

МІНІСТЕРСТВО ОСВІТИ І НАУКИ, МОЛОДІ ТА СПОРТУ УКРАЇНИ
НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ УКРАЇНИ
«КІЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ»

**АНГЛІЙСЬКА МОВА
ПРОФЕСІЙНОГО СПРЯМУВАННЯ**

**МЕТОДИЧНІ ВКАЗІВКИ ДО ПРАКТИЧНИХ ЗАНЯТЬ СТУДЕНТІВ
ІІІ КУРСУ ХІМІКО-ТЕХНОЛОГІЧНОГО ФАКУЛЬТЕТУ
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ПЕРЕДМОВА

Методичні вказівки розроблені для студентів III курсу хіміко-технологічного факультету спеціальності «Технічна електрохімія» відповідно до навчальної програми як додатковий матеріал до основного підручника Н.О. Давидова, І.В. Нікітченко «Англійська мова для природничих наук», який передбачає формування і розвиток вмінь та навичок студентів працювати з іншомовною літературою за фахом, збагачення словникового запасу та оволодіння навичками професійно-орієнтованого спілкування.

Методичні вказівки містять сучасні автентичні професійно-орієнтовані матеріали з електрохімії, оброблені та адаптовані для студентів хіміко-технологічного факультету.

Вказівки складаються з 8 розділів, в яких розроблені наступні теми: «Chemistry and electricity», «Redox in electrochemistry», «Chemistry of voltaic cells», «Electrochemical cells. Cell description conventions», «Transport of charge within the cell», «Electroneutrality», «Potential differences at interfaces» і «Electrodes and electrode reactions». Кожний розділ має єдину внутрішню структуру:

1. Фонетичні вправи, спрямовані на навчання студентів правильної вимови спеціальної тематичної лексики розділу.
2. Текст за фахом.
3. Система вправ (усних та письмових), спрямованих на перевірку розуміння тексту, закріплення активної тематичної лексики, граматики, розвиток навичок усного та письмового перекладу, комунікативних навичок та закріплення мовного матеріалу.
4. Завдання для остаточного обговорення теми.

Методичні вказівки забезпечують широкі можливості аудиторної і самостійної роботи.

UNIT 1. ELECTROCHEMISTRY

LEAD-IN

1. You are going to read a text about major discoveries that led to the foundation of electrochemistry as a science. Before you read discuss the following:

1. What is the connection between chemistry and electricity?
2. What is electrochemistry? What does it study?
3. What scientists made important contributions to electrochemistry? What were their discoveries?
4. What are the applications of modern electrochemistry?

2. Practice the pronunciation of the following words:

applied voltage [ə'plaɪd 'vəultɪdʒ]

electricity [,ɪlek'trɪsətɪ], [e,ɪk'-]

electrified atoms [ɪ'lektrɪfaɪd 'ætəmz]

electric current [ɪ'lektrɪk 'kʌr(ə)nt], əmər. [kɜ:r(ə)nt]

to decompose a compound[tə ,di:kəm'pəuz ə 'kɒmpaʊnd]

moistened paper ['mɔɪs(ə)nd 'peɪpə]

primitive battery ['prɪmɪtɪv 'bætəri]

sodium hydroxide melt ['səudiəm haɪ'drəksaɪd 'melt]

source of bonding forces ['sɔ:s əv 'bɒndɪŋ 'fɔ:sɪz]

electrochemical power source [ɪ'lektrəu'kemɪk(ə)l 'paʊə 'sɔ:s]

sacrificial anode [,sækri'fiʃ(ə)l 'ænəud]

phenomenon [fi'nəmɪnən]

phenomena [fi'nəmɪnə]

to overpower the attraction [tu ,əuvə'paʊə ðɪ ə'trækʃ(ə)n]

3. Match discoveries with the names of scientists:

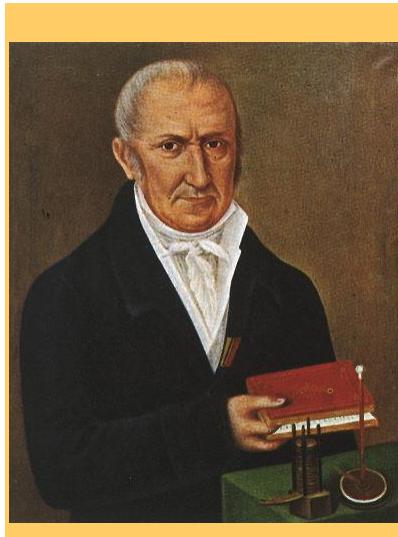
	Scientists		Discoveries
1.	William Gilbert (1544-1603)	A	effectively demonstrated the first electrochemical battery. His invention formed the basis of modern batteries and other phenomena including corrosion and sacrificial anodes.
2.	Luigi Galvani (1737-1798)	B	found that the battery's terminals dipped in water generated hydrogen and oxygen; discovered electrolysis or chemical reaction driven by electric current.
3.	Alessandro Volta (1745-1827)	C	known as the “father of magnetism” for his work on magnets, was among the first to experiment with electricity. He devised methods to produce as well as strengthen magnets.
4.	William Nicholson and Anthony Carlisle	D	used electrolysis to isolate metals such as sodium, potassium, calcium, magnesium, and lithium; concluded that electricity induced chemical action and that chemical combination occurred between oppositely charged substances.
5.	Jacob Berzelius (1779-1848)	E	formulated the electron pair theory.
6.	Humphrey Davy (1778-1829)	F	proposed that animal tissue contained an unknown vital force (called it “animal electricity”), which activated nerves and muscles when touched with metal probes.
7	Michael Faraday (1791-1867)	G	proposed that all atoms are electrified, hydrogen and the metals being positive, the nonmetals negative.
8	G. N. Lewis	H	discovered the laws of electrolysis and set the foundations for the classical field theory of electromagnetic behaviour.

READING

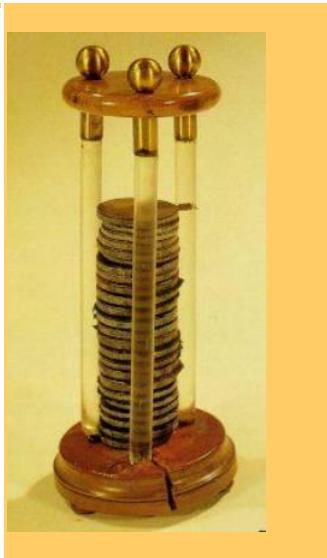
4. Look through the passage, divide it into two logical parts and choose suitable titles for them out of the given ones:

- | | |
|-----------------------------------|------------------------------------|
| 1. The Scope of Electrochemistry | 4. The History of Electrochemistry |
| 2. The Nature of Electrochemistry | 5. Chemistry and Electricity |
| 3. Modern Electrochemistry | |

The connection between chemistry and electricity is a very old one, going back to Alessandro Volta's discovery, in 1793, that electricity could be produced by placing two **dissimilar** metals on opposite sides of a moistened paper.



"I have the pleasure of communicating to you, Sir, and through you to the Royal Society, some striking results at which I have arrived in pursuing my experiments on the electricity excited by the simple mutual contact of metals of different sorts..."

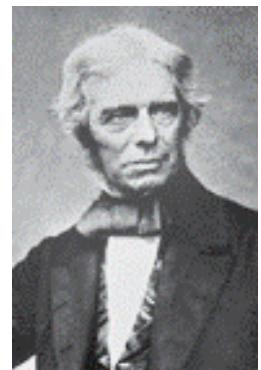


In 1800, William Nicholson and Anthony Carlisle, using Volta's primitive battery as a source, showed that an electric current could decompose water into oxygen and hydrogen. This was surely one of the most significant experiments in the history of chemistry, for it implied that the atoms of hydrogen and oxygen were associated with positive and negative electric charges, which must be the source of bonding forces between them.

By 1812, the Swedish chemist Jacob Berzelius could propose that all atoms are electrified, hydrogen and the metals being positive, the nonmetals negative. In electrolysis, the applied voltage was thought to overpower the attraction between these opposite charges, pulling the electrified atoms apart in the form of ions (named by Berzelius from the Greek for

“travelers”). It would be almost exactly a hundred years later before the shared electron pair theory of G.N. Lewis could offer a significant improvement on this view of chemical bonding.

Meanwhile the use of electricity as a means of bringing about chemical change continued to play a central role in the development of chemistry. Humphrey Davy prepared the first **elemental** sodium by electrolysis of a sodium hydroxide melt. It was left to Davy's former assistant, Michael Faraday, to show that there is a direct relation between the amount of electric charge passed through the solution and the **quantity** of electrolysis products. James Clerk Maxwell immediately saw this as **evidence** for the “molecule of electricity”, but the world would not be receptive to the concept of the electron until the end of the century.

			
Alessandro Volta	Humphrey Davy	Jacob Berzelius	Michael Faraday

Today, electrochemistry is a rigorous science concerned with the quantitative relations among the chemical, surface, and electrical properties of systems. Electrochemistry has strong links to many other fields of science. Electrochemical concepts proved particularly fruitful for studying and interpreting a number of very important biological processes.

Modern electrochemistry has vast applications. Electrochemical processes form the basis of large-scale chemical and metallurgical production of a number of materials. Electrochemical phenomena are responsible for metallic corrosion, which causes untold losses in the economy. Modern electrochemical power sources (primary and secondary batteries) are used in many fields of engineering, and their production figures are measured in billions of units. Other electrochemical processes and devices are also widely used.

LANGUAGE DEVELOPMENT

5. Match the highlighted words in the text with their synonyms below.

- | | |
|-------------------------|-------------------------|
| 1. different | 5. put forward/suggest |
| 2. the amount or number | 6. used |
| 3. connected | 7. suggested |
| 4. primary or basic | 8. facts or indications |

6. Match the words with their definitions.

1	decompose	A	energy stored chemically for conversion into electricity
2	elemental	B	an electromotive force or potential difference expressed in volts
3	electric current	C	break down (a chemical compound) into its component elements or simpler constituents
4	(applied) voltage	D	a mutual attraction between two atoms resulting from a redistribution of their outer electrons
5	electric charge	E	an atom or molecule with a net electric charge due to the loss or gain of one or more electrons
6	chemical bond	F	a flow of electricity which results from the ordered directional movement of electrically charged particles
7	ion	G	consisting of a single chemical element

7. Translate sentences into Ukrainian. Pay special attention to the words in italics.

1. Electricity could be produced *by placing* two dissimilar metals on opposite sides of a moistened paper.

2. Humphrey Davy prepared the first elemental sodium *by electrolysis* of a sodium hydroxide melt.
3. In electrolysis, the applied voltage *was thought to overpower* the attraction between these opposite charges, *pulling* the electrified atoms *apart* in the form of ions.
4. There is a direct relation between the amount of electric charge *passed through* the solution and the quantity of electrolysis products.

