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BASICS OF ANALYTICAL CHEMISTRY

Учебное пособие
по профессиональному английскому языку

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Учебное пособие включает одиннадцать тем по аналитической химии, содержащих тексты по специальности. Целью пособия является формирование уровня иноязычной профессионально-ориентированной коммуникативной компетенции, который позволяет использовать английский язык как средство общения на уровне международных требований для продолжения образования и в профессиональной деятельности в условиях глобализации рынка интеллектуального труда.

Пособие подготовлено на кафедре европейских языков совместно с кафедрой ХТРЭ и предназначено для студентов старших курсов и аспирантов химических специальностей.

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Предисловие

Данное учебное пособие по профессиональному английскому языку «Основы аналитической химии» предназначено для работы со студентами старших курсов и аспирантов химических специальностей.

Целью пособия является формирование уровня иноязычной профессионально-ориентированной коммуникативной компетенции, который позволяет использовать английский язык как средство общения на уровне международных требований для продолжения образования и в профессиональной деятельности в условиях глобализации рынка интеллектуального труда.

Уникальность пособия состоит в том, что оно содержит аутентичные тексты по аналитической химии и проблемные задачи. Разговорная практика в специальном курсе построена, в основном, с опорой на схемы и тексты по данной тематике. Структура пособия позволяет гибко варьировать формы работы, вовлекая обучающихся в дискуссии «преподаватель - группа», организуя работу студентов в парах, а также стимулируя монологические высказывания.

Учебное пособие состоит из разделов, включающих работу над грамматикой, расширением потенциального словаря, развитием навыков чтения, говорения и письма, а также предполагает выполнение студентами заданий по аннотированию, реферированию, презентации научных статей и решение задач по аналитической химии на английском языке. Пособие позволяет использовать полученные студентами знания для самостоятельной подготовки устных сообщений, докладов, презентаций по темам или проблемам профессионального характера. В конце пособия приложен терминологический словарь с объяснением значений основных терминов, применяемых в аналитической химии, что помогает студентам лучше понять те явления, которые рассматриваются в учебном пособии.

Опыт преподавания по данному пособию показал, что после проработки всех его разделов студенты не только читают и переводят оригинальную литературу, но и могут подготовить сообщения и выступления по прочитанному источнику на английском языке, выступить с докладом на конференции и сделать презентацию.

Авторы выражают благодарность рецензентам, замечания которых помогли существенно улучшить данное пособие.

Авторы

UNIT 1
Subject of Analytical Chemistry
Grammar: Passive Voice

1. Warm-up:
Before reading the passage ask students of your group their opinions on some aspects of analytical chemistry.

- *What do you think of analytical chemistry?*
- *Is it useful for people? Why?*
- *What does analytical chemistry deal with?*

2. Study the meanings of the following words and think of the sentences with these words.

deal with, v	do business with (II, III form - dealt)
branch, n	subdivision, section
quality, n	attribute, characteristic, property, degree of excellence
quantity, n	number, amount, specified or considerable amount
up-to-date, adj	new, advanced, modern
technique, n	[te'kni:k], method of performance
interaction, n	contact, relations, co-operation between particles
obtain, v	to get, to acquire, to receive, to succeed in doing smth
cutting edge	forefront, front position
currently, adv	at present, now
instance, n	example; particular case; v - to illustrate, to exemplify.
oxidation number, n	numerical quantity of electrostatic charge assigned to a molecule atom.
oxidation, n	the process of increasing the oxidation number.
reduction, n	the process of decreasing the oxidation number.
oxidizing agent, n	(An acceptor of electrons) it gains electrons and it is said to be reduced by the reducing agent.
reducing agent, n	(a donor of electrons) it looses electrons and it is said to be oxidized by the oxidizing agent.

REDOX reaction, n	process of the transfer from reducing agent to oxidizing agent.
forensic, adj	relating to scientific tests used to help with laws.
fertilizer, n	[fWtaI'laIzq], natural or artificial substance added to soil to make it more fertile (that can produce good crops).
contaminant, n	that makes smth. impure.
residue, n	['rezidjH], a small amount of smth that remains after the main part is taken or used
blood, n	[blAd], the red liquid flowing through the bodies of humans and animals.
disease, n	[dI'zJz], illness of the body.
defendant, n	a person accused in a crime.
efficacy, n	['efIkqsI], the state or quality of being effective.
precipitate, n	[prI'sIpItqt], substance chemically precipitated
fingerprint, n	a mark made by the lower surface of the tip of the finger used for identifying people.
ban, v	to forbid to do smth officially.
diuretic, n	[dalju'retIk], a substance causing an increase in the flow of urine.
analgesic, [xnqlGJsIk], n sedative , n anesthetic, n	substances that relieve pain
immunoassay, n	immune-analysis
elution, n	extraction from adsorbent, washout.
craft, n	skill
routine	[ru:'tJn], regular course: regularity or procedure
appropriately, adv	suitably, correctly, fittingly
feasibility, n	practicality

3. Skim the passage and answer the following questions using the information from the text or from any other sources. Ask your partners about these problems.

- *What does analytical chemistry concern with?*
- *What do all chemists routinely make?*
- *What is one of the distinctions between analytical chemistry and chemical analysis?*
- *Is analytical chemistry a separate branch of chemistry?*
- *What role does analytical chemistry play in our life?*
- *Is it important to know about chemical composition of various substances? Why?*
- *What fields of application of analytical chemistry are mentioned in the text?*

WHAT IS ANALYTICAL CHEMISTRY?

We begin this section with a simple question: what is analytical chemistry? Like all fields of chemistry, analytical chemistry is too broad and active discipline for us to easily or completely define in an introductory textbook. Instead, we try to say a little about what analytical chemistry is, as well as a little about what analytical chemistry is not. Analytical chemistry is often described as the branch of chemistry responsible for characterizing the composition of matter, both qualitatively (what is present) and quantitatively (how much is present). This description is misleading. After all, almost all chemists routinely make qualitative and quantitative measurements. The argument has been made that analytical chemistry is not a separate branch of chemistry, but simply the application of chemical knowledge.

In fact you probably have performed quantitative and qualitative analyses in other chemistry courses. For example, many introductory courses in chemistry include qualitative schemes for identifying inorganic ions and quantitative analyses involving titrations. Unfortunately, this description ignores the unique perspective that analytical chemists bring to the study of chemistry. The craft of analytical chemistry is not in performing a routine analysis on a routine sample (which is more appropriately called chemical analysis), but in improving established methods, extending existing methods to new types of samples, and developing new methods for measuring chemical phenomena.

Here is one example of this distinction between analytical chemistry and analytical analysis. Mining engineers evaluate the economic feasibility of extracting an ore by comparing the cost of removing the ore with the value of its contents. To estimate its value they analyze a sample of the ore.

