

Past-paper walk-through

pH and Solubility ■ 8.11

eXercise

Questions in this set

- 2025 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

2025 ■ Q1

Answer the following questions about magnesium.

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

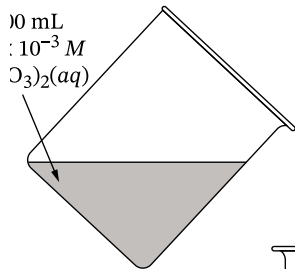
[Bar graph titled “Relative Abundance” vs. “Mass (amu)”]; y-axis from 0 to 100 in increments of 20; x-axis shows tick marks at 24, 25, 26; a single thick vertical bar is drawn at mass 24 reaching a relative abundance of about 79.]

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.

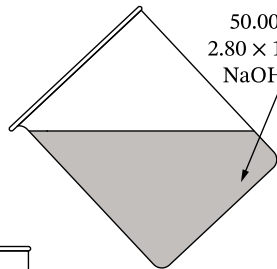
(a)(ii) Describe the difference in atomic structure that accounts for the difference in mass between magnesium-25 and magnesium-26.

Question 1



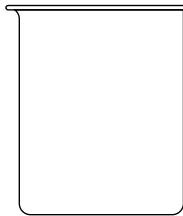
10.0 mL
 $1.0 \times 10^{-3} M$
 $\text{Ca}_3(\text{PO}_4)_2(aq)$

Beaker 1

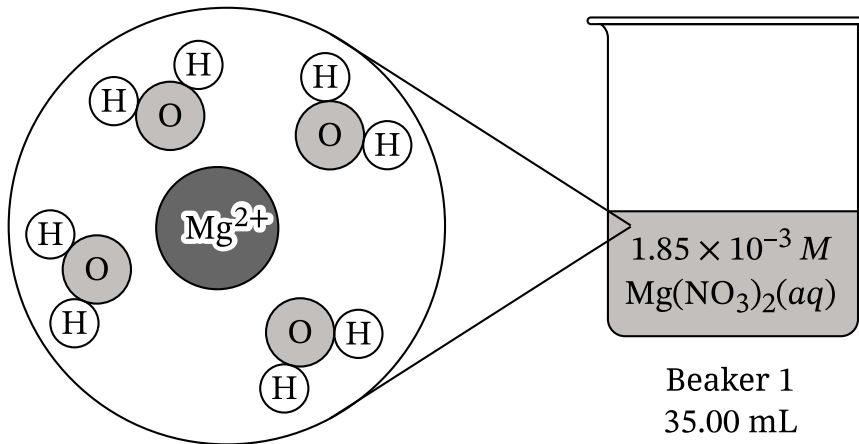


50.00 mL
 $2.80 \times 10^{-4} M$
 $\text{NaOH}(aq)$

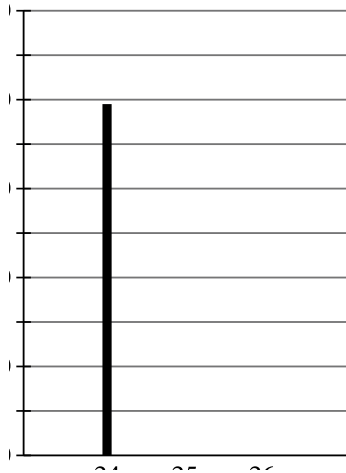
Beaker 2



Question 1



Question 1



Question 1

2025 ■ Q1

Answer the following questions about magnesium.

(b) A student prepares a $1.85 \times 10^{-3} \text{ M}$ solution of $\text{Mg}(\text{NO}_3)_2(\text{aq})$ in beaker 1 and a $2.80 \times 10^{-4} \text{ M}$ solution of $\text{NaOH}(\text{aq})$ in beaker 2, as shown.

[Particle diagram: a magnesium ion, Mg^{2+} , at the center surrounded by six water molecules (H_2O), each oriented with its oxygen atom pointing toward the central Mg^{2+} ion and its two hydrogen atoms pointing outward.]

[Beaker 1: labeled " $1.85 \times 10^{-3} \text{ M Mg}(\text{NO}_3)_2(\text{aq})$ ", "Beaker 1", "35.00 mL".]

[Beaker 2: labeled " $2.80 \times 10^{-4} \text{ M NaOH}(\text{aq})$ ", "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 $1.85 \times 10^{-3} \text{ M}$ $\text{Mg}(\text{NO}_3)_2(\text{aq})$ with 50.00 mL of $2.80 \times 10^{-4} \text{ M}$ $\text{NaOH}(\text{aq})$, as shown in the diagram. Calculate $[\text{Mg}^{2+}]$ after the two solutions are combined but before any reaction takes place. (Assume that volumes are additive.)

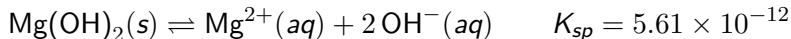
[Diagram of two conical/Erlenmeyer flasks being poured into an empty Beaker 3. Left flask: "35.00 mL", " $1.85 \times 10^{-3} \text{ M}$ ", " $\text{Mg}(\text{NO}_3)_2(\text{aq})$ ", labeled "Beaker 1". Right flask: "50.00 mL", " $2.80 \times 10^{-4} \text{ M}$ ", " $\text{NaOH}(\text{aq})$ ", labeled "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.



(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, $[\text{OH}^{-}] = 1.65 \times 10^{-4} \text{ M}$. 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 $\text{HNO}_3(aq)$ to decrease the pH of a saturated solution containing undissolved $\text{Mg}(\text{OH})_2(s)$. Does the amount of undissolved $\text{Mg}(\text{OH})_2(s)$ increase, decrease, or remain the same as the $\text{HNO}_3(aq)$ 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 $1.85 \times 10^{-3} \text{ M Mg(NO}_3)_2(\text{aq})$ and $2.80 \times 10^{-4} \text{ M NaOH(aq)}$ 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

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

Solution 1

(d)

Mark scheme

■ Using $M_1 V_1 = M_2 V_2$: $M_2 = \frac{(1.85 \times 10^{-3} \text{ M})(0.03500 \text{ L})}{0.03500 \text{ L} + 0.05000 \text{ L}} = 7.62 \times 10^{-4} \text{ M}.$

So $[\text{Mg}^{2+}]$ after combining but before reaction is $7.62 \times 10^{-4} \text{ M}.$

Solution 1

(e)

Mark scheme

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

(e)(i)

Mark scheme

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

Solution 1

(e)(ii)

Mark scheme

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

(e)(iii)

Mark scheme

- $Q (2.07 \times 10^{-11}) > K_{sp} (5.61 \times 10^{-12})$, 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 $\text{Mg}(\text{OH})_2(\text{s})$ will decrease. The H^+ from $\text{HNO}_3(\text{aq})$ reacts with OH^- , decreasing $[\text{OH}^-]$ and causing $Q < K_{\text{sp}}$. As a result, more $\text{Mg}(\text{OH})_2(\text{s})$ will dissolve until equilibrium is reestablished, resulting in less undissolved $\text{Mg}(\text{OH})_2(\text{s})$.