The clock reaction

A TEMI LESSON PLAN





Overview

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| What’s the mystery? | Two translucent liquids are mixed. At first nothing happens, the resulting solution is still translucent. Suddenly with no warning the solution turns blue-black all at once. |
| Domain(s) | Chemistry  Redox reactions, Rate of reaction (kinetics). |
| Age group | Grades 10-12 (15-17 years old) |
| Expected time for the mystery | Approx. Time for teacher preparation – Up to one hour for preparation of the solutions and trials to see that the reaction takes place as planned.  Approx. Time in classroom - Up to 6 periods of 45min. One period to engage and explore; one to explain; three to plan, perform and present the creative activity that incorporates the color change. |
| Safety/Supervision | Iodine (I2) is produced in the reactions. The reaction vessels should be tapped. At the end of the reaction the Iodine that is produced should be neutralized with Na2S2O3 solution. |
| Preparation & List  of Materials | * Potassium iodide, KI 0.1M (Solution A) * Hydrogen peroxide, 3% H2O2 (aq) in an acidic environment + starch (Solution B) * Sodium thiosulphate, Na2S2O3•5H2O ~0.05M (Solution C) * Neutralizing solution – Sodium thiosulphate, Na2S2O3•5H2O ~0.05M (the solution is the same as Solution C. It is written separately to remember to prepare an additional amount for neutralization) * 3 × 10 ml graduated cylinders * 3 large test tubes * Suitable test tube rack * 3 rubber stoppers for the test tubes * 3 plastic pipettes |
| learning objectives | Introduction of interesting Redox reactions.  Introduction of reactions rates, the effects of fast and slow reactions and their uses. |
| Author | Ran Peleg, Malka Yayon, Dvora Katchevich, Rachel Mamlok-Naaman, Avi Hofstein and David Fortus, Weizmann Institute of Science |



L Guidance notes for teachers

Engage: Capture student’s attention

Student watches the following silent movie - <http://goo.gl/9G7fDz>

While watching they write observations and questions.

If the movie cannot be shown the teacher can conduct the experiment live. Suitable amounts of solutions A+C are mixed in a jug. Solution B is poured into a wine glass. The solutions in the jug and in the wine glass are mixed and poured back and forth until the solution has changed colour.

During the process the teacher tells a short story – "I ran out of blackcurrant juice, so I bought water and with magic and some chemistry turned it into juice."

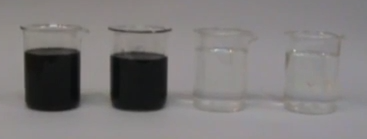


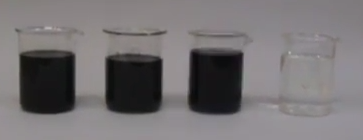
Explore: Collect data from experiments

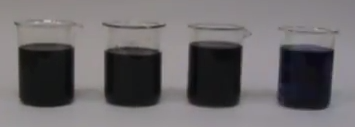
Students are asked to perform experiments which guide them step by step (1-3) to understand the phenomena of the clock reactions.

1. Students mix solutions A and B. This immediately generates a black colour.
2. Students mix solutions A and B in the presence of solution C; the appearance of colour is delayed. Each student group receives different volume of solution C, causing different delays in the appearance of the colour.
3. A representative from each group is asked to perform the experiment (2) together with all other representatives at the same time before the class. The black color appears at different times forming a visual 'xylophone' (see <http://goo.gl/uMrHcE> ).









Explain : What’s the science behind the mystery?

Students are given the information regarding the reactions that occur and that starch is an indicator for the presence of iodine, the presence of both in a solution induces a black color. Students are then asked to explain the phenomenon.

The full explanation is as follows.

Two competing reactions are taking place in the reaction vessel:

* + 1. H2O2 (aq) + 2H3O+(aq) + 2I−(aq) → I2(aq)  + 4H2O(l)
    2. 2S2O32−(aq) + I2(aq) → S4O62−(aq) + 2I−(aq)

Reaction 1: Oxidized iodide, I-(aq), into iodine, I2. The latter appears black in the presence of starch.

Reaction 2: Reduced the iodine back into colourless iodide.

Since reaction 2 is faster than reaction 1, the solution remains colourless (since any iodine formed is quickly transformed into iodide)

These two reactions occur simultaneously until the thiosulfate ions, S­2O32-, which are the limiting agent, run out. When this happens only reaction 1 takes place, all iodide turns to iodine and the solution becomes black.

Extend: What other related areas can be explored?

The teacher collects data from the different groups regarding the time of the black colour appearance and the volume of the inhibiting solution. The class analyses the data using a table on the board and draws a graph of the volume of the inhibitory solution against the time of the black colour appearance.

The trend line with the mathematical equation of the slope in the graph is used to explain the concept of the calibration graph and its use.

Students are asked to design an experiment in which the black color appears in synchronization with a sound change in a song or any other creative purpose.

Each group presents the experiment planned before the class.

Evaluate: Check the level of student scientific understanding

Students prepare a lab report which assesses skills such as making observations, asking questions, designing an experiment, writing explanations and hypothesizing. Students have to explain why the experiment is called the 'clock reaction'.

Tips on how to teach and present this mystery

The engage stage can be performed by showing Video 1, or by performing the clock reaction in large quantities. If the teacher feels comfortable, we suggest and encourage telling a story which is relevant to the students.

