Past-paper walk-through

Introduction to Solubility Equilibria ▪ 7.11

eXercise

Questions in this set

- 2026 Q1
- 2025 Q1
- 2023 Q7
- 2022 Q7
- 2021 Q6
- 2017 Q6
- 2015 Q4
- 2014 Q1

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 $3.95\ \mathrm{J/(g \cdot °C)}$.)

(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 1

2025 ▪ Q1

Answer the following questions about magnesium.

(a) An incomplete mass spectrum for magnesium is shown in the diagram.

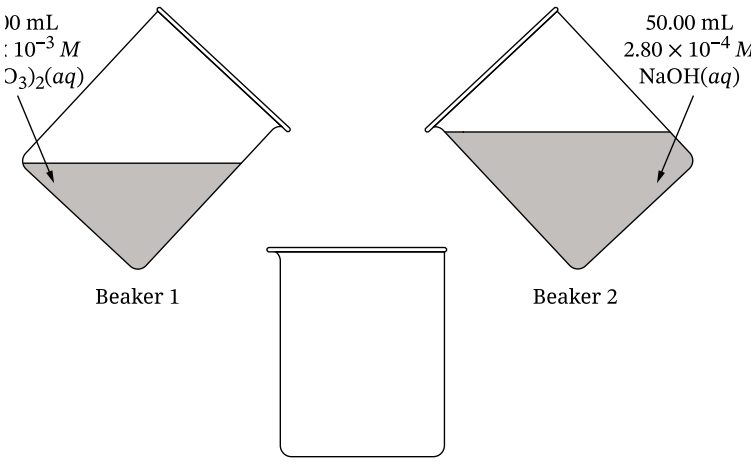
[Bar graph titled "Relative Abundance" vs. "Mass (amu)"; y-axis from 0 to 100 in increments of 20; x-axis shows tick marks at 24, 25, 26; a single thick vertical bar is drawn at mass 24 reaching a relative abundance of about 79.]

The percent abundance of magnesium-24 is 79%. The percent abundances of the other two natural isotopes of magnesium, magnesium-25 and magnesium-26, are approximately equal.

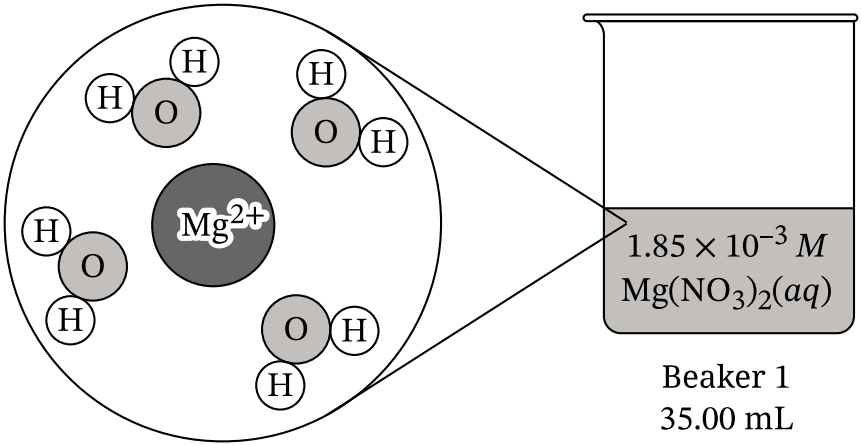
(a)(i) Complete the mass spectrum in part A by drawing thick lines in the appropriate locations to represent the percent abundance of magnesium-25 and magnesium-26.

(a)(ii) Describe the difference in atomic structure that accounts for the difference in mass between magnesium-25 and magnesium-26.

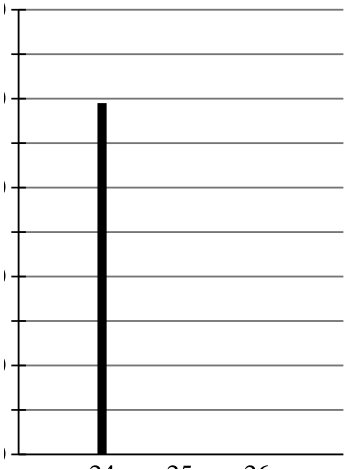
Question 1


)0 mL
: 10^{-3} M
$O_3)_2(aq)$
Beaker 1
50.00 mL
2.80×10^{-4} M
NaOH(aq)
Beaker 2

Question 1



Question 1



Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(b) A student prepares a 1.85×10^{-3} *M* solution of $Mg(NO_3)_2(aq)$ in beaker 1 and a 2.80×10^{-4} *M* solution of $NaOH(aq)$ in beaker 2, as shown.