4. Fill in the gaps with appropriate word(s) from a box given below.

ANALYTICAL OBJECTIVES OR WHAT ANALYTICAL CHEMISTS DO

Analytical chemistry concerns with the chemical characterization of matter. Chemicals make up everything we use or consume, and knowledge of the chemical composition of many substances is important in our daily lives. Analytical chemistry plays an important role in nearly all aspects of chemistry, for example, agricultural, clinical, environmental, 1)…*(relating to scientific tests used to help with laws)*, manufacturing, metallurgical, and pharmaceutical chemistry. The nitrogen content of a 2) *…(that can produce good crops)* determines its value. Foods must be analyzed for 3)…*(that makes smth impure) (*e.g. pesticide residues) or vitamin content. The air in cities must be analyzed for carbon monoxide. 4) *…(the red liquid flowing through the bodies of humans)* glucose must be monitored in diabetics (and, in fact, most diseases are diagnosed by chemical analysis). The presence of trace elements from a gun powder on a murder 5)… *(a person accused in a legal cast)* hand will prove a gun was fired. The quality of manufactured products often depends on proper chemical proportions, and measurement of the constituents is a necessary part of quality control. The carbon content of steel will determine its quality. The purity of drugs will determine their 6)…. *(quality of being effective).*

fertilizer	blood	defendant's	contaminant	efficacy	forensic

Oral Practice

5. Work in pairs.
Make up a dialogue about objectives and necessity of analytical chemistry.

6. Read the following passage carefully and find answers to the following questions.

- *What is the difference between qualitative analysis and the quantitative one?*
- *Which kind of these analyses is more important for people? Give reasons for your opinion.*
- *Where is the quantitative analysis applied?*

QUALITATIVE AND QUANTITATIVE ANALYSIS

The discipline of analytical chemistry consists of qualitative analysis and quantitative analysis. The former deals with the identification of elements, ions, or compounds present in a sample (we may be interested in whether only a given substance is present), while the latter deals with the determination of how much of one or more constituents is present. The sample may be solid, liquid, or gas. The presence of gunpowder residue on a hand generally requires only qualitative knowledge, not of how much is there, but the price of coal will be determined by the percent of sulfur impurity present.

Qualitative tests may be performed by selective chemical reactions or with the use of instrumentation. The formation of a white precipitate when adding a solution of silver nitrate to a dissolved sample indicates the presence of chloride. Certain chemical reactions will produce colors to indicate the presence of classes of organic compounds, for example, ketones. Infrared spectra will give "fingerprints" of organic compounds or their functional groups.

For quantitative analysis, a history of the sample composition will often be known (it is known that blood contains glucose), or else the analyst will have performed a qualitative test prior to performing the more difficult quantitative analysis. Modern chemical measurement systems often exhibit sufficient selectivity that a quantitative measurement serves as a qualitative measurement. However, simple qualitative tests are usually more rapid than quantitative procedures.

Qualitative analysis is composed of two fields: inorganic and organic. The former is usually covered in introductory chemistry courses, whereas the latter is best left until after the student has had a course in organic chemistry.

In comparing qualitative versus quantitative analysis, consider, for example, the sequence of analytical procedures followed in testing for banned substances at the Olympic Games. The list of prohibited substances includes about 500 different active constituents: stimulants, steroids, beta-blockers, diuretics, narcotics, analgesics, local anesthetics, and sedatives. Some are detectable only as their metabolites. Many athletes must be tested rapidly, and it is not practical to perform a detailed quantitative analysis on each. There are three phases in the analysis: the fast-screening phase, the identification phase, and possible quantification. In the fast-screening phase, urine samples are rapidly tested for the presence of classes of compounds that will differentiate them from "normal" samples. Various techniques include immunoassays, gas chromatography, and liquid chromatography. About 5% of the samples can indicate the presence of unknown compounds that may or may not be prohibited but need to be identified. Samples showing a suspicious profile during the screening undergo a new preparation cycle (possible hydrolysis, extraction), depending on the nature of the compounds that have been detected. The compounds are then identified using the highly selective combination of gas chromatography/mass spectrometry (GC/MS). In this technique, complex mixtures are separated by gas chromatography and they are then detected by mass spectrometry, which provides molecular structural data on the compounds. The MS data, combined with the time of elution from the gas chromatograph, provide a high probability of the presence of a given detected compound. GC/MS is expensive and time consuming and so it is used only when necessary. Following the identification phase, some compounds must be precisely quantified since they may normally be present at low levels, e.g., from food, pharmaceutical preparations, or endogenous steroids, and elevated levels must be confirmed. This is done using quantitative techniques such as spectrophotometry or gas chromatography. This text deals principally with quantitative analysis. In the consideration of applications of different techniques, examples are drawn from the life sciences, clinical chemistry, environmental chemistry, occupational health and safety applications, and industrial analysis.

7. Look through the text once more. From the five titles presented below choose the one which expresses better the main idea of the text. Explain your choice.

- *the identification of elements*
- *simple qualitative tests*
- *the fast-screening phase*
- *the identification phase*
- *possible quantification*

8. Put questions to the text given above and ask your group-mates.

9. State whether the information below true or false.

- *Analytical chemistry does not concern with chemical characterization of matter.*
- *Blood glucose must be monitored in diabetics.*
- *Analytical chemistry deals with the identification of elements.*
- *Qualitative tests may not be performed by selective chemical reactions.*
- *Analytical chemistry is not used by policemen.*

10. Read the following text and say what problems are discussed here, then find the facts supporting your idea.

TECHNIQUES

There are many techniques of materials analysis. They are all based on interaction of material and energy. This interaction permits obtaining a signal that is then detected and processed for further information.

The types of analysis techniques conform to various types of energy:

Spectroscopic analysis

Spectroscopic methods of analysis deal with interaction of the analytical samples and electromagnetic radiation.

Electrochemical analysis

Electrochemical methods of analysis deal with interaction of material and an electric field.

Mass analysis

Mass or gravimetric methods of analysis are based on the interaction of material and a gravity field.

The given method makes it possible to apply both gravity forces and electromagnetic fields, for instance mass spectrometry. This method is based on the interaction of analytical sample with electric and magnetic fields.

Thermal analysis

For example, calorimetric and thermogravimetric analyses, which deal with interaction of material and heat.

The detection and analysis of multiple simultaneous signals is the subject of cutting-edge research in analytical chemistry. In order to utilize the techniques available currently, complex material mixtures must be separated into simpler samples for individual analysis.

Overall scheme of analytical methods of analysis is given in Fig. 1.

