Past-paper walk-through

Net Ionic Equations ▪ 4.2

eXercise

Questions in this set

- 2026 Q1
- 2026 Q2
- 2025 Q6
- 2024 Q3
- 2023 Q3
- 2022 Q7
- 2021 Q1
- 2021 Q3
- 2019 Q3
- 2018 Q1

Questions in this set

- 2015 Q6
- 2015 Q3

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 1

2026 ▪ Q1

A student performs a calorimetry experiment with KCl.
(a)(i) Consider the K^+ ion in KCl.
Write the complete ground-state electron configuration for the potassium ion, K^+.
(a)(ii) Which has the larger radius, the K^+ ion or the K atom? **Explain** your reasoning using principles of atomic structure.

Question 1

Mass of water	97.5 g
Mass of KCl (s)	6.80 g
Initial temperature of water	24.5°C
Final temperature of solution	21.1°C

Question 1

2026 ▪ Q1

A student performs a calorimetry experiment with KCl.

(b) The following information applies to parts B, C, D, and E.

A student performs an experiment to determine the enthalpy of solution, ΔH_{soln}, of KCl. The student places water in a calorimeter, measures the initial temperature, adds KCl(s), and stirs until the KCl dissolves completely. The temperature is continuously monitored during the experiment. Data from the experiment are given in the following table.

Quantity	Value
Mass of water	97.5 g
Mass of KCl (s)	6.80 g
Initial temperature of water	$24.5°C$
Final temperature of solution	$21.1°C$

Describe how the student can use the temperature readings during the experiment to determine when the dissolution is complete.

Question 1

2026 ▪ Q1

A student performs a calorimetry experiment with KCl.

(c)(i) Use the data in the table to do the following.

Calculate the magnitude of the thermal energy, q, in joules, transferred during the dissolution. Show the work that leads to your answer. (Assume that the solution has a specific heat capacity of 3.95 J/(g · °C).)

(c)(ii) **Calculate** the value of the molar enthalpy of solution, ΔH_{soln}, in kJ/mol, for KCl given that 0.0912 mol of KCl dissolved. Show the work that leads to your answer. Include the sign with your answer.

Question 1

2026 ▪ Q1

A student performs a calorimetry experiment with KCl.

(d) The calorimeter is not perfectly insulated. Would this cause the magnitude of ΔH_{soln} calculated in part C (ii) to be greater than, less than, or equal to the accepted value? **Justify** your answer.

Question 1

2026 ▪ Q1

A student performs a calorimetry experiment with KCl.

(e) The student performs a second experiment using the same mass of water but 6.80 g of RbCl(s) instead of 6.80 g of KCl(s). The magnitude of the molar enthalpy of solution, ΔH_{soln}, of RbCl is approximately equal to that of KCl.

Is the magnitude of ΔT in the RbCl experiment greater than, less than, or equal to that in the KCl experiment? **Justify** your answer. (Assume that the specific heat capacities of the solutions are equal.)

Question 1

2026 ▪ Q1

A student performs a calorimetry experiment with KCl.

(f)(i) RbCl has a K_{sp} of 57 at $20°$C.
Write the net ionic equation for the dissolution of RbCl in pure water.
(f)(ii) **Calculate** the molar solubility of RbCl in a saturated solution at $20°$C. Show the work that leads to your answer.
(f)(iii) A second saturated solution is prepared by dissolving RbCl(s) in 1.0 M KCl(aq) at $20°$C instead of in pure water. Will the molar solubility of RbCl in 1.0 M KCl(aq) be greater than, less than, or equal to the molar solubility calculated in part F (ii)? **Justify** your answer.

Question 2

2026 ▪ Q2

Answer the following questions about the chromate ion, CrO_4^{2-}, and the dichromate ion, $Cr_2O_7^{2-}$.

