TEACHING IDEAS SHARED FROM SAILS TEACHER EDUCATION PROGRAMME

Galvanic Cells

This resource has been developed through the SAILS Teacher Education Programmes (2012-2015) but was not developed as a finalized SAILS Inquiry and Assessment Unit. These materials are shared to inspire further use of inquiry and assessment of inquiry skills in the science classroom.

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Galvanic Cells

Level: Upper secondary school – higher level

Duration: 4 hours (including 2 h of laboratory work)

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Section 1: Topic

The subject allows to make open-inquiry experiments and is characterized by a large number of parameters, which may become the subject of investigation. This fact makes subject suitable for implementation in classes with large number of students and ensure personalization of experiment.

Section 2: Content

The experiment can be executed with a group of students who are familiar with build and the action scheme of Daniell's cell, however before the introduction of concept of galvanic series, calculation of the electric potential using the standard potential and the Nernst equation. For content knowledge see Appendix I

Section 3: Inquiry Skills

- Identify a problem to be investigated.
- Discussion with peers
- Ask scientific questions
- Formulate a hypothesis
- Identify and define variables
- Design experimental procedures
- Manual skills
- Collect meaningful data accurately and precisely
- Analyze data for trends and relationships
- Construct and interpret graphs
- Draw appropriate conclusions from evidence
- Search for information
- Test the accuracy of results
- Identify possible reasons for inconsistent results

For placement of opportunities to asses listed inquiry skills in a learning sequence see Appendix II and III.

Section 4: Learning Outcomes

After unit students are expected to be able to:

- plan and describe an investigation of cell potential in respect to anolyte and catholyte concentration.
- build a galvanic cell and measure its electric potential,
- discuss how dilatation of anolyte and catholyte influence a cell potential,
- use Nernst equation for calculation of electric potential for a cell that works in conditions different than s.t.p.

Section 5: Suggested Learning Sequence

The general research problem: How to get the highest voltage of a cell?

Phase I: Planning (1 h)

Discussion: What parameters can affect the voltage generated by a cell?

For the purposes of this unit, only the experiment in which students examine the impact of the concentration of anolyte and catholyte will be described, however, it is possible to examine the impact of other factors (ex.: temperature, the size of the metal plates, volume of the solutions, type of salt bridge solution etc. Additionally the effect of parameters on the current or duration of cell action can be measured.)

The students are divided into groups of 2-3. Groups are randomly allocated to two metal plates (ex.: Al, Zn, Cu, Pb, etc.). The task for the groups is to propose an experiment that will examine the impact of the concentration of solutions in the half-cells on the voltage generated by the cell.

The groups should prepare a plan of experiment that covers:

a) The research hypothesis with reasoning.
b) A list of variables (dependent variable, independent variable and controlled variables).
c) Schema of the research.
d) The action plan with a detailed description of the actions.

Each group prepares the plan of experiment in two copies. One copy shall be given to the teacher, the other is subject to the discussion on the forum. Students improve and complete prepared plans of the experiment. If a teacher plans to compare the results between groups or present joint report, the students should take the same values of controlled variables and unified schema of the research.

Phase II: Conduct an experiment (2 h)

A groups of students execute prepared action plans and write down the received results. It is possible to complement the set of controlled variables with parameters that appear to be important during measurements (for example, cleaning the tiles after measuring).

Phase III: Conclusions (1 h)

The analysis of the results is conducted by students in new groups. Each student in the group should have results for different layout of half-cells. Groups work independently while preparing the report. The report should include:

a) Analysis of trends in the obtained results.
b) Graphic presentation of the results.
c) The answer to the selected research question.

d) Theoretically calculated values of the electric potential of the cell using the values of standard potentials and Nernst's equation.
e) Estimation of measurement error and its source.

In the case that students analyze the effects of various factors on the voltage of the cell, on the basis of their reports they may prepare a summary presentation. The obtained results should be referenced to the Nernst formula.

