Teacher’s Guide

Methyl orange
- online synthesis -

Chemistry Network
Department of Research and Theory in Education
VU University Amsterdam, The Netherlands, 2012
1. Teacher Guide: Methyl Orange

Teaching guide for six lessons. Study time for the students: 10 – 20 hrs

Below you find a time schedule for the inquiry project, ‘Methyl Orange’. The first three parts (1-3) are integrated in the chemistry lessons and the others (4-8) will be done outside the chemistry lessons. The students’ first task is to become familiar with the inquiry. Therefore you give a demonstration and the students do a guide experiment. After this the students will analyse and evaluate the inquiry done by Haenen, Van Harmelen & Oortwijn (2012). These three student researchers investigated the optimal flow rates to produce methyl orange in a micro reactor. Some questions arise. How ‘fair’ and accurate is their inquiry? Are their inquiry results trustworthy? Are their conclusions valid? These are questions that the students will answer by critically analysing the article written by these three student researchers. Doing this we expect the students – in a team of two – to perform a better inquiry. As a team they will write a first report on their inquiry. You need to publish the first reports on a website. In this way the students can discuss their results with peers, giving and receiving suggestions. They have to use these suggestions to improve their report, when writing their final article. All articles will compete for a research award.

Schedule for the procedure of the ‘Methyl Orange’ inquiry project (10-20 hours):

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Part of the project</th>
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<tbody>
<tr>
<td>Start with the task</td>
<td>1. Understand aim and nature of the inquiry project</td>
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<tr>
<td></td>
<td>• Predict, observe, explain</td>
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<td></td>
<td>• Conduct guide experiment</td>
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<td></td>
<td>• Judge accuracy, reliability and validity</td>
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<tr>
<td>Conduct inquiry</td>
<td>3. Own inquiry in teams</td>
</tr>
<tr>
<td>Write report</td>
<td>4. Report</td>
</tr>
<tr>
<td>Send first report</td>
<td>5. Report to: teacher</td>
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<tr>
<td></td>
<td>All reports on a website</td>
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<tr>
<td>Peer discussion</td>
<td>6. Peer discussion</td>
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<tr>
<td></td>
<td>The peer discussion on:</td>
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<tr>
<td></td>
<td>• Accuracy in the inquiry set-up</td>
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<td></td>
<td>• Accuracy in performing the inquiry</td>
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<td></td>
<td>• Reliability of the results</td>
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<tr>
<td></td>
<td>• Validity of the conclusions</td>
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<tr>
<td>Process comments</td>
<td>7. Teamwork:</td>
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<tr>
<td></td>
<td>Processing the comments received, improve report</td>
</tr>
<tr>
<td>Send final article</td>
<td>8. Article to: teacher</td>
</tr>
<tr>
<td></td>
<td>All final articles on a website</td>
</tr>
<tr>
<td>Receive prize</td>
<td>Jury selects the best inquiry</td>
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</table>
Before the six lessons

1. An introduction in class of approximately 15 minutes, with:

   A. The aims of the inquiry task

      The students:
      - Gain knowledge on the process of diazotation
      - Gain knowledge on the production of methyl orange in a micro reactor
      - Judge accuracy and reliability in a research
      - Design a ‘fair’ inquiry, measure accurately, determine whether measurements are reliable and lead to valid conclusions
      - Are part of a simulated research community and gain knowledge on peer discussion

      How to achieve these aims?
      1. Do the inquiry task guided by the questions in the workbook
      2. Predict, observe and explain in the demonstration: methyl orange
      3. Conduct a guide experiment: building methyl orange
      4. Evaluate Haenen, Van Harmelen & Oortwijn article: “Synthesis of methyl orange in a micro reactor”
      5. Formulate own inquiry question and plan the experiments to answer this question
      6. Conduct planned experiments
      7. Write a report about this inquiry and submit the report
      8. Discuss results with peers in a peer review
      9. Rewrite report into a final version or article
      10. Submit final article to an independent jury, e.g. other science colleagues or experts from outside; they select the best inquiry and award a prize

   B. The nature of the inquiry task

      - A scientific inquiry with measuring accurately

      Why is accurate and reliable research so important?
      - To acquire knowledge
      - An inquiry should be accurate, reliable and repeatable in order to convince other researchers of the (tentative) reliability of the results

      Why is the inquiry interesting?

