Investigative Study in Chemistry

- Exemplars of Learning and Teaching Activities

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Department of Chemistry
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Contents

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Science Education Section
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Notes for Teachers

Notes for Teachers

Introduction

Twenty hours of lesson time are allocated for the implementation of investigative study in the NSS chemistry curriculum. It aims to provide students with opportunities to design and conduct investigations to solve authentic problems. After participating in investigative study, students will increase their understanding of the science subject matter investigated, gain an understanding of how scientists study the natural world, develop the ability to conduct investigations, and develop the habit of mind associated with science. Besides, investigative study provides students with the opportunity to develop their skills in communication, creativity, collaboration, critical thinking, problem-solving, information technology and time management, etc. If the study is carefully planned, students should be able to finish the investigation with a sense of achievement, a sense of satisfaction and a feeling of self-confidence.

In general, investigative study involves the following stages:

(a) Identifying relevant information and defining questions for study;
(b) Planning an investigation; choosing equipment and resources;
(c) Performing an investigation;
(d) Organising and analysing information; drawing conclusions based on available evidence;
(e) Presenting the findings.

The suggested rundown of the activities is given in Table 1 on (p. 9). A set of general student notes has been prepared to enable students to understand each stage of the investigative study. To avoid overloading students with too much information, teachers may draw students' attention to the learning points mentioned in the student notes at the beginning of each stage of investigative study. Instead of providing all details, guiding questions and a set of record forms are provided for guiding students to think about the essential aspects of the investigations that should be considered. For the reference of teachers, some aspects regarding the implementation of investigative study are given as follows.

Selection of Investigation Topic

Selection of investigation topic is often a challenge to students. Some students may wish to select their own topic while others prefer to work on topic assigned by their teachers. However, some students may waste a lot of time, and could not come up with a topic for a meaningful and feasible investigation. To facilitate the selection of topic for investigative study, several exemplars of investigative study representing different types of scientific inquiry in chemistry, which were tried out in secondary schools, are presented below.

- Making your own acid-base indicator (to extract a substance and test its uses)
- Salt content in snack foods (to determine the quantity of a substance)
- How to make it hot? (to construct a device and test for it)

A good investigation should start with or at least involve a component stimulating curiosity or provoking a sense of wonder. The above investigations emphasise the solving of authentic problems in daily life and target students of average ability. It is intended to stimulate and motivate students by asking them to apply their knowledge and skills to solve meaningful problems. Investigations involving analysis of real samples could often motivate students to complete the experiments involved.

The investigations can be conducted safely using simple equipment commonly available in school chemistry laboratories. Students should be able to find out the relevant background information and experiment details from reference books and the Internet. Reasonable variability of investigations is possible as students can solve the problem using different methods and samples. Though the student handouts in this resource book can be readily used, teacher may consider fine-tuning the level of difficulty and complexity of the investigations to suit the needs of their students. Further guidance in form of worksheets may also be prepared to scaffold students' learning in investigative study.

Besides, a list of possible topics with brief descriptions of the problems is prepared for the reference of teachers. Some of the topics are newly developed based on recent issues in daily life; while some of them are "scaled down" versions of the projects of the previous Hong Kong Chemistry Olympiad for Secondary Schools. These projects are selected as they involve solving authentic problems which is a key element for stimulating students' curiosity in learning and engaging them in scientific inquiry. It is inappropriate to ask students to repeat the whole project of the competition. Students should focus their investigations on using one method to analyse 2-3 samples instead of using several methods to analyse many samples. The list is by no means exhaustive and students can certainly come up with more titles based on their own ideas. Many reference books on chemistry investigations are available and can provide useful information. Please refer to the relevant section of this chapter.

Prior Knowledge and Laboratory Experience

Students should be provided with sufficient background chemical knowledge and some prior experience in conducting inquiry-based chemistry experiments before conducting an investigative study. The following aspects should be emphasised:

- How to work together in a group to develop an investigation plan and solve a problem?
- How to select an appropriate question for the study, e.g. brainstorming techniques?
- How to search for relevant information from various sources?
- How to write an investigation plan and explain it to other people?
- How to carry out the proposed investigation?
- How to write a laboratory report or make a poster for presentation?

Short and simple investigations can be arranged, preferably at an early stage of the curriculum, to develop the skills required for a complete investigative study. By doing so, students will progress from "cook-book" type experiments to more open-ended investigations which involve finding the answers to questions they have formulated themselves.

Supervision and Guidance

Though students have greater control over what they do than in ordinary practical work, it does not mean that they should be left on their own without proper teacher supervision and guidance. On the contrary, teachers should discuss regularly with each group of students to monitor their progress and provide suggestions or assistance whenever necessary. For instance, students may modify their plans as they go along. It is important to remind students to make careful planning in the first place and supervise students closely. In addition to experimental procedures, it is a good idea to ask students to design a table in which data are going to be filled. It helps teachers ensure that students are clear about what will be done during the experiments.

Questions could be posed to elicit students' understanding, lead them to articulate their ideas, and trigger divergent thinking. To understand students' progress, apart from requesting students to submit written information such as proposals and worksheets and observing their activities, teachers may also request students to give an oral presentation, to share ideas in an on-line discussion forum or to draw a mind map showing their ideas.

Students need different amount and type of support, guidance and challenge. Teachers should be sensitive enough to offer support to slow starters, to provide extra guidance to less able students, and to add further challenges for more able students. For example, teachers may vary the amount of instructions and information (e.g. materials and equipment) given in the student handouts for investigations. As the performance of slow starters improves, teachers should gradually switch from active involving in the learning process, to allowing students to learn more independently.

Besides, investigative study should be treated as a learning process instead of producing a sophisticated report or product. Teachers should vary the scale, nature and demand of learning tasks for students of differing abilities. For less able students, teachers may break down a complicated investigation into a series of simple ones. However, for capable students, such a scientific investigation can be made more demanding by asking for more background information, including more variables, collecting more data, or adopting more sophisticated instrumentation and skills.

Student diversity can be viewed as an opportunity to get students to provide mutual support, particularly when they work collaboratively to solve problems in investigative study. Students of different abilities can be grouped together so that the more and the less able can share their knowledge.

Use of Lesson Time

A portion of the curriculum time is set aside for investigative study. Assume that there are four 40-minute periods per week and they are all double periods (2.67 hrs / week), the twenty hours of lesson time allocated to investigative study will have a span of 7.5 weeks as shown below. This arrangement does not require alteration of the school's time table.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2 (a)	3	4 (a)	5	6
7	8	9 (b)	10	11 (b)	12	13
14	15	16 (b)	17	18	19	20
21	22	23 (c)	24	25 (c)	26	27
28	29	30 (c)	31			
				1 (c)	2	3
4	5	6 (c)	7	8 (d)	9	10
11	12	13 (d)	14	15 (e)	16	17
18	19	20 (e)	21	22 (e)	23	24

Note: 80 minutes per session; (a)-(e) refer to the stages of investigative studies mentioned in the section "Introduction".

Alternatively, investigative study can be implemented after final examination in S5. It can be completed within two weeks. This model has the advantage of keeping students' momentum and allows them to finish the study in relatively shorter period of time. However, other subjects may implement similar studies in same period. Good coordination between different subjects is essential. Other time around major school holiday e.g. Easter could also be considered.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2 (a)	3	4 (b)	5	6
7	8 (c)	9 (c)	10 (d)	11	12 (e)	13

Note: 3-4 hours per session.

The duration for each stage should be flexibly adjusted. Some students prefer spending more time in doing and trying out experiments instead of searching information or writing proposal. A reasonable period of time should be provided before the start of the stage for conducting the investigation so that the necessary materials could be prepared by laboratory technicians or acquired by students themselves. Some investigations may be better to be carried out in a continuous time slot, say 3 hours, instead of 80 minutes. These practical sessions could be arranged during school holiday or post examination period. Teacher should adjust the schedule flexibly to maximise the use of the allocated lesson time.

Assessment

Continuous assessment of students' progress helps teachers decide how well students are doing in the investigative study – when it's time to move on to the next stage, when it's time to backtrack, and when it's time to scaffold students' understanding. During an investigative study, teachers can observe students' practical skills or conduct an interview or a meeting with students to understand their progress, and provide feedback on how the investigation can be improved. Students' reports can provide a more complete picture of students' understanding of the chemical concepts and principles involved, as well as their ability to handle and interpret data obtained in investigations.

When it comes to awarding assessment marks, teachers may be concerned about the workload involved. To address this issue, a set of forms and worksheets are prepared to facilitate learning and assessment of investigative study. Firstly, the worksheets prompt students to think about the things that they should address and help students keep proper records. Secondly, to reduce students' workload in reporting, instead of asking each group to write up a detailed report, each group may submit one completed copy of the worksheets, or the presentation files used for assessment. Besides, teachers may ask students to summarise their findings in a poster or leaflet and then distribute to classmates for sharing.

A sample teacher assessment form is prepared for teacher's reference. Assessment of investigative study can be focused on three areas, namely the design, process and report. Under each area, several assessment criteria are suggested. Of course, teachers can formulate their own sets of assessment criteria and decide the weighting of each criterion. The criteria used are for illustration only; other criteria that reflect the important aspects of investigative study can also be used. In order to let students understand their teacher's expectation, the assessment criteria may be given to students before the investigative study is carried out. Teachers should exercise their professional judgment on how to provide feedbacks to students about their overall performance in investigative study.

Group investigations have many advantages for learning especially in developing students' collaboration. However, teachers may be concerned about the difficulty in arriving a fair mark for individuals. A self-and-peer assessment form is designed to collect students' views on their relative contributions to the group's work. Together with the observations made by teachers in each stage of investigation, teachers can have more information to determine the individual marks by adjusting the corresponding group marks.

Table 1: Suggested Rundown of Learning and Teaching Activities in Chemistry Investigative Study

Stage	Suggested Activity
(a) Searching for and defining questions for investigation (~3 hrs) Venue: Computer room or MMLC	• Teacher arouses students' interests in doing scientific investigation by providing stories of scientific discoveries and scientists, relevant issues covered in news and TV programmes, etc. • Teacher briefs students about the rationale, schedule and requirements of investigative study (IS) and introduces the topic for investigation. Highlight the main points in student handouts, especially the risk assessment. Teacher may also explain some basic techniques in web search, if necessary. • Teacher arranges the grouping of students and collects the relevant information. • It is advised to conduct this session in a computer room/ MMLC or laboratory with computers and Internet connection so that students can search information after the briefing.
(b) Developing an investigation plan (~4 hrs) Venue: Computer room or MMLC	• Teacher discusses with each group of students in turn about their initial plan and provides feedbacks. Alternatively, teacher may request each group of students to give oral presentation of their plans. Some teachers may not prefer the latter so as to avoid students copying others ideas. • Teacher prompts students to think about the aspects that they should consider, especially the feasibility of their plan, distribution of work and time management. • Teacher requests students to submit their revised proposals on time for the preparation of apparatus and materials by the laboratory technician. • Students acquire samples and other resources for their investigations.
(c) Conducting the investigation (~6 hrs) Venue: Chemistry laboratory	• Before this session, teacher requests the laboratory technician to try out the major experiments and acquire the necessary chemicals and apparatus.

Stage	Suggested Activity
	• With the help of the laboratory technician, teacher provides materials and apparatus requested by students in their approved proposal and some commonly used laboratory apparatus, e.g. test tubes, droppers, beakers, and the materials requested by students during the course of investigation. • Teacher helps students revise / learn the necessary laboratory techniques, facilitates students to carry out the experiments they planned, and provides support, guidance and encouragement to students. • Teacher supervises students to safely carry out the investigations and make observations in groups of 3-5. Teacher may request the laboratory technician to assist in supervision of students. • Teacher prompts students to think about what they are measuring and observing, and helps students rectify their mistakes when carrying out experiments.
(d) Organising and analysing data for a justified conclusion (~4 hrs) Venue: Computer room or MMLC	• Teacher helps students to review some basic techniques in organising and analysing data. • Teacher briefs students about the reporting requirements. • Teacher guides students to organise and analyse the data collected. Discuss with each group in turn to understand their progress.
(e) Presenting findings with written reports, posters and other means (~3 hrs) Venue: Computer room / MMLC / Chemistry laboratory	• Allow time for students to do the final preparation for presentation. • Teacher arranges each group to give a 10-15 minute presentation to the class. • Laboratory technician makes a video record of the presentations, if needed. • Teacher and other students listen to the presentations. • Teacher asks questions about the investigations and encourages other students to raise questions e.g. compare the results obtained by different groups using similar methods and explain the discrepancies, if any. • Teacher debriefs the whole class about their work done in investigations. • Teacher asks students to complete the peer and self assessment form, and submit the reports, presentation files, etc. • Teacher assesses the performance of each student based on his observations and information collected. Teacher completes the teacher assessment form.

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Notes for Students

Notes for Students

What is Investigative Study?

Investigative study aims to provide you with opportunities to design and conduct investigations to solve authentic problems. You will have more control over what you do than in ordinary practical work. You will also have the opportunity to experience the ways that scientists generate new information by studying the natural world and proposing explanations based on the evidence from your work. Then, you will understand that science is more than 'getting the right answer', but a 'best' answer against the criteria based on one's judgment. Besides, this investigative study also provides an opportunity for you, as a group of 3-5 students, to work together to demonstrate what you have achieved.

You have about 20 hours of lesson time to work with your group members to conduct the investigative study. In general, investigative study involves the following stages:

(a) Searching for and defining questions for investigation (about 3 hours)
(b) Developing an investigation plan (about 4 hours)
(c) Conducting the investigation (about 6 hours)
(d) Organising and analysing data for a justified conclusion (about 4 hours)
(e) Presenting findings with written reports, posters and other means (about 3 hours)

You are expected to make use of your knowledge and understanding of chemistry, together with generic skills, including but not limited to creativity, critical thinking, communication and problem-solving skills, to engage in a group-based experimental investigative study. Through the learning process in this study, you can also enhance your practical skills and develop an awareness of laboratory safety.

What will you learn?

How much you learn depends on your degree of participation. After participating in investigative study, you will increase your understanding of the science subject matter being investigated, gain an understanding of how scientists study the natural world, develop the ability to conduct investigations, and develop the habit of mind associated with science. As the study is a group work, you are encouraged to share tasks, to pool your gathered information, to brainstorm, to listen, to criticise positively and to accept constructive criticism. You are encouraged to discuss your ideas with your members and teacher using email and discussion forum.

After conducting the investigative study, you should be able to

- justify the appropriateness of an investigation plan;
- put forward suggestions to improve the validity and reliability of a scientific investigation;
- use accurate terminology and appropriate reporting styles to communicate findings and conclusions of a scientific investigation;

- evaluate the validity of conclusions with reference to the process of investigation and the gathered data and information;
- demonstrate mastery of manipulative skills and observation skills as well as a good general bench performance;
- show appropriate awareness of the importance of working safely in laboratory and elsewhere; and
- share ideas and participate actively in group work.

Searching for information

You could search information on the Internet or from books and magazines in the library. Internet allows you to go beyond textbooks to find current and authentic information to help you understand concepts, acquire knowledge, observe and explore the world outside schools. Information search may be very time consuming. It is essential to use proper keywords when widening or narrowing down your web search. Make use of the guiding questions provided on the student handouts. If you find something useful, ensure the information is reliable and up-to-date before you use them.