Phase IV: Verification of the obtained knowledge and skills

I. Use of Lawson type multiple choice questions

Sample questions:

Q1. Electrode formed with Cu plate immersed in a solution of Cu^{2+} having a concentration of 0.1 mol · dm^{-3} have been connected with electrode formed with Cu plate immersed in a solution of Cu^{2+} having a concentration of 0.1 mol · dm^{-3}. The circuit was closed with salt bridge and voltage was measured. It was observed:

a) The difference of potentials, voltage > 0 V,
b) No difference of potentials, voltage = 0 V,
c) The difference of potentials, voltage < 0 V,

because:

a) to generate the voltage connection of two different half-cells is necessary.
b) both $Cu|Cu^{2+}$ half-cells have an equal potential.
c) the value of the half-cell potential depends on the metal ions concentration. In accordance with the adopted conventions generated voltage should be positive.
d) the value of the half-cell potential depends on the metal ions concentration. A negative value of charge results from the direction of electrons movement.

Q2. If the standard potentials of all electrodes had been related to $Li|Li^{+}$ electrode, instead of the standard hydrogen electrode, for Daniell's cell it would be observed:

a) The difference of potentials, voltage > 0 V,
b) No difference of potentials, voltage = 0 V,
c) The difference of potentials, voltage < 0 V,

because:

a) cell would work normally, but the change of the reference electrode would give to all electrodes potentials negative values.
b) cell would work normally, and thanks to the adopted conventions the value of potential difference would be expressed with positive number.
c) there would be change of half-cells functions, anode would become cathode, and vice versa.
d) both Cu and Zn would have a higher value of the standard potential than the Li, therefore, such a cell couldn't work.

Q3. The student has planned a study of impact of temperature on the voltage of a cell. For this purpose he made a cell of a Fe plate immersed in a solution of Fe^{2+} 1 mol·dm^{-3} and plate of Pb immersed in a solution of Pb^{2+} 1 mol·dm^{-3}. He decided to heat the half-cell built of iron by 50^{o}C, recording the value of voltage and temperature. He should observe:

a) Increase of the voltage value,
b) Decrease of the voltage value,
c) No changes of the voltage value,

because:

a) the anode was heated.
b) the cathode was heated.
c) the temperature has no effect on the voltage of the cell.
d) the temperature has no effect on the voltage of the cell built of half-cells in which the ions concentration is 1 mol · dm^{-3} .

Q4. The student has planned a study of influence of ions concentration on the voltage of the cell. For this purpose he decided to use two half-cells:

1. Sn plate immersed in a solution of Sn^{2+},
2. Pb plate immersed in a solution of Pb^{2+}.

He planned to build a series of cells using Sn^{2+} and Fe^{2+} solutions with concentrations:

	The concentration of Sn^{2+} mol·dm^{-3}	The concentration of Fe^{2+} mol·dm^{-3}
Cell 1	0.1	0.1
Cell 2	0.01	0.01
Cell 3	0.001	0.001

Measuring the voltage of the subsequent cells, he should observe:

a) Increase of the voltage value
b) Decrease of the voltage value
c) No changes of the voltage value

because:

a) ions concentration has no effect on the voltage value of the cells if it is built of half-cells in which the concentration of the ions have the same value.
b) ions concentration has no effect on the voltage value of the cell.
c) dilution of solutions reduces the value of the half-cells potentials.
d) Dilution of solutions increases the value of the half-cells potentials.

