МІНІСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ УКРАИНЫ

НАЦИОНАЛЬНЫЙ ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ
„ХАРЬКОВСКИЙ ПОЛИТЕХНИЧЕСКИЙ ИНСТИТУТ”

МЕТОДИЧЕСКИЕ УКАЗАНИЯ

по английскому языку по теме „Электрохимия”

для студентов и магистров Н-факультета

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Вступление

Методические указания предназначены для аудиторной и самостоятельной работы студентов всех курсов и магистров факультета технологии неорганических веществ по специальности «Электрохимия».

Основная цель указаний – расширение знаний студентов по специальности, формирование терминологического словарного запаса и совершенствование коммуникативных навыков на английском языке.

Материалы состоят из тематических разделов (Units), которые подразделяются на части (Parts). Каждая часть включает текст для изучающего чтения, предтекстовые упражнения, направленные на усвоение лексического минимума по теме, и послетекстовые упражнения для развития коммуникативной компетенции студентов.

Все тексты основаны на аутентичних источниках, подобраны в соответствии с основними понятиями электрохимии.

Unit 1 ELECTROCHEMISTRY BASICS

Part 1.1 Introduction to Electrochemistry

Before reading:

❖ ***Learn the following key words from the text:***

electrochemistry – электрохимия
electricity – электричество
reaction – реакция
electric current – электрический ток
bond – связь
fuel cell – топливный элемент
compound – соединение (химическое)
application – применение, использование
electroplating – гальванопокрытие, нанесение гальванического покрытия
corrosion – коррозия

❖ ***Read the following words. Pay attention to their pronunciation.***

- electrochemistry, electricity, electron, electric, electrical, energy, electrolysis, electrosynthesis, electrodeposition, electroforming;
- chemistry, chemical, atom, ion, component, element, battery, process, method, analysis, mechanism technique, system, nature, organism, neuron, spontaneously, non-spontaneous, industrial, analytical, decorative, biological, interdisciplinary, metallurgical.
- aluminum, chlorine, copper, zinc, silver, gold, iron, lead, chrome, sodium, potassium;
- alkali, glucose, alcohol, ethanol.

❖ ***Read and translate the following text:***

ELECTROCHEMISTRY

Electrochemistry is a branch of chemistry concerned with the relation between electricity and chemical change. This definition is too general since in almost every reaction there will be a transfer of electrons among the atoms of the participating species during the splitting and formation of chemical bonds. However, the term "electrochemistry" is usually referred to those reactions, in which charged species are components of the reaction medium.

Many spontaneously occurring chemical reactions liberate electrical energy, and some of these reactions are used in batteries and fuel cells to produce electric power. Conversely, electric current can be utilized to bring about non-spontaneous chemical reactions. In this case, the electrical energy is converted to chemical energy. The principal application of this process is to break down more complex compounds into simpler ones or to separate compounds into their elements. This is done in a process called electrolysis.

Electrochemistry is present in a wide range of uses in our daily life. One of the most obvious applications is that of batteries and fuel cells. These are produced with certain chemicals in them, which will react with each other and produce an electrical current as soon as the switch is closed.

The second important application implies the opposite process, which is called electrosynthesis. It is the use of electricity to generate new chemical products. In this case electricity is added to the reaction. Electrosynthesis is widely used in industrial processes such as purification of metals, production of chlorine and alkalis.

Electroplating (or electrodeposition) is another typical application of electrochemistry. It is widely used to produce protective and decorative coatings on metals. Utensils and jewelry are often silver or gold plated to improve appearance. Sometimes the whole jewelry piece is made by an electrodeposition process called "electroforming".

Many commonly used metals can be extracted from their ores by electrochemical methods. Some of these are: aluminum, copper, zinc, silver, lead and many more.

Another field where electrochemistry finds relevance is the study of corrosion processes. Corrosion is an example of a natural electrochemical reaction. Iron oxidation or "rust" is well known. The purpose of electrochemistry in this field is to understand the mechanism of corrosion and to device methods to avoid it or to protect from it. Metal articles are often protected from corrosion by coating them in the process of electroplating with a more corrosion resistant metal, chrome plating is a good example.

Electrochemistry also finds a wide range of applications in analysis. The examples are measurement of glucose in the blood by a glucose sensor, detection of alcohol in drunken drivers through the redox reaction of ethanol.

There are various extremely important electrochemical processes in nature. All living organisms use electrochemistry to one degree or another. They have noticeable electric fields which are generated by chemical reactions in their bodies, and electrochemical reactions are involved in a number of biological processes. Photosynthesis and respiration involve redox reactions, making them electrochemical in nature. The action potentials that travel down neurons are based on electric current, generated by the movement of sodium and potassium ions into and out of cells.

The above is only a brief overview of many aspects of everyday life connected to electrochemistry.

Electrochemistry is an interdisciplinary subject. Its scope and practical applications cover several fields of science including metallurgical processes, biology, analytical techniques, space research, energy systems, etc.

Post-text exercises:

1. Complete the sentences using the words from the box:

Corrosion Methods Purification Reaction Electric Power Fuel Cells Application Analysis Electrosynthesis Electrochemistry Liberate Interdisciplinary

1. In almost every ______ there will be a transfer of electrons among the atoms of the participating species during the splitting and formation of chemical bonds.

2. Many spontaneously occurring chemical reactions ______ electrical energy, and some of these reactions are used in batteries and fuel cells to produce ______.
3. One of the most obvious applications of ______ is that of batteries and ______.
4. The second important application implies the opposite process which is called_____.
5. Electrosynthesis is widely used in industrial processes such as______of metals, production of chlorine and alkalis.
6. Electroplating is another typical ______ of electrochemistry.
7. Many commonly used metals can be extracted from their ores by electrochemical ______.
8. Electrochemistry also finds a wide range of applications in ______.
9. Another field where the electrochemistry science finds relevance is the study of ______ processes.
10. Electrochemistry is an ______ subject.

II. Answer the questions:

1. What is electrochemistry concerned with?
2. Why is almost every chemical reaction considered electrochemical?
3. Is electric current produced or used in chemical reactions?
4. What are the most important applications of electrochemistry in our daily life?
5. In what way are electrochemical processes used in batteries and fuel cells?
6. What industrial applications of electrochemistry are mentioned in the text?
7. What is the purpose of electrochemistry in the study of corrosion?
8. Give examples of electrochemical processes in nature.

Part 1.2 The Central Issue In Electrochemistry

Before reading:

❖ ***Learn the following key words from the text:***

redox reaction	–	окислительно-восстановительная реакция
oxidation	–	окисление
oxidized	–	окисленный
reduction	–	восстановление
reduced	–	восстановленный
reducing agent,	–	восстановитель
reductant	–	окислитель
oxidizing agent,	–	заряд (электрический), заряжать
oxidant		(электрически)
charge	–	катион
	–	анион
cation	–	полуреакция
anion	–	степень (состояние) окисления
half reaction		
oxidation (oxide) state		

❖ ***Read the following words. Pay attention to their pronunciation.***

Concept, negative, negatively, positive, positively, cation, anion, substance, neutral, normally, type, detail.

❖ ***Read and translate the following words paying attention to their formation**:*

- React – react**ion** – react**ant**;
- Charge – **to** charge – charg**ed**;
- Oxide – oxida**tion** – oxid**ant** – **to** oxid**ize** – oxidiz**ing** – oxidiz**ed**;
- **To** reduce – reduc**ed** – reduc**ing** – reduct**ion** – reduct**ant**.

