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Introduction to Complexation and Masking Within a Computer-Enriched Module for Analytical Chemistry

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INTRODUCTION

In recent years, there has been an increase in computer applications for teaching chemistry. The use of Web-based materials by students in chemical education has been increasing rapidly [1]. In organic chemistry education, a modular approach has been used together with self-testing in a system termed the Web-based Enhanced Learning and Resource Network [i.e., the "WE_LEARN" system] [2]. The use of WebCT has led to an increase in students' learning within first-year chemistry courses in chemistry education [3]. Brooks developed a software system related to Web-based classes that aims to evaluate homework and examinations automatically [4]. Robinson investigated the possible effects of using computer simulations on Scientific Discovery Learning [5]. The workload of educators could decrease if the above-mentioned applications were included in the chemistry curriculum [6]. LUCID, which was developed for the "Introduction to Chemistry" and "General Chemistry" classes for two semesters, is a program that promotes cooperative learning [7]. All of the above-mentioned applications have been postulated to offer more positive influences on students' learning than the traditional teaching methods. Interactive multimedia packages are beginning to take their place in the chemical education community.

The Internet accessibility of these multimedia packages makes them accessible to a wider community, as opposed to the limited and constant teaching tools available only in textbooks. Among the other advantages of these packages, students could access these materials easily in libraries or their homes from anywhere in the world and learn about scientific changes and developments simultaneously [8]. In a study by Carpi, a website was built that consisted of explanations of scientific concepts, explanatory animations and related links for science classes in a high school. Most of the modules included interactive activities where the students could learn by doing. Each module contained connections to the other links. In this study, the website of the lesson and the details of its pedagogical design were explained, followed by a comparison of the exam results before and after the site was constructed [9]. Daniel and Saat in Malaysia developed a web-based modular approach where the resources were acquired through the Internet. An exam consisting of three parts was administered to the students and they were asked to search through the website on the current subject [10]. Windelspecht designed a technology-based lesson consisting of modules in his study on the integration of technology into education [11].

Godrick and Hartman created a joint laboratory class for the departments of biology and chemistry at Boston University. The subjects of the laboratory were distributed into modules called resources of energy for life, indication of ascorbic acid, reaction dynamics, indication of macromolecules and manipulation [12]. All of these computer-based methods contrast strongly with traditional teaching methods. In traditional teaching methodology, a lecturer presents a lesson through an oral presentation. This method is specific with "interpretative", "informative" and "illustrative" characteristics.

The advantages of this method include the fact that it is useful for the presentation of the beginning of a lesson and for transferring knowledge to large groups. To date, a single lecturer has been easier and more economical, accounting for the usage of traditional methods from the very beginning of one's chemistry education and then throughout one's entire chemistry career. However, teachers need to know the characteristics of the method clearly to obtain maximum effectiveness. Long and boring presentations can cause incomplete communication, where the students enter a passive learning mode in which they do not ask questions [13].

> ***The major purpose of the current study was to evaluate the level of knowledge that college students might gain as a result of learning by a module prepared by the author at Hacettepe University. The subjects of the modules were "complexation and masking" and were applied by way of an Internet-based computer-assisted method. This study also aimed to make the study of "complexation and masking" to be fun and interesting for students, eliminate the monotony caused by traditional teaching methods, save time by spreading the usage of computer-based learning modules that have been developed elsewhere, and enable teaching to go beyond the boundaries of the school building by using the Internet.***

We report here our results concerning our efforts to test the level of knowledge gained by a group of students using Web-based modules as compared to the level of knowledge gained using traditional teaching methods. The level of knowledge gained was measured using standard pre- and post-test methodology, as described below. In this study, the web-based modules were found to be a more effective teaching device than were traditional teaching methods.

EXPERIMENTAL METHODOLOGY

Participants and Division into Groups

This study was carried out with the involvement of 84 3rd-year university students (54 females and 30 males), who were attending the Internet Class of Chemistry Education at Hacettepe University, Faculty of Education, Department of Chemistry Education and who were attending courses in Chemistry Education and Chemistry Education Seminar Lessons. All of the students have previously taken and passed the course "Introduction to General Chemistry". These students were randomly divided into an experiment group and a control group of 42 students each.

Pre- and Post-Testing

The data to be evaluated were gathered by applying a pre- and a post-test concerning the material to be learned in these modules. We have defined this test as a "Chemistry Achievement Test (CAT)". The test consisted of 10 open-ended questions, which are listed in Appendix I. These questions were based on concepts in the subject area of "complexation and masking", which is the same area as the web-based modules that were used in this study. The inner validity of the Chemistry Achievement Test was achieved by consulting with outside experts in the field of knowledge. Both the experimental group and the control group took the CAT as a pre-test prior to any instruction on the subject matter.

Subject Matter That Was Taught

Table: 1
Content of the web-based modules teaching "complexation and masking"

Concepts Taught	Demonstration Experiment
1. Eliminating water hardness with complex	- (a) Determination of water hardness with

formation	**EDTA (see Fig.I)**
2. Determination reactions based on complex formation	**-(b) Determination of Aluminum with Alizarin S (see FigII)** **- (c) Masking of Sn (IV) solution with oxalat ion [see FigIII]** **- (d) Determination of nitrate. (see FigIV)** **- (e)Determination of Ammoniac with Nessler Reactive (see FigV)** **- (f) Formation of Potassium 18-crown-6-ether complexes (see FigVI)**
3. Separation reactions based on complex formation	**- (g) Separation of Nickel and Cobalt (see FigVII)** **- (h) Separation of Copper and Cadmium (see FigVIII)** **- (i)Determination of Copper [II] ion (see FigIX)**
4. Crystallization and color change reactions based on complex formation	**- (j) Micro determination of Silver [II] ion (see FigX)**
. 5. Masking reactions based on complex formation	**-(k) Masking of Al^{3+} salts with Fluoride (see Fig.XI)** **-(l) Masking of Sn[IV] solution with Oxalate (see Fig.XII)**

Whether using the conventional methods or the web-based modules, the same basic concepts were presented to the students. A rough outline of the concepts, and how these concepts were explained is shown in Table: 1.