[Particle diagram: a magnesium ion, Mg^{2+}, at the center surrounded by six water molecules (H2O), each oriented with its oxygen atom pointing toward the central Mg^{2+} ion and its two hydrogen atoms pointing outward.]

[Beaker 1: labeled "1.85×10^{-3} *M* $Mg(NO_3)_2(aq)$", "Beaker 1", "35.00 mL".]

[Beaker 2: labeled "2.80×10^{-4} *M* $NaOH(aq)$", "Beaker 2", "50.00 mL".]

The particle diagram shown represents a magnesium ion, Mg^{2+}, in beaker 1. A sodium ion, Na^+, in beaker 2 has a weaker attraction to water than the Mg^{2+} does. Explain this phenomenon using Coulomb's law and each of the following.

(b)(i) The relative charge of the ions

Question 1

(b)(ii) The relative radii of the ions

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(c) Calculate the pH of the solution in beaker 2.

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(d) A student combines 35.00 mL of 1.85×10^{-3} *M* $Mg(NO_3)_2(aq)$ with 50.00 mL of 2.80×10^{-4} *M* $NaOH(aq)$, as shown in the diagram. Calculate $\left[Mg^{2+}\right]$ after the two solutions are combined but before any reaction takes place. (Assume that volumes are additive.)

[Diagram of two conical/Erlenmeyer flasks being poured into an empty Beaker 3. Left flask: "35.00 mL", "1.85×10^{-3} *M*", "$Mg(NO_3)_2(aq)$", labeled "Beaker 1". Right flask: "50.00 mL", "2.80×10^{-4} *M*", "$NaOH(aq)$", labeled "Beaker 2". Both flasks have an arrow pointing down into the empty "Beaker 3" between them.]

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(e) The dissolution of magnesium hydroxide is represented by the following equation.

$$\mathrm{Mg(OH)_2}(s) \rightleftharpoons \mathrm{Mg^{2+}}(aq) + 2\,\mathrm{OH^-}(aq) \qquad K_{sp} = 5.61 \times 10^{-12}$$

(e)(i) Write the expression for the solubility product constant, K_{sp}.

(e)(ii) After the two solutions are combined in beaker 3 as described in part D, but before any reaction takes place, $\left[\mathrm{OH^-}\right] = 1.65 \times 10^{-4}$ M. Using your answer to part D, calculate the value of the reaction quotient, Q.

(e)(iii) Using the reaction quotient, Q, predict whether a precipitate should form as the mixture in beaker 3 approaches equilibrium. Justify your answer.

Question 1

2025 ▪ Q1

Answer the following questions about magnesium.

(f) In a separate experiment, the student adds $HNO_3(aq)$ to decrease the pH of a saturated solution containing undissolved $Mg(OH)_2(s)$. Does the amount of undissolved $Mg(OH)_2(s)$ increase, decrease, or remain the same as the $HNO_3(aq)$ is added? Justify your answer.

Solution 1

(a)

Mark scheme

- No separate response required — this is the context/stem describing the incomplete mass spectrum (magnesium-24 at 79% abundance) that parts (i) and (ii) below refer to.

(a)(i)

Mark scheme

- Draw two vertical bars at masses 25 and 26, each reaching a relative abundance of approximately 10 to 11 (since Mg-25 and Mg-26 together make up the remaining ~21% and are approximately equal, so roughly 10–11% each).

Solution 1

(a)(ii)

Mark scheme

- Magnesium-26 has one more neutron than magnesium-25 does (Mg-25 has 13 neutrons, Mg-26 has 14 neutrons; both isotopes have 12 protons, since they are the same element).

Solution 1

(b)

Mark scheme

- No separate response required — this is the context/stem introducing the 1.85×10^{-3} *M* $Mg(NO_3)_2(aq)$ and 2.80×10^{-4} *M* NaOH(aq) solutions (with a particle diagram of hydrated Mg^{2+}) that parts (i) and (ii) below refer to.

