Past-paper walk-through

Types of Chemical Bonds ▪ 2.1

eXercise

Questions in this set

- 2026 Q5
- 2016 Q3
- 2015 Q6

Reading the mark scheme

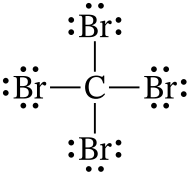
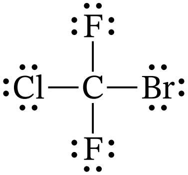
- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 5

2026 ▪ Q5

The following information applies to parts A and B.
The Lewis diagram of $CBrClF_2$ is shown.
[Lewis diagram of $CBrClF_2$: central C atom bonded to F (top, with three lone pairs), Cl (left, with three lone pairs), Br (right, with three lone pairs), and F (bottom, with three lone pairs).]
(a) Which of the bonds in $CBrClF_2$ (C–Br, C–Cl, or C–F) is the most polar? **Justify** your answer.

Question 5

Formula	CBr_4	$CBrClF_2$
Lewis diagram		
Boiling point	463 K	269 K

Question 5

2026 ▪ Q5

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The Lewis diagram of $CBrClF_2$ is shown.

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(b) In a molecule of $CBrClF_2$, the F–C–F bond angle is $106.8°$ and the Br–C–Cl bond angle is $112.3°$. **Explain** the difference in bond angles using principles of atomic structure and VSEPR theory.

Question 5

2026 ▪ Q5

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[Lewis diagram of $CBrClF_2$: central C atom bonded to F (top, with three lone pairs), Cl (left, with three lone pairs), Br (right, with three lone pairs), and F (bottom, with three lone pairs).]

(c)(i) Lewis diagrams and boiling points for CBr_4 and $CBrClF_2$ are given in the following table.

| Formula | CBr_4 | $CBrClF_2$ | |—|—|—| | Lewis diagram | [Central C bonded to four Br atoms, each Br bearing three lone pairs] | [Central C bonded to F (top), Cl (left), Br (right), F (bottom), each halogen bearing three lone pairs] | | Boiling point | 463 K | 269 K |

Clearly **identify** all the intermolecular forces in pure $CBr_4(l)$ and in pure $CBrClF_2(l)$.

Question 5

$CBr_4(l)$:

$CBrClF_2(l)$:

(c)(ii) In terms of the relative strengths of all the intermolecular forces, **explain** why pure $CBr_4(l)$ has a higher boiling point than pure $CBrClF_2(l)$ does.

Question 3

2016 ▪ Q3

$$M + I_2 \rightarrow MI_2$$

To determine the molar mass of an unknown metal, M, a student reacts iodine with an excess of the metal to form the water-soluble compound MI_2, as represented by the equation above. The reaction proceeds until all of the I_2 is consumed. The $MI_2(aq)$ solution is quantitatively collected and heated to remove the water, and the product is dried and weighed to constant mass. The experimental steps are represented below, followed by a data table.
[Diagram: a sequence of process illustrations. First row: a beaker on a balance reading 125.457 g; an arrow labeled "Add M" points to a beaker on a balance reading 126.549 g (with solid M added); an arrow labeled "Add I2" points to a beaker on a balance

Question 3

reading 127.570 g (with solid I2 added, shown as a darker layer on top of the M). Second row: an arrow labeled "Add H2O" points from the beaker with M and I2 to a beaker where "reaction occurs" (labeled MI2(aq) at the bottom with "leftover M" also labeled); an arrow labeled "solution collected" points to a test tube containing MI2(aq); an arrow labeled "heat" points to a test tube; an arrow labeled "reheat" points to a final test tube containing solid MI2(s) at the bottom.]
| Data for Unknown Metal Lab | | |—|—| | Mass of beaker | 125.457 g | | Mass of beaker + metal M | 126.549 g | | Mass of beaker + metal M + I_2 | 127.570 g | | Mass of MI_2, first weighing | 1.284 g | | Mass of MI_2, second weighing | 1.284 g |
(a) Given that the metal M is in excess, calculate the number of moles of I_2 that reacted.

