2025

AP® Chemistry

Sample Student Responses and Scoring Commentary

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Free-Response Question 1

- ☑ **Scoring Guidelines**
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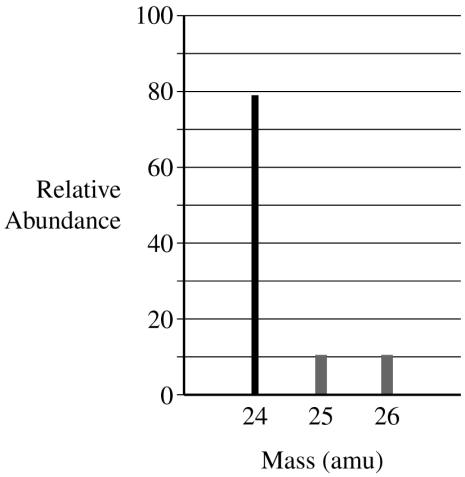
Question 1: Long Answer — 10 points

A (i) For the correct plotted lines: **Point 01**

The abundance for the two lines should be between 10 and 11.



(ii) For the correct answer: **Point 02**

Magnesium-26 has one more neutron than magnesium-25 does.

B (i) For a correct explanation: **Point 03**

The charge on the sodium ion is less than the charge on the magnesium ion. A smaller charge results in a weaker Coulombic attraction between Na^+ *and water.*

(ii) For a correct explanation: **Point 04**

The Na^+ *ion is larger than the* Mg^{2+} *ion, so the distance between the* Na^+ *and the oxygen on the water molecule will be greater. As distance increases, Coulombic attraction decreases.*

C For the correct calculated value: **Point 05**

$$pOH = -\log(2.80 \times 10^{-4}) = 3.553$$

$$pH = 14 - pOH = 14 - 3.553 = 10.447$$

D For the correct calculated value: **Point 06**

$$M_1V_1 = M_2V_2$$

$$M_2 = \frac{(1.85 \times 10^{-3}\,M)(0.03500\text{ L})}{(0.03500\text{ L} + 0.05000\text{ L})} = 7.62 \times 10^{-4}\,M$$

E (i) For the correct expression: **Point 07**

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

(ii) For the correct calculated value, consistent with part D and part E (i): **Point 08**

$Q = [Mg^{2+}][OH^-]^2 = (7.62 \times 10^{-4})(1.65 \times 10^{-4})^2 = 2.07 \times 10^{-11}$

(iii) For the correct prediction and justification, consistent with part E (ii). **Point 09**

Examples of acceptable responses may include the following:

- $Q > K_{sp}$, *so a precipitate will form.*
- *The concentration of the ions in solution (represented by Q) is greater than that of a saturated solution, so a precipitate will form.*

F For the correct answer and justification: **Point 10**

Decrease. The H^+ *from* $HNO_3(aq)$ *will react 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* $Mg(OH)_2(s)$.

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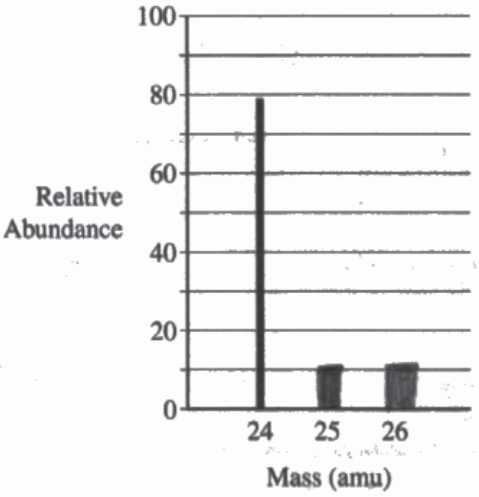
Question 1

Part A

i.



ii. Both magnesium-25 and magnesium-26 have 12 protons. Magnesium-26, however, has 14 neutrons while magnesium-25 has 13 neutrons. This additional neutron is responsible for the difference in mass.

Question 1 is continued on the next page.

