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# Fundamental study for development of STEAM program based on recognition about ionization tendency of metal

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*Abstract*—**This study is to explore the recognition for pre-teachers about ionization tendency of metals (reactivity of metals) among the electrochemical field.**
**From this result, it was found that some pre-teachers did not have full understanding of ionization tendency and standard reduction potential. They are also confused the definition of ionization tendency with correlation on the periodic table or ionization energy.**
**It can be determined that this result might be due to the lack of detailed regulation of the level of usage of the contents related to ionization tendency in high schoolchemistry textbooks.**

***Index terms –Recognition, Ionization tendency, Chemistry textbook***

## I. INTRODUCTION

As for the concept of oxidation and reduction in the current Korean science curriculum, it has been explained as the exchange of oxygen in the elementary and middle school curriculum [1-4]. However, in the high school curriculum, its explanation involves the exchange of electron and the concept of oxidation state [1-4]. Since students cannot directly observe the exchange of electron or the change of oxidation state, many of them have several misconceptions [5]. Therefore, some studies have continued to be conducted, which includes the improvement of learning method to prevent students from have misconceptions regarding electrochemistry. Especially, Sanger [6-9] carried out the study to analyze textbooks ranging from science textbook to college textbook, and reported that the errors of the description in the textbooks made students have naturally misconceptions.

Now that science textbooks focus on making students easily understand basic scientific concepts, rather than exactly explaining scientific facts, the descriptions a bit away from scientific facts have been allowed. Nevertheless, a considerable number of explanations of basic concept about electrochemistryare away from scientific facts in the current high school chemistry textbook, even most of science teachers had their students accept those explanations without doubt. Therefore, students learning chemistry through those inaccurate textbooks cannot help but have chemical misconceptions; and even college or graduate students are making many mistakes in the research process due to those misconceptions. Further, this can discourage students from choosing chemistry when deciding their major, raising serious concerns among colleges.

There have been only few studies regarding ionization tendency of metal in domestic and abroad study, while studies about cell reaction or electrolysis reaction have been carried out by science education researchers[10-14].

Therefore, this study focused on recognition about ionization tendency of metal (the reactivity of metal) for pre-teachers (first and third year students), and connection between their recognition and the descriptions in the textbooks from which they learned chemistry in high school.Moreover, this study aimed to consider the problems with the descriptions in textbooks, and suggest ways to improve them, and examine the development of materials for changes in conceptions and its effects.

## II. METHODS

### *A. Research subjects*

The contents regarding ionization tendency of metal are in the latter half of Chemistry I and II. Subjects of this study became students in the department of chemistry education of A college in Busan City and B college in Gyeongsangnam-do who completed both Chemistry I and II courses: 16 first-year students and 21third-year students.

In order to analyze the descriptive passages in textbooks, what is needed was 10 types of the $6^{th}$ high school chemistry II textbooks [15-24] and eight types of the $7^{th}$ high school chemistry II textbooks [25-32]. Chemistry I textbooks were also analyzed because they include the contents of ionization tendency. In addition, high school chemistry textbooks used in foreign countries (six countries, 22 types) were analyzed as well [33].

### *B. Method of study*

The identification of the concepts regarding ionization tendency was followed by the development of a questionnaire based on the $7^{th}$science curriculum. The developed questionnaire was first modified through a pilot test, and then it was finally modified and supplemented through the reviews by two science education expert and chemistry teacher.

### *C.Contents of the questionnaire and analysis criteria*

The following analysis criteria were used to identify students' recognition and analyze the descriptive passages of textbooks.

1) Students' recognition about ionization tendency
2) Textbooks' descriptive passages about ionization tendency
3) The absoluteness and relativity of ionization tendency
4) Difference between ionization tendency and ionization energy

The response rate of multiple-choice questions was expressed as a percentage. As for questions requiring reasons or descriptions, analysis and categorization of the answers were conducted to present the number of respondents by category.

## III. RESULT AND DISCUSSION

### *A. Students' perception about ionization tendency of metal*

Pre-teachers were required to describe the definition of ionization tendency of metal in order to know what image they have about ionization tendency of metal. Their answers are largely divided into five categories as shown in table 1 and figure 1.

Major answers to the question about the ionization tendency of metal for first-year college students were "tendency for metal to become a positive ion" (50%) or "tendency for metal to be oxidized" (31%). Answers of a small number of first-year college students include "speed of electron". As for third-year college students, answers of 43%, the highest percentage, were "tendency for metal to become a positive ion" and "tendency for metal to be oxidized". Other answers include "element on the right and upper position in the periodic table is higher".

First-year college students who have not yet completed courses and some of third-year college students who have completed courses for their major over three years failed to describe the definition of ionization tendency. They misunderstood connection with the periodic table of elements or confused ionization tendency with ionization energy, suggesting they have no accurate understanding of ionization tendency.