II. Open task question can be used

Example:

Analyze the problem: *Can voltage be generated by a connection of two* Cu|*Cu*$^{2+}$ *half-sells?* Consider what parameters could have an impact on such arrangement. Select a parameter which could impact significantly on the layout, and then plan an investigation in which this problem can be solved. Your work should include:

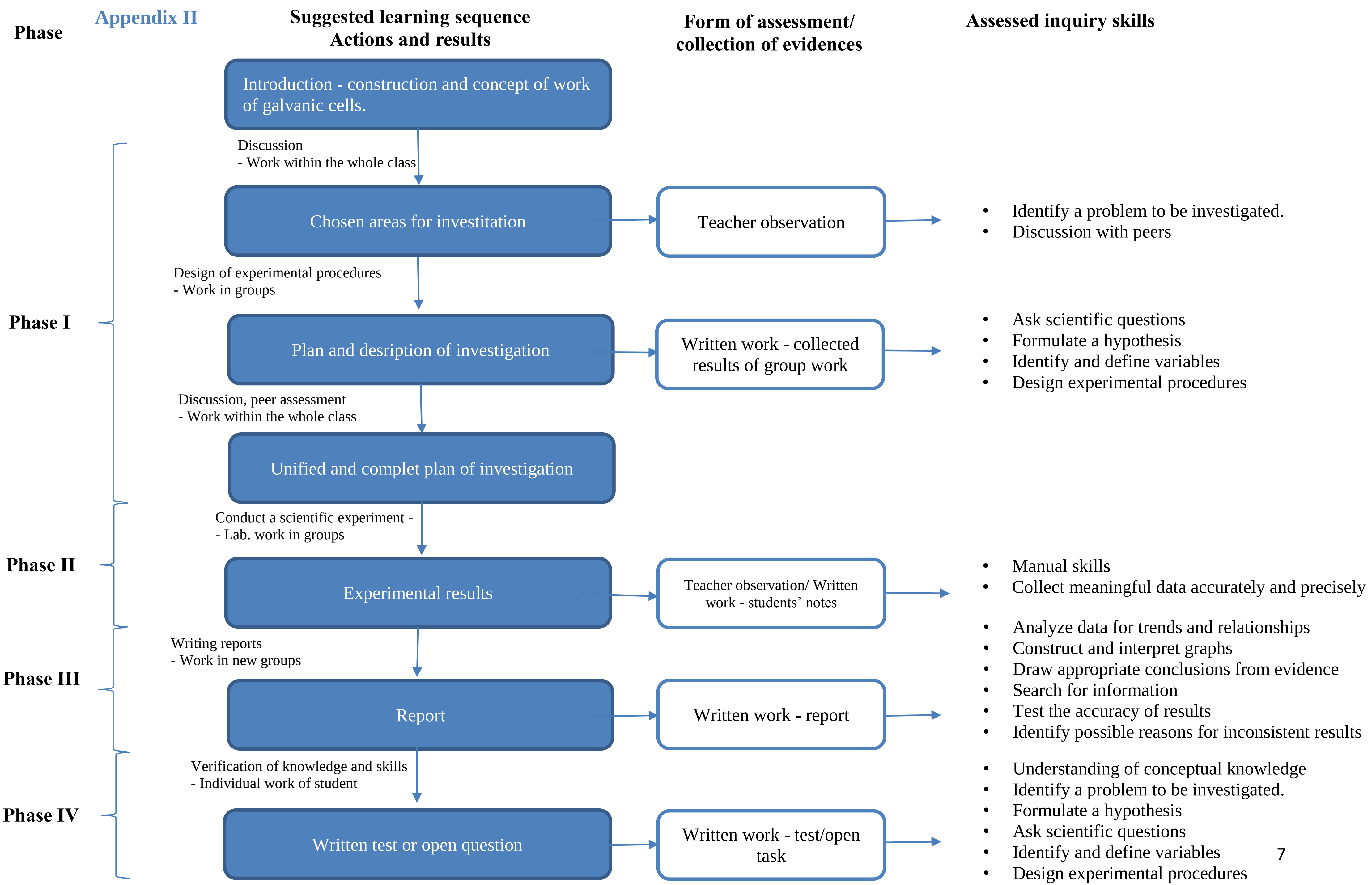
a) Research question.
b) The hypothesis.
c) A list of variables.
d) Scheme of the test.
e) The action plan with a detailed description.

