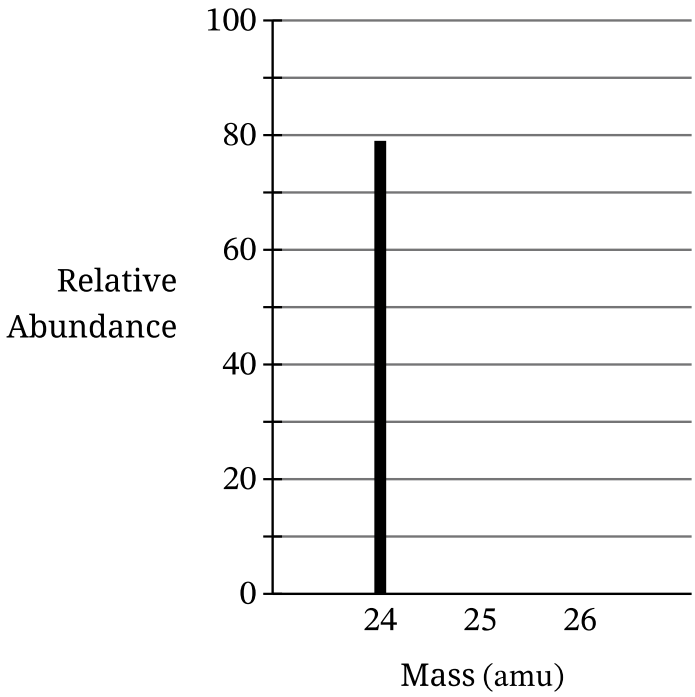
**1.** Answer the following questions about magnesium.

**A.** An incomplete mass spectrum for magnesium is shown in the diagram.

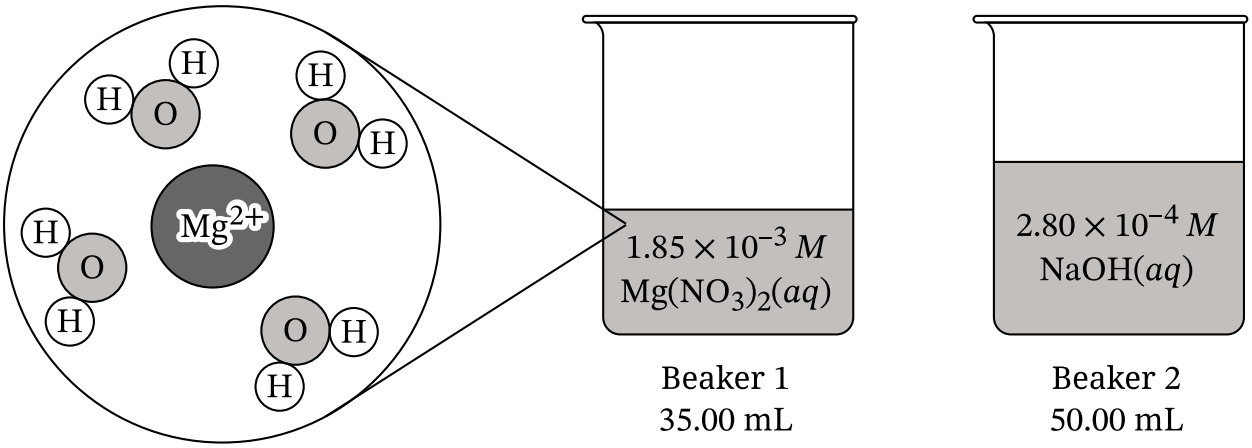



The percent abundance of magnesium-24 is 79%. The percent abundances of the other two natural isotopes of magnesium, magnesium-25 and magnesium-26, are approximately equal.

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.

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

A student prepares a $1.85\times10^{-3}\ M$ solution of $\mathrm{Mg(NO_3)_2}(aq)$ in beaker 1 and a $2.80\times10^{-4}\ M$ solution of $\mathrm{NaOH}(aq)$ in beaker 2, as shown.