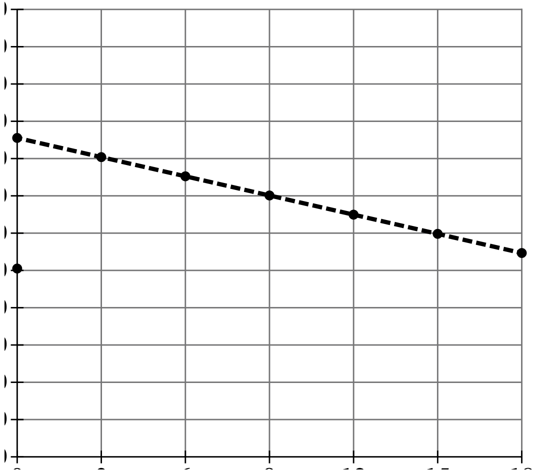
(a)(i) The bonds between chromium and oxygen in CrO_4^{2-} can be represented as covalent bonds. One possible Lewis diagram for the CrO_4^{2-} ion is shown in Figure 1.
[Figure 1: Lewis diagram of CrO_4^{2-} — a central Cr atom single-bonded to three O atoms (each with three lone pairs) and double-bonded to one O atom (with two lone pairs), the whole structure enclosed in brackets with a $2-$ charge.]
Based on VSEPR theory, **predict** the molecular geometry of the CrO_4^{2-} ion.

(a)(ii) On Figure 2, **draw** a complete Lewis diagram for a resonance structure of CrO_4^{2-} that results in a formal charge of zero on two of the O atoms and a formal charge of -1 on the other two O atoms. Your diagram should contain the same number of valence electrons as in Figure 1.

Question 2

[Figure 2: A blank template showing Cr in the center bonded to four O atoms arranged above, left, right, and below, enclosed in brackets with a $2-$ charge, for the student to complete.]

Question 2



Question 2

Question 2

2026 ▪ Q2

Answer the following questions about the chromate ion, CrO_4^{2-}, and the dichromate ion, $Cr_2O_7^{2-}$.

(b)(i) When reacted with a strong acid like $HNO_3(aq)$, $CrO_4^{2-}(aq)$ can be converted to $Cr_2O_7^{2-}(aq)$ and $H_2O(l)$ in a reversible reaction.
Write a balanced net ionic equation for the reaction between $CrO_4^{2-}(aq)$ and a strong acid.

(b)(ii) Is the reaction a redox reaction? **Justify** your answer based on the oxidation number of Cr.

Question 2

2026 ▪ Q2

Answer the following questions about the chromate ion, CrO_4^{2-}, and the dichromate ion, $Cr_2O_7^{2-}$.

(c) The following information applies to parts C and D.

In acidic solutions, $Cr_2O_7^{2-}(aq)$ reacts to form $CrO_3(aq)$ according to Equation 1.

$$\text{Equation 1: } Cr_2O_7^{2-}(aq) + 2H_3O^{+}(aq) \rightarrow 2CrO_3(aq) + 3H_2O(l)$$

$CrO_3(aq)$ can be electrolyzed to plate objects with a thin layer of chromium metal according to Equation 2.

$$\text{Equation 2: } CrO_3(aq) + 6H^{+}(aq) + 6e^{-} \rightarrow Cr(s) + 3H_2O(l) \qquad E^\circ = -1.32\text{ V}$$

Question 2

Is the reaction represented by Equation 2 thermodynamically favorable or unfavorable under standard conditions? **Justify** your answer with a calculation of ΔG°. Show the work that leads to your answer.

Question 2

2026 ▪ Q2

Answer the following questions about the chromate ion, CrO_4^{2-}, and the dichromate ion, $Cr_2O_7^{2-}$.

(d) **Calculate** the number of grams of Cr(s) that could be plated onto the surface of a steel rod when 15.0 A of current is applied for 3250 seconds. Show the work that leads to your answer.

Question 2

2026 ▪ Q2

Answer the following questions about the chromate ion, $\mathrm{CrO_4^{2-}}$, and the dichromate ion, $\mathrm{Cr_2O_7^{2-}}$.

(e) In a separate experiment, an iron wire is placed directly in a solution of $0.50\ M$ $\mathrm{Cr_2O_7^{2-}}(aq)$ with pH $= 1.99$. The concentration of $\mathrm{Cr_2O_7^{2-}}(aq)$ remaining is recorded over time, and the results are presented in Figure 3.
[Figure 3: Graph of $[\mathrm{Cr_2O_7^{2-}}]$ (M) vs. Time (minutes); y-axis 0.00 to 0.50 in increments of 0.05, x-axis 0 to 48 in increments of 4; curve is concave up, decreasing from approximately $(0, 0.50)$ through $(4, 0.44)$, $(8, 0.38)$, $(12, 0.33)$, $(16, 0.29)$, $(20, 0.26)$, $(24, 0.23)$, $(28, 0.21)$, $(32, 0.18)$, $(36, 0.16)$, $(40, 0.14)$, $(44, 0.12)$, to approximately $(48, 0.10)$.]
Explain how the data in Figure 3 support the conclusion that the reaction is first order with respect to $\mathrm{Cr_2O_7^{2-}}$.