Appendix I. Assessment opportunities

With reference to the assessment table Fradd & all (2001) the teacher has the ability to assess the following elements of the exercise on the basis of observation and on written work.

Phase	Assessed inquiry skills	Form of assessment/ collection of evidences
Phase I: Planning	Identify a problem to be investigated.	Teacher observation
	Discussion with peers	Teacher observation
	Ask scientific questions	Teacher observation/Written evidence - collected results of work in groups
	Formulate a hypothesis	Written evidence - collected results of work in groups
	Identify and define variables	Written work - collected results of work in groups
	Design experimental procedures to test the prediction.	Written work - collected results of work in groups
Phase II: Conduct an experiment	Manual skills	Teacher observation
	Collect meaningful data, organize, and analyze data accurately and precisely	Teacher observation/ Written work - students' notes
Phase III: Conclusions	Analyze data for trends and relationships	Written work - report
	Construct and interpret graphs	
	Draw appropriate conclusions from evidence	
	Search for information	
	Apply statistical methods to test the accuracy of results	
	Identify possible reasons for inconsistent results	
Phase IV: Verification of the obtained knowledge and skills	Understanding of conceptual knowledge	Written work-test/open task
	Identify a problem to be investigated.	Written work - open task
	Using induction, formulate a hypothesis or model incorporating logic and evidence.	Written work - open task
	Ask scientific questions	Written work - open task
	The definition of variables	Written work - open task
	Design experimental procedures to test the prediction.	Written work - test/ open task

Appendix II


Phase
Suggested learning sequence
Actions and results
Form of assessment/
collection of evidences
Assessed inquiry skills
Introduction - construction and concept of work of galvanic cells.
Discussion
- Work within the whole class
Chosen areas for investitation
Teacher observation
Identify a problem to be investigated.
Discussion with peers
Design of experimental procedures
- Work in groups
Phase I
Plan and desription of investigation
Written work - collected results of group work
Ask scientific questions
Formulate a hypothesis
Identify and define variables
Design experimental procedures
Discussion, peer assessment
- Work within the whole class
Unified and complet plan of investigation
Conduct a scientific experiment -
- Lab. work in groups
Phase II
Experimental results
Teacher observation/ Written work - students' notes
Manual skills
Collect meaningful data accurately and precisely
Writing reports
- Work in new groups
Phase III
Report
Written work - report
Analyze data for trends and relationships
Construct and interpret graphs
Draw appropriate conclusions from evidence
Search for information
Test the accuracy of results
Identify possible reasons for inconsistent results
Verification of knowledge and skills
- Individual work of student
Phase IV
Written test or open question
Written work - test/open task
Understanding of conceptual knowledge
Identify a problem to be investigated.
Formulate a hypothesis
Ask scientific questions
Identify and define variables
Design experimental procedures

Appendix III – Content knowledge

Galvanic Cell is a system, in which spontaneous chemical reactions release energy in the form of an electric current. Cell is made of two half-cells and half-cell is a metal plate immersed in the solution of its ions. Between the connected half-cell potential difference occurs, which can be measured by voltmeter. For this purpose the metal plates are connected to the voltmeter with cables, and the circuit must be closed by so-called salt bridge. Salt bridge not only closes the circuit, but also ensure the possibility of ions movement between the half-cells, which is necessary for the preservation of an inert load of half-cells during the work. Salt bridge is usually made of glass U-pipe filled up with a saturated aqueous solution of potassium nitrate. The electrode at which oxidation process occurs is called the anode. It has a negative sign, as it accumulates electrons from the oxidation of metal. The electrode where reduction process is observed is called the cathode. Sign of the cathode is positive.

