Project description for participation in the European Science on Stage festival from 29 June – 2 July 2017 in Debrecen
[For countries **with** National Steering Committee]

Please fill in the grey-marked fields and send it back by 22nd January to your National Committee of Science on Stage (bernanbergen@yahoo.fr) . Additional material can be sent separately as attachment.

Please note that you agree with this document that your project description will be published in the conference material and on the Science on Stage webpage. Personal contact details will not be given to third parties.

Main contact person

Title (Dr, Prof, etc.)**:** Teaching-Assistant

First Name: Hamad

Surname: Karous

School / institution: University of Liège

Your subjects: Chemistry

Town: Liège

Country: Belgium

Are you a school teacher?

☐ **Yes** ☒ **No**

Details (name, country, email) of further persons who would like to present the project with you at the festival:

Have you participated in a Science on Stage festival before?

☐ **Yes** ☒ **No**

How many years of teaching experience do you have? 1 year at secondary school and 2 years at university

How did you get to know about Science on Stage?

☐ Direct mailing from National Steering Committee

☒ Other Science on Stage events ☐ Social Media ☐ Colleagues

☐ Internet (webpage:) ☐ Announcement in magazine (name:)

☐ Other channels:

Guiding Theme: Cooperation for Science Teaching

Category: Please, allocate your project to one category

☒ **Fair**

The Fair is the main element of the Science on Stage festival. All teachers present their projects 'from teachers for teachers' at stands. Additionally you can apply to present your project in form of a:

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☐ **Workshop**

If Workshop, please include in the project description an **agenda of the workshop** you would like to conduct at the festival.

☐ **On Stage Performance**

If On Stage Performance: ☐ **lecture or** ☐ **performance**

If On Stage Performance, please give a link to a **video of the On Stage activity** (e.g. youtube or dropbox):

Remark: *The selection of the participants in the categories Workshop and On Stage activity will be made by the* ***international festival committee****.*

Project title: Experiments to improve chemistry learning by modelling

Abstract: ***(max. 700 characters incl. spaces):***

The process of modelling is inherently widespread in teaching approaches and in general human interaction with the world. When facing a new situation in their everyday life, students most common way of reacting is to ask for an example. This example can be then be seen as a model of the associated knowledge with some limitations. Models are indeed defined by their specific content and by the way they are elaborated or structured. In the context of science teaching, it is commonly observed that students misunderstand the exact role of models and underestimate their limitations. For instance, they often believe that models represent the unique truth, ignoring their inherent adaptability. Moreover, the importance of the modelling process and of an adequate analysis of the different dimensions spanned by the model concept itself is not sufficiently addressed in the various curricula. To overcome these misconceptions, a modelling approach is presented with the aim of helping students to become familiar with various scientific concepts associated with chemistry such as chemical kinetics, electrochemistry and chemical equations. In this study, modelling procedures have been developed within the framework of experimental activities. The active participation of students is promoted through the following activities: realizing and observing experiments dedicated to various concepts, modelling the associated results individually or in groups, taking part in guided discussions supervised by the teacher.

Involved disciplines: Chemistry

Age group (of the students): 15-18

Materials used in this project:

Experiment	Materials and Products
1	100 mL beakers, 100 mL measuring cylinders, effervescent tablets (Alka Seltzer), dish soap, distilled water, vinegar and acetone.
	Three glass tubes (see figure below experiment 2), stoppers,

2	2 pipettes or 2 syringes, solution of iron nitrate ($c(Fe(NO_3)_3)$= 1 mol /L), solution of potassium thiocyanate (c(KSCN) = 1 mol /L), solution of nitric acid ($c(HNO_3)$= 0.1 mol / L).
3, 4 and 5	Modelling clay or candle wax, clay pot, crystallizer, 2 beakers of 150 mL or 250 mL, cables with crocodile clips, multimeter, voltmeter, small engine or music card, emery paper, scissors, pipettes, carbon electrode, aluminum cans, sodium chloride, zinc electrode, copper electrode, solution of copper sulphate, (c (CuSO4) = 1mol / L and 0,1 mol / L), solution of zinc sulphate, (c (ZnSO4) = 1 mol / L), solution of potassium nitrate (c (KNO3) = 1 mol / L), solution of potassium hexacyanoferrate (II), distilled water.

What is innovative about your project?

In the educational proposition, we have encouraged the introduction of experimental protocols to teach several scientific concepts. This research emphasizes on spontaneous reasoning and on the importance of letting the student build his knowledge on his own, with the guidance of the teacher limited to key-points of the teaching process. The aim is therefore to give more autonomy to the students thanks to more open tasks and activities that require higher cognitive skills through modelling activities.

What can other teachers implement from your project in their classes?

