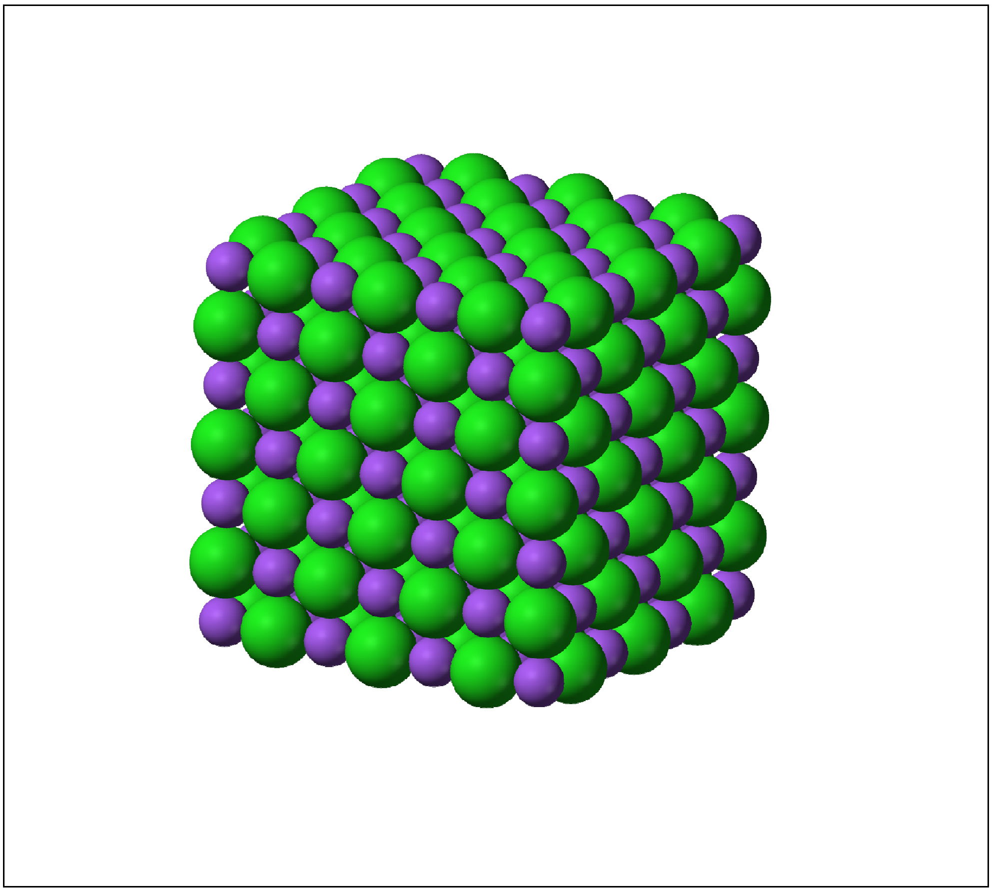
Practical Assignment Chemistry 16-17

ICY – road salt

10 – 20 hours



Chemistry Network
Centre for Educational Training, Assessment and Research
Vrije Universiteit Amsterdam The Netherlands, January 2011

Name :

School :

Cooperated with :

Road salts

$CaCl_2$
Calcium chloride

$C_{12}H_{22}O_{11}$
Molasses

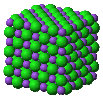
$CO(NH_2)$
Urea

$MgCl_2$
Magnesium chloride

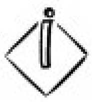
$Ca_{3\text{-}4}Mg_{7\text{-}6}(CH_3CO_2)_{20}$
Calcium magnesium ethanoate

$NaCl$
Sodium chloride

Mark :

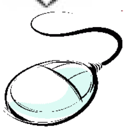


Content



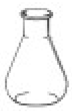
Look for information

Answer questions

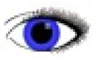


Use computer

Use model



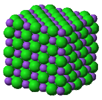
Do experiments



Make observations

Write inquiry question
Write inquiry plan

Keep a record of the inquiry



Planning

Below you find a time schedule for the inquiry project, 'Icy'. The first three parts (*1-3*) are integrated in the chemistry lessons and the others (*4-8*) will be done outside the chemistry lessons. Your first task is to become familiar with the inquiry. Therefore your teacher will give you a demonstration and you will do a guide experiment. After this you will analyse and judge research done by Iru, Luib & Nelem (2010). These three researchers investigated the effect of NaCl(s) on the melting of ice. Some questions arise. How 'fair' and accurate is their research? Are their research results trustworthy? Are their conclusions valid? Are there alternatives for NaCl(s) as a road salt? These are questions that you will answer by critically analysing the article written by these three researchers. Following this we expect you – in a team of two – to perform a better inquiry. As a team you will write a first report on your inquiry. All of the first reports will be published on the Internet. In this way you can discuss your results with peers all over the world, giving and receiving suggestions. You have to use these suggestions to improve your report, when you write your final article. All of the articles will compete for the 10th *Natuurwetenschap & Techniek chemistry inquiry award* of 500 Euro.