      The students can, in teams:
      - Acquire chemical knowledge and knowledge about empirical evidence
      - Critically discuss empirical evidence in their peers’ inquiry
      - Win a research award
      - Publish their results on a website or in the school magazine
What should be handed in for a mark?
- The completed student workbook
- The inquiry plan
- The participation in the peer discussion
- The final article

2. Distribute the printed student materials (workbook) and the article of:
   Haenen, Van Harmelen & Oortwijn (2012)

3. Focus the students’ attention on the ‘Study Guide’ (workbook p. 22) and the planning of the project (workbook p. 4)

4. Ask the students to make teams of two or three
Lesson 1: Understand what Haenen, Van Harmelen & Oortwijn (2012) investigated

Introduction
1. Introduce the workbook and the ‘Planning’, see Student workbook p. 4.
   Introduce what the students have to do in the first lesson. Refer to the workbook ‘Study guide’, p. 22.
2. Let the students read the introduction in the workbook, p. 3.
   Refer to the list of concepts on p. 23. The students can complete this list bit by bit as the inquiry project proceeds.

Demonstration: methyl orange
3. Let the students individually predict and write down what they expect to happen when an methyl orange is put in an acidic and a basic solution.
   Ask them to answer Questions 2.1, workbook p. 5.
4. Discuss the predictions (what they expect) and explanations (why they expect this).

<table>
<thead>
<tr>
<th>Materials needed for the demonstration:</th>
<th>Procedure:</th>
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</thead>
<tbody>
<tr>
<td>Methyl orange indicator</td>
<td>A household vinegar solution</td>
</tr>
<tr>
<td>Two Erlenmeyer flasks</td>
<td>A soap solution</td>
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</tbody>
</table>

Safety and remarks:
No

5. Ask the students – in their teams – to write down their observations, conclusion and explanation; Questions 2.2, workbook p. 5
6. Discuss the explanation of colour change. Questions 2.2 (i) and (ii), workbook p. 5/6

Homework
7. Ask the students to browse the internet to find information on the synthesis and use of methyl orange.
8. Students should read the article of Haenen et al. (2012) on “Synthesis of methyl orange in a micro reactor”
Lesson 2 and 3: Guide experiment and judgement of Haenen et al.’s inquiry

Introduction
1. Introduce what the students need to do in these lessons. Refer to workbook “Study guide” p. 22.

Guide experiment: one molecule of methyl orange
2. In teams the students use model kits or a computer to build one molecule of methyl orange.

<table>
<thead>
<tr>
<th>To build and view models on a computer use the following instruction / use of chemsk10_.exe</th>
</tr>
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<tbody>
<tr>
<td>* Install chemsketch10_.exe. Go to <a href="http://www.acdlabs.com">www.acdlabs.com</a> to download Chemsketch 10. Select</td>
</tr>
<tr>
<td>Download Freeware ACD/Chemsketch 10 and follow the on-screen procedure.</td>
</tr>
<tr>
<td>* Open, if necessary, the download ChemSk file and click on the ChemSketch hyperlink.</td>
</tr>
<tr>
<td>* Click ok, followed by cancel, then ok</td>
</tr>
<tr>
<td>* Now the building of molecules can start:</td>
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<tr>
<td>- In the left site of the screen you can select atoms or groups (click atom or template); e.g.</td>
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<tr>
<td>activate a C atom and click in the white screen. This will give CH₄. Click on CH₄ to bond</td>
</tr>
<tr>
<td>another C atom. One click on the bonding will change a single bond to a double bond.</td>
</tr>
<tr>
<td>- When the structure is ready. Click above “10” on “Lasso”. Go to the white screen and select</td>
</tr>
<tr>
<td>the structure. Then go to “Tools” 3D structure optimiser. Followed by ACD/Labs and select</td>
</tr>
<tr>
<td>3D viewer. Go back to Chemsketch (at the bottom of your screen) and then to “copy to 3D”.</td>
</tr>
<tr>
<td>In the upper part you then see all kind of functions e.g. sticks and balls etc.</td>
</tr>
</tbody>
</table>