It is known that, in analytical chemistry, some metal cations form coordination compounds with atoms, molecules or ions that are called ligands and have unpaired electron pairs. These compounds are complex and have an important part in analytical chemistry. In the determination of cations and anions together and in quantitative determination, the complex formation of these compounds are used. In complexometric titrations, EDTA is used because of its being multidentate. But Ph affects the stability and formation of a complex agent. In these applications, a complexation agent is used as a masking agent. Masking is based on the stable complex formation of cation or anion in the mixture with masking agent.

In the module, it was aimed to teach the basic concepts such as eliminating water hardness with complex formation, determination reactions based on complex formation, separation reactions based on complex formation, crystallization and color change reactions based on complex formation, masking reactions based on a complex formation. Above these, in the first topic taught was about the masking of ions by using complex formation between anions and cations. By using the masking of ions, analytical determination and qualitative determination of ions can be made. With this aim, in the module that we prepared, the complex formation of cyanide ions with metal cations, masking of TinIV ions with oxalate and masking of aluminum salts with florid were chosen. The second subtitle in the module was the explanation of determination reactions based on complex formation to the students. As an example, *Determination of Ammoniac with Nessler Reactive* was chosen. In the applications, Ligands that form complexes and multidentate ligands such as EDTA were used.

Application of Traditional Methods Instructional Methodology

The control group was taught about the subject of "complexation and masking" by traditional methods of instruction. The content of the subject matter is exactly the same as is taught by the web-based modules. However, the chemical equations were discussed using a blackboard as the medium. The only educational materials were the textbook, blackboard.

Web-Based Modules Instructional Methodology

Web-based modules were used as the primary teaching method. These modules have been published on the Internet as a portion of Creative Chemistry on the Internet [CCI, http://www.cci.ethz.ch/], and were prepared by the Chemistry Contact Network [CCN, http://www.ccn.ethz.ch/], which is a project of Prof. Nesper at the department of Inorganic Chemistry of the ETH Zurich. Experiments about the subjects of "Complexation and Masking" within the CCI on the ETH website can be watched by using Real Player [14, 15]. During the display of experiments, instructions are shown on the screen. In addition to this, students watched detailed information about the experiments and the reactions at the time of the viewing the module. For each of the experiments, students of the experimental group were provided with color pictures, graphics, diagrams, tables, animations and short educational films in order to enable them to see and learn about the chemicals that were in the module, results of the experiments, obligatory safety measures, and color changes.

We emphasize that all of these materials, especially, the color pictures, animations and short films, were presented via Internet methodologies that the students could use and reuse at their own pace. Significant data related to each experiment and reactions were presented to the students in subtitles. While working on the modules that involve experiments such as the precipitation of alkaline earth salts, pH-dependant precipitation of phosphates, precipitation and dissolution of sulfides from the H_2S group, and precipitation and dissolution of silver [Ag^+] and Pb[II] salts, students were given the opportunity to view images related to experiments through step-by-step film slides on a full screen. Examples of these materials are given in Appendix 2. By presenting important theoretical information and the chemical reactions just below the images, the correlation between the practical and the theoretical aspects of the subjects is easily illustrated. In order to minimize defective and false learning of students during the use of computer-assisted learning modules, students were allowed the opportunity to repeat experiments. More details of these modules are given in Appendix 2

FINDINGS

The Chemistry Achievement Test (CAT) was administered as a post-test one week after each group began their study methodology. The students were notified one day in advance that the CAT post-test exam was to be given.

The results of these post-test evaluations are shown in Table: 2. When analyzing this data, it is immediately obvious that the group that used Internet-assisted learning modules showed a significantly higher average on the post-test compared to the control group, which was taught using the traditional methodology.

Table: 2
Statistical evaluation of the results obtained by the different study methodologies

		Pre-Test	Post-Test			
	N	x	x	s	t	p
Experimental Group	42	18.76	83.76	14.119	-6.262	0.000
Control Group	42	20.50	70.11			

N: Number of students
x: average
s: Standard deviation
t: t-Test coefficient
p: significance

DISCUSSION AND CONCLUSIONS

The effects of web-based learning modules on the achievement and learning levels of students were examined in this study on the subjects of complexation and masking. After the students were distributed into control and experiment groups, the students in the control group were taught the subject of complexation and masking together with basic concepts and important features using the

traditional methods of lecture and blackboard with an emphasis on related reactions. No student-centered teaching methodologies or technologies were used within this group. In contrast, students in the experiment group were provided learning modules that were prepared on the general subjects of complexation and masking as they are generally taught within the area of general chemistry.

These modules consisted of the basic concepts and Internet links to demonstration experiments in order to facilitate the understanding of the subject matter. The students were provided with photos relating to the subject matter, short movies, tables, graphics and animations of experiments, essential concepts, color changes and reactions. The possible misconceptions and misunderstandings were overcome through providing replays when necessary. The modules, with their Internet links, enabled not only the students to learn at their own pace, but also allowed for the educational processes to be extended beyond the physical boundaries of the school environment. A significant difference in the performance on the achievement test, favoring the experiment group, was observed when the post-test results were evaluated. The students with high levels of comprehension and memorization skills in both control and treatment groups were successful in the pre-test. The traditional method used in the teaching of the control group was less effective in the achievement levels when compared to that of the treatment group. The students of the experimental group, who were taught using the computer-assisted learning modules, or, in other words, who learned by seeing and experiencing the subject matter, had more positive attitudes towards chemistry [16]. Freeing the students from the monotonous traditional teaching methods and making the chemistry classes more interesting and enjoyable positively affect academic achievement. The data acquired by the evaluation of the post-test were also the indicators of this issue. Similar studies have also shown that web-based materials acquired via the Internet were effective in increasing the achievement levels in chemistry education [16, 17].

In summary, the application of computer-assisted learning modules in chemistry education was found to have a positive effect on the students' achievement and learning levels.