(b)(i)

Mark scheme

- The charge on the sodium ion (Na^+, $+1$) is less than the charge on the magnesium ion (Mg^{2+}, $+2$). A smaller charge results in a weaker Coulombic attraction between Na^+ and water.

Solution 1

(b)(ii)

Mark scheme

- The Na^+ ion is larger (has a greater ionic radius) than the Mg^{2+} ion, so the distance between Na^+ and the oxygen atom of the water molecule will be greater. As distance increases, Coulombic attraction decreases, so Na^+ is less strongly attracted to water than Mg^{2+}.

Solution 1

(c)

Mark scheme

- $\mathrm{pOH} = -\log(2.80 \times 10^{-4}) = 3.553.$ $\mathrm{pH} = 14 - \mathrm{pOH} = 14 - 3.553 = 10.447.$

Solution 1

(d)

Mark scheme

- Using $M_1V_1 = M_2V_2$: $M_2 = \dfrac{(1.85 \times 10^{-3}\ M)(0.03500\ \text{L})}{0.03500\ \text{L} + 0.05000\ \text{L}} = 7.62 \times 10^{-4}\ M.$
  So $[\text{Mg}^{2+}]$ after combining but before reaction is $7.62 \times 10^{-4}\ M$.

Solution 1

(e)

Mark scheme

- No separate response required — this is the context/stem giving the $Mg(OH)_2$ dissolution equilibrium and $K_{sp} = 5.61 \times 10^{-12}$ that parts (i)–(iii) below refer to.

(e)(i)

Mark scheme

- $K_{sp} = [Mg^{2+}][OH^-]^2$.

Solution 1

(e)(ii)

Mark scheme

- Using $[Mg^{2+}] = 7.62 \times 10^{-4}$ M (from part D) and $[OH^-] = 1.65 \times 10^{-4}$ M (given): $Q = [Mg^{2+}][OH^-]^2 = (7.62 \times 10^{-4})(1.65 \times 10^{-4})^2 = 2.07 \times 10^{-11}$.

(e)(iii)

Mark scheme

- Q $(2.07 \times 10^{-11}) > K_{sp}$ (5.61×10^{-12}), so a precipitate should form. Equivalently: the concentration of ions in solution (represented by Q) is greater than that of a saturated solution, so a precipitate will form.

Solution 1

(f)

Mark scheme

- The amount of undissolved $Mg(OH)_2(s)$ will decrease. The H^+ from $HNO_3(aq)$ reacts with OH^-, decreasing $[OH^-]$ and causing $Q < K_{sp}$. As a result, more $Mg(OH)_2(s)$ will dissolve until equilibrium is reestablished, resulting in less undissolved $Mg(OH)_2(s)$.

Question 7

2023 ▪ Q7

Strontium hydroxide dissolves in water according to the following equation. The K_{sp} expression for strontium hydroxide is provided.

$$\mathrm{Sr(OH)_2}(s) \rightleftharpoons \mathrm{Sr^{2+}}(aq) + 2\,\mathrm{OH^-}(aq) \qquad K_{sp} = [\mathrm{Sr^{2+}}][\mathrm{OH^-}]^2$$

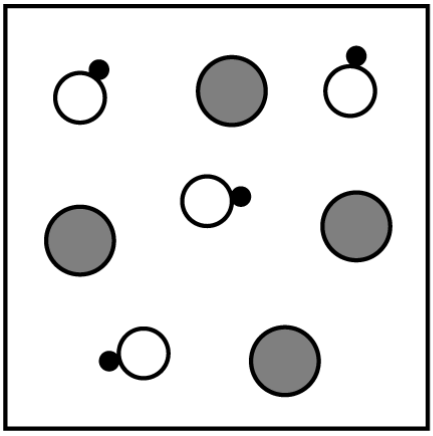
[Particle diagram inside a square box: two "$\mathrm{Sr^{2+}}$" gray circles and several "$\mathrm{OH^-}$" circles (open circle with a small black dot) scattered inside — roughly 3 gray $\mathrm{Sr^{2+}}$ circles and 4 $\mathrm{OH^-}$ circles shown. Legend beside the box: gray circle = $\mathrm{Sr^{2+}}$; open circle with dot = $\mathrm{OH^-}$.]