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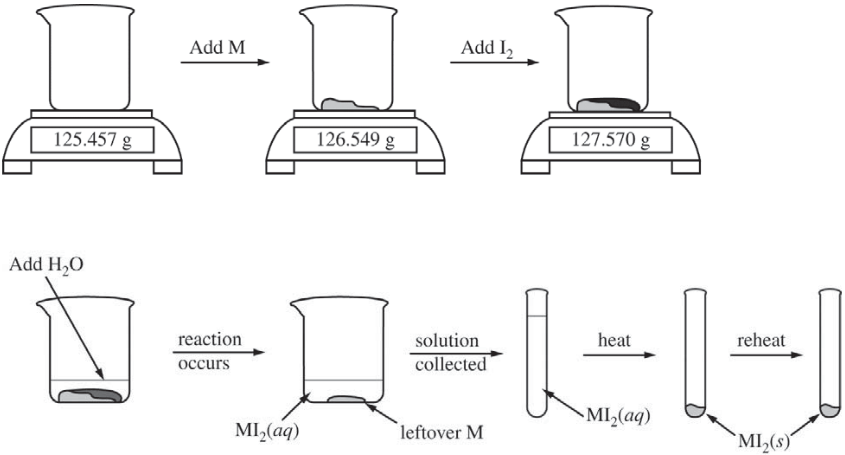
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Half reaction	$E°$ (V)
$S_4O_6^{2-}(aq) + 2\,e^- \rightarrow 2\,S_2O_3^{2-}(aq)$	0.08
$I_2(s) + 2\,e^- \rightarrow 2\,I^-(aq)$	0.54
$O_2(g) + 2\,H^+(aq) + 2\,e^- \rightarrow H_2O_2(aq)$	0.68

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2016 ▪ Q3

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(b) Calculate the molar mass of the unknown metal M.

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2016 ▪ Q3

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(c) The student hypothesizes that the compound formed in the synthesis reaction is ionic.

Propose an experimental test the student could perform that could be used to support the hypothesis. Explain how the results of the test would support the hypothesis if the substance was ionic.

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2016 ▪ Q3

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(d) The student hypothesizes that Br_2 will react with metal M more vigorously than I_2 did because Br_2 is a liquid at room temperature.

Explain why I_2 is a solid at room temperature whereas Br_2 is a liquid. Your explanation should clearly reference the types and relative strengths of the intermolecular forces present in each substance.

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(e) While cleaning up after the experiment, the student wishes to dispose of the unused solid I_2 in a responsible manner. The student decides to convert the solid I_2 to $I^-(aq)$ anion. The student has access to three solutions, $H_2O_2(aq)$, $Na_2S_2O_3(aq)$, and $Na_2S_4O_6(aq)$, and the standard reduction table shown below.

Half reaction	E° (V)
$S_4O_6^{2-}(aq) + 2e^- \rightarrow 2S_2O_3^{2-}(aq)$	0.08
$I_2(s) + 2e^- \rightarrow 2I^-(aq)$	0.54
$O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O_2(aq)$	0.68

Which solution should the student add to $I_2(s)$ to reduce it to $I^-(aq)$? Circle your answer below. Justify your answer, including a calculation of E° for the overall reaction.

Question 3

$H_2O_2(aq)$ $Na_2S_2O_3(aq)$ $Na_2S_4O_6(aq)$

Question 3

2016 ▪ Q3

$$M + I_2 \rightarrow MI_2$$

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(f) Write the balanced net-ionic equation for the reaction between I_2 and the solution you selected in part (e).

Solution 3

(a)

Mark scheme

- Mass of I2 reacted = 127.570 g − 126.549 g = 1.021 g I2. 1.021 g I2 × (1 mol I2 / 253.80 g I2) = 0.004023 mol I2. 1 point for the correct number of moles of I2.