8. Complete this table to make word families. Use a dictionary to help you.

Translate the words and their derivatives.

<i>Verb</i>	<i>Adjective</i>	<i>Noun</i>
immerse – занурювати	immersible - занурюваний, immersed - занурений	immersion – занурення
Decompose		
Apply		
Electrify		
Attract		

9. Fill in the correct word(s) from the list below. Use the word(s) only once. Find Ukrainian equivalents to the following English word expressions.

to bring about, to produce, to decompose, to overpower, applied, means, forces.

1. water into oxygen and hydrogen
2. the attraction between the opposite charges
3. to be the source of the bonding
4. the chemical change
5. to be a of bringing about chemical change

6. electricity

7. voltage

10. Fill in the gaps using *for, into, on, to, with*. Then choose any three of the completed phrases and make sentences to show their meaning.

1. to decompose sth sth

2. to be associated sth/sb

3. improvement sth

4. evidence sth

5. to be receptive sth

11. Find English equivalents to the following Ukrainian word expressions.

1. долати силу тяжіння між протилежними зарядами

2. прикладена напруга

3. електричний струм

4. визначати наявність сил (хімічного) зв'язку

5. розкладати воду на кисень і водень

6. користуючись примітивним акумулятором Вольта як джерелом електроенергії

SPEAKING AND WRITING

12. In pairs talk about famous scientists and their contributions to electrochemistry.

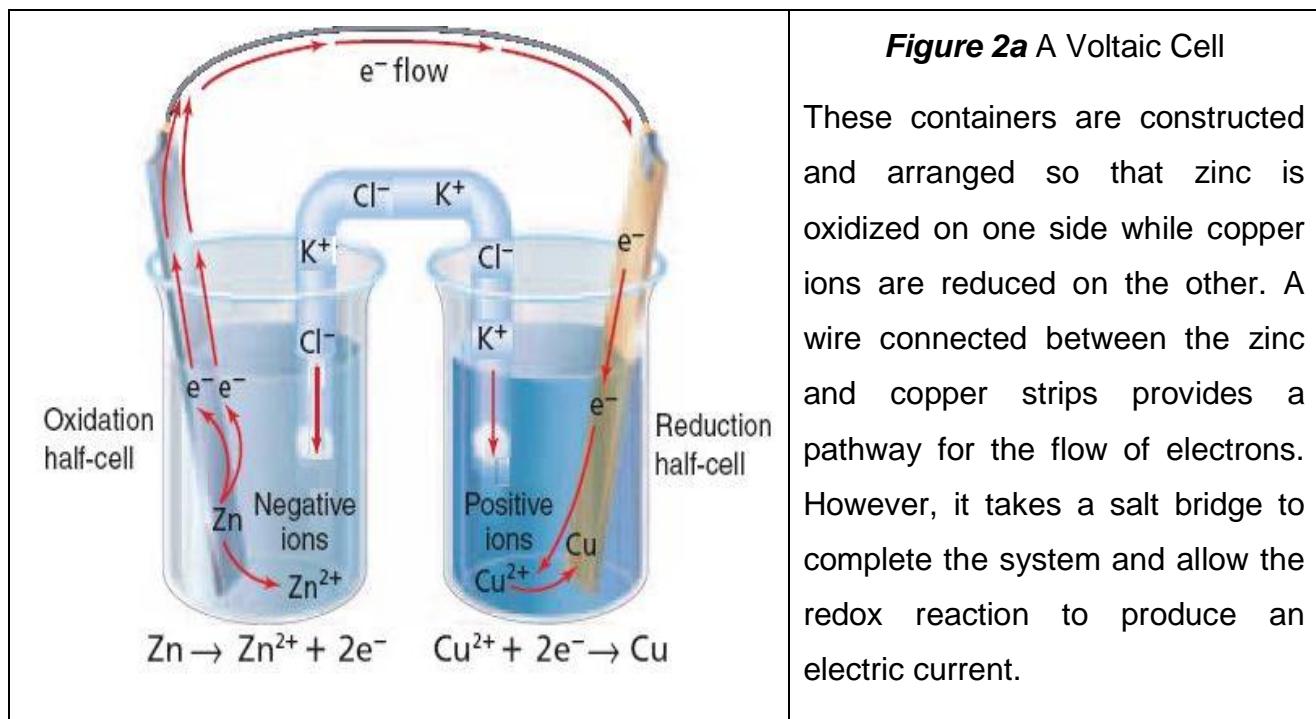
13. Write down the summary to the text “Chemistry and electricity”.

UNIT 2. REDOX IN ELECTROCHEMISTRY

LEAD-IN

1. You will read a text about redox reactions in electrochemistry. Before you read discuss the following:

1. What is the main characteristic of oxidation-reduction reactions?
2. What do all redox reactions involve? (a transfer of electrons)
3. In terms of electrons, what happens when an atom is oxidized? When an atom is reduced?
4. Try to describe **Figure 2a**.



2. Practice the pronunciation of the following words:

- oxidized species ['oksidaɪzd 'spi:ʃi:z]
- net ionic equation ['net aɪ'ɒnik ɪ'kweɪʒən]
- to donate electrons [tə dəʊ'nɛɪt ɪ'lektrɒnz]

- electron transfer [ɪ'lektrɒn 'trænsfɜː]
- to transfer electrons [tə træns 'fɜː ɪ'lektrɒnz]
- to prohibit a reaction [tə prə'hɪbit ə rɪ'ækʃ(ə)n]
- conducting wire [cən'dʌktɪŋ 'waɪə], **амер.** ['waɪə]
- zinc sulphate ['zɪŋk 'sʌlfet]
- beaker ['bi:kə]
- to flow through [tə 'fləu 'θruː]
- electric current [ɪ'lektrɪk 'kʌrɪ(ə)nt], **амер.** ['kɜːrɪ(ə)nt]
- to cause a reaction [tə 'kɔ:z ə rɪ'ækʃən]
- redox occurs ['rɪdoks ə'ke:z]

READING

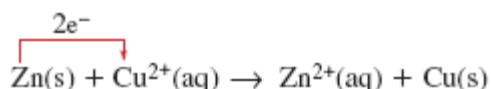
3. Read this article and decide if the statements (1-5) are true (T) or false (F), according to the text.

1. The species that is oxidized in a redox reaction is the reducing agent and loses electrons. The species that is reduced is the oxidizing agent and gains electrons.
2. In a voltaic cell, the oxidation and reduction half reactions of a redox reaction are separated and ions flow through a salt-bridge conductor.
3. A salt bridge serves as a pathway for electrons to flow from the oxidation half-reaction to the reduction half-reaction.
4. A metal wire is a pathway constructed to allow the passage of positive and negative ions from the oxidation half-reaction to the reduction half-reaction.
5. The flow of electrons through the wire and the flow of ions through the salt bridge generate the electric current.

Redox in Electrochemistry

All **redox reactions** involve a **transfer** of electrons from the **species** that is oxidized to the species that is reduced. In the simple redox reaction zinc atoms are oxidized to form Zn^{2+} ions. The two electrons donated from each zinc atom are accepted by a Cu^{2+} ion, which

changes to an atom of copper metal. The following net ionic equation illustrates the electron transfer that occurs.



Two half-reactions make up this **redox process**:



What do you think would happen if you separated the oxidation half-reaction from the reduction half-reaction? Can redox occur? Consider **Figure 2a** in which a zinc strip is immersed in a solution of zinc sulfate and a copper strip is immersed in a solution of copper (II) sulfate. Two problems prohibit a redox reaction in this situation. First, with this setup there is no way for zinc atoms to transfer electrons to copper (II) ions. This problem can be solved by connecting a metal wire between the zinc and copper strips, as shown in **Figure 2b**. The wire serves as a pathway for electrons to flow from the zinc strip to the copper strip.

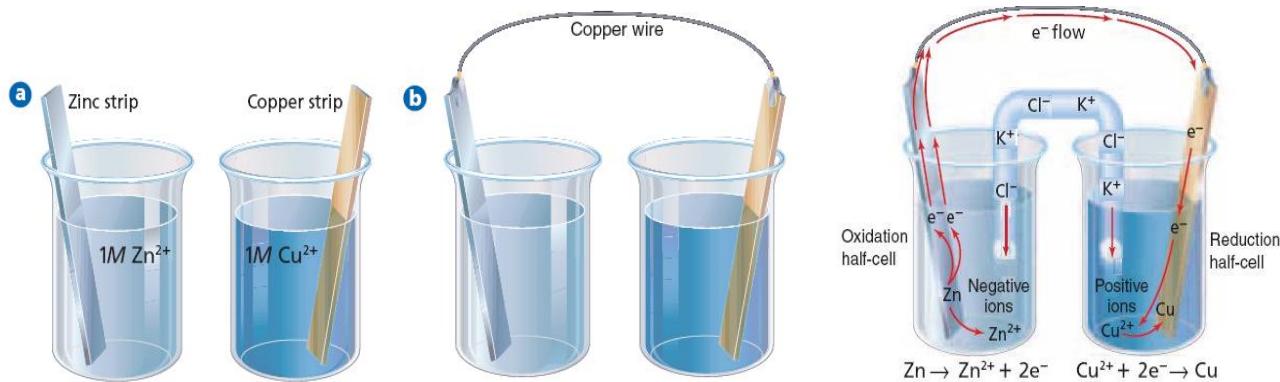


Figure 2b

Even with the conducting wire, another problem exists that prohibits the redox reaction. A positive charge builds up in one solution and a negative charge builds up in the other. The buildup of positive zinc ions on the left prohibits the oxidation of zinc atoms. On the other side, the buildup of negative ions prohibits the reduction of copper ions. To solve this problem a salt bridge must be built into the system. A salt bridge is a pathway constructed to allow the passage of ions from one side to another, as shown in **Figure 2b**. A salt bridge consists of a

tube containing a conducting solution of a soluble salt, such as KCl, held in place by an agar gel or other form of plug. The ions can move through the plug but the solutions in the two beakers cannot mix.