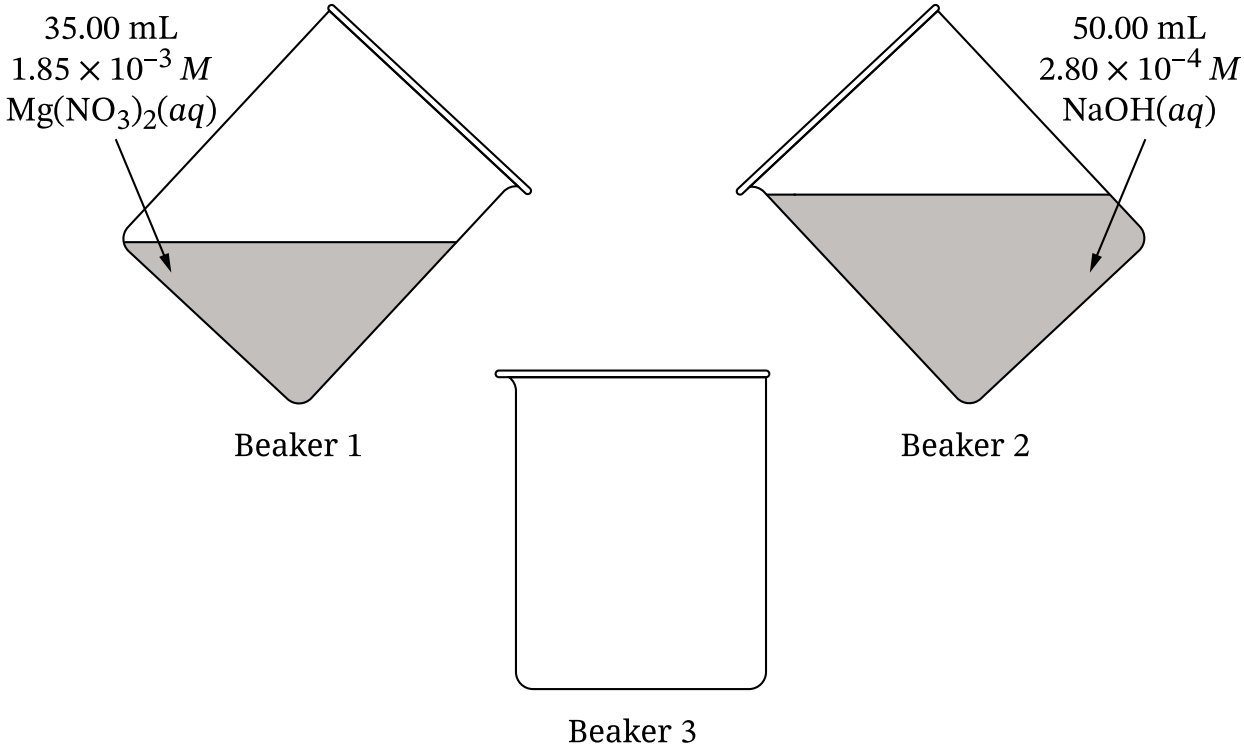

**B.** The particle diagram shown represents a magnesium ion, $\mathrm{Mg^{2+}}$, in beaker 1. A sodium ion, $\mathrm{Na^{+}}$, in beaker 2 has a weaker attraction to water than the $\mathrm{Mg^{2+}}$ does. Explain this phenomenon using Coulomb's law and each of the following.

i. The relative charge of the ions

ii. The relative radii of the ions

**C.** Calculate the pH of the solution in beaker 2.

**D.** A student combines 35.00 mL of $1.85\times10^{-3}\ M\ \mathrm{Mg(NO_3)_2}(aq)$ with 50.00 mL of $2.80\times10^{-4}\ M\ \mathrm{NaOH}(aq)$, as shown in the diagram. Calculate $\left[\mathrm{Mg^{2+}}\right]$ after the two solutions are combined but before any reaction takes place. (Assume that volumes are additive.)




**E.** The dissolution of magnesium hydroxide is represented by the following equation.

$$\mathrm{Mg(OH)_2}(s) \rightleftarrows \mathrm{Mg^{2+}}(aq) + 2\ \mathrm{OH^-}(aq) \quad K_{sp} = 5.61\times10^{-12}$$

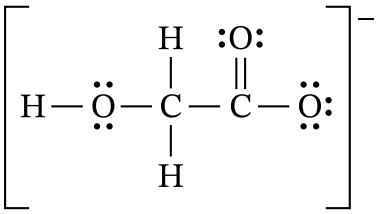
i. Write the expression for the solubility product constant, $K_{sp}$.

ii. After the two solutions are combined in beaker 3 as described in part D, but before any reaction takes place, $\left[\mathrm{OH^-}\right] = 1.65\times10^{-4}\ M$. Using your answer to part D, calculate the value of the reaction quotient, $Q$.

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

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

**7.** Answer the following questions about the glycolate ion, $C_2H_3O_3^-$, which acts as a base in aqueous solution. A Lewis diagram for the ion is provided.



