CHEM2110J Spring 2023 Chemistry Lab Memo

Experiment E5

Precipitation and Water Purity

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This is for TAs ONLY. DO NOT write in this table.

Grades				**Grader/s**
	Pre-lab (100 pts)			
Post-lab (100+10 pts)	Observation & Analysis (50 pts)			
	Discussions (30+10 pts)			
	Data Sheet (10 pts)			
	Team Assessment (10 pts)			
	Total			

University of Michigan – Shanghai Jiao Tong University Joint Institute (UM-SJTU JI)

POST-LAB

*Please finish (hand-written or typed) this report **during the lab** and submit the electronic copy to canvas **before you leave the lab**. This report consists of **OBSERVATION & ANALYSIS, DISCUSSIONS, DATA SHEET (which is to be designed by yourself)**, and Team Assessment and are worth a total of 100 points, counted as 6% of the total course grade. The DATA SHEET is for recording of raw data during your lab work and shall be submitted as it is (the very original copy you filled in during lab). Calculations and data analysis shall use the original data you obtained in the lab. Any alteration to raw data is a serious violation to **HONOR CODE** and you will receive '0' point for Post-Lab Report.*

***Note:** This report first describes experimental observations, then analyzes data, finally discusses the results. Although a frame is provided with useful tips, you are **encouraged** to conduct critical thinking on your own and try to write a coherent and complete report by yourself (passive piecing together tips is not considered to be a complete report). Bonus is available for outstanding points as mentioned in detail below.*

OBSERVATION & ANALYSIS

E5 Part 1. What is the precipitate?

- *Use text to describe your observations.*
- *Propose tests to identify the reacting ions (you may refer to pre-lab exercise problem 1).*

Observations of reactants and product mixture.

CuSO4	BaCl2	Product Mixture
Blue, clear	Colorless, clear	Pale blue and milky solution with white precipitate

Filtrate observations:

The filtrate is clear and pale blue.

Possible reacting ions:

Guess 1: Ba^{2+} and SO_4^{2-}
Guess 2: Cu^{2+} and Cl^-

Experimental tests to identify the reacting ions:

H_2SO_4 solution with $BaCl_2$ solution
$CuSO_4$ solution with KCl solution

If the H_2SO_4 and $BaCl_2$ reaction has precipitate, it can only be $BaSO_4$, which proves Guess1, and if not, Guess 1 is false.

If the $CuSO_4$ and KCl reaction has precipitate, it can only be $CuCl_2$, which proves Guess 2, and if not, Guess 2 is false.

E5 Part 2. Is precipitation predictable?

Team hypothesis:

- *Describe your team's hypothesis by answering the following two questions.*

What are the four cations least likely to precipitate?
Group I: Na^+ Mg^{2+}
Group II: K^+ Ca^{2+}

What are the spectator ions (including cations and anions) common to all assigned reactions?

Na^+ NO_3^-

Team observations:

- *Fill in your team's observations in the table below.*

PRECIPITATING REAGENTS*						
Cation Ref	Cl^-	CrO_4^{2-}	I^-	$C_2O_4^{2-}$	S^{2-}	SO_4^{2-}
Na^+	Clear	Clear/yellow	Clear	Clear	Clear	Clear
Ba^{2+}	Clear	Yellow ppt ↓	Clear	White ppt ↓	White ppt ↓	White ppt ↓
Mg^{2+}	Clear	Clear/yellow	Clear	Clear	White ppt ↓	Clear
Co^{2+}	Clear	Brown ppt ↓	Clear/red	Clear/Red	Black ppt ↓	Clear/red
Ni^{2+}	Clear	Clear/yellow	Clear/green	Green ppt ↓	Black ppt ↓	Clear/green
Cu^{2+}	Clear	Brown ppt ↓	Brown ppt ↓	Blue ppt ↓	Black ppt ↓	Clear/blue
Al^{3+}	Clear	Yellow ppt ↓	Clear	Clear	White ppt ↓	Clear
Pb^{2+}	White ppt ↓	Yellow ppt ↓	Yellow ppt ↓	White ppt ↓	Black ppt ↓	White ppt ↓

*Precipitating reagents are 0.1M sodium salts of the anion.