Remember to keep proper record of the essential information of the references e.g. the book title, relevant page number, author(s) and year of publication in the log sheet ✍ so that you could refer to them later or use them to support your argument when reporting your findings. Web-browsers usually allow you to bookmark websites. You can also print out the useful information from the website or copy the URL in a text document.

Developing an investigation plan

If carefully planned, you should be able to finish the investigation with a sense of achievement, a sense of satisfaction and a feeling of self-confidence because you have experience what it is like to be a chemist. Guiding questions on the student handouts given by the teacher and the proposal form ✍ will give you direction for developing your investigation plan. The following are general considerations that you should make:

- What exactly are you going to investigate? Is it worthy to investigate? What is already known? What new information is needed?
- What questions interest you? Is your research question answerable within the constraints of time and resources?
- What method will you use? You may use an 'established' methodology on a new topic or apply a 'new' methodology to an established topic.
- Can the investigation be organised into a sequence of experiments?
- How many samples will you be able to analyse?
- How many experiments will you conduct? How long will each experiment take? Do you have enough time to complete all the experiments?
- How will you share the tasks among your members?
- How will you record and organise your data and observations?
- What chemicals and apparatus will you use? Are they readily available? Are they safe to use? Do you know how to operate the apparatus?

- How many kinds of chemical will you use? Note that you only have a limited supply of chemicals.
- What are the safety precautions? How to properly dispose of the chemical used? Carry out a risk assessment as described in the next session.
- What observations and measurements will you make?
- How will you control variables? For example, if you are investigating how the nature of electrolyte affects the voltage of a chemical cell, you will need to think about how to keep other conditions such as the temperature constant.

You may begin by brainstorming ideas and questions, discussing the problem given and listing as many different methods as you can. Each person in the group could select a method and write it up in note form. Discuss the advantages and disadvantages of each method. Consider factors such as accuracy, validity and reliability of the methods. Select the 'best' method that you think could solve the problem using equipment available in the laboratory and within the time allocated. Organise your ideas using concept maps or flow diagrams. You could write down your ideas and rough work in your copy of proposal form ✍. After discussion, please fill in the information in an extra copy of the proposal form as a record of the work of your group. You may also type in your proposal using a word processor. Your teacher will discuss with each group in turn. The meeting log sheet ✍ provided will give you some ideas on what could be discussed in the meeting.

You may modify your plan as you go along, but it is important to make careful planning before you start. Plan your investigation carefully so that you can finish your experiments within the allocated time. You must have your proposal approved by your teacher before starting any practical work. Undesirable modifications of experiments may result in laboratory accidents, so you must discuss with your teacher first.

It is important to include safety considerations in the planning process to minimise the risk of harming oneself and others. A risk assessment should be carried out as part of your investigation plan and have it checked by your teacher before starting the activities. You need to deliberate whether your experiment is safe before the investigations are carried out.

Risk assessment is a systematic way of identifying hazards involved in an activity, assessing how likely the hazards will actually cause harm and deciding the preventive measures to be taken to control these risks. You should also be prepared for the relevant emergency procedures in advance.

The following are the steps involved in risk assessment of science experiments:

1. Identifying hazards (substances, procedures or equipment).
2. Assessing how likely the hazard will actually cause harm.
3. Deciding the control measures to be taken to reduce risks to an acceptable level, e.g. using a smaller quantity of substances, a more diluted solution, a less hazardous chemical, a lower voltage, a fume cupboard, personal protective equipment, etc.
4. Finding out how to dispose of hazardous residues properly.

Safety information about the chemicals e.g. material safety data sheets (MSDS) can be obtained from the following websites:

- http://www.cityu.edu.hk/flc/msds_2_1.pdf
- http://www.ilpi.com/msds/#Government
- http://msdssearch.com
- http://www.ilo.org/public/english/protection/safework/cis/products/icsc
- http://www.hhmi.org/research/labsafe/overview.html

After completing the risk assessment form ✍, have it checked by your teacher before you start any investigation.

Carrying out your investigation

You may have many ideas and things to try out, so you have to spend the allocated time efficiently and productively. Share the tasks properly among your group members. However, tasks that could be done by one person should not be shared. Tasks such as carrying out titrations could be done by each member in turn.

It is advisable to do a few small scale trials using small test tubes or microscale apparatus before carrying out large scale investigation. It also avoids shortage and wastage of chemicals. Remember to take proper safety precautions in your risk assessment to ensure the safety of yourself and others. In addition, general safety precautions in the laboratory should be observed. You should never leave any experiments underway unattended. Whenever any strange and unsafe phenomenon is observed, report to the teacher and laboratory technician immediately.

Careful observation is essential at this stage. Make sufficient relevant observations and measurements to reduce error and obtain reliable evidence. It is important to record all your results and observations. You will not be able to recall all the details later. Apart from keeping written record of experimental results in the observation and measurements record form ✍, you can take digital photos of the results as well as your experimental setup. If you are using a datalogger and sensors to record your data, make sure you have saved the data properly.

You need to evaluate whether your work is going as planned or not. Therefore, it is important to work out your results as you go along, rather than leaving these all to the end. Consider modifying your original plan after thorough discussion with your group members and teacher. Your teacher and laboratory technician will be more than happy to give you assistance and guidance.

Do not be discouraged if your experiments fail or if you seem to be getting unexpected results. It is a good chance to test your persistence in solving problem. Many important scientific discoveries were made when scientists obtained unexpected results. In addition, there is almost no investigation will succeed on the first run. More importantly, you should use your chemical knowledge to explain the unexpected results.

Organising and analysing data

You have to organise and analyse the data or information collected. You should evaluate the reliability and quality of your experimental data, and evaluate the methods used as well as their limitations. You have to decide which sets of data could be used to support your arguments. Use tables, graphs, diagrams and photos to show your results where appropriate. You have to look into the following aspects:

- What happened when you changed something? Why did this happen?
- Do the results agree with your predictions?
- Were there any unusual readings? Why did you think these happened?
- What are the major sources of error? In what ways could you have improved what you did?
- How does your results compare with other groups doing similar investigations?
- What could you do next?
- What conclusions could you draw from your data?

Apart from organising your data by paper and pencil (data analysis record form ✍), you can use computer application software to improve your efficiency. For example, you can do repeated calculations and plot graphs using computer spreadsheet software. You can also prepare your proposal and report using word processing software. Presentation software can also help you organise your ideas and present your findings systematically. Each of you could be responsible for drafting different parts of the work. Print them out to facilitate editing and discussion. You can then critically discuss and modify them if necessary.

Reporting your investigation

After so much hard work, it comes to the final stage of the investigative study. You have to use your collected data to justify your conclusion scientifically. Your teacher will advise you on how the investigation should be reported.

Generally, each group should submit one report for assessment and record purpose. Besides, an oral presentation of your findings will help the teacher and your classmates understand what you have achieved. The length of a written report should be around ten A4 pages. Page number should be included in every page of your written report. If time is not allowed, the worksheets/forms completed with the relevant information together with the PowerPoint presentation file are also acceptable as a report for your investigation.

Listed below are the aspects that you can address in your reporting:

- A clear description of what you were investigating and the relevant chemical principles;
- Details of your choice of methods and a description of what you did, with clearly labeled diagrams of your apparatus and materials used;
- Procedures and safety precautions;
- Difficulties encountered and any modifications of your plan to overcome the difficulties;
- Tables summarising your results, graphs and diagrams whenever they are appropriate;

- Treatment of data involving calculations;
- Comments on the results obtained;
- Sources of errors and suggestions for improvement;
- A conclusion of the investigation;
- A list of references;
- Distribution of work among your group members;
- Reflections of what have you learned in this investigation.

Each group will have about 10-15 minutes for presentation. Each of you will have a chance to share your findings with the teacher and classmates. It may be the first time you give a presentation in front of the whole class. Take this opportunity to practice your communication skills. The following are some points that you should note:

- You should get familiar with the content of your presentation so that you can help the audience understand the main points of your investigation.
- Spend more time to discuss the aspects listed above. Factual information could be described briefly.
- Before the presentation, give the teacher a written summary of your data analysis will help him/her better understand what you are presenting.
- Be prepared for questions from the audience about your findings. Your answers to these questions will show your understanding of your findings and the chemistry behind.
- Correct units of measurement and terminology should be used.
- Avoid using too much text in your presentation file. The font size of text should not be too small. Use different colours to highlight the important words so that you can easily refer to them during your presentation. However, the colour of the text should be significantly different from the background to give a reasonable contrast.
- Use graphs and tables to summarise your numerical data to enhance comprehension.
- Use laser pointer or the mouse pointer to direct the audience to the information that you are talking about. Allow sufficient time for the audience to read the information on your slides.
- Do not obstruct audiences' view to your slides while you are presenting.
- Do not turn your back to the audience when you are presenting. Keep good eye contact with the audience and project your voice loud enough so that everyone will be able to hear you.
- Test software and audio-visual equipment to be used before you carry out the presentation.
- When other groups present their findings, be attentive and learn from your classmates. Ask appropriate questions to understand more about their investigations.

Assessment

Assessment is essential to provide information about your learning progress in relation to knowledge, skill and understanding. It helps you understand your strengths and weaknesses. A number of assessment methods like observation, questioning, oral presentation, poster presentation session and the scrutiny of written products (investigation plan, reports, posters, etc.) can be used where appropriate.

With assessment, teacher can identify what emphasis should be made to the next stage of investigation. The information can be collected from the teacher (teacher assessment form), your peer and yourself (self and peer assessment form ✍). The following assessment criteria will be considered in assessing your performance in investigative study.

- Feasibility of the investigation plan (the study is a researchable one);
- Understanding of relevant chemistry concepts and concerns about safety;
- Manipulative skills and general bench performance;
- Ability to solve problems;
- Proper data collection and recording procedures, and ways to handle possible sources of error;
- Ability to analyse and interpret data obtained from first-hand investigation;
- Ability to evaluate the validity and reliability of the investigation process and the findings;
- Ability to communicate and defend the findings in front of the teacher and peers;
- Appropriateness in using references to back up the methods and findings;
- Attitudes towards the investigation.

Exemplars of Chemistry Investigative Study

A Carbonate Rocket

Student Handout

Purpose

To determine the best propellant for a toy rocket.

Introduction

You are a product designer in a research and development department of a toy company. One of the products is a gas propelled rocket. The rocket is launched by adding water and a fizzy tablet into the chamber at the base of the rocket. Because of the reaction between the two ingredients, gas is formed and the gas pressure accumulated causes the rocket to separate from the base and fly into the air.

Fig. 1: A toy rocket

Recently some customers complained that the height reached by the rocket was too low. Your boss asks you to develop a better propellant for the toy rocket from household substances.

Guidelines

1. Search for information about the reaction between water and fizzy tablet. What are the chemicals responsible for the reaction? What is the reaction between them? What gas will be produced?
2. Search for information about other methods that can be used to propel a toy rocket.

   What are the methods and principles?

   What are the differences between these methods?
3. With the possible methods in mind, choose the one which you think is the best and design step-by-step procedures to investigate how to determine for the best propellant (e.g. by varying the types and proportion of chemicals used). How do you vary the experimental conditions in order to achieve the best propellant?
4. What chemicals and apparatus would you use?
5. How can you measure the distance travelled by the rocket accurately?
6. Prepare an outline of your method including material list, procedures and safety measures. Get approval from your teacher before actually carrying out the investigations.

Safety

1. Avoid contact of skin and eyes with acidic substances.
2. Wash immediately with plenty of water if chemicals spilled on your skin.
3. Avoid the powdered substances getting into eyes.
4. Keep a safe distance from the rocket when launching it. Ensure the rocket is launched vertically.

Materials and Apparatus

- A 10 cm^3 measuring cylinder
- An electronic balance
- A weighing bottle / a piece of paper
- Measuring tape (2 m)

(Other chemicals or apparatus may be provided upon request.)

A Carbonate Rocket

Teacher Notes

Introduction

This activity allows students to work in small groups to plan experimental procedures and identify the variables for investigation. The reactions involved in this activity are simple acid-base reactions. It helps students revise and apply the concept of fair test, which is fundamental in carrying out scientific investigation. Students will also learn the reactions actively rather than memorising them.

One Possible Approach

1. Students select suitable substances, e.g. a baking powder and vinegar as propellant.
2. Students place measuring tape near the wall.
3. Students place the materials into the chamber and wait for launching.
4. Students record the maximum height reached by the rocket.
5. Students repeat the above steps to obtain concordant results.
6. Students repeat the experiment with different types and proportions of reagents.

Curriculum Links

Topic IV	Acids and Bases
Topic IX	Rate of Reaction

Prior Knowledge and Laboratory Experience

- Identification of different types of variables (fair test)
- Reaction between carbonates and acids
- Rate of reaction

Remarks

1. Teacher can ask students to do preliminary planning for the experiment one week before. Then students will discuss the plans in a single or double lesson. Once their plans are finalised, experiments could be carried out in an open area. Teacher works as a facilitator to guide the students to achieve the aim of the activity. Students should submit reports afterwards.
2. For safety, try to prevent students from launching rockets at the same time. Moreover, household chemicals (e.g. drain cleaner) that are corrosive should not be used.
3. With this toy rocket, teacher can demonstrate the reaction between carbonates and acids and also its application. From the experimental results and the use of different materials, students and teacher can also discuss the factors affecting the reaction rate. For example,

if both solid oxalic acid and carbonate salt are used, addition of water is essential for the launching. Then the importance of water on producing ionisable ions for reaction can be illustrated.

4. Toy rocket based on the same principle is available on the market. The one shown in Fig. 2 is available from the Hong Kong Association for Science and Mathematics Education. The toy rocket can be replaced by an empty canister with lid e.g. from packages for effervescent vitamin C tablets or photographic films.

Fig. 2: A toy rocket

Sample Data and Calculations

Combination of active ingredients	0.86 g baking soda & 8 cm^3 vinegar	1 g baking soda & 8 cm^3 vinegar	0.86 g baking soda & 8 cm^3 2 M ethanoic acid
The maximum height reached (m)	1.37	1.95	1.14
Rank	2	1	3

1. Hints for choosing the best combination of substances:

- The capacity of the rocket chamber can be measured from the volume of water added to it. The capacity of upper-half chamber is 7 cm^3 and lower-half chamber is 10 cm^3, so the volume of liquid samples used should not exceed 10 cm^3.
- Carbonate salts of Group I elements should not be used as they react too quickly.
- Calcium carbonate is also not suitable because the reaction rate is too slow.
- Magnesium carbonate is a suitable choice because it slowly dissolves in acid and the rocket can be launched in about 10 seconds.
- More concentrated acids and larger amount of powder can be used, but it may not improve launching power. If a large amount of powder is added into the chamber, most of the space has been occupied. Then the amount of acid used will be less and the powder may not react completely with acid.

2. Estimate the volume and pressure of CO_2 generated when the rocket is launched

Since household products (e.g. baking powder) have unknown composition or concentration, we use the reaction between magnesium carbonate and 2 M ethanoic acid for the estimation. With 1 g $MgCO_3$ and 8 cm^3 of 2 M ethanoic acid, the rocket launched to a similar height as that of 0.86 g baking soda and 8 cm^3 2 M ethanoic acid.

$$MgCO_3(s) + 2CH_3COOH(aq) \longrightarrow (CH_3COO)_2Mg(aq) + CO_2(g) + H_2O(l)$$

No. of moles of ethanoic acid = (8/1000) x 2 = 0.016 mol
No. of moles of magnesium carbonate used = 0.016/2 = 0.008 mol
Mass of magnesium carbonate used = 0.008 x 84 = 0.672 g

Excess magnesium carbonate (1 g) is used to compensate the loss before capping and the impurity of reactant.