We put the necessary scientific and didactic information at the other teachers' disposal for all the suggested experiments in data sheets, so that they can easily be reproduced in other classes. For each experiment, we suggest that the macroscopic observations be schematically represented and that the phenomenon be translated into some symbolic language, the written chemical reaction, often on the basis of quantitative data presented as graphics or tables.

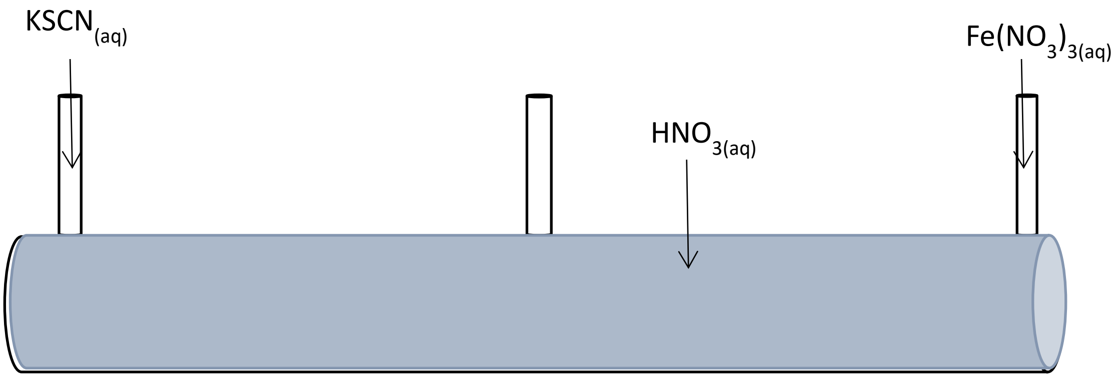
Personal quotation concerning your project: On ne comprend pas la question: estimation de coût des différentes expériences?

Project description: ***(max. 12,000 characters incl. spaces / approx. 2.5 pages)***

1. **<u>Experiment 1: Diffusion in aqueous medium</u>**

In this sequence of experiment, the students will get familiarized, through modelling, with the concepts of molecular motion and intermolecular collisions, introduced to account for the experiments.

a. In the tube (see picture below) filled with a 0.1M solution of nitric acid (de Berg, Maeder, & Clifford, 2016) at room temperature, inject 1 mL of $KSCN_{(aq)}$ on the one side and 1 mL of $Fe(NO_3)_{3(aq)}$ on the other side.
b. Observe the phenomenon that is results.
c. Do the experiment again with the second tube while checking the time that it takes for the phenomenon to begin.
d. In a tube filled with a 0.1M solution of nitric acid at 60 °C, inject 1 mL of $KSCN_{(aq)}$ on the one side and 1 mL of $Fe(NO_3)_{3(aq)}$ on the other side.
e. Check the time that it takes for the phenomenon to begin.



Questioning

Explain how the product was formed from the reaction and write the equation for the reaction. Model the phenomenon that leads to this reaction at the submicroscopic[1] scale. Draw a diagram that integrates a representation of molecules (circles, squares, etc.) and their motions.
Compare the results of both experiments (at room temperature and at 60 °C) and suggest an interpretation.

Observations

A color change can be observed at a rather precise position along the tube. This is because of the formation of the following product: $Fe(SCN)^{2+}_{(aq)}$. The speed of diffusion increases when the experiment is carried out in a hot solution of nitric acid.

Explanation

The reagents that were injected on both sides of the tube migrate to the middle to form the product according to the following reaction:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \longrightarrow Fe(SCN)^{2+}_{(aq)}$$

The speed of diffusion of the particles (atoms, molecules and ions) depends on their size and on the temperature. The Fe^{3+} ions migrate faster than SCN^{-} ions. At the moment when these ions meet, a red color appears because of the reaction forming the complex product.

2. **<u>Experiment 2: Chemical kinetics</u>**

Operation 2a

In the first beaker, add 50 mL of distilled water. In the second beaker, add 30 mL of acetone and 20 mL of distilled water. Drop an effervescent tablet in each beaker at the same time and compare.

Operation 2b

In each 100 mL beaker, drop an effervescent tablet and the same quantity (5ml) of dish soap. Then, add 20 mL of vinegar in one beaker and 20 mL of water in the other at the same time. Compare.

Operation 2c

In a first measuring cylinder, place an effervescent tablet that has been crushed in its wrapping. In the second measuring cylinder, place a whole effervescent tablet. Add the same quantity of dish soap in both the cylinders. Then, add 20 mL of vinegar at the same time in each cylinder. Compare.

[1] The term "submicroscopic" refers to the atomic, ionic or molecular level.

Operation 2d

Pour 50 mL of distilled water in each beaker. Cool down the first one to 5 °C, write down the temperature of the second one (around 20 °C) and heat up the third up to 70 °C. Add an effervescent tablet in each beaker successively and write down carefully the time that it takes for each tablet to completely disappear.