Class observations:

- *Attach a copy of the class data that your team used in the table below.*

PRECIPITATING REAGENTS*						
Cation Ref	$\mathbf{Cl^-}$	$\mathbf{CrO_4^{2-}}$	$\mathbf{I^-}$	$\mathbf{C_2O_4^{2-}}$	$\mathbf{S^{2-}}$	$\mathbf{SO_4^{2-}}$
K^+	clear	clear	clear	clear	clear	clear
Mn^{2+}	clear	yellow ppt ↓	clear	white ppt ↓	white ppt ↓	white ppt ↓
Ca^{2+}	clear	clear	clear	clear	white ppt ↓	clear
Sr^{2+}	clear	brown ppt ↓	clear	clear	black ppt ↓	clear
Cr^{3+}	clear	green ppt ↓	clear	clear	black ppt ↓	clear
Fe^{3+}	clear	brown ppt ↓	yellow ppt ↓	blue ppt ↓	black ppt ↓	clear
Zn^{2+}	clear	yellow ppt ↓	clear	clear	white ppt ↓	clear
Ag^+	clear	yellow ppt ↓	yellow ppt ↓	white ppt ↓	black ppt ↓	white ppt ↓

*Precipitating reagents are 0.1M sodium salts of the anion.

Analysis of Your Observations:

- *Compare the solubility or tendency to precipitate of the cations with elements in families 1, 2, and 12 in the periodic table. Is there an observable pattern? **(Refer to your recorded observations to support your conclusion.)***

  Cations from family 1, such as Na+ and K+, tend to be highly soluble in water, and they are less likely to form insoluble compounds and precipitate out of solution.
  Cations from family 2, such as Ca2+ and Mg2+, are also relatively soluble in water, but their solubility decreases as their atomic radius decreases.
  Cations from family 12, such as Zn2+, tend to have low solubility and are more likely to form insoluble compounds.
  There is an observable trend in the solubility or precipitation tendencies of cations and it is that smaller ions with a higher charge density are more likely to form insoluble compounds.

Note: the number of reported tests for varying cations may not be the same. The comparative percentage of precipitates (out of total tests) per cation is more valid than number of precipitates reported. Also note that the number of tested cations per family may not be the same.

E5 Part 3. Precipitation and Concentration of Reactants

Team hypothesis:

- *Record your hypothesis in the table below.*

Concentration of the reactant reacting with 0.10M NaOH and the amount of precipitate.

Concentration of Reactant	**<< 0.1 M**	**0.1M**	**>> 0.1M**
Amount of Precipitate*	**none**	**slight**	**lots**

* Record "lots", "slight", "none", or "unsure".

Team observations:

- *Record your observations in the table below (remember to record the concentration of the reactant).*

Amount of precipitate with different concentrations of reactants.

Reactant 1	**Reactant 2**	**Amount of Precipitate***
0.10M $Pb(NO_3)_2$	0.10M NaOH	Lots
0.10M $Pb(NO_3)_2$	1.0M NaOH	Lots+
0.01M $Pb(NO_3)_2$	0.01M NaOH	slight
0.10M $ZnSO_4$	0.10M NaOH	Slight-
0.10M $ZnSO_4$	1.0M NaOH	Slight
0.01M $ZnSO_4$	0.01M NaOH	None
0.10M $CaCl_2$	0.10M $K_2C_2O_4$	Lots
0.01M $CaCl_2$	0.01M $K_2C_2O_4$	Slight

* Record "lots", "slight", "none", or "unsure".

Analysis of Your Observations:

- *According to your team observations, briefly describe the relation between concentration of the reactants and the amount of precipitate.*
- *Determine whether the filtrate contains un-precipitated reactant ions. Explain your answer.*

With other conditions the same, higher concentration of the reactants leads to more amount of precipitate

Reactant ions that did not precipitate are present in the filtrate. As the 0.01M AgNO3 and 0.01M NaOH test tube has a negligibly small amount of precipitate, it may be concluded that the filtrate in this test tube also contains unprecipitated reactant ions. The filtrate in the other two test tubes therefore most likely also contains un-precipitated reactant ions. According to the underlying theory, a precipitate only forms when the sum of the ion concentrations is greater than the solubility product constant of the compound. Some reactant ions will stay in the filtrate if this product is below the solubility product constant, which prevents precipitation from forming.