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Dr. Penn has a long history of being dedicated to serving the profession of chemistry and the community in which he lives. This tradition began with his time in graduate school, where he simultaneously earned his Ph.D. at the University of Wisconsin-Madison and was heavily involved in both the service side a nd the administrative side of Briarpatch, an organization dedicated to assisting troubled teenagers. Currently, in addition to his normal service load to the profession of chemistry, as exemplified by his membership on the Committee on Computers in Chemical Education,

Dr. Penn serves as the Exalted Ruler of the Morgantown Lodge 411 of the Benevolent and Protective Order of Elks, a non-profit charitable organization dedicated to serving the needs of the community and

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FOOTNOTES

1. **Donovan, W.J., Nakhleh, M.B., 2001, Students' Use of Web-Based Tutorial Materials and Their Understanding of Chemistry Concepts, *Journal of Chemical Education,* v78, n7, 975-980.**

2. **Penn, J.H., Nedeff, V.M., Gozdzik, G., 2000, Organic Chemistry and the Internet: A Web-based Approach to Homework and Testing Using the WE-LEARN System, *Journal of Chemical Education ,* v77, n2, 227-231.**

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[http://www.cci.ethz.ch]

15. CCN [Chemistry Contact Network] http://www.ccn.ethz.ch]

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APPENDIX: 1
THE CHEMISTRY ACHIEVEMENT TEST [CAT]

The Chemistry Achievement Test consists of the following open-ended questions.

1. **There are how many parts of EDTA that can form complexes?**
2. **Masking reagents can also make complexes. What is the reason of using masking reagents?**
3. **How can you identify Cd and Ca ions with EDTA?**
4. **What is a ligand?**
5. **What is the complexation ratio of EDTA with Fe $^{+3}$, Ni^{+2}, Cr^{+3}, Na^{+} ions?**
6. **What is a coordination number?**
7. **Identification of hardness of water can be made with EDTA. What is the reason behind hardness of water?**
8. **Ammonium is a weak base. Which substances can be used for its complexometric identification?**
9. **Which qualifications should a compound have in order to be in a complex structure?**
10. **Is PH important for complexometric identifications? If your answer is yes. Explain its reason.**

APPENDIX: 2
OVERVIEW OF THE WEB-BASED MATERIALS

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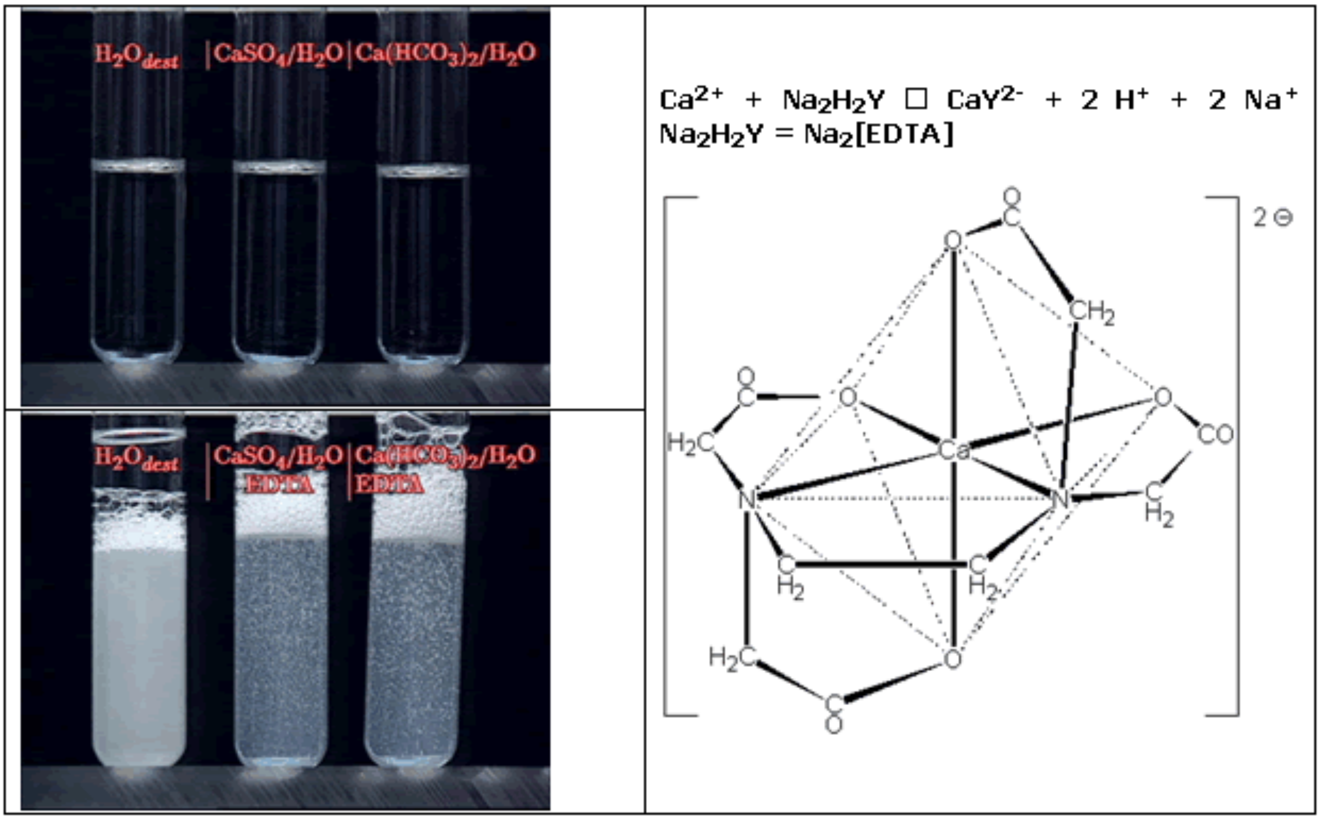