When the metal wire and the salt bridge are in place, electrons flow through the wire from the oxidation half-reaction to the reduction half-reaction while positive and negative ions move through the salt bridge. A flow of charged particles, such as electrons, is called an electric current. The flow of electrons through the wire and the flow of ions through the salt bridge make up the electric current. The energy of the flowing electrons can be put to use in lighting a bulb or running an electric motor.

The completed device shown in **Figure 2a** is an *electrochemical cell*. An electrochemical cell is an apparatus that uses a redox reaction to produce electrical energy or uses electrical energy to cause a chemical reaction. A *voltaic cell* is a type of electrochemical cell that converts chemical energy to electrical energy by a spontaneous redox reaction. **Figure 2c** shows a version of the original voltaic cell as devised by its inventor Alessandro Volta.

 A black and white portrait of Alessandro Volta, an Italian physicist, standing in a room. He is wearing a dark coat over a white cravat and a white waistcoat. To his right, there is a table with various scientific instruments, including a tall glass jar and some smaller containers.	<p>Figure 2c</p> <p>The voltaic cell is named for Alessandro Volta (1745–1827), the Italian physicist who is credited with its invention in 1800.</p>
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VOCABULARY PRACTICE

4. Match the highlighted words in the text with their synonyms.

- 1) generate/produce
- 2) prevent from happening/make impossible
- 3) dipped
- 4) happen

- 5) route/road
- 6) transmission/transport
- 7) increase/accumulation
- 8) a very small piece of something/particle

5. Translate sentences into Ukrainian. Pay special attention to the words in italics.

1. A positive charge *builds up* in one solution and a negative charge *builds up* in the other.
2. The *buildup* of positive zinc ions on the left prohibits the oxidation of zinc atoms.
3. With this *setup* there is no way for zinc atoms to transfer electrons to copper ions.
4. All the necessary equipment was *set up* yesterday.
5. Electrons *flow* through the wire from the oxidation half-reaction to the reduction half-reaction.
6. A *flow* of charged particles, such as electrons, is called an electric current.

6. Fill in the correct word(s) from the list below. Use the word(s) only once. Find Ukrainian equivalents to the following English word expressions.

light, cause, convert, builds up, immersed, gained/lost, solved, donated, constructed

- a) electrons from each zinc atom
- b) a zinc strip in a solution
- c) the problem to be
- d) electrons
- e) a pathway to allow the passage of ions
- f) a positive charge in one solution
- g) to a chemical reaction
- h) to chemical energy to electrical energy
- i) to a bulb

7. Find English equivalents to the following Ukrainian word expressions.

1. накопичувати позитивні іони цинку
2. уповільнювати хід окисно-відновної реакції
3. призупиняти окислення іонів міді
4. перенесення/переміщення електронів
5. потік заряджених частинок
6. цинкова пластинка занурюється у розчин
7. відбувається окисно-відновна реакція
8. протікати крізь металевий дріт
9. генерувати електричний струм
10. викликати/спричиняти хімічну реакцію

8. Fill in the gaps with words formed from the words in capitals.

Electrochemistry

Electrochemistry is a branch of (0) **chemistry** dealing with chemical (1) that involve (2) current and potentials. Some chemical reactions that proceed (3) can generate electrical current, which can be used to do (4) work; while other chemical reaction can be forced to proceed by using electrical current. While all this may sound rather esoteric, many (5) devices based on these reactions, and many products made by these reactions are well-known, everyday household items.

(0) CHEMIST

(1) REACT

(2) ELECTRIC

(3) SPONTANIOUS

(4) USE

(5) PRACTICE

9. Match the words with their definitions.

1	net ionic equation	A	electricity that is put into a piece of electrical equipment such as a battery
2	charge	B	the glass object inside a lamp that produces light and has to be replaced regularly
3	electric current	C	a representation of a chemical reaction in a solution, where strong electrolytes are written as ions, showing only those components that are directly involved in the chemical change
4	wire	D	a blue-white metal that is used to make brass and to cover and protect objects made of iron
5	beaker	E	thin metal in the form of a thread, or a piece of this
6	chemical equation	F	a flow of electric charge through a conductor
7	light bulb	G	a soft reddish-brown metal that allows electricity and heat to pass through it easily, and is used to make electrical wires, water pipes etc
8	zinc	H	a glass cup with straight sides that is used in chemistry for measuring and heating liquids
9	copper	I	a pathway constructed to allow positive and negative ions to move from one solution to another
10	salt bridge	J	a representation of a chemical reaction showing the relative numbers of reactant and product molecules

SPEAKING AND WRITING

10. In groups discuss the following questions.

1. Under what conditions can a redox reaction be used to cause an electric current to flow through a wire?
2. What are the components of a voltaic cell?
3. What is the role of each component in the operation of the cell?
4. What is the function of a salt bridge in a voltaic cell?
5. What feature of an oxidation–reduction reaction allows it to be used to generate an electric current?
6. A salt bridge is essential to a voltaic cell for all of the following reasons EXCEPT
 - a) it allows ions to move from the solution of one cell to the other.
 - b) it causes electric current to flow between the two electrodes of a cell.
 - c) it relieves the buildup of positive charge on the anode side of the cell.
 - d) it allows electrons to move from the solution of one cell to the other.

11. Write five or seven sentences describing the redox process that take place in a voltaic cell and account for the direction of electron flow. Use the words *electron, positive ion, negative ion, metal wire, salt bridge, oxidation, reduction, half-reaction, electric current* in your sentences.

UNIT 3. CHEMISTRY OF VOLTAIC CELLS

LEAD-IN

1. You will read a text about voltaic cells. Before you read discuss the following:

1. What is a voltaic cell?
2. What are the parts of a voltaic cell?
3. What is the role of each part in the operation of the cell?
4. Are there any difference between an electrochemical cell and a voltaic cell?

2. Practice the pronunciation of the following words.

Voltaic cell [vɔl'teɪk sel]

Anode [ˈænəud]

Cathode [ˈkæθəud]

Voltage [ˈvəʊltɪdʒ]

Measure [ˈmeʒə]

Exist [ɪg'zɪst]

Occur spontaneously [ə'kɜː spɔn'teinjəslɪ]

Accept electrons [ək'sept ɪ'lektrɒnz]

Conduct electricity [kən'dʌkt ,ɪlæk'trɪsɪti]

READING

3. Read the text and match the headings (a-d) with the correct paragraphs (1-4).

- a) Spontaneity of the redox reaction. ()
- b) The rule of the golf ball. ()
- c) The arrangement of an electrochemical cell. ()
- d) The potential difference of an electrochemical cell. ()

Chemistry of Voltaic Cells

1. _____

An electrochemical cell consists of two parts, called half-cells, in which the separate oxidation and reduction reactions take place. Each half-cell contains an electrode, which is the object that conducts electrons to or from another substance, usually a solution of ions. In **Figure 2b (Unit 2)**, the beaker with the zinc electrode is where the oxidation part of the redox reaction takes place. The beaker with the copper electrode is where the reduction part of the reaction takes place. The reaction that takes place in each half-cell is the half-reaction, sometimes called half-cell reaction. The electrode where oxidation takes place is called the **anode** of the cell. The electrode where reduction takes place is called the **cathode** of the cell.

2. _____

In electrochemistry, electrical potential energy is a measure of the amount of current that can be generated from a voltaic cell to do work. Electric charge can flow between two points only when a difference in electrical potential energy exists between the two points. In an electrochemical cell, these two points are the two electrodes. The potential difference of a voltaic cell is an indication of the energy that is available to move electrons from the anode to the cathode.

3. _____

To better understand this concept, consider the analogy illustrated in **Figure 3**. A golf ball that lands on a hillside will roll downhill into a low spot because a difference in gravitational potential energy exists between the two points. The kinetic energy attained by a golf ball rolling down a hill is determined by the difference in height (potential energy) between the high point and the low point. Similarly, the energy of the electrons flowing from anode to cathode in a voltaic cell is determined by the difference in electrical potential between the two electrodes. In redox terms, the voltage of a cell is determined by the difference in the tendency of the electrode material to accept electrons.

4. _____

Thinking again of the golf ball analogy, the force of gravity causes the ball always to roll downhill to a lower energy state, not uphill to a higher energy state. In other words, the golf

ball rolling process occurs spontaneously only in the downhill direction. In the zinc–copper cell under standard conditions, copper (II) ions at the cathode accept electrons more readily than the zinc ions at the anode. In other words, the redox reaction occurs spontaneously only when the electrons flow from the zinc to the copper.

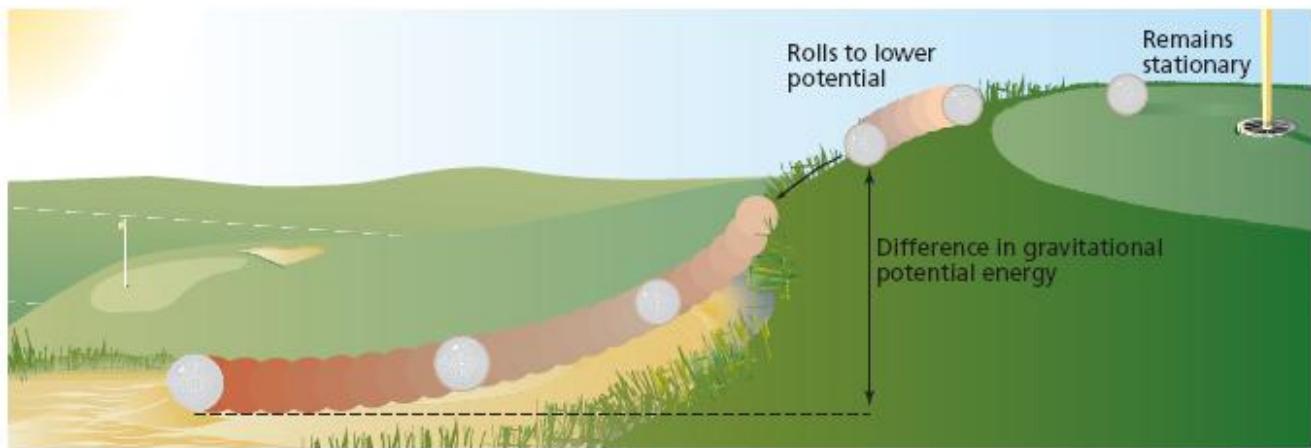


Figure 3 In this illustration of gravitational potential, we can say that the golf ball has potential energy relative to the bottom of the hill because there is a difference in the height position of the ball from the top of the hill to the bottom. Similarly, an electrochemical cell has potential energy to produce a current because there is a difference in the ability of the electrodes to move electrons from the anode to the cathode.