The Explore stage (1-2) is self-explainable (Video 2), while performing in front of the class (3) the teacher has to direct the performance as following:

1. All the students stand in a line, and wait to mix solution B at the same time. The teacher may order them by the volume of solution C or in a random manner.
2. The "stage" should help students focus on the reaction (Video 3), this can be done by:
   1. To put a white paper as background below and behind the reaction containers.
   2. The reaction takes time; think what to say while the reaction occurs. "What do you expect to see?", "which will appear next?", etc..

The Extend stage should be a happening in class. Each group presents the song that was chosen and there should be a "tension" to see if the colour change is in synchronization with the music.

The following videos suggest ways in which the mystery can be presented:

**For the engage stage:**

Video 1 – <http://goo.gl/PvqKSd> - "the TEMI vineyard"

**For the explore stage:**

Video 2 - <http://youtu.be/QOR4kJy3P78> – The basic reaction

Video 3 - <http://goo.gl/wBYKoX> – The visual Xylophone

All videos were filmed by the Weizmann team.

Teaching Skills using Gradual Release of Responsibility

Notes: Most Mysteries can also be used to teach Inquiry skills. A ‘Skill-teaching ’ TEMI lesson needs to use a modified 5E cycle where the Explain stage precedes the Explore. This is because it is necessary for the teacher to model the skill before, students practice it, as described in the box below:

The lesson begins with a demonstration of the mysterious phenomenon (engage stage). During the demonstration students also see the teacher performing the mixing of the reaction.

In the explore stage, they imitate the teacher's actions and follow strict instructions. The students need to use and understand the idea of a calibration curve to perform the extend stage. In the extend stage they are encouraged to 'own' the reaction and control it so that it 'performs' as they choose - using a song they like.

Students thus gain control of planning and engineering the reaction.

During the activity students learn the following enquiry skills: Engagement in scientific questions; giving priority to evidence; formulating explanations from evidence; connecting explanations to knowledge; graphic representations, calibration graph and its meaning.

**THE STUDENT WORKSHEET CAN BE COPIED AND USED IN THE CLASSROOM**

 Student worksheet

Introduction to mystery

Two translucent liquids are mixed. At first nothing happens the resulting solution is still translucent. Suddenly with no warning the solution turns blue-black all at once.

You will see a demonstration of a mysterious chemical reaction. How does the reaction know when to turn black? Is there some magical ingredient that can't be seen? Does the teacher add some mysterious chemical when we don't see or is the mysterious chemical already in the reaction vessel?

We will try to decipher a reaction that 'has a mind of its own'.

Engage What’s interesting?

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| **Task** | Watch the following video silent movie - <http://goo.gl/9G7fDz>  What happens in the video? Why do you think it happens?  While watching write what you see and questions relating to what is happening. You may watch the video more than once. |

Explore What’s happening?

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| **Materials** | You will get three solutions:  Solution A – Potassium iodide, KI 0.1M  Solution B – Hydrogen peroxide, 3% H2O2 (aq) in an acidic environment + starch  Solution C – Sodium thiosulphate, Na2S2O3•5H2O ~0.05M  You will also get the following materials:  3 × 10 ml graduated cylinders  3 large test tubes  Suitable test tube rack  3 rubber stoppers for the test tubes  3 plastic pipettes  Stopwatch  Gloves which must be worn at all times |
| **Instructions** | Mark the three cylinders with the letters A, B and C. Make sure that you always use one cylinder for each solution.  a. Measure 5 ml of solution A using the graduated cylinder marked "A" and pour it into a large test tube.  b. Measure 10 ml of solution B using the graduated cylinder marked "B".  c. Pour solution B into the test tube containing A. Close the test tube with a stopper, mix lightly and write your observations.  d. Measure 5 ml of solution A using the graduated cylinder marked "A" and pour it into a clean large test tube.  e. Measure 3 ml of solution C using the graduated cylinder marked "C" and add them to the test tube containing A.  f. Measure 10 ml of solution B using the graduated cylinder marked "B".  g. Pour solution B into the test tube containing solutions A+C. Start the stopwatch, close the test tube with a stopper, mix lightly and write your observations.  h. Repeat instructions d-g in the class presentations according to the teacher's instructions. |

Explain What’s causing it?

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| **Task 1** | Try to explain your observations based on the following reactions:   * + 1. H2O2 (aq) + 2H3O+(aq) + 2I−(aq) → I2(aq)  + 4H2O(l)     2. 2S2O32−(aq) + I2(aq) → S4O62−(aq) + 2I−(aq) |
| **Task 2** | The teacher will gather the findings of all groups in class. How do you suggest we present the data? |

Extend What’s similar?

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| **Task 1:** | In your groups – plan a creative activity that is based and incorporates the colour change. For example the solution turns colour at a highlight in a song that is played.  Plan an experiment including the following stages:  • Detail all the steps of the experiment.  • List the equipment and materials needed on the equipment request form.  • Consult with the teacher and make changes if necessary.  • Submit the list of equipment and materials to the laboratory technician. |

Evaluate What’s my understanding?

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| **Task 1:** | Present the creative activity that incorporates the color change. |
| **Task 2:** | Prepare a formal lab report that includes an explanation of the phenomenon, and details of your methods and procedures. |