Figure: I
Determination of Water Hardness With EDTA

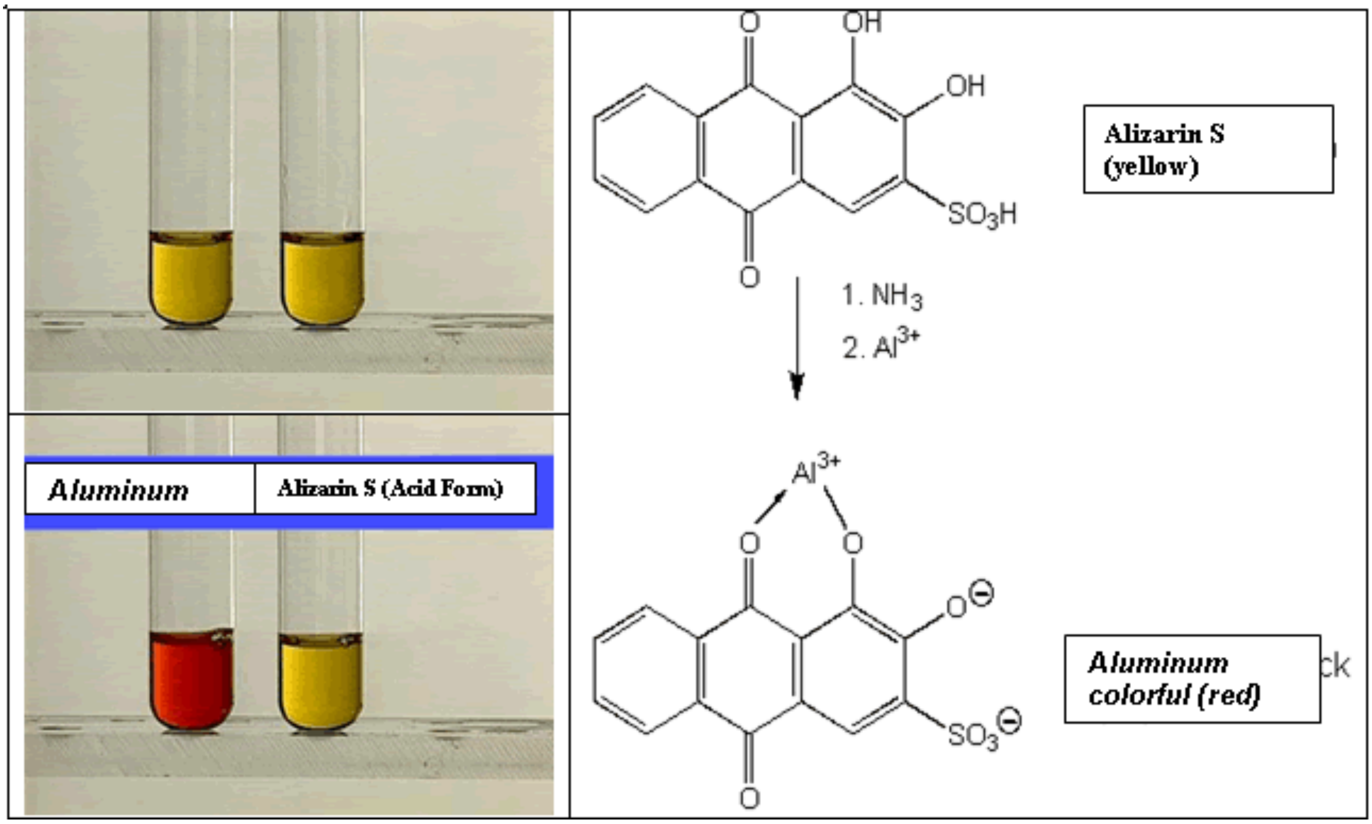
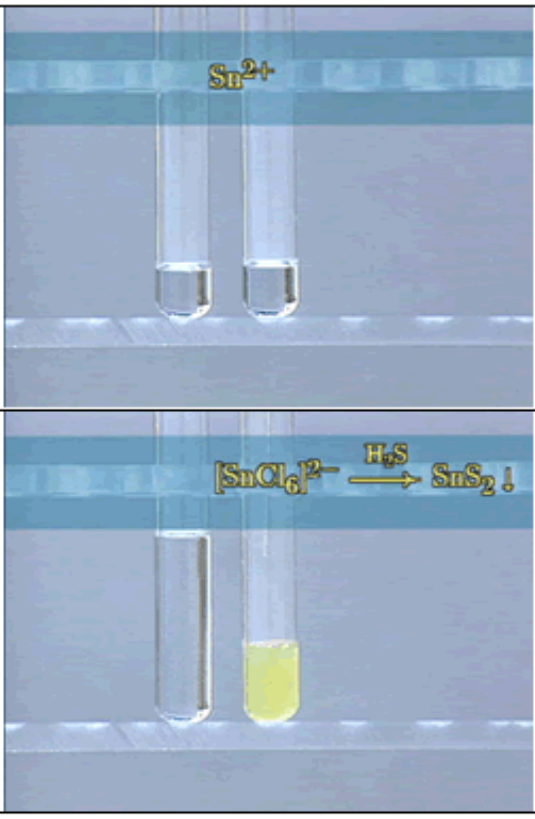