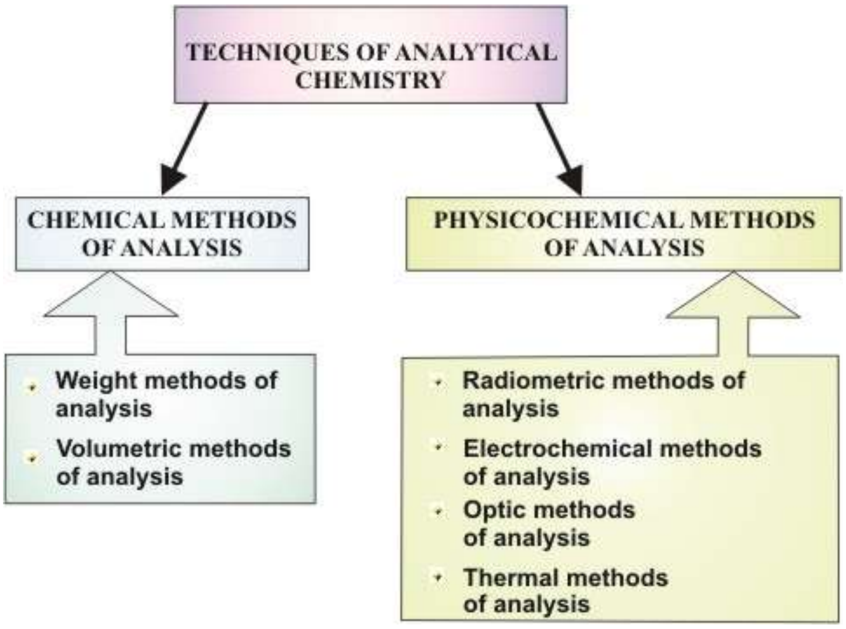


Fig. 1. Techniques of analytical chemistry

11. Tell about the difference between chemical and physicochemical methods of analysis.

12. Look at the scheme and say a few words about each of the methods posed by the authors (What are they based on? What is the purpose of their measurements?).

13. Read the following sentences and then define what method of analysis they refer to. Fill in the table below with the corresponding numbers.

- *1. The given method of analysis makes it possible to define the weight content of the element in the substance.*
- *2. In this method of analysis the devices are used for measuring the heat quantity.*
- *3. In the course of the given analysis it is necessary to carry out thorough ashing of the filtered material on the filter paper.*
- *4. In this method the qualitative analysis is carried out by eliminating the radioactive radiation spectrum.*
- *5. The set of the given method is based on the interaction of the light flux and the analytical material.*
- *6. The present method of analysis uses a redox chemical reaction and a titration process without using the additional equipment.*
- *7. The given method of analysis uses the group of electrodes, through which the exterior influence of a quantity of electricity on the analytical sample is applied.*

Chemical methods of analysis	
Physico-chemical methods of analysis	

14. Skim the following passage and answer the questions below.

- *What do analytical methods rely on?*
- *Where do chemists keep their glassware?*
- *What does a standard method for analysis of concentration involve?*

APPLICATION OF TECHNIQUES IN ANALYTICAL CHEMISTRY

Analytical methods rely on scrupulous attention to cleanliness, sample preparation and accuracy.

Many practitioners keep all their glassware in an acid and analytical equipment should be washed in special pure solvents to prevent sample contamination.

A standard method for analysis of concentration involves plotting a calibration curve.

If the concentration of element or compound in a sample is too high for the detection range of the technique, it can simply be diluted in a pure solvent. If the amount in the sample is below an instrument range of measurement, the method of addition can be used. In this method a known quantity of the element or compound under study is added, and the difference between observed total concentration of solution and concentration added is the actual amount in a sample.

PUBLIC OPINION POLL

15. Which of the things on the list do you think could be areas where analytical methods could be applied?

Branch of science/technology	Spectroscopic analysis	Mass analysis	Thermal analysis
Nuclear energy			
Biotechnology			
Genetic engineering			
Space exploration			
Agriculture astrology			
Medical research			
Control and reduction of pollution			
Robotics			
Information technology			
T o t a l			

16. Discuss the results of the public opinion poll in the class. Give reasons for your opinion.

GRAMMAR REVISION
The Passive Voice

To be +V_3 (V_{ed})

	Simple	Continuous	Perfect
Present	I am asked/sent	I am being asked/sent	I have been asked/sent
Past	I was asked/sent	I was being asked/sent	I had been asked/sent
Future	I shall be asked/sent	–	I shall have been asked/sent

1. In the following sentences the verbs are given in the Passive Voice. Rewrite these sentences using the verbs in the Active Voice.

1).The purity of drugs is determined by their efficacy. 2). Qualitative tests may be performed by selective chemical reactions. 3). Presence of classes of organic compounds is indicated by the certain chemical reactions. 4).The compounds are identified using the highly selective combination of gas chromatography/ mass spectroscopy. 5). "Fingerprints" of organic compounds or their function groups are given by infrared spectra. 6) Much has been written about this in the press. 7) The experiment has been carried out successfully. 8) The important document has been found at last. 9) Electrons have been spoken of as moving in orbits about the atomic nucleus. 10) It had been already mentioned that many of the elementary gases could exist in diatomic molecules.

2. Choose a suitable phrase in column "B" to accompany the passive constructions in column "A" and translate the sentences into Russian.

A	B
1. Food must be analyzed	a) for carbon monoxide
2. The air in the cities must be analyzed	b) in diabetics
3. Blood glucose must be monitored	c) by chemical analysis
4. Most diseases must be diagnosed	d) by selective chemical reactions
5. Qualitative tests may be performed	e) for contaminants or vitamin contents

3. Translate the following sentences into Russian. Pay attention to Tenses in the Passive Voice.

1. Much attention is being given to the modern equipment of research laboratories. 2. The idea of constructing a new plant in our city was being widely discussed some years ago. 3. Wide investigation is being carried on in the field of machine-building now. 4. Many old plants and shops are being reconstructed now. 5. Great progress is being made in machine-building at present time. 6. This experiment was being carried out under low pressure. 7. New automation equipment is being installed in our shop. 8. During the war the radar was being used for detecting airplanes. 9. Plastic materials are being used for home constructions for a long time. 10. Much attention is now being paid to the use of polymers because they possess many desirable properties. 11. Nylon is being used to replace rubber and wood in a great variety of articles.12. Infrared energy is being used in automatic regulation of chemical and biological processes temperature. 13. This experiment is now being carried out in vacuum. 14. Many different machines were being produced at this plant in 2005.

4. Choose the appropriate forms of verbs given in brackets.

1. Two methods of reproducing sound in motion picture (*have been found, has found)* 2. The majority of valves *(have already been replaced, have replaced)* with tiny transistors. 3. By the end of the year a large variety of semiconductor devices *(will have been produced, will produce, will have produced)*. 4. New methods of obtaining polymers (*have applied, have been applied)* at our plant. 5. Almost all chemical elements which *(have found, have been found)* on Earth have been discovered in the Sun and the planets of solar system. 6. It *(has equipped, has been equipped)* with them by the end of the last year. 7. Some powerful radio stations (*have recently been built, will have built*) in the northern regions.