4. Read the text again and decide if the statements 1 - 6 are true (T) or false (F), according to the text.

1. In a voltaic cell, oxidation takes place at the cathode, and reduction takes place at the anode.
2. Voltaic cell converts chemical energy into electrical energy. It consists of two parts called half-cells.
3. The oxidation half-cell shows the number of electrons lost when a species is reduced.
4. The reduction half-cell shows the number of electrons lost when a species is reduced.
5. When two different metals, one in each half-cell, are used in the voltaic cell, a potential difference is produced.
6. Redox reaction always occurs spontaneously.

VOCABULARY PRACTICE

5. Match the highlighted words in the text with their synonyms.

- | | |
|--------------------------|-----------------|
| a) quickly and easily | e) take/receive |
| b) obtainable/accessible | f) happens |
| c) reached | g) defined |
| d) includes | |

6. Match the words with their definitions.

1	anode	A	in an electrochemical cell, the electrode where reduction takes place
2	cathode	B	one of two parts of an electrochemical cell in which the separate oxidation or reduction reaction occurs
3	half-reaction	C	electrical force measured in volts
4	half-cell	D	in an electrochemical cell, the electrode where oxidation takes place
5	voltage	E	one of two parts of a redox process, one presenting oxidation and the other reduction
6	energy	F	energy stored in a substance because of its composition; is released or absorbed as heat during chemical reactions or processes
7	potencial energy	G	the capacity to do work or produce heat
8	kinetic energy	H	a very small piece of matter with a negative electrical charge that moves around the nucleus of an atom
9	electron	I	energy resulting from the motion of an object; dependent on the mass of the object and the square of its velocity

7. Match the first part of the sentence (1-5) with the second part (a-e).

1. An electrochemical cell reaction like any oxidation-reduction reaction can be written ()
2. In the case of a cell, these half-reactions correspond... ()
3. Since the cell reaction is the sum of the half-cell reactions, it is convenient... ()
4. Unfortunately, there is no way of measuring a half-cell potential—we always need two half-cells... ()
5. By convention, the half-cell reaction, has been chosen ... ()
 - a) ...to think of dividing the cell potential into half-cell potentials.
 - b) ...as the sum of an oxidation half-reaction and a reduction half-reaction.
 - c) ...to the reactions at the two electrodes.
 - d) ...as the primary reference half-cell with standard potential taken to be $E^\circ = 0.000 \text{ V}$.
 - e) ...to make a cell, the potential of which is measurable.

8. Fill in the gaps using *of, through, to, from, between, in, under*. Then choose any three of the completed phrases and make sentences to show their meaning.

1. to consist sth; 2. to be due sth/sb; 3. convert sth sth; 4. to flow sth sth; 5. to move sth sth; 6. redox terms; 7. standard conditions; 8. other words.

9. Fill in the correct word(s) from the list below. Use the word(s) only once. Find Ukrainian equivalents to the following English word expressions.

Kinetic, voltage, conduct, accept, contain, amount, available

- | | |
|---|----------------------------------|
| 1. electrons to/from substance | 4. of a cell is determined |
| 2. energy attained by a golf ball | 5. electrons |
| 3. energy that is to move electrons | 6. the cathode |
| | 7. of electrical current |

10. Find English equivalents to the following Ukrainian word expressions.

- a) сила тяжіння
- b) окисно-відновна реакція протікає довільно
- c) за нормальних умов

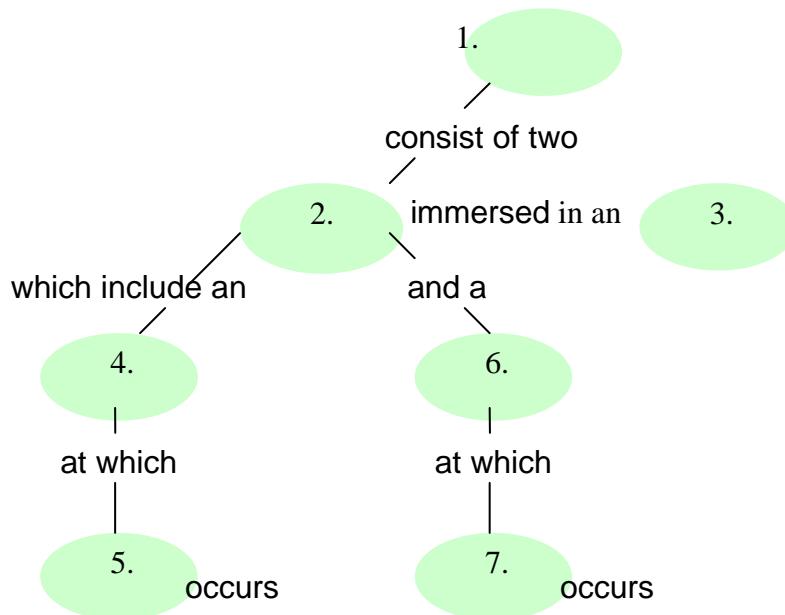
- d) гальванічний елемент
- e) досягнутий рівень енергії
- f) визначати (електричну) напругу елемента
- g) швидко і легко приймати електрони

SPEAKING AND WRITING

11. In groups discuss the following questions.

1. What are the parts of an voltaic cell?
2. What is the electrical potential energy in electrochemistry?
3. When does the redox reaction occur spontaneously?
4. Why do electrons flow from one electrode to the other in a voltaic cell?

12. Complete the concept map using the following terms: *reduction, electrodes, voltaic cells, anode, oxidation, cathode, electrolyte*.



13. Write two or three sentences describing the processes that take place in a voltaic cell and account for the direction of electron flow. Use the words *cathode, node, oxidation, reduction, and potential difference* in your sentences.

UNIT 4. ELECTROCHEMICAL CELLS. CELL DESCRIPTION

CONVENTIONS

LEAD-IN

1. You will read a text about electrochemical cells and an adopted special symbolic notation used to describe a cell. Before you read discuss the following:

- 1) Is it possible to control a redox reaction?
- 2) Can we measure the amount of electric charge that passes through the electrodes and the number of moles of reactants in the electrochemical cell? How?
- 3) Are there any agreements about describing the process in the galvanic cell?

2. Practice the pronunciation of the following words and expressions.

- Ammeter ['æmɪtə]
- Allow [ə'lau]
- Although [o:l'ðəu]
- Also ['o:lsəu]
- Nomenclature [nəu'menklətʃə]
- Reverse direction [rɪ've:s di'rekʃ(ə)n, dai-]
- Careful experiment ['keəfl ɪk'sperɪmənt]
- Measured in coulombs ['meʒəd in 'ku:lomz]
- Porous barrier ['po:rəs 'bærɪə]
- External circuit [ɪk'ste:nl 'sə:kɪt]
- Net equation ['net ɪ'kweɪʒ(ə)n]
- Chemical species ['kemɪkl 'spi:ʃi:z]
- Proceed to the right [prə'si:d tə ðə rait]
- Excess electrons ['ekses ɪ'lektrɒnz]
- Variable resistance ['veəriəbl ri'zist(ə)ns]

READING

3. Read this article and decide if the statements 1 - 4 are true (T) or false (F), according to the text.

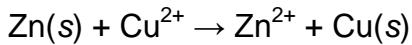
1. A typical electrochemistry cell consists of two compartments separated by a metallic conductor.
2. A porous barrier that separates two solutions prevents them from mixing and does not allow ions to diffuse through.
3. Redox reactions can be measured and controlled due to electrochemical cells.
4. The chemical species that undergo reduction are shown on the right side, and those that undergo oxidation are shown on the left.

Electrochemical cells. Cell description conventions

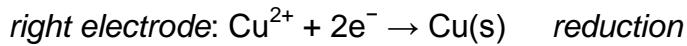
This arrangement is called a galvanic cell. A typical cell might consist of two pieces of metal, one zinc and the other copper, each immersed in a solution containing a dissolved salt of the corresponding metal. The two solutions are separated by a porous barrier that prevents them from rapidly mixing but allows ions to diffuse through.

If we simply left it at that, no significant amount of reaction would take place. However, if we connect the zinc and copper by means of a metallic conductor, the excess electrons that remain when Zn^{2+} ions go into solution in the left cell would be able to flow through the external circuit and into the right electrode, where they could be delivered to the Cu^{2+} ions which become “discharged”, that is, converted into Cu atoms at the surface of the copper electrode.

The net reaction is the same as before the oxidation of zinc by copper (II) ions:



but this time, the oxidation and reduction steps take place in separate locations:



Electrochemical cells allow measurement and control of a redox reaction. The reaction can be started and stopped by connecting or disconnecting the two electrodes. If we place a

variable resistance in the circuit, we can even control the rate of the net cell reaction by simply turning a knob. By connecting a battery or other source of current to the two electrodes, we can force the reaction to proceed in its non - spontaneous, or reverse direction.

By placing an ammeter in the external circuit, we can measure the amount of electric charge that passes through the electrodes, and thus the number of moles of reactants that get transformed into products in the cell reaction.

Electric charge ***q*** is measured in coulombs. The amount of charge carried by one mole of electrons is known as the ***faraday***, which we denote by ***F***. **Careful** experiments have determined that $1\text{ F} = 96467\text{ C}$. For most purposes, you can simply use 96,500 coulombs as the value of the faraday.

When we measure electric current, we are measuring the **rate** at which electric charge is transported through the circuit. A current of one ampere corresponds to the flow of one coulomb per second.