Figure: II

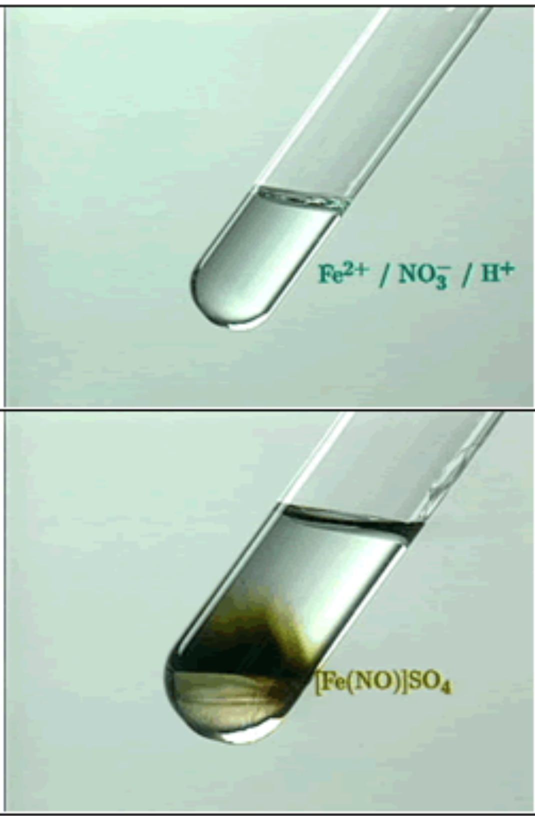
Determination of Aluminum With Alizarin S



$$SnCl_2/HCl \xrightarrow{Br_2} [SnCl_6]^{2-} \xrightarrow{H_2S} SnS_2\downarrow$$

$$[SnCl_6]^{2-} \xrightarrow{4\,C_2O_4^{2-}} [Sn(C_2O_4)_4]^{4-} \xrightarrow{H_2S} \text{kein} \quad \textit{No react.}$$