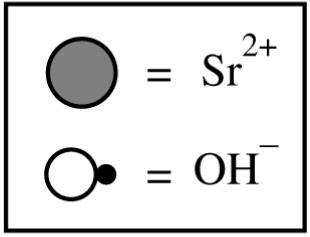
(a) A student draws the particulate diagram shown to represent the ions present in an aqueous solution of $\mathrm{Sr(OH)_2}$. (Water molecules are intentionally omitted.) Identify the error in the student's drawing.

Question 7

(b)(i) The student prepares a saturated solution by adding excess $Sr(OH)_2(s)$ to distilled water and stirring until no more solid dissolves. The student then determines that $[Sr^{2+}] = 0.043\ M$ in the solution.
Calculate the value of $[OH^-]$ in the solution.
(b)(ii) Calculate the value of K_{sp} for $Sr(OH)_2$.
(c) The student prepares a second saturated solution of $Sr(OH)_2$ in aqueous $0.10\ M\ Sr(NO_3)_2$ instead of water. Will the value of $[OH^-]$ in the second solution be greater than, less than, or equal to the value in the first solution? Justify your answer. (Assume constant temperature.)

Question 7





Solution 7

(a)

Mark scheme

- Accept either: the student's drawing shows an incorrect ratio of Sr^{2+} to OH^- ions (should be 1:2, since $Sr(OH)_2$ dissociates into one Sr^{2+} and two OH^-); or, equivalently, the drawing is not charge-balanced (the total positive and negative charge shown does not sum to zero).

Solution 7

(b)(i)

Mark scheme

- From the dissociation stoichiometry,

$$[\mathrm{OH}^-] = 2[\mathrm{Sr}^{2+}] = \frac{0.043 \text{ mol } \mathrm{Sr}^{2+}}{1 \text{ L}} \times \frac{2 \text{ mol } \mathrm{OH}^-}{1 \text{ mol } \mathrm{Sr}^{2+}} = 0.086 \ M \ \mathrm{OH}^-.$$

(b)(ii)

Mark scheme

- $K_{sp} = [\mathrm{Sr}^{2+}][\mathrm{OH}^-]^2 = (0.043)(0.086)^2 = 3.2 \times 10^{-4}$.

Solution 7

(c)

Mark scheme

- Less than. Because the 0.10 M $Sr(NO_3)_2(aq)$ solution already contains a common ion, $Sr^{2+}(aq)$, the solubility of $Sr(OH)_2$ will be decreased (common-ion effect), resulting in a lower value of $[OH^-]$ than in the first (pure water) solution.

Question 7

2022 ▪ Q7

A Lewis electron-dot diagram of the oxalate ion, $C_2O_4^{2-}$, is shown.
[A Lewis electron-dot structure of the oxalate ion $C_2O_4^{2-}$: two carbon atoms singly bonded to each other, each carbon also double-bonded to one O atom and singly bonded to another O atom bearing a negative charge, with appropriate lone pairs shown on all oxygen atoms, consistent with the resonance-averaged/standard depiction of oxalate.]
(a) Identify the hybridization of the valence orbitals of either carbon atom in the oxalate ion.
(b) Silver oxalate, $Ag_2C_2O_4(s)$, is slightly soluble in water. The value of K_{sp} for $Ag_2C_2O_4$ is 5.40×10^{-12}.
(b)(i) Write the expression for the solubility-product constant, K_{sp}, for $Ag_2C_2O_4$.
(b)(ii) Calculate the molar solubility of $Ag_2C_2O_4$ in neutral distilled water.

Question 7

(b)(iii) The molar solubility of $Ag_2C_2O_4$ increases when it is dissolved in $0.5\ M\ HClO_4(aq)$ instead of neutral distilled water. Write a balanced, net-ionic equation for the process that occurs between species in solution that contributes to the increased solubility of $Ag_2C_2O_4(aq)$ in $HClO_4(aq)$.

Question 7

Solution 7

(a)

Mark scheme

- sp^2 — each carbon in the oxalate ion ($C2O4^2$) is trigonal planar (bonded to an O, a double-bonded/resonance O, and the other C), giving sp^2 hybridization of its valence orbitals.

Solution 7

(b)

Mark scheme

- This is the stem/introduction to part (b): silver oxalate, Ag2C2O4(s), is slightly soluble in water, with Ksp $= 5.40 \times 10^{12}$ for Ag2C2O4. No points are allocated to the stem itself — the graded sub-parts are 7bi, 7bii, and 7biii.