In order to make it easier to describe a given electrochemical cell, a special symbolic notation has been adopted. In this notation the cell of Fig. 3 would be

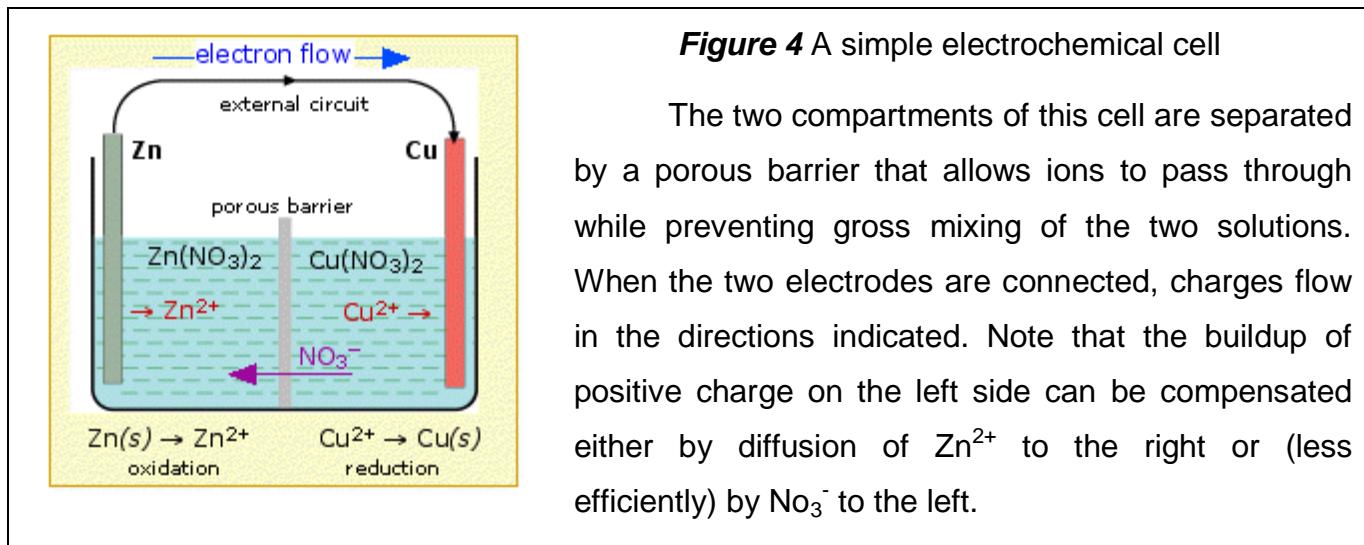


In this notation, the vertical bars indicate phase boundaries; the double vertical bar in the middle denotes the phase boundary between the two solutions. As a matter of convention, the chemical species that undergo reduction when the cell reaction **proceeds** to the right according to the net equation are shown on the right side, and those that undergo oxidation are shown on the left. Note carefully that this is entirely independent of the physical location of the two electrodes in the actual cell in **Figure 4**.

There are several other conventions relating to cell notation and **nomenclature** that you are expected to know:

- An electrode where the oxidation occurs is called the **anode** is where oxidation occurs, and the **cathode** is an electrode where the reduction occurs.
- Electric current flows from the cathode to the anode. Electrons flow from anode to cathode

- If electrons flow from the left electrode to the right electrode when the cell operates in its spontaneous direction, the potential of the right electrode will be higher than that of the left, and the cell potential will be positive.



VOCABULARY PRACTICE

4. Match the highlighted words in the text with their synonyms.

- 1) changeable
- 2) permit
- 3) having noticeable effects
- 4) speed
- 5) terminology
- 6) moves (in the particular direction)
- 7) thorough
- 8) with the use or help of

5. What do the following abbreviations mean? Decode them.

- | | | |
|----------|------|---------|
| 1) (s) | 3) c | 5) Q |
| 2) e^- | 4) F | 6) (aq) |

6. Match the first part of the sentence (1-5) with the second part (a-e).

1. A typical cell might consist of ...()
2. The two solutions are separated by ...()
3. The reaction can be started and stopped by ...()
4. If we place a variable resistance in the circuit, we can even control ...()
5. The amount of charge carried by ...()
 - a) connecting or disconnecting the two electrodes.
 - b) two pieces of metal, one zinc and the other copper, each immersed in a solution.
 - c) one mole of electrons is known as the faraday.
 - d) a porous barrier that prevents them from rapidly mixing but allows ions to diffuse through.
 - e) the rate of the net cell reaction.

7. Match the words with their definitions.

1	circuit	A	an apparatus that uses a redox reaction to produce electrical energy or uses electrical energy to cause a chemical reaction.
2	conductor	B	a type of electrochemical cell that converts chemical energy to electrical energy by a spontaneous redox reaction.
3	electrochemical cell	C	a substance, body, or system that conducts electricity, heat, etc
4	voltaic cell	D	a complete path through which an electric current can flow
5	resistance	E	unit of electric charge; the quantity of electricity transported in one second by a current of 1 ampere
6	ammeter	F	the opposition to a flow of electric current through a circuit component, medium, or substance.
7	coulomb	G	an instrument for measuring an electric current in amperes

8. Complete this table to make word families. Use a dictionary to help you.

Translate the words and their derivatives.

<i>Verb</i>	<i>Adjective</i>	<i>Noun</i>
immerse – занурювати	immersible - занурюваний, immersed - занурений	immersion – занурення
Measure		
Vary		
Differ		
Allow		

9. Fill in the correct word(s) from the list below. Use the word(s) only once. Find Ukrainian equivalents to the following English word expressions.

Reverse, careful, reaction, reduction, surface, variable, rapidly, rate, means, porous

1. to place a resistance in the circuit
2. be separated by a barrier
3. to prevent solutions from mixing
4. to connect the zinc and copper by of a metallic conductor
5. to control the of the net cell reaction
6. the reaction proceeds in its direction
7. at the of the copper electrode
8. to conduct experiments
9. the cell proceeds to the right
10. to undergo

10. Fill in the gaps using *through, into, from, in*. Then choose any three of the completed phrases and make sentences to show their meaning.

1. to proceed sth; 2. to pass sth; 3. to get transformed sth; 4. to diffuse sth; 5. to prevent sth sth; 6. to convert sth sth, 7. to flow

11. Find English equivalents to the following Ukrainian word expressions.

1. впливати на різницю потенціалів
2. розмістивши амперметр у зовнішньому колі
3. протікати крізь зовнішнє коло
4. примусити реакцію протікати в протилежному напрямку
5. дозволяти вимірювати параметри і контролювати хід реакції
6. умовні позначення

12. Fill in the gaps with words formed from the words in capitals.

The Electrochemical cell

An electrochemical cell is a device that produces an electric current from energy released by a **0) spontaneous** redox reaction. This kind of cell includes the Galvanic cell or Voltaic cell, named after Luigi Galvani and Alessandro Volta, both **1)** who conducted several experiments on chemical reactions and electric current during the late 18th century.

Electrochemical cells have two **2)** electrodes (the anode and the cathode). The anode is defined as the electrode where **3)** occurs and the cathode is the electrode where the **4)** takes place. Electrodes can be made from any **5)** conductive materials, such as metals, semiconductors, graphite, and even conductive polymers. In between these electrodes is the electrolyte, which contains ions that can freely move.

0) SPONTAIN

3) OXIDE

1) SCIENCE

4) REDUCE

2) CONDUCT

5) SUFFICIENT

SPEAKING AND WRITING

13. In groups discuss the following questions.

1. What is the function of the porous barrier in the cell?
2. What is the function of the metallic conductor?
3. How can we control the rate of the net cell reaction?
4. What conventions are used to describe the process in the electrochemical cell?
5. Identify the following information about each question. What element is oxidized?

Reduced? What is the oxidizing agent? Reducing agent?

- a) $2P + 3Cl_2 \rightarrow 2PCl_3$
- b) $C + H_2O \rightarrow CO + H_2$
6. How many electrons will be lost or gained in each of the following half-reactions?

Identify whether it is an oxidation or reduction.

- a) $Cr \rightarrow Cr^3$
- b) $O_2 \rightarrow O^{2-}$
- c) $Fe^{+2} \rightarrow Fe^{3+}$

14. Write down the summary to the text “Electrochemical cells. Cell description conventions”.

UNIT 5. TRANSPORT OF CHARGE WITHIN THE CELL

LEAD-IN

1. You will read a text about transport of charge within the cell. Before you read discuss the following:

1. What is an electrical cell?
2. What kinds of charges do you know?
3. What is the relation between
 - a) Charge and speed?
 - b) Radius and speed?
 - c) What do you know about transport of charge in the cell?

2. Practice the pronunciation of the following words.

- External circuit [ɪk'ste:nl 'sə:kɪt]
- Acquire a charge [ə'kwaɪə ə tʃa:dʒ]
- Require work [rɪ'kwaɪə wə:k]
- Counterion ['kauntə'aɪən]
- Alleviate [ə'li:vieɪt]
- Nitrate ions ['naɪtreɪt 'aɪənz]
- Minute amount [maɪ 'nju:t ə'maʊnt]
- Sustain the cell reaction [sə'steɪn ðə 'sel rɪ'ækʃ(ə)n]
- Precise measurement [pri'sais 'meʒəment]
- Porous membrane ['po:rəs 'membreɪn]
- Junction potential ['dʒʌŋkʃ(ə)n pə'tenʃ(ə)l]

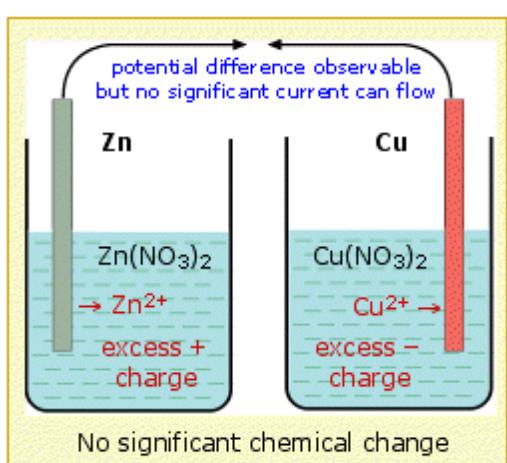
READING

3. Read this article and decide if the statements 1 - 5 are true (T) or false (F), according to the text.

1. A chemical reaction generates electric energy spontaneously in a galvanic cell.
2. In any electrochemical cell, the cathode is the electrode at which some species gains electrons.
3. The amount of charge carried by positive and negative ions depends on their relative mobilities.
4. The negative ions have higher mobilities and carry the larger fraction of charge.
5. In a voltaic cell, the salt bridge drives electrons from one half-cell to another.

Transport of charge within the cell

In order for the cell of **Figure 5** to operate, not only must there be an **external** electrical circuit between the two electrodes, but the two electrolytes (the solutions) must be in contact. The need for this can be understood by considering what happens to the two solutions as the cell reaction proceeds. Positive charge (in the form of Zn^{2+}) is added to the electrolyte in the left compartment, and removed (as Cu^{2+}) from the right side, causing the solution in contact with the zinc to **acquire** a net positive charge, while a net negative charge would build up in the solution on the copper side of the cell. These violations of electroneutrality would make it more difficult (require more work) to introduce additional Zn^{2+} ions into the positively charged electrolyte or for electrons to flow into right compartment where they are needed to reduce the



Cu^{2+} ions, thus effectively stopping the reaction after only a **minute** amount has taken place.