Figure: III
Masking of Sn [IV] solution With Oxalat Ion



$6\ FeSO_4 + 2\ HNO_3 + 3\ H_2SO_4$ □ $3\ Fe_2[SO_4]_3 + 2\ NO + 4\ H_2O$

$[Fe[H_2O]_6]SO_4 + NO$ □ $[Fe[H_2O]_5NO]SO_4 + H_2O$

Figure: IV
Determination of Nitrate

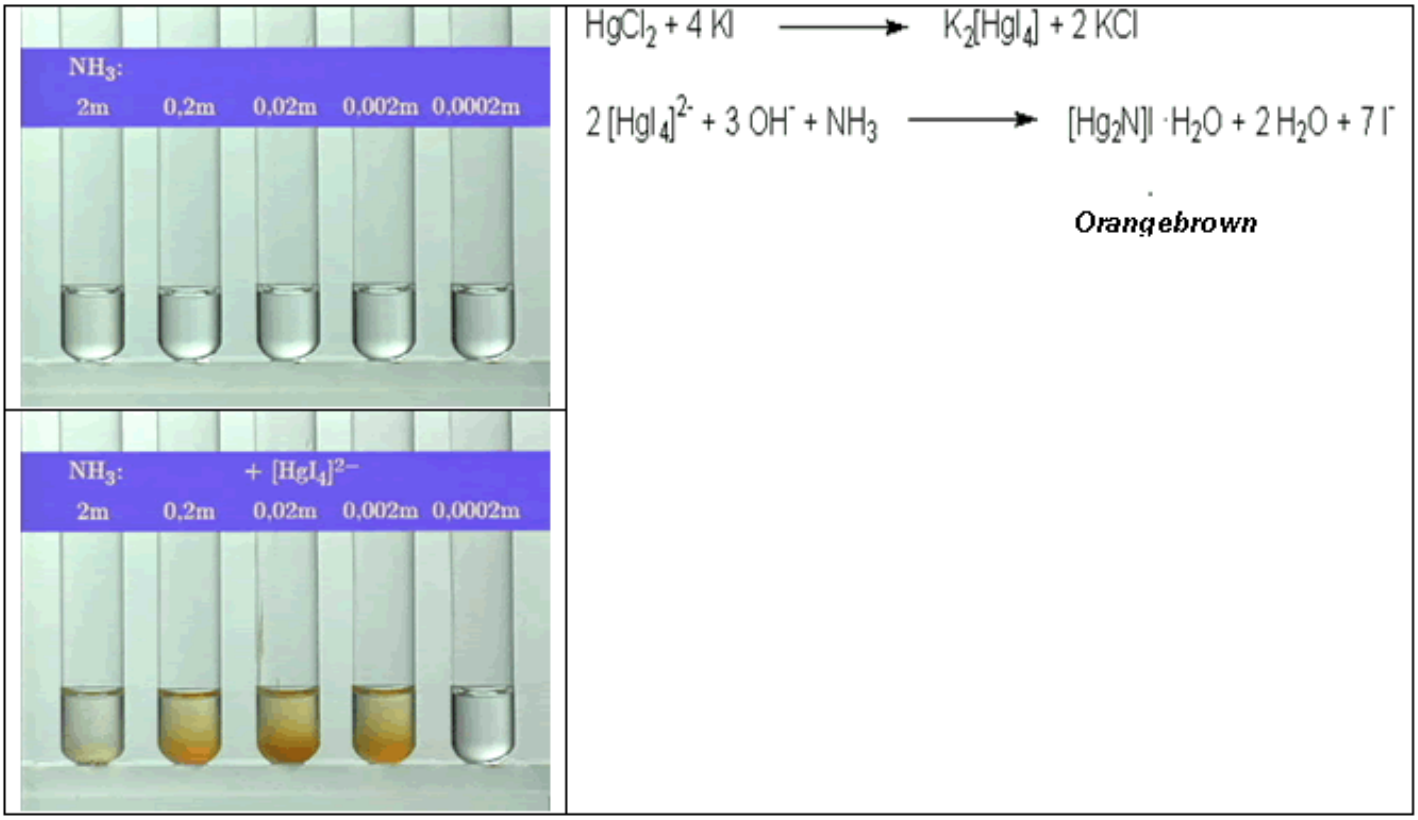


Figure: V
Determination of Ammoniac With Nessler Reactive