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Question 1

Part B

From Coulomb's Law, $F_{coulombic} \propto \frac{q_1 q_2}{r^2}$.

i. Mg^{+2} has a larger oxidation number of +2 compared to +1 for Na^{+1}. From the numerator of Coulomb's Law, a larger charge means a larger force. Mg^{+2} has a larger positive charge than Na^{+1}, meaning Na^{+1} will have a weaker attraction to the partial negative charge of the O in water than Mg^{+2}.

ii. From the denominator of Coulomb's Law, a larger separation means a smaller Coulombic force or attraction. Both Na^{+1} and Mg^{+2} have 10 electrons, but Na^{+1} has one less proton than Mg^{+2} (11 vs. 12), so it will have less proton pull on each individual electron, resulting in a larger electron cloud and larger ionic radius for Na^{+1}. This larger radius for Na^{+1} results in a larger separation between the Na^{+1} ion and water molecule, resulting in a weaker attraction than with Mg^{+2}.

Part C

$$pOH = -\log[OH^-] = -\log(2.8 \times 10^{-4}) = 3.55$$

$$pH = 14 - pOH = 10.45$$

Question 1 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

Part D

$$\frac{\frac{1.85\times10^{-3}\text{ mol } Mg(NO_3)_2}{1\text{ L}}\times 0.0350\text{ L}}{0.085\text{ L}} = 7.62\times10^{-4}\text{ M } Mg(NO_3)_2$$

$$[Mg(NO_3)_2] = [Mg^{+2}] = 7.62\times10^{-4}\text{ M } Mg^{+2}$$

Part E

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

ii. $Q = (7.62\times10^{-4})(1.65\times10^{-4})^2 = 2.07\times10^{-11}$

iii. Since $Q > K$, the reaction will shift left to approach equilibrium, producing $Mg(OH)_{2(s)}$. So yes, a precipitate should form.

Question 1 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

Part F

The amount of undissolved $Mg(OH)_{2(s)}$ decreases. The added $HNO_{3(aq)}$ completely dissociates into $H^+_{(aq)}$ and $NO^-_{3(aq)}$. The increased $[H^+]$ decreases the $[OH^-]$ ($K_w = [H_3O^+][OH^-]$). The decreased $[OH^-]$ causes the equation from Part E to shift right from Le Chatelier's Principle, decreasing the amount of $Mg(OH)_{2(s)}$ left undissolved.

Continue to Question 2.

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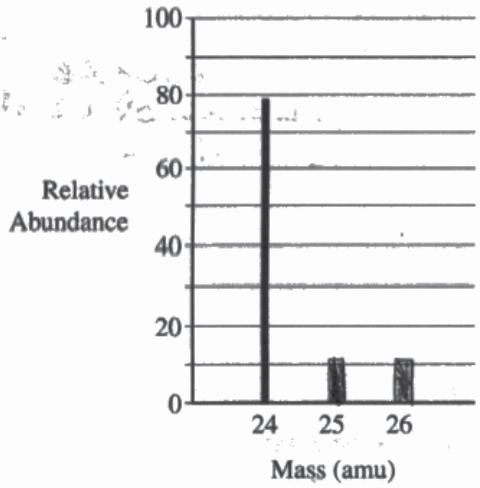
Part A

Question 1



i. $1 - .79 = .21 \div 2 = .105 \approx 10.5\%$

ii. Each isotope has a different number of neutrons resulting in each one having a different mass.

Question 1 is continued on the next page.

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Question 1

Part B

i. N_2^+ has a weaker attraction because it has a smaller charge, since Mg has a charge of +2 it is looking to gain 2 negative charges compared to N_2 only needing 1.

ii. N_2^+ is bigger than Mg^{+2} so the nucleus does not have as strong of a pull as Mg does.

Part C

$-\log(2.8\times10^{-4}) = pOH$

$pOH = 3.55$

$14 - 3.55 = 10.45$

$pH = 10.45$

Question 1 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

Part D

1.85×10^{-3} mol / .155 L = 6.475×10^{-5}

$Mg(NO_3)_2 + 2NaOH \longrightarrow 2NaNO_3 + MgOH$

Part E

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

ii. $Q = \frac{1.65 \times 10^{-4}}{6.475 \times 10^{-4}}$ $Q = .255$

iii. Yes, a precipitate should form because $Q > K$ so the reverse reaction is favored and $Mg(OH)_2(s)$ will form.