We assume the launching takes place at room temperature and pressure conditions. Molar volume at r.t.p. = 24 dm^3.

(a) The volume of CO_2 generated:
$0.008 \times 24\ dm^3 = 0.192\ dm^3 = 192\ cm^3$

(b) The pressure built up in this case, using ideal gas equation:
$PV = nRT$
$P\ (7/106) = 0.008 \times 8.314 \times 298$
$P = 2831.5\ kPa = 27.94\ atm$

Common Sources of Error

- Weighing error
- Incomplete reaction between the powder and the acid
- The error of measuring the launching height

References

- 兒童科學第7期 2005匯識教育
- http://pbskids.org/zoom/activities/sci/lemonjuicerockets.html

Getting Copper from its Ore

Student Handout

Purpose

To extract copper metal from a given ore sample.

Introduction

You are a member of a team of chemists working for a mining company. A sample of copper ore weighing about 5 g is collected for analysis. It is believed that the ore contains a mixture of $CuCO_3$ and $Cu(OH)_2$ which are both insoluble in water. Design a cost effective method to extract copper metal from the ore sample. Your team must carry out the experiment of your design and collect supporting data to prove that the method is workable. Your team would get 5 % from the profit as a bonus.

Guidelines

1. What types of reactions will achieve the desired outcome? Can it be achieved in one step or more?
2. How will you isolate your product from the excess reagents?
3. Illustrate your ideas using balanced chemical equations and a flow chart (if necessary).
4. Write an outline of your method to your teacher for approval before carrying out the extraction.
5. Calculate the extraction efficiency ($= \frac{\text{mass of copper extracted}}{\text{mass of ore sample}} \times 100\%$) of your method after carrying out the extraction.
6. Calculate the cost of your method based on the following information.

Dilute sulphuric acid (2M), 1 L	\$ 4.0
Dilute hydrochloric acid (1M), 1 L	\$ 4.8
Zinc powder, 100 g	\$ 17.0
Charcoal powder, 100 g	\$ 12.0
Magnesium ribbon, 100 g	\$ 120.0

   A laboratory Bunsen burner consumes 1.33 kJ town gas per second if the gas tap is fully turned on. Cost of town gas: \$0.21 / MJ (information obtained from Hong Kong and China Gas Company Limited in 2006.)
   Rate of electricity: \$1.265 / kWh (information obtained from Hongkong Electric Holding Limited in 2006)

7. Compare different methods of different teams and find out the most cost-effective method.

Safety

Beware of hot objects.

Materials and Apparatus

- Dilute sulphuric acid
- Dilute hydrochloric acid
- Zinc powder
- Magnesium ribbon
- Electronic balance
- Oven
- 250 cm^3 beakers
- Filter paper and funnel
- Deionised water
- Crucible
- Tongs
- Glass rods
- Spatula
- Measuring cylinders
- Charcoal powder
- Graphite electrodes
- d.c. power supply

(You may not need to use all of the above items. Other chemicals or apparatus may be provided upon request.)

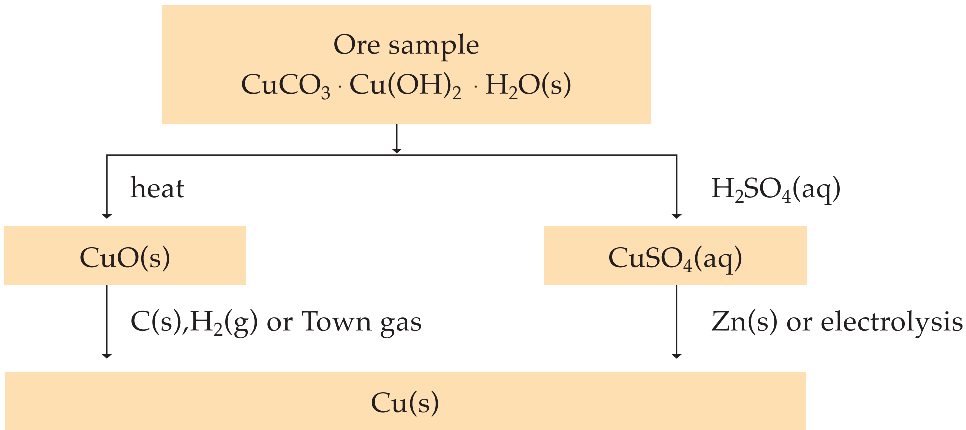
Getting Copper from its Ore

Teacher Notes

Introduction

Apart from developing students' skills in scientific investigation, this activity also helps students consolidate the relevant concepts covered in S4. Students also learn from the activity that there are often more than one way to solve a problem. Some groups may use carbon reduction and the other groups use the displacement method, so that the extraction efficiencies of these two methods can be compared.

Possible Approaches



1. Dissolution in dilute acid followed by displacement with zinc

Dissolve 2 g of the ore sample in excess (20 cm^3) 2 M sulphuric acid to give a blue solution. Then add excess (~1 g) zinc powder to displace all the copper ions from the solution. Zinc granules can also be used, but it will take a few hours to displace all the copper. The mass of zinc needed can be estimated from the amount of sulphuric acid used. Heat is given out during the reaction. The blue colour of the solution becomes paler until it eventually turns clear and brown solid is formed (see Fig. 1 & 2). A small amount of 2 M sulphuric acid could be further added to dissolve the remaining zinc, leaving the copper unreacted. All the zinc metal should be gone when hydrogen gas stops forming. The copper is washed with distilled water in a filter funnel (see Fig.3). Filter the mixture. The filtered copper is put in an oven at 50^{o}C for drying.

Reactions involved:

$$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$$

$$Cu(OH)_2(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + 2H_2O(l)$$

$$CuSO_4(aq) + Zn(s) \rightarrow Cu(s) + ZnSO_4(aq)$$

Fig. 1

Fig. 2

Fig. 3

2. Carbon reduction

Mix 2 g of the ore sample with two spatula measures of charcoal powder in a crucible. Cover the mixture with a layer of charcoal powder. Put the crucible on a tripod and pipe clay triangle and heat very strongly for about 10 minutes (see Fig. 4). Hold the crucible with tongs and tip the powder from the crucible into a beaker half-filled with water. This prevents the re-oxidation of the copper formed, but extra care is needed for this procedure. The charcoal is removed by decantation, i.e. the beaker is swirled so that the heavier copper falls to the bottom and the water and charcoal are poured off. More water may be added to repeat the process (see Fig. 5). The copper is put in an oven at 50^{O}C for drying (see Fig.6).

Fig. 4 : Reaction mixture after strong heating

Fig. 5

Fig. 6 : Product

Reactions involved:

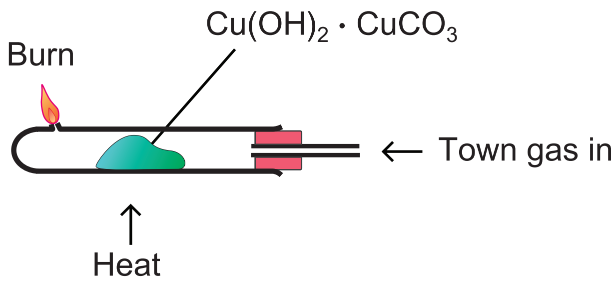
$$CuCO_3(s) \xrightarrow{heat} CuO(s) + CO_2(g)$$

$$Cu(OH)_2(s) \xrightarrow{heat} CuO(s) + H_2O(l)$$

$$2CuO(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$$

3. Reduction by town gas

The separation of copper from excess carbon in the product mixture may be too tedious for students to carry out and is subjected to low yield. Instead, the ore sample can be heated to form copper oxide first in a hard glass boiling tube with a small hole near closed end. The copper oxide formed is then heated in a small stream of town gas for reduction as shown in the setup below. To prevent the copper from re-oxidation, the stream of town gas should be kept passing through the apparatus until it is cold after the reduction process.



A typical composition of town gas would be about 51% hydrogen, 15% carbon monoxide, 21% methane, 10% carbon dioxide and nitrogen, and about 3% of other alkanes.

Reactions involved:

$CuCO_3(s) \xrightarrow{heat} CuO(s) + CO_2(g)$

$Cu(OH)_2(s) \xrightarrow{heat} CuO(s) + H_2O(l)$

$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$

$CuO(s) + CO(g) \rightarrow Cu(s) + CO_2(g)$

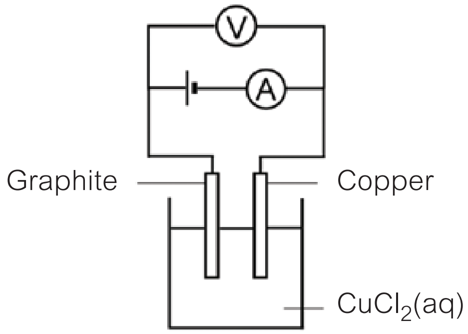
4. Electrolysis

Dissolve 2g of the ore sample completely in 90 cm^3 of 1 M HCl(aq) to obtain $CuCl_2$ solution.

$Cu(OH)_2(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + 2H_2O(l)$

$CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$

Use the $CuCl_2$ solution as electrolyte, weigh a copper strip and use it as cathode. Carry out electrolysis as shown in the setup below. The copper(II) ion in the electrolyte will not be completely reduced after an one-hour reaction, although the colour of the electrolyte turns pale. The copper reduced will not attach firmly on the copper electrode and will shed off in the electrolyte. Therefore, the copper reduced needs to be separated from the electrolyte by filtration.



Exemplars of Chemistry Investigative Study
Getting Copper from its Ore

Curriculum Links

Topic III Metals
Topic IV Acids and Bases
Topic VII Redox Reactions, Chemical Cells and Electrolysis

Prior Knowledge and Laboratory Experience

- Reactions of metals
- Reactions of acids and bases
- Redox reactions and electrolysis

Remarks

1. Instead of using the entire sample in one go, students should use a small portion to try out whether the proposed method works.
2. After the product is dried in oven, the colour of copper turns darker than that before drying. This may be the result of re-oxidation of copper. Therefore, avoid drying of the product in oven for too long.
3. Basic copper(II) carbonate ($CuCO_3 \cdot Cu(OH)_2 \cdot H_2O(s)$) available from chemical suppliers could be given as "copper ore". If sand is present in the sample, product formed from reduction of the copper(II) oxide would be contaminated with sand.
4. Teacher may delete the information from the list of chemicals and equipment given, as it may provide too much hints to students in solving the problem. Besides, for more able students, "junk" items can be provided for distraction.

Sample Data and Calculations

1. Extraction Efficiency

$$\text{Extraction efficiency} = \frac{\text{mass of copper extracted}}{\text{mass of ore sample}} \times 100\%$$

Method	Mass of copper ore used / g	Mass of copper obtained / g	Extraction efficiency / %
Displacement	2	1.11	55.5
Carbon reduction	2	0.66	33.0
Reduction by town gas	2	1.10	55.0
Electrolysis	2	0.23	11.5

According to the information about the contents of the basic copper(II) carbonate displayed on the bottle, the sample contains about 64% copper. This data could be used to calculate the theoretical mass of copper to be extracted.

Carbon reduction is less efficient as some copper powder is lost during decantation. Comparing the above methods for reducing copper, reducing copper by town gas is the most efficient in terms of time and yield. Also, the cost of fuel used is acceptable.

2. Reduction by Town Gas

According to the information provided by Hong Kong and China Gas Company Limited on 20 April, 2006, a laboratory Bunsen burner consumes 1.33 kJ town gas per second if the gas tap is fully turned on. In this investigation, the Bunsen burner was fully turned on for 2 minutes for heating. In addition, town gas was passed through the boiling tube with gas tap half-opened for 4 minutes, including the time for reduction of copper and cooling of the setup.

Town gas used in the experiment: [1.33 kJ x 120] + [(1.33 kJ / 2) x 240] = 319.2 kJ
Rate of town gas: $0.21 / MJ
Cost of town gas used in the experiment: $0.21 x (319.2 / 1000) = $0.07

3. Electrolysis

Time used: 1 hr
Voltage: 2 V
Current: 0.2 A (remained constant throughout the experiment)
Amount of electricity used: (2 x 0.2) / 1000 kWh = 0.0004 kWh
Rate of electricity: $1.265 / kWh (information obtained from Hongkong Electric Holding Limited on 20 April, 2006)
Cost of electricity used in the experiment: $1.265 x 0.0004 = $0.0005
Cost of 1M HCl: $4.8 / L (purchased in 2004)
Cost of HCl used in the experiment: $4.8 x (90/1000) = $0.43

Common Sources of Error

- Some students may use the entire sample provided in one go.
- Excess zinc is not removed from the product.
- The relative amounts of reagents used are not right.
- Copper extracted is re-oxidised.

References

- Davies, K. (1990). *In Search of Solutions.* London: Royal Society of Chemistry.
- Osborne, C. & Johnston, J. (2000). *Classic Chemistry Experiments.* Cambridge, U.K.: The Royal Society of Chemistry.
- http://www.chemguide.co.uk/inorganic/extraction/copper.html

Chemical Cells

Student Handout

Purpose

To construct and test a chemical cell.

Introduction

In a chemical cell, chemical energy is converted to electrical energy. The flow of electrons in an external circuit indicates the occurrence of redox reactions at the electrodes.

You are a writer of a science magazine for children. As the title for the coming issue is chemical cells, you are required to prepare an article on how to make a chemical cell from household chemicals and materials. The chemical cell should be able to power a small electrical device e.g. digital clock.

Guidelines

1. What household chemicals and materials could be used as the container, electrodes and electrolyte for your chemical cell?
2. Will the nature of electrodes, distance between them, the amount and nature of electrolyte affect the voltage/current of your chemical cell?
3. How will you test your chemical cell?
4. What electrical device(s) could be powered by your chemical cell?
5. What information should be provided in your magazine article?
6. Prepare a proposal for approval before actually carrying out the investigation. You may use diagrams and chemical equations to illustrate your plan.

Safety

Some household chemicals may be irritant or corrosive. Beware of sharp edges when preparing metal electrodes.

Materials and Apparatus

- 2.5 V light bulbs
- Digital multimeter
- Datalogger with voltage and current sensors
- Connecting wires with crocodile clips
- Sand paper
- Measuring cylinder

(Other chemicals or apparatus may be provided upon request.)

Chemical Cells

Teacher Notes

Introduction

This activity allows students to design and construct a chemical cell and then test its performance. Students can construct a chemical cell by using household materials and chemicals. They can control different variables, e.g. materials for electrodes and electrolytes, to find out which combination gives a larger cell voltage. They can connect several cells in series to provide a large electrical current to power an electrical device. After all, students should explain the chemical reactions involved in the cell using chemical equations, text and diagrams.