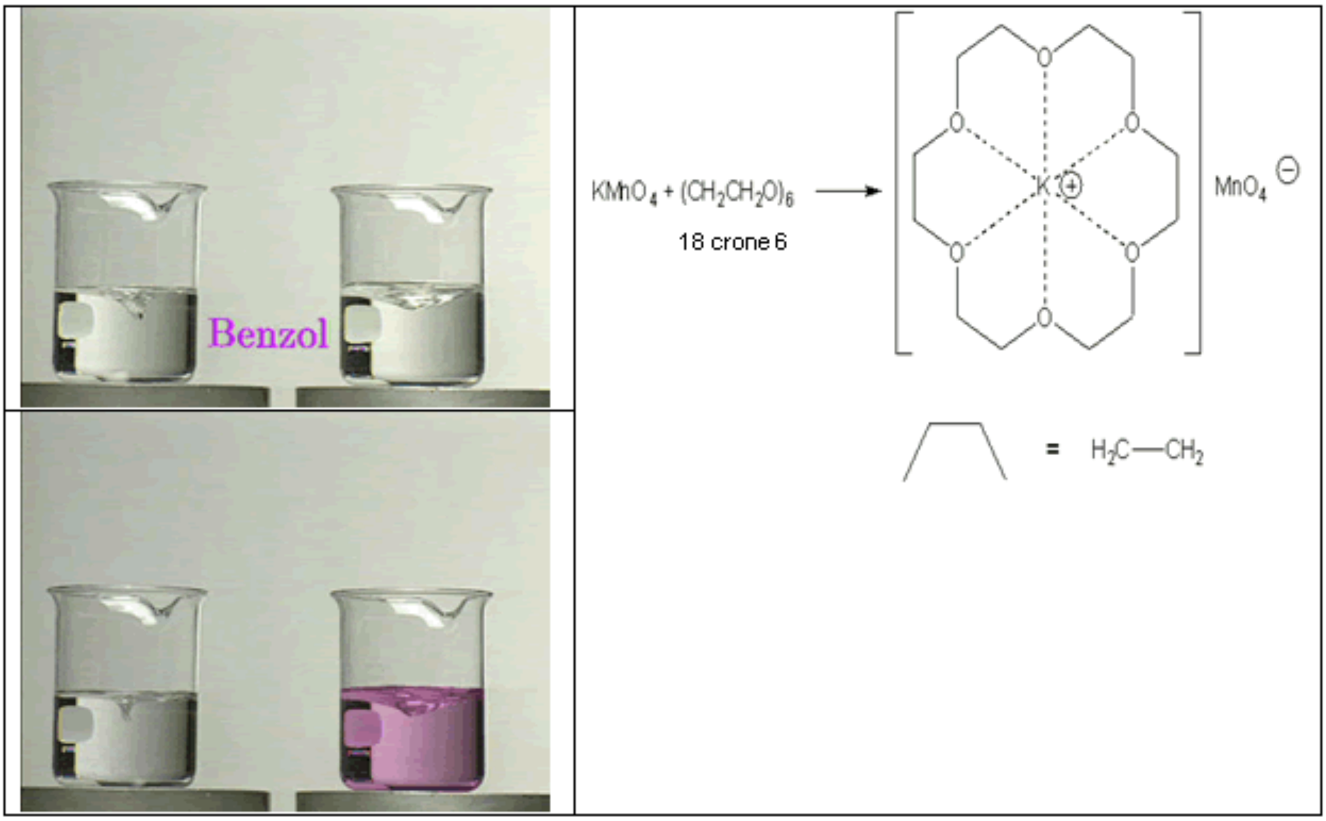


Figure: VI
Formation of Pottasium 18-Crone-6-Ether Complex

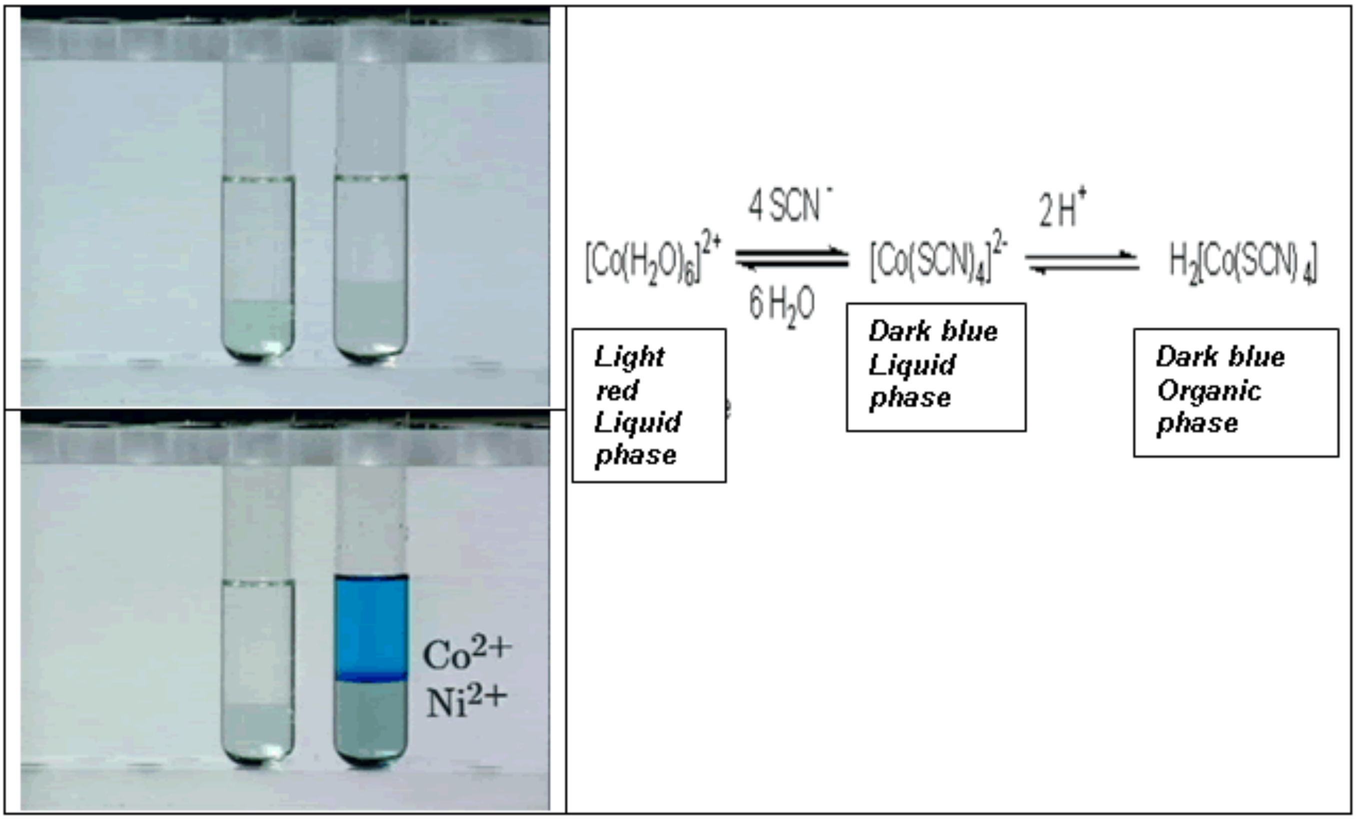


Figure: VII
Separation of Nickel and Cobalt

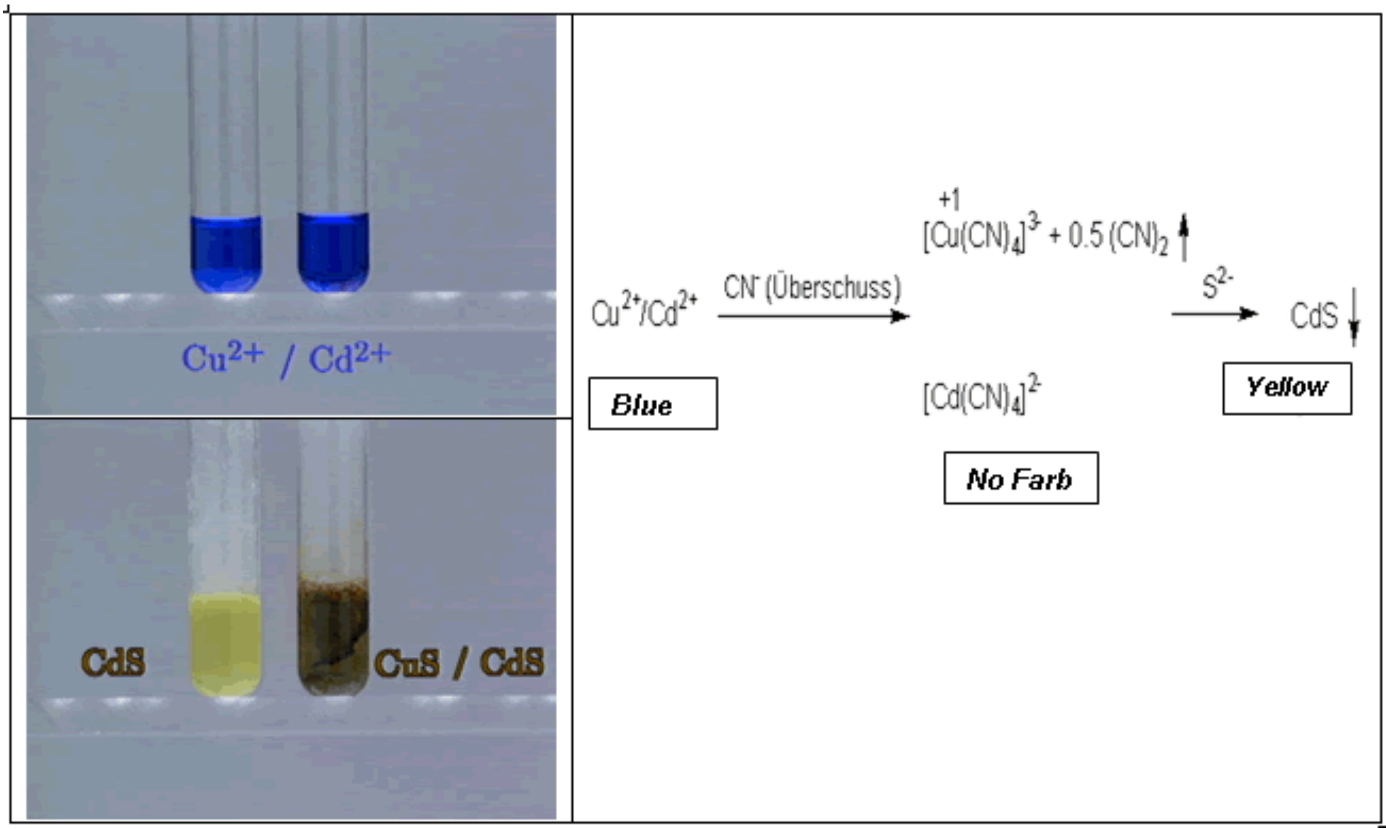
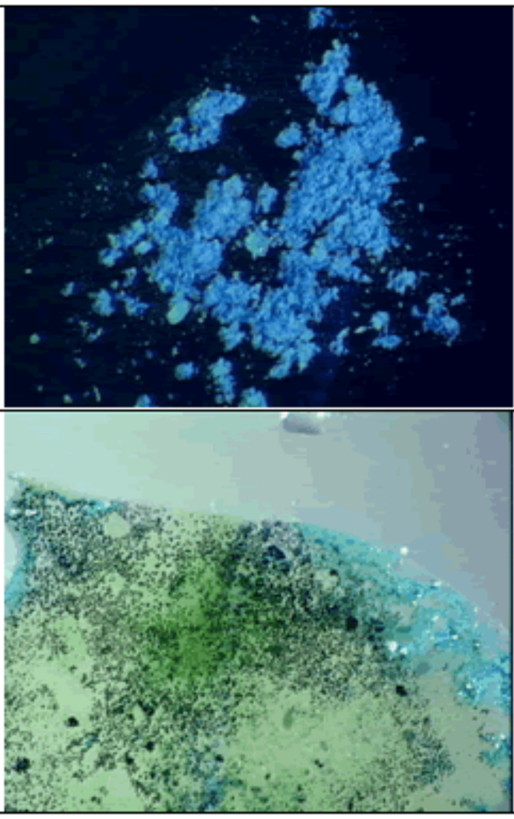
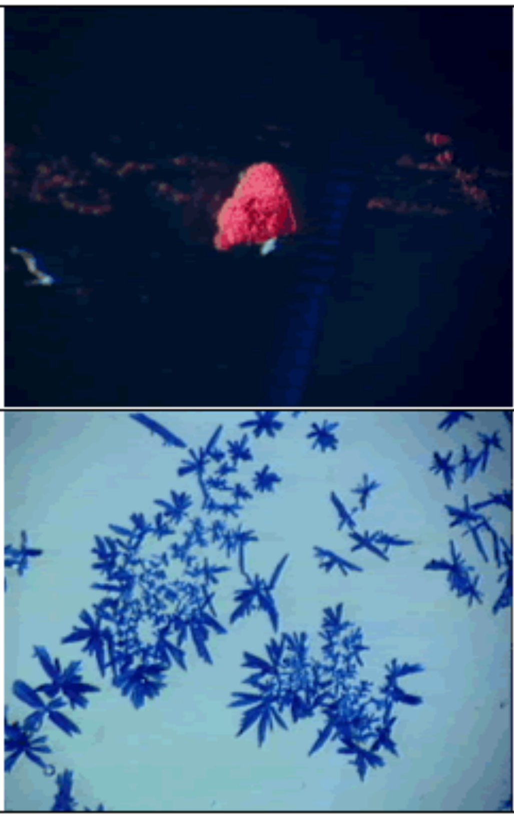