<Table 1> Description of the definition about the ionization tendency of metal

| Type | Response ratio | |
|---|---|---|
| | 1st year students (n=16) | 3rd year students (n=21) |
| Tendency for metal to become a positive ion (A) | 8 (50%) | 9 (43%) |
| Tendency for metal to be oxidized (B) | 5 (31%) | 9 (43%) |
| Connection with reactivity of metal (C) | 2 (13%) | 0 (00%) |
| Others (D) | 0 (00%) | 3 (14%) |
| Non-response (E) | 1 (06%) | 0 (00%) |
| Total | 16 | 21 |

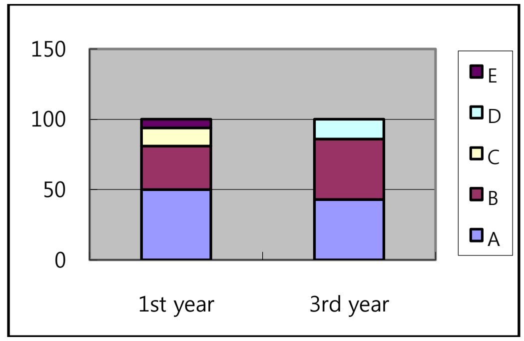



Figure 1. Digram for student's definition of the ionization tendency of metal.

And then, the descriptions about ionization tendency in textbooks (high school) were examined to investigate the reason of their misconceptions (table 2). The term 'ionization tendency' is never used in three among the 6th chemistry II textbooks, and only seven textbooks include the terms 'ionization tendency' or 'ionization series'. When it comes to how ionization tendency is dealt with in those seven textbooks, four of them contain many contents related to it, including the reactivity between each metal and the schematization of ionization tendency, while other three textbooks comparatively lack detailed explanation. As for the description methods of the 7th chemistry II textbook, three textbooks use the term 'ionization tendency' and give explanation about it (table 2).

In chemistry I textbooks, the differences in the reactivity of metals are explained as ionization tendency (table 3). In chemistry II textbooks, by contrast, the tendency to easily lose electrons of metal is defined as ionization tendency. And it says: "According to the measurement of standard reduction potential of half reactions of several metals, the arrangement in order of values from smallest to largest is equivalent to the list arranged in order to the tendency to lose electrons of metals from easiest to hardest. This order is referred to as ionization tendency".

By the definition, ionization tendency is the tendency for metal to become a positive ion in contact with liquid. The sequence of ionization is decided by the value of the standard electrode potential of metals/metallic cations in a solution. Ionization series mean the arrangement in order of the tendency to be ionized from largest to smallest [34].

<Table 2>Desciptions about the ionization tendency of metal on Korean chemistry II textbook (Eo is standard reduction potential)

| Textbook | Description | Metal | Eo |
|---|---|---|---|
| 6A | This is easy to get lost, or that are listed in the order in the electronic material on the oxidation-reduction reaction. | Zn Co Ni H Cu Ag | - |

| | | | |
|---|---|---|---|
| 6B | Eo value (-) sign means that the material is less prone to gain electrons than $H_3O^+$. Greater ionization tendency. Small ionization tendency. | Zn Pb Cu Ag | O |
| 6C | This shows the standard electrode potential for several electrode reactions. Here they tend to be larger upward toward reduction. And tend to be smaller toward the bottom of the reduction. | - | O |
| 6D | When you list as many standard reduction potentials of the half reaction values in ascending order by measuring the metal tends to be the order of the easiest metals to lose electrons. This sequence is referred to as the ionization tendency. | K Ca Na Mg Al Ze Fe Ni Sn Pb H Cu Hg Ag Pt Au | O |
| 6E | The sign of the value of the standard reduction potential (-) and the larger the absolute value tends to be a large active metal oxide. | - | O |
| 6F | The sign of the standard reduction potential value (-), it is difficult to accept electrons than protons, when the (+) means that are easy to accept electrons than protons. | - | O |
| 6G | Compare the turn order with a standard cathode ionization potential of metal. Easy to become ionized (Eo is small). | Zn Pb Cu Ag | O |
| 6H | Metal and water has properties meet taking place in the electronic solution to become cations. This characteristic is referred to as the ionization tendency. | K Ca Na Mg Al Zn Fe Ni Sn Pb H Cu Hg Ag Pt Au | O |
| 6I | The metal is the order of the tendency to lose an electron is called ionization. It has shown what the relationship is between the ionization potential and the standard reduction. | K Ca Na Mg Al Zn Fe Ni Sn Pb H Cu Hg Ag Pt Au | O |
| 6J | Electromotive force of the cell is larger the larger the difference in ionization tendency between metals used as an electrode. | K Ca Na Mg Al Zn Fe Ni Sn Pb H Cu Hg Ag Pt Au | O |
| 7A | We learned that the order of ionization tendency metals tend to lose electrons easily. | K Ca Na Mg Al Zn Fe Ni Su Pb (H) Cu Hg Ag Pt Au | - |
| 7B | Reactive metal which is oxidized to basing the e ions in the electrolyte solution is different depending on the type of metal. And then comparing the intensity we looked listed in order of strongest as shown in the following table. | K Ba Ca Nqa Mg Al Zn Fe Ni Sn Pb (H) Cu Hg Ag Au | - |
| 7C | The standard reduction potentials are likely to be shown the degree of reduction. So, the metal is susceptible to oxidation degree of the cation to lose electrons, that is can be compared to the ionization tendency of metal. The ionization tendency of these is in order. | K Ca Na Mg Al Zn Fe Ni Su Pb (H) Cu Hg Ag Pt Au | O |
| 7F | Atom of a metallic element tends to become a cation generally lose electrons. Therefore, the electrons in the metal are basing aqueous solution of cationic nature that become ionization. Metal represents the different ionization tendency in accordance with the type. Divided into groups as shown in Japanese textbooks are described. | K Ca Na Mg Al Zn Fe Ni Su Pb (H) Cu Hg Ag Pt Au | - |

Table 3 is a summary of the explanation regarding the ionization tendency in Chemistry I textbooks in the 6thand 7theducational curriculum. Six out of ten Chemistry I textbooks in the 6theducational curriculum dealt with ionization tendency. In the 7th educational curriculum, four textbooks dealt with the ionization tendency.