Time schedule for the 'Icy' project (10-20 hours):

Start	**Part of the project**	**Date**	**2011**
February	1. *Understand aim and nature of the inquiry project*	February	**Start with the task**
	2. *Understand the research of Iru, Luib & Nelem:* • Predict, observe, explain • Conduct guide experiment • Judge accuracy, reliability and validity	February	
	3. *Own inquiry in teams*	March	**Conduct research**
March	4. *Write report*		
April	5. *Send report* to a.j.van.dijk@vu.nl	**13 April**	**Send report**
	All reports with photographs on the website http://www.onderwijscentrum.vu.nl/internetsymposium	20 April	
	6. *Peer discussion in Internet symposium*	**20 April**	**Start Internet discussion**
April/May/ June	The Icy symposium discussion on: • Accuracy in the inquiry plan • Accuracy in performing the inquiry • Reliability of the results • Validity of the conclusions	18 May	**Check 'symposium'**
	7. *Teamwork*: Processing the comments received, improve report		
	8. *Send final report* to: a.j.van.dijk@vu.nl	**1 June**	**Final articles should be ready!**
June	All first and final reports will be put on the website: http://www.onderwijscentrum.vu.nl/internetsymposium	8 June	**First reports and final articles on the Internet**
	Independent Jury nominates the five best researches	17 June	**Nomination of the best researches**
	Prize will be announced at the site	**24 June**	**And the winner is …!**
November	Publication of the results of the best inquiry in: Natuurwetenschap & Techniek http://www.nwtonline.nl	November	nwt

1 Introduction

Nowadays chemistry forms an integral part of daily life. Whether it is clothes, food, body care, cars, computers or drugs, everything people produce involves chemistry. Without inventions and chemical research the world would be very different. Chemists conduct research to acquire directly applicable knowledge, but sometimes also to understand things better. Most of the time they build on research done by other chemists. Building on knowledge of others can be advantageous because you do not need to examine things yourself. On the other hand previous research causes problems of its own. When results are not reliable, invalid conclusions may be drawn. Other research can be distorted by invalid information and this may have serious consequences. That's why accurate and reliable research is important.

> One of the aims of this inquiry project is to understand how to measure **'fair'** and **accurate** in your inquiry. This accuracy is necessary to get **reliable results** in your inquiry. The only way to draw **valid conclusions** is to get reliable results.

Only when 'fair' and accurate measurements are taken, research results will be reliable and valid conclusions can be drawn. Research should also be designed in such a way that other researchers can repeat it. This does not mean, however, that knowledge based on research results in itself is justified. Further investigations or other research can yield results that are slightly different or even undermine acquired knowledge. Researchers communicate about their research methods and their conclusions in professional magazines, journals and on the Internet. Another way of informing the public and politicians is by means of papers and television.

The researchers Iru, Luib & Nelem (2010) investigated the effect of NaCl(s) on the melting of H_2O(s) or ice. You analyse and judge their research on whether they designed their experiments in a 'fair' way and measured accurately. Are their results reliable and did they draw valid conclusions?

These questions are to be tackled in small teams. The answers will result in designing your own (team) inquiry that of course will be designed and carried out in an as 'fair' and accurate manner as possible. You will write (as a team) a report about your inquiry that you will send to a.j.van.dijk@vu.nl. Your report will be visible to fellow researchers at others schools. In the Internet Icy symposium you discuss the inquiry of another investigation team. That team will give critical comments on your own inquiry as well. When the symposium is finished every team has to correct and improve their report. This will be your final article.

Each inquiry team will send their final article to a.j.van.dijk@vu.nl. A professional jury will judge all discussions and incoming final articles and will also select the best inquiry. Those students whose inquiry is considered the best will win the 10th *Natuurwetenschap & Techniek* chemistry inquiry award and their results will be published in *Natuurwetenschap & Techniek*, November 2011.

2 Demonstration: ice in seawater and tap water

Two ice cube of exactly the same size are available. One is put in a Styrofoam cup with 100 mL of tap water and one is put in a Stryrofoam cup with 100 mL of seawater. Both cups have the same initial temperature.

Prediction

What do you expect to happen in each cup?

2A I expect that ……………………….

Why?

Write down your observations, conclusions and explanation.