3. Follow the procedure for the guide experiment and ask the students – in their teams – to build one molecule of methyl orange and to define the diazotation process in 3.1 (i) and (ii) (workbook p. 7) and to find the molecular formulas and molecular masses of sulfanilic acid and methyl orange in 3.2 (i) (workbook p. 8).
Let them calculate the maximum amount of methyl orange that theoretically can be formed out of 16.7 mmol sulfanilic acid.

Judging the inquiry of Haenen et al.:
4. Let the students work (in teams) on the questions in 4.1 (i), (ii) and (iii) (workbook p. 9)
   After that discuss accurate measurement [4.1; (i)], depends on e.g.:
   - Used spectrophotometer

Discuss what to do to find out if a measurement is reliable [4.1; (ii)]:
   - Repeat the experiment
   - How many times to repeat, depends on the deviation between the measurements.

Discuss reliability of a series of measurements [4.1; (iii)], depends on:
   - The experiment should be set-up in a ‘fair’ way
   - All experiments should be conducted in exactly the same way
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- The deviation between measurements should not exceed 0.5%

5. Let the students (in teams) work out the rest of the questions in chapter 4; p. 9-16.
   Be sure that they get to know and understand the meaning of accuracy, reliability and validity in an inquiry.

Lesson 4: Students’ own inquiry project: question and plan

Introduction:
1. Introduce what the students need to do: (re)formulate the inquiry question and design an inquiry plan (see workbook “Study guide” p. 22).
   As indicated on p. 17 in the workbook the students need to do an experiment that will increase the continuous flow or the yield of methyl orange.
   NB: possibilities are:
   -repeat the experiment
   -change temperatures, all other variables constant
   -change rate flows, all other variables constant

Inquiry in teams:
2. Let the students work out the “inquiry in teams” (workbook p. 17-18)
   The students’ inquiry questions should be:
   a. Unambiguous: contains one problem
   b. Relevant: related to the topic methyl orange
   c. Concrete: the question should contain the dependent variable and independent variable
   The student’s inquiry plan should be handed in and checked on:
   d. Whether they have planned the right conditions for the experiment?
   e. Whether they have indicated when to register for the conduction of the experiment?
3. Give the students feedback on their inquiry plans and a go and refer to the MANUAL
4. Remind the students to keep a record of the inquiry (workbook p. 19).
5. Ask the students to reserve inquiry time for the conduction of the online experiments

Lesson 5: Conduction of the planned inquiry

Introduction:
1. Introduce what the students need to do:
   -discuss the various plans

Conduction of the experiments:
2. Let the students conduct the experiment
Further approach in the project

3. Discuss with the students the part in the project “Outside the chemistry lessons”, so that all students know what still needs to be done.

Outside the chemistry lessons

Check, now and then, whether the teams do the following:

1. Write a first version of their report with the following guidelines (workbook p. 20):

- **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 the 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.

- 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 **teamnumber_first name_first name**.

- Add the **email addresses of all team members**.

2. **Submit** the **first version** of the report on a website
3. **Discuss** the published report of at least one other team in a symposium.
   Use the following categories (*workbook p. 21*):

   - 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 observations are accurate.
   - Discuss whether the results are well presented.
   - Discuss whether the right calculations are made.
   - 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.

4. Use comments from the peer discussion to **improve their first report**

5. **Rewrite their report into a final version: article**
   Again use the guidelines *workbook p. 21*

6. **Submit their final article**

7. Ask the jury to find the best inquiry