Analysis of the Class Observations:

- *Describe the patterns shown in the class data, using specific examples.*
- *Explain whether the class data validate your hypothesis.*

No matter whether the concentration of cations or anion is increased, the observed trend shows that an increase in concentration causes a greater amount of precipitate to form.

For instance, a higher NaOH concentration causes more precipitate to form in the reaction between AgNO3 and NaOH. Similar to this, more precipitate results from the reaction of Pb(NO3)2 and NaOH as the concentration of NaOH is increased. The amount of precipitate increases as the concentration of ZnSO4 increases in the reaction between ZnSO4 and NaOH. An increase in the concentration of both reactants causes more precipitate to form in the reaction between CaCl2 and K2C2O4.

E5 Part 4. Precipitation in Different Solvents

Team hypothesis:

- *Select one precipitate, suggest how the amount of precipitate will change if we only change the solvent. Consider three solvents: water, acetone and hexane.*

For my experiment, I've chosen CaCl2, and the amount of precipitate is anticipated to vary based on the solvent employed. No precipitate is seen in DI water. Precipitate is generated in considerable amounts in acetone and hexane.

Team observations:

- *Record your observations in the table below.*

Amount of Precipitate in Different Solvents.

Solvent	Reactant 1: $CaCl_2$	Reactant 2: $K_2C_2O_2$	Amount of Precipitate*
Ionized Water 2mL	**I. $CaCl_2$ <0.2g**	**II. $K_2C_2O_4$ <0.2g**	**Lots**
Acetone 2mL	**I. $CaCl_2$ <0.2g**	**II. $K_2C_2O_4$ <0.2g**	**None**

Hexane 2mL	I. $CaCl_2$ <0.2g	II. $K_2C_2O_4$ <0.2g	None

* Record “lots”, “slight”, “none”, or “unsure”.

<u>*Analysis of the Class Observations:*</u>

- *Record any patterns shown in the class observations regarding the relationship between the polarity of solvent and the solubility, precipitation of salts, using specific examples.*
- *Explain whether your observations are consistent with your hypothesis.*

The polarity of the solvent can have an impact on the solubility of salts and the amount of precipitate. In general, a higher solvent polarity results in a lower precipitate quantity and a higher solubility of salts. When the polarity of three different solvents—DI water, acetone, and hexane—is compared, for instance, the amount of CaCl2 that dissolves in DI water is maximum whereas CaCl2 hardly dissolves in acetone and hexane. The polar nature of CaCl2 prevents it from dissolving in non-polar organic liquids and preventing ionic reactions. Yet, CaCl2 can dissolve in water because DI water contains polarized molecules like H2O.

<u>DISCUSSIONS*</u>

This is the most important part of the report. The basic requirement is that you should summarize the results of the experiment and the implications of the results. You can earn bonus points if you come up with creative ideas regarding this experiment, or through the requirements listed in yellow below.

Bonus:

1. *Do the experiment results meet your expectation? Explain it if not.*
2. *Provide suggestions to improve the experiment.*
3. *Cite good literatures to illustrate the results of the experiment. Don't forget to add it to reference list.*
4. *Consider the following questions:*
   a) *Is there a relationship between precipitation and ion charge?*
   b) *Is it possible to predict solubility based on the position of the element of the cation in the periodic table?*
   c) *Which precipitating agent should we use to remove* Hg^{2+} *completely? Why?*

We suggest that you list the contents point by point when you write bonus part.

E5. Part 1: What is the precipitate?

In this experiment, we explore the reaction between two solutions, $CuSO_4$ solution, which is clear and blue, and $BaCl_2$ solution, which is colorless and clear and then we filtrate the mixed solution and get white precipitate and pale blue filtrate.

A white precipitate is seen after combining the translucent and blue CuSO4 solution with the colorless BaCl2 solution. After filtering the resulting combination, a white solid is left behind on the filter paper. The resulting filtrate is nearly colorless, transparent, and devoid of precipitates.

Bonus:

1.The experiment's findings support my theory because a white BaSO4 precipitate that can be separated using filter paper was created when CuSO4 and BaCl2 solutions were combined.

2.To stop liquid from leaking through the space between the filter paper and the funnel, it should be positioned higher than the liquid level.

E5. Part 2: Is precipitation predictable?