❖ ***Read and translate the following text:***

REDOX REACTIONS

One of the underlying concepts in electrochemistry is the reduction/oxidation or redox reactions because electrochemical reactions are redox reactions carried out under special circumstances.

An atom is electrically neutral and is made of the nucleus and negatively charged electrons swirling around it. It can lose or gain electrons to form charged ions. There are two types of electric charge: positive and negative. Positively charged ions are called cations, negatively charged ions are called anions. Discharge of ions involves loss or gain of electrons.

The loss of electrons of a substance in an electrochemical reaction is called oxidation, and the gain of electrons is called reduction. The substance, which loses electrons, is also known as the reducing agent or reductant, and the substance, which accepts electrons, is called the oxidizing agent, or oxidant. In a reaction the oxidizing agent is always reduced, the reducing agent is always oxidized.

A reaction in which both oxidation and reduction are occurring is called a redox reaction. These are very common, as one substance loses electrons the other accepts them. A redox reaction can be divided into two half reactions, an oxidation half reaction and a reduction half reaction.

The oxidation state of an ion is the number of electrons it has accepted or donated compared to its neutral state (which is defined as having an oxidation state of 0). If an atom or an ion donates an electron in a reaction, its oxidation state is increased, if an element accepts an electron, its oxidation state is decreased. For example, when sodium reacts with chlorine, sodium donates one electron and gains an oxidation state of +1. Chlorine accepts the electron and gains an oxidation state of -1. The sign of the oxidation state actually corresponds to the value of each ion's electronic charge.

There are, of course, many other details involved, but the essence of electrochemistry is the spatial separation of the oxidation part (the donation of electrons to the electrode) and the reduction part (the receiving of electrons from the electrode) of the overall reaction.

Post-text exercises:

I. Match the English words with the Russian equivalents:

1) electrically	a) state
2) redox	b) agent
3) reducing	c) reaction
4) special	d) bond
5) electric	e) neutral
6) ionic	f) circumstances
7) oxidation	g) charge

II. Fill in the blanks:

1. There are two types of electric______: positive and negative.
2. Positively charged ions are called______negatively charged ions are called______.
3. A reaction in which both oxidation and reduction are occurring is called a______.
4. The ______ state of an ion is the number of electrons it has accepted or donated compared to its neutral state.
5. If an atom or an ion donates electron in a reaction its oxidation state is ______, if an element accepts an electron its oxidation state is ______.
6. The ______ of the differently charged sodium and chlorine ions is the reason why they then form an ionic bond.
7. The essence of electrochemistry is the spatial separation of the oxidation part (the ______ of electrons to the electrode) and the reduction part (the ______ of electrons from the electrode) of the overall reaction.

III. Answer the questions:

1. What is the essence of electrochemistry?
2. Under what conditions are charged ions formed?
3. What is an atom made of?
4. What are the main types of electric charge?
5. What is the oxidation state of an atom?

6. What happens to the oxidation state when an atom donates an electron?
7. What does the sign of the oxidation correspond to?
8. How do we call
   - the reaction in which both oxidation and reduction are occurring?
   - positively charged ions?
9. What is
   - the reducing agent or reductant?
   - the oxidizing agent or oxidant?

UNIT 2 ELECTROLYSIS
Part 2.1 Electrolysis

Before reading:

❖ ***Learn the following key words from the text:***

electrolysis	– электролиз
ectrolytic cell	– электролитическая ячейка
ectrolyte	– электролит
electrode	– электрод
dissociate	– распадаться, разлагаться, растворяться
dissolve	– растворяться
external voltage	– внешнее напряжение
solution	– раствор
solute	– растворенное вещество
conductor	– проводник
anode	– анод
cathode	– катод
anodic reaction	– анодная реакция
cathodic reaction	– катодная реакция

❖ ***Read the following words. Pay attention to their pronunciation.***

- energy, inert, gas, temperature, contact, opposite, function, cathode, concentrated, proportion, metal, polarity, bipolar;
- electrolysis, electrolytic, electrolyte, electrode;
- separating, dissociate, through, consist, dilute, either, pressure;
- carbon, hydrogen, acid, base, salt, valence, element, compound.

❖ ***Read and translate the following words paying attention to their formation:***

- ion – ion**ic**; anode – anod**ic**; cathode – cathod**ic**;
- electro**lyte** – electro**lytic**; conduct – conduct**ive**.

❖ ***Read and translate the following text:***

ELECTROLYSIS

Electrolysis is a method of separating bonded elements and compounds by passing an electric current through them. The term "electrolysis" comes from Greek words that mean "loosening by electricity". Electrolysis takes place in a vessel, containing electrolyte and electrodes, and which is called electrolytic cell. The process requires an electrolyte and an external source of electrical energy to induce a reaction.

An electrolyte is a substance that dissociates into free ions when dissolved (or molten) to produce an electrically conductive medium. The electrolyte in the cell is inert unless driven by external voltage into a redox reaction with the electrodes. Electrolytes generally exist as acids, bases or salts. Electrolytes are also known as ionic solutions, because they generally consist of ions in solution. Some gases may act as electrolytes under conditions of high temperature or low pressure. An electrolyte may be concentrated or dilute. If a high proportion of the dissolved solute dissociates to form free ions, the solution is strong; if most of the dissolved solute does not dissociate, the solution is weak.

An electrode in the electrolytic cell is a conductor, usually made of a metal or an alloy, sometimes of carbon, which is used to make contact with an electrolyte. An electrode is referred to as either an anode or a cathode. The anode is the negative polarity contact of the cell, where electrons come up from the electrolytic cell. At the anode anions react chemically and give off electrons (oxidation or anodic reaction and oxidation occurs). The opposite of the anode is the cathode. The cathode is the positive electrode at which reduction (or cathodic reaction) occurs: electrons are added to cations to complete the valence shell or bond. Each electrode may become either the anode or the cathode, depending on the voltage applied to the cell. A bipolar electrode is an electrode that functions as the anode of one cell and the cathode of another cell. Common results of reduction at the cathode are hydrogen gas or pure metal from metal ions. The flow of electrons is always from anode-to-cathode outside of the cell or device and from cathode-to-anode inside the cell or device.

Post-text exercises:

I. Complete the sentences using the text, translate them.

1. Electrolysis is a method of _____.
2. Electrolytic cells are composed of _____.
3. An electrolyte is a substance that _____.
4. Electrolytes generally exist as _____..
5. An electrode in the electrolytic cells is _____.
6. An electrode is referred to as either _____.
7. The anode is the negative polarity contact where electrons _____.
8. The cathode is the positive electrode at which _____.

II. Answer the questions:

1. What does the word “electrolysis” mean?
2. Where does the word “electrolysis” come from?
3. Where does electrolysis take place?
4. What is electrolytic cell composed of?
5. What does electrolysis require to induce a reaction?
6. Why are electrolytes also known as ionic solutions?
7. What are the two types of an electrode?
8. What are common results of reduction at the cathode?