Possible Approaches

1. Students are required to identify the variables for investigations. Some possible variables for investigations are listed below:
   - The effect of the sizes (surface area) of electrodes;
   - The effect of the types of metal electrodes e.g. iron, aluminium, zinc;
   - The effect of the types of electrolytes e.g. lemon juice concentrate, fresh lemon, vinegar, salt and sugar solutions, soft drinks, tea or coffee;
   - The effect of the concentrations of electrolytes;
   - The effect of the temperature.
2. A chemical cell can be constructed using a copper strip and a magnesium ribbon as electrodes and orange juice as electrolyte. The voltage generated will be about 2.72 V. The chemical cell can power a 1.5 V operated clock. Instead, the electrodes can be inserted directly into fruits e.g. potato and banana.
3. A homemade zinc-carbon cell can be constructed using the following procedures. Make some starch paste by mixing some starch and water and then boiling it. Add sufficient quantity of manganese dioxide to the starch paste, making a very thick paste of manganese dioxide. Spread the manganese dioxide paste evenly on the zinc plate. Take some cotton wool soaked with ammonium chloride solution and flatten it onto the manganese dioxide paste. Then, cover the cotton wool with another layer of manganese dioxide paste. Put the carbon plate over this layer of manganese dioxide and your dry cell is ready to use.
4. Dry cell kit with all the necessary materials for construction is also available in the market (see Fig. 1).

Fig. 1 : Student dry cell kit

5. A chemical cell can be constructed using aluminium sheet from soft drink can and pencil lead as electrodes and a mixture of 0.1 M NaOH(aq) and 1 M NaCl(aq) as electrolyte. The cell produces a voltage of about 1.46 V and a current of about 0.23 A. The cell can power a digital clock for over 50 hours.

$$\text{Carbon electrode: } 2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$$
$$\text{Aluminium electrode: } Al(s) + 4OH^-(aq) \longrightarrow Al(OH)_4^-(aq) + 3e^-$$

6. The discharge of the constructed cell can be investigated by connecting its terminals to a small electrical appliance in parallel. Monitor the voltage of the cell using a digital multimeter or datalogger at regular time interval.

7. Student may construct a chemical cell using a carbon rod and an aluminium sheet as electrodes and bleach solution as electrolyte and putting them in a small empty plastic container, e.g. the container of a Chinese medicine (Po Chai Pills 保濟丸). To produce a large voltage, several cells are connected in series and put into an empty canister of photographic film (see Fig. 2-4).

Fig. 2 : This battery consists of four cells connecting in series encapsulated in a film roll canister.

Fig. 3 : This battery consists of nine cells. Its voltage is between 2 – 2.5V.

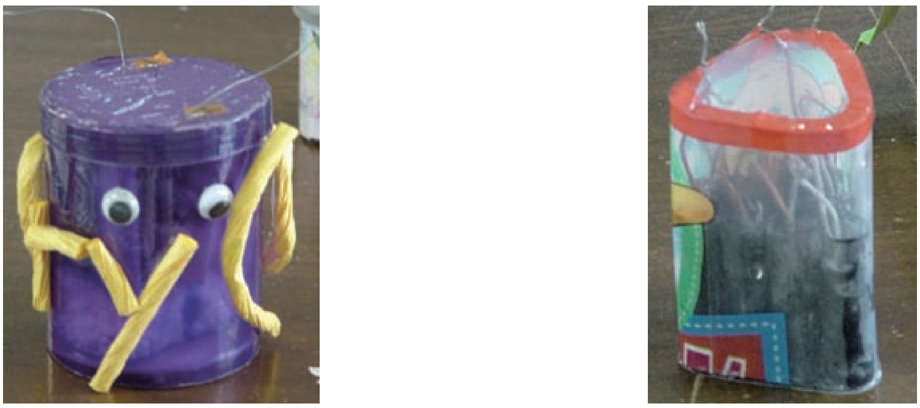


Fig. 4 : Some students made a beautiful decoration on the chemical cell.

8. Some students produce colourful diagrams to illustrate the construction of their chemical cells (see Fig. 5).

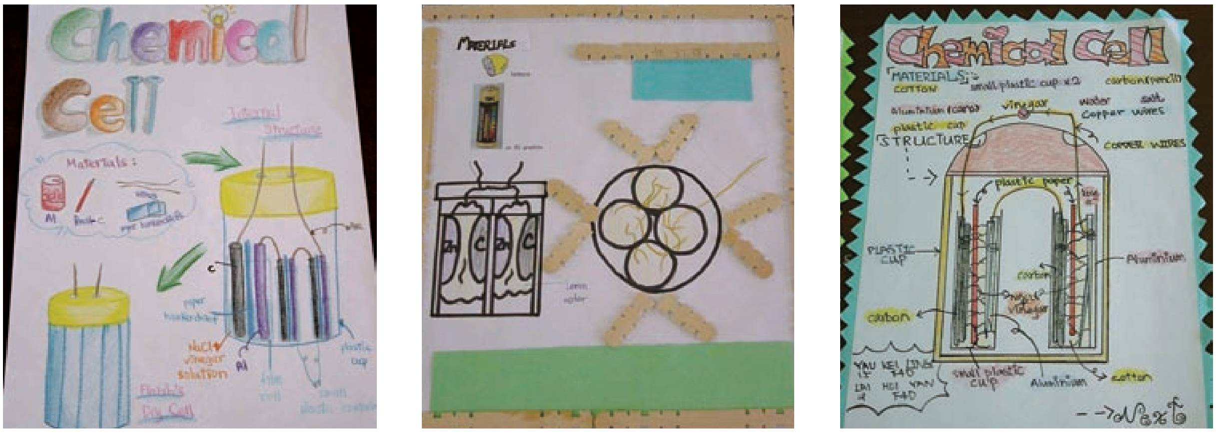


Fig. 5 Diagrams for presentation.

Curriculum Link

Topic VII Redox Reactions, Chemical Cells and Electrolysis

Prior Knowledge and Laboratory Experience

- Redox reactions
- Chemical cells and electrolysis

Remarks

1. For demonstration, a sample cell made of household chemicals and materials could be constructed. It can give students some ideas on how to follow and modify.
2. As the internal resistance of the constructed chemical cells is very large, it may not be possible to power a small electrical appliance. However, some cells can power a very small motor or LED.
3. The voltage should be measured immediately as it drops rapidly after an electrolyte is added.

References

- Orange Juice Clock, Chemistry Comes Alive 3
  http://jchemed.chem.wisc.edu/jcesoft/CCA/CCA3/MAIN/OJCLOCK/PAGE2.HTM

- http://www.selah.k12.wa.us/SOAR/SciProj2005/KevinB.html

Making Your Own Acid-Base Indicator

Student Handout

Introduction

Acid-base indicators are organic dyes that change colours at different pH values. Most indicators are synthesised from chemical reactions, but some indicators can be easily extracted from plant materials e.g. red cabbage, beetroot, blackcurrant and black bean using water or an organic solvent.

Cabbage from soil of different pH values

You work for a waste disposal company. You have just received a shipment of expired household oven cleaner. Before properly disposing of the product, you must know whether the concentration of the alkalis exceeds the limit defined in the waste disposal regulation. Unfortunately, you have run out of the acid-base indicators you normally use for titration. However, you noticed a head of red cabbage and some other vegetables and fruits in your refrigerator. Could you use the plant pigment extracted from the cabbage as indicator for your titration? What other plant materials could be used?

Tasks

You have about 20 hours of lesson time to work with your group members to solve the above problem. Discuss how to share the tasks among your group members and take note of the following. In addition to face-to-face meetings, you may discuss your ideas with your members and teacher using email and discussion forum.

1. Search for information on what substances could be used as acid-base indicators. You may use search engines (e.g. Yahoo or Google), textbooks or reference books. Keep proper record of your information search (complete the information search log sheet ✍).

   You may consider the following when searching for information.

   - What is an acid-base indicator?
   - What is the chemical principle involved in acid-base indicators?
   - What substances inside plant materials (e.g. red cabbage) can be used as acid-base indicator? What are their basic chemical structures?
   - What are the colours of commonly used acid-base indicators, e.g. methyl orange and phenolphthalein, at different pH values? How to determine whether the indicator is suitable for a titration between a strong alkali and a weak acid?

2. With the chosen plant materials, design step-by-step procedures to find out one plant extract that can be used as indicator for the acid-base titration. Illustrate your ideas using a diagram or a flow chart. It is advisable to divide your investigation into several experiments.

   You may consider the following when designing your experiments.

   - How to extract the pigments from plant materials? What solvent can be used to dissolve the pigments? What are the quantities of plant material and solvent needed for preparing your indicator?
   - What are their colours at different pH values?
   - How much indicator should you use in each titration?
   - Is the oven cleaner a strong or weak alkali? What alkaline substance(s) does the oven cleaner contain? What is the approximate concentration of the alkalis in the expired oven cleaner?
   - What is the chemical reaction(s) involved in the titration? Outline calculation steps based on chemical stoichiometry. What assumptions have you made?
   - How do you test whether your indicator is suitable for the titration? What is your criterion? What is the expected colour change? Is your indicator suitable for titration of strong alkalis against strong acids or weak acids?
   - What chemicals and apparatus will you use? What safety precautions should be taken? How will you dispose of the waste that you produce?
   - What are the pros and cons of using your indicator over acid-base indicators commonly found in the laboratory?

   Before carrying out your investigation, prepare a proposal using the proposal form ✍ and seek advice from your teacher.

3. Carry out your investigation and record all observations (complete the observations and measurements record form ✍).

4. Organise and analyse your data (complete the data analysis record form ✍). Please address the following aspects in your reporting:

   - Objectives of your investigation
   - The underlying chemical principle of your method
   - Procedures and safety precautions
   - Any modifications of steps and difficulties involved
   - Tables summarising titration results
   - Treatment of data involving calculations
   - Comments on the results obtained
   - Sources of errors and suggestions for improvement
   - A conclusion of the investigation

- Further investigations that can be conducted
- References
- Distribution of work among your group members
- Reflections of what you have learned in this investigation

5. Give an oral presentation of your investigation.

Safety

Avoid direct contact with chemicals. Wash immediately with plenty of tap water if chemicals spill on your skin. Do not touch any hot objects with your bare hands. Flammable solvent should be heated in a hot water bath on a hotplate instead of direct heating using naked flame.

Never ingest any plant materials used in experiments. Never use plants which are known to contain irritants that induce allergy or dermatitis on skin contact. Plant pigments may stain your hands. Wear disposable plastic gloves when handling the plant materials. When dealing with plant specimens which bear spines or thorns, care must be taken. Wear suitable protective gloves when necessary. Use sharp tools carefully. Wash hands after handling plant materials.

You should carefully assess the risk involved in your experiments and look up relevant safety precautions. Safety information about the chemicals used or produced in your investigation is available from relevant Material Safety Data Sheets (MSDSs). Dispose of chemical wastes and excess materials properly.

Materials and Apparatus

- 0.5 M sodium hydroxide solution

- Ethanol

- 0.5 M ethanoic acid
- 0.5 M hydrochloric acid
- Buffer solutions of pH 1-12
- Distilled water
- 10 times diluted oven cleaner solution
- Common titration apparatus and laboratory glassware
- Microscale chemical apparatus (plastic pipette and well-plate)
- pH meter (or data logger with pH sensor)
- Cutting board

(Other chemicals or apparatus may be provided upon request.)

Making Your Own Acid-Base Indicator

Teacher Notes

Introduction

This investigation is designed to provide students with hands-on experience of extracting useful substances from plant materials and testing their use as indicators for acid-base titrations.

Possible Approaches

This investigation can be divided into two parts. The first part involves extracting pigments from plant materials and testing their colours in different pH values. The second part involves testing whether the pigment can be used as an indicator for acid-base titration and then using the indicator to determine the concentration of the unknown substance.

Using water or ethanol, students can extract pigments from about 3 samples of plant materials. The following plant materials could be used: beetroot, black bean, peels of grape, cherry, blueberries, mangosteen (山竹果) and dragon fruit (火龍果), and petals of geranium (天竺葵), rose and hibiscus. Processed plant materials e.g. curry powder (contains yellow ginger), "Ribena", cranberry juice drink and black currant juice drink could also be investigated. Then, students can test the colours of the pigments in solutions of different pH values. A plant pigment with sharp colour change at a particular pH range is selected for use in acid-base titration.

Positive and negative results are equally important in scientific inquiry. Students may come up with no suitable plant extracts for titration. Yet they can report the results and explain why they think the plant extracts are not suitable.

Red cabbage

Cranberry juice drink

Grape juice drink

Students can first titrate the diluted oven cleaner solution against the standard acid using a commonly used indicator, e.g. phenolphthalein in this case. Then repeat the titration using the prepared indicator. By comparing these two titres, students can decide whether the prepared indicator is suitable for the titration.

Alternatively, titration experiments are conducted to construct titration curves for the titrations between the diluted oven cleaner solution and acids of different strengths. pH meter or data logger with pH sensor could be used to measure the pH of the reaction mixture. Then students can inspect whether the plant extract will have critical colour change at the pH ranges of the vertical parts of titration curves. Using the suitable plant extract as the indicator, the concentration of the alkali in the oven cleaner can be determined.

Curriculum links

Topic IV Acids and Bases

Prior Knowledge and Laboratory Experience

- Reactions of acids and bases
- Molarity calcuations
- Basic concepts of pH measurement
- Acid-base titration

Remarks

1. Teacher may need to help students review relevant concepts, e.g. selection of suitable indicators for acid-base titrations. Students should recognise that plant extract showing many different colours at different pH values may not be a suitable indicator for acid-base titration. It will be best illustrated with the colours of commonly used indicators such as methyl orange and phenolphthalein at different pH values. A simulation activity developed by Royal Society of Chemistry is available at the following URL: http://www.chemit.co.uk/uploads/java/rsc_indicator/applet.htm. The applet allows students to select a combination of acid and base solutions from a menu, along with a choice of indicator. The simulation then draws the graph of the titration of the acid by the base, showing the equivalence point of the titration and the end point of the indicator.

2. Indicators prepared from some plant materials, e.g. grape or cherry peels, may deteriorate quickly. If they are to be used at a later stage, they should be stored in a refrigerator. Some plant extracts, e.g. beetroot, may change colour upon standing in air. They have to be freshly prepared for titration.

3. Anthocyanins are water soluble vacuolar flavonoid pigments that correspond to the red to blue range of the visible spectrum, depending on the pH value of the surrounding solution. They are found exclusively in the plant kingdom, providing colour to everything from fruits to autumn leaves.

Different anthocyanins have been shown to contain the same carbon skeleton and differ only in the nature of the substituent groups. Because of the change in chemical structure in response to changes in pH values, anthocyanins change from red in acids to blue in bases. Anthocyanins are therefore often used as pH indicator.

