

## ANALYSIS OF CATIONS

Qualitative analysis is based on the classification of ions into analytical groups. The cations are divided into five analytical groups. Each group has a **group reagent** (a compound that forms insoluble precipitates with cations of that group).

Classification of cations

Group	Cations	Group reagent	Precipitates
I	$\text{Ag}^+$ , $\text{Pb}^{2+}$	2M HCl	$\text{AgCl}$ , $\text{PbCl}_2$
II	$\text{Cu}^{2+}$ , $\text{Hg}^{2+}$	$\text{H}_2\text{S}$ (or AKT in acidic solution)	$\text{CuS}$ , $\text{HgS}$
III	$\text{Fe}^{3+}$ , $\text{Zn}^{2+}$	$(\text{NH}_4)_2\text{S}$ + ammonium buffer	$\text{Fe}_2\text{S}_3$ , $\text{ZnS}$
IV	$\text{Ca}^{2+}$ , $\text{Ba}^{2+}$	$(\text{NH}_4)_2\text{CO}_3$	$\text{CaCO}_3$ , $\text{BaCO}_3$
V	$\text{K}^+$ , $\text{Mg}^{2+}$ , $\text{NH}_4^+$	None	-

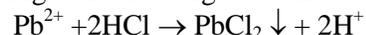
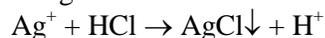
### GROUP I CATIONS

Group I: cations: silver ( $\text{Ag}^+$ ) and lead ( $\text{Pb}^{2+}$ ).

Group reagent - 1M HCl.

#### 1. Reaction with the group reagent

Put about 5 drops of  $\text{Ag}^+$  and  $\text{Pb}^{2+}$  salts into two separate test tubes. To each tube add 5 drops of 2M HCl.



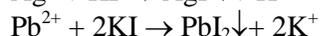
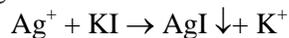
Insoluble chlorides will precipitate.

Observe the color of these precipitates.

#### 2. Characteristic reactions

##### 2.1. Reaction with potassium iodide (KI)

Put 5 drops of  $\text{Ag}^+$  and  $\text{Pb}^{2+}$  salts into two separate test tubes. To each tube add 5 drops of KI solution.

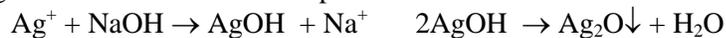


Insoluble iodides will precipitate.

Observe the color of these precipitates.

##### 2.2. Reaction with a strong base (NaOH)

Put 5 drops of  $\text{Ag}^+$  and  $\text{Pb}^{2+}$  salts into two separate test tubes. To each tube add 5 drops of NaOH solution.

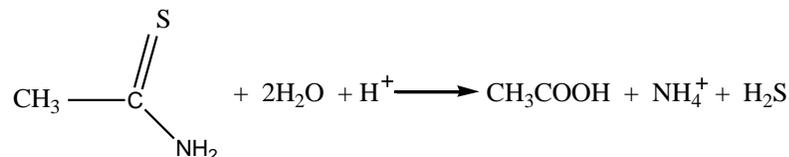


Observe the color of the precipitates.

## GROUP II CATIONS

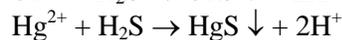
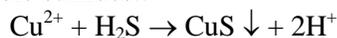
Group II: cations: copper ( $\text{Cu}^{2+}$ ) and mercury ( $\text{Hg}^{2+}$ ).

Group reagent -  $\text{H}_2\text{S}$ .  $\text{H}_2\text{S}$  is produced from AKT (thioacetamide) which hydrolyses to  $\text{H}_2\text{S}$  in acidic solution under heating:



### 1. Reaction with the group reagent

Put 5 drops of  $\text{Cu}^{2+}$  and  $\text{Hg}^{2+}$  salts into two separate tubes. To each tube add 5 drops of 2M HCl and 15 drops of AKT. Place the tubes in the boiling water bath.  $\text{H}_2\text{S}$  released from AKT converts cations of this group into insoluble sulfides:.

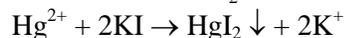


Observe the color of these precipitates.

### 2. Characteristic reactions

#### 2.1. Reaction with potassium iodide (KI)

Put 5 drops of  $\text{Cu}^{2+}$  and  $\text{Hg}^{2+}$  salts into two separate test tubes. To each tube add 5 drops of KI solution.

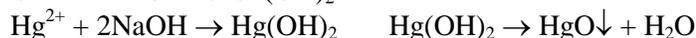
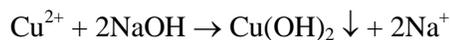


Insoluble iodides will precipitate.

Observe the color of these precipitates.

#### 2.2. Reaction with a strong base (NaOH)

Put 5 drops of  $\text{Cu}^{2+}$  and  $\text{Hg}^{2+}$  salts into two separate test tubes. To each tube add 5 drops of NaOH solution.



Observe the color of precipitates.

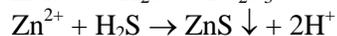
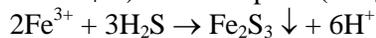
## GROUP III CATIONS

Group III: cations: iron ( $\text{Fe}^{3+}$ ) and zinc ( $\text{Zn}^{2+}$ ).

Group reagent -  $(\text{NH}_4)_2\text{S}$ .

### 1. Reaction with the group reagent

Put 5 drops of  $\text{Fe}^{3+}$  and  $\text{Zn}^{2+}$  salts into two separate tubes. To each tube add a few drops of ammonium buffer ( $\text{NH}_3 \cdot \text{H}_2\text{O} + \text{NH}_4\text{Cl}$ ) and 5 drops of  $(\text{NH}_4)_2\text{S}$ .