III. Find whether the following statements are true or false, correct the false statements:

1. Electrolytic cells are composed of a vessel containing electrolytes and electrodes.
2. Electrolytes generally exist as fats, acids or salts.
3. An electrolyte may be only concentrated.
4. There are three types of an electrode: an anode, a cathode and a cation.
5. The anode is the negative polarity contact of the cell.
6. A bipolar electrode is an electrode that functions as the anode of one cell and the cathode of another cell.

Part 2.2 Electrolytic Process

Before reading:

❖ ***Learn the following key words from the text:***

liquid	– жидкость, жидкий
flow	– поток, течь
decompose	– разлагаться, распадаться, расщепляться
attract	– притягивать
electrical power supply	– источник электрического тока
electrolyze	– электролизовать, производить электролиз, подвергать электролизу
sulfuric acid	– серная кислота
quantitative	– количественный

❖ ***Read the following words. Pay attention to their pronunciation.***

- electrolyze, metallic, gaseous, process, metallurgy, industry, standard, temperature, apparatus, basic, equivalent, detail, aspect, mass, product, proportional, analyze;

- hydrogen, oxygen, sodium, platinum, chlorine, chloride, sulfuric acid, sodium chloride;
- provide, decompose, dissociate, attract, quantity, quantitative, deposit, weight, yield.

❖ ***Read and translate the following text:***

ELECTROLYTIC PROCESS. LAWS OF ELECTROLYSIS

An electrolytic cell is activated by applying an electrical current between the anode and cathode immersed in the liquid. Ions in the solution flow toward the electrodes. If ions are positively charged cations they flow toward the cathode and are reduced. If ions are negatively charged anions they flow to the anode and are oxidized. The energy, required to separate the ions and cause them to gather at the respective electrodes, is provided by an electrical power supply. At the electrodes electrons are absorbed or released by the ions, forming a collection of the desired element or a compound. For example, when water is electrolyzed, hydrogen gas (H_2) bubbles at the cathode, and oxygen gas (O_2) rises at the anode.

For example, molten sodium chloride (table salt - NaCl) can be electrolyzed to yield metallic form of sodium and gaseous chlorine. In molten salt when a current is passed through it, the anode oxidizes chlorine. The cathode reduces sodium which deposits on the cathode using electrons to complete the sodium valence shell. This process can yield industrial amounts of metallic sodium and gaseous chlorine and is widely used in metallurgy industry.

Another example is the electrolysis of water. At standard temperature and pressure conditions water doesn't decompose into hydrogen and oxygen. However a special laboratory devise has been designed for this purpose, where a pair of inert electrodes, usually made of platinum, acts as anode and cathode in the electrolytic process. After the water (if pure) has been placed in the apparatus, nothing happens, hence there are not enough ions to let the passage of electrons occur. To start the electrolysis, an electrolyte should be placed in sodium chloride or sulfuric acid.

The electrolysis of salt water or acidic water is an easy example of electrolysis. Usually water is electrolyzed as mentioned in electrolysis of water yielding gaseous oxygen at the anode and gaseous hydrogen at the cathode. On the other hand, sodium chloride in water dissociates in Na^+ and CI^- ions, anion will be attracted to the cathode, thus reducing sodium ion, and the cation will be attracted to the anode oxidizing chloride ion.

Michael Faraday developed quantitative aspects of electrolysis in 1834, describing them by two basic laws.

The first law of Faraday states that the mass of the products yielded on the electrodes is proportional to the quantity of current supplied to the cell and the molar mass of the substance analyzed. In other words, the amount of a substance deposited on each electrode of an electrolytic cell is directly proportional to the quantity of electricity passed through the cell.

Faraday formulated the second law of electrolysis stating, "The amounts of bodies, which are equivalent to each other in their ordinary chemical action, have equal quantities of electricity naturally associated with them." In other terms, the quantities of different elements deposited by a given amount of electricity are in the ratio of their chemical equivalent weights.

Of course, electrochemists worry about a number of additional details involved in these systems. What are the electrical potential differences between the electrodes? How will these potentials change when current is flowing? How will the ions carry the current in the electrolyte between the electrodes? What are the best chemicals (to be oxidized/reduced) to be used? What are the best electrode materials to be used? What is the best electrolyte to be used?

Post-text exercises:

1. ***Complete the sentences using the text, translate them:***

1. An electrolytic cell is activated by ______.
2. Water at standard temperature and pressure conditions doesn't decompose into______.
3. The electrolysis of salt water or acidic water is an easy example of ______.
4. Quantitative aspects of electrolyses were developed by ______.

5. The first law of Faraday states that ______.
6. The quantities of different elements deposited by a given amount of electricity are ______.
7. Electrochemists worry about ______.

II. Answer the questions:

1. Under what conditions is an electrolytic cell activated?
2. If ions are positively charged cations, in what direction do they flow?
3. What happens to the ion at the anode?
4. What should be done to start the electrolysis?
5. What happens to water at standard temperature and pressure conditions?
6. What process is widely used in metallurgy industries?
7. Who developed quantitative aspects of electrolysis?
8. What does the first law/the second law state?
9. What questions are electrochemists worried about?

III. Find whether the following statements are true or false, correct the false statements:

1. An electrolytic cell is activated by applying the voltage to the cell.
2. Ions in the solution flow toward electrolytes.
3. Michael Faraday developed one law.
4. Water is electrolyzed in electrolysis yielding gaseous oxygen in the cathode and gaseous hydrogen in the anode.
5. Albert Einstein developed quantitative aspects of electrolysis.
6. The first law of Faraday states that the amount of a substance deposited on each electrode of an electrolytic cell is directly proportional to the quantity of electricity passed through the cell.
7. The second law of Faraday states that the quantities of different elements deposited by a given amount of electricity are not in the ratio of their chemical equivalent weights.

Part 3.1 Process of Electrodeposition. Electroplating

Before reading:

❖ ***Learn the following key words from the text:***

electroplating	–	гальванопокрытие, нанесение гальванического покрытия (методом электролитического осаждения)
electrodeposition	–	электролитическое осаждение, электроосаждение
coat (with)	–	наносить покрытие
coating	–	покрытие
plate (with)	–	металлизировать, наносить гальваническое покрытие
corrosion resistance	–	сопротивление коррозии, коррозионная стойкость
thickness	–	толщина
substrate	–	подложка
plating bath	–	электролитическая ванна
plating metal	–	металл для гальванического покрытия
layer	–	слой

❖ ***Read the following words. Pay attention to their pronunciation.***

- process, metallic, geometry, geometric, finally, uniform, accurate, phenomenon, control, substrate;
- electroplating, appearance, surface, attract, corrosion, layer;
- chromium, silver, gold, zinc, tin.

❖ ***Give Russian equivalents of the following word combinations:***

Chromium plating, silver plating, gold plating, plating metal, plating bath, plating tank, plating speed, plating solution, electroplated layer, plated coatings, the object to be plated, the recessed areas, sharp faceted corners, thickness irregularity effects, sophisticated plating baths formulae, performance of electroplated coatings.

❖ ***Read and translate the following text:***

ELECTROPLATING

Electroplating is the process of producing a coating, usually metallic, on a surface by action of electric current.

Electroplating is also often called "electrodeposition" and the two terms are used interchangeably. As a matter of fact, electroplating occurs by the process of electrodeposition. This process includes many steps and requires considerable pretreatment, treatment and post-treatment.