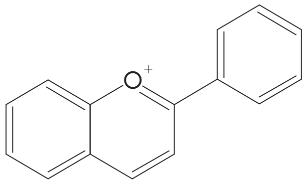
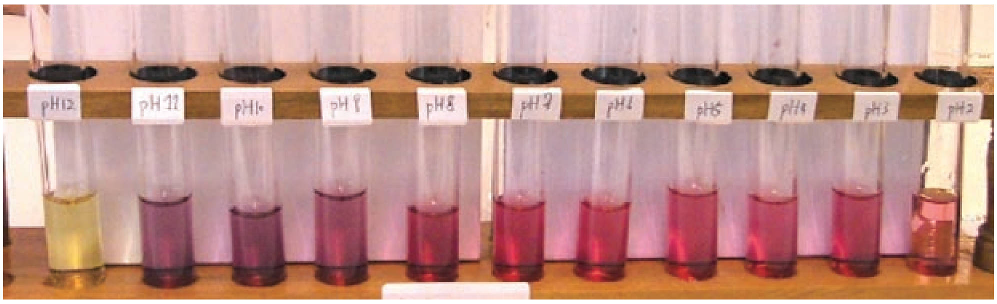


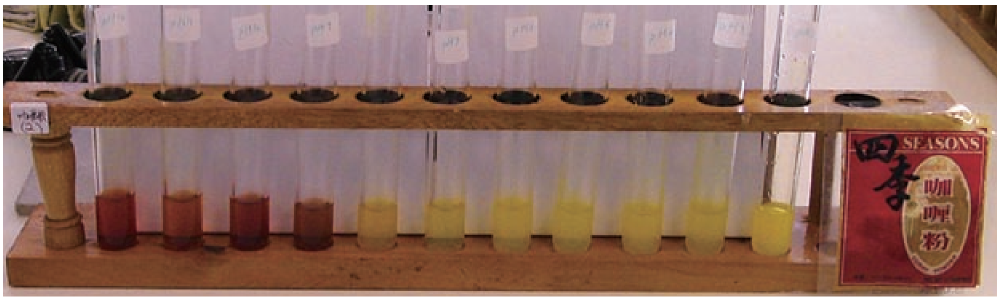
Fig. 1: Basic structure of anthocyanins

4. The following plant extracts have been tested which show distinctive colour change at the end point of acid-base titration. For example, beetroot is suitable for titration of strong alkalis with strong and weak acids.

	Alkaline	Acidic
Beet root	yellow	red
Curry powder	yellow	orange



Beet root



Curry powder

Fig. 2 Colours of beet root and curry powder extracts in solutions of different pH values

Experimental Details

Part A: Extraction of plant pigments

1. Cut coloured plant materials into small pieces.
2. Place a measured amount of materials in a beaker and add 30 cm^3 of distilled water.
3. Use a hotplate to heat the materials for 10 minutes. Stir the materials occasionally while they are being heated (see Fig.3 and Fig. 4).
4. After cooling down, obtain the plant extracts by filtration.

Fig. 3: Heating plant materials in distilled water

Fig. 4: From top left to bottom right: red cabbage, kiwi, blueberry, cherry, grape, dragon fruit peel

Part B: Preparation of buffer solutions and making choice of suitable acid-base indicator

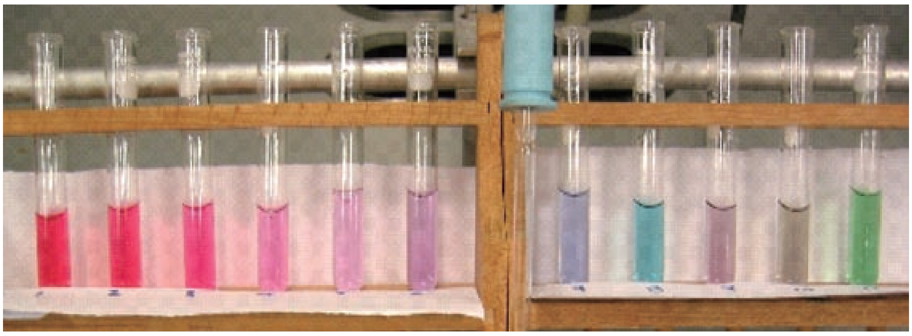
Buffer solutions of pH 1-12 can be provided to students. The chemical compositions described in the table below will give the solutions with the approximate required pH. To prepare the solution of the target pH, check the solution with a pH meter: if the pH is too high, adjust the pH to the target value by adding 1 M HCl; if the pH is too low, adjust the pH to the target value by adding 1 M NaOH. Dilute each of the mixtures with distilled water to 50 cm^3.

pH	Chemical compositions		
1	50 cm^3 0.1M HCl		
2	5 cm^3 0.1M HCl		
3	11.2 cm^3 0.10M HCl	+	0.51 g potassium hydrogen phthalate
4	0.05 cm^3 0.10M HCl	+	0.51 g potassium hydrogen phthalate
5	11.3 cm^3 0.10M NaOH	+	0.51 g potassium hydrogen phthalate
6	2.8 cm^3 0.10M NaOH	+	0.34 g potassium phosphate monobasic
7	14.6 cm^3 0.10M NaOH	+	0.34 g potassium phosphate monobasic
8	23.4 cm^3 0.10M NaOH	+	0.34 g potassium phosphate monobasic
9	2.3 cm^3 0.10M HCl	+	0.24 g sodium tetraborate
10	9.2 cm^3 0.10M NaOH	+	0.24 g sodium tetraborate
11	11.4 cm^3 0.10M NaOH	+	0.11 g sodium hydrogencarbonate
12	5 cm^3 0.10 M NaOH		

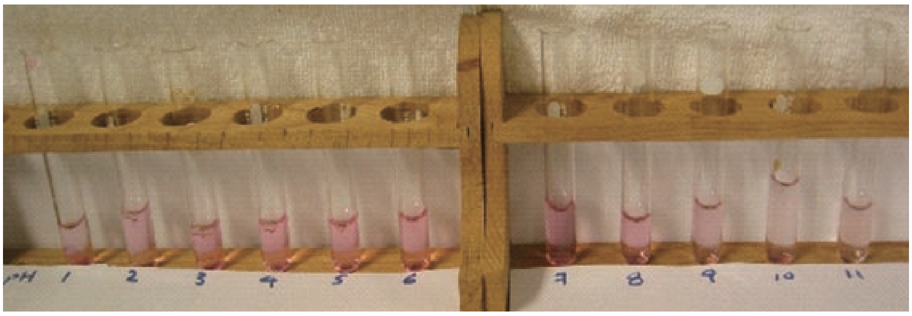
1. Measure and record the pH value of the buffer solutions using pH meter.
2. Label 12 clean test tubes with the pH values of the solution.
3. Fill each tube one-third full with the corresponding solution of known pH. Add approximately 1 cm^3 of the plant extract to each test tube and mix the solution.
4. Record the colours of the plant extract at different pH values.
5. Repeat steps 1-4 with other plant extracts.
6. Determine which plant extract is suitable as an indicator for titration of strong alkalis with strong and/or weak acids.

Sample Data (see Fig. 5)

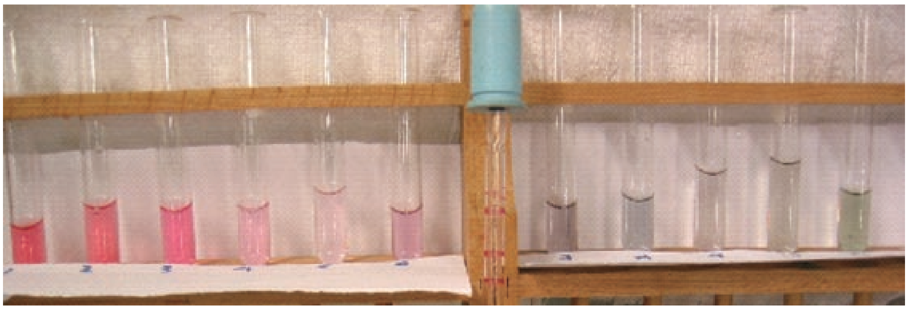
pH	1	2	3	4
Red cabbage	Deep red	Reddish purple	Reddish purple	Purple
Dragon fruit peel	Light red	Light red	Light red	Light red
Blueberry peel	Red	Red	Purple	Pink
Grape juice drink	Red	Red	Light red	Pink
pH	5	6	7	8
Red cabbage	Light pale purple	Pale purple	Violet	Blue
Dragon fruit peel	Light red	Light red	Light red	Light red
Blueberry peel	Light pink	violet	Dark violet	Blue
Grape juice drink	Nearly colourless	Light pink	Grayish purple	Blue
pH	9	10	11	12
Red cabbage	Dark violet	Dark Green	Green	Green
Dragon fruit peel	Light pink	Nearly colourless	Nearly colourless	Nearly colourless
Blueberry peel	Grey	Grayish green	Green	Green
Grape juice drink	Violet	Light brown	Green	Green



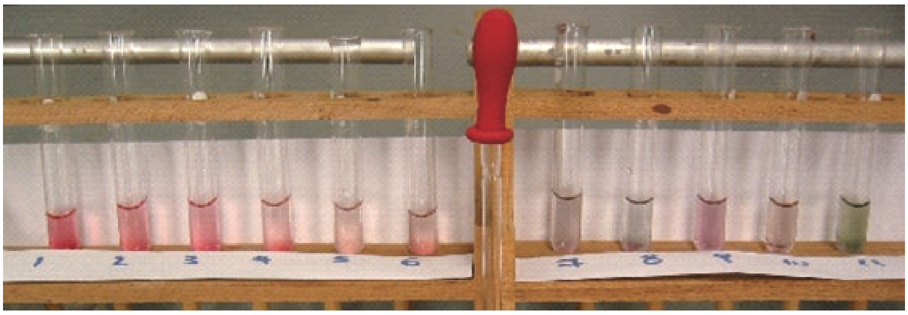
Red cabbage



Dragon fruit peel



Blueberry peel



Grape juice drink

Fig. 5: Colours of plant extracts in solutions of different pH values

Questions for Further Discussion

1. Apart from having a sharp colour change at a particular pH range, what other factors would you consider when selecting a plant extract as an acid-base indicator?
2. Write the equation for the equilibrium of weak acid and its salt, using HA to represent the weak acid, A^- for the salt anion, H^+ for hydrogen ion.
3. What are the limitations of these natural indicators?

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Salt Content of Snack Foods

Student Handout

Introduction

Somehow you may eat snacks especially when you are watching sport games, movie or TV programmes. Salt is often added to snacks as flavouring. Snacks usually contain high level of salts and fat. Excessive intake of salt and fat has been linked to health problems such as high blood pressure.

You are a scientist working for the Consumer Council. In the coming issue of "Choice magazine", the editorial board would like to report on the "healthiness" of different brands of snacks such as potato chips and biscuits. You are required to compare the salt contents in different snacks, especially those labeled as low salt content.

Tasks

You have about 20 hours of lesson time to work with your group members to solve the above problem. Discuss how to share the tasks among your group members and take note of the following. In addition to face-to-face meetings, you may discuss your ideas with your members and teacher using email and discussion forum.

1. Search for information on methods for determining salt content in foodstuffs. You may use search engines (e.g. Yahoo or Google), textbooks or reference books. Keep proper record of your information search (complete the information search log sheet ✍)

   You may consider the following when searching for information.

   - Read a food label of a snack. Is there any information about the salt content?
   - What is the chemical nature of salt?
   - What is the recommended maximum daily intake of salt?
   - What is the underlying chemical principle in various methods of salt content determination?
   - Select one method that involves reaction with chloride ions.

2. With the possible methods in mind, choose the one that you think is the best and design step-by-step procedures to determine the salt content of 2 to 3 snack samples of your choice. Alternatively, you could use two different methods to determine the salt content of the same snack sample and compare the results. Illustrate your ideas using a diagram or a flow chart. It is advisable to divide your investigation into several experiments.

You may consider the following when designing your experiments.

- How to separate the salt from the food? What solvent could be used to dissolve the salt? The separation process may be very slow. How will you speed up the process? Apart from laboratory apparatus, what household items can be used?
- What are the chemical reactions involved in your method?
- What assumptions have you made in your method?
- Are there any other substances present in the food, which may interfere with your method of determination? How to remove the interference if it seriously affects your experimental results?
- How much sample will you use for analysis?
- How to check whether your method is reliable? What is your criterion?
- How will you report your results of the analysis so that you can compare the salt contents of different brands of snacks?
- What chemicals and apparatus will you use? What safety precautions should be taken? How will you dispose of the waste that you produce?
- Outline the calculation steps based on chemical stoichiometry. What unit would you use to report the salt content? What assumptions have you made?

Before carrying out your investigation, prepare a proposal using the proposal form ✍ and seek advice from your teacher.

3. Carry out your investigation safely and record all observations (complete the observations and measurements record form ✍).

4. Organise and analyse your data (complete the data analysis record form ✍). Please address the following aspects in your reporting:

- Objectives of your investigation
- The underlying chemical principle of your method
- Procedures and safety precautions
- Any modifications of steps and difficulties involved
- Tables summarising your results
- Treatment of data involving calculations
- Comments on the results obtained
- Sources of errors and suggestions for improvement
- Recommendations to the general public
- A conclusion of the investigation
- Further investigations that can be conducted
- References
- Distribution of work among your group members
- Reflections of what you have learned in this investigation

Does your result agree with the figures of salt content displayed on the label of the snacks (if any)? What may be the reasons for the discrepancy? Is there any difference in salt content between normal and 'low salt' foods? Try to design further experiments to find it out.

5. Give an oral presentation of your investigation.

Safety


EYE PROTECTION MUST BE WORN
必須戴上安全眼鏡

No eating or drinking is allowed in the laboratory. Never ingest any snacks used in the experiments. Do not touch any hot objects with your bare hands. Avoid direct contact with chemicals. Wash immediately with plenty of tap water if chemicals spill on your skin.

You should carefully assess the risk involved in your experiments and look up relevant safety precautions. Safety information about the chemicals used or produced in your investigation is available from relevant Material Safety Data Sheets (MSDSs). Dispose of chemical wastes and excess materials properly.

Materials and Apparatus

- 0.1M silver nitrate solution
- 5% potassium chromate indicator


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- Distilled water
- Filter paper
- Common titration apparatus and laboratory glassware

(Other chemicals or apparatus may be provided upon request.)

Salt Content of Snack Foods

Teacher Notes

Introduction

Nutrition information is one of the most useful parts of the food label which can always be found on the prepackaged food. Consumers rely on the labels to make wise nutritional choices as the labels can, to a certain extent, tell the healthiness of the food. However, food manufacturers may use the food label or attractive food package to entice more people to buy the product.

This investigation demonstrates the application of analytical chemistry in everyday life. The main objective of this investigation is to ask students to investigate the salt contents in snacks and compare the results with the figures given on the food labels. Students are required to devise and carry out quantitative analysis of salt in different brands of snacks.

Possible Approaches

The sodium content of foods can be determined by many methods. Assuming all chloride comes from sodium chloride, the sodium content of the sample can then be calculated from the chloride content. Methods such as Mohr and Volhard titrations are official methods of analysis of chloride content for many products. The above methods are less expensive than the analysis using atomic absorption spectroscopy or inductively coupled plasma-atomic emission spectroscopy adopted in the testing laboratories. In addition, these methods are possible to be carried out in secondary school laboratories.

Precipitation titrations and gravimetric method can be used to determine the salt contents in snack foods. Mohr method is a direct titration method using standard silver nitrate solution as the titrant. It is useful for determining chloride in neutral or unbuffered solutions. Volhard method involves adding excess $AgNO_3$(aq) to precipitate chloride in the acidic medium, and the excess Ag^+(aq) is determined by back titration with standard potassium thiocyanate solution. Gravimetric method is the simplest one, but it requires careful weighing of the samples which should contain a fairly significant concentration of chloride ions. The precipitated silver chloride is also subjected to photodecomposition.

Students' investigations may involve using:

- one of the above methods to compare salt contents of three brands of snack of the same kind;
- one of the above methods to compare salt contents of three snack food samples e.g. biscuits, pawn sticks, peanuts; or
- two of the above methods to analyse the salt content of a food sample and compare the results obtained.