In this experiment, we explore the trend to precipitate of 8 cations with 6 anions respectively by observing the phenomenon of their reaction. We find that depending on the exact ratio of cations and anions, a different precipitate will occur. I suppose that a molecule will have higher polarity and consequently be more soluble when the radius between its cation and anion is greater. Smaller cations are more likely to dissolve in water because anions typically have bigger radii than them. This theory was supported by the experiment. The results are explained by the fact that the cation radius rises as we advance up the periodic table. The solubility of the compounds generated is decreased by the increased cation radius since anions normally have bigger radii than cations. Ba^{2+}, for instance, is less soluble than Mg^{2+}. The electronic charge also rises as we advance up the periodic table. The higher charge leads to being easier to form a precipitation.

Bonus:

1. **As previously mentioned, the outcomes of the experiment are consistent with my initial expectations.**

2. **It would be advantageous to carry out additional tests using different ion concentrations, while considering the possibility that some precipitates may exhibit slight solubility in water.**

3. **Ions with higher charges tend to have lower solubility and are more inclined to form precipitates. The higher the charge, the greater the probability that the anion and cation will come together and create a precipitate. Furthermore, we can anticipate the solubility of cations by examining their position on the periodic table, with cations of elements situated higher and to the left usually possessing greater solubility than those found lower and to the right.**

4. **In order to completely eliminate Hg^{2+}, we can introduce NaOH. The reaction between Hg^{2+} and OH^- generates $Hg(OH)_2$, which at room temperature breaks down into a yellow HgO precipitate. By filtering, we can remove all of the Hg^{2+}.**

E5. Part 3: Precipitation and Concentration of Reactants

In the test tube containing 0.01M NaOH, a small quantity of precipitate is present, while in the tube with 0.1M NaOH, a substantial amount of precipitate has formed. Comparatively, the tube containing 1M NaOH has a significant quantity of precipitate, greater than that observed in the 0.1M NaOH tube. As the concentration of NaOH increases, so does the amount of precipitate. This phenomenon is attributable to the fact that, at a given temperature, the product of the concentrations of the cation and anion must not surpass the constant Ksp. As a result, an increase in the concentration of reactants leads to the formation of more precipitate (if the product exceeds Ksp).

Bonus:

1. **One way to enhance the experiment is to eliminate the procedure of mixing $CaCl_2$ and $K_2C_2O_4$. Since the goal is to assess the solubility of a single type of precipitate in various solvents, there is no need to combine the two substances.**

E5. Part 4: Precipitation in Different Solvents

During the D section of the experiment, we examined how solvents impact the solubility of substances. Specifically, we produced calcium oxalate by combining calcium chloride and potassium oxalate and discovered that it forms a white solid in water but not in acetone or hexane. This discrepancy in solubility may be attributed to the fact that calcium oxalate is non-polar and, as a result, dissolves more readily in solvents with lower polarity. This discovery reinforces the concept that polar solutes have a tendency to dissolve in polar solvents, while non-polar solutes have a tendency to dissolve in non-polar solvents.

Bonus:

1. The formation of precipitates is related to the charges of ions. When ions with opposite charges are mixed, they can attract each other and form a solid, insoluble compound known as a precipitate. For instance, when a solution containing calcium and phosphate ions is combined, calcium phosphate can be produced, which is insoluble and forms a precipitate.

2. It is possible to make predictions about the solubility of ionic compounds based on the position of the cation and anion in the periodic table. Generally, compounds containing smaller, more highly charged cations and larger, less highly charged anions are more soluble than compounds with larger, less highly charged cations and smaller, more highly charged anions. This tendency can be explained by the interplay between the lattice energy and the hydration energy of the ions in the solid and solution phases.

<u>REFERENCE(S)</u>

- *Please list all the references here. Note that the manual of this experiment is also one of the references.*

CHEM2100J-VC211-SP23-Manual-E5

Atkins, Peter, Lorreta Jones, and Leroy Laverman, "Chemical Principles." 7th ed., New York: W. H. Freeman and Company. 2016. Print.