(b)(i)

Mark scheme

- Ksp $= [\text{Ag}]^2[\text{C2O4}^2]$.

Solution 7

(b)(ii)

Mark scheme

- Let molar solubility = s, so [Ag] = 2s and [C2O4^{2}] = s: 5.40 $\times$ 10 ^{12} = (2s)^{2}(s) = 4s^{3}, giving s = 1.11 $\times$ 10 M.

(b)(iii)

Mark scheme

- Balanced net-ionic equation for the process that increases solubility in acid (any one accepted, state symbols not required): C2O4^{2} (aq) + H3O (aq) $\rightarrow$ HC2O4 (aq) + H2O(l); or C2O4^{2} (aq) + H (aq) $\rightarrow$ HC2O4 (aq); or C2O4^{2} (aq) + 2H3O (aq) $\rightarrow$ H2C2O4(aq) + 2H2O(l); or C2O4^{2} (aq) + 2H (aq) $\rightarrow$ H2C2O4(aq).

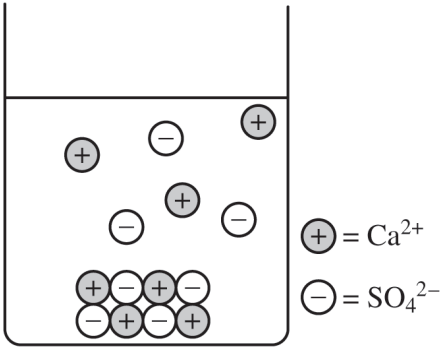
Question 6

2021 ▪ Q6

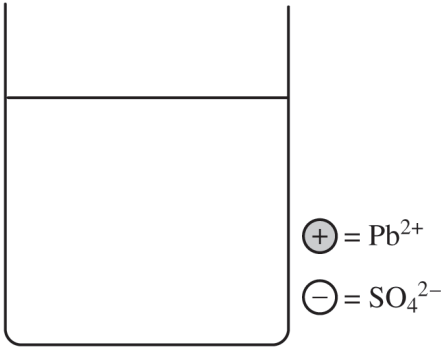
A student is studying the properties of $CaSO_4$ and $PbSO_4$. The student has samples of both compounds, which are white powders.

(a) The student tests the electrical conductivity of each solid and observes that neither solid conducts electricity. Describe the structures of the solids that account for their inability to conduct electricity.

Question 6



Higher Conductivity Solution



Lower Conductivity Solution

Question 6

2021 ▪ Q6

A student is studying the properties of $CaSO_4$ and $PbSO_4$. The student has samples of both compounds, which are white powders.

(b) The student places excess $CaSO_4(s)$ in a beaker containing 100 mL of water and places excess $PbSO_4(s)$ in another beaker containing 100 mL of water. The student stirs the contents of the beakers and then measures the electrical conductivity of the solution in each beaker. The student observes that the conductivity of the solution in the beaker containing the $CaSO_4(s)$ is higher than the conductivity of the solution in the beaker containing the $PbSO_4(s)$.

Which compound is more soluble in water, $CaSO_4(s)$ or $PbSO_4(s)$? Justify your answer based on the results of the conductivity test.

Question 6

2021 ▪ Q6

A student is studying the properties of $CaSO_4$ and $PbSO_4$. The student has samples of both compounds, which are white powders.

(c) The left side of the diagram below shows a particulate representation of the contents of the beaker containing the $CaSO_4(s)$ from the solution conductivity experiment.

[Diagram: two beakers side by side, each containing liquid. Left beaker, labeled "Higher Conductivity Solution": scattered small circles marked "+" (labeled Ca^{2+}) and "−" (labeled SO_4^{2-}) floating individually in the liquid (several of each, dispersed), plus a small cluster of undissolved solid at the bottom made of alternating "+" and "−" circles packed together. Right beaker, labeled "Lower Conductivity Solution": empty/blank, to be filled in by the student, with the same legend $+ = Pb^{2+}$, $- = SO_4^{2-}$.]

Question 6

Draw a particulate representation of $PbSO_4(s)$ and the ions dissolved in the solution in the beaker on the right in the diagram. Draw the particles to look like those shown to the right of the beaker. Draw an appropriate number of dissolved ions relative to the number of dissolved ions in the beaker on the left.