Observations

Conclusion

Explanation

2B (i) Do you still agree with your expectations as written under “prediction” [2A]?
Yes / No, because

2B (ii) What causes the change in the cups?

Browse and use information from ’the icy-tracker’ on www.onderwijscentrum.vu.nl/internetsymposium (2010-2011), click ‘organisation’ and then ‘inquiry’ to find support to your answers.

3 Guide experiment: ice and salt

The researcher Iru et al. (2010) investigated the effect of cooking salt or NaCl(s) on the melting of crushed ice or H_2O(s).

Prediction

What do you expect about the effect of NaCl(s) on the melting of H_2O(s)?

3A I expect, that NaCl(s) will have:
no effect / will speed up the melting process / will slow down the melting process.

Why?

Discuss your expectation with one other group in class.

Observations

3B Compare for 10 minutes the melting time of crushed ice with $NaCl(s)$ to crushed ice without $NaCl(s)$

Use:
- -the same amounts (50g) of crushed ice
- -a stop watch
- -5.0g of cooking salt or $NaCl(s)$
- -two funnels
- -two measuring cylinders
- -a spoon

Write down your observations

Conclusion and discussion

3C	Write down your conclusion and discussion. Is your expectation in line with your observations? Do you still agree upon your explanation?

Browse and use information from 'the Icy-tracker' on www.onderwijscentrum.vu.nl/internetsymposium (2010-2011), click 'organisation' then 'inquiry' to find support to your answers.

4 Judging the research of Iru, Luib & Nelem

'The effect of NaCl(s) on Ice'

Before analyzing Iru et al.'s research on 'fairness', accuracy, reliability and validity you will first answer some questions concerning accurate and reliable measurements.

§4.1 Orientation on accurate and reliable measurements

Suppose that you would like to study the effect of NaCl(s) on the melting of ice.

What would you do to measure as accurately as possible? Explain

4A

Assume that the recorded volume of $H_2O(l)$ at a certain time equals 30 mL.

What would you do to find out if this measurement is reliable? Explain.

4B

When is a series of measurements reliable? Explain.

4C

§4.2 The research of Iru, Luib, & Nelem: accuracy, reliability, validity

The research question of Iru et al. (2010) was: *'what is the effect of NaCl(s) on the melting of $H_2O(s)$?'*
From the demonstration and guide experiment you have learned that salt needs to dissolve in water to have an effect on the freezing point of water.
In paragraph 4.1 you have thought about reliability of measurements. In order to be capable of measuring accurately, experiments need to be designed in a 'fair' way. You need accurate measurements to come to reliable results. Only when results are reliable one can draw the most valid conclusions. So the question is how to design your experiments as 'fair' as possible to measure most accurately.
To achieve accurate measurements researchers have to follow certain procedures. You will practice this procedure using the article of Iru et al. (2010):

> How 'fair' is the design of the research of Iru et al.?
> How accurate are the measurements of Iru et al.?
> How reliable are the measurements or results of Iru et al.?
> How valid is the conclusion drawn by Iru et al.?

By practicing these steps you will be able to critically judge other research and be capable of doing an accurate inquiry yourself.

A. How 'fair' is the design of the research of Iru et al.?
To judge a research design, you need to identify all of the variables that play a role in the experiment. To take accurate measurements researchers want to know which variable they will measure. Variables are quantities (e.g. temperature), which can be measured as a number. Usually variables also have a unit (e.g. degree Celsius). Researchers should also carefully take into account other factors (e.g. when measuring the height of a person the floor on which the person stands should be straight), which can interfere with the variable to be measured. When taking variables into account:

1. **List** all of the variables;
2. Choose **one** of the variables
3. **Change** this variable;
4. **Measure the effect** of this change; and at the same time
5. Keep all other variables and factors **constant**.

Researchers distinguish three types of variables:

Independent variable	This is the variable to be **changed**
Dependent variable	This is the variable to be **measured**
Control variables	These are the variables to be kept **constant**

By using distinct variables it is easier for researchers (and other interested people) to understand the research and follow its progress. 'Fair' handling of variables is a difficult aspect of research design. For researchers it is difficult both to recognize 'all' of the variables and to exclude those variables and factors that they do not want to measure or to change. In other words: to keep all interfering variables and factors constant.

Now it’s up to you (in groups) to recognize the different variables in the experimental procedure of the research of Iru et al. (2010) and to find out whether they handled the variables carefully.
Use the part on ‘Experimental procedure’ in the article of Iru et al. (2010); see appendix page a or surf to www.onderwijscentrum.vu.nl/internetsymposium (2010-2011), click ‘organization’ then ‘inquiry’ till you reach the article.