Solution 3

(b)

Mark scheme

- Because M + I2 $\rightarrow$ MI2, moles of M = moles of I2 = 0.004023 mol. Mass of M = mass of MI2 − mass of I2 = 1.284 g − 1.021 g = 0.263 g M. Molar mass of M = 0.263 g / 0.004023 mol = 65.4 g/mol. 1 point for the correct number of grams of M, 1 point for the correct molar mass of M (65.4 g/mol).

Solution 3

(c)

Mark scheme

- Dissolve the compound in water (or melt it) and test whether the solution/melt conducts electricity; conduction indicates mobile ions are present, supporting that the compound is ionic. (Equivalently: heat the compound and observe its melting/boiling point — a very high melting/boiling point supports it being ionic.) 1 point for proposing an appropriate test, 1 point for correctly explaining how the results would support the ionic hypothesis.

Solution 3

(d) Mark scheme

- Both Br2 and I2 are nonpolar molecules, so the only intermolecular forces present are London dispersion forces. These forces are stronger in I2 because it is larger, with more electrons and/or a more polarizable electron cloud; the stronger dispersion forces give I2 a higher melting point, making it a solid at room temperature, while Br2 (weaker dispersion forces) is a liquid. 1 point for identifying London dispersion forces as the relevant IMF in both substances, 1 point for explaining why the forces are stronger in I2 than in Br2 (larger size / more electrons / more polarizable electron cloud).

Solution 3

(e)

Mark scheme

- Na2S2O3(aq) should be circled. The reaction between S2O3^2−(aq) and I2(s) is thermodynamically favorable because E°cell is positive: $E° = E°$(reduction of I2 to I−, 0.54 V) − E°(reduction of S4O6^2− to S2O3^2−, 0.08 V) $= +0.46$ V, and $\Delta G° = -nFE°$ is therefore negative. 1 point for the correct choice (Na2S2O3), 1 point for a correct justification including the E° calculation (+0.46 V, positive, so favorable).

Solution 3

(f)

Mark scheme

- I2 $+$ 2 S2O3^2$-$ $\rightarrow$ 2 I$-$ $+$ S4O6^2$-$. 1 point for the correct, balanced net-ionic equation.

Question 6

2015 ▪ Q6

A student learns that ionic compounds have significant covalent character when a cation has a polarizing effect on a large anion. As a result, the student hypothesizes that salts composed of small cations and large anions should have relatively low melting points.

Compound	**Melting Point (°C)**
LiI	449
KI	686
LiF	845
NaF	993

Question 6

(a) Select two compounds from the table and explain how the data support the student's hypothesis.
(b) Identify a compound from the table that can be dissolved in water to produce a basic solution. Write the net ionic equation for the reaction that occurs to cause the solution to be basic.

Question 6

Compound	Melting Point (°C)
LiI	449
KI	686
LiF	845
NaF	993

Solution 6

(a) Mark scheme

- Example: choose LiI and KI. LiI has a small cation (Li+) and a large anion (I-); KI has a larger cation (K+) but the same large anion (I-). LiI's melting point (449 C) is lower than KI's (686 C), so the compound with the smaller, more polarizing cation on the same large anion has the lower melting point, supporting the hypothesis that small-cation/large-anion salts have relatively low melting points. (Equally acceptable pairs: LiI vs. LiF – same small cation, LiI has the larger anion I- and the lower melting point, 449 C $<$ 845 C; or LiI vs. NaF – LiI, with its small cation and large anion, has a much lower melting point, 449 C, than NaF, 993 C.) 1 point for choosing an appropriate pair of compounds from {LiI/KI, LiI/LiF,

Solution 6

LiI/NaF}; 1 point for an explanation that correctly supports the hypothesis using the melting-point data.

Solution 6

(b)

Mark scheme

- Either LiF or NaF is an acceptable choice: F- is the conjugate base of the weak acid HF, so it hydrolyzes in water to give a basic solution (Li+ and Na+ are spectator ions and do not affect pH). Net ionic equation: F-(aq) + H2O(l) <-> HF(aq) + OH-(aq). 1 point for choosing one of the two correct compounds (LiF or NaF); 1 point for writing the correct, balanced net-ionic hydrolysis equation.