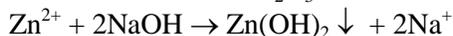
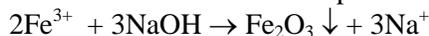
Insoluble sulfides will precipitate.

Observe the color of these precipitates.

## 2. Characteristic reactions

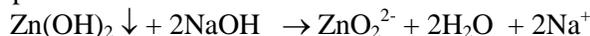
### 2.1. Reaction with a strong base (NaOH)

Put 5 drops of  $\text{Fe}^{3+}$  and  $\text{Zn}^{2+}$  salts into two separate test tubes. To each tube add 5 drops of NaOH solution.



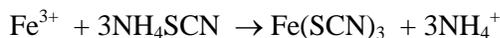
Observe the color of precipitates.

$\text{Zn}(\text{OH})_2 \downarrow$  is amphoteric and will dissolve in the excess of NaOH.



### 2.3. Reaction with ammonium thiocyanate ( $\text{NH}_4\text{SCN}$ )

Put 5 drops of  $\text{Fe}^{3+}$  and  $\text{Zn}^{2+}$  salts into two separate test tubes. To each tube add 5 drops of  $\text{NH}_4\text{SCN}$  solution.



Observe the color of  $\text{Fe}(\text{SCN})_3$  solution.

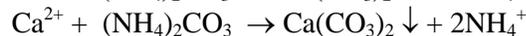
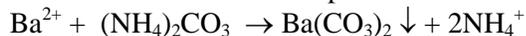
## GROUP IV CATIONS

Group IV: cations: barium ( $\text{Ba}^{2+}$ ) and calcium ( $\text{Ca}^{2+}$ ).

Group reagent –  $(\text{NH}_4)_2\text{CO}_3$ .

### 1. Reaction with the group reagent

Put 5 drops of  $\text{Ba}^{3+}$  and  $\text{Ca}^{2+}$  salts into two separate tubes. To each tube add a few drops of  $(\text{NH}_4)_2\text{CO}_3$ .



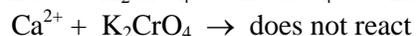
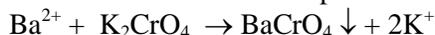
Insoluble carbonates will precipitate.

Observe the color of these precipitates.

## 2. Characteristic reactions

### 2.1. Reaction with potassium chromate $\text{K}_2\text{CrO}_4$

Put 5 drops of  $\text{Ba}^{3+}$  and  $\text{Ca}^{2+}$  salts into two separate tubes. To each tube add a few drops of  $\text{K}_2\text{CrO}_4$



Observe the color of  $\text{BaCrO}_4$  precipitate.

## GROUP V CATIONS

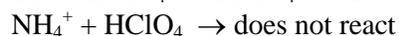
Group V: cations: potassium ( $\text{K}^+$ ), ammonium ( $\text{NH}_4^+$ ) and magnesium ( $\text{Mg}^{2+}$ ).

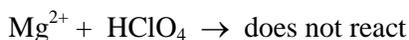
Group reagent – **no group reagent**

## 2. Characteristic reactions:

### 2.1. Reaction with perchloric acid $\text{HClO}_4$

Put 5 drops of  $\text{K}^+$ ,  $\text{NH}_4^+$  and  $\text{Mg}^{2+}$  salts into three separate tubes. To each tube add a few drops of  $\text{HClO}_4$





Observe the color of  $\text{KClO}_4$  precipitate.

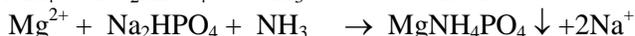
### 2.2. Reaction with Nessler reagent

Put 5 drops of  $\text{K}^+$ ,  $\text{NH}_4^+$  and  $\text{Mg}^{2+}$  salts into three separate tubes. To each tube add a few drops of Nessler reagent.

Only  $\text{NH}_4^+$  reacts with this reagent. Observe the color of the precipitate.

### 2.3. Reaction with sodium hydrogen phosphate $\text{Na}_2\text{HPO}_4$

Put 5 drops of  $\text{K}^+$ ,  $\text{NH}_4^+$  and  $\text{Mg}^{2+}$  salts into three separate tubes. To each tube add a few drops of  $\text{Na}_2\text{HPO}_4$  and a few drops of ammonia solution.



Observe the color of  $\text{MgNH}_4\text{PO}_4$  precipitate.

### Analysis of a solution containing one cation

- Identify the group of a cation.  
To a few drops of the tested solution add group reagent of group I.  
If the precipitate forms you have a cation from group I and you don't perform reactions with other group reagents.  
If there is no precipitate, to a new tube add a few drops of the tested solution and group II reagent.  
Repeat the operations until you find the group.  
If there is no precipitate with any of group reagents it means that your cation is from group V.
- Once you identified the group, perform all characteristic reaction for cations of that group and identify your cation.
- Write the Table as in the following example:

Identification of a cation		
OPERATION	OBSERVATION	CONCLUSION
t.s*. + HCl	No precipitate	No cation from group I
t.s. + HCl + AKT (heating)	Black precipitate	Cation from group II
t.s. + KI	Red precipitate	$\text{Hg}^{2+}$
t.s. + NaOH	Yellow precipitate	$\text{Hg}^{2+}$

\*tested solution

Student's No	$\text{Hg}^{2+}$
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- Under the table write the equation of all positive reactions that you performed.