1. Mohr Method

In this method, the amount of chloride ions are determined by titrating the sample with a standard solution of $Ag^+(aq)$, using $CrO_4^{2-}(aq)$ as an indicator. $Ag^+(aq)$ ions react with both $Cl^-(aq)$ and $CrO_4^{2-}(aq)$ ions to give precipitates. However, since AgCl(s) has a lower solubility than $Ag_2CrO_4(s)$, AgCl(s) is formed first. After all $Cl^-(aq)$ ions in the sample are consumed, the first drop of $Ag^+(aq)$ in excess will react with the chromate indicator, giving a red precipitate.

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$	Precipitation Reaction
$2\ Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$	End-Point Reaction

In this method, neutral medium should be used since, in alkaline solutions, silver ions will react with the hydroxide ions and form $Ag_2O(s)$. In acidic solutions, silver chromate(VI) will be dissolved. Therefore, the pH of solution should be kept at about 7. If an acidic solution of a chloride is to be analysed, the following alternatives can be considered:

- Neutralise the acid with excess calcium carbonate (chloride free) and use potassium chromate as indicator in the titration;
- Add excess silver nitrate and estimate the excess by potassium thiocyanate (see Volhard Method below) ;
- Use an adsorption indicator (Fajans' Method).

2. Volhard Method

In the Volhard method for the determination of chloride and other anions, a measured volume of standard silver nitrate solution is added to the sample solution; excess amount of silver nitrate is needed to react with the halide:

$Ag^+(aq) + X^-(aq) \rightarrow AgX(s) + \text{excess } Ag^+(aq)$	Precipitation Reaction

The excess silver ion is then back-titrated with standard thiocyanate using saturated ammonium iron(III) sulphate solution as indicator:

$SCN^-(aq) + \text{excess } Ag^+(aq) \rightarrow AgSCN(s)$	Back-Titration Reaction
$SCN^-(aq) + Fe^{3+}(aq) \rightarrow Fe(SCN)^{2+}(aq)$	End Point Reaction

If the silver halide precipitate is less soluble than silver thiocyanate, the excess silver ions can be titrated directly with potassium thiocyanate. This applies to silver bromide and silver iodide. However, silver chloride is more soluble than silver thiocyanate and must be removed by filtration so that it is not converted to silver thiocyanate during the titration:

$$SCN^-(aq) + AgCl(s) \rightarrow AgSCN(s) + Cl^-(aq)$$

In the past, a small amount of nitrobenzene was added to coat the precipitated AgCl(s), and thereby eliminate the need for filtration. However, nitrobenzene has now been identified as a health hazard and is no longer used in this way.

3. Gravimetric Method

Known mass of snack is grinded and dissolved in a known amount of hot distilled water. The filtrate is collected and the chloride ions in it are precipitated by adding excess silver nitrate solution. The mass of AgCl(s) is determined by weighing.

There are two main sources of error in this method. Firstly, the presence of any other halides in the filtrate makes the recorded mass higher than the theoretical one. It is because they produce a silver halide which is even more insoluble than silver chloride. Also, silver chloride is light sensitive and excessive photodecomposition will occur, forming a violet-purple precipitate:

$$AgCl(s) \xrightarrow{\text{sunlight}} Ag(s) + \tfrac{1}{2} Cl_2(g)$$

Because of the formation of the finely divided silver metal, the recorded mass will be lower than the theoretical value. If silver ion is present, in addition to the above, the following reaction will also occur as a result of the photodecomposition reaction:

$$3Cl_2(g)+3H_2O(1)+5Ag^+(aq) \xrightarrow{\text{sunlight}} 5AgCl(s)+ClO_3^-(aq)+6H^+(aq)$$

If this reaction predominates, the recorded mass will be higher than the theoretical value. To minimize such errors, exposure to sunlight should be minimized as far as possible.

Curriculum Links

Topic XV Analytical Chemistry

Prior Knowledge and Laboratory Experience

- Precipitation reaction of silver chloride
- Volumetric analysis

Remarks

1. Snacks such as potato chips should not be grinded as the filtration of the solution mixture takes a long time to complete. Instead, hot water can be used to dissolve the chloride ions of the samples.

2. Nutrition information regarding sodium content may be provided on labels of some snack packages. The information can be used to estimate the volume of titrant. Typical salt content of potato chip is around 1 g sodium per 100 g sample.

3. Healthy 19- to 50-year-old adults should consume 1.5 g of sodium and 2.3 g of chloride each day, so as to replace the average amount lost through perspiration and to achieve a diet that provides sufficient amounts of other essential nutrients. Elevated blood pressure, which may lead to stroke, coronary heart disease and kidney disease, is associated with high sodium intake. On average, blood pressure rises progressively as salt intake increases. A tolerable upper intake level - a maximum amount that people should not exceed - is set at 5.8 g of salt (equivalent to 2.3 g of sodium) per day.

Experimental Details

Safety Precautions

1. Keep silver nitrate away from your skin and clothes. Silver salts are readily reduced to metallic silver which forms stains that are difficult to remove.
2. Potassium chromate(VI) is very toxic. It is also irritating to eyes, skin and the respiratory system. Wear suitable gloves and eye protection. Use a fume cupboard if the solid is a fine powder.
3. Potassium thiocyanate is harmful.
4. Ammonium iron(III) sulphate indicator solution is irritant.
5. Nitric acid is corrosive. It can cause severe burns. Skin turns yellow on contact and may peel off. Vapour is dangerous to eyes and the respiratory system. Great care should be taken when handling concentrated acid.

Solutions and Chemicals Required

- Standard 0.1 M silver nitrate solution
  Dry 5 g of $AgNO_3$ for 1-2 hours at 100°C, but not longer. Cool for 30-40 minutes in a desiccator. Accurately weigh (to the nearest 0.1 mg) about 4.25 g of $AgNO_3(s)$ and make up to 250 cm^3 solution using distilled water. Store the solution in a clean, dry 500 cm^3 glass-stoppered amber bottle. (Silver nitrate solution of unknown concentration can be standardized by a standard solution of sodium chloride.)

- Potassium chromate (VI) indicator solution (5 %, about 0.25 M)
  Dissolve 1 g of K_2CrO_4 in 20 cm^3 of distilled water.

- Potassium thiocyanate solution (0.05 M)
  Weigh 2.43 g of solid KSCN and dissolve it in 500 cm^3 of distilled water in a volumetric flask.

- Ammonium iron(III) sulphate solution (saturated)
  Add 8 g of $NH_4Fe(SO_4)_2{\cdot}12H_2O$ to 20 cm^3 of distilled water and add a few drops of concentrated nitric acid.

- Nitric acid (1:1, concentrated, 6M and very dilute)
  1:1 nitric acid is about 5 mol dm^{-3} and made by carefully mixing concentrated nitric acid (70%) with deionised water in equal volumes.

Mohr Method

Determination of Chloride Content of Potato Chips

1. Weigh accurately approximate 10 g of potato chips in a 250 cm^3 beaker, then add about 125 cm^3 of hot distilled water into the beaker.
2. Stir the mixture carefully for 30 s, wait for 1 minute, stir again for 30 s, then let it cool down to room temperature.
3. Filter the solution through glass wool. Transfer the filtrate to a 250 cm^3 volumetric flask and make it up to the mark with distilled water.
4. Using a pipette, transfer 25.0 cm^3 of the filtered solution to a 250 cm^3 conical flask. Add 1 cm^3 of 5% potassium chromate(VI) indicator to the solution.
5. Titrate the solution with standard 0.1 M $AgNO_3$ to the first visible pale reddish brown colour of silver chromate(VI) that persists for 30 s. The potassium chromate(VI) indicator initially gives a cloudy solution of a faint lemon-yellow colour. Record the volume of titrant used.
6. Repeat the titration two to three times to obtain concordant results.

Volhard Method

Part A: Standardisation of 0.05 M Potassium Thiocyanate Solution

KSCN is a very deliquescent solid. Standardisation with standard silver nitrate solution is required to determine the concentration of the KSCN solution prepared.

1. Pipette 10.0 cm^3 of standard 0.1 M silver nitrate solutions to a 125 cm^3 conical flask. Add 5 cm^3 of 1:1 nitric acid and 1 cm^3 of ammonium iron(III) sulphate solution as indicator.
2. Titrate with potassium thiocyanate solution, swirl the solution constantly until the reddish brown colour begins to spread throughout the solution.
3. Then add potassium thiocyanate solution dropwise, shaking the solution thoroughly between additions of drops. The end point is the first appearance of a dark red colour due to the presence of iron(III) thiocyanate complex. This is more easily seen if the precipitate is allowed to settle after each addition near the end point. Besides, it will be helpful to compare the colour with a solution made by adding 5 cm^3 of 6M nitric acid and 2 cm^3 of ammonium iron(III) sulphate indicator to 75 cm^3 of water. Record the volume of titrant used.
4. Repeat the titration two to three times to obtain concordant results.

Part B: Determination of Chloride Content of Potato Chips

1. Weigh accurately approximate 10 g of potato chips in a 250 cm^3 beaker, then add about 125 cm^3 of hot distilled water into the beaker.
2. Stir the mixture carefully for 30 s, wait for 1 minute, stir again for 30 s, then let it cool down to room temperature. Filter the solution through glass wool into a 250 cm^3 conical flask.
3. Add 50.0 cm^3 of 0.1 M $AgNO_3$(aq) to the filtrate, and then 5 cm^3 of 1:1 nitric acid into the conical flask. Stopper the flask with a rubber bung and shake until the precipitated silver chloride settles, leaving a clear supernatant liquid.
4. Filter the solution through a piece of dry filter paper (the solution must be filtered because silver chloride is more soluble than silver thiocyanate and tends to react with iron(III) thiocyanate.). Transfer the filtrate to a 250 cm^3 volumetric flask and make it up to the mark with distilled water.
5. Using a pipette, transfer 50.0 cm^3 of the filtrate solution into a conical flask, add 1 cm^3 of saturated ammonium iron(III) sulphate indicator and titrate the excess silver nitrate with 0.05 M potassium thiocyanate solution. The end point is the first appearance of a dark red colour due to the iron(III) thiocyanate complex. Record the volume of titrant used.
6. Repeat the titration two to three times to obtain concordant results.

Determination of Chloride by Gravimetric Analysis

1. Weigh accurately approximate 10 g of potato chips in a 250 cm^3 beakers, then add about 125 cm^3 of hot distilled water into the beaker.
2. Stir the mixture carefully for 30 s, wait 1 minute, stir again for 30 s, then let it cool down to room temperature.
3. Filter the solution using suction filtration.
4. Add approximately 0.5 cm^3 of concentrated nitric acid to the filtrate.
5. Add standard 0.1 M silver nitrate solution to the conical flask from a burette until no more new precipitate forms. Allow the solution to stand for a minute and then test to see if it is completely precipitated by adding one drop of silver nitrate solution.
6. Let the mixture stand in dark for at least one hour until the precipitate coagulates.
7. Before filtering with Buchner funnel and filter flask, weigh the filter paper. Then filter the supernatant liquid. Wash the precipitate in the conical flask three times with a few cm^3 of very dilute nitric acid and pour each washing through the Buchner funnel.
8. Transfer the precipitate to the Buchner funnel. Wash any loose particles from the conical flask with a little distilled water. Wash the precipitate on the Buncher funnel three times with a few cm^3 of very dilute nitric acid and then a few cm^3 of distilled water.
9. Carefully place the filter paper containing the precipitate on a watch glass and dry overnight.
10. Weigh the dried filter paper and precipitate and calculate the mass of $AgCl(s)$ obtained.
11. Repeat the above procedures with a known amount of standard sodium chloride solution to check the accuracy of the method.

Questions for Further Discussion

1. It is essential in this investigation that glassware is washed with distilled water, but not tap water. Why?
2. Some snacks are marketed as "low salt" content. How can the manufacturer reduce the "salt" content without altering the taste of the snacks?

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How to Make It Hot?

Student Handout

Introduction

Self-heating drinks or meals are very convenient for mountain climbing and other survival expeditions. These products require no additional fuel to heat them and assure each individual a hot drink or meal. This technology was also developed for military expeditions and space travel.

You are working as a chemist in a food company. Your company would like to develop a self-heating container for instant foodstuff. You are asked to design a self-heating package which could be used to heat up the food or drink contained to 60°C within a few minutes and maintains the temperature for 15 minutes. The package should be heated up by chemical reaction(s) rather than combustion of fuel. The package should also be convenient to carry and easy to use; and the food or drink is to be served straight out of the package.

Tasks

You have about 20 hours of lesson time to work with your group members to solve the above problem. Discuss how to share the tasks among your group members and take note of the following. In addition to face-to-face meetings, you may discuss your ideas with your members and teacher using email and discussion forum.

1. Search for information on the working principle of self-heating packages and what substances could react to generate heat. You may use search engines (e.g. Yahoo or Google), textbooks or reference books. Keep proper record of your information search (complete the information search log sheet ✍).

   You may consider the following when searching for information.

   - What chemicals react to produce a steady supply of heat? What are the chemical reactions involved? What are the types of reactions involved?
   - Why are the chemicals used? What factors should be considered?
   - How to calculate the quantities of heat produced from the reaction?
   - What is the general design of a self-heating package?

2. With the chemical reaction(s) of your choice, design step-by-step procedures to construct and test the performance of your self-heating package. Illustrate your ideas using a diagram or a flow chart. It is advisable to divide your investigation into several experiments.

You may consider the following when designing your experiments.

- What chemicals and apparatus would you use?
- The chemicals used may be corrosive. Besides, exothermic reactions can be hard to control. What safety precautions should be taken? How will you dispose of the waste that you produce?
- What is the volume of the drink/food that the package can hold? What material will you use to hold the drink/food?
- How much chemicals should be used to heat up the drink/food to the required temperature?
- What is the quantity of heat generated from your reaction? Show your calculations and give the assumptions that you have made.
- How to measure the heat produced? Which part of the package should you measure the temperature? How often should you measure the temperature? How to prevent the heat loss to the surrounding?
- How should the heating component and the drink/food being heated be arranged? How to start the heating reaction? How to test the performance of your self-heating package?
- What products would you recommend to be marketed using the self-heating package?
- Is it possible to recycle the chemicals used? If not, how would you advise your customer to dispose of the used package properly?
- Is your product safe for use by customers? How to ensure that the food/drink will not be contaminated by the chemicals used for heating?

Before carrying out your investigation, prepare a proposal using the proposal form ✍ and seek advice from your teacher.

3. Carry out your investigation and record all observations (complete the observations and measurements record form ✍).

4. Organise and analyse your data (complete the data analysis record form ✍). Please address the following aspects in your reporting:

- Objectives of your investigation
- The underlying chemical principle of your method
- Procedures and safety precautions
- Any modifications of steps and difficulties involved
- Treatment of data involving calculations
- Comments on the results obtained
- Sources of errors and suggestions for improvement
- A diagram of your self-heating package with instructions on how to activate the heating, and the unit cost of your self-heating package
- A conclusion of the investigation
- Further investigations that can be conducted
- References
- Distribution of work among your group members
- Reflections of what you have learned in this investigation

5. Give an oral presentation of your investigation.

Safety

NEVER allow reactions to occur in a closed system. Exothermic reactions can be hard to control, so don't use too much chemicals at one time. Do not touch any hot objects with your bare hands. No eating or drinking is allowed in the laboratory. Avoid direct contact with chemicals. Wash immediately with plenty of tap water if chemicals spill on your skin. If glass thermometer is to be used, use them carefully to avoid breakage.