There are several reasons why you might want to coat a surface with a metal. Chromium plating improves the appearance and wear of objects. Zinc or tin coatings may be applied to confer corrosion resistance. Sometimes electroplating is done simply to increase the thickness of an item. Silver plating and gold plating of jewelry or silverware is typically done to improve the appearance and value of the items.

Electroplating is done in an electrolyte – a solution of salt of the plating metal, also known as a "plating bath". The plating metal is the anode of the electrolytic cell. The object to be plated is made the cathode and is called "substrate". The anodes are generally positioned at the edges of the plating tank and the cathode is located in its centre. An electric current is passed through the electrolyte, the anode, and the cathode. The ions of the salt solution carry a positive charge and are thus attracted to the negatively charged object – the cathode. When they reach the object, it provides electrons to reduce the positively charged ions to metallic form. Finally, the metal ions are removed from the solution and are deposited on the surface of the object as a thin layer. It is this process, which we know as electrodeposition.

For example, in an acid solution Cu is oxidized to Cu^{2+} by losing two electrons. Cu^{2+} associates with the anion SO_4^{2-} in the solution to form copper sulfate. At the cathode Cu^{2+} is reduced to metallic Cu by gaining two electrons.

The thickness of the electroplated layer on the substrate is determined by the time duration of the plating. The longer the object remains in the operating plating bath, the thicker the resulting electroplated layer will be.

Typically, layer thicknesses varies from 0.1 to 30 microns, though nothing prevents the deposition of thicker or thinner layers.

The geometric shape and contour of the object to be plated also affect the thickness of the deposited layer. In general, objects with sharp corners and features will tend to have thicker deposits on the outside corners and thinner ones on the recessed areas. The cause of this difference is that the current distribution is not uniform. More accurate explanation of this phenomenon involves the geometry of the electric field lines that exist between the electrodes in the solution.

In practice, an item with sharp faceted corners is difficult, actually, almost impossible to plate uniformly. The proper placements of the anodes, as well as modification of the current density, are required to overcome the thickness irregularity effects.

Today sophisticated plating baths formulae have been developed and are routinely employed. Layer thickness, performance of electroplated coatings are under strict control. New developments enable greater plating speed, better throwing power (the ability of a plating solution to produce a relatively uniform distribution of metal upon a cathode of irregular shape), as well as reliable coatings.

Post-text exercises:

I. Find whether the following statements are true or false, correct the false statements:

1. The words electroplating and electrodeposition are used interchangeably.
2. Electrodeposition is the process of producing a coating, usually non-metallic, on a surface by means of electric current.
3. Silver or gold coatings may be applied to confer corrosion resistance.
4. The process of electrodeposition requires considerable pretreatment, treatment and post-treatment.
5. The thickness of the electroplated layer on the substrate is not determined by the time duration of the plating.

6. The geometric shape and contour of the object to be plated also affect the thickness of the deposited layer.

II. Match the columns:

1) plating	a) plating
2) chromium	b) resistance
3) considerable	c) bath
4) corrosion	d) layer
5) electroplated	e) pretreatment

III. Answer the questions:

1. What process do we call electroplating?
2. What are the reasons to coat a surface with a metal?
3. What is the other name of electroplating?
4. What is the plating bath?
5. Where are the anodes generally positioned at?
6. Where is the cathode located?
7. Why are the metallic ions of the salt attracted to the object?
8. Where is electroplating performed?
9. What determines the thickness of the deposited layer?

IV. Fill in the blanks with the words given below:

Thickness Plating Duration Electrolyte Power Coatings Surface Corrosion Resistance

1. There are several reasons why you may want to coat a ______ with a metal.
2. Zinc or tin coatings may be applied to confer ______.
3. Sometimes electroplating is done to increase the _____ of an item.
4. Gold ______ of jewelry is done to improve the appearance and value of the items.

5. As a matter of fact, electroplating occurs by the process of ______.
6. Electroplating is done in an ______ – a solution of salt of the plating metal.
7. The thickness of the electroplated layer on the substrate is determined by the time ______ of the plating.
8. Layer thicknesses, performance of electroplated ______ are under strict control.

Part 3.2 Surface Preparation

Before reading:

❖ ***Learn the following key words from the text:***

surface	–	поверхность
electroplater	–	гальванотехник
pretreatment	–	предварительная обработка
remove	–	удалять
cleaning	–	очистка
slow	–	медленный
fast	–	быстрый

❖ ***Read the following words. Pay attention to their pronunciation.***

Undesirable, surface, adhesion, prior, iron, magnesium.

❖ ***Read and translate the following word combinations:***

Plating action, plating operations, plating process, processing steps, success of electroplating or surface conversion, metal surface treatment, work-piece finishing operations, the surface chemistry and processing history, substrate damage removing, rinsing work-piece finishing operations, quenching oil, rust proofing oil, drawing compounds, stamping lubricants, ultrasonic agitation, brush abrasion.

❖ ***Read and translate the following text:***

SURFACE PREPARATION

Electroplating processes will not, as a rule, conceal surface imperfections such as scratches, dents or pits. Actually, the plating process often makes most surface blemishes even more visible. Thus, it is important to remove any undesirable surface marks prior to the plating action.

It is commonly accepted and often quoted by electroplaters that one can make a poor coating perfect with excellent pretreatment, but one cannot make an excellent coating with poor pretreatment.

Success of electroplating or surface conversion depends on removing contaminants and films from the substrate. Organic and nonmetallic films cause poor adhesion and even prevent deposition. The surface contamination can be extrinsic, comprised of organic debris, and mineral dust from the environment or preceding processes. It can also be intrinsic, one example being a native oxide layer.

Most metal surface treatment and plating operations have three basic steps:

- Surface cleaning or preparation. Usually it includes employing of solvents, alkaline cleaners, acid cleaners, abrasive materials, and/or water.
- Surface modification. That includes change in surface attributes, such as application of metal layer and/or hardening.
- Rinsing or other work-piece finishing operations to obtain the final product.

Cleaning methods are designed to minimize substrate damage by removing the film or debris. If the surface chemistry and processing history are known, one can anticipate cleaning needs and methods. Specific residues include lubricants, phosphate coating, quenching oils, rust proofing oils and others. It must be remembered that all metals form oxides and inorganic films. Some of these are protective, such as aluminum oxide formed on aluminum alloys. Some films can even be plated directly over aluminum oxide. On the other hand, some films are nonprotective, such as iron oxide on steel.

The cleaning must account for the fact that surface oxides reform at different rates on various metals. For example, in case of iron or nickel, the oxide reforms slowly enough that the article can be transferred from a cleaning solution to a plating bath at a normal rate. In case of aluminum or magnesium, the oxide reforms very fast, thus special processing steps are required to preserve the metal surface while it is being transferred to electroplating.

Cleaning processes are based on two approaches: physical and chemical cleaning. In physical cleaning mechanical energy is introduced to release contaminants from the surface. Examples are ultrasonic agitation and brush abrasion. In chemical cleaning contaminant films are removed by active materials, dissolved or emulsified in the cleaning solution. Extrinsic contaminants are removed with surface-active chemicals. Intrinsic films are removed with aggressive chemicals that dissolve the contaminant and often react with the surface itself. The energy involved in surface preparation is substantial.