In order to **sustain** the cell reaction, the charge carried by the electrons through the external circuit must be accompanied by a compensating transport of ions between the two cells. This means that we must provide a path for ions to move directly from one cell to the other. This ionic transport involves not only the electroactive

species Cu^{2+} and Zn^{2+} , but also the counterions, which in this example are NO_3^- . Thus an excess of Cu^{2+} in the left compartment could be alleviated by the drift of these ions into the right side, or equally well by diffusion of nitrate ions to the left. More detailed studies reveal that both processes occur, and that the relative amounts of charge carried through the solution by positive and negative ions depends on their relative mobilities, which express the velocity with which the ions are able to make their way through the solution. Since negative ions tend to be larger than positive ions, the latter tend to have higher mobilities and carry the larger fraction of charge.

In the simplest cells, the barrier between the two solutions can be a porous membrane, but for precise measurements, a more complicated arrangement, known as a salt bridge, is used. The salt bridge consists of an intermediate compartment filled with a concentrated solution of KCl and fitted with porous barriers at each end. The purpose of the salt bridge is to minimize the natural potential difference, known as the junction potential, that develops (as mentioned in the previous section) when any two phases (such as the two solutions) are in contact. This potential difference would combine with the two half-cell potentials so as introduce a degree of uncertainty into any measurement of the cell potential. With the salt bridge, we have two liquid junction potentials instead of one, but they tend to cancel each other out.

VOCABULARY PRACTICE

4. Match the highlighted words in the text with their synonyms.

1. extremely small
2. speed
3. outer
4. a larger amount of sth than is allowed or needed
5. maintain
6. exact
7. obtain
8. show

5. Match the words with their definitions.

1	velocity	A	the driving force in a galvanic cell that pulls electrons from the reducing agent in one compartment to the oxidizing agent in the other
2	mobility	B	a smaller enclosed space inside something larger
3	compartment	C	the speed of something that is moving in a particular direction
4	cell potential	D	electricity that is put into a piece of electrical equipment such as a battery
5	charge	E	the ability to move easily

6. Match the words to make collocations.

- | | |
|-----------------|-----------------|
| 1. external | a) amount |
| 2. active | b) membrane |
| 3. relative | c) compartment |
| 4. porous | d) measurements |
| 5. minute | e) mobilities |
| 6. intermediate | f) species |
| 7. precise | g) circuit |

7. Fill in the correct word(s) from the list below. Use the word(s) only once. Find Ukrainian equivalents to the following English word expressions.

excess, porous, occur, concentrated, mobilities, species, reaction, accompanied, charge

1. to acquire a net positive
2. to sustain the cell
3. to be by the transport of ions
4. electroactive
5. to alleviate the ion
6. to reveal that both processes

7. to depend on relative
8. the barrier can be a membrane
9. intermediate compartment filled with a solution

8. Match the beginnings and the endings of the sentences.

1. The charge carried through the external circuit must be...(.)
 2. Natural potential difference is the junction potential that develops...()
 3. An excess of Cu²⁺ could be reduced...()
 4. Combination of the junction potential and the two half-cell potentials ...()
 5. The relative amount of charge carried through the solution by ions ...()
 6. The salt bridge consists of an intermediate compartment...()
 7. These violations of electroneutrality would require more work...()
- a) ...accompanied by a transport of ions between two cells.
b) ...filled with a concentrated solution of KCl.
c) ...for electrons to flow into the right compartment.
d) ...depends on their relative mobility.
e) ...by diffusion of nitrate ions.
f) ...when two solutions are in contact.
g) ...brings a degree of uncertainty into the measurement of the cell potential.

9. Find English equivalents to the following Ukrainian word expressions.

1. набувати сумарний позитивний заряд
2. підтримувати хід реакції
3. накопичуватися в розчині
4. електроактивні частинки
5. переміщення заряду
6. для більш точних результатів вимірювання
7. що відбувається, коли триває реакція
8. залежати від відносної рухливості іонів
9. різниця потенціалів
- 10.потребують більше енергії

11. кількість заряду залежить від

10. The following sentences contain some mistakes. Find and correct them.

1. In order for the system to operate, all rules must to be observed.
2. This changes would make it more difficult to introduce additional ions into the positive charged electrolyte.
3. The importance of this process can be understand by taking into account what happens with substances while the reaction is proceeding.
4. Such molecules is necessary to make the reaction proceed more effectively.
5. Salt bridge provides us with two liquid junction potentials, but they tends to cancel each other out.

SPEAKING AND WRITING

11. In groups discuss the following questions.

1. What conditions are necessary for the cell of Fig.5 to operate?
2. What does the ionic transport involve?
3. What can be used as the barrier between two solutions in the simplest cells?
4. What is the purpose of the salt bridge?
5. What ions are larger: negative or positive? What can the size of ions influence?

12. Write down the summary to the text “Transport of charge within the cell”.

UNIT 6. ELECTRONEUTRALITY

LEAD-IN

1. You will read a text about the electroneutrality principle. Before you read discuss the following:

1. What do electrochemical processes involve?
2. What is electroneutrality? Describe **Figure 6** on page 32.
3. What is the role of the electroneutrality principle in electrochemical processes?

2. Practice the pronunciation of the following words.

- discourage a process [dɪs'kʌrɪdʒ ə 'prəuses]
- excess (*n*) [ɪk'ses], ['ekses]
- excess (*adj*) ['ekses]
- excess of charge [ɪk'ses əv tʃɑ:dʒ], ['ekses]
- immerse a piece of metal [ɪ'mɜ:s ə pi:s əv metəl]
- cause a charge to build up ['ko:z ə 'tʃɑ:dʒ tu 'bɪldʌp]
- liquid phase ['lɪkwɪd 'feɪz]
- come to a halt [kʌm tu ə hɔ:lt]
- inhibition of the process [,ɪnhi'bɪʃ(ə)n əv ðə 'prəuses]
- chemical means ['kemɪk(ə)l 'mi:nz]
- electron acceptor [ɪ'lektrɒn ək'septə]
- couple something with something ['kʌpl 'sʌmθɪŋ wið 'sʌmθɪŋ]
- the reaction proceeds [ðə r'reakʃ(ə)n prə'si:dz]
- copper sulfate ['kɔ:pə 'sʌlfet]

READING

3. Read this article and decide if the statements 1 - 7 are true (T) or false (F), according to the text.

1. An excess of positive or negative charge in a solution leads to the inhibition of the process of building up opposing charges in two phases (metallic and liquid).

2. There are two ways of removing excess electrons from the metal either by using an external circuit or by bringing an electron acceptor into contact with the electrode.
3. It is impossible to restore electroneutrality to the two phases by immersing the zinc in a solution of copper sulfate instead of pure water.
4. The result of the electroneutrality principle is the thermodynamic work required to separate opposite charges, or to bring similar charges into closer contact.

Electroneutrality

Nature seems to strongly **discourage** any process that would lead to an excess of positive or negative charge in matter. Suppose, for example, that we **immerse** a piece of zinc metal in pure water. A small number of zinc atoms go into solution as Zn ions, leaving their electrons behind in the metal: $\text{Zn(s)} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$

As this process goes on, the electrons which remain in the zinc cause a negative charge to build up within the metal which makes **it increasingly** difficult for additional positive ions to leave the metallic phase. A similar buildup of positive charge in the liquid phase adds to this **inhibition**. Very soon, therefore, the process **comes to a halt**, resulting in a solution in which the concentration of Zn^{2+} is still too low (around 10^{-10} M) to be detected by ordinary chemical **means**. (**Figure 6**)

Transport of zinc ions from the metal to water; the buildup of negative charge in the metal (and positive charge in the solution) soon brings the process to a halt.

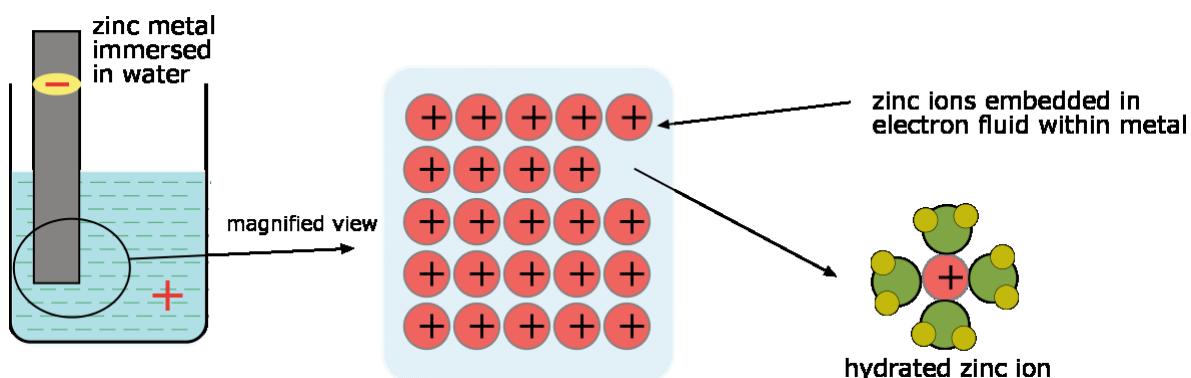
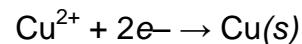
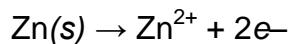


Figure 6: Oxidation of metallic zinc in contact with water

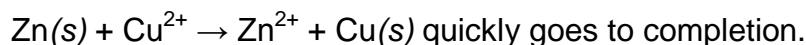
There would be no build-up of opposing charges in the two phases if the excess electrons could be removed from the metal or the positive ions consumed as the reaction **proceeds**. For example, we could remove the electrons left behind in the zinc through an external circuit that forms part of a complete electrochemical cell. Another way to remove electrons is to bring a good electron acceptor (that is, an oxidizing agent) into contact with the electrode. A suitable electron acceptor would be hydrogen ions; this is why acids attack many metals. For the very active metals such as sodium, water itself is a sufficiently good electron acceptor.

The degree of charge unbalance that is allowed produces differences in electric potential of no more than a few volts, and corresponds to unbalances in the concentrations of oppositely charged particles that are not chemically significant. There is nothing mysterious about this prohibition, known as the electroneutrality principle; it is a simple consequence of the thermodynamic work required to separate opposite charges, or to bring like charges into closer contact. The additional work raises the free energy of the process, making **it** less spontaneous.