In the 6theducational curriculum, the number of metallic elements that reveal the ionization tendencies is smaller than that in Chemistry II textbook. In some textbooks, even the order of ionization tendencies opted out 5 metals and only displayed 10 metallic elements.

Chemistry II textbooks should naturally deal with deeper chemistry than Chemistry I; but this cannot explain that 5 metallic elements must be increased in order to explain ionization tendency. When ionization tendency is explained well enough with only around 10 ions in Chemistry I, Chemistry II should have no reason to suggest more elements.

Next, the numbers of metals suggested for the explanation of ionization tendency were analyzed. Four textbooks suggested 15 metals; two textbooks suggested 4 metals; and one textbook used 6 metals only to explain ionization tendency. The numbers of elements suggested differed in respective textbooks.

<Table 3> Desciptions about the ionization tendency of metal on Korean chemistry I textbook

| Textbook | Description | Metal |
|---|---|---|
| 6C | Reaction between metal and acid | - |
| 6D | Metal’s reactivity to water or acid show different | K Ca Na Mg Al Zn Fe Ni Sn Pb H |

| | | |
|---|---|---|
| | properties, such a metal reactivity is called as an ionization tendency. | Cu Hg Ag Pt Au |
| 6E | It is well known as they have a difference reactivity about dilute acid by metal kinds. Like as this, the reactivity of every metal is different. | K Ca Na Mg Al Zn Fe Sn Pb Cu Ag Au |
| 6F | Easy enough to lose electrons | Ca Na Al Zn Fe Sn Pb H Cu Ag Au |
| 6G | Iron could be lose electrons than copper and it have become cation. This phenomenon refers to the ionization tendency. | - |
| 6H | The size of the reactive is different according to the type of metal | K Ca Na Mg Al Zn Fe Ni Sn Pb H Cu Hg Ag Pt Au |
| 6I | The results from comparing the reactivity of different metal, the size is the same as the order table. And it is represented divided into water, and the acid and reaction, oxygen in air. | K Ca Na Mg Al Zn Fe Ni Sn Pb (H) Cu Hg Ag Pt Au |
| 6J | Some compare the reactivity of metals with hydrogen look like Figure. And it is represented divided into water, and the acid and reaction, oxygen in air. | K Ca Na Mg Al Zn Fe Sn Pb Cu Hg Ag Pt Au |
| 7A | Through a number of experiments compared the reactivity of the metal can be obtained the following results. | K Ca Na Mg Al Zn Fe Ni Sn Pb (H) Cu Hg Ag Pt Au |
| 7C | This tendency is called metal cations tend to lose electrons become ionized. The one big metal ionization tendency greater reactivity. This is listed in the order of ionization tendency compared to the metal and some hydrogen. | K Ca Na Mg Al Zn Fe Ni Sn Pb (H) Cu Hg Ag Pt Au |

***B. Perception about ionization level of Ni, Sn and Pb***

The students were required to answer the question about ionization capacity of Ni, Sn and Pb, which have intermediate values related to ionization tendency, among 15 typical metallic elements presented in textbooks (table 4 and figure 2).

The ionization of these metals in solutions does not happen easily in daily lives. However, 19% of first-year college students and 33% of third-year college students answered that these metals are easy to ionize.

The interviews with those students who answered that ionization easily happens showed that they thought “since these metals have intermediate values related to ionization tendency, the ionization levels are comparatively higher.” Thus, they answered that ionization is highly likely to happen even in solutions. Noticeably, third-year college students answered that ionization easily happens, considering about just the order of ionization tendency, though they completed courses for their major over three years. This is probably because they lack the accurate understanding of the physical meaning of standard reduction potential and the quantitative standard of ionization tendency of metal.

<Table 4> Students’ recognition about ionization tendency of Ni, Sn and Pb

| Ionization tendency of Ni, Sn and Pb | Response ratio | |
|---|---|---|
| | 1st year students (n=16) | 3rd year students (n=21) |
| Very easily ionize (A) | 0 (0%) | 0 (0%) |
| Easily ionize (B) | 3 (19%) | 7 (33%) |
| Hard to ionize (C) | 12 (75%) | 12 (57%) |
| Impossible to ionize (D) | 1 (6%) | 2 (10%) |
| Non-response (E) | 0 (0%) | 0 (0%) |
| Total | 16 | 21 |

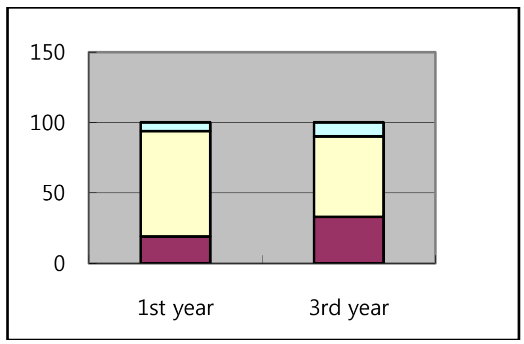



Figure 2. Diagram for students’ recognition about ionization tendency of Ni, Sn and Pb,

***C. Perception about the Absoluteness of the Order of Ionization Tendencies***

Next, students examined the absoluteness of the order of ionization tendencies. The following question was asked: “Can the order of ionization tendencies of 15 metals suggested in the textbooks are changed?”. And the question also required students to describe their answers for the next question: “If the order were able to change, in what conditions is the change possible?”

