

Lab 3 - Analysis of Cations

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1 Pre-Lab

1.1 Purpose

1. Understand solubility and precipitation
2. Understand how these apply to the equilibrium constant, K_{sp}
3. Use analysis to identify metal cations in an unknown sample based on experimentation.
4. Perform a flame test.

1.2 Definitions

Analysis - An investigation of the characteristics of a substance to discover its identity.

Cation - A positively charged ion.

Reactants - The substances that go into a chemical reaction.

Products - The substances produced at the end of a reaction.

Solvent - A solvent is a substance that dissolves a solute, resulting in a solution.

Solubility - The maximum amount of a substance that will dissolve in a given amount of a solvent at a specified temperature.

Precipitation - Formation of a separable solid substance from a solution, either by converting the substance into an insoluble form or by changing the composition of the solvent to diminish the solubility of the substance in it.

Reagent - A substance or compound added to a system to cause a chemical reaction, or test if one occurs.

1.3 Equations / Keys

1.3.1 Insoluble compounds and their K_{sp} values

K_{sp} (solubility product constant) = The equilibrium constant for a solid substance dissolving in an aqueous solution. It represents the level at which a solute dissolves in solution. The more soluble a substance is, the higher the K_{sp} value it has.

Formula	Name	$K_{sp}(25^\circ C)$
$BaSO_4$	Barium sulfate	$1.08 * 10^{-10}$
$PbSO_4$	Lead sulfate	$2.53 * 10^{-8}$
$CaSO_4$	Calcium sulfate	$4.93 * 10^{-5}$
$Cu(OH)_2$	Copper hydroxide	$4.80 * 10^{-20}$
$Co(OH)_2$	Cobalt hydroxide	$1.00 * 10^{-15}$
$Ni(OH)_2$	Nickel hydroxide	$6.00 * 10^{-16}$
$Ca(OH)_2$	Calcium hydroxide	$6.50 * 10^{-6}$

1.3.2 Possible Sets

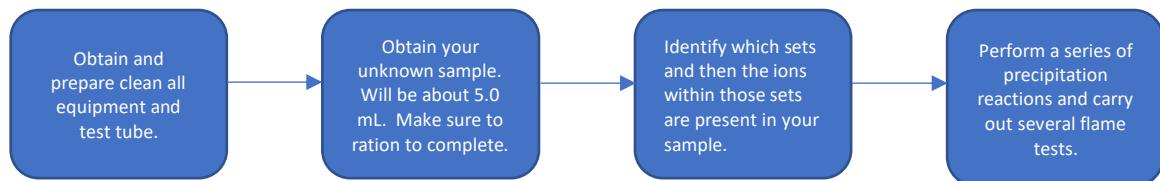
Set	Cations
1	Pb^{2+}, Ag^+
2	$Fe^{3+}, Cu^{2+}, Ni^{2+}, Co^{2+}$
3	Ba^{2+}, Ca^{2+}
4	K^+, Li^+

