

Question 1

1. A student performs a calorimetry experiment with KCl.

Part A

Consider the K^+ ion in KCl.

- i. **Write** the complete ground-state electron configuration for the potassium ion, K^+ .
- ii. Which has the larger radius, the K^+ ion or the K atom? **Explain** your reasoning using principles of atomic structure.

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.

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

Part B

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

Part C

Use the data in the table to do the following.

- i. **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 $3.95 \text{ J/(g}\cdot^\circ\text{C)}$.)
- 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.

Part 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.

Part E

The student performs a second experiment using the same mass of water but 6.80 g of $\text{RbCl}(s)$ instead of 6.80 g of $\text{KCl}(s)$. 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.)

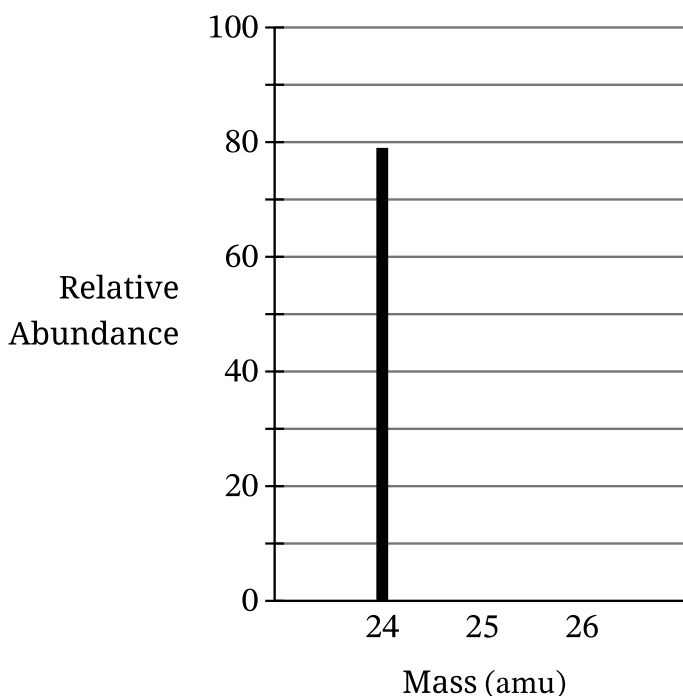
Part F

RbCl has a K_{sp} of 57 at 20°C .

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

1. Answer the following questions about magnesium.

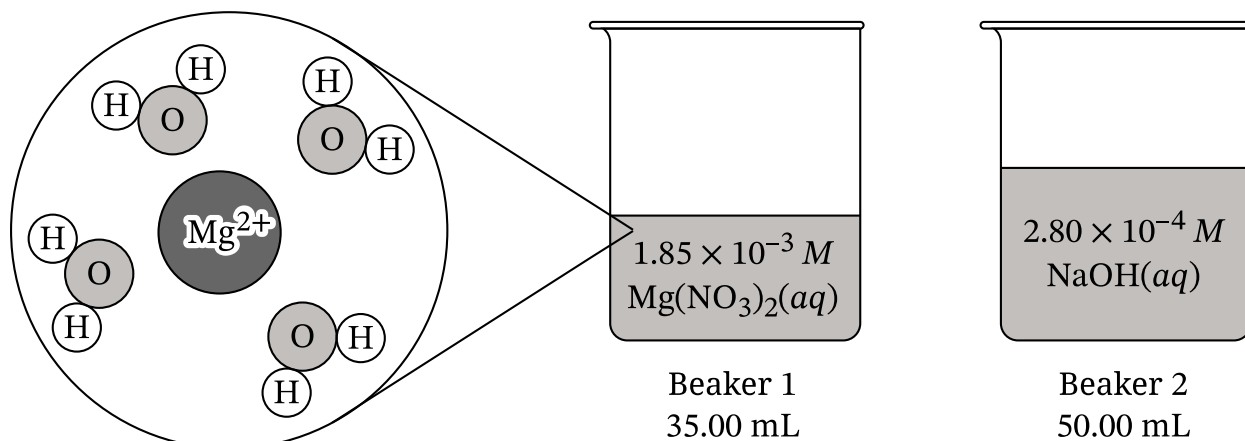
A. An incomplete mass spectrum for magnesium is shown in the diagram.