Among freshmen, 8 students (50%) responded that the order of ionization tendencies never changes, which suggests that most students believed in the invariability of the order of ionization tendencies. Among juniors, students (43%) believed in the order’s absoluteness, while 12 students (57%) responded that it could change. But their descriptions that supported their opinion were: “It could change in extreme temperature or pressure changes." or "In the case of finding the new element." However, this means they thought that changes in the absolute order of ionization tendencies in the normal conditions were impossible.

As for all Chemistry I and II textbooks in the 6thand 7theducational curriculum, no textbook mentioned the possibility for change in the order of ionization tendencies. Moreover, in the educational circumstances regarding the order of ionization tendencies of metals in high school, many classes simply required students to memorize the order of reactivity of metals, and did not let them understand the principles, such as solving the question of "How the differences of the reactivity of metals occur?" This is the major factor that makes students perceive the absoluteness of the metals" order.

<Table 5> Student responses about the possibility of change in the order of ionization tendencies

| Change possibility of order of ionization | Response ratio | |
|---|---|---|
| | 1st year students (n=16) | 3rd year students (n=21) |
| Impossible(A) | 8 (50%) | 9 (43%) |
| Possible(B) | 5 (32%) | 12 (57%) |
| Etc(C) | 3 (19%) | 0 (0%) |
| Total | 16 | 21 |

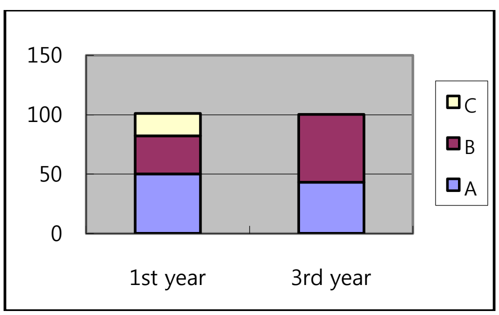



Figure 3. Diagram for students'recognition about the possibility of change in the order of ionization tendencies.

***D. Students' understanding about the relativity of ionization tendency***

Students' answers for the question that asked to schematize how the ionization tendencies of 15 metals were classified in 2 types. As it was mentioned previously, many students thought that they had declined uniformly, even when the differences of the standard reduction potentials of each metal, in other words, the differences in ionization degrees did not change uniformly.

Among their answers, the percentage of students who picked a picture of the uniform declination (Figure 4-a) was 75%(12/16) among freshmen, and 86%(18/21) among juniors; the step curve change (Figure 4-b) was chosen by 6%(1/16) of freshmen and 10%(2/21) of juniors. In the descriptions of the textbooks in the 6thand 7th educational curriculum, the order of ionization tendencies was suggested through indices that show whether the reactivity occurs well or not by varying the directions or sizes of pointers that are lined on the left and right or in the upper and lower parts of the graph. Such analogue expressions make students to understand the concept clearly by indicating that the differences in ionization degrees are clear and distinct between metals.

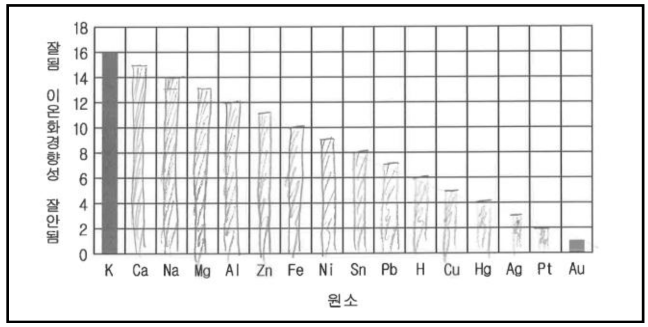



Figure 4-a). A diagram on relativity of ionization tendency.

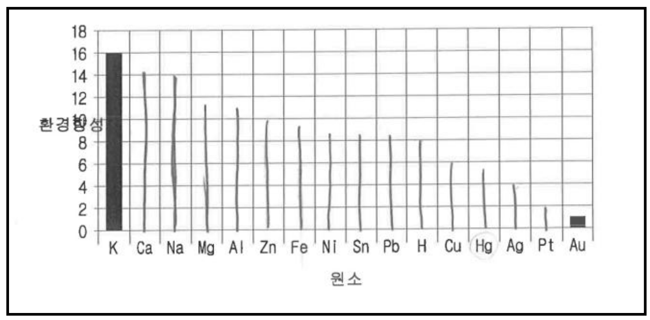



Figure 4-b). A diagram on relativity of ionization tendency.

***E. Perception about standard reduction potential***

In order to observe in what degree students understood standard reduction potential in its physical meaning, the following question was asked: "In what ways the standard reduction potentials of the metals that are ionized relatively easily (K, Ca, Na) and those of the metals more difficult to be ionized (Cu, Hg, Ag) in aqueous solution are measured?"