The only way we can get the oxidation of the metal to continue is to **couple** it with some other process that restores electroneutrality to the two phases. A simple way to accomplish **this** would be to immerse the zinc in a solution of copper sulfate instead of pure water. The zinc metal quickly becomes covered with a black coating of finely-divided metallic copper. The reaction is a simple oxidation-reduction process, a transfer of two electrons from the zinc to the copper:



The dissolution of the zinc is no longer inhibited by a **buildup** of negative charge in the metal, because the excess electrons are removed from the zinc by copper ions that come into contact with **it**. At the same time, the solution remains electrically neutral, since for each Zn ion introduced to the solution, one Cu ion is removed. The net reaction



VOCABULARY PRACTICE

4. Match the highlighted words in the text with their synonyms.

1. connect
2. the slowing or prevention of a process, reaction
3. more and more
4. a gradual accumulation or increase
5. dip in a liquid
6. to inhibit; prevent
7. a method, instrument, or process
8. stops moving
9. goes on and does not stop

5. Fill in the gaps using *as, in, into, to, with*. Then choose any three of the completed phrases and make sentences to show their meaning.

1. to come a halt; 2. to go completion; 3. to immerse sth sth; 4. to come contact sth; 5. to couple sth sth; 6. to result sth; 7. be covered sth; 8. correspond sth; 9. known

6. Match the words to make collocations.

- | | |
|--------------|--------------|
| 1. electron | a) agent |
| 2. charge | b) acceptor |
| 3. net | c) particles |
| 4. charged | d) reaction |
| 5. oxidizing | e) means |
| 6. excess | f) phase |
| 7. chemical | g) unbalance |
| 8. liguid | h) electrons |

7. Fill in the correct word(s) from the list below. Use the word(s) only once. Find Ukrainian equivalents to the following English word expressions.

detected, removed, restore, lead, build up

1. This process can to an excess of positive or negative charge.
2. The concentration of Zn ²⁺ is too low to be by ordinary chemical means.
3. The of positive charge adds to the inhibition of the process.
4. In order to electroneutrality to the two phases we immerse the zinc in a solution of copper sulfate instead of pure water.
5. The excess electrons are from the zinc by copper ions.

8. Find in the text and explain what the following underlined highlighted words mean:

1. What word/phrase does *it* refer to? (...which makes **it** increasingly...§2, line 2)
2. What word/phrase does *it* refer to? (...making **it** less...§4, line 7)
3. What word/phrase does *this* refer to? (...to accomplish **this** would be...§5, line 3)
4. What word/phrase does *it* refer to? (...that come into contact with **it**...§6, line 3)

9. Fill in the gaps with words formed from the words in capitals.

According to the electroneutrality principle the bulk matter cannot have a (0) **chemically**-significant (1) of positive and negative ions.
(2) of a metal in water can proceed to a (3) extent only if some means is provided for removing the excess negative charge that remains. This can be done by electron- (4) ions in solution, or by (5) electrons out of the metal through an external circuit.

(0) CHEMIST

(3) MEASURE

(1) BALANCE

(4) ACCEPT

(2) SOLUTION

(5) DRAW

10. Find English equivalents to the following Ukrainian word expressions.

1. приводити до накопичення негативного заряду
2. перемістити/видалити електрони через зовнішній ланцюг
3. ввести акцептор електронів (окиснювач)
4. розчин пентагідрата сульфату міді
5. наносити тонко дисперговане металеве мідне покриття
6. рівень дисбалансу заряду
7. накопичення позитивного заряду сприяє уповільненню процесу

SPEAKING AND WRITING

11. In groups discuss the following questions.

1. What happens to the zinc electrons in the metallic phase and to the ions in the liquid phase?
2. What is the cause of the opposing charges buildup in the two phases?
3. In what ways could the excess of electrons be removed from the metal?
4. Could you explain the electroneutrality principle?
5. In what way could we accomplish the oxidation of the metal?
6. Why is the dissolution of the zinc no longer inhibited by a build up of negative charge in the metal?

12. Write down the summary to the text “Electroneutrality”.

UNIT 7. POTENTIAL DIFFERENCES AT INTERFACES

LEAD-IN

1. You will read a text about potential differences at interfaces. Before you read discuss the following:

1. What kinds of reactions does electrochemistry study?
2. What do we refer to charged particles?
3. What is the electrode process? Where does it take place? What does it produce?
4. What does **Figure 7** depicts?

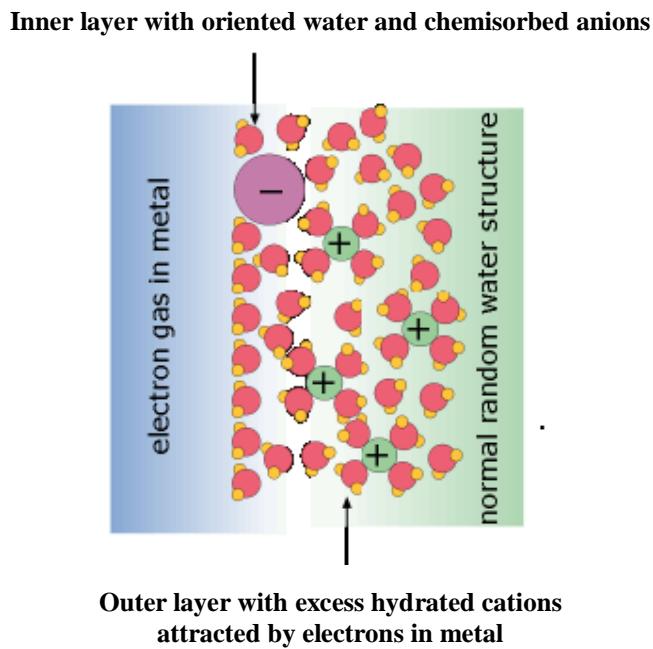


Figure 7 Electric double layer at an electrode surface

2. Practice the pronunciation of the following words:

- Molecule ['molikju:l]
- Molecular [mə'lekju:lə]
- Surface ['sə:fəs]
- Interface ['ɪntəfeis]
- Boundary ['baundəri]

- Electrode [ɪ'lektrəud]
- Electrolyte [ɪ'lektrəlaɪt]
- Lead (n) ['li:d]
- Anion ['ænaiən]
- Diameter [daɪ'æmɪtə]
- Exert [ɪg'zə:t]
- Double layer ['dabl 'leɪə]
- Interfacial potential difference [ɪntə'feɪʃəl pə'tenʃ(ə)l 'dɪfərəns]
- Excess hydrated cation ['ekses 'haɪdrētɪd 'kætaiən]

READING

3. Read this article and decide if the statements (1-6) are true (T) or false (F), according to the text.

1. The electric double layer consists of external monomolecular layer of absorbed water molecules and ions, and an internal diffuse region.
2. An electrode process is a chemical reaction between the electrode and electrolyte.
3. An electrode process takes place within the double layer and produces a significant unbalance in the electric charges of the electrode and the solution.
4. A very small voltage can produce a very large potential gradient.
5. Interfacial potentials cannot exist between any two phases in contact, in the absence of chemical reactions.
6. Interfacial potential differences are not directly observable.

Potential Differences at Interfaces

The transition region between two phases consists of a region of charge unbalance known as the electric double layer. As its name implies, it consists of an inner monomolecular layer of adsorbed water molecules and ions, and an outer diffuse region that compensates for any local charge unbalance that gradually merges into the completely random arrangement of the bulk solution. In the case of a metal immersed in pure water, the electron fluid within the metal causes the polar water molecules to adsorb to the surface so as to create two thin flat

surfaces of positive and negative charge. If the water contains dissolved ions, some of the larger (and more polarizable) anions will loosely bond (chemisorb) to the metal, creating a negative inner layer which is compensated by an excess of cations in the outer layer.

Electrochemistry is the study of reactions in which charged particles (ions or electrons) cross the interface between two phases of matter, typically a metallic phase (the electrode) and a conductive solution, or electrolyte. A process of this kind can always be represented as a chemical reaction and is known generally as an electrode process. Electrode processes take place within the double layer and produce a slight unbalance in the electric charges of the electrode and the solution. Much of the importance of electrochemistry lies in the ways that these potential differences can be related to the thermodynamics and kinetics of electrode reactions. In particular, manipulation of the interfacial potential difference affords an important way of exerting external control on an electrode reaction.

The interfacial potential differences which develop in electrode-solution systems are limited to only a few volts at most. This may not seem like very much until you consider that this potential difference spans a very small distance. In the case of an electrode immersed in a solution, this distance corresponds to the thin layer of water molecules and ions that attach themselves to the electrode surface—normally only a few atomic diameters. Thus a very small voltage can produce a very large potential gradient. For example, a potential difference of one volt across a typical 10^{-8} cm interfacial boundary amounts to a potential gradient of 100 million volts per centimeter—a very significant value indeed!

Interfacial potentials are not confined to metallic electrodes immersed in solutions; they can in fact exist between any two phases in contact, even in the absence of chemical reactions. In many forms of matter, they are the result of adsorption or ordered alignment of molecules caused by non-uniform forces in the interfacial region. Thus colloidal particles in aqueous suspensions selectively adsorb a given kind of ion, positive for some colloids, and negative for others. The resulting net electric charge prevents the particles from coming together and merging, which they would otherwise tend to do under the influence of ordinary Van der Waals attractions.

The usual way of measuring a potential difference between two points is to bring the two leads of a voltmeter into contact with them. It's simple enough to touch one lead of the

meter to a metallic electrode, but there is no way you can connect the other lead to the solution side of the interfacial region without introducing a second electrode with its own interfacial potential, so you would be measuring the sum of two potential differences. Thus single electrode potentials, as they are commonly known, are not directly **observable**.

VOCABULARY PRACTICE

4. Match the highlighted words in the text with their synonyms.

1. totally
2. replaces/balances
3. seen/noticed
4. combines into
5. at the maximum
6. fasten
7. adds up to
8. small in degree
9. essential /important
10. little by little

5. Find in the text and explain what the following underlined highlighted words mean:

1. What word/phrase does *it* refer to? (As its name implies, it consists of ...§1, line 2)
2. What word/phrase does *that* refer to? (...region that compensates for...§1, line 3)
3. What word/phrase does *that* refer to? (...unbalance that gradually merges...§1, line 4)

6. Find English equivalents to the following Ukrainian word expressions.

1. різниця (електричних) потенціалів
2. відсутність рівноваги
3. призводити до порушення рівноваги
4. дифузна зона/ділянка
5. основна маса розчину
6. хаотичне розташування (атомів)

7. здійснювати зовнішній контроль
8. градієнт потенціалу
9. міжфазний потенціал/границя
10. пересікати границю/поверхню розділу

7. Match the words with their definitions.

1	Interface	A	a positively charged ion; an ion that is attracted to the cathode during electrolysis
2	Electrode	B	wire used to connect a piece of electrical equipment to the power supply
3	Electrolyte	C	the top layer of an area of water
4	Lead	D	a positively charged ion; an ion that is attracted to the cathode during electrolysis
5	Surface	E	a very small piece of matter with a negative electrical charge that moves around the nucleus (=central part) of an atom
6	Anion	F	a small piece of metal or a wire that is used to send electricity through a system or through a person's body
7	Cation	G	the surface where two things touch each other
8	Electron	H	a liquid that allows electricity to pass through it
9	Ion	I	an atom which has been given a positive or negative force by adding or taking away an electron

8. Complete this table to make word families. Use a dictionary to help you.

Translate the words and their derivatives.