5. Read and translate the following sentences into Russian. Explain the use of tenses.

1. The output chemical products will have been greatly increased by the end of the year. 2. The examinations will have been passed by the student by the end of January. 3. This problem has not been given the greatest attention to. 4. The teacher corrected the article that had been translated by the student. 5. Since the monument had been made of granite, it was not destroyed by age. 6. Many uses have been found for this material for its properties. 7. By 8 o’clock all the necessary work will have been done. 8. By the evening the plant will have been given a new plan. 9. Our drawings will have been finished by the end of the term. 10. It had already been mentioned that many of the elementary gases could exist in diatomic molecules.

SELF-CHECK

I. Translate the following sentences into English. Choose the necessary form of the verb given in brackets.

1. В прошлом году построили много домов (built, had built, were built, are built).

2. Когда я приехал в этот город, этот дом строился (was built, had been built, was building, was being built).

3. Много домов строится в Томске (are built, have been built, was being built).

4. Этот дом будет построен в следующем году (will have been built, will be built, will build).

II. Translate the following sentences into Russian. Mind the Passive forms of the verbs. Begin your translation with the preposition.

1. Electrons have been spoken of as moving in orbits about the atomic nucleus. 2. This law is generally spoken of as the Second Law of Thermodynamics. 3. In general the oxidation number may be thought of as an electrical charge of the atom. 4. A base is referred to as a substance that accepts protons from another substance. 5. This new phenomenon has been much written about. 6. Many of these substances are not affected by atmospheric oxygen. 7. Complete precipitation is often ensured by the use of the common ion effect. 8. A few of the uses of aluminum have already been referred to in the article published this month. 9. Cellulose acetate is unaffected by weak acids, oils and most solvents. 10. Since X-ray patterns for some amorphous substances are similar to those of fluid liquids, they are looked upon as liquids which have high viscosities, and are often referred to as super-cooled liquids. 11. The preparation of sodium chromate from chromate ores has already been spoken of. 12. The heating of the solution was followed by a sudden cooling, which resulted in forming of a new product. 13. Gold is slowly attacked by fused nitrates and alkali-metal hydroxides. 14. Glass and silica are not attacked by sulphuric acid of any strength.

III. Use the verbs given in brackets in the necessary Tense and Voice.

- *The teacher (to explain) new material at every lesson.*
- *New material (to explain) by the teacher at every lesson.*
- *The teacher (to explain) new material now.*
- *New material (to explain) by the teacher now.*
- *The teacher (to explain) new material this week.*
- *The teacher (to explain) new material for 10 minutes since 9 o’clock in the morning.*
- *The teacher (to explain) new material yesterday.*
- *New material (to explain) by the teacher yesterday.*
- *The teacher (to explain) new material yesterday at 10 o’clock.*

- *New material (to explain) by the teacher yesterday at 10 o'clock.*
- *The teacher (to explain) new material tomorrow.*
- *New material (to explain) by the teacher tomorrow.*
- *The teacher (to explain) new material tomorrow by the end of the first lesson.*

UNIT 2
Chemical Methods of Analysis
Weight Method of Analysis: Gravimetry
Grammar: Modal Verbs;
to be; to have.

1. Warm up

Before reading the passage ask students of your group their opinions on some aspects of analytical chemistry.

- *Have you ever faced with chemical analysis in your life? Would you describe this situation?*
- *Have you ever done the gravimetric analysis in the laboratory of chemistry?*
- *Why is the weight method of analysis called gravimetric?*

2. Match the given words in "A" with their synonyms in "B".

A	B
1. Confidence	a) Bunch
2. Completeness	b) Encourage, give incentive
3. Igniting	c) Assurance, certainty
4. Factor	d) Completion, entirety
5. Negligible	e) Set fire
6. Growth	f) Coefficient
7. Imperfection	g) Small
8. Cluster	h) Increase, expansion
9. Promote	i) Defectiveness, incompleteness

3. Skim the passage and answer the following questions using the information from the text or from any other sources.

- *What is gravimetric analysis?*
- *What reactions can be used in gravimetric analysis?*
- *What steps are needed to complete a gravimetric analysis?*

GRAVIMETRIC ANALYSIS

Gravimetric analysis is the quantitative measurement of an analyte or a compound containing the analyte by weighing a pure, solid form of the analyte. Gravimetry is one of the most precise and also accurate methods of quantitative analysis. The limit of detection (the lowest concentration of a substance that can be detected at a certain level of confidence) by gravimetry is 0.10 % and accuracy is equal to 1 - 2 parts per thousand.

Reactions of the different types such as substitution reactions, exchange reactions, decomposition reactions, complexion reactions, and also electrochemical process can be used in gravimetric analysis.

The following individual steps are needed to complete a gravimetric analysis:

1. *Preparation of the solution of the sample.*

2. Quantitative precipitation of the analyte from solution. If the approximate amount of analyte is known, the excess, which is 1.5 times more than required (for the completeness of precipitation), is added.

3. *Collecting the precipitate by filtration.*

4. *Washing it to remove impurities.*

5. *Drying or igniting.*

If the collected precipitate is in a form suitable for weighing, it must be heated to remove water and the solvent. Ignition is usually required if a precipitate must be converted to a more suitable form for weighing. Many metals that are precipitated by organic reagents or by sulfide can be ignited to their oxides.

6 *Calculation.*

Calculations associated with the gravimetric method are based on stoichiometry. The analyte concentration in the sample is calculated from the weight of the precipitate and knowledge of its chemical composition. The gravimetric factor:

$$K = \frac{M(sought)}{M(weight)}$$

Note that one or both of the formula weights must be multiplied by an integer in order to keep the same number of atoms of the key element in the numerator and denominator.

Here are some examples of gravimetric factors.

Substance sought	Substance weight	Gravimetric Factor
Al	Al_2O_3	$2M(Al)/M(Al_2O_3)$
CO_2	$BaCO_3$	$M(CO_2)/M(BaCO_3)$
Cr_2O_7	$BaCrO_4$	$M(Cr_2O_7)/2M(BaCrO_4)$
Fe_3O_4	Fe_2O_3	$2M(Fe_3O_4)/3M(Fe_2O_3)$

4. What are the requirements for precipitations in gravimetry? Read the information below and find the answer to this question.