You should carefully assess the risk involved in your experiments and look up relevant safety precautions. Safety information about the chemicals used or produced in your investigation is available from relevant Material Safety Data Sheets (MSDSs). Dispose of chemical wastes and excess materials properly.

Materials and Apparatus

- Common laboratory apparatus and glassware
- Digital thermometer or temperature sensor connected to a data logger

(Other chemicals or apparatus may be provided upon request.)

How to Make It Hot?

Teacher Notes

Introduction

This investigation provides students with an opportunity to apply their chemical knowledge to design a self-heating package and test the performance of the product constructed. It also allows students to demonstrate their creativity when constructing the product from common household materials and selecting the food/drink to be heated up.

Possible Approaches

Basically, this investigation could be divided into 2 parts. The first part is to study the quantities of heat produced from different chemical reactions. For example, students can investigate the best mass combination of calcium oxide and water to give the highest temperature rise. They may try different quantities of calcium oxide and water (see the table below) to get the maximum temperature rise. This should give students a preliminary idea of how much chemicals should be used in their device.

CaO/g Water/cm^3	10	20	30
20			
40			
60			

Apart from using the reaction between CaO and water, students may try other chemical reactions, e.g. oxidation of iron powder, displacement reaction between magnesium or zinc powder and copper(II) sulphate solution, dissolution of anhydrous calcium chloride in water and reaction of a mixture of magnesium and iron powder with water. Some reactions, e.g. neutralisation of acids and alkalis solutions, may not be suitable as the heat produced could not be sustained for long.

The second part is to make use of the data obtained in the first part to design a self-heating food container. Students should justify their choices based on the amount of heat evolved, reaction rate, cost, etc. Students may come up with many creative ideas to use the constructed device to reheat coffee, warm milk for baby, melt chocolate or fry egg, etc. The substances to be heated up often dictate which chemicals and how much chemicals should be used.

The chemicals for generating heat can be placed underneath the drink/food to be heated as in ordinary cooking. Other orientations, e.g. inside or surrounding the food, can be investigated (see Fig. 1-4).

Fig. 1 : A self-heating device constructed from an aluminium can and a large disposable polystyrene cup. The chemicals for heating could be placed in the aluminium can or the polystyrene cup.

Fig. 2 : A device constructed from a plastic soap holder and a heart-shaped cooking metal plate.

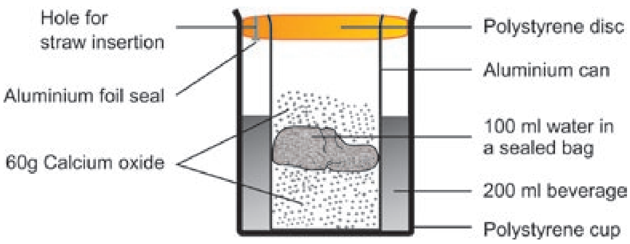


Fig. 3 : A more sophisticated design of a self-heating device. A pin is poked through the polystyrene disc and the water bag inside to start the reaction.

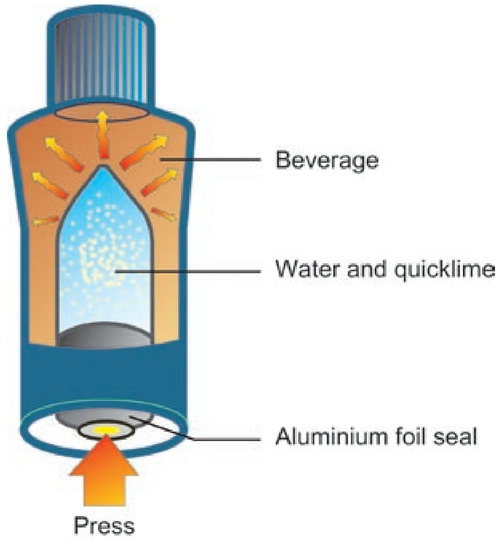


Fig. 4 : Another design of a self-heating container for beverage.

Curriculum Links

Topic III	Metals
Topic IV	Acids and Bases
Topic VIII	Chemical Reactions and Energy

Prior Knowledge and Laboratory Experience

- Properties and reactions of acids and bases/alkalis
- Some exothermic reactions
- Experimental skills in studying heat changes of chemical reactions

Remarks

1. The most commonly used chemical in self-heating device is calcium oxide, also known as lime or quicklime. Quicklime requires careful handling as it can react vigorously with water to become calcium hydroxide or hydrated lime, a process known as 'slaking'. The enthalpy change of the reaction is approximately -82.2 kJ mol^{-1}.

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s) \qquad \Delta H\ -82.2\ kJ\ mol^{-1}$$

2. As old stock of calcium oxide may be slaked, the calcium oxide should be newly acquired and tested before the investigation to avoid disappointment. Store calcium oxide in an airtight container or a desiccator to avoid the reaction with moisture and carbon dioxide.

3. Students should bring their own materials such as aluminium cans and large disposable polystyrene cups for making the containers.

Experimental Details

Safety Precautions

- Safety spectacles should be worn at all times.
- Avoid skin contact with chemicals. Wear protective gloves if necessary.
- Care must be taken when adding water into the calcium oxide powder as the reaction is very exothermic. **The heat produced may melt the plastic containers or crack glass beakers**.
- Heat produced may vaporise the water and create excess pressure inside the reaction vessel. Never allow the reaction to occur in a closed system.
- Never mix calcium oxide with acid. The reaction is violent and can spatter the hot acid.
- Care should be taken in disposing of calcium oxide as a delayed exothermic reaction with water may occur.

Part A: Thermodynamic analysis of calcium oxide in water

1. Measure 50 cm^3 of water using a measuring cylinder.
2. Use a thermometer or a temperature sensor connected to a data logger to measure the initial temperature of water.
3. Place 15 g of CaO in a polystyrene cup. Add 50 cm^3 of water into the cup carefully. ***Caution:*** Large amount of heat will be generated. In extreme cases it can melt the polystyrene cup or cause paper to catch fire.
4. Stir the mixture and measure the temperature at one-minute intervals for 20 minutes (see Fig. 5-6).

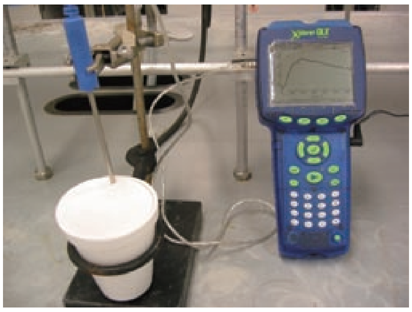


Fig. 5 : The setup for measuring temperature change.

Fig. 6 : LCD display of the data logger showing the temperature change of the reaction mixture.

5. Plot a graph showing the change of temperature across time.
6. Determine the highest temperature reached and hence the increase in temperature. Calculate the energy released of the reaction.
7. Repeat the experiment with different amount of calcium oxide and water if necessary.

Part B: Construction of a self-heating food / drink container

Note: The following design is just one of the many possible designs for the self-heating container. Teachers should let the students design their own systems.

1. Put 15 g calcium oxide and a bag of 50 cm^3 water inside an aluminium can (see Fig. 7-8).

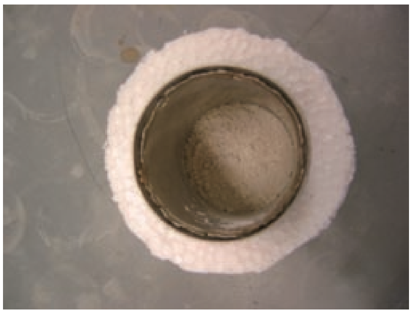


Fig. 7 : 15 g of calcium oxide inside the can.

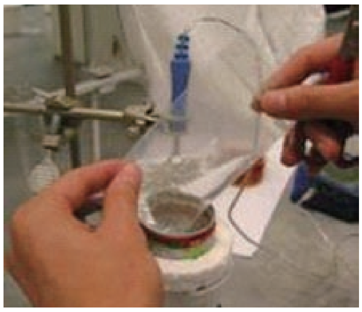


Fig. 8 : A bag of water is placed in the can.

2. Pour 50 cm^3 of drink into the polystyrene cup (see Fig. 9).
3. Put a polystyrene ring on the upper part of the can and place the can into the polystyrene cup (see Fig. 10).

Fig. 9 : Pour the drink into the polystyrene cup

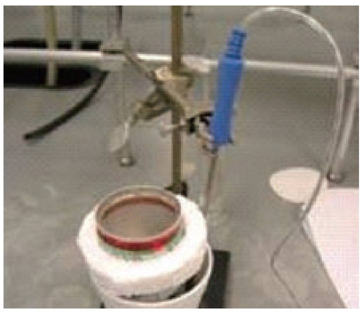


Fig. 10: Put the can inside the polystyrene cup

4. Cut the bag to let the water flow out to start the reaction (see Fig. 11).

Fig. 11 : Cut the bag and let the water come out

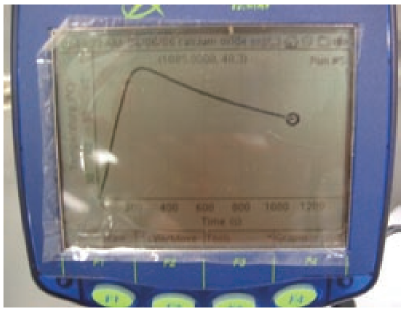


Fig. 12 : Record the temperature change

5. Cover the can with aluminium foil. Stir the mixture carefully and measure the temperature at one-minute intervals for 20 minutes (see Fig.12).

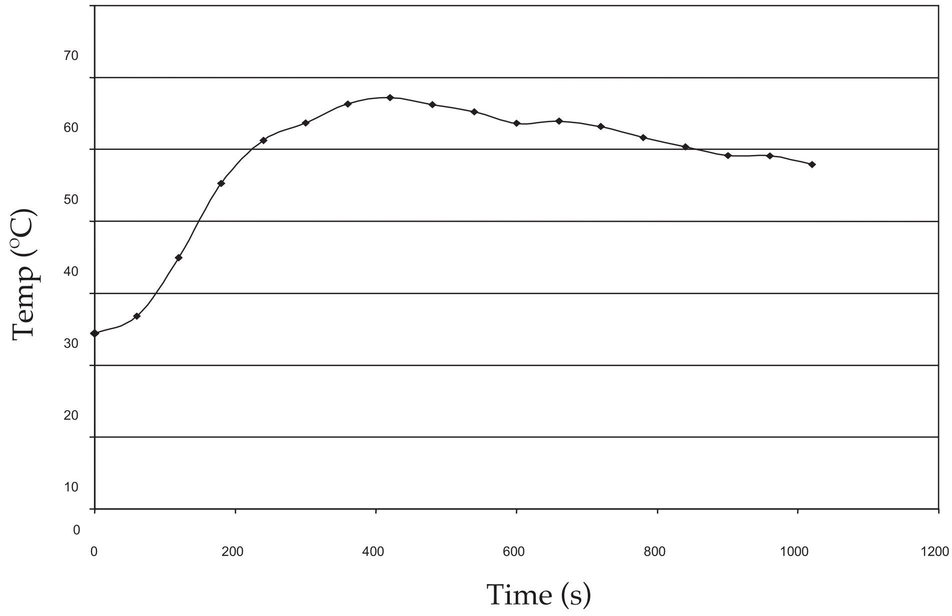
Sample Data

Part A

Time(s)	Temp.(°C)	Time(s)	Temp.(°C)
0	24.3887	540	55.2152
60	26.8027	600	53.5943
120	34.9648	660	53.9184
180	45.2706	720	53.1564
240	51.2568	780	51.6286
300	53.6541	840	50.3600
360	56.3108	900	49.1568
420	57.1667	960	49.0701
480	56.2029	1020	47.9149

Table 1 : Temperature of the mixture of 15 g of calcium oxide and 50 cm^3 water

Temperature (°C) of the mixture of 15g CaO and 50ml water against time (s)



Energy absorbed by the drinks:

$\Delta H = m\ c\ \Delta T$

$= 0.05 \times 4.2 \times 33 = 6.93$ kJ

Given that: $CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$ ΔH -82.2 kJ mol^{-1}

Energy evolved in the reaction:

$\Delta H = 82.2 \times \frac{15}{56.1} = 21.98$ kJ

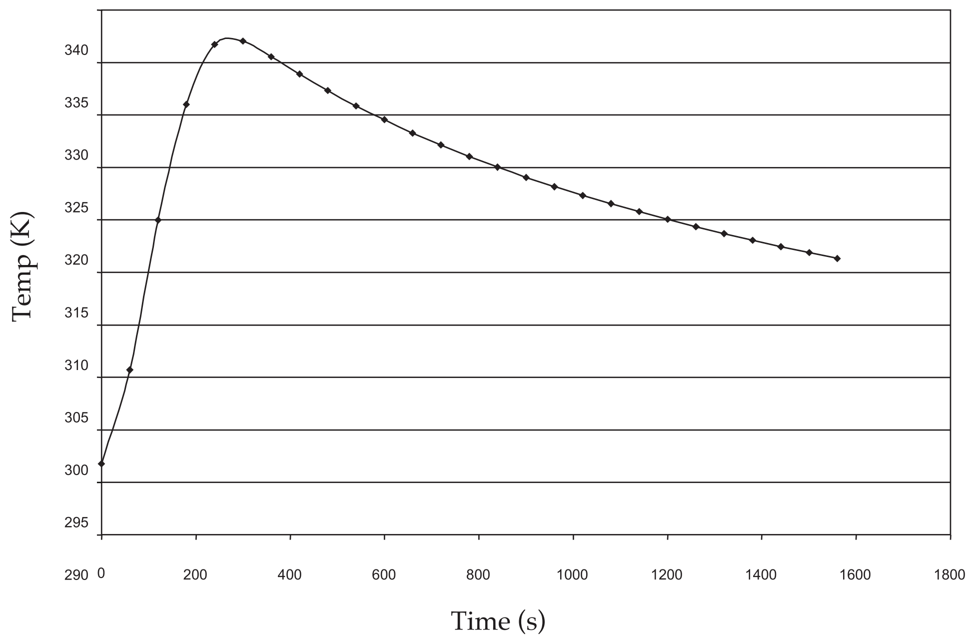
Heating efficiency $= \frac{6.93}{21.98} \times 100\% = 31.5\%$

Part B

Time(s)	Temp.(°C)	Time(s)	Temp.(°C)
0	23.6204	1200	46.8904
60	32.5616	1260	46.2063
120	46.8461	1320	45.5184
180	57.8448	1380	44.8941
240	63.5621	1440	44.3128
300	63.8527	1500	43.7395
360	62.4111	1560	43.1842
420	60.7536	1560.5	43.1745
480	59.1636	1561	43.1716
540	57.7140	1561.5	43.1677
600	56.3858	1562	43.1614
660	55.1132	1562.5	43.1620
720	53.9817	1563	43.1568
780	52.8814	1563.5	43.1494
840	51.8918	1564	43.1472
900	50.8875	1564.5	43.1443
960	50.0289	1565	43.1398
1020	49.1821	1565.5	43.1358
1080	48.4049	1566	43.1324
1140	47.6400	1566.5	43.1227

Table 2 : Temperature of 50 cm^3 of tea surrounding the aluminium can with 15 g of calcium oxide and 50 cm^3 water

Temperature (K) of tea against time (s)



Questions for Further Discussion

1. Given that the standard enthalpies of formation of calcium hydroxide, calcium oxide and water are -1003 kJ mol^{-1}, -635 kJ mol^{-1} and -286 kJ mol^{-1} respectively, calculate the standard enthalpy change of the following reaction. Compare your answer with the results obtained in your experiment.

$$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$$

2. How can you improve the heating efficiency of your design?

3. Another type of self-heating lunch box utilizes sodium acetate trihydrate as the heating ingredient. Discuss the mechanism of this kind of self-heating package. What are the pros and cons of using sodium acetate trihydrate over calcium oxide as heating reagent?