Recognizing variables in the research of Iru et al. (2010):

	List all variables and factors that influence the measurements in the experiment as done by Iru et al. (2010).
4D (i)	Variables:
4D (ii)	Factors:

	What is the independent variable in the experiment done by Iru et al. (2010)?
4E	

	What is the dependent variable in the experiment done by Iru et al.?
4F	

	What are the control variables in experiment done by Iru et al.?
4G	

Did Iru et al. forget any control variables?
4H (i) If yes, which one(s)?
4H (ii) Compare your answers to these of the other groups in your class.

B. How accurately did Iru et al. measure?

When the variables – related to the question under research – are known, the next step is to think about the design and set-up of the experiments. It is important to decide carefully, in advance how to conduct the actual experiment, both the set-up and the measurements. Iru et al. had to make decisions about:

i. How much NaCl(s) to use?
ii. How much water(s) or ice to use?
iii. How often the volume should be measured and in what range of time?
iv. How often should each experiment be repeated?
v. What instrument should be used to measure the volume of the melted water?
vi. To what significant figure can the measuring instrument be read off?

With a well-developed research you will be less likely to encounter unpleasant surprises while the experiment is being conducted.
To find out whether Iru et al. (2010) did collect accurate measurements, you judge the decisions made by them in their experimental procedure, see appendix, page b. Discuss and answer in your group the following questions.

Decisions regarding the experimental set-up
4I (i) Did Iru et al. choose a suitable amount of NaCl(s)? Explain.

4I (ii) Did Iru et al. choose a suitable amount of ice or water(s)? Explain.

Decisions regarding the measuring instrument

4J (i) Is the measuring instrument used by Iru et al. accurate enough? Explain.

4J (ii) Did they read off the volume to a correct significant figure? Explain.

Decisions regarding the number of measurements

4K Iru et al. conducted each the experiment in triplo.
Was this enough times, according to you? Explain.

C. How reliable are the measurements or results of the research of Iru et al.?

Before collecting measurements researchers think about how to collect their observations and data, how to present and analyze their results. Collected measurements are presented in tables and graphs. Furthermore, researchers always need to check whether their results are reliable. When measurements show too much deviation, they need to be repeated. Repetition of measurements enhances the reliability.

You are now to judge whether Iru et al. presented their measurements in a correct manner and whether their measurements are reliable.

Presentation of measurements

4L (i) Iru et al. presented the their results in Table 1 as:

Time (in minutes)	With NaCl (mL)	Without NaCl (mL)
0	0	0
10	11.5 ±1.5	0
20	17 ±1	0
30	21.5 ±1.5	3 ±1
40	25.5 ±1.5	8 ±1
50	30 ±1	9 ±1
60	34.5 ±0.5	12 ±2
70	37.5 ±0.5	15 ±1
80	40 ±0	19 ±1
90	42 ±0	21 ±2
100	45 ±1	24 ±1
110	42.5 ±2.5	27 ±1.5
120	49.5 ±1.5	30 ±1
130	50 ±2	33 ±1
140	51 ±1	36.5 ±1.5
150	52 ±2	38 ±1
160	53.5 ±1.5	40 ±1
170	54.5 ±1.5	42.5 ±1.5
180	55.5 ±1.5	43 ±1
190	56 ±1	45 ±1
200	56 ±1	46 ±1
210	56 ±1	48 ±1
220	56 ±1	49 ±1
230	56 ±1	50 ±1

Table 1: Amount of water (mL) released when crushed ice is treated with and without NaCl(s).

4L (ii) Did they present the measurements in a correct manner? Explain.

Iru et al. used a graph (see Figure 1) to find the speed of melting of crushed ice with (upper line) and without (lower line) NaCl(s).

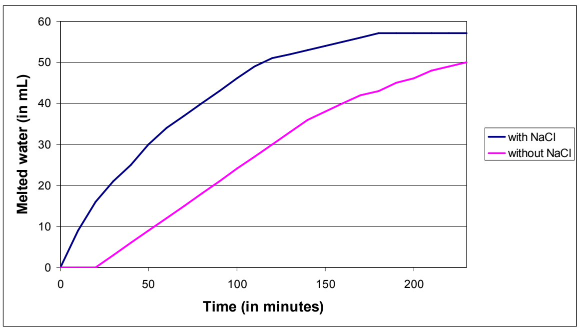


Figure 1: Averaged measured amount of melted water (in mL) from crushed ice with and without NaCl(s).

4L (iii) Did they use the correct variables on the x-axis and y-axis? Explain.

Is Figure 1 a good representation of the measurements as shown in Table 1? Explain.

Reliability of measurements

4M (i) Iru et al. (2010) presented their measurements in see Table 1.