To perform gravimetric analyses successfully, the precipitations formed should meet the following requirements:

- *The substance being analyzed should be precipitated completely. The precipitate should be sufficiently insoluble so that the amount lost due to solubility will be negligible.*
- *The precipitate must not contain impurities. It should consist of large crystals so that they can be easily filtrated. All precipitates tend to carry some of the other constituents of the solution with them. This contamination should be negligible; it is minimized also by keeping the crystals large.*
- *Since the analyte is almost always weighed in a form different from the precipitated form, the precipitate formed should be easy and completely converted into the weighed form.*
- *A gravimetric precipitate should be a compound of the known chemical composition.*
- *A gravimetric precipitate should be a chemically stable substance.*

These requirements can be fulfilled if we correctly choose precipitating agents, conditions of precipitating, filtrating, washing and igniting the precipitate.

5. Choose a suitable phrase in column "B" to accompany phrases in column "A" and translate the sentences into Russian.

A	B
1. A gravimetric precipitate … 2. The substance being analyzed … 3. This contamination … 4. Since the analyte is almost always weighed in a form different from the precipitated form, …	a) the precipitate formed should be easy and completely converted into the weighed form. b) should be negligible. c) should be precipitated completely. d) should be a compound of the known chemical composition.

6. Look through the text below and find the answers supporting the idea of questions:

- *What is the mechanism of forming the precipitates?*
- *What are the conditions for analytical precipitation?*

7. Translate the sentences marked with an asterisk, explain grammar constructions in these sentences.

When a solution of precipitating agent is added to a test solution to form a precipitate, the actual precipitation occurs in a series of steps:

First, supersaturation occurs (around the point where the precipitating agent is added), that is, the solution phase contains more of the dissolved salt than occurs at equilibrium (if *MeA* is the precipitate being formed, $K_{sp}\ (MeA) < [Me^{+}] \cdot [A'']$). This is a metastable condition and the driving force will be for the system to approach equilibrium (saturation).

This is started by nucleation.* *For nucleation to occur, a minimum number of particles must come together to produce microscopic nuclei of the solid phase.* Although nucleation should theoretically occur spontaneously, it is usually induced, for example, on dust particles, or scratches on the vessel surface.

**Nucleation is followed by the particle growth, in which ions are added to the nuclei, and which continues until equilibrium is reached.* During this stage the initial nucleus will grow by deposition of other precipitate particles to form a crystal of a certain geometric shape. The rate of crystallization depends on the concentrations of the reacting ions. If these are very high, the rate of crystallization is also high. With increased growth rate, there is an increased chance of imperfections in the crystal and trapping of impurities.

However, if the obtained particles are very small and have a very large surface-to-mass ratio (which promotes surface adsorption), they may pass through the colloidal state as they grow. As a precipitate forms, the ions are arranged in a fixed pattern, so that the net surface change is zero. **However, the surface does tend to adsorb the ion of the participate particle that is in excess in the solution; this imparts a change.* The adsorption creates a primary layer that is strongly adsorbed. It will attract ions of the opposite charge in a counter layer and give an overall neutral particle. There will be solvent molecules interspersed between the layers. Near the equivalence point the electrostatic forces among the particles, which tend to keep them apart because they all have changes of the same sign, become smaller than the short-range forces of attraction that tend to bring them together. When the short-range forces predominate, the particles coagulate, giving particle clusters or aggregates that are large enough to settle out rapidly. However, if the secondary layer is loosely bound to the primary one, the surface charge will tend to repel like particles, creating a colloidal state.

Changing the condition of precipitation, both the crystalline and colloidal precipitates of the same substance can be obtained.

8. Match the given words in "A" with their synonyms in "B".

A	B
1. nucleation	a) catch, grasp
2. scratch	b) pass on, convey
3. trap	c) encourage, support
4. promote	d) spread, scatter
5. impart	e) burn of nuclei
6. intersperse	f) scrape, graze

9. Read the following passage and translate the sentences marked with an asterisk. Explain grammar used here.

Conditions of the Formation of Crystalline and Colloidal Precipitates

The particle size of precipitates will depend on the relative supersaturation of the solution during the precipitation process.

According to this ratio the particle size of precipitates is inversely proportional to the relative supersaturation of the solution during the precipitation process. This formula is correct if the different volumes of the solutions of the equal concentration are mixed. **The lower the solubility of the precipitate and larger the concentration of the mixed reagents, the smaller crystals form and larger the rate of orientation is.*

**Conversely, the smaller the difference Q-S (i.e. the higher the solubility of the precipitate and smaller the concentration of the mixed reagents), the higher the rate of orientation is and few large crystals form.* To precipitate large crystals, which can be easily washed and filtrated, it is necessary to precipitate from dilute solutions by adding dilute precipitating reagents slowly, with effective stripping (this keeps Q low) and precipitate from hot solutions (this increases S).*

Many precipitates do not give a favorable ratio, especially very **insoluble** ones. Hence, it is impossible to yield a crystalline precipitate and the precipitate is colloidal (large number of small participles). Therefore, it is necessary to create conditions of the coagulation of small particles. The process of **coagulation** is reversible. An added electrolyte (e.g. an acid or salts of ammonium) will result in a closer secondary layer and will promote coagulation. Heating (70 - 80 °C) tends to decrease **adsorption** and the effective charge in the adsorbed layers, thereby aiding coagulation. **Stripping** will also help.

10. Explain the words given in bold.

Oral Practice

11. Tell about your scientific research in the University.
Use the following expressions:

- *Gravimetry is one of the most precise and also accurate methods of quantitative analysis.*
- *We are developing a new process.*
- *We are going to apply a new method.*
- *My research has not been completed yet.*
- *At present we are conducting research in …*

12. Make up gravimetric factors for the following substances

Substance sought	Substance weight	Gravimetric Factor
ZrO_2	$ZrOCl_2 \cdot 8H_2O$	
Th	Th_2O_7	
U	U_3O_8	
U_3O_8	$UO_2(NO_3)_2$	
U_3O_8	$(NH_4)_4UO_2(CO_3)_3$	
Ce	$Ce(NO_3)_3 \cdot 2NH_4NO_3 \cdot 4H_2O$	
Li_2O	$LiAl[Si_2O_6]$	
SO_3	$Na3[Pd(S_2O_3)_2]$	

13. Calculate the mass of the substances sought given in the table (the 1-st column), provided the total mass of the substances (the 2-nd column) is equal to 100 g.