<Table 6> Students' recognition about the questionnaire: "How to measure standard reduction potential of K, Ca, Na?"

| Metals | How to decide standard reduction potentials | Response ratio | |
|---|---|---|---|
| | | 1st year students (n=16) | 3rd year students (n=21) |
| K, Ca, Na | Directly measured experiment results(A) | 2 (13%) | 3 (15%) |
| | Theoretical calculation results(B) | 5 (31%) | 1 (5%) |

| | | | |
|---|---|---|---|
| | Experiment results complemented by theoretical calculation results(C) | 9 (56%) | 17 (81%) |
| | No answer(D) | 0 (0%) | 0 (0%) |
| Cu, Hg, Ag | Directly measured experiment results(A) | 4 (25%) | 3 (15%) |
| | Theoretical calculation results(B) | 6 (38%) | 1 (5%) |
| | Experiment results complemented by theoretical calculation results(C) | 6 (38%) | 17 (81%) |
| | No answer(D) | 0 (0%) | 0 (0%) |

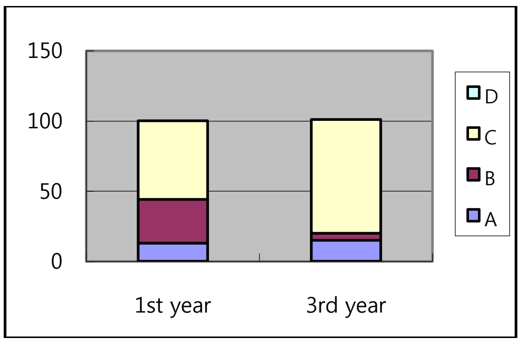



Figure 5. Diagram for students' recognition about "How to measure standard reduction potential of K, Ca, Na?".

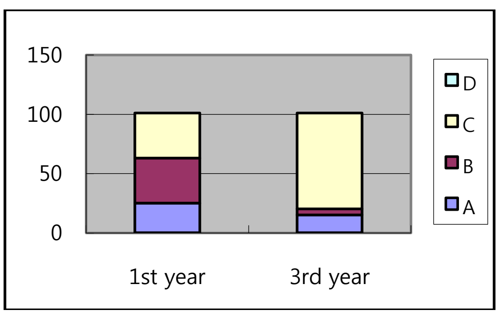



Figure 6. Diagram for students' Recognition about "How to measure standard reduction potential of Cu, Ag, Hg?".

Among the answers of college freshmen regarding K, Ca, Na, those with experiment results complemented by theoretical calculation results took up the most part (56%). And those with theoretical calculation results took up only 31%. Also, 81% of juniors chose the wrong answer of experiment results complemented by theoretical calculation results.

In high school, the reactivity of K, Ca, and Na is dealt with in Chemistry I, and most textbooks describe that the metals "make explosive reactions in contact with water." That is, considering the instability of the metals in aqueous solution, experiments cannot directly measure their standard reduction potentials; the numbers could only be acquired through theoretical calculation using the thermodynamics principles.

On the other hand, in answers regarding Cu, Hg, Ag, only 38% of freshmen and 81% of juniors responded with experiment results complemented by theoretical calculation results. And only 25% and 15% of students gave the scientific answer, which was that the figures are obtained from the directly measured experiment results.

In most textbooks in the 6$^{th}$ educational curriculum, in order to explain the ionization tendency of metals, standard reduction potential was considered as an explanation system. In the 7$^{th}$ educational curriculum, however, only one textbook explained the ionization tendency of metals based on the concept of standard reduction potential. The usage of the explanation system based on the concept of standard reduction potential has diminished in the 7$^{th}$ educational curriculum compared to the previous curriculum.

Standard reduction potential is the key factor that decides the reactions in cell reactions and electrolysis reactions. It could be said that standard reduction potential is no longer explained during the educational course of ionization tendency of metal, which are in the former part of the textbook, because the potential is mainly explained later in cell reactions and electrolysis reactions. However, the education period of standard reduction potential should be adjusted, in order to make it be dealt with in the part of the ionization tendency of metal.

According to the chemistry education course and guide for high school [1-4], oxidization and reduction are dealt with in the latter part of the Chemistry II textbook for high school students, which describes "By adopting the oxidation state, oxidization and reduction are dealt with, and chemical cells and electrolysis are explained as their practical examples." Regarding the explanation of the ionization tendency of metal, each textbook displays different explanations because science education course and guide does not specify the degree of explanation. In the 7$^{th}$ educational curriculum, the explanation regarding the ionization tendency of metal did not change dramatically. It does not change in terms of education period and content in the newly revised chemistry education course.

***F. Inquiry Activity 1: for understanding the variability of Ionization tendency***

To make students understand that the order of ionization tendencies is not absolute but subject to change according to experiment level or environment and that it is not simple to fix the order at an everyday life level, the following inquiry activity was developed and then applied in classes.

The main content of the inquiry activity is having students calculate the values of standard reduction potentials of some metals referring to reference materials such as handbook of chemistry. From the result of the activity, the students understand that the values of standard reduction potentials of some metals (Ag, Ce and Fe) calculated by in an experiment can turn out different from those presented in textbooks and that the order of ionization tendencies can change, too.

<Table 7> Relative differences between theoretical values of standard reduction potentials and actual experiment results according to the measurement conditions

| Electrochemical Reaction | Theoretical SRP | Standard Reduction Potential |
|---|---|---|
| $Ag^{+} + e^{-} = Ag$ | | +0.792 (1 M $HClO_4$) |
| | | +0.770 (1 M $H_2SO_4$) |
| $Ce^{4+} + e^{-} = Ce^{3+}$ | +1.710V | +1.700 (1 M $HClO_4$) |
| | | +1.600 (1 M $HNO_3$) |
| | | +1.440 (1 M $H_2SO_4$) |
| $Fe^{3+} + e^{-} = Fe^{2+}$ | +0.771V | +0.710 (0.5 M HCl) |
| | | +0.680 (1 M $H_2SO_4$) |
| | | +0.530 (10 M HCl) |

Table 7 shows the comparison between the values of standard reduction potentials of some metals presented in the handbook of chemistry (reference material) and those calculated under various experiment environments. For example, as for cesium (Cs), when the solution is 1 M $HClO_4$, the experiment result turns out 1.700V which has a difference of 10mV with the theoretical result. When the solution is 1 M $H_2SO_4$, a relative difference turns out 270 mV (reference material). In the case of Fe and Ag, the table suggests that the difference between experiment results and theoretical results of standard reduction potentials vary from 90 mV at minimum and to 241mV at maximum, according to the conditions under which the experiment is carried out.