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

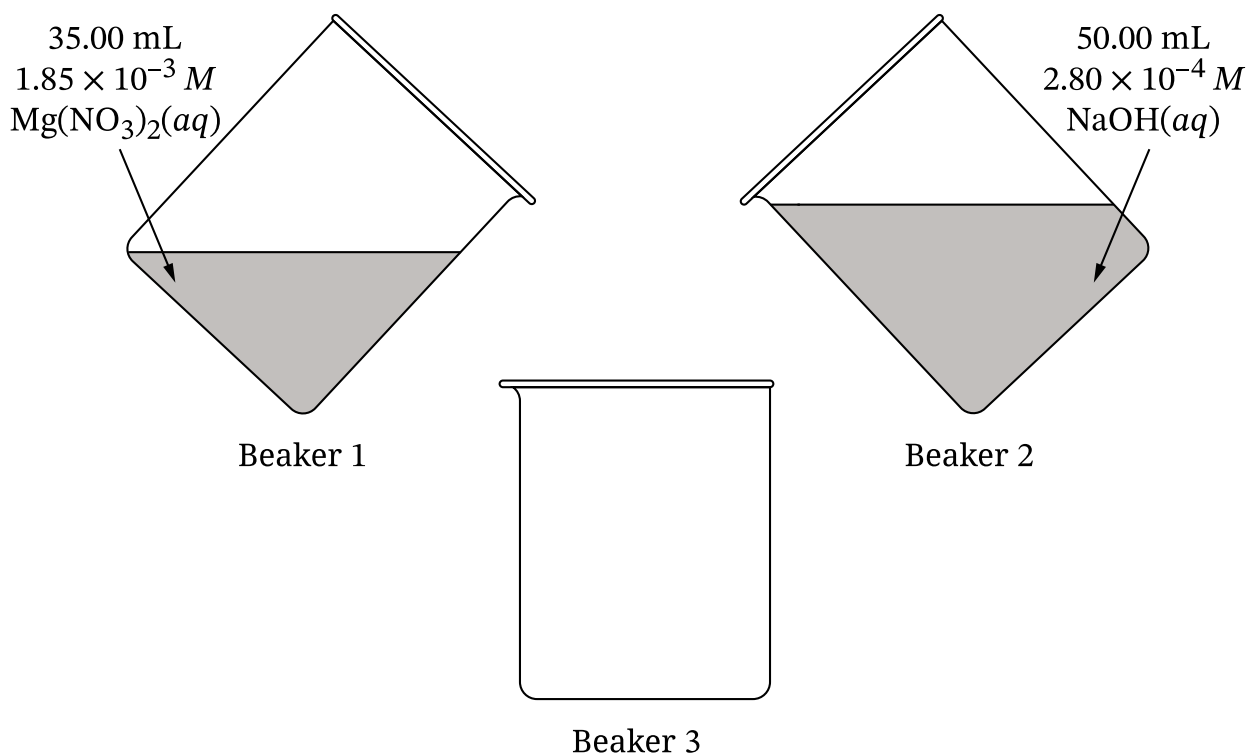


B. The particle diagram shown represents a magnesium ion, Mg^{2+} , in beaker 1. A sodium ion, Na^+ , in beaker 2 has a weaker attraction to water than the Mg^{2+} does. Explain this phenomenon using Coulomb's law and each of the following.

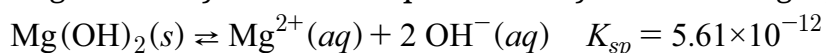
- i. The relative charge of the ions
- ii. The relative radii of the ions

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

- D. A student combines 35.00 mL of $1.85 \times 10^{-3} \text{ M Mg(NO}_3)_2(aq)$ with 50.00 mL of $2.80 \times 10^{-4} \text{ M NaOH}(aq)$, 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.)

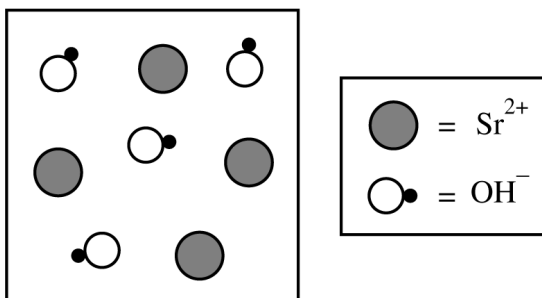


- E. The dissolution of magnesium hydroxide is represented by the following equation.



- Write the expression for the solubility product constant, K_{sp} .
 - 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 .
 - 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 $\text{HNO}_3(aq)$ to decrease the pH of a saturated solution containing undissolved $\text{Mg(OH)}_2(s)$. Does the amount of undissolved $\text{Mg(OH)}_2(s)$ increase, decrease, or remain the same as the $\text{HNO}_3(aq)$ is added? Justify your answer.