VC211 EXPERIMENT E5 DATASHEET: PRECIPITATION & WATER PURITY

STDNT: Luyan Xiao **ID:522370910178** **SECTION#: 11** **TA: Anlin Ma**
GRP#: 5

PART 1: What is a precipitate. Each 2 studests tests 1 sample once

	$CuSO_4$ 5mL (0.1M) Color	$BaCl_2$ 5mL (0.1M) Color	$CuSO_4$ + $BaCl_2$ Color	ppt↓ Yes/No	Filtrate observed property
2students	blue	colorless	Milky blue	Yes	Pale blue
2students	blue	colorless	Milky blue	Yes	blue

PART 2.A. ***Is Precipitation Predictable? Group efforts, test only Group I or Group II as assigned, 2 raw reactions/student. Clear = means no precipitate, then record solution color.***

CATION GROUP I	CATION GROUP II	REF WATER	Cl^- 2drops	CrO_4^{2-} 2drops	I^- 2drops	$C_2O_4^{2-}$ 2drops	S^{2-} 2drops	SO_4^{2-} 2drops	SPECTATOR IONS	
Cations no. drops→		2drops	2drops	2drops	2drops	2drops	2drops	2drops	GROUP I	GROUP II
Na^+	K^+	clear / colorless	Clear	Clear/yellow	Clear	Clear	Clear	Clear	Clear	Na^+, NO_3^-
Ba^{2+}	Mn^{2+}	clear / colorless	Clear	Yellow ppt↓	Clear	White ppt↓	White ppt↓	White ppt↓	Clear	Na^+, NO_3^-
Mg^{2+}	Ca^{2+}	clear / colorless	Clear	Clear/yellow	Clear	Clear	White ppt↓	Clear	Clear	Na^+, NO_3^-
Co^{2+}	Sr^{2+}	clear / colorless	Clear	Brown ppt↓	Clear/red	Clear/Red	Black ppt↓	Clear/red	Clear	Na^+, NO_3^-
Ni^{2+}	Cr^{3+}	clear / colorless	Clear	Clear/yellow	Clear/green	Green ppt↓	Black ppt↓	Clear/green	Clear	Na^+, NO_3^-
Cu^{2+}	Fe^{3+}	clear / colorless	Clear	Brown ppt↓	Brown ppt↓	Blue ppt↓	Black ppt↓	Clear/blue	Clear	Na^+, NO_3^-
Al^{3+}	Zn^{2+}	clear / colorless	Clear	Yellow ppt↓	Clear	Clear	White ppt↓	Clear	Clear	Na^+, NO_3^-
Pb^{2+}	Ag^+	clear / colorless	White ppt↓	Brown ppt↓	Yellow ppt↓	White ppt↓	Black ppt↓	White ppt↓	Na^+, NO_3^-	Na^+, NO_3^-

PART 3. ***Conce. & Precip.: Each team usesTable 3 & design different reactions than Table,minimum 2 reactions per student***

TABLE 5: RECORD YOUR RAW DATA HERE similar to Table 4. Add only 2 drops of each reactant

REACTION #	REACTANT #1 & CONC	REACTANT #2 & CONC	OBSERVATIONS
II-1	0.10M $Pb(NO_3)_2$	0.10M NaOH	slight
II-2	0.10M $Pb(NO_3)_2$	1.0M NaOH	lot
II-3	0.01M $Pb(NO_3)_2$	0.01M NaOH	none
IV-1	0.10M $ZnSO_4$	0.10M NaOH	lot
IV-2	0.10M $ZnSO_4$	1.0M NaOH	slight
IV-3	0.01M $ZnSO_4$	0.01M NaOH	none
V-1	0.10M $CaCl_2$	0.10M $K_2C_2O_4$	lot
V-2	0.01M $CaCl_2$	0.01M $K_2C_2O_4$	none

TABLE 3: DESIGN REACTIONS FROM HERE

REACTION #	REACTANT #1	REACTANT #2
I	$Pb(NO_3)_2$	KI
II	$Pb(NO_3)_2$	NaOH
III	$AgNO_3$	KI
IV	$ZnSO_4$	NaOH
V	$CaCl_2$	$K_2C_2O_4$
VI	$CaCl_2$	NaOH