Questioning

These several experiments allow the students to identify easily a simple process the factors that influence the rate of dissolution of the effervescent tablet, as well as the influence of the solvent (water or acetone mixed with water). The students are requested to model the phenomenon that leads to this reaction at the submicroscopic scale (Used in symbolic language to translate their observations used symbolic writing the chemical reaction).

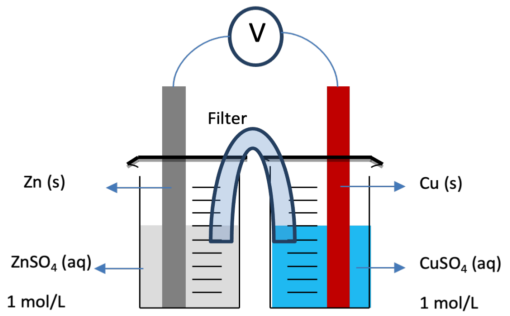
3. Experiment 3: The Daniell cell battery: two different constructions

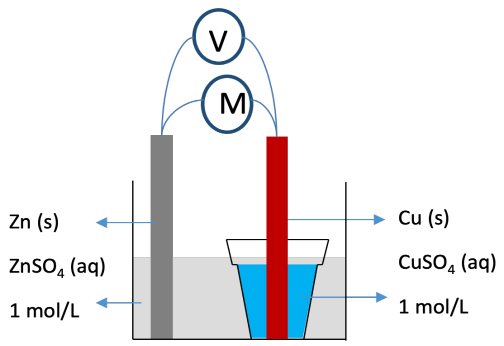
During this experiment, the students will have to interpret and compare two possible ways used to building the Daniell cell battery. They will have to measure the voltage at the terminals of the battery as well as the intensity of the current when the battery is short-circuited and the voltage of the terminals when the current is allowed to flow.

Preparatory work

The day before the experiment, take the small clay pot, whose bottom has been previously sealed with modelling clay or candle wax, and soak it into an aqueous solution saturated with sodium chloride. The electrolyte bridge is formed with a filter paper soaked in a potassium nitrate solution (c=1 mol/L).

Measures to be performed with each construction





a. Measure the voltage at the terminals of the Daniell cell with no current flow, using a multimeter set to voltmeter mode.
b. Try to start the engine.
c. If the engine works, measure the voltage at the terminals of the Daniell cell as well as the intensity of the electric current that flows through the engine with a multimeter set to amperometer mode. Draw a diagram of the circuit which involves the connections of the voltmeter and of the amperometer.
d. Remove the engine and short-circuit the battery. Measure the intensity of the current.

Observations

The two different constructions of the Daniell cell produce the same voltage (approximately 1.1 V) when no electric current is flowing. The engine preferentially works in the 'clay pot' construction. The 'beaker' construction only debits a weak electric current which does not allow the engine to work.

Questioning

Describe the similarities and the differences that can be inferred from the measurements that were made.

Make a model on a submicroscopic scale in order to show the difference between these measurements. This modelling must describe the functioning of both Daniell cells on a submicroscopic scale in order to find an explanation that matches the macroscopic observations. We can focus in the description of the task on modelling the migration of ions through the wall of the modelling clay and along the filter paper.

Conclusion

The Daniell cell made with the two beakers and the electrolyte bridge (which is a filter paper soaked in potassium nitrate solution) cannot produce an electric current that is intense enough. This is due to the high value of this battery's internal resistance, because of the type of electrolyte bridge which only allows for a slow transfer of ions. This leads to an important ohmic voltage drop when the battery is put into operation.

In the case of the 'clay pot' construction, the exchange surface for ions is significantly bigger. This considerably reduces the ohmic voltage drop.

4. **Experiment 4: Identification of the reactions occurring at the electrodes of the Daniell cell battery**

During this experiment, the students must identify the products of the reactions that occur at the electrodes of the Daniell cell battery and write down the corresponding reactions.

Preparatory work

The day before the experiment, take the small clay pot, whose bottom has been previously sealed with modelling clay or candle wax, and soak it into an aqueous solution saturated with sodium chloride.

Instructions

In the beaker, dilute approximately 100 mL of potassium nitrate solution with distilled water until reaching a total volume of approximately 300 mL. Fill the small clay pot three-quarters full with the copper sulphate and put it in the beaker. Immediately pour the diluted KNO_3 solution in the beaker. Complete the construction of the Daniell cell with a carbon electrode in the $CuSO_4$ solution and a zinc strip (previously rubbed with emery paper and rinsed with distilled water) in the KNO_3 solution. Measure the voltage at the terminals of the battery and identify the direction of the electric current. Start the engine. Then, short-circuit the two electrodes for **half an hour**.