Post-text exercises:

I. Find whether the following statements are true or false, correct the false statements:

1. Electroplating doesn't conceal surface imperfections such as scratches, dents or pits.
2. It is generally known that one can make an excellent coating perform with poor pretreatment.
3. Most surface treatment and plating operations have two basic steps.
4. Success of electroplating depends on removing contaminants from the substrate.
5. In physical cleaning mechanical energy is used to only extrinsic contaminants from the surface.
6. Intrinsic films are removed by surface-active materials.

II. Answer the questions:

1. Why is it important to remove any undesirable surface marks before the plating action?
2. What is often quoted by electroplaters?
3. Why are pretreatment methods used?

4. What are three basic steps of most surface treatment?
5. What does success of electroplating depend on?
6. What are the types of the surface contamination?
7. What approaches are cleaning processes based on?
8. Does electroplating process conceal surface imperfections?

III. Read the text below. Look carefully at each sentence. Some of the sentences are correct but some have a word which should not be there.

1. Most metal surface treatment and plating operations have of three basic steps:
2. Surface cleaning or have preparation. This include employing of solvents, alkaline cleaners, acid cleaners, rain, abrasive materials and water drops.
3. Surface modification group. That includes change in surface attributes, such as like application of metal layer and/or hardening.
4. Rinsing or other work-piece finishing operations to obtain of the final product.

Part 3.3 Industrial Uses Of Electroplating

Before reading:

- ***Learn the following key words from the text:***

purpose	–	цель
processing	–	обработка
steel	–	сталь
chrome-plating	–	хромирование
branch	–	отрасль

- ***Read the following words. Pay attention to their pronunciation.***
  - industry, industrial, automobile, functional, decorative, processing, technological, technique, component, design, multilayer, centimeter, material, special, practitioner, conductivity, corrosion, deposit;
  - aluminum, palladium, nickel, copper.

❖ ***Read and translate the following text:***

INDUSTRIAL USES OF ELECTROPLATING

Electroplating is used in many industries for functional and/or decorative purposes.

Newly developed electrolytes and processing methods are able to provide corrosion prevention. Plain steel or aluminum parts become beautiful when they are electroplated with nickel, chromium or brass. Some well known examples are chrome-plating of steel parts on automobiles. Zinc electroplating and passivation provide a double protection system for steel components.

Technological areas, in which methods of electroplating also constitute an essential component, are all branches of electronics: macro and micro, optics, opto-electronics and sensors.

Electroplating can be used to silver copper or brass electrical connectors, since silver tarnishes more slowly and has a higher conductivity than other metals. Low voltage connectors, used in telecommunications switchgear, computers and other electronic devices, are typically plated with gold or palladium over a layer of nickel.

It should be noted that modern electroplating equips the practitioner with the ability to design the properties of surfaces. Furthermore, the ability to deposit very thin multilayers less than a millionth of a centimeter via electroplating represents a new avenue of producing new materials.

Some special techniques that involve depositing a material on an electrode are anodization, electrowinning, electroextraction, electrogalvanization, gilding, electrotyping, electropolishing.

Post-text exercises:

I. Fill in the blanks:

1. Electroplating is used for______or ______ purposes.
2. Steel or aluminum parts become more beautiful when they are______with nickel, chromium or brass.
3. Electroplating can be used to silver copper or brass electrical_____.

4. The ability to deposit very thin multilayers via______ represents a new avenue of producing new materials.
5. Zinc electroplating and passivation provides a double protection ______ for steel components.
6. It should be noted that modern electroplating equips the practitioner with the ability to _______ the properties of surfaces.

II. Answer the questions:

1. What purposes is electroplating used for?
2. When do plain steel or aluminum parts become beautiful?
3. What can provide corrosion prevention?
4. What do zinc electroplating and passivation provide for steel components?
5. Technological areas in which methods of electroplating also constitute an essential component are all branches of chemistry, aren't they?
6. What special techniques that involve depositing a material on an electrode are mentioned in the text?

Part 3.4 Anodizing

Before reading:

❖ ***Learn the following key words from the text:***

anodizing (anodising), anodization oxide layer	–	анодирование
resistant to corrosion	–	оксидный слой
adherent	–	устойчивый к коррозии
surface	–	плотно прилегающий
pipe crystals of corundum	–	поверхность
pore	–	трубчатые кристаллы корунда
sealing stage	–	пора
dye	–	этап герметизации
	–	краска, красить

❖ ***Read the following words. Pay attention to their pronunciation.***

- electrolytic, process, unique, atmosphere, moderate, protection, natural, discussion, technological, importance, champagne, architectural. Product, microscopic;
- circuit, properties, adherent, porous;
- tin, tantalum, aluminum, hydrogen, oxygen;
- sulfuric, oxide, hydrate, acetate.

❖ ***Give Russian equivalents of the following word combinations:***

The part to be treated; acid solution; direct current; dyeing process.

❖ ***Read and translate the following text:***

ANODIZING

Anodizing (also spelled "anodising", particularly in the UK) or anodization is an electrolytic process to increase the natural oxide layer on certain metals. The process derived its name from the fact that the part to be treated forms the anode of an electrical circuit. Anodizing makes the surface of metals resistant to corrosion. The process is also used to decorate surfaces.

The thickness of the oxide layer and its properties vary greatly depending on the metal, with only the aluminum and tantalum films being of technological importance. We will use aluminum for most of the examples in the discussion of anodizing**.**

Aluminum is unique: when exposed to the atmosphere, it forms a natural oxide layer, which provides moderate protection against corrosion. This layer is strongly adherent because it is chemically bound to the metal surface as compared to oxidation (corrosion) in steel, where rust puffs up and flakes off, constantly exposing new metal to corrosion. The oxide layer produced by anodizing in addition to the natural one is thicker, thus it increases both the hardness and the corrosion resistance of the metal surface.

In anodizing the oxide layer is made by passing a direct current through an acid solution, usually sulfuric, with the aluminum object serving as the anode. The current releases hydrogen at the cathode and oxygen at the surface of the anode, creating a buildup of aluminum oxide.

The oxide forms microscopic hexagonal "pipe" crystals of corundum, each having a central pore (which is also the reason that an anodized part can take on colour in the dyeing process). These pores allow the oxide to grow much thicker than passivating conditions would allow. At the end of the treatment the pores are allowed to close (sealing stage), forming a harder-than-usual (and therefore more protective) surface layer. In fact, it is this porous coating that is considered the product of anodizing.

Conditions, such as acid concentration, solution temperature and current must be controlled so that uniform pores several nanometers wide appear in the metal's oxide film. If this coating is scratched, normal passivation processes protect the damaged area.

Anodizing also allows aluminum to be dyed. The oxide surface can be dyed before the sealing stage, because the dye enters the pores. Alternatively, a metal (usually tin) can be electrolytically deposited in the pores of the coating to provide colours that are more light-fast (resistant to fading). The number of dye colours is almost endless, ranging from pale champagne to black. Bronze shades are preferred for architectural use.

After dyeing the surface is usually sealed by using hot water, sometimes mixed with nickel acetate, to convert the oxide into its hydrated form. This reduces the porosity of the surface as the oxide swells. This also reduces dye fading and can increase corrosion resistance.

Post-text exercises:

I. Complete the sentences:

1. Anodizing is a process used to protect _____.
2. The process derived its name from _____.
3. Aluminum, when exposed to the atmosphere, forms _____.
4. The oxide forms microscopic_____.
5. Hexagonal pores allow the oxide to grow _____.
6. Before _____ the oxide surface can be dyed.
7. Bronze shades are preferred for _____.