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



- (a) A student draws the particulate diagram shown to represent the ions present in an aqueous solution of $\text{Sr}(\text{OH})_2$. (Water molecules are intentionally omitted.) Identify the error in the student's drawing.
- (b) The student prepares a saturated solution by adding excess $\text{Sr}(\text{OH})_2(s)$ to distilled water and stirring until no more solid dissolves. The student then determines that $[\text{Sr}^{2+}] = 0.043\text{ M}$ in the solution.
- (i) Calculate the value of $[\text{OH}^-]$ in the solution.
- (ii) Calculate the value of K_{sp} for $\text{Sr}(\text{OH})_2$.

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Continue your response to **QUESTION 7** on this page.

- (c) The student prepares a second saturated solution of $\text{Sr}(\text{OH})_2$ in aqueous $0.10\text{ }M\text{ Sr}(\text{NO}_3)_2$ instead of water. Will the value of $[\text{OH}^-]$ in the second solution be greater than, less than, or equal to the value in the first solution? Justify your answer. (Assume constant temperature.)

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END OF EXAM

. A Lewis electron-dot diagram of the oxalate ion, $\text{C}_2\text{O}_4^{2-}$, is shown.

(a) Identify the hybridization of the valence orbitals of either carbon atom in the oxalate ion.

(b) Silver oxalate, $\text{Ag}_2\text{C}_2\text{O}_4(s)$, is slightly soluble in water. The value of K_{sp} for $\text{Ag}_2\text{C}_2\text{O}_4$ is 5.40×10^{-12} .

(i) Write the expression for the solubility-product constant, K_{sp} , for $\text{Ag}_2\text{C}_2\text{O}_4$.

(ii) Calculate the molar solubility of $\text{Ag}_2\text{C}_2\text{O}_4$ in neutral distilled water.

(iii) The molar solubility of $\text{Ag}_2\text{C}_2\text{O}_4$ increases when it is dissolved in $0.5\text{ M HClO}_4(aq)$ 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 $\text{Ag}_2\text{C}_2\text{O}_4(aq)$ in $\text{HClO}_4(aq)$.

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6. 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.

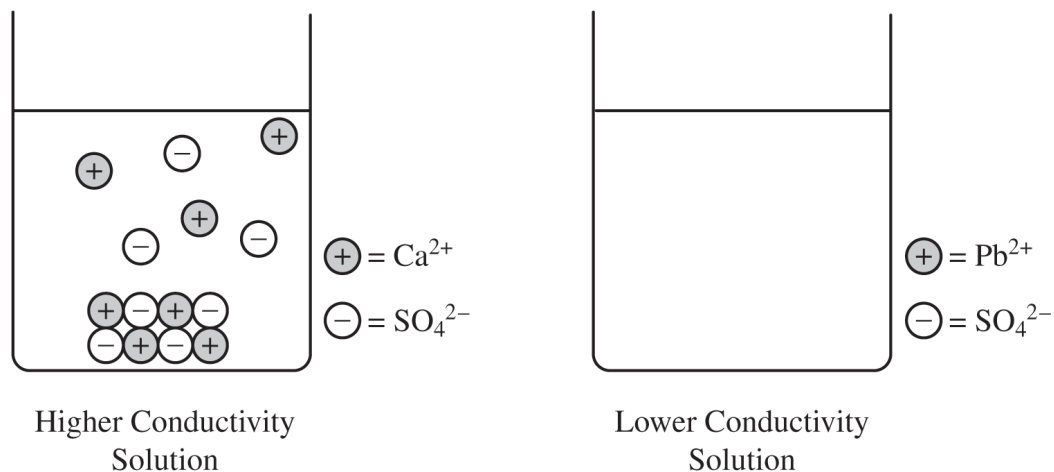
The student places excess $\text{CaSO}_4(s)$ in a beaker containing 100 mL of water and places excess $\text{PbSO}_4(s)$ in another beaker containing 100 mL of water. The student stirs the contents of the beakers and then measures the electrical conductivity of the solution in each beaker. The student observes that the conductivity of the solution in the beaker containing the $\text{CaSO}_4(s)$ is higher than the conductivity of the solution in the beaker containing the $\text{PbSO}_4(s)$.

(b) Which compound is more soluble in water, $\text{CaSO}_4(s)$ or $\text{PbSO}_4(s)$? Justify your answer based on the results of the conductivity test.

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The left side of the diagram below shows a particulate representation of the contents of the beaker containing the $\text{CaSO}_4(s)$ from the solution conductivity experiment.