14. Full the table represented below

Element sought	Precipitating reagent	Chemical reaction	Precipitate weighed
Ba^{2+}	$SO4^{2-}$	$Na_2SO_4 + BaCl_2 \rightarrow BaSO_4\downarrow + 2NaCl$	$BaSO_4$

Element sought	Precipitating reagent	Chemical reaction	Precipitate weighed
		$Fe_2(SO_4)_3 + 6NaOH \rightarrow 2Fe(OH)_3 + 3Na_2SO_4$	
		$Th(NO_3)_4 + 2(NH_4)_2C_2O_4 \rightarrow$ $\rightarrow Th(C_2O_4)_2\downarrow + 4NH_4NO_3$	
		$AgNO_3 + HCl \rightarrow AgCl_3\downarrow + HNO_3$	
		$NiCl_2 + 2HC_4H_7O_2N_2 \rightarrow$ $\rightarrow Ni(C_4H_7O_2N_2)_2\downarrow + 2HCl$	
		$3FeCl_2 + 6NH_4OH \rightarrow 3Fe(OH)_3\downarrow + 6NH_4Cl$; $2Fe(OH)_3 \rightarrow Fe_2O_3 + 3H_2O$	

GRAMMAR REVISION

1. Translate the following sentences into Russian paying attention to the modal verbs.

1. These scientists should have developed several prototypes. 2. Because of the atomic nature of matter the early universe could never have been completely smooth. 3. He can translate articles concerning technical problems. 4. At the very center of the sphere there may be a core of unknown composition and properties. 5 The electrons must get closer to one another when matter is compressed. 6. I ought to concentrate here on the conceptual content of relativity theory. 7. He ought to be more careful with this new piece of equipment.

2. Translate the following sentences into Russian paying attention to the meanings of the verb "to have".

1. The laboratory of general chemistry **has** many benches with a number of drawers. 2. A first-year student **has to** carry out a number of experiments in the laboratory of general chemistry. 3. This term the students **have** carried out a number of experiments. 4. These substances **have** very low solubility. 5. They **have to** find out the solubility of this substance. 6. They **have** found the solubility of this substance and now can investigate its properties better. 7. This metal **has** found wide application both in industry and in agriculture. 8. They **have to** raise the temperature greatly as the mixture doesn't boil. 9. Hydrogen peroxide **has** been heated. 10. Hydrogen peroxide **has** a lower vapor pressure than water. 11. The evaporation **has to** be carried out in the water-bath. 12. This crucible **has** been used for heating some solutions. 13. This solution **has** an unpleasant odor; he has to open the window. 14.

Rhombic sulphur **has to** be kept at a temperature of 96°C. 15. If it is necessary to purify water, you will **have to** pass it through porous paper. 16. It **has to** be noted that chlorine dioxide reacts with water and yields a mixture of chlorous and chloric acid. 17. It **has** been already noted that hydrogen is found in the free state only in minute quantities. 18. To do so he **had to** use tacit assumption that a line has infinite length.

3. Translate the following sentences into Russian paying attention to the meanings of the verb "to be".

1. This substance is colorless and odorless. 2. Liquids which are not appreciably soluble in each other, are called immiscible liquids. 3. Many new research institutes are being built in our country. 4. They are discussing a very important problem dealing with the development of new branches of chemistry. 5. The volume of an object increases when it is heated. 6. There is a large new laboratory in our Institute. 7. This experiment is to be carried out again, the results are wrong. 8. The meeting of our Chemical Society is to take place tomorrow at 5 o'clock. 9. He is to graduate from the Polytechnic University in 2010. 10. This solution was to be heated in a porcelain crucible. 11. The solution was heated and evaporated. 12. The glassware is to be washed very thoroughly when the experiment is over. 13. The source of the idea is to be sought (to seek) earlier. 14. We are to pass the first exam on the 10th of January. 15. Everybody is to obey traffic regulations. 16. The quantity of a sample is to be measured before experiment. 17. Every laboratory is to be provided with a ventilating hood. 18. For this purpose a beam of positrons is to be sent along a narrow antiproton beam traveling at the same speed. 19. The gas is to be collected over water. 20. Different apparatus as well as materials are to be kept in these containers.

4. Find the sentences in which "to be" is a modal verb:

1. The laboratory was lit up very well. 2. This substance is to be heated to a high temperature. 3. In this experiment we were to find out all the properties of this substance. 4. This example was referred to by our teacher. 5. Hot water is to be poured in a flask. 6. If dry chlorine gas is passed into liquid trichloride in a cooled container, pentachloride is formed. 7. Silver is not attacked by oxygen under ordinary conditions. 8. The use of this gas is to be omitted as it is very harmful. 9. If the boiling point of the solution is to be established, you should carry out this experiment. 10. Many ores which are to be refined often contain considerable quantities of impurities. 11. He is working at a very important experiment; it is to help our researchers to finish their work. 12. The vapor pressure of this unstable phase is greater than that of the stable phase at the same temperature.

SELF-CHECK

Translate the text in writing, mind modal verbs (for 20 minutes).

The chemical industry needs instruments for accurate measuring. Good measuring instruments are able to give rapid results. Without modern instrumentation chemical processes were often controlled by a human operator who had to decide what needed to be done. It was rather difficult to do. The results had often to be checked thoroughly. There are many different kinds of measuring instruments and there is much information about the instruments, which are to be used in chemical plants. The purpose of all measuring devices is to control a chemical reaction. In a process controlled by a human operator, the temperature, for example, can be read from a thermometer. The operator is to decide whether the temperature is all right. Then he has to make some measurements. In the automated system, some mechanical or electrical device must replace the human operator to decide whether a process correction is needed and, if so, the extent of the necessary correction.

UNIT 3
Introduction into Theoretical Electrochemistry.
REDOX Theory
Grammar: Modal Verbs with the Perfect Infinitive;
Indirect Speech;
Polysemantic Words.

1. Warm up

- *Do you know the meaning of the word "half-cell"?*
- *What members are used in a salt bridge? What is the purpose of a salt bridge?*

2. Before reading the text study the meanings of the following words and think of the sentences with these words.

dissolve, v	absorb or melt in fluid; break up; disappear, soften, liquefy.
acid, n	sour substance; in chemistry: one of a class of compounds, which combine with bases (alkalis, oxides, etc.).
chunk, n	large peace, mass, lump, portion; v – break apart.
hydro-, prefix	forms compounds with hydrogen (often meaning "water").
liberate, v	set free

convert, v	change, exchange, renovate, and alter.
mixture, n	combination, blend, assortment.
immerse, v	drip, plunge into liquid, absorb.
bubble, n	A ball formed of liquid and contain air or gas.
cell, n	small cavity, (element); electrolytic cell in chemistry.
give off, v	hand over.
attract, v	draw, approach, magnetize, create a center of attention.
release, v	give up, set free
overcome, v	rise above, prevail over, overwhelm.
saturate, v	soak thoroughly, cause to dissolve maximum amount.
circuit, n	path for electric current.
concentration, n	reduction to small space, gathering to one point; increasing the substance quantity per unit of volume.
relative, adj.	dependent on relation to something else; considered in relation or in proportion to something else.
reference, n	recommendation, orientation.
recognize, v	know again, notice.
anode	The electrode where oxidation occurs
salt bridge	A connection between two solutions that allows the movement of current in the form of ionic charge.
cathode	The electrode where reduction occurs

3. Give the Russian for:

Electrochemical reactions; spontaneous oxidation-reduction reactions, oxidizing agents; reducing agent; mossy zinc; hydrochloric acid; significant amount; half reactions; ion solution; external wire; Nerst equation.

