles are asymmetrically arranged. Consequently, the bond dipoles do not cancel out, resulting in the molecule being polar. HCN is a linear, symmetrical molecule; however the bond dipoles are not equal, and therefore cannot cancel out despite the symmetry of the molecule, hence the dipole reinforces. Therefore, the molecule is polar.	• Correctly identifies polarity. • Identifies a difference in electronegativity between atoms in bonds.	• Links asymmetry of H_2S molecule to non-cancellation / reinforcement of dipole in this molecule. • Links relative strength of polar bonds to non-cancellation / reinforcement of dipole in HCN molecule, despite symmetry.	• Correctly justifies polarity of BOTH molecules with reference to electronegativity differences between atoms in bonds, bond polarity, and symmetry of dipole arrangement.
(d) (i) (ii)	$n(CH_3NH_2) = \frac{1890}{158} = 11.962$ mol $m = n \times M$ $m = 11.962 \times 31.0 = 370.82$ g (371 g 3s.f.)  	• One step correct. • Identifies correct energy diagram by partially, but correctly labelling with either $\Delta_r H$ position (value not needed) **or** reactants and products.	• Correct answer for (i) OR (ii).	• Correct answer for (i) **AND** (ii). (Δ_rH position and value needed.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e	3e

Q	Evidence	Achievement	Merit	Excellence

<table>
<tr>
<td>TWO
(a)</td>
<td>
<table>
<tr><th>Solid</th><th>Melting point (°C)</th><th>Type of solid</th><th>Type of particle</th><th>Attractive forces between particles</th></tr>
<tr><td>$SiO_2(s)$
(silicon dioxide)</td><td>1700</td><td>3D covalent network</td><td>atoms</td><td>covalent bonds</td></tr>
<tr><td>$SiCl_4(s)$
(silicon tetrachloride)</td><td>–69</td><td>molecular</td><td>molecules</td><td>weak intermolecular forces</td></tr>
<tr><td>$CuCl_2(s)$
(copper (II) chloride)</td><td>620</td><td>ionic</td><td>ions</td><td>ionic bonds</td></tr>
<tr><td>Al(s)
(aluminium)</td><td>660</td><td>metallic</td><td>metal atoms / metal cations and delocalised electrons</td><td>metallic bonds</td></tr>
</table>
</td>
<td>• Two rows correct.
OR
Two columns correct.</td>
<td>• Whole table correct</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>SiO_2 is a 3D covalent network solid made of Si and O atoms held together by strong covalent bonds, making it very rigid and strong. Large amounts of energy are required to break / overcome the strong covalent bonds in order to melt; therefore the temperature of the melting point is high.
Whereas $SiCl_4$ is a molecular substance, made of discrete molecules of $SiCl_4$. Within these molecules there are strong covalent bonds; however, between these $SiCl_4$ molecules, there are only weak intermolecular forces of attraction holding them together. Therefore, only a relatively small amount of energy is required to break these weak forces, and hence its melting point is significantly lower.
The difference in melting point of these substances is due to the differences in the strength of the attractive forces between particles.</td>
<td>• Identifies melting point is related to strength of attractive forces in either example.
OR
Identifies that forces between particles must be broken for a solid to melt.
• Describes structure of either substance.</td>
<td>• Links strength of forces between particles to the energy requirement (for temperature) of melting point for ONE substance.</td>
<td>• Links structure and bonding in each substance to the difference in temperature required for melting.</td>
</tr>
</table>