Figure: VIII
Separation of Copper and Cadmium



$$Cu^{2+} + Pb^{2+} + 2K^{+} + 6NO_2^{-} \longrightarrow K_2CuPb(NO_2)_6 \downarrow$$

Figure: IX
Micro Determination of Copper [II] Ion



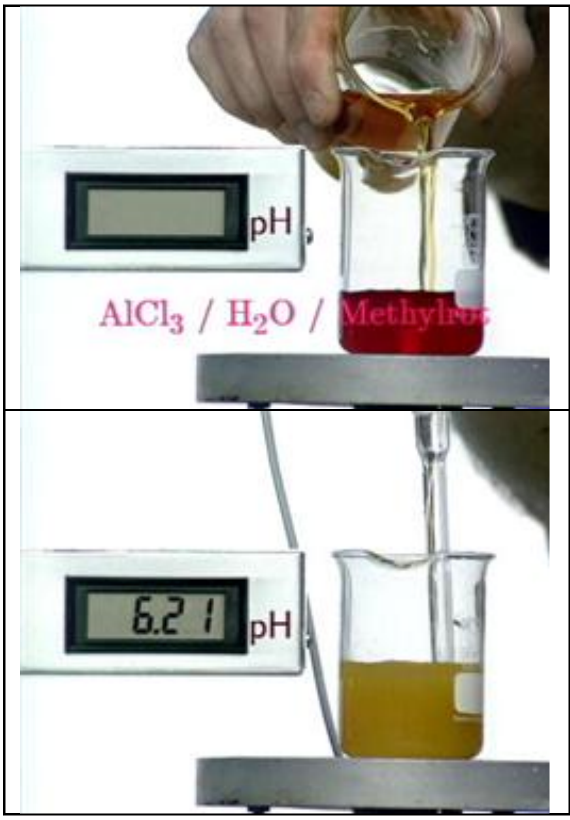
$$HgO + 2HNO_3 \longrightarrow Hg(NO_3)_2 + H_2O$$

White Crystals

$$Hg^{2+} + Co^{2+} + 4SCN^{-} \longrightarrow Co[Hg(SCN)_4] \downarrow$$

Blue Crystals

Figure: X
Micro Determination of Silver [II] Ion

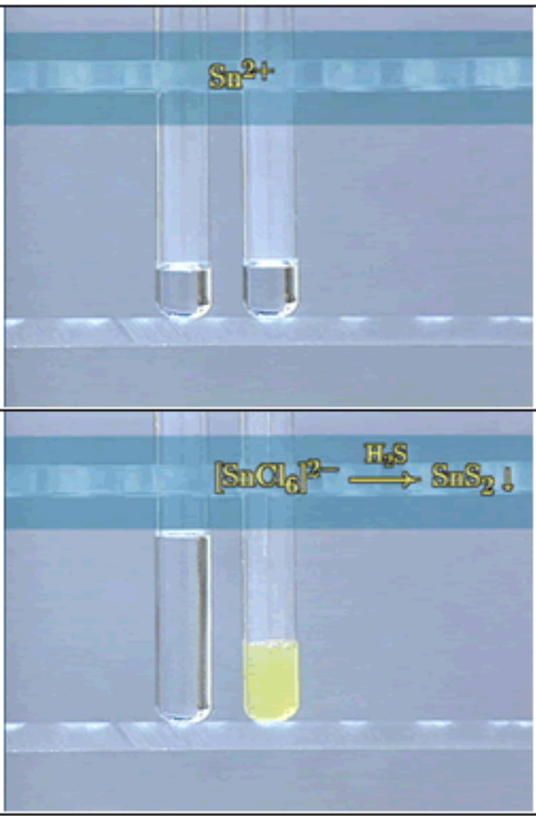


$$AlCl_3 + 6\,H_2O$$

$$\downarrow$$

$$[Al(H_2O)_5(OH)]^{2+} + H^+ + 3\,Cl^- \underset{}{\overset{6\,F^-}{\rightleftharpoons}} [AlF_6]^{3-} + 3\,Cl^- + 6\,H_2O$$

Figure: XI
Masking of Al^{3+} Salts With Florid



$$SnCl_2/HCl \xrightarrow{Br_2} [SnCl_6]^{2-} \xrightarrow{H_2S} SnS_2\downarrow$$

$$[SnCl_6]^{2-} \xrightarrow{4\,C_2O_4^{2-}} [Sn(C_2O_4)_4]^{4-} \xrightarrow{H_2S} \textit{No react}$$

Figure: XII

Masking of Sn[IV] Solution With Oxalat