The experiment results of standard reduction potentials presented in Chemistry textbooks can be obtained when the experiment conditions are adjusted to those under which the theoretical results were calculated and when using expensive equipment. But, if the experiment was done under the usual level of environment such as that of chemical experiments in middle or high schools, or that of general chemistry experiments in universities and using old measuring equipment, the difference with the theoretical results would be widened. There is also a study reporting that after the measurement of the values of standard reduction potentials of various metals in aqueous solution, which was carried out in a high school-level laboratory, the ionization tendencies of the metals turn out as follows: Zn > Fe > Al >Pb> Ni > Cu > Ag.

The measurement results contributed to the students' understanding that even the metals of the same kinds could have different values of standard reduction potentials by up to 200 mV according to the change of solutions used in measurement. Also, they realized that the metals having relative values of standard reduction potentials by up to 200 mV, it was not appropriate to consider the order of their ionization tendencies as absolute at an everyday life level. [41-43]

### *G. Inquiry Activity 2: for understanding the variability of the order of ionization tendencies*

Through the above inquiry activity, the students obtained a just understanding on the non-absoluteness of the order of ionization of metals presented in textbooks. However, they performed the second inquiry activity to apply this to the fifteen kinds of metals used in their textbooks.

Table 8 shows the differences between the standard electrode potentials of the metals used to explain ionization tendency in the handbook of chemistry (reference material) and those of their adjacent metals. As reviewed above, in case that values of standard electrode potentials are within 200 mV, between the alkaline earth metals, K and Ca; and Ca and Na, the differences are 85mV and 126 mV, respectively. In the case of Fe and Ni, the difference is only 189 mV and that between Ni and Sn indicates 119 mV, and in particular, between Sn and Pb, the difference is only 12 mV. The difference between the two nonmetals, $H_2$ and Pb is also just 126 mV. Especially, the difference of the standard reduction potentials between Hg and Ag turns out the least: 3 mV. The difference of 3 mV is narrower than the scope of experiment errors (±21 mV) calculated in the repetitive measurements of this inquiry process. This must be understood by students. And the descriptions in chemistry textbooks that give an absolute order on these relative standard reduction potentials are not scientific. Understanding was given that the difference of standard reduction potentials between the metals suggested in textbooks are between 12 mV to 189 mV which means that the order of ionization tendencies in everyday life has clear potential to change per the condition of measurement solution and that the order of ionization tendencies of these metals cannot be set in stone.

<Table 8> Standard Reduction Potential of Metals and Relative Potential Difference with Adjacent Metals

| Half reaction | Standard electrode potential/ V | Relative potential difference with neighbor metal / V |
|---|---|---|
| $K^{+} + e^{-} = K$ | -2.925 | |
| $Ca^{2+} + 2e^{-} = Ca$ | -2.840 | **0.085** |
| $Na^{+} + e^{-} = Na$ | -2.714 | **0.126** |
| $Mg^{2+} + 2e^{-} = Mg$ | -2.356 | 0.358 |
| $Al^{3+} + 3e^{-} = Al$ | -1.676 | 0.680 |
| $Mn^{2+} + 2e^{-} = Mn$ | -1.180 | 0.496 |
| $Zn^{2+} + e^{-} = Zn$ | -0.763 | 0.417 |
| $Fe^{2+} + 2e^{-} = Fe$ | -0.440 | 0.323 |
| $Ni^{2+} + 2e^{-} = Ni$ | -0.257 | **0.183** |
| $Sn^{2+} + 2e^{-} = Sn$ | -0.138 | **0.119** |
| $Pb^{2+} + 2e^{-} = Pb$ | -0.126 | **0.012** |
| $2H^{+} + 2e^{-} = H_2$ | +0.000 | **0.126** |
| $Cu^{2+} + 2e^{-} = Cu$ | +0.337 | 0.337 |
| $Hg_2^{2+} + 2e^{-} = 2Hg$ | +0.796 | 0.459 |
| $Ag^{+} + e^{-} = Ag$ | +0.799 | **0.003** |
| $Pt^{2+} + 2e^{-} = Pt$ | +1.188 | 0.389 |
| $Au^{3+} + 3e^{-} = Au$ | +1.520 | 0.332 |

In order to dispel misconceptions regarding the subject, and to display clearly that the differences in ionization degrees exist between metals, the use of the graph that contains the standard reduction potentials schematized as a graph below was suggested to examine student responses.

In the survey of applicability to college freshmen and juniors, when the ionization tendency was explained using Figure 7, positive responses were drawn out: 70 percent and 75 percent respectively responded that the explanation helped to understand clearly the relative differences and characteristics of the standard reduction potentials of each metal.