2 Flowcharts

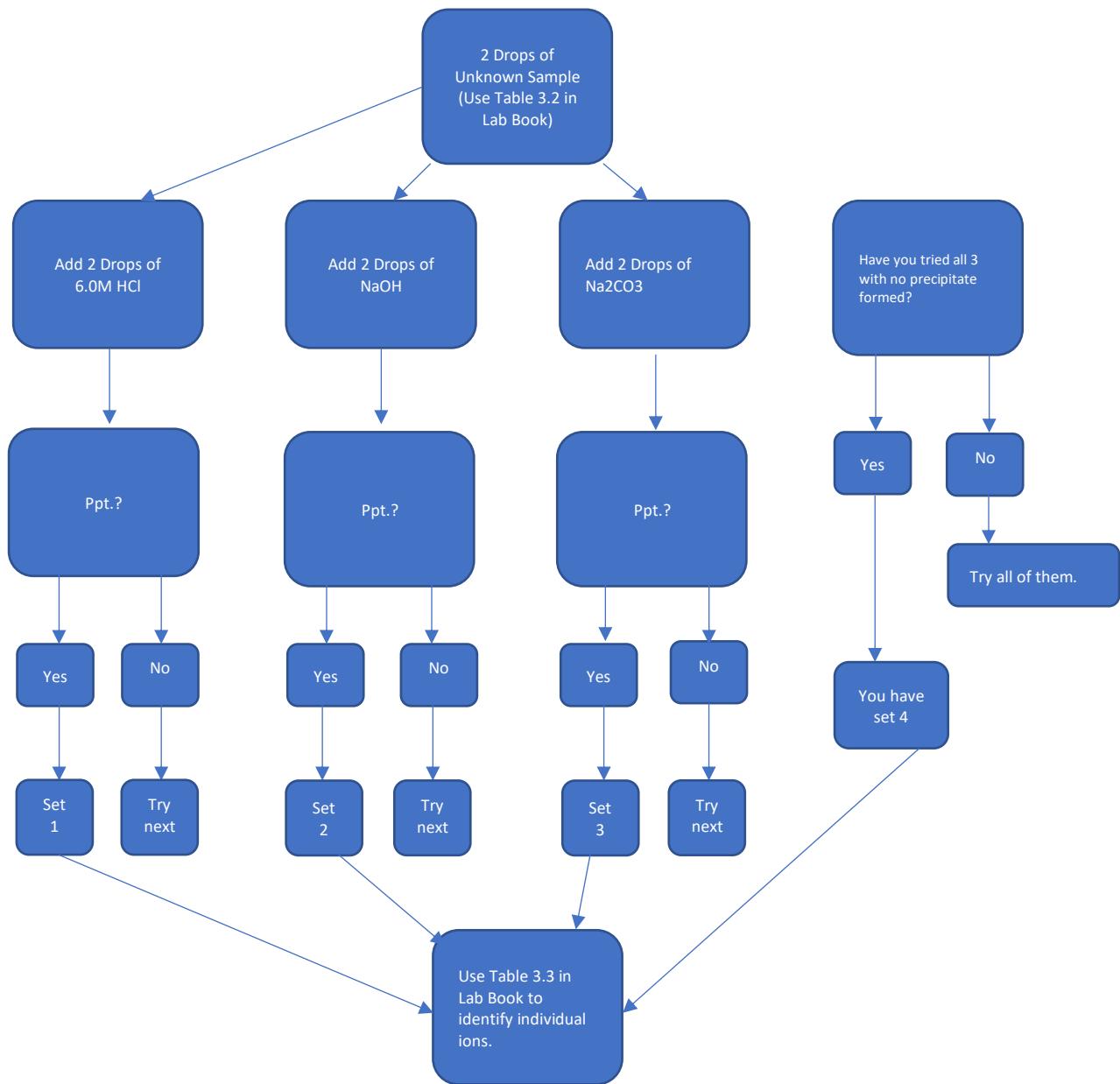
Please see the following page for flowchart.

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OVERVIEW



PART ONE – IDENTIFY SETS



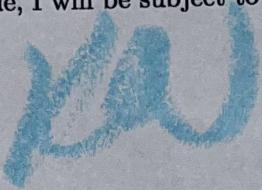
3 Waste Collection

Waste collection into pre-labeled containers: Ions that have been mixed with a reagent chemical have to be collected separately, in individual containers.

4 Declaration of Academic Integrity

I certify that this is my own work and I understand that if I am found to be in violation of the honor code, I will be subject to the highest penalty.

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5 Calculations

Reagent sets	Observation	Implication
6.0M HCl	Precipitation/white ppt.	I have set 1
0.10M Na ₂ CO ₃	White ppt.	I have set 1 or set 3
1.0M NaOH	Black ppt	I have set 2, CO ²⁺
<hr/>		
Ions		
.10M HCl	white ppt	✓ Ag ⁺
.10M K ₂ CrO ₄	Red/Brown ppt	✓ Ag ⁺
.10M KSCN	White ppt	✓ Ag ⁺
.10M KI	light yellow ppt.	✓ Ag ⁺
.10M K ₄ [Fe(CN) ₆]	light green ppt	✓ Co ²⁺
<hr/>		
1% dimethylglyoxime Solutions (DMG)	orange	No match / No precipitate
0.1 M Na ₂ SO ₄	Nothing	✓ Ca ²⁺
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Flame Test	Orange-red	✓ Ca ²⁺

I was given the unknown substance "J". Through my observations and implications, I determined that I had Set 1, Set 2, and Set 3. It was further determined that I had Ag^+ , Co^{2+} , and Ca^{2+} from each set, respectively.