When looking at a series of measurements, e.g. after 60 minutes, we see:

Time (in minutes)	With NaCl (mL)	Without NaCl (mL)
60	34.5 ±0.5	12 ±2

With 34.5 ±0.5 Iru et al. state that the measured volume values, with NaCl(s) lie between 34.0 and 35.0 mL.
Their measurements deviate 0.5 from the average volume which is 34.5 mL.
Suppose that the volume values are allowed to deviate **within** 0.5% of the average result.

4M (ii) Which of the values in Table 1 are accurate enough to be reliable?
Encircle them in the Table.
What possible causes of inaccuracy in Iru et al.'s measurements occur:

(1) Low significance of the volume values. Yes / No Explain.

(2) Low number of measurements. Yes / No Explain.

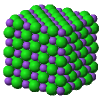
(3) Lack of keeping control variables and factors constant. Yes / No Explain.

(4) Other causes. Yes / No Explain.

D. How valid is the conclusion of Iru et al.?

A conclusion can be considered as valid when experiments are accurately designed and carefully executed. Of course, experiments should be designed in such a way that answering the research question is possible. Iru et al. (2010) research question was: *'what is the effect of NaCl(s) on the melting of $H_2O(s)$?'*. To answer this question they took six identical measuring cylinders and six identical funnels. Then the funnels were put on top of the measuring cylinders and left at room temperature. In three set-ups each funnel was filled with 50g crushed ice and in the other three set-ups each funnel was filled with 50g crushed ice and 5.0g of NaCl(s). Then every 10 minutes the amount of water that appeared in the funnels of each set-up was noted till all the ice was molten. The values for each moment of measuring – with NaCl(s) and without NaCl(s) – were averaged and put in graphs. Then the graphs were analysed on similarities in and differences between the two set-ups.
The results were presented in Table 1 and Figure 1. From the results as presented in Table 1 and Figure 1, Iru et al. concluded that *'the melting process of crushed ice with NaCl(s) started immediately, whereas the melting of crushed ice without NaCl(s) started more slowly'*. Moreover, *'After about 50 minutes the melting process of both set-ups – crushed ice with and without NaCl(s) – became equal in speed as is indicated by the same slope ($\alpha = 17^o$) for both melting processes. This remained for another 50 minutes. It seems that after some time the NaCl(s) does not have an effect on the melting process of crushed ice anymore. An explanation could be that all the NaCl(s) is dissolved and that more salt is needed to see a further effect'*.

	Validity of the conclusion drawn by Iru et al. (2010)
4N (i)	Look at the values that you considered to be reliable, the encircled ones, in table 1, and state whether you do agree with the conclusions drawn by Iru et al.? Yes / No Explain.
4N (ii)	Is the experimental design of Iru et al. valid to find an answer on the research question as stated in their article. Yes / No. Explain.



5 Inquiry in teams

The research question of Iru et al. (2010) was *'what is the effect of NaCl(s) on the melting of $H_2O(s)$?'*
Out of their discussion further questions arose e.g.:

> "What will the effect of more salt be? Or what will happen when salts, that can produce three moles of ions, like $MgCl_2$, are used? Does a MX_2 salt act more quickly and is that the reason that it is sometimes used as a road salt in the United States and Canada? Or is it better to use double salts? Or is it possible to use 'green' alternatives, like mixing a salt with molasses or urea, or mixing different salts?
> Whatever the case may be, using salts on roads corrode bikes and cars (3). Moreover, they a have negative effect on the growing of plants next to roadways. Is it possible to find 'green' alternatives?´

To answer one of these questions, or your own question, you design and conduct your own inquiry. You will do an inquiry and write an inquiry plan in a 'fair', accurate, reliable and a step-by-step manner.
It is all up to you! Before starting your own inquiry answer the following questions.

An inquiry question can be investigated when this question has an independent (what are you going to change?) and a dependent (what are you going to measure?) variable.

5.1 Formulate your own inquiry question

5A

5B Write down:
(i) your hypothesis

(ii) based on which theory

Now write your own inquiry plan as a team.

5.2 Inquiry plan

A copy of this inquiry plan document can be found at: www.onderwijscentrum.vu.nl/internetsymposium (2010-2011), click ‘organisation’, ‘inquiry’ and then ‘inquiry plan’.

A. Variables

Dependent variable	
5C	What variable are you going to measure? Explain why.

Independent variable	
5D	What variable are you going to change? Explain why.

Control variables	
5E	Which variables and factors do you need to control - keep constant - in your experiment? Explain why.

B. Decisions on the experiment, the experimental set-up and the measurements

How to make accurate measurements?