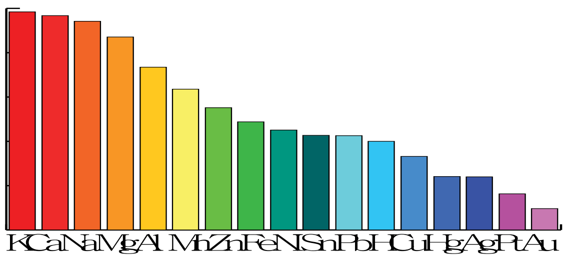



Figure 7. Order of Ionization Tendencies Based on the Schematized Standard Reduction Potentials

***H. Perception about the differences between ionization tendency and ionization energy***

Students' answers about the definition of ionization tendency of metal revealed that they explained ionization tendency as the regular changes in the periodic table, or used ionization tendency without differentiating from ionization energy. In order to examine such misconceptions, students were asked to describe the differences between ionization tendency and ionization energy.

Among student answers, the percentages of students who described the relationship between ionization tendency and ionization energy as being in inverse proportion, like the answer "The smaller ionization energies, ionization becomes easier, increasing ionization tendencies", were 56%(9/16) in freshmen and 62%(13/21) in juniors, which means upper graders displayed higher response rates.

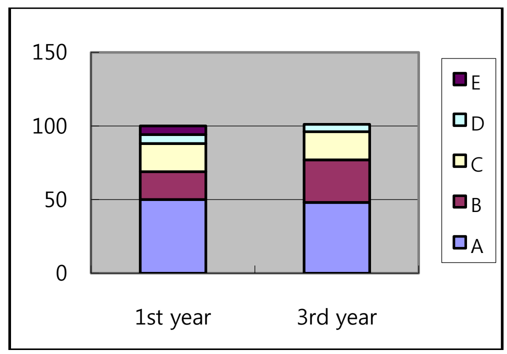
While ionization tendencies and ionization energies of metals could be considered as having the same meaning in the view of they both lose electrons, ionization tendencies occur in aqueous solution where hydration energies are included, which means they don't follow the tendencies of ionization energies that involve loss of electrons in the vacuum state. However, some students failed to discern such differences.

***I. Do 17 Metals Are All Necessary?***

In general, Chemistry textbooks in the 6th and 7th educational curriculum as well as college course books [35-37] are also commonly used to explain reactivity of 15 or more metals. Students were asked the following question: "In what criteria were these metals chosen as standard materials to explain ionization tendency?"

<Table 9> Student Responses to "the reasons why metallic elements were chosen in order to display ionization tendency of metal"

| Reason | Response ratio | |
|---|---|---|
| | 1st year students (n=16) | 3rd year students (n=21) |
| Elements easily accessible in everyday lives were chosen (A) | 8 (50%) | 10 (48%) |
| One or two elements of each family were chosen (B) | 3 (19%) | 6 (29%) |
| Elements determined by the agreements of international scientists were chosen (C) | 3 (19%) | 4 (19%) |
| I don't know (D) | 1 (6%) | 1 (5%) |
| No answers (E) | 1 (6%) | 0 (0%) |
| Total | 16 | 21 |




<Figure 8> Diagram for Students' Responses to the Reasons Why Metallic Elements were Chosen in order to Display Ionization tendency of Metal

As for 1st year students, most students chose the answer that elements determined by the metallic elements in everyday lives (50%) and displayed many various others who chose the agreements of international scientists (19%) and specific elements of each family (19%). As for 3rd year students, many students chose the answer with specific elements of each family (29%) and the elements in everyday lives (48%).

In chemistry textbooks in the 6th and 7th educational curriculum as well as college course books [35-37], the reasons are not explained as to how the elements were chosen and used based on what criteria, and why 15 elements must be used. Even the reference books do not exactly explain why 15 metallic elements were chosen as standard materials that explain ionization tendency, which means the choice of metals was not based on any scientific reasons [38-40].

The 15 metals in Chemistry II textbooks for high school is just a convention that was passed down for decades without scientific evidence. When new textbooks for new educational curriculum were to be designed, the discourse and modified statements are needed to the subject [41-43].

***J. Comparative study on the explanation about ionization tendency in other countries' chemistry textbooks***

This study carried out an analysis on the explanations provided by the chemistry textbooks in U.K., Australia, Canada, Japan, Singapore, Germany, and France [33, 44-55]. The number of kinds of metals presented in these text books is shown in Table 10.

In most of the foreign textbooks, ionization tendency was expressed as reactivity series or activity of metals; this shows that the explanations about ionization series are focused on the reactivity of metals. Thus, the contents barely dealt with the quantitative aspects in which standard reduction potential was applied, and only level of reactivity was relatively presented. By contrast, the Japanese textbooks used the term "ionization tendency."

<Table 10> Explanations on ionization tendency in international text books

| | Ionization tendency |
|---|---|
| UK 1 | K, Na, Li, Ca, Mg, Al, Zn, Fe, Pb, Cu, Au |
| UK 2 | (K, Na, Ca) (Mg, Al, Zn, Fe, Ni, Sn) (Pb, Cu, Hg, Ag, Pt, Au) |
| Australia | Mg, Al, Zn, Fe, Ni, Sn, Pb |
| Canada | Li, K, Ba, Ca, Na, Mg, Al, Zn, Cr, Fe, Cd, Co, Ni, Sn, Pb, Cu, Hg, Ag, Pt, Au |
| Japan 1 | (K, Ca, Na) (Mg, Al > Zn, Fe) (Ni, Sn, Pb) (Cu, Hg) (Ag) (Pt, Au) |
| Japan 2 | (Li, K, Ca, Na) (Mg, Al > Zn, Fe) (Ni, Sn, Pb) (Cu, Hg) (Ag) (Pt, Au) |

The first type textbooks of UK used a total of eleven metal atoms but the quantitative account for their orders was not provided. Also, the comparison on the kinds of metals and their orders, Li (Lithium) was newly introduced and the positions of Ca (Calcium) and Na (Potassium) were switched. This shows that the order of reactivity of these two metals, which have a theoretical difference of 126 mV between the values of standard reduction potentials are not absolutely fixed.

