Selective Precipitation

Qualitative Analysis:
Separating & Identifying Metal Ions II

Precipitation and Separation of Ions

$CuS(s) \rightleftharpoons Cu^{2+}(aq) + S^{2-}(aq)$

- At any instant in time, $Q = [Cu^{2+}][S^{2-}]$.
  - ❖If $Q > K_{sp}$, precipitation occurs until $Q = K_{sp}$.
  - ❖If $Q = K_{sp}$, equilibrium exists.
  - ❖If $Q < K_{sp}$, solid dissolves until $Q = K_{sp}$.
- Based on solubilities, ions can be selectively removed from solutions.
- Consider a mixture of $Zn^{2+}(aq)$ and $Cu^{2+}(aq)$. CuS ($K_{sp} = 6 \times 10^{-37}$) is less soluble than ZnS ($K_{sp} = 2 \times 10^{-25}$), CuS will be removed from solution before ZnS.

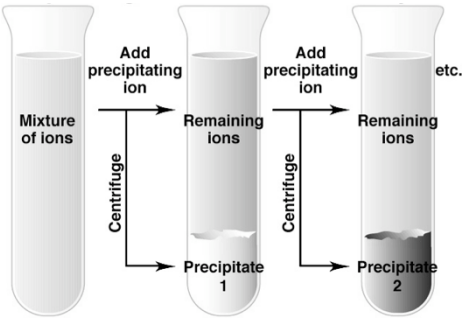
Precipitation and Separation of Ions

- As H_2S is added to the green solution, black CuS forms in a colorless solution of $Zn^{2+}(aq)$.
- When more H_2S is added, a second precipitate of white ZnS forms.

Selective Precipitation of Ions

- Ions can be separated from each other based on their salt solubilities.
- Example: if HCl is added to a solution containing Pb^{+2} and Cu^{2+}, the lead precipitates (K_{sp} for $PbCl_2$ is 1.6×10^{-5}) while the Cu^{2+} remains in solution.
- Removal of one metal ion from a solution is called *selective precipitation*.

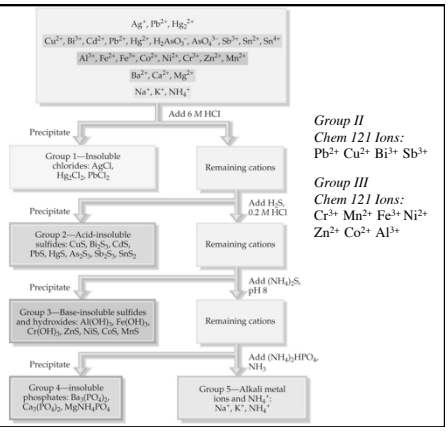
The General Procedure for Separating Ions in Qualitative Analysis



QUESTION

To separate a solution containing 0.000 10 M silver and 0.10 M lead ions, as done in some qualitative analysis separation schemes, a source of I^- may be slowly added to the mixture of ions. Which will precipitate first: AgI ($K_{sp} = 1.5 \times 10^{-16}$) or PbI_2 ($K_{sp} = 1.4 \times 10^{-8}$)? Also, what would be the concentration of I^- necessary to see that first precipitation?

A. AgI; $[I^-]$ would be 1.5×10^{-12} M
B. AgI; $[I^{-1}]$ would be 1.4×10^{-4} M
C. PbI_2; $[I^-]$ would be 1.4×10^{-7} M
D. PbI_2; $[I^-]$ would be 1.4×10^{-6} M



Chem 121: Possible Ions

Ion Group 1: Insoluble chlorides

Ag^+, Pb^{2+}

Ion Group 2: Acid-insoluble sulfides

Cu^{2+}, Sb^{3+}, Bi^{3+}, Pb^{2+}

Ion Group 3: Base-insoluble *sulfides* and hydroxides

Zn^{2+}, Mn^{2+}, Ni^{2+}, Fe^{2+}, Co^{2+} as sulfides,
and Al^{3+}, Cr^{3+} as hydroxides
(Cr^{3+} Mn^{2+} Fe^{3+} Ni^{2+} Zn^{2+} Co^{2+} Al^{3+})

Ion Group 4: Insoluble phosphates

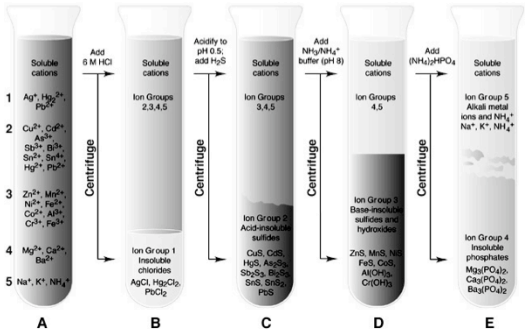
Ion Group 5: Alkali metal and ammonium ions

QUESTION

In the qualitative analysis scheme for metal ions, how are the Analytical Group II cations separated from the cations of Analytical Groups III?

A) by addition of HCl, forming insoluble metal chlorides
B) by addition of H_2SO_4, forming insoluble metal sulfates
C) by addition of H_2S in acidic solution, forming insoluble metal sulfides
D) by addition of H_2S in basic solution, forming insoluble metal sulfides or hydroxides
E) by addition of $(NH_4)_2CO_3$ or $(NH_4)_3PO_4$, forming insoluble metal carbonates or phosphates

Qualitative Analysis for Separating Cations

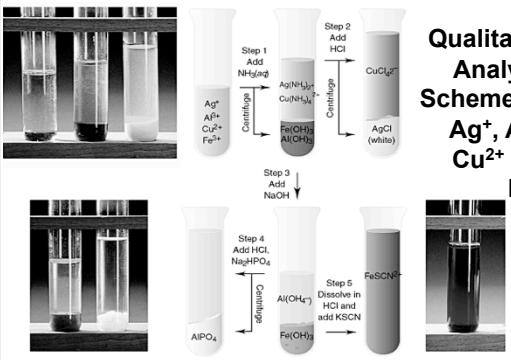


QUESTION

When a mixture containing cations of Analytical Groups I–III is treated with H_2S in acidic solution, which cations are expected to precipitate?

A) Analytical Group I only
B) Analytical Group II only
C) Analytical Group III only
D) Analytical Groups I and II
E) Analytical Groups II and III

A Qualitative Analysis Scheme for Ag^+, Al^{3+}, Cu^{2+} and Fe^{3+}



QUESTION

The cation M^{2+} reacts with NH_3 to form a series of complex ions as follows:

$M^{2+} + NH_3 \rightleftharpoons M(NH_3)^{2+}$ $\quad K_1 = 10^2$

$M(NH_3)^{2+} + NH_3 \rightleftharpoons M(NH_3)_2^{2+}$ $\quad K_2 = 10^3$

$M(NH_3)_2^{2+} + NH_3 \rightleftharpoons M(NH_3)_3^{2+}$ $\quad K_3 = 10^2$

A 1.0×10^{-3} mol sample of $M(NO_3)_2$ is added to 1.0 L of 15.0 *M* NH_3 ($K_b = 1.8 \times 10^{-5}$). Choose the dominant species in this solution:

A) M^{2+} B) $M(NH_3)^{2+}$ C) $M(NH_3)_2^{2+}$
D) $M(NH_3)_3^{2+}$ E) $M(NO_3)_2$