The most popular example of galvanic cell is the Daniell's cell. This cell consists of half-cell made up of zinc plate immersed in an aqueous solution of $ZnSO_4$ and half-cell, in which the copper plate is immersed in an aqueous solution of $CuSO_4$. Cathode in the Daniell's cell is the copper plate while the anode is zinc plate.

a) On the cathode copper reduction process occurs:

$$Cu^{2+} + 2\,e \rightarrow Cu$$

While on the anode oxidation process of zinc:

$$Zn \rightarrow Zn^{2+} + 2\,e$$

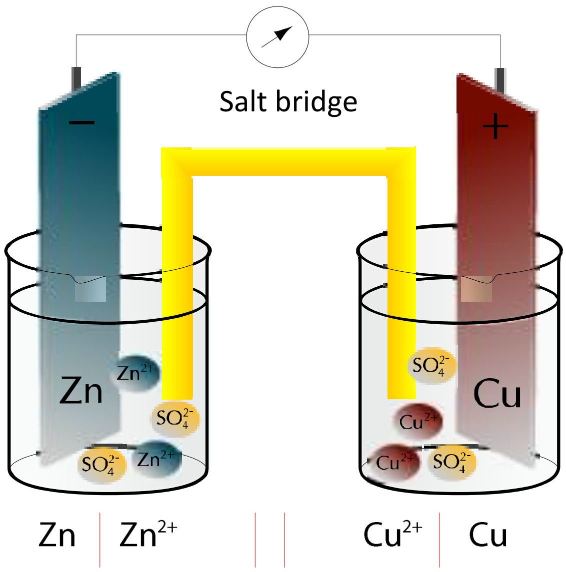
b) The total process in Daniell's cell:

$$Cu^{2+} + Zn \rightarrow Cu + Zn^{2+}$$

c) Electricity in the cell flows from the copper cathode to zinc anode, while the electrons from the zinc anode to copper cathode.

d) Scheme of the cell:

$$(-)\ Zn\,|\,Zn^{2+}\,\|\,Cu^{2+}\,|\,Cu\ (+)$$



The electric potential of a cell is defined as the difference of the potentials between the electrodes of inoperative cell:

$$\Delta V = E_{cathode} - E_{anode}$$

A multiplicity of processes related to the transfer of charge between the different phases makes the potential of a single half-cell value not directly measurable. For that purpose potential of the individual half-cell is determined in relation to the model half-cell - standard hydrogen electrode.

Standard hydrogen electrode is a platinum plate, immersed in a solution containing hydrogen cations H^+ with the concentration of 1 mol · dm^{-3} and rinsed by the hydrogen gas H_2 at a pressure of 100 kPa. Its potential equals 0 V, regardless of the temperature. Hydrogen half-cell scheme takes the form:

$$Pt \mid H_2 \mid H^+$$

To determine the standard potential for examined half-cell, it is needed to build a cell using the standard hydrogen half-cell and tested one. Cell should work in standard conditions, including the concentration of metal ions = 1 mol · dm^{-3}.

Knowing the values of standard potentials of the half-cells, we are able to determine the standard potential for each cell.

Nernst Equation allows you to set the value of the potential of the half-cell working in non-standard conditions:

$$E_{oxy/red} = E^0{}_{oxy/red} + \frac{RT}{zF} \ln \frac{C_{oxy}}{C_{red}}$$

or in a simplified form for temperature 25 ^oC

$$E_{oxy/red} = E^0{}_{oxy/red} + \frac{0{,}059\ V}{z} \log \frac{C_{oxy}}{C_{red}}$$

R - gas constant 8,31 J · mol^{-1}· K^{-1}; T - the temperature in Kelvin; z - the number of electrons varying oxygenated form of reduced form (stoichiometric coefficient for electrons in the half-equation); F - Faraday constant 96500 C · mol^{-1};
C_{oxy} - the concentration of the oxidized form; C_{red} - concentration of reduced form; $E^o{}_{oxy/red}$ - standard potential of the half-cell.