What instrument for measurement are you going to use to measure as accurate as possible? Explain.

5F

What is the accuracy of the instrument?

Up to what significant figure can you read your instrument? Are repeated measurements needed? Explain.

5G

Which materials do you need? List these materials below.

5H

Make a drawing of your experimental set-up.

5I

What results do you expect?
Explain why.

5J

5K Check whether your inquiry plan is really answering your inquiry question.
If not, change your question into a question that fits to your plan.

Discuss your plan with your teacher. If she/ he agrees, you can start your experiments.
Good luck!

5.3 Keep a record of the inquiry

A copy of this inquiry plan document can be found at: www.onderwijscentrum.vu.nl/internetsymposium (2010-2011), click ‘organisation’, ‘inquiry’ and then ‘keep a record of the inquiry’.

Inquiry dairy

Date	Work done	Remarks / Observations

6 First and final report, Internet symposium: guidelines

This booklet needs to be handed in to the teacher. As a team you will get a mark for your inquiry plan, your final report and for your participation in the peer discussion in the Internet symposium.

§6.1 Writing a report: guidelines

The layout of a report depends on the journal you are writing for. A report will be published when it satisfies criteria posed by the journal. This will also be the case for your article. After publishing the reports on the Internet, the Icy symposium or peer discussion starts. You can use the comments to improve your first report as you write a final article. These articles will also be published on the Internet. Then a professional jury will compare all articles and nominate the five best research teams for the 10th *Natuurwetenschap & Techniek* Chemistry inquiry award of 500 euro.
Take Iru et al.'s article as an example. Your report should contain the following:

- **Snappy but relevant title**
- **Names of the authors and submission date**
- **Summary of the inquiry**
- **Introduction** with the reason of or problem in the inquiry guided by theory on the problem, with the **inquiry question** and with a **hypothesis** and the **theoretical assumptions** concerning the answer on the inquiry question.
- **Experimental design** with a description of the method of investigation, of the way of handling the different **variables** and of the way of handling the **accuracy** in the experimental set-up and the measuring itself.
- **Results** with a description of the **relevant observations/ measurements** that are correctly put into **tables and graphs**.
- **Discussion and conclusion** with a critical interpretation of your results and with a valid answer to your inquiry question.
- **Evaluation** with a critical description of the experimental set-up, with suggestions for improvements and further inquiry questions.
- **Bibliography** with relevant resources like textbooks, websites, magazines, articles.

Further guidelines:

- Use correct **English** and use a layout in **2 columns**.
- Enclose a **picture** or **drawing** of the experimental set-up (max. **100 kb**).
- The report should not exceed **1500 words** (max. **500 kb**).
- **Label** your document with your **schoolcode teamnumber_first name_first name**.
- Add **separately the email addresses of all team members.**
- Add a digital picture of your team (max. **100 kb**) with your **schoolcode teamnumber_first name_first name**.
- **Send** the report as well as your final article to: a.j.van.dijk@vu.nl

§6.2 The peer discussion in the Internet Icy symposium

To have a meaningful and fruitful discussion with another inquiry team at a school elsewhere, you first need to read their report. Then judge their inquiry report by using the following categories.

- Discuss whether the (in)dependent variables are visible in the inquiry question.
- Discuss whether the assumptions and theory about the hypothesis are correct.
- Discuss whether all relevant control variables are considered.
- Discuss whether the measurements are accurate.
- Discuss whether the results are well presented.
- Discuss whether the reliability of the results is checked.
- Discuss whether the discussion and conclusions are valid.
- Discuss whether the validity of the inquiry as a whole is described in the evaluation.
- Discuss whether the bibliography is relevant.

Halfway the Internet symposium, on 18 May, the jury will check how well you have been participating in the discussion. This will be part of the jury's final judgement.

7 Study guide

Before	**Understand what your inquiry project is about:** - Read the planning - Choose your inquiry partner
Lesson 1	**Understand what Iru, Luib & Nelem (2010) investigated:** - Read the introduction - Follow the demonstration: ice in seawater and tap water - Find information in the icy-tracker **Homework:** - **Look at the website, browse the site and the icy-tracker** - **Read the article of Iru, Luib & Nelem (2010)**
Lesson 2	**Judge the research of Iru, Luib & Nelem:** - Conduct the guide experiment: ice and salt - Orientation on accurate and reliable measurements - Read about variables - Judge Iru, Luib & Nelem's article on handling variables - Judge Iru, Luib & Nelem's article on accuracy
Lesson 3	**Judge the accuracy and reliability in Iru, Luib & Nelem's research:** - Judge Iru, Luib & Nelem's experimental set-up - Judge the reliability of Iru, Luib & Nelem's measurements - Judge the presentation of Iru, Luib & Nelem's results - Judge the validity of Iru, Luib & Nelem's conclusion
Lesson 4	**Your own inquiry project: question and plan** - Formulate an inquiry question - Design an inquiry plan - Hand in your inquiry plan to the teacher
Lesson 5/6	**Your own inquiry project:** - Conduct your planned experiments - Collect measurements
	Your own inquiry project: - Write a first report as a team (see **Planning**) - Send your first report **with the right code** to: a.j.van.dijk@vu.nl - Discuss the report of another team in the Icy Internet symposium - Improve your report and write a final report - Send your final report **with the right code** to: a.j.van.dijk@vu.nl The jury only **judges final reports of teams that participated in the symposium**.