Question 6

2021 ▪ Q6

A student is studying the properties of $CaSO_4$ and $PbSO_4$. The student has samples of both compounds, which are white powders.

(d) The student attempts to increase the solubility of $CaSO_4(s)$ by adding 10.0 mL of 2 M $H_2SO_4(aq)$ to the beaker, and observes that additional precipitate forms in the beaker. Explain this observation.

Solution 6

(a)

Mark scheme

- Ionic solids do not have free-moving (mobile) ions — the ions are locked in fixed positions within the rigid crystal lattice — so there are no charge carriers able to move through the solid. Therefore there is no conduction of electricity.

Solution 6

(b)

Mark scheme

- CaSO4. The greater electrical conductivity of the CaSO4(aq) solution relative to the PbSO4(aq) solution implies a higher concentration of dissolved ions, which comes from CaSO4 dissolving/dissociating to a greater extent than PbSO4 — i.e., CaSO4 is more soluble than PbSO4.

Solution 6

(c)

Mark scheme

- The particulate diagram for the (lower-conductivity) PbSO4 beaker should show solid PbSO4 undissolved at the bottom (drawn similarly to the solid CaSO4 shown in the higher-conductivity beaker), together with fewer dissociated Pb2+ and SO4^2- ions dispersed in the solution than are shown in the CaSO4 beaker — reflecting PbSO4's lower solubility — while still showing an equal number of Pb2+ cations and SO4^2- anions in solution (1:1 stoichiometry / charge balance).

Solution 6

(d)

Mark scheme

- The additional precipitate is CaSO4 that forms in response to the increased [SO4^2-] introduced by the added H2SO4(aq). By Le Chatelier's principle (the reaction quotient Q now exceeds Ksp), the added common ion SO4^2- shifts the dissolution equilibrium of CaSO4 toward the solid, forming more CaSO4(s) — the common-ion effect.

Question 6

2017 ▪ Q6

Answer the following questions about $Mg(OH)_2$. At $25°C$, the value of the solubility product constant, K_{sp}, for $Mg(OH)_2(s)$ is 1.8×10^{-11}.

(a) Calculate the number of grams of $Mg(OH)_2$ (molar mass 58.32 g/mol) that is dissolved in 100. mL of a saturated solution of $Mg(OH)_2$ at $25°C$.

(b) The energy required to separate the ions in the $Mg(OH)_2$ crystal lattice into individual $Mg^{2+}(g)$ and $OH^-(g)$ ions, as represented in the table below, is known as the lattice energy of $Mg(OH)_2(s)$. As shown in the table, the lattice energy of $Sr(OH)_2(s)$ is less than the lattice energy of $Mg(OH)_2(s)$. Explain why in terms of periodic properties and Coulomb's law.

Reaction	Lattice Energy (kJ/mol)
$Mg(OH)_2(s) \rightarrow Mg^{2+}(g) + 2\,OH^-(g)$	2900
$Sr(OH)_2(s) \rightarrow Sr^{2+}(g) + 2\,OH^-(g)$	2300

Question 6

Reaction	Lattice Energy (kJ/mol)
$Mg(OH)_2(s) \rightarrow Mg^{2+}(g) + 2\ OH^-(g)$	2900
$Sr(OH)_2(s) \rightarrow Sr^{2+}(g) + 2\ OH^-(g)$	2300

Solution 6

(a)

Mark scheme

- Ksp = [Mg2+][OH-]^2 = (x)(2x)^2 = 4x^3 = 1.8x10^-11. x = cube root(1.8x10^-11 / 4) = 1.65x10^-4 M = [Mg2+] = solubility of Mg(OH)2. Mass = 0.100 L x (1.65x10^-4 mol/L) x (58.32 g Mg(OH)2 / 1 mol Mg(OH)2) = 9.6x10^-4 g Mg(OH)2. 1 point earned for calculating the solubility of Mg(OH)2; 1 point earned for calculating the correct mass based on the solubility of Mg(OH)2.