Also, between Fe (Iron) and Pb (Lead), the two elements, Ni (Nickel) and Sn (Tin), which have relative differences of 119 mV and 12mV between the values of standard reduction potentials, are excluded. As pointed out above, the orders of Hg and Ag, which have a difference of 3mV between the values of standard reduction potentials are also skipped.

The second type textbooks of U.K. chose a different way of explanation. They classified reactivity levels mainly into three categories and into the reaction with water, acid, and oxygen.

As for Australia, the textbooks used the name "Professor MAZINTL" to help students understand the concepts. MAZINTL composes of the initials of English names of the following elements: magnesium, aluminum, zinc, iron, nickel, tin and lead. A total of nine elements were used and alkaline metals and precious metals were all omitted.

In the case of Canada, the textbooks used the biggest number of elements: twenty. Particularly, Li (Lithium), Ba (Barium), Cr (Chrome), Cd (Cadmium), Co (Cobalt) and others were used.

The first type textbooks of Japan, similarly to the second type textbooks of U.K., made groups of two to three metals and classified them into seven categories. Then, they divided again their reactivity into three categories: reaction with water, acid and air, in a table. It did not subdivide the reactivity of the two alkaline metals, K and Ca and Ni, Sn, Pb, which have similar relative differences among the values of standard reduction potentials, either. Also, it included Li, which is recently emerging as a rare material for making cellular phones. The second type textbooks of Japan, similarly to the first type, classified metals into seven categories to present their reactivity.

It would be more helpful in enhancement of students' understanding of concepts, to use less metals and present their reactivity by categorizing them, rather than make students simply memorize the reactivity of metals.

## VI. CONCLUSION

Thisstudy is to explore the recognition about ionization tendency of metals (reactivity of metals) among the electrochemical field of chemistry pre-teachers (first and third year students)

From this result, it was found that some pre-teachers did not have full understanding of definition of ionization tendency and they confused the definition of ionization tendency with correlation on the periodic table or ionization energy. In the exploration of 1) The use of the term ionization tendency and definitive explanation, 2) The number of metal elements used in the description, 3) The use of the concept of standard reduction potential in the descriptions of chemistry textbook about ionization tendency, there were many differences in the level of dealing with the material. It can be determined that this is due to the lack of detailed regulation of the level of usage of the contents related to ionization tendency in chemistry curriculum and chemistry curriculum handbooks.

Also, it could be seen that there was lack of proper concepts about measurement methods of standard reduction potential and physical meaning that decides the degree of ionization of metals. Exploration activities were planned and applied to lessons to allow students to understand that the ionization tendency order suggested in textbooks is not absolute and that according to experiment level or environmental conditions, the order can easily change, and that it is difficult to set the order in everyday life. As a result, it could be confirmed that the actual measurement value differs from the standard reduction potential value suggested in textbooks and that as a result the order of ionization tendency can change.

It was figured out that students have misconceptions because of thinking there was clear difference of ionization degree between metals and by suggesting the use of standard reduction potential diagrams illustrated with graphs to conveniently express the existence of difference between ionization degree at the metals and reduce these misconceptions, a result that it helped in the understanding of scientific concepts was obtained.

Ionization tendency and ionization energy can be seen as having the same meaning in the perspective that they both lose electrons, but ionization tendency in metals is a reaction that occurs in aqueous solutions and because hydration energy is included, the ionization energy tendency dealing with losing electrons in vacuum is not strictly followed. However, most students could not differentiate between these differences.

Looking at descriptions of ionization tendency shown in chemistry textbooks abroad (UK, Australia, Canada, Japan) the metal Li (lithium) was newly introduced and sometimes the order of calcium and potassium were changed. 10 to 20 metals were used in the descriptions. However, unlike Korea, rather than listing, the metals were divided into categories and reactions in water, acid, and air were suggested as charts.

Let us reduce the number of metals greatly. Looking at the metal elements used in the last several decades, there are elements with reduced usage such as mercury or lead, due to the toxicity. Compared to this, the element lithium, which is used in batteries of cell phones recently is becoming the target of interest. Therefore, if there are no large problems in substituting these elements that will become central elements of future life, comparing ionization tendencies with these elements will become good material for arousing students' interest. It is determined that by omitting toxic substance lead and $H_2$ which is not a metal and represented as about eight, burden on the students will also decrease.

In consideration of the differences of standard reduction potentials and selecting only one metal that is within the 200 mV difference, and through reviews such as excluding metals such as lead and mercury which is a prime cause of environmental pollution, it is determined that the description of tendencies of the following ten (nine) metals is adequate. The introduction of lithium here is due to the consideration of the increase in use and social interest as a substance used in rechargeable batteries of cell phones which are popular recently. Let us express presentation of Li > Na > Mg > Al > Zn > Fe >Sn> $H_2$> Cu > Ag > Au also in categories. The suggestion method, unlike the textbooks of UK and Japan, divided into three categories to classify the degree of reactivity and represented reactions in water, acid, and oxygen.

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