8 List of concepts

Complete the list of concepts. Work gradually on this list as the project proceeds.
Describe the following concepts:

FREEZING-POINT DEPRESSION

FREEZING-POINT DEPRESSION CONSTANT

CORROSION

INDEPENDENT VARIABLE

DEPENDENT VARIABLE

CONTROL VARIABLES

ACCURACY

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The effect of NaCl(s) on ice

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Summary
Salt spread on roads is a common sight in regions with cold winters. This spreading is done to let water freeze at a lower temperature and delay ice formation. When salt dissolves in water the freezing point of the solution is lower than that of water itself. This raises the question of what the effect is on the melting of ice or $H_2O(s)$ when cooking salt or NaCl(s) is added. Comparison of the melting of 50g of $H_2O(s)$ with and without 5.0g NaCl(s) resulted in a much faster start of the melting process of the $H_2O(s)$ with salt. But it also raised further questions such as what will happen when the amount of salt is increased or when another type of salt is used. Are 'green' alternatives possible to avoid corrosion on bikes, or negative effects on growing plants?

Road salt, volume measurements, freezing-point depression constant

Introduction

The observation that seawater freezes at about 1 °C lower than tap water helped chemists realize that salts lower the freezing point of water. Therefore NaCl(s) or common cooking salt is often spread on streets to prevent ice from forming in freezing weather. NaCl(s) dissolved in $H_2O(l)$ indeed lowers the freezing point of water.

It was experimentally determined that one mole of sugar or urea dissolved in 1.0 kg or 1.0 L of water will lower the freezing point of the water by 1.86 °C (1). This value is called the freezing-point depression constant (k_f). The freezing-point depression constant depends on the solvent. Each solvent has its own experimentally determined constant e.g. for acetone the k_f = 2.40. So one mole of a substance dissolved in 1.0 kg of acetone will lower the freezing point of acetone by 2.40 °C.

Further investigations showed that one mole of NaCl(s) (58.5g) in 1 L of water doubles the drop in freezing point. Sodium chloride dissolves to give Na^+ and Cl^- ions, and both kinds of ions nearly independently contribute to the lowering of the freezing point.

$$NaCl(aq) \longrightarrow Na^+(aq) + Cl^-(aq)$$

One mole on NaCl produces two moles of ions and therefore a double lowering of the freezing effect occurs.

Experimentally it was found that a road surface covered with a 10% [10g NaCl(s) in 100g of water] salt solution would not freeze until the temperature reached -6 °C. Essential in this process seems that the salt (NaCl) must be dissolved (2).

This raises the question: *what is the effect of NaCl(s) on the melting of $H_2O(s)$?*

Our hypothesis is that the melting process of the ice with the NaCl(s) will start slowly, because in the beginning there will be no $H_2O(l)$ available. But because of the hygroscopic feature of NaCl(s) a little surface of water on the ice will soon be formed and speed up the melting process.

Experimental procedure and approach

We took six identical measuring cylinders and six identical funnels. Then the funnels were put on top of the measuring cylinders and left at room temperature. In three set-ups each funnel was filled with 50g crushed ice cubes and in the other three set-ups each funnel was filled with 50g crushed ice cubes and 5.0g of NaCl(s).

Data gathering and analysis

Then every 10 minutes the amount of water that appeared in the funnels of each set-up was noted till all the ice was molten. The values for each moment of measuring – with NaCl(s) and without NaCl(s) – were averaged and put in a graph. Then the graph was analysed for similarities in and differences between the two set-ups.

Results

We observed that immediately after the NaCl(s) was added to the crushed ice a layer of water was formed. Moreover, it took 230 minutes to let the crushed ice in all of the funnels melt.
Table 1 presents the averaged amount plus deviations of melted water (in mL) of crushed ice that was treated with NaCl(s) and without NaCl(s).