<i>Verb</i>	<i>Adjective</i>	<i>Noun</i>
Immerse – занурювати	immersible - занурюваний, immersed - занурений	immersion – занурення
Measure		
Compensate		
Charge		
Conduct		
Amount		

9. Find Ukrainian equivalents to the following English word expressions.

1. transition region
2. to consist of an outer diffuse region
3. to compensate for any charge unbalance
4. random arrangement
5. bulk solution
6. be immersed in the solution
7. be compensated by an excess of cations
8. to exert external control
9. to span a small distance
10. to produce a potential gradient
11. interfacial boundary
12. to bring the leads into contact
13. to attach sth to the electrode surface
14. to have a small voltage
15. to prevent particles from merging
16. to measure a potential difference

SPEAKING AND WRITING

10. In groups discuss the following questions.

1. What is the nature of the electric double layer?
2. What processes take place during the absorption?
3. Does a larger anion or cation have bigger polarization?
4. What properties does electrolyte possess?
5. Where do electrode processes take part?
6. What voltage has the double layer?
7. What is the size of the double layer?

11. Write down a summary to the text “Potential difference at interfaces”.

UNIT 8. ELECTRODES AND ELECTRODE REACTIONS

LEAD-IN

1. You will read a text about electrodes and electrode reactions. Before you read discuss the following:

1. What is an electrode? What types of electrodes do you know?
2. What reactions do we refer to electrode?
3. What is an electroactive species?

2. Practice the pronunciation of the following words.

- electroactive species [ɪ'lektrəʊ'æktyv 'spi:ʃi:z]
- hydrated cation ['haɪdrēɪtɪd 'kætaiən]
- quantum-mechanical tunneling ['kwɔːntəm mɪ'kænɪk(ə)l 'tʌn(ə)lɪŋ]
- gaseous species ['gæsɪəs 'spi:ʃi:z]
- succession of steps [sək'seʃ(ə)n əv steps]
- electrode surface [ɪ'lektrəud 'sɜːfɪs]
- coulombic forces ['kuːləmɪk fɔːsɪz]
- supply of electrons [sə'plai əv ɪ'lektrɒnz]

READING

3. Read the text and match the headings (a-d) with the correct paragraphs (1-4).

- | | |
|-----------------------------------|-----------------------------|
| a) Ion-ion electrodes. () | c) Electrode reactions. () |
| b) Insoluble-salt electrodes. () | d) Gas electrodes. () |

Electrodes and electrode reactions

1. _____

An *electrode reaction* refers to the net oxidation or reduction process that takes place at an electrode. This reaction may take place in a single electron-transfer step, or as a **succession** of two or more steps. The substances that receive and lose electrons are called the *electroactive species*.

In the example of the Zn/Cu cell we have been using, the electrode reaction involves a metal and its hydrated cation; we call such electrodes metal-metal ion electrodes. There are a number of other kinds of electrodes which are widely encountered in electrochemistry and analytical chemistry.

2. _____

Many electrode reactions involve only ionic species, such as Fe^{2+} and Fe^{3+} . If neither of the electroactive species is a metal, some other metal must serve as a **conduit** for the supply or removal of electrons from the system. In order to avoid complications that would arise from electrode reactions involving this metal, a relatively inert substance such as platinum is commonly used. Such a half cell would be represented as $\text{Pt(s)} \mid \text{Fe(aq)} \parallel$ and the half-cell reaction would be $\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}^{3+}(\text{aq}) + \text{e}^-$

The reaction **occurs** at the surface of the electrode (**Fig 7 below**). The electroactive ion diffuses through the electrode surface and attaches to it by van der Waals and coulombic forces. In doing so, the waters of hydration that are normally attached to any ionic species must be displaced. This process is always endothermic, sometimes to such an extent that only a small fraction of the ions be able to contact the surface closely enough to undergo electron transfer, and the reaction will be slow. The actual electron-transfer occurs by quantum-mechanical tunnelling.

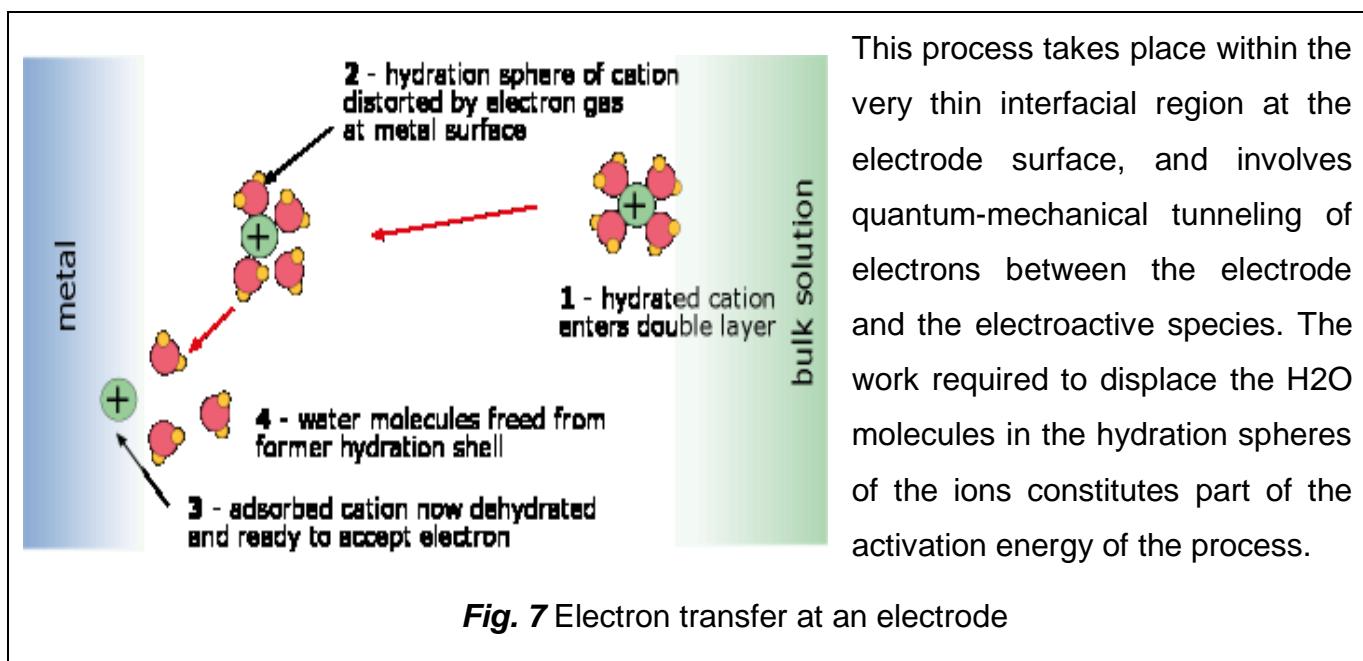


Fig. 7 Electron transfer at an electrode

3. _____

Some electrode reactions involve a gaseous species such as H₂, O₂, or Cl₂. Such reactions must also be carried out on the surface of an electrochemically inert conductor such as platinum. A typical reaction of considerable commercial importance is



Similar reactions involving the oxidation of Br₂ or I₂ also take place at platinum surfaces.

4. _____

A typical electrode of this kind consists of a silver wire covered with a thin coating of silver chloride, which is insoluble in water. The electrode reaction consists in the oxidation and reduction of the silver: AgCl(s) + e⁻ → Ag(s) + Cl⁻(aq)

The half cell would be represented as || Cl⁻(aq) | AgCl(s) | Ag(s)

Although the usefulness of such an electrode may not be immediately apparent, this kind of electrode finds very wide application in electrochemical measurements, as we shall see later.

4. Read the text again and decide if the statements 1 - 4 are true (T) or false (F), according to the text.

1. Electroactive species are substances that receive or lose electrons.
2. An electrode reaction may take place only in a single electron-transfer step.
3. In ion-ion reactions any metal can be used as a conduit for the supply or removal of electrons from the system.
4. To diffuse through the electrode surface and attach to it the electroactive ion needs van der Waals and coulombic forces.

VOCABULARY PRACTICE

5. Match the highlighted words in the text with their synonymous words/phrases given in the list below.

- | | |
|------------|-----------|
| 1. happens | 2. series |
|------------|-----------|

- | | |
|------------------------------|--------------------------|
| 3. conduit | 6. lies in |
| 4. evident; obvious | 7. despite the fact that |
| 5. is composed or made up of | 8. impossible to solve |

6. Fill in the gaps using *as, at, for, of, in, on, to, through*. Then choose any three of the completed phrases and make sentences to show their meaning.

1. to refer sth; 2. to consist sth; 3. to be attached sth; 4. to occur the surface of the electrode; 5. to be represented sth; 6. to serve a conduit the supply of electrons; 7. be widely encountered electrochemistry; 8 to diffuse the electrode surface; 9. to find wide application sth.

7. Match the words to make collocations.

- | | |
|--------------|--------------|
| 1. coulombic | a) conductor |
| 2. electrode | b) cation |
| 3. gaseous | c) species |
| 4. hydrated | d) chloride |
| 5. electron | e) forces |
| 6. inert | f) surface |
| 7. silver | g) transfer |

8. Find English equivalents to the following Ukrainian word expressions.

- a) квантово-механічний тунельний перехід/ефект
- b) слугувати каналом для подачі або вилучення електронів з системи
- c) електроактивні елементи/іони
- d) гідратований катіон
- e) знаходити широке застосування

SPEAKING AND WRITING

9. Prepare a presentation on the topic “Electrodes and electrode reactions”.

10. Write down the summary to the text “Electrodes and electrode reactions”.

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