Solution 6

(b) Mark scheme

- The Sr2+ ion is larger than the Mg2+ ion because it has additional occupied energy levels (shells), since Sr is below Mg in the same group. Coulomb's law states that the force of attraction between a cation and an anion is inversely proportional to the square of the distance between them. Since the distance between Mg2+ and OH- is shorter than the distance between Sr2+ and OH-, the attractive forces in Mg(OH)2 are stronger, and therefore its lattice energy (2900 kJ/mol) is greater than that of Sr(OH)2 (2300 kJ/mol). 1 point earned for the correct comparison of cation sizes; 1 point earned for indicating that smaller interionic distances lead to a greater lattice energy.

Question 4

2015 ▪ Q4

Answer the following questions about the solubility of $Ca(OH)_2$ ($K_{sp} = 1.3 \times 10^{-6}$).

(a) Write a balanced chemical equation for the dissolution of $Ca(OH)_2(s)$ in pure water.

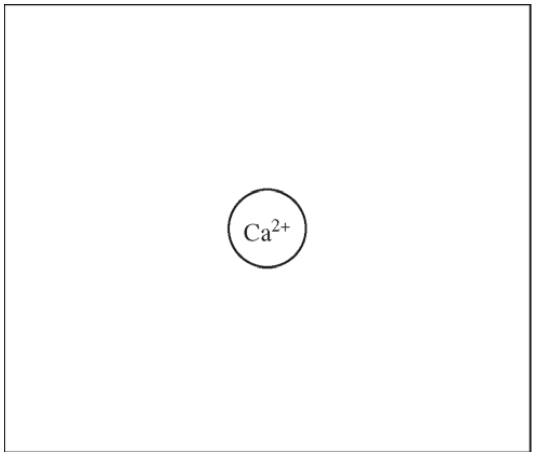
(b) Calculate the molar solubility of $Ca(OH)_2$ in 0.10 M $Ca(NO_3)_2$.

(c) In the box below, complete a particle representation diagram that includes four water molecules with proper orientation around the Ca^{2+} ion.

Represent water molecules as a bent (V-shaped) two-circle symbol representing the two hydrogen atoms attached to a central oxygen.

[A square box containing a circle labeled Ca^{2+} at its center, for the student to add four correctly-oriented water-molecule symbols around it.]

Question 4



Solution 4

(a)

Mark scheme

- Ca(OH)2(s) <-> Ca2+(aq) + 2 OH-(aq). 1 point for the correct balanced dissolution equation.

Solution 4

(b)

Mark scheme

- Ksp = [Ca2+][OH-]^2 = 1.3x10^-6. Let x = molar solubility of Ca(OH)2 in the presence of 0.10 M Ca(NO3)2 (common-ion effect): 1.3x10^-6 = (0.10+x)(2x)^2 ~ (0.10)(4x^2), assuming x << 0.10 (1 point for the correct stoichiometry and setup, including the common-ion approximation). Solving: 1.3x10^-5 = 4x^2, x = 0.0018 M. Molar solubility of Ca(OH)2 = 0.0018 M (1 point for the correct final numeric answer).

Solution 4

(c)

Mark scheme

- The particle diagram should show at least three of the four bent (V-shaped) water molecules correctly oriented around the central Ca2+ ion, with the oxygen (partial-negative/lone-pair) side of each water molecule pointing toward the positively charged Ca2+ ion (i.e., the two hydrogens point outward, away from the ion). 1 point for a diagram meeting this criterion.

Question 1

2014 ▪ Q1

[Table of experimental data:]
| Mass of KI tablet | 0.425 g | |—|—| | Mass of thoroughly dried filter paper | 1.462 g | | Mass of filter paper + precipitate after first drying | 1.775 g | | Mass of filter paper + precipitate after second drying | 1.699 g | | Mass of filter paper + precipitate after third drying | 1.698 g |

A student is given the task of determining the I^- content of tablets that contain KI and an inert, water-soluble sugar as a filler. A tablet is dissolved in 50.0 mL of distilled water, and an excess of 0.20 *M* $Pb(NO_3)_2(aq)$ is added to the solution. A yellow precipitate forms, which is then filtered, washed, and dried. The data from the experiment are shown in the table above.

(a)(i) For the chemical reaction that occurs when the precipitate forms, write a balanced, net-ionic equation for the reaction.

Question 1

(a)(ii) For the chemical reaction that occurs when the precipitate forms, explain why the reaction is best represented by a net-ionic equation.