Identification of the reaction occurring with the Daniell cell battery

Remove the two electrodes and observe carefully. Take a few mL of the solution contained in the crystallizer to which you add 2 to 3 drops of the potassium hexacyanoferrate (II) solution in order to test it for the presence of Zn^{2+} ions.

Questioning

Give at least two different observations that can, according to you, help us deduct the type of reaction that occurs at each electrode.

Make a model, for example as a sequence of drawings at the submicroscopic level, representing **the evolution over time** of chemical phenomena that occur at the interfaces of the two electrodes with the solutions.

Conclusion

The formation of the brown-red metal layer on the carbon electrode allows us to conclude that copper ions from the solution have in fact been reduced.

The appearance of the zinc strip and the positive identification test carried out with the potassium hexacyanoferrate (III) solution allow us to conclude that the zinc has been oxidized.

The formation of the white precipitate can be represented as follows:

$$2\ K_4[Fe(CN)_6]\ (aq) + 3\ Zn^{2+}(aq) \rightarrow K_2Zn_3[Fe(CN)_6]_2(s) + 6\ K^+\ (aq)$$

The chemical equations corresponding to the reactions occurring at the electrodes of the Daniell cell are therefore as follows:

At the zinc electrode: Oxidation: $Zn(s) \rightarrow Zn^{2+}(aq) + 2\ e^-$

At the carbon electrode: Reduction: $Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$

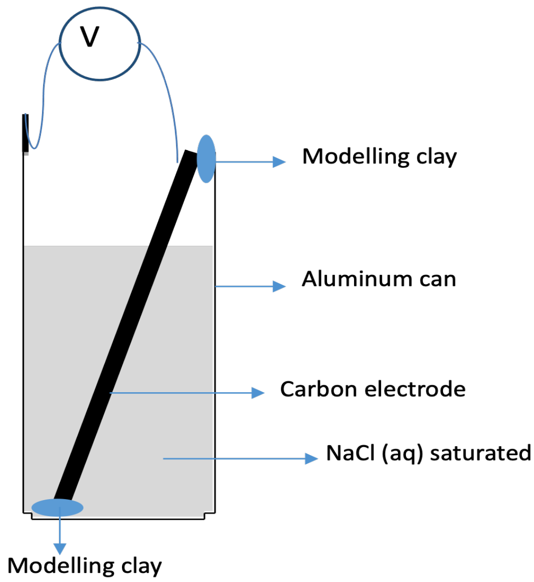
5. **Experiment 5: Soda can battery**

Build a battery with one or several aluminum cans.

Operating method

Cut the lid of several aluminum cans, rinse them and rub their internal surfaces with emery paper or file them down in order to remove the coat of protective varnish. Put a carbon electrode on a small piece of modelling clay in order to isolate it from the bottom of the can. Also stick a small piece of modelling clay on the edge of the can, where the electrode touches the surface so that the carbon electrode won't be in short-circuit with the aluminum.

Dissolve two spoonfuls of sodium chloride into 150 mL of distilled water and pour this solution in the can. Measure the voltage of the battery that is created. Then, connect a musical postcard.



Observations and explanation:

One single battery produces a voltage of 1.0-1.1 V. The NaCl solution allows the destruction of aluminum oxide layer and the anodic oxidation of the aluminum. We can observe the reduction of dissolved oxygen at the carbon electrode.

At the anode (Oxidation):

$$4\ Al(s) + 4\ Cl^-(aq) + 16\ H_2O(l) \rightarrow 4\ Al(OH)_2Cl(aq) + 8\ H_3O^+(aq) + 12\ e^-$$

At the cathode (Reduction):

$$3\ O_2(g) + 6\ H_2O(l) + 12\ e^- \rightarrow 12\ OH^-(aq)$$

Globale reaction

$$4\ Al(s) + 4\ Cl^-(aq) + 6\ H_2O\ (l) + 3\ O_2(g) \rightarrow 4\ Al(OH)_2Cl(aq) + 4\ OH^-(aq)$$

Questioning

Build a second battery can and a third one. Connect them in a series and measure the voltage as well as the intensity of the current in the short circuit configuration.

Suggest a schematic model at the submicroscopic level, possibly using symbols (squares, circles, etc.) for the molecules and ions, that describes the disappearance of the reactants and the appearance of the products at both electrodes, as well as the migration of the charged particles (ions and electrons).

References/Sources:

Cahay R., Linard R., Mouton R., Monfort B., Brasseur C., Vieujean C.,Defize T. (2013). Fascicules des « Chimistes en herbe » la cinétique.

De Berg, K., Maeder, M., & Clifford, S. (2016). A new approach to the equilibrium study of iron(III) thiocyanates which accounts for the kinetic instability of the complexes particularly observable under high thiocyanate concentrations. *Inorganica Chimica.*

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