Time (in minutes)	With NaCl (mL)	Without NaCl (mL)
0	0	0
10	11.5 ±1.5	0
20	17 ±1	0
30	21.5 ±1.5	3 ±1
40	25.5 ±1.5	8 ±1
50	30 ±1	9 ±1
60	34.5 ±0.5	12 ±2
70	37.5 ±0.5	15 ±1
80	40 ±0	19 ±1
90	42 ±0	21 ±2
100	45 ±1	24 ±1
110	42.5 ±2.5	27 ±1.5
120	49.5 ±1.5	30 ±1
130	50 ±2	33 ±1
140	51 ±1	36.5 ±1.5
150	52 ±2	38 ±1
160	53.5 ±1.5	40 ±1
170	54.5 ±1.5	42.5 ±1.5
180	55.5 ±1.5	43 ±1
190	56 ±1	45 ±1
200	56 ±1	46 ±1
210	56 ±1	48 ±1
220	56 ±1	49 ±1
230	56 ±1	50 ±1

Table 1: Amount of water (mL) released when crushed ice is treated with and without NaCl(s).

Figure 1 shows the averaged measured amount of melted water(l) in mL when crushed ice was treated with NaCl(s) (the upper line) and without NaCl(s) (the lower line).

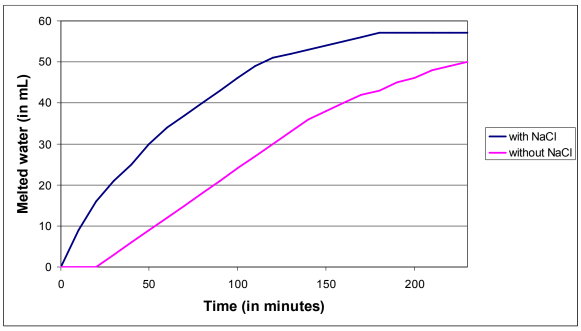

Figure 1: Averaged measured amount of melted water (in mL) from crushed ice with and without NaCl(s).

In Figure 1, the upper line, we see that with NaCl(s) the slope between 0 and 30 minutes is:
Δ y/ Δ x = 21.5-0/30-0 = 0.70 = tan α. So $\alpha = 45^o$.
Between 50 and 100 minutes the slope of crushed ice with NaCl(s), the upper line, is: Δ y/ Δ x = 45-30/100-50 = 0.30 = tan α. So $\alpha = 17^o$. And the slope of crushed ice without NaCl(s), the lower line, is: Δ y/ Δ x = 24-9/100-50 = 0.30 = tan α. So $\alpha = 17^o$

Conclusion and discussion

Looking critically at our experimental procedure and approach we see that in the set of experiments of crushed ice without NaCl(s) – we kept the same variables constant: the amount of crushed ice, the room temperature and the time taken. We measured the same dependent variable (volume of the melted water) and in one of the set-ups we added NaCl(s), so that a comparison between the two set-ups was possible.
As is shown in Figure 1 the melting process of crushed ice with NaCl(s) started immediately, whereas the melting of crushed ice without NaCl(s) started more slowly. This phenomenon was expected because of the hygroscopic feature of NaCl(s). This expectation concurs with our observation that immediately after adding NaCl(s) a layer of water was formed on the crushed ice.
After about 50 minutes the melting process of both set-ups – crushed ice with and without NaCl(s) – became equal in speed as is indicated by the same slope ($\alpha = 17^o$) for both melting processes. This remained so for another 50 minutes. It seems that after some time the NaCl(s) does not have an effect on the melting process of crushed ice anymore. An explanation could be that all the NaCl(s) is dissolved and that more salt is needed to see a further effect.
This raises further questions for inquiry: what will the effect of more salt be? Or what will happen when salts, that can produce three moles of ions, like $MgCl_2$, are used? Does a MX_2 salt act more quickly and is that the reason that it is sometimes used as a road salt in the United States and Canada? Or is it better to use double salts? Or is it possible to use 'green' alternatives, like mixing a salt with molasses or urea, or mixing different salts?
Whatever the case may be, using salts on roads corrode bikes and cars (3). Moreover, they a have negative effect on the growing of plants next to roadways. Is it possible to find 'green' alternatives?

Bibliography

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Some words explained.

accuracy	nauwkeurigheid
amount	hoeveelheid
average	gemiddelde
control variables	controlevariabelen
dependent	afhankelijk
dependent variable	afhankelijke variabele
deviation	afwijking
hygroscopic	hygroscopisch
independent variable	onafhankelijke variabele
inquiry	onderzoek
reliable	betrouwbaar
reliability	betrouwbaarheid
slope	richtingscoëfficiënt
snappy	pakkend
to concur	overeenstemmen
to submit	insturen
validity	geldigheid