G. C. 2-3 Analysis of Cations 25

Table 3-2: Observed reactions to identify the sets

Set No.	Ions	6.0 M HCl	1.0 M NaOH	0.1 M Na_2CO_3
1	Pb^{2+}	White ppt.	—	White ppt.
2	Ag^+	White ppt.	—	White ppt.
2	Fe^{3+}	—	Brown ppt.	—
	Cu^{2+}	—	Blue ppt.	—
	Co^{2+}	—	Green ppt. turns black	—
	Ni^{2+}	—	Green ppt.	—
3	Ba^{2+}	—	—	White ppt.
	Ca^{2+}	—	—	—
4	K^+	—	—	—
	Li^+	—	—	—

Note: For the reactions above, a "—" indicates that no precipitate can be seen.

Table 3-3: Observed reactions to identify the ions

Set No.	Ions	Specific Reactions	Flame Test
1	Pb^{2+}	+ K_2CrO_4 = yellow ppt. + KI = yellow ppt. + 0.10 M Na_2SO_4 = white ppt.	NA
	Ag^+	+ $KSCN$ = white ppt. + K_2CrO_4 = red/brown ppt. + 0.10 M HCl = white ppt. + KI = light yellow ppt.	NA
2	Fe^{3+}	+ $KSCN$ = deep red soln. eventually turns to white PPT + $K_4[Fe(CN)_6]$ = blue ppt.	NA
	Cu^{2+}	+ $K_4[Fe(CN)_6]$ = red ppt. + $KSCN$ = no ppt.	Blue
	Co^{2+}	+ $K_4[Fe(CN)_6]$ = grass green ppt.	NA
	Ni^{2+}	+ DMG = red/pink ppt. + $K_4[Fe(CN)_6]$ = green ppt.	NA
3	Ba^{2+}	+ K_2CrO_4 = yellow ppt. + 0.1 M Na_2SO_4 = white ppt.	NA
	Ca^{2+}	+ 0.10 M Na_2SO_4 = no ppt. + 1.00 M Na_2SO_4 = cloudy white ppt. with stirring (mix it thoroughly for 30 seconds or you might not be able to observe any reaction)	Orange-red
4	K^+	NA	Light purple
	Li^+	NA	Bright red

Discussion and Conclusion

I was given an unknown substance labeled “J” on the test tube. After receiving the 10 reagents to test my unknown substance with, I readied my well tray. I placed 3 drops of my unknown substance in 3 separate wells and used Table 3.2 to determine the sets. I added 2 drops of 6.0 M HCl to the first well and got a white ppt, implying that I had Set 1. Next, I added 2 drops of 0.10 M Na₂CO₃ to another well and got a white ppt again. This implied I could either have Set 1 or Set 3. Lastly, I added 2 drops of 1.0 M NaOH to the third well. This time I had a black ppt form, implying I had Set 3, most likely Co²⁺. There was nothing to indicate I had Set 4 in my unknown substance, so I eliminated the presence of Set 4.

At this point, I had 7 reagents left to test, so I added 3 drops of my unknown substance to 7 more wells. I preceded to add two drops of each remaining 7 reagents: 1 reagent to each of the 7 wells. For all the following tests, I also stirred the mixture for at least 30 seconds (excluding the flame test). Adding 0.10 M HCl and 0.10 M KSCN yielded a white ppt, 0.10 M K₂CrO₄ yielded a red/brown ppt, and 0.10 M KI yielded a light-yellow ppt. All 4 of these implied the presence of Ag⁺. Adding 0.10 M K₄[Fe(CN)₆] yielded a light-green ppt, which implied the presence of Co²⁺. Adding 0.10 M Na₂SO₄ yielded nothing, which implied Ca²⁺. When I added DMG something strange happened: the solution turned orange, but there was no ppt present. This confused me at first, so I repeated this portion of the experiment with a larger amount of each substance and stirred the mixture for a longer amount of time to see if a ppt would form. None did, so I ruled it out from implying a specific substance.

The last test I had was the flame test and the color was orange red, which confirmed my earlier finding of Ca^{2+} . In conclusion, based on these experiments I believe unknown sample "J" to contain Sets 1, 2, and 3. I further believe the cations Ag^+ , Co^{2+} , and Ca^{2+} are present.