Question 1

Mass of KI tablet	0.425 g
Mass of thoroughly dried filter paper	1.462 g
Mass of filter paper + precipitate after first drying	1.775 g
Mass of filter paper + precipitate after second drying	1.699 g
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Question 1

2014 ▪ Q1

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(b) Explain the purpose of drying and weighing the filter paper with the precipitate three times.

Question 1

2014 ▪ Q1

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(c) In the filtrate solution, is $[K^+]$ greater than, less than, or equal to $[NO_3^-]$? Justify your answer.

Question 1

2014 ▪ Q1

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(d) Calculate the number of moles of precipitate that is produced in the experiment.

Question 1

2014 ▪ Q1

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(e) Calculate the mass percent of I^- in the tablet.

Question 1

2014 ▪ Q1

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(f) In another trial, the student dissolves a tablet in 55.0 mL of water instead of 50.0 mL of water. Predict whether the experimentally determined mass percent of I^- will be greater than, less than, or equal to the amount calculated in part (e). Justify your answer.

Question 1

2014 ▪ Q1

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(g)(i) A student in another lab also wants to determine the I^- content of a KI tablet but does not have access to $Pb(NO_3)_2$. However, the student does have access to 0.20 *M* $AgNO_3$, which reacts with $I^-(aq)$ to produce $AgI(s)$. The value of K_{sp} for AgI is 8.5×10^{-17}.

Question 1

Will the substitution of $AgNO_3$ for $Pb(NO_3)_2$ result in the precipitation of the I^- ion from solution? Justify your answer.

(g)(ii) The student only has access to one KI tablet and a balance that can measure to the nearest 0.01 g. Will the student be able to determine the mass of AgI produced to three significant figures? Justify your answer.

Solution 1

(a)(i)

Mark scheme

- Balanced net-ionic equation: $Pb^{2+}(aq) + 2\,I^{-}(aq) \rightarrow PbI_2(s)$. Full credit requires correct formulas/charges and coefficients balanced for both mass and charge.

Solution 1

(a)(ii)

Mark scheme

- The net-ionic equation is best because it shows only the species that actually react to form the precipitate — PbI2(s) forming from Pb2+(aq) and I-(aq) — while omitting the spectator ions that do not participate, K+(aq) and NO3-(aq).

Solution 1

(b)

Mark scheme

- The filter paper and precipitate must be dried and weighed repeatedly (to a constant mass, i.e. until successive weighings agree) to ensure that all of the water/moisture has been driven off, so the recorded mass reflects only the dry PbI2 precipitate.

Solution 1

(c)

Mark scheme

- $[K^+]$ is less than $[NO_3^-]$, because the source of NO3-, the 0.20 M Pb(NO3)2(aq), was added in excess (beyond what was needed to precipitate all the I-), so leftover NO3- remains in solution without a matching amount of K+.

Solution 1

(d)

Mark scheme

- Mass of precipitate = 1.698 g − 1.462 g = 0.236 g PbI2(s). Moles of PbI2 = 0.236 g × (1 mol PbI2 / 461.0 g PbI2) = 5.12×10^{-4} mol PbI2.

Solution 1

(e)

Mark scheme

- Moles I- $= 5.12 \times 10^{-4}$ mol PbI2 $\times$ (2 mol I-/1 mol PbI2) $= 1.02 \times 10^{-3}$ mol I- (1 point for the moles of I-). Mass I- $= 1.02 \times 10^{-3}$ mol $\times$ 126.91 g/mol $=$ 0.130 g I-; mass percent $=$ 0.130 g / 0.425 g KI tablet $= 0.306 = 30.6$

Solution 1

(f)

Mark scheme

- The mass percent of I- will be the same (equal to part e), because Pb2+(aq) was added in excess, ensuring essentially all I- is precipitated regardless of the extra water; the additional water is removed during filtration and drying, leaving the same mass of dried precipitate.

Solution 1

(g)(i)

Mark scheme

- Yes. Addition of excess 0.20 M AgNO3(aq) will precipitate essentially all of the I- ion present in solution because AgI is very insoluble, as shown by its very small Ksp value (8.5×10^{-17}).

(g)(ii)

Mark scheme

- No. Since masses can only be measured to $\pm$0.01 g, and the dry AgI(s) precipitate produced will have a mass less than 1 g, the mass will be known to only two significant figures, not three.