4. Match each word in "A" with its synonym in "B".

A. Occur, pair, weak, following, significant, essentially, separate, operate, lose, immediately, combine, add, complete, process, within.

B. Considerable, couple, subsequent, work, instantaneously, unite, attach, feeble, procedure, take place, take apart, inside, effectively, total, misplace.

5. Read the passage as fast as possible. From the text presented below choose sentences which express better the main idea of this text. Explain your choice.

REDOX THEORY

Redox reactions include all chemical processes in which atoms have their oxidation number (oxidation state) changed.

The term “redox” comes from the two concepts of reduction and oxidation. It can be explained in simple terms:

- *oxidation describes the loss of an electron by a molecule, atom or ion;*
- *reduction describes the gain of an electron by a molecule, atom or ion.*

However, these descriptions (though sufficient for many purposes) are not truly correct. Oxidation and reduction properly refer to a change in oxidation number — the actual transfer of electrons can never occur. In practice, the transfer of electrons will always cause a change in oxidation number, but there are many reactions which are classified as "redox", though no electrons are transferred (such as those involving covalent bonds).

Substances that have the ability to oxidize other substances are said to be oxidative and are known as *oxidizing agents, oxidants or oxidizers*. Put in another way, the oxidant removes electrons from the other substance, and is thus reduced itself. Oxidants are usually chemical substances with elements in high oxidation numbers (*e.g., H_2O_2, MnO_4^-, CrO_3, $Cr_2O_7^{2-}$, OsO_4)* or highly electronegative substances that can gain one or two extra electrons by oxidizing a substance *(O, F, Cl, Br)*.

Substances that have the ability to reduce other substances are said to be reductive and are known as *reducing agents, reductants, or reducers.* Put in another way, the reductant transfers electrons to the substance. Reductants in chemistry are very diverse. *Metal reduction* - electropositive elemental metals can be used *(Li, Na, Mg, Fe, Zn, Al).* These metals donate or *give away* electrons readily. Other kinds of reductants are *hydride transfer reagents ($NaBH_4$, $LiAlH_4$)*, these reagents are widely used in organic chemistry, primarily in the reduction of carbonyl compounds to alcohols. Another useful method is reductions involving hydrogen gas *(H_2)* with a palladium, platinum, or nickel catalyst. These *catalytic reductions* are primarily used in the reduction of carbon-carbon double or triple bonds.

The chemical way to look at redox processes is that *the reductant transfers electrons to the oxidant*. Thus, in the reaction, the *reductant* or *reducing agent* loses electrons and is *oxidized* and *the oxidant* or *oxidizing agent* gains electrons and is reduced.

6. Answer the following questions.

- *What does the term "REDOX" mean?*
- *What is "oxidation number"?*
- *What is called oxidant? Give your own example.*
- *What is called reluctant? Give your own example.*

7. Read the following passage carefully and answer the questions below:

- *What does this text concern with?*
- *Would you write the formula of the first law of thermodynamics?*
- *What does the first law of thermodynamics deal with?*
- *What is the purpose of a salt bridge?*

According to the first law of thermodynamics, the energy given off in a chemical reaction can be converted into heat, work, or a mixture of heat and work. By running the half-reactions in separate containers, we can force the electrons to flow from the oxidation to the reduction half-reaction through an external wire, which allows us to capture as much as possible of the energy given off in the reaction as electrical work.

We can start by immersing a strip of zinc metal into a 1 *M* Zn^{2+} ion solution, as shown in the figure below. Then we immerse a piece of platinum wire in a second beaker filled with 1 *M* HCl and bubble H_2 gas over the Pt wire. Finally, we connect the zinc metal and platinum wire to form an electric circuit.

We've now made a system in which electrons can flow from one half-reaction, or **half-cell,** to another. The same driving force that makes zinc metal react with acid when the two are in contact, should operate in this system. Zinc atoms on the metal surface lose electrons to form Zn^{2+} ions which go into solution.

Oxidation: $Zn \longrightarrow Zn^{2+} + 2\,e^-$

The electrons given off in this half-reaction flow through the circuit and eventually accumulate on the platinum wire to give this wire a net negative charge. The H^+ ions from the hydrochloric acid are attracted to this negative charge and migrate toward the platinum wire. When the H^+ ions touch the platinum wire they pick up electrons to form hydrogen atoms which immediately combine to form H_2 molecules.

Reduction: $2\,H^+ + 2\,e^- \longrightarrow H_2$

The oxidation of zinc metal releases Zn^{2+} ions into the Zn/Zn^{2+} half-cell. This half-cell, therefore, picks up a positive charge that interferes with the transfer of more electrons. The reduction of H^+ ions in the H_2/H^+ half-cell leads to a net negative charge as these H^+ ions are removed from the solution. This negative charge also interferes with the transfer of more electrons.

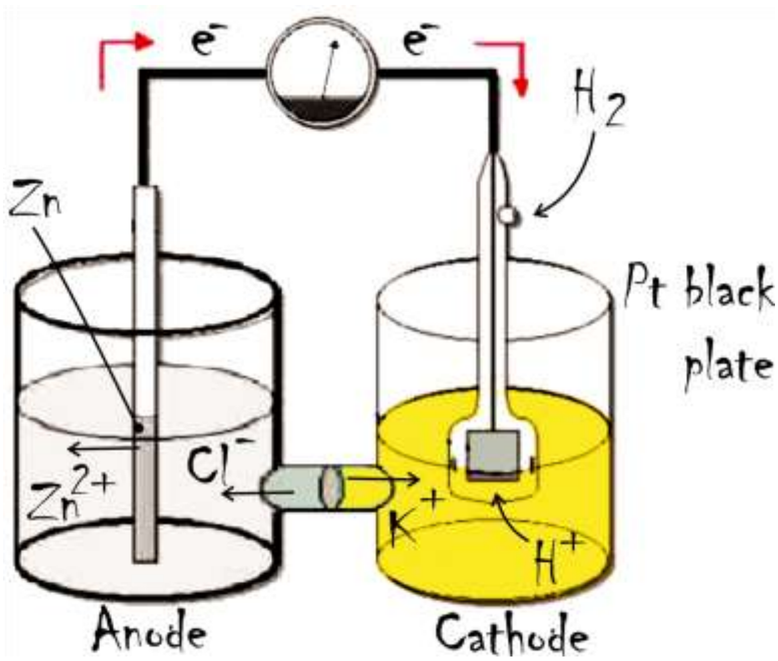


Fig. 2. Galvanic Cell

To overcome this problem, we complete the circuit by adding a U-tube filled with a saturated solution of a soluble salt such as KCl. Negatively charged Cl^- ions flow out of one end of the U-tube to balance the positive charge on the Zn^{2+} ions created in one half-cell. Positively charged K^+ ions flow out of the other end of the tube to replace the H^+ ions consumed in the other half cell. The U-tube is called a **salt bridge** because it contains a solution of a salt that literally serves as a bridge to complete the electric circuit.