Question 2

2026 ▪ Q2

Answer the following questions about the chromate ion, CrO_4^{2-}, and the dichromate ion, $Cr_2O_7^{2-}$.

(f) The following information applies to parts F and G.

The student creates a plot of $\ln[Cr_2O_7^{2-}]$ versus time for a trial with an initial concentration of 0.50 *M* $Cr_2O_7^{2-}(aq)$, as shown in Figure 4.

[Figure 4: Graph of $\ln[Cr_2O_7^{2-}]$ vs. Time (minutes); y-axis -2.40 to 0.00 in increments of 0.20, x-axis 0 to 18 in increments of 3; dashed line of best fit through points starting near $(0, -0.65)$ decreasing roughly linearly to approximately $(18, -1.35)$.]

Calculate the value of the rate constant, *k*, for the reaction. Report your answer in units of min^{-1}. Show the work that leads to your answer.

Question 2

2026 ▪ Q2

Answer the following questions about the chromate ion, CrO_4^{2-}, and the dichromate ion, $Cr_2O_7^{2-}$.

(g) The student then runs a second trial of the experiment under identical conditions but uses an initial concentration of 0.25 *M* $Cr_2O_7^{2-}(aq)$ instead of 0.50 *M* $Cr_2O_7^{2-}(aq)$. On Figure 4, carefully **draw** the plot of $\ln[Cr_2O_7^{2-}]$ versus time that would be expected for the second experiment. The point at time zero has already been plotted.

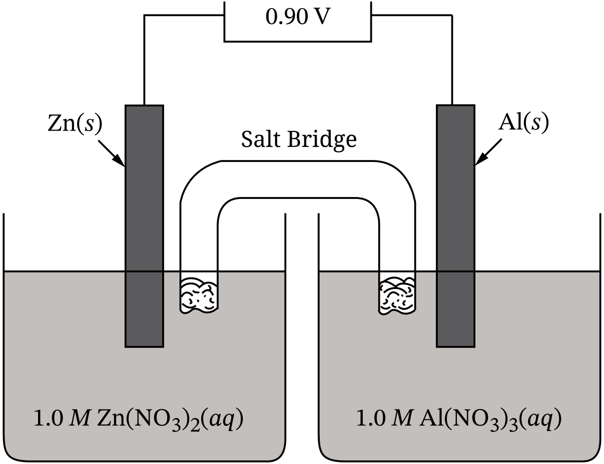
Question 6

2025 ▪ Q6

A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the Zn(s) electrode increases in mass and the Al(s) electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram. [Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "Zn(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M Zn(NO$_3$)$_2$(aq)". The right electrode is labeled "Al(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M Al(NO$_3$)$_3$(aq)". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]
| Half-Reaction | E° (V) | |—|—| | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | | $Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 |

(a) Write the half-reaction for the oxidation that occurs at the anode.

Question 6



Question 6

Reduction Half-Reaction	E° (V)
$Au^{3+}(aq) + 3\ e^- \rightarrow Au(s)$	$+1.50$
$Zn^{2+}(aq) + 2\ e^- \rightarrow Zn(s)$	-0.76
$Mn^{2+}(aq) + 2\ e^- \rightarrow Mn(s)$	-1.19
$Al^{3+}(aq) + 3\ e^- \rightarrow Al(s)$	-1.66
$Be^{2+}(aq) + 2\ e^- \rightarrow Be(s)$	-1.85

Question 6

Half-Reaction	E° (V)
$Zn^{2+}(aq) + 2\ e^- \rightarrow Zn(s)$	-0.76
$Al^{3+}(aq) + 3\ e^- \rightarrow Al(s)$	-1.66

Question 6

2025 ▪ Q6

A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the Zn(s) electrode increases in mass and the Al(s) electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.
[Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "Zn(s)" (with an arrow pointing to it), immersed in a beaker of "$1.0\ M$ Zn(NO_3)$_2$(aq)". The right electrode is labeled "Al(s)" (with an arrow pointing to it), immersed in a beaker of "$1.0\ M$ Al(NO_3)$_3$(aq)". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]
| Half-Reaction | E° (V) | |—|—| | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | |
$Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 |

(b) Write the balanced net ionic equation for the overall reaction that occurs in the galvanic cell.