II. Answer the questions:

1. What is anodizing?
2. What does aluminum form when exposed to the atmosphere?
3. What qualities does the aluminum oxide coating possess?
4. What is the uniqueness of aluminum?
5. Why is an aluminum passive oxide layer strongly adherent?
6. How is the oxide layer made in anodizing?
7. Why does anodizing increase both the hardness and the corrosion resistance of the metal surface?
8. How is anodizing used to decorate surfaces?
9. Why is the sealing stage necessary?

III. Discuss the following statements:

- anodizing is an electrolytic process;
- the uniqueness of aluminum;
- conditions such as acid concentration, solution temperature and current must be controlled;
- anodizing allows aluminum to be dyed;
- after dyeing the surface is usually sealed.

Part 3.5 Electrowinning and Electrorefining

Before reading:

❖ ***Learn the following key words from the text:***

win the metal – извлекать металл из руды
electrowinning – электровыделение, электрохимическое извлечение металла из руды
electroextraction – электровыделение электрохимическое извлечение металла из руды
electrorefining – электролитическая очистка, электроочистка
purification – очистка
ore – руда
impurity – примесь

molten salt	–	расплавленная соль
deposit	–	осаждаться
flat-plate cathode	–	пластинчатый, плоский катод
reticulated cathode	–	сетчатый катод
anode sludge/anode slime	–	анодный шлам, осадок

❖ ***Read the following words. Pay attention to their pronunciation.***

- production, process, industrially, commercially, nature, naturally, aqueous, electrolyzed, technique, conductive, electrolyte, original;
- refining, unrefined, electrowon, procedure, nonferrous, reticulated, recycling, to purify;
- copper, lead, molybdenum, cadmium, cobalt, zinc, platinum arsenic, aluminum, chromium, manganese, plutonium, cesium strontium;
- alkali, alkaline, sulfides, sulfidic, oxidized, acidic.

❖ ***Read and translate the following text:***

ELECTROWINNING AND ELECTROREFINING

The process of extracting a metal from an ore is known as winning the metal. The process of purification of a metal that has been extracted from the ore is called refining.

Electrowinning and electrorefining (different parts of the same procedure) are techniques that allow extraction and purification of nonferrous (noniron-based) metals. Electrowinning, also called electroextraction, is the use of electrolysis to separate metals from their ores. The resulting metals are said to be electrowon. Electrorefining uses a similar process to remove impurities from a metal.

The most common electrowon metals are lead, copper, gold, silver, zinc, aluminum, chromium, cobalt, manganese, the rare-earth metals, and alkali(ne) metals. For aluminum this is the only practically used production process. Several industrially important active metals (which react strongly with water) are produced commercially by electrolysis of their pyrochemical molten salts.

Most metals occur in nature in oxidized form in their ores and thus must be reduced to their metallic forms. In electrowinning the ore is dissolved in an aqueous electrolyte or in a molten salt and the resulting solution is electrolyzed. The metal is extracted as it is deposited at the cathode, while the anodic reaction is usually oxygen evolution.

Several metals are naturally present as metal sulfides; these include copper, lead, molybdenum, cadmium, nickel, silver, cobalt, and zinc. In addition, gold and platinum group metals are associated with sulfide base metal ores. Most metal sulfides or their salts are electrically conductive and this allows electrochemical redox reactions to occur efficiently in the molten state or in aqueous solutions. Some metals, including arsenic and nickel, do not electrolyze out but remain in the electrolyte solution, these are then reduced by chemical reactions to refine the metal.

Because metal deposition rates are related to available surface area, maintaining properly working cathodes is important. Two cathode types exist: flat-plate and reticulated, each having its own advantages. Flat-plate cathodes can be cleaned and reused, and plated metals recovered. Reticulated cathodes have a much higher deposition rate compared to flat-plate cathodes. However, they are not reusable and must be sent off for recycling.

In electrorefining the anodes consist of unrefined impure metal and as the current passes through the acidic electrolyte the anodes are corroded into the solution and refined pure metal is deposited on the cathodes.

Electrorefining is the least expensive way to purify metals because it produces a pure metal in just one step. Another benefit of electrorefining is that after the process for the original target metal is complete, there might be valuable "leftovers." For example, after electrorefining copper, there are usually tiny amounts of silver and gold, released from the anode but which are not deposited at the cathode. These metals sink to the bottom of the electrolytic cell, where they form a substance called "anode sludge" or "anode slime". The gold and silver can be collected and purified, although they need to go through more steps.

Many electrowinning and electrorefining systems are available to remove toxic (and sometimes valuable) metals from industrial wastes. Experiments using electrowinning and electrorefining to process waste nuclear fuel and to separate such metals as plutonium, cesium and strontium have been carried out.

Post-text exercises:

I. Answer the questions:

1. What is electrowinning?
2. What other term does electrowinning have?
3. What are the most common electrowon metals?
4. In what form do the most metals occur in nature?
5. What metals are naturally present as metals sulfides?
6. What metals don't electrolyze out?
7. What are the two cathode types?
8. What is the difference between flat and reticulated cathodes?
9. Why is electrorefining the least expensive way to purify metals?
10. What other uses of electrowinning and electrorefining systems are mentioned in the text?

II. Complete the sentences:

1. The process of ______ is called refining.
2. Electrowinning is the use of electrolysis to______.
3. The most common electrowon metals are _______.
4. In electrowinning the ore is ______.
5. Gold and platinum group metals are associated with ______.
6. Another benefit of electrorefining is that _______.
7. Experiments using electrowinning and electrorefining to process ______ have been carried out.

III. Add some information to the following statements:

- electrowinning and electrorefining are techniques that allow extraction and purification of nonferrous (noniron-based) metals;
- several metals are naturally present as metal sulfides; these include copper, lead, molybdenum, cadmium, nickel, silver, cobalt and zinc;
- electrorefining is the least expensive way to purify metals;

- after electrorefining copper, there are usually tiny amounts of silver and gold.

UNIT 4 ELECTROCHEMISTRY AND CORROSION

Part 4.1 Electrochemical Corrosion

Before reading:

❖ ***Learn the following key words from the text:***

corrosion	–	коррозия
corrode	–	ржаветь, подвергаться коррозии, корродировать
environment	–	окружающая среда
environmental conditions	–	условия окружающей среды
rust	–	ржавчина, ржаветь
site	–	участок
corrosion cell	–	коррозионная ячейка
promote corrosion	–	ускорять (стимулировать) коррозию
prevention of corrosion	–	предотвращение коррозии

❖ ***Read the following words. Pay attention to their pronunciation.***

- corrosion, material, chemical, tendency substance, type, typically, original, metallic, nature, component, ionic, atmospheric, process, product, mineral, mechanism, ionic, physical, distance, microscopic, meter, natural, normal, thermodynamically, spontaneously, aqueous;
- rusting, gradual, destruction, primarily, environment, environmental, either, occur, considerable, salt, oxidizer, square, soluble, insoluble.