Question 1 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

Part F

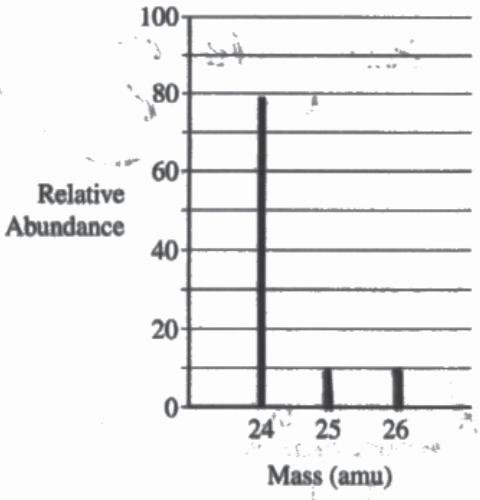
The amount of undissolved $Mg(OH)_2$ should increase because the solution started as $Mg(NO_3)_2$ so adding HNO_3 would add a common ion and decrease the K_{sp}.

Continue to Question 2.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Part A

Question 1



ii) Magnesium-25 has a +1 ionic charge making it's atomic mass less than that of Mg-24. Similarly, Mg-26 has a smaller mass than Mg-25 & Mg-24, because of a +2 ion. These ions cause the atom to go left a period and therefore lose electrons.

Question 1 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

Part B ✓

Coulombs Law: Magnitude of the attractive force varies directly with the product of opposite charges & indirectly w/ savare the distance btw. attractive forces.

i) The charge of the Na^+ ion has a weaker
ii) attraction to water than Mg^{2+} bcuz Mg is ~~dosen't~~ more electro negative.

ii) Mg^{+2} is larger because it has a bigger electron shell.

Part C ✓

$pH = -\log [H_3O^+]$

$pH = -\log [2.80 \times 10^{-4}]$

$pH = 3.553$

Question 1 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

Part D ✓

$Mg(NO_3)_{2\,(aq)} + NaOH_{(aq)} \rightarrow NO_3Na + (OH)_2Mg$

$[Mg^{2+}] = 28.57$

$\text{molarity} = \frac{\text{moles}}{L} = \frac{1}{0.035} = 28.57$

Part E ✓

i) $K_{sp} = \frac{[Mg][OH^2]}{[Mg(OH)^2]}$

ii) $Q = 5.5 \times 10^{-5}$ $\quad \frac{1.65 \times 10^{-4}}{3}$

iii) A precipitate will form because $Q > K$, and therefore there will be sufficient energy to create a precipitate.

Question 1 is continued on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

Part F ✓

Since the student added a strong acid, $HNO_{3(aq)}$, the amount of undissolved $Mg(OH)_{2(s)}$ increases because as a strong acid HNO_3 ionize completely in aqueous solutions, And therefore reacts wl $Mg(OH)_2$ and creates more product.

Continue to Question 2.

Question 1

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

NEW for 2025: The question overviews can be found in the *Chief Reader Report on Student Responses* on AP Central.

Sample: 1A
Score: 10

Point 01: 1
Part A (i): The point was earned for drawing two lines for 25 and 26 between 10 and 11 relative abundance.

Point 02: 1
Part A (ii): The point was earned for stating that magnesium-25 has 13 neutrons and magnesium-26 has 14 neutrons.

Point 03: 1
Part B (i): The point was earned for explaining that the magnesium ion "has a larger positive charge" than the sodium ion, causing the sodium ion to have a weaker attraction to the partial negative oxygen in water.

Point 04: 1
Part B (ii): The point was earned for explaining that sodium ion has a "larger radius," which "results in a larger separation between the Na^+ ion and water molecule, resulting in a weaker attraction."

Point 05: 1
Part C: The point was earned for correctly calculating pOH from the hydroxide ion concentration and calculating a pH value of 10.45. Significant figures are not assessed on this point.

Point 06: 1
Part D: The point was earned for correctly showing the initial magnesium concentration multiplied by $0.035\ L$ and divided by $0.085\ L$ to obtain $7.62 \times 10^{-4}\ M$ for the final concentration.

Point 07: 1
Part E (i): The point was earned for correctly showing magnesium and hydroxide with correct charges in brackets and squaring the hydroxide ion concentration.

Point 08: 1
Part E (ii): The point was earned for showing the correct substitution of concentrations into the K_{sp} expression to calculate 2.07×10^{-11} for Q.