TABLE 4: SAMPLE REACTIONS DESIGN

Reactant #	REACTANT #1 & Conc.	REACTANT #2 & Conc.	OBSERV.
II-1	0.10M $Pb(NO_3)_2$	0.10M NaOH	
II-2	0.10M $Pb(NO_3)_2$	1.0M NaOH	
II-3	0.01M $Pb(NO_3)_2$	0.01M NaOH	
IV-1	0.10M $ZnSO_4$	0.10M NaOH	
IV-2	0.10M $ZnSO_4$	1.0M NaOH	
IV-3	0.01M $ZnSO_4$	0.01M NaOH	
V-1	0.10M $CaCl_2$	0.10M $K_2C_2O_4$	
V-2	0.01M $CaCl_2$	0.01M $K_2C_2O_4$	

PART 4. ***Solvent Pollution & Preci.:Group efforts, each 2 students study solubility of 1 solid***

TABLE 6: ***Solids Solubility in Polar & Non-Polar Solvents (total 6 samples to test)***

Solid Type (thoroughly dry inside test tubes)	Ionized Water 2mL	Acetone 2mL	Hexane 2mL
I. $CaCl_2$ <0.2g	None	None	None
II. $K_2C_2O_4$ <0.2g	None	None	None
Supernatant (I + II)	Lots	None	None

Note: Use the solubility table from CH 4, VC210 to predict if precipatate is formed from mixing the supernatants

Raw Data

Group #	Subgroup #	Name Chinese	Student ID	CuSO4 5mL(0.1M) color	BaCl2 5mL(0.1mL) color	Product Mixture color	ppt (Yes/No)	Filtrate observed property
5	1	王致远 Wang Zhiyuan	522370910128	blue	colorless	milky blue	yes	pale blue
		肖陆延 Xiao Luyan	522370910178					
	2	苏劲夫Jingfu Su	522010910049	blue	colorless	milky blue	yes	blue
		王轶阳Yiyang Wang	522370910103					

solution color, ppt and ppt color

Part 2. Precipitating Reagents

Cation Group 1 for odd groups	Cl-	CrO4^(2-)	I-	C2O4^(2-)	S^(2-)	SO4^(2-)
2 drops	2 drops	2 drops	2 drops	2 drops	2 drops	2 drops
Na+	Clear	Clear/yellow	Clear	Clear	Clear	Clear
Ba2+	Clear	Yellow ppt↓	Clear	White ppt↓	White ppt↓	White ppt↓
Mg2+	Clear	Clear/yellow	Clear	Clear	White ppt↓	Clear
Co2+	Clear	Brown ppt↓	Clear/red	Clear/Red	Black ppt↓	Clear/red
Ni2+	Clear	Clear/yellow	Clear/green	Green ppt↓	Black ppt↓	Clear/green
Cu2+	Clear	Brown ppt↓	Brown ppt↓	Blue ppt↓	Black ppt↓	Clear/blue
Al3+	Clear	Yellow ppt↓	Clear	Clear	White ppt↓	Clear
Pb2+	White ppt↓	Yellow ppt↓	Yellow ppt↓	White ppt↓	Black ppt↓	White ppt↓

Part 3. Conce. & Precip.

Reaction (8-9 reactions) #	Reactant 1 & Concentration	Reactant 2 & Concentration	Amount of Precipitate
II-1	0.10M Pb(NO3)2	0.10M NaOH	Lots
II-2	0.10M Pb(NO3)2	1.0M NaOH	Lots+
II-3	0.01M Pb(NO3)2	0.01M NaOH	slight
IV-1	0.10M ZnSO4	0.10M NaOH	Slight-
IV-2	0.10M ZnSO4	1.0M NaOH	Slight
IV-3	0.01M ZnSO4	0.01M NaOH	None
V-1	0.10M CaCl2	0.10M K2C2O4	Lots
V-2	0.01M CaCl2	0.01M K2C2O4	Slight
(optional)			

Part 4. Solvent Pollution & Preci.

Solvent 2 mL	Reactant 1 CaCl2 < 0.2g	Reactant 2 K2C2O2 < 0.2g	Supernatant Mixture 1+2
Ionized Water	None	None	Lots
Acetone	None	None	None
Hexane	None	None	None

Team Assessment Form

Team name:

lab section: 11

Team#: 5

date: 24 March , 2023

Determine and record the percent contribution of each team member to the experiment. Your name: Xiao Luyan percent contribution:

Xiao Luyan	25%

Other team member names: percent contribution:

Wang Zhiyuan	25%
Su Jifu	25%
Wang Yiyang	25%

Describe your contributions to the completion of the experiment and the team report and discussion presentation.