❖ ***Read and translate the following words paying attention to their formation:***

- to corrode – corroding – corrosion;
- to conduct – conductive – conductor – conduction

❖ ***Read and translate the following text:***

INTRODUCTION AND OVERVIEW OF ELECTROCHEMICAL CORROSION

Corrosion is the gradual destruction of material by chemical reaction with its environment. All materials are susceptible to corrosion but it is primarily associated with metals.

Corrosion of metals results from their overwhelming tendency to react with oxygen, water and other substances. This type of damage produces oxides or salts of the original metal. Rusting, the formation of iron oxides, is a well-known example.

Metallic corrosion is electrochemical in nature. In common sense of the word corrosion means electrochemical oxidation of metals. The chemical component of corrosion involves the combination of water ions, oxygen and other negatively charged ions with positively charged ions to form an oxide. The electrical component of corrosion involves the movement of electrons across a metal surface like electricity flowing in a copper wire.

The metallic surface usually possesses "sites" for oxidation and reduction. A typical situation is when a piece of metal has anodic and cathodic sites on the same surface. If the surface becomes wet, corrosion may take place through ionic exchange in the surface water layer between the anode and cathode. These sites make up an electrochemical "corrosion cell". In addition to the surface oxidation, any two dissimilar metals placed in contact with one another and with an electrolyte (such as atmospheric moisture or water) will form a corrosion cell as well.

Every electrochemical corrosion cell must have four components:

1) the anode, which is the metal part that is corroding;

2) the cathode, which is the metal, whose surface provides sites for the environment to react;

3) the electrolyte (the aqueous environment) in contact with both the anode and the cathode to provide a path for ionic conduction.

4) the electrical connection between the anode and the cathode to allow electrons to flow between them.

Corrosion processes involve at least two electrochemical reactions. The dissolution of the anode metal to form either soluble ionic products or insoluble corrosion products is an anodic or oxidation reaction. The cathodic or reduction reaction consumes the electrons generated by the anodic reaction.

Since electrochemical corrosion involves the release of ions to the environment and movement of electrons within the material, this mechanism can occur only if the environment can contain ions and the material can conduct electrons. Metals are conductive, so the electrons can flow through the metal from the anodic to the cathodic regions. The electrical connection is made by a conductor between the two physical sites, which are often separated by very small distances.

The areas, over which the anodic and cathodic reactions occur, vary greatly and may extend from microscopic areas to hundreds of square meters.

Corrosion of most metals is inevitable. Under normal environmental conditions, the thermodynamically stable states of most metals are the cations, rather than the metal itself. This is the reason that considerable energy must go into the extraction of a metal from its ore. However, once the metal is extracted, it tends to spontaneously revert back to its previous, more stable form. To do so, the metal must lose electrons, and this requires the presence of an electron acceptor or oxidizing agent. In other words, metals have a strong driving force to return to the native, low energy oxide state. This return to the oxide state is what we call corrosion. For example, gold and silver can be found in the earth in their natural, metallic state and they have little tendency to corrode. Iron is a moderately active metal and corrodes readily in the presence of water. The natural state of iron is iron oxide (Fe_2O_3). Rust also has a chemical composition of Fe_2O_3.

The most prominent oxidizer is oxygen, but hydrogen ions and the cations of any more "noble" metal also promote corrosion. Dissolved salt and other minerals in water accelerate the rate of corrosion.

Atmospheric air is the most common environmental electrolyte, but seawater, rain, as well as man-made solutions, are the environments most frequently associated with corrosion problems.

Prevention of corrosion includes: proper material selection, change of the environment, cathodic protection.

Post-text exercises:

I. Fill in the blanks:

1. All materials are susceptible to ___ but it is associated with metals.
2. Metallic corrosion is _______ in nature.
3. The metallic surface usually possesses "sites" for ______ and reduction.
4. Corrosion processes involve at least two ______ reactions.
5. ______ and ______ can be found in the earth in their natural, metallic state and they have little tendency to corrode.
6. Atmospheric air is the most common _____ electrolyte.
7. Corrosion of most metals is______.

II. Find whether the following statements are true or false, correct the false statements:

1. Corrosion is the destruction of metal by the effect of water, chemicals, etc.
2. Corrosion of metals does not result from their tendency to react with oxygen, water and other substances.
3. The metallic surface usually possesses "holes" for oxidation and reduction.
4. These sites make up an electrochemical "corrosion cell".
5. Corrosion processes involve at least one electrochemical reaction.
6. The most prominent oxidizer is hydrogen, but oxygen ions and the cations of any more "noble" metal also promotes of corrosion.

II. Answer the questions:

1. What does corrosion in common sense of the word mean?
2. Describe the chemical and electrical components of corrosion.
3. What does the corrosion of metals result from?
4. If the surface becomes wet, how can corrosion take place?
5. Name the components of the corrosion cell.
6. What types of products are formed at the anode metal as the result of oxidation reaction?
7. What does the cathode of the corrosion cell provide?
8. Why is corrosion of most metals inevitable?

9. How do we call the return of metals to the native oxide state?
10. What strong oxidants and promoters of corrosion do you know?

Part 4.2 Passivity

Before reading:

❖ ***Learn the following key words from the text:***

passivation/passivity	–	пассивация, пассивирование
layer	–	слой
passive film	–	пассивный (пассивационный) слой
stainless steel	–	нержавеющая сталь
protective	–	защитный
bring on passivation	–	вызывать пассивацию
concrete	–	бетон
breakdown (breaching) of passivity	–	разрушение пассивного слоя
repassivation		
resist corrosion	–	репассивация, повторная пассивация
	–	не поддаваться коррозии

❖ ***Read the following words. Pay attention to their pronunciation.***

- barrier, microstructure, micrometer, specific, factor, temperature, normally, concrete, liquid, mechanism, mechanical, nature;
- further, alloy, influential, environment, exposure, species, metal, localized;
- aluminum, titanium, silicon, mercury;
- alkaline, chloride ions, fluoride ions.

❖ ***Read and translate the following text:***

PASSIVATION

Passivation or passivity is the spontaneous formation of a layer of corrosion products, known as passive film, on the metal's surface that acts as a barrier to further oxidation. The chemical composition and microstructure of a passive film are different from the underlying metal. The layer stops growing at less than a micrometer thick. This effect is in some sense a property of the material. Passivation is seen in aluminum, stainless steel, titanium, and silicon. A passive film must provide a protective barrier so that the extent of corrosion damage is minimized. Rust of iron is not considered passivation and is not protective anyway.

The conditions required for passivation are specific to the material, but many other factors are influential. Some conditions that inhibit passivation include: high pH for aluminum, low pH or the presence of chloride ions for stainless steel, high temperature for titanium and fluoride ions for silicon. On the other hand, sometimes unusual conditions can bring on passivation in materials that are normally unprotected, as the alkaline environment of concrete does for steel rebar. Exposure to a liquid metal such as mercury or hot solder can often circumvent passivation mechanisms.

Breakdown (or breaching) of passivity leads to the formation of localized corrosion. It causes the disruption of the passive film and thus exposes discrete unprotected sites on the metal surface to the environment. Two types of breakdown process exist: chemical and mechanical. The nature of chemical breakdown is poorly understood. Mechanical breakdown occurs when passive film is ruptured as a result of stress or abrasive wear. It should be noted that each of these breakdown types involves damaging species. Chloride ion, abundantly available in nature, is one of them.

Fortunately, competing with the breakdown there is the repair process – repassivation.