Point 09: 1
Part E (iii): The point was earned for predicting that a precipitate will form due to Q being greater than K_{sp}.

Point 10: 1
Part F: The point was earned for stating that the H^+ from nitric acid will decrease the concentration of hydroxide ions, causing the reaction to shift to the right, decreasing the amount of undissolved $Mg(OH)_2(s)$.

Question 1 (continued)

Sample: 1B
Score: 5

Point 01: 1
Part A (i): The point was earned for drawing two lines of approximately 10.5 relative abundance.

Point 02: 1
Part A (ii): The point was earned for correctly relating the difference in masses of the isotopes to a different number of neutrons.

Point 03: 1
Part B (i): The point was earned for explaining that the sodium ion has a weaker attraction to water because it has a smaller charge than the magnesium ion. The additional statement about gaining negative charges is unrelated to Coulomb's law and does not negate earning the point.

Point 04: 0
Part B (ii): The point was not earned. While the response correctly states that the sodium ion is larger than the magnesium ion, the response refers to the pull of the nucleus, rather than the interparticle attraction between the ion and water.

Point 05: 1
Part C: The point was earned for correctly calculating the pOH and pH of the solution. Significant figures are not assessed on this point.

Point 06: 0
Part D: The point was not earned. The calculation setup written ($1.85 \times 10^{-3}\ \text{mol} = \text{mol} / 0.035$) shows a method to calculate the moles of magnesium ions, but it does not calculate the molarity after the two solutions are combined.

Point 07: 0
Part E (i): The point was not earned because the equilibrium expression provided includes $[2\text{OH}^-]^2$ instead of $[\text{OH}^-]^2$.

Point 08: 0
Part E (ii): The point was not earned. Even though the calculated magnesium concentration from part D was used in this calculation, the mathematical setup calculates the quotient of the ion concentrations instead of the product. Additionally, the hydroxide concentration is not squared in the response as it should be.

Point 09: 1
Part E (iii): The point was earned for correctly stating that the calculated value for Q from part E (ii) is greater than K and predicting that a precipitate will form.

Point 10: 0
Part F: The point was not earned because the response claims that the amount of undissolved magnesium hydroxide should increase. The justification that the nitrate is a common ion is flawed because neither nitrate nor hydrogen ions are present in the K_{sp} expression, and only a change in temperature could decrease the value of K_{sp}.

Question 1 (continued)

Sample: 1C
Score: 2

Point 01: 1
Part A (i): The point was earned for drawing both lines at a relative abundance of 10.

Point 02: 0
Part A (ii): The point was not earned because the response attributes the difference in mass to ion charges instead of to the number of neutrons.

Point 03: 0
Part B (i): The point was not earned because the response attributes the weaker ion/water attraction to the electronegativity of the magnesium rather than the magnitude of the ion charges.

Point 04: 0
Part B (ii): The point was not earned because the response incorrectly states that the magnesium ion is larger than the sodium ion. Additionally, no connection is made between the relative sizes of the ions and their interparticle distances to water molecules.

Point 05: 0
Part C: The point was not earned because the response substitutes the value of $[OH^-]$ as if it were $[H_3O^+]$. The calculated value shown is actually pOH, not pH.

Point 06: 0
Part D: The point was not earned because the response assumes that the moles of Mg^{2+} is 1 instead of multiplying the initial molarity and initial liters to determine the moles of Mg^{2+} in solution. Additionally, the response divides by the initial volume of $Mg(NO_3)_2$ instead of by the final volume of the mixture.

Point 07: 0
Part E (i): The point was not earned because the response includes a term for the concentration of solid $Mg(OH)_2$. Additionally, the charges of the ions are omitted, and the square term for $[OH^-]$ is inside the bracket instead of outside.

Point 08: 0
Part E (ii): The point was not earned because the response divides the concentration of OH^- by 3 instead of multiplying the square of the $[OH^-]$ by the concentration of Mg^{2+} calculated in part D.

Point 09: 1
Part E (iii): The point was earned for correctly stating that the calculated value for Q in part E (ii) is greater than K_{sp} and predicting that a precipitate will be formed.

Point 10: 0
Part F: The point was not earned because the response incorrectly attributes the decrease in solid magnesium hydroxide to a direct reaction between the acid and the solid magnesium hydroxide instead of with the hydroxide ions in solution.