Question 6

2025 ▪ Q6

A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the Zn(s) electrode increases in mass and the Al(s) electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.
[Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "Zn(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Zn(NO_3)_2(aq)$". The right electrode is labeled "Al(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M $Al(NO_3)_3(aq)$". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]
| Half-Reaction | E° (V) | |—|—| | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | |
$Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 |

(c) Initially, each electrode has a mass of 50.0 g. The cell is allowed to run for a period of time and is then stopped. Which electrode's mass changed the most? Justify your answer with a calculation.

Question 6

Reduction Half-Reaction	E° (V)
$Au^{3+}(aq) + 3\,e^- \rightarrow Au(s)$	$+1.50$
$Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$	-0.76
$Mn^{2+}(aq) + 2\,e^- \rightarrow Mn(s)$	-1.19
$Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$	-1.66
$Be^{2+}(aq) + 2\,e^- \rightarrow Be(s)$	-1.85

Question 6

2025 ▪ Q6

A scientist constructs a galvanic cell as shown in the diagram. As the cell operates, the Zn(s) electrode increases in mass and the Al(s) electrode decreases in mass. A data table with the standard reduction potentials for the substances follows the diagram.
[Galvanic cell diagram: a voltmeter reading "0.90 V" connects two electrodes across the top. The left electrode is labeled "Zn(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M Zn$(NO_3)_2(aq)$". The right electrode is labeled "Al(s)" (with an arrow pointing to it), immersed in a beaker of "1.0 M Al$(NO_3)_3(aq)$". The two beakers are connected by a U-shaped "Salt Bridge" with cotton plugs at each end, shown dipping into each solution.]
| Half-Reaction | E° (V) | |—|—| | $Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$ | -0.76 | |
$Al^{3+}(aq) + 3\,e^- \rightarrow Al(s)$ | -1.66 |

(d) The standard Zn/Al cell has a value of E°_{cell} equal to 0.90 V. The scientist needs a galvanic cell that produces a greater voltage. The scientist has access to the chemical systems in the table. If the scientist uses the Zn half-cell and one of the other options

Question 6

from the table, what is the MAXIMUM voltage that could be generated at standard conditions?

Solution 6

(a)

Mark scheme

- $\mathrm{Al}(s) \rightarrow \mathrm{Al}^{3+}(aq) + 3\,e^{-}$ (oxidation half-reaction at the anode; state symbols not required).

Solution 6

(b)

Mark scheme

- $2\,\mathrm{Al}(s) + 3\,\mathrm{Zn}^{2+}(aq) \rightarrow 2\,\mathrm{Al}^{3+}(aq) + 3\,\mathrm{Zn}(s)$ (balanced net ionic equation for the overall galvanic cell reaction; state symbols not required).

Solution 6

(c) Mark scheme

- Zn experiences the greater change in mass. Assuming the entire 50.0 g Al anode reacts: $50.0 \text{ g Al} \times \dfrac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \dfrac{3 \text{ mol Zn}}{2 \text{ mol Al}} \times \dfrac{65.38 \text{ g Zn}}{1 \text{ mol Zn}} = 182 \text{ g Zn produced}$ — far more than the 50.0 g of Al consumed. Equivalently, per mole of reaction: 3 mol Zn $\times$ 65.38 g/mol $=$ 196.1 g Zn deposited vs. 2 mol Al $\times$ 26.98 g/mol $=$ 53.96 g Al consumed, so the mass of Zn produced always exceeds the mass of Al consumed.

Solution 6

(d)

Mark scheme

- Pair the Zn half-cell (oxidation: $\text{Zn}(s) \rightarrow \text{Zn}^{2+}(aq) + 2\,e^-$, $E^\circ = +0.76$ V) with the Au^{3+}/Au half-reaction as the cathode ($E^\circ = +1.50$ V, the largest reduction potential available, greater than Mn or Al): $E^\circ_{cell} = 1.50 \text{ V} + 0.76 \text{ V} = 2.26 \text{ V}$. This is the maximum voltage obtainable from the table.

Question 3

2024 ▪ Q3

$$2\,Ag(s) + H_2S(g) \rightarrow Ag_2S(s) + H_2(g)$$

3. Sterling silver is an alloy that is commonly used to make jewelry and consists of 92.5

(a) What are the oxidation numbers of silver in $Ag(s)$ and $Ag_2S(s)$?

$Ag(s)$ $Ag_2S(s)$