(c) Draw a particulate representation of $\text{PbSO}_4(s)$ 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.

(d) The student attempts to increase the solubility of $\text{CaSO}_4(s)$ by adding 10.0 mL of 2 M $\text{H}_2\text{SO}_4(aq)$ to the beaker, and observes that additional precipitate forms in the beaker. Explain this observation.

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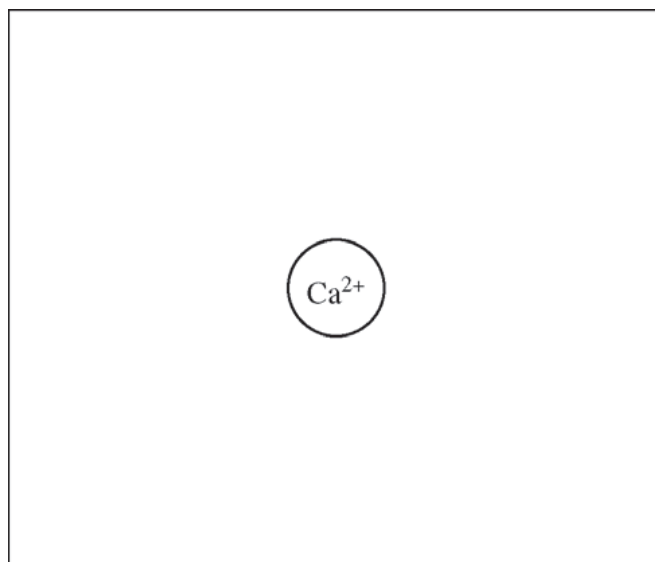
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6. Answer the following questions about $\text{Mg}(\text{OH})_2$. At 25°C , the value of the solubility product constant, K_{sp} , for $\text{Mg}(\text{OH})_2(s)$ is 1.8×10^{-11} .
- (a) Calculate the number of grams of $\text{Mg}(\text{OH})_2$ (molar mass 58.32 g/mol) that is dissolved in 100. mL of a saturated solution of $\text{Mg}(\text{OH})_2$ at 25°C .
- (b) The energy required to separate the ions in the $\text{Mg}(\text{OH})_2$ crystal lattice into individual $\text{Mg}^{2+}(g)$ and $\text{OH}^-(g)$ ions, as represented in the table below, is known as the lattice energy of $\text{Mg}(\text{OH})_2(s)$. As shown in the table, the lattice energy of $\text{Sr}(\text{OH})_2(s)$ is less than the lattice energy of $\text{Mg}(\text{OH})_2(s)$. Explain why in terms of periodic properties and Coulomb's law.

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

4. Answer the following questions about the solubility of $\text{Ca}(\text{OH})_2$ ($K_{sp} = 1.3 \times 10^{-6}$).
- (a) Write a balanced chemical equation for the dissolution of $\text{Ca}(\text{OH})_2(s)$ in pure water.
- (b) Calculate the molar solubility of $\text{Ca}(\text{OH})_2$ in $0.10 \text{ M Ca}(\text{NO}_3)_2$.
- (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 .



CHEMISTRY**Section II****7 Questions****Time—90 minutes****YOU MAY USE YOUR CALCULATOR FOR THIS SECTION.**

Directions: Questions 1–3 are long free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 7 minutes each to answer and are worth 4 points each.

Write your response in the space provided following each question. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.

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

1. 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 $0.20\text{ M Pb}(\text{NO}_3)_2(\text{aq})$ 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) For the chemical reaction that occurs when the precipitate forms,
 - (i) write a balanced, net-ionic equation for the reaction, and
 - (ii) explain why the reaction is best represented by a net-ionic equation.
 - (b) Explain the purpose of drying and weighing the filter paper with the precipitate three times.
 - (c) In the filtrate solution, is $[\text{K}^+]$ greater than, less than, or equal to $[\text{NO}_3^-]$? Justify your answer.
 - (d) Calculate the number of moles of precipitate that is produced in the experiment.
 - (e) Calculate the mass percent of I^- in the tablet.
 - (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.

- (g) A student in another lab also wants to determine the I^- content of a KI tablet but does not have access to $\text{Pb}(\text{NO}_3)_2$. However, the student does have access to 0.20 M AgNO_3 , which reacts with $\text{I}^-(aq)$ to produce $\text{AgI}(s)$. The value of K_{sp} for AgI is 8.5×10^{-17} .
- (i) Will the substitution of AgNO_3 for $\text{Pb}(\text{NO}_3)_2$ result in the precipitation of the I^- ion from solution? Justify your answer.
 - (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.