**A.** On the Lewis diagram in part A, circle the atom that accepts the proton when the glycolate ion reacts with water.

When the glycolate ion reacts with water, it forms glycolic acid, $HC_2H_3O_3$, according to the following equation. The $K_b$ expression for the reaction is provided.

$$C_2H_3O_3^-(aq) + H_2O(l) \rightleftarrows HC_2H_3O_3(aq) + OH^-(aq) \qquad K_b = \frac{[HC_2H_3O_3][OH^-]}{[C_2H_3O_3^-]}$$

**B.** At 25°C, a $2.5\ M$ solution of glycolate is found to have $[OH^-] = 1.3 \times 10^{-5}\ M$.

i. Calculate the value of $K_b$ for the glycolate ion.

ii. Using your answer to part B (i), calculate the value of $K_a$ for glycolic acid at 25°C.

Glycolic acid can be produced from the hydrolysis of methyl glycolate, $C_3H_6O_3$. A proposed mechanism for the reaction is given.

Step 1: $C_3H_6O_3 + H_3O^+ \rightleftarrows C_2H_5O_3^+ + CH_3OH$

Step 2: $\underline{C_2H_5O_3^+ + H_2O \rightleftarrows HC_2H_3O_3 + H_3O^+}$

Overall: $C_3H_6O_3 + H_2O \rightleftarrows HC_2H_3O_3 + CH_3OH$

**C.** A student claims that $H_3O^+$ is a catalyst for the reaction. Do you agree or disagree? Justify your answer based on the mechanism given.

**STOP**

**END OF EXAM**

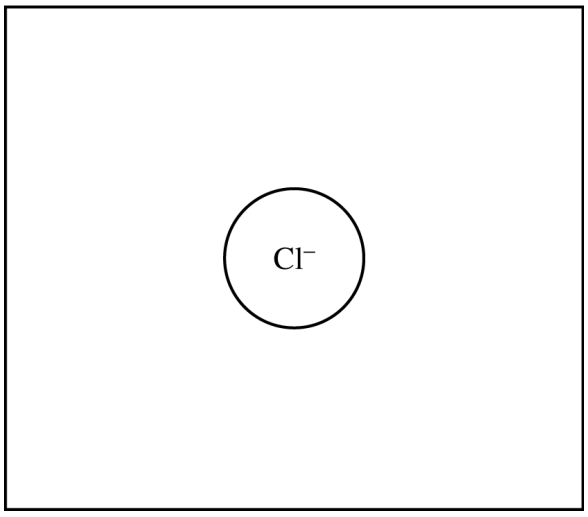
. $HCl$ is a molecular gas as a pure substance but acts as an acid in aqueous solution.

(a) A sample of $HCl(g)$ is stored in a rigid $6.00$ L container at $7.45$ atm and $296$ K.

(i) Calculate the number of moles of $HCl(g)$ in the container.

(ii) The rigid $6.00$ L container of $HCl(g)$ is cooled to a temperature of $271$ K. Calculate the new pressure, in atm, of the $HCl(g)$.

(b) When $HCl$ ionizes in aqueous solution, $Cl^-(aq)$ ions are formed. In the following box, draw <u>three</u> water molecules with proper orientation around the $Cl^-$ ion. Use  to represent water molecules.



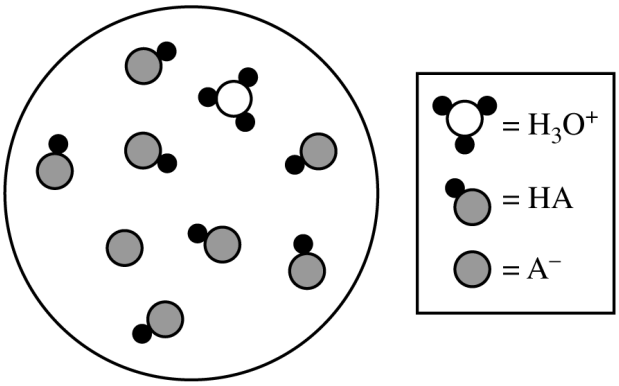

**GO ON TO THE NEXT PAGE.**

Continue your response to **QUESTION 5** on this page.

| Acid (HA) | Anion ($A^-$) | $K_a$ Value |
|---|---|---|
| $HNO_2$ | $NO_2^-$ | $5.6 \times 10^{-4}$ |
| HCl | $Cl^-$ | $2.0 \times 10^{7}$ |
| $HClO_4$ | $ClO_4^-$ | $1.6 \times 10^{15}$ |

The $K_a$ values for three acids are shown in the preceding table.

(c) The following particulate diagram represents the ionization of one of the acids in the data table. Water molecules have been omitted for clarity. Which acid ($HNO_2$, HCl, or $HClO_4$) is represented in the diagram? Justify your answer using the information in the table.

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