Thus, a metal or an alloy that effectively resists corrosion would be the one, whose surface not only forms a passive film, but also strongly resists its breakdown and is capable of repassivation. For example, aluminum has excellent corrosion resistance due to the barrier oxide film that is bonded strongly to the surface and, if damaged, reforms immediately.

The breakdown-repassivation process is involved in many but not all of the various types of corrosion.

Post-text exercises:

***I. Answer the questions*:**

1. What is understood by passivation?
2. What must a passive film provide to be effective?
3. In what metals is passivation seen?
4. Why is rust of iron not considered passivation?
5. What conditions required for the passivation are important?
6. The breakdown-repassivation process is involved in many various types of corrosion, isn't it?
7. What is the negative effect of the breakdown processes?
8. Name the types of breakdown processes. Describe briefly each of them.
9. What is one of the major species causing breakdown of the passivity?
10. Why is aluminum given as an example of a corrosion resistant metal?

II. Match the English word-combinations:

1. spontaneous	a) metal
2. chemical	b) species
3. underlying	c) film
4. passive	d) composition
5. corrosion	e) resistance
6. damaging	f) formation

Ill. Match the endings of the sentences:

1. Two types of breakdown process exist:
2. Passivation is seen in the materials such as
3. To be effective, a passive film must provide
4. Breakdown processes lead to
5. Aluminum has excellent

a) corrosion resistance
b) aluminum, stainless steel, titanium.
c) formation of localized corrosion
d) chemical and mechanical.
e) a protective barrier

Part 4.3 Cathodic Protection

Before reading:

❖ ***Learn the following key words from the text:***

cathodic protection – катодная защита
galvanic cathodic protection system – гальваническая катодная защита
impressed current cathodic protection system – катодная защита с посторонним (внешним) источником тока
sacrificial anode – "жертвенный" анод, протектор
sacrificial anode cathodic protection system – протекторная катодная защита
electromotive (force) series of metals – электрохимический ряд напряжений (ряд активности) металлов
outside power – внешний источник питания
external power source – внешний источник питания

❖ ***Read the following words. Pay attention to their pronunciation.***

- potential, corrosive, contact, function, regular, basis, structure, system;
- procedure, protection, current, sacrificial, enhance, advantage, disadvantage, maintenance, require, supply, external, source, electromotive series.

❖ ***Read and translate the following text:***

CATHODIC PROTECTION SYSTEMS

Cathodic protection is a procedure used to protect an object from corrosion by making it the cathode of the corrosion cell. Its principle is:“Supplying electrons to the base material.”

There are two main types of cathodic protection systems: galvanic and impressed current. Both systems supply electrons to the metal, which will become more negative and its dissolution will be prevented.

Galvanic cathodic protection system makes use of the corrosive potentials of different metals. A metal to be protected is coupled to a piece of another, more easily corroded metal to act as the anode. The latter corrodes instead of the protected metal and is called a sacrificial anode. Thus, this type of protection is also called a sacrificial anode cathodic protection system**.**

To understand the action of sacrificial anodes for cathodic protection, it is necessary to have in mind the electromotive (force) series of metals. According to their inherent reactivity metals are ranked in the electromotive force series. The most noble metal is at the top and has the highest positive electrochemical potential. The most active metal is at the bottom and has the most negative electrochemical potential. When the tendency for metal to go into solution as metal ions increases (leaving an excess of electrons on the metal surface), the metal becomes more electronegative. Thus, since zinc, aluminum, and magnesium are more electronegative than steel, they are increasingly able to supply electrons to the more electropositive steel when are in electrical contact in water, and will effect cathodic protection of the steel surface. Clearly, if steel were coupled to copper in the sea water, steel would supply electrons to copper which would become cathodically protected, and the corrosion of the steel would be enhanced.

An advantage of sacrificial anode systems is the flexibility in application. Anodes can be installed in a variety of configurations. No outside power is required for cathodic protection to be effective. Another advantage is the minimal maintenance required for these systems to function. Disadvantages of sacrificial anode systems include the limited protection current available and limited life. Anodes can lose their activity and become passivated, developing a non-conducting film on their surfaces so that they are no longer able to supply current. Sacrificial anodes are subject to rapid corrosion and require replacement on a regular basis.

Impressed current cathodic protection systems use the same elements as the galvanic protection system, but the structure is protected by applying a current to it from an anode. As for the galvanic system, the anode and the structure are connected by an insulated wire. The main difference between galvanic and impressed current systems is that the galvanic system relies on the difference in potential between the anode and the structure, whereas the impressed current system uses an external power source to drive the current.

Cathodic protection systems are used to protect a wide range of metallic structures in various environments. Common applications are: marine structures, underground pipelines, water heaters and reinforcement bars in concrete.

Post-text exercises:

I. Fill in the blanks:

1. There are two main types of cathodic protection systems: _______ and _______.
2. A galvanic cathodic protection system makes use of the _______ of different metals.
3. An advantage of sacrificial anode systems is the ______ in application.
4. Anodes can be installed in a variety of ______.
5. Cathodic protection systems are used to _______ a wide range of metallic structures in various environments.
6. Disadvantages of sacrificial anode systems include the _______ protection current available and limited life.
7. Sacrificial anodes are subject to rapid _______ and require replacement on a _______ basis.

II. Answer the questions:

1. Why is cathodic protection used?
2. What are the main types of cathodic protection systems?
3. Describe the action of the galvanic cathodic protection system.
4. Why is galvanic system called sacrificial anode protection system?
5. How are metals ranked in electromotive series?
6. What is the role of electromotive series of metals in cathodic protection mechanism?
7. What is the main difference detween galvanic and impressed current systems?
8. What are advantages and disadavantages of
    - galvanic system ?
    - impressed current systems?

LIST OF CHEMICAL ELEMENTS

Name of element	*Transcription*	*Russian name*
Aluminum	[ə'lu:mɪnəm]	алюминий
Arsenic	['ɑːs(ə)nɪk]	мышьяк
Cadmium	['kædmɪəm]	кадмий
Carbon	['kɑːb(ə)n]	углерод
Cesium	['si:zɪəm]	цезий
Chlorine	['klɔːri:n]	хлор
Chromium (Chrome)	['krəumɪəm] [krəum]	хром
Cobalt	['kəubɔːlt]	кобальт
Copper	['kɔpə]	медь
Hydrogen	['haɪdrəʤən]	водород
Iron	['aɪən]	железо
Lead	[led]	свинец
Magnesium	[mæg'ni:zɪəm]	магний
Manganese	['mæŋgəni:z, mæŋgə'ni:z]	марганец
Mercury	['mɜːkj(ə)rɪ, 'mɜːkjurɪ]	ртуть
Molybdenum	[mə'lɪbdənəm]	молибден
Nickel	['nɪkl]	никель
Oxygen	['ɔksɪʤən]	кислород
Palladium	[pə'leɪdjəm]	палладий
Platinum	['plætɪnəm]	платина
Silicon	['sɪlɪkən]	кремний
Sodium	['səudɪəm]	натрий
Strontium	['strɔntɪəm]	стронций
Sulfur	['sʌlfə]	сера
Tantalum	['tænt(ə)ləm]	тантал
Titanium	[tɪ'teɪnɪəm, taɪ'teɪnɪəm]	титан
Zinc	[zɪŋk]	цинк

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