(c)	The Si–Cl bonds are polar and arranged symmetrically; therefore the $SiCl_4$ molecule is non-polar. Water is a polar molecule with partially positive H atoms and a partially negative O atom due to the polar O–H bonds. The attractive forces between water molecules are relatively strong, compared to those between $SiCl_4$ molecules. The strength of the attractive forces between the non-polar solute ($SiCl_4$) and the polar solvent (H_2O) are not sufficient to overcome the existing strength of attractive forces between H_2O molecules or between $SiCl_4$ molecules. $SiCl_4$, being non-polar, would be expected to dissolve in a non-polar solvent. As the attractive forces between $SiCl_4$ molecules are similar to the attractive forces between molecules of non-polar solvents, they can replace each other; therefore $SiCl_4$ could dissolve. Copper(II) chloride is an ionic compound. When placed in the polar water, the partially negative O atom of water molecules attract the positive copper (Cu^{2+}) ions, and the partially positive H atoms attract the negative chloride (Cl^-) ions. The strength of this attractive force is strong enough to overcome the ionic bonds within the $CuCl_2$ ionic lattice and the force of attraction between water molecules, allowing $CuCl_2$ to dissolve.  	• Identifies $SiCl_4$ as non-polar and water as polar. OR Identifies $SiCl_4$ would dissolve in a non-polar solvent. • Identifies attractions are required between water and the solute / $SiCl_4$ / $CuCl_2$, for it to dissolve.	• Links relative strength of attractive forces between solute and solvent particles to solubility for ONE solute. • Links polarity to solubility / relative strength of attractive forces between solute and solvent particles for ONE solute.	• Justifies solubility of $SiCl_4$ with reference to polarity, relative strength of attractive forces, and need to overcome existing forces. AND Includes reason for why $SiCl_4$ would be expected to dissolve in a non-polar solvent. • Explains solubility of $CuCl_2$, with reference to polarity, relative strength of attractive forces, and need to overcome existing forces. AND Use of diagram to illustrate $CuCl_2$ answer

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e	3e

Q	Evidence	Achievement	Merit	Excellence
THREE (a)(i)	$n(\text{propane}) = \frac{1000}{44.1} = 22.676$ mol Energy = $22.676 \times \frac{-2044}{1} = -46\,349.206$ kJ 46 300 kJ released (3sf) Accept 46 500 kJ if working shows use of 44 g mol^{-1} from periodic table molar mass values.	• One step of process correct, e..g. moles of either or used 1 or 100 instead of 1000.	• Either part (i) or (ii) correct.	• Calculates how much more energy is produced by propane, uses correct process for all calculations and units.
(ii)	$n(\text{butane}) = \frac{1000}{58.1} = 17.212$ mol Energy = $17.212 \times \frac{-2877}{2} = -24\,759.036$ kJ 24 800 kJ released (3sf) Same rounded answer using M of 58 g mol^{-1} from periodic table molar mass values.			
(iii)	Difference 46 300 – 24 800 = 21500 kJ more released from propane per kg OR Raw values 46 349.206 – 24 759.036 = 21 590.17 kJ (21 600 kJ, 3sf) OR Accept 46 500 – 24 800 = 21 700 kJ if working shows use of periodic table molar mass values.			

(b)	**Bonds broken:** $2 \times$ H–H = $2 \times 436 = 872$ $1 \times$ O=O = 498 **Total: 1370** **Bonds formed:** $4 \times$ O–H = $4x$ **Total: $4x$** $\Delta_r H = \Sigma_{\text{bonds broken}} - \Sigma_{\text{bonds formed}}$ $-484 = 1370 - 4x$ $4x = 1370 + 484$ $4x = 1854$ $x = 1854 \div 4$ $x = 463.5$ kJ mol^{-1} O–H bond enthalpy is 464 kJ mol^{-1} (3sf)	• Correctly calculates total bonds broken (1370) . OR Gives a total for bonds formed (4x).	• Correct process with minor error.	• Correct answer with units and 3SF
(c)(i)	To conduct electricity, a substance must contain free-moving charged particles.	• Correct definition.		
(ii)	Al is a metallic solid, made up of metal atoms / cations in a 3D lattice with delocalised valence electrons, held together by non-directional strong metallic bonds. These delocalised electrons are both free-moving and charged particles, which results in Al being a conductor of electricity. Therefore, Al is a good choice for overhead power lines transporting electricity and / or electrical components in devices. The Al atoms / cations are arranged in layers held together by delocalised valence electrons. When a force is applied, the layers can slide over one another, due to the non-directional metallic bonding. This enables Al to be reshaped under force without breaking its bonding or damaging its structure; hence it is malleable. Therefore, Al is a good choice for shaping protective shells for smartphones and laptops.	• Describes the structure of a metallic solid. • Identifies non-directional bonds required for malleability.	• Links conductivity to presence of delocalised valence electrons. • Links malleability to non-directional metallic bonds allowing particles to move without breaking these bonds.	• Comprehensively explains both conductivity and malleability of aluminium and links it to their suitability for the uses stated.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e	3e

Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 07	08– 13	14 – 18	19 – 24