References

- Boschmann, E. (1970). A classroom demonstration of exothermicity. *Journal of Chemical Education.* **47**, p.A206.
- Brouwer, H. (1996). Work done by a chemical reaction. *Journal of Chemical Education.* **73**, p.354.
- Hornbeck, L. G. (1966). Heat of hydration of CaO. *Journal of Chemical Education.* **43**, p.A1079.
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Possible Topics for Chemistry Investigative Study

Possible Topics for Chemistry Investigative Study

A.Quantitative Analysis

Vitamin C in fruit juices

Vitamin C (ascorbic acid) is vital to our health. Deficiency of vitamin C can cause scurvy. You can obtain vitamin C from fruits and vegetables. Which foodstuff contains a higher content of vitamin C? You can employ titrimetric methods to determine vitamin C content in different foodstuffs. You might

- compare the vitamin C content in different fruits (e.g. orange, kiwi fruit, lemon, etc) and find out which fruit contains the highest vitamin C content.
- investigate the effect of temperature on the vitamin C content in a particular fruit.

(Hint: Vitamin C is a weak reducing agent.)

Is there too much sulphur dioxide in foodstuffs?

Foods, especially fruits, dried foodstuffs and wine, can be preserved by sulphur dioxide. However, too much sulphur dioxide remained in the treated foodstuff not only imparts an unpleasant taste, but also causes allergies.

As a chemist working in a testing laboratory, you have received a job commissioned by the Consumer Council to determine whether the sulphur dioxide content in longan (龍眼) and day lily (金針菜) is in excess. You need to consider:

- What analytical method should be used? What are the limitations of your method?
- How much samples should be used?
- How do you prepare the samples for analysis?
- What is the acceptable daily intake of sulphur dioxide?

Do your answers suggest these foodstuffs available in the market contain too much sulphur dioxide?

How fast do chlorine bleaches deteriorate?

Chlorine bleaches slowly lose their power when standing in air. As a chemist of a bleach manufacturing company, investigate whether chlorine bleaches deteriorate significantly under different conditions. You need to think about:

- Why does the strength of a bleach solution change upon storage?
- What method could be used to monitor the change in concentration of the active ingredient in chlorine bleach?
- How would you investigate factors e.g. sunlight or temperature on the strength of chlorine bleaches?

Do your answers suggest that the deterioration of chlorine bleach is likely to be a significant problem for the manufacturers and users of chlorine bleaches?

Too much phosphate in washing powder and detergents?

"Phosphates" are added to most domestic laundry powders and detergents to enhance the cleansing action. However, if too much phosphate is discharged into the sea or rivers, "eutrophication" will occur. As phosphates in detergents cause much harm to the environment, we are going to analyze different brands of washing powder on the market, aiming to compare their phosphate contents. You might

- determine the phosphate contents in different brands of washing powder by a colorimetric method.

Determination of Nitrite in Cured Meat

Sodium nitrite, $NaNO_2$, is extensively used for curing meat and preserving food. It produces a pink colour in meat. However, excessive intake of nitrites causes a fall in the level of haemoglobin in blood. In the long term this leads to malnutrition and reduced lifespan. Besides, under certain conditions, the natural breakdown products of proteins, known as amines, can combine with nitrites to form compounds known as nitrosamines. Most of these nitrosamines are known carcinogens in test animals. Spectroscopic or titrimetric methods can be employed to determine the nitrite content in cured meat products. You may

- choose one of the methods to compare the nitrite content in several meat products;
- check which product contains the highest nitrite content and whether it exceeds the acceptable level.

B. Preparative Experiments

Bio-diesel

The oil crises in 1973 forced the world to look for alternatives to fossil fuel. Recently, the fluctuation in the oil price has once again rekindled the issue. Serious research has been going on all over the world and people have come up with various alternatives such as ethanol and biodiesel.

Biodiesel can be prepared from waste cooking oil and fat by transesterification with methanol.

Prepare a biodiesel and compare its properties (e.g. heat of combustion) with diesel.

Useful Products From Expired Milk

You are a chemist in a dairy farm products company. One day your boss told you that there was some returned expired milk. He requested you to see whether it can be turned into something useful for sale.

Prepare a useful product from expired milk and compare its properties with similar commercial products.

Extraction of Limonene from Citrus Fruit Peels

Limonene is a naturally occurring substance found in the essential oils of spearmint, caraway, lemon and orange. Orange zest (the orange coloured part) contains about 0.5-1.0% of limonene by weight. Limonene can be used to replace toxic and hazardous petroleum-derived chemicals. Two most commonly used methods for isolating limonene are solvent extraction and steam distillation.

Using one of the above methods, extract limonene from several fruit samples and compare their limonene contents.

Determining a Better Formula for a Soap Bubble Solution

Many children like playing with soap bubbles. As a scientist in the product development team of a big toy store, you are asked to determine a better formula for a soap bubble solution. You need to think about:

- How does soap bubble form?
- What is the criterion for a better formula, e.g. making soap bubbles stay in air for a longer period of time, producing a larger amount of bubbles or making them as large as it can?
- What constituents in the solution can affect the properties of the soap bubbles formed?

Greener Bleaching Agent

Commonly used bleach is a chemical that can whiten or oxidise substances. Examples of common active ingredients in bleaches are sodium hypochlorite (commonly called "chlorine bleach") and calcium hypochlorite (bleaching powder). Chlorine bleach is commonly used as a disinfectant by homemakers and janitors. Mixing bleach and cleaners containing ammonia can create toxic chloramine gases and volatile explosions. You are required to design an effective way for bleaching but using a green chemistry approach.

C. Design and Make

Instant Cold Pack

Cold packs are used by athletes to minimise swelling of injuries such as muscle and joint sprains. One type of cold pack is constructed with a large pouch containing a dry chemical plus an inner pouch of water. The cold pack is activated by breaking the seal on the inner pouch of water and shaking the pack vigorously. This action mixes the water with the dry chemical, starting an endothermic reaction.

Design and construct a cold pack, and then test its performance.

Recycling Copper from Printed Circuit Board (PCB) Etchant

During the manufacture of PCB, copper metal on the surface of the printed circuit is dissolved by an ammoniacal etching solution. The copper ions form complex ions with ammonia in the etching solution. Spent etchant contains a high concentration of toxic copper ions. Recycling copper from the spent etchant not only reduce harmful effects to the environment, but also the cost of production.

Design and construct a system to recycle copper from the spent etchant, and then test its performance.

Indoor Carbon Dioxide Filter

On average, we spend more than 80% of our time at homes, in offices and other indoor environment. Carbon dioxide level is a key indicator for indoor air pollution. Living things breathe out carbon dioxide. A high level of carbon dioxide in indoor environment means there is an inadequate supply of fresh air, which makes you feel sleepy, and provide a warning of possible build-up of other indoor air pollutants. Carbon dioxide in the air can be absorbed by chemicals such as calcium oxide.

Design an environmental friendly and economical indoor carbon dioxide filter to reduce the concentration of indoor carbon dioxide to an acceptable level, and then test its performance.

Water Purification System

Supply of clean drinking water can be a big problem, particularly in some developing countries. People often have to use untreated water from wells or rivers. Such water is often contaminated with germs and toxic metal ions.

Design a low-cost and portable system that removes toxic substances from drinking water, and then test its performance.

Carbon Dioxide Meter

Living things breathe out carbon dioxide. A high level of carbon dioxide in indoor environment means there is an inadequate supply of fresh air. According to the Indoor Air Quality Certification Scheme in Hong Kong, if CO_2 levels reach 800 ppm it is likely that occupants will start complaining about the comfort level. It will make you feel sleepy, and provide a warning of possible build-up of other indoor air pollutants.

Design and construct a device to indicate the level of carbon dioxide in air by chemical means, and then test its performance.

Forms

Work Schedule

Stage	Date	Time	Venue
(a) Searching for and defining questions for investigation (~3 hrs)			
(b) Developing an investigation plan (~4 hrs)			
(c) Conducting the investigation (~6 hrs)			
(d) Organising and analysing data for a justified conclusion (~4 hrs)			
(e) Presenting the investigation findings with written reports, posters or other means (~3 hrs)			

Group Details

Group number : ______________________

Role	Name	E-mail address	Telephone
Group Leader			
Assistant Group Leader			
Member			
Member			
Member			

Information Search Log Sheet

Group number : ____________________ Page 1 of ______

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

Reading / Browsing Date : ________ Time spent on studying the information : ______

Relevant information :

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

Reading / Browsing Date : ________ Time spent on studying the information : ______

Relevant information :

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

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Relevant information :

Information Search Log Sheet

Group number : ____________________ Page 2 of _______

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Relevant information :

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

Reading / Browsing Date : ________ Time spent on studying the information : _______

Relevant information :

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

Reading / Browsing Date : ________ Time spent on studying the information : _______

Relevant information :

Information Search Log Sheet

Group number : ____________________ Page 3 of ______

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

Reading / Browsing Date : ________ Time spent on studying the information : ______

Relevant information :

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

Reading / Browsing Date : ________ Time spent on studying the information : ______

Relevant information :

Book / Website : ____

Author : ____________ Publisher / Organisation : ______________ Year : ________

Reading / Browsing Date : ________ Time spent on studying the information : ______

Relevant information :

Proposal Form

Group number : ______________________________

Title of investigation : ______________________________

Aims : ______________________________

____

Reason(s) for carrying out the investigation :

____

____

Number of experiments to be conducted : ______________________________

Titles of the experiments :

____

____

____

____

____

____

Materials Required :

Please give the estimated quantity of chemicals and apparatus required.

Chemicals and amount needed (e.g. 10 g $CaO(s)$)	Apparatus and quantity (e.g. 250 cm^3 beaker x 2)

Risk Assessment

Please list the potential hazards of the substances being used or produced, procedures and equipment; and the safety precautions that should be taken. Also think about what emergency procedures could be taken in case of accidents.

Hazardous substances being used or made, hazardous procedures or equipment	Nature of the hazards (e.g. toxic, flammable)	Control measures and precautions (e.g. use chemicals of lower hazard; reduce the scale; use fume cupboard or safety screen, wear protective gloves or safety spectacles, etc.)	Emergency action to be taken in case of accident	Sources of information (e.g. *Safety in Science Laboratories*, ICSCs, MSDSs or Hazcards, etc.)

Disposal of residues :

Procedures :

Diagrams of design and experimental setup

(Label all parts with explanation of their functions)

Procedures (you may explain your plan according to the experimental procedure, or your design in point form)

Expected results and findings:

Reasons for making your prediction:

Major references:

Signature of teacher : ______________________ Date : ______________________

Meeting with Teacher Log Sheet

Group number : ____________________

Title of investigation : ____________________

Date of meeting : ____________________ Time : ____________________

Things to be clarified regarding the investigation :

Work completed so far :

Problems encountered and solutions :

Teacher's suggestions / comments:

Targets to be achieved before the next meeting :

Date, time & location of next meeting : ____________________

Signature of teacher : ____________________ Date : ____________________

Observations and Measurements Record Form

Group number : ____________________ Page 1 of ________

Title of experiment : ____

Record your experimental results below. Think about what to record and how to record your data, use table where appropriate. Remember to record all relevant observations and measurements to reduce error and obtain reliable evidence.

Signature of teacher : ____________________ Date : ____________________

Observations and Measurements Record Form

Group number : ____________________ Page 2 of ________

Title of experiment : ____

Record your experimental results below. Think about what to record and how to record your data, use table where appropriate. Remember to record all relevant observations and measurements to reduce error and obtain reliable evidence.

Signature of teacher : ____________________ Date : ____________________

Observations and Measurements Record Form

Group number : ____________________ Page 3 of ________

Title of experiment : ____

Record your experimental results below. Think about what to record and how to record your data, use table where appropriate. Remember to record all relevant observations and measurements to reduce error and obtain reliable evidence.

Signature of teacher : ____________________ Date : ____________________

Calculation Record Form

Group number : ________________ Page 1 of _______ Date : ______________

Title of experiment : ____

Please show your calculations in the space below :

Calculation Record Form

Group number : ____________ Page 2 of ______ Date : ____________

Title of experiment : ____

Please show your calculations in the space below :

Data Analysis Record Form

Group number : ____________ Page 1 of ______ Date : ____________

Title of experiment : ____

In the space below, please write down your modifications to the experimental procedures proposed, comments on the results obtained, sources of errors, suggestions for improvement and conclusion, etc. Use additional sheet, if necessary.

(i) Modifications to the experimental procedures proposed

Data Analysis Record Form

Group number : ______________ Page 2 of ______ Date : ____________

Title of experiment : ____

In the space below, please write down your modifications to the experimental procedures proposed, comments on the results obtained, sources of errors, suggestions for improvement and conclusion, etc. Use additional sheet, if necessary.

(ii) Comments on the results obtained

Data Analysis Record Form

Group number : ________________ Page 3 of _______ Date : ______________

Title of experiment : ____

In the space below, please write down your modifications to the experimental procedures proposed, comments on the results obtained, sources of errors, suggestions for improvement and conclusion, etc. Use additional sheet, if necessary.

(iii) Sources of errors, and suggestions for improvement

(iv) Conclusion

Teacher Assessment Form

Student name : ____________________

Class : __________ Group number : __________

Title of investigation : ____________________

Assessment Criteria:

Design		Weighting (Max mark)	Group Mark	Student's Mark
	Feasibility of investigation plan			
	Use of appropriate method and references			
	Procedures			
	Choice of apparatus and chemicals			
	Risk Assessment			
	Sub-total			

Process				
	Experimental techniques and safety precautions			
	Recording of observations and data			
	Quality of experimental results			
	Problem solving and time management			
	Participation			
	Sub-total			

Report				
	Use of chemical terminology and language			
	Data treatment and analysis			
	Interpretation of results			
	Evaluation of results and validity of conclusion			
	Communication skills			
	Sub-total			
	Total			

Comments :

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Signature of teacher : __________ Date : __________

Self and Peer Assessment Form

Name : ____________________

Class : __________ (   ) Group number : __________

Title of investigation : ____________________

Rate the performance of yourself and each team member on a scale from 1 to 3 in each of the area listed. (3 = Above average, 2 = Average, 1 = Below average)

Area	Self	Members (Full Name)			
Planning					
Participation					
Data collection					
Data analysis					
Report writing					
Ideas and suggestions					
Total					

Which part(s) of the investigation were you responsible for?

____

____

____

____

What have you learned during the whole investigation period? (use additional sheet, if necessary)

____

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Signature of teacher : __________ Date : __________

Note

Note

Note