8. Think and say a few words about each of the problems posed by authors and their importance for analytical chemistry.

9. Describe the galvanic cell operation.

10. Point out the oxidant and reductant in the following chemical reactions:

- $UF_4 + F_2 \rightarrow UF_6$;

- $Zn + 2HCl \rightarrow ZnCl_2 + H_2$;
- $BeCl_2 + Mg \rightarrow MgCl_2$;
- $C + O_2 \rightarrow CO_2$;
- $2UF_5 \rightarrow UF_4 + UF_6$;
- $Br_2 + 3F_2 \rightarrow 2BrF_3$;
- $CuI_2 \rightarrow Cu + I_2$

11. Write semi-reactions of the oxidation and reduction processes for the following reactions:

- $BeSO_4 + 4NaOH \rightarrow Na_2BeO_2\downarrow + Na_2SO_4 + 2H_2O$;
- $BeO + C + Cl_2 \xrightarrow{900\text{–}1000^0C} BeCl_2 + CO$;
- $8HI + H_2SO_4 \rightarrow 4I_2 + H_2S + 4H_2O$;
- $KNO_3 + Al + KOH + H_2O \rightarrow NH_3 + KAlO_2$;
- $NH_3 + O_2 \xrightarrow{750^0C} NO + H_2O$;
- $5U(SO_4)_2 + 2KMnO_4 + 2H_2O \rightarrow 5UO_2SO_4 + K_2SO_4 + 2MnSO_4 + 2H_2SO_4$

GRAMMAR REVISION
Modal Verbs with the Perfect Infinitive

1. Before doing exercises read and remember the following charts.

1. **Must, may, might + Perfect Infinitive** express uncertainty, possibility or supposition of doing smth in the past. They correspond to the Russian *вероятно, должно быть, возможно*.

2. **Cannot/couldn't + Perfect Infinitive** express incredulity, doubt. They correspond to Russian *не может быть*

3. **Might/ Could + Perfect Infinitive** express unreal supposition if the action refers to the past. They correspond to Russian *мог бы, можно было бы*

4. **Should/ought to + Perfect Infinitive** show that the obligation was not carried out in the past. . They correspond to Russian *следовало бы, надо было бы*

5. **Need not+ Perfect Infinitive** express lack of necessity of doing smth in the past. . They correspond to Russian *не было необходимости*.

2. Sentences to be translated into Russian.

1. Similar results may have been obtained by other researchers. 2. You ought to have compared these phenomena. 3. You should have carefully considered his suggestion. 4. Yon can't have read about these results elsewhere. 5. You should have used this new device. 6. They must have taken special measures to reduce the weight of the mechanical part. 7. He ought to have completed the experiment. 8. These scientists should have developed several prototypes. 9. Because of the atomic nature of matter the early universe could never have been completely smooth. 10. He could have translated articles concerning technical problems. 11. You ought to have concentrated on the conceptual content of relativity theory. 12. They may have been told to examine all the found precipitates. 13. Some day atomic energy might have been used to control the weather of the world. 14. All the preparations must have been completed long ago.15. Such a line cannot have been set up in practice. 16. You ought to have taken into consideration all the advantages and disadvantages to decide what system is the best for the future work. 17. This substation cannot have been completed in the short period of two years. 18. Our engineers may have solved many complicated problems.

3. Point out sentences in which the predicate expresses modality.

- *This gigantic plan is to be completed in the short period of 5 years.*
- *Landing lights should be installed on an airplane.*
- *We shall use all the methods we have to overcome the difficulties.*
- *Their aim was to measure the pressure within the apparatus.*
- *These are the requirements that must be met by a satisfactory method.*
- *Everything will have to be prepared beforehand.*

Indirect Speech

1. Translate the following sentences into Russian.

Compare your variant with the model.

Model:

– I wonder whether there is any solution to this problem.

– Хотелось бы мне знать, есть ли какое-то решение этой задачи.

1. I wonder if there are any papers concerned with this problem. 2. I want to know whether there is any relation between the two sets of number. 3. I would like to know as well whether there is any evidence in favor of this hypothesis. 4. It would be interesting to ask if there is any way to solve this problem. 5. I would like to know as well if there are any discrepancies between the experimental results and the predications of the theory. 6. It is of interest to see if there are any achievements in this field.

2. Answer student's 1 indirect questions (exercise 1) in the negative.

Model: St.1: *I wonder whether there is any solution to this problem.*

St. 2: *As far as I know there is no solution to this problem.*

3. Answer the speaker's question by an indirect question. Say, that you would like using information in exercise 1. Follow the model (work in pairs)

Model: Speaker*. Is this man a physicist? (I wonder myself whether …)*

Student: *I wonder myself whether he is a physicist.*

- *Is he an experimentalist? (I wonder if …)*
- *Is he a theoretician? (I am not sure if …)*
- *Does he study analytical chemistry? (I'd like to know if …)*
- *Will he speak at the conference? (Who knows whether …)*
- *Has he come to any conclusion? (Do you know if …)*
- *Are his conclusions different from ours? (I'd like to know if …)*
- *Are his data in favor of the hypothesis? (It would be interesting to know if…)*
- *Did his conclusions prove right? (I wonder if …)*
- *Did his conclusions prove wrong? (I am interested to know whether…)*
- *Are you interested in his work? (I wonder if …)*

Polysemantic Words

1. Remember the meaning of the word "affect".

Affect, v	влиять, воздействовать на …
To be unaffected	оставаться без изменения
To be affected by	подвергаться воздействию, влиянию …
Is (are) affected by	на … влияет
Is (are) unaffected by	на … не влияет

2. Translate the following sentences paying attention to the word "affect". Don't mix with the word "effect".

1) Roentgen discovered that some unknown radiation had the ability **to affect** a photographic plate even though it was covered with a **light-tight** *(светонепроницаемый)* material. 2) Gold is hardly **affected by** nitric, sulphuric and hydrochloric acids. 3) Radioactivity is **unaffected by** temperature, nor is it influenced by any known catalyst. 4) Attention should be paid to the fact that the reaction rate is **affected by** temperature, concentration, catalyst and so on. 5) Among the substances **unaffected by** oxygen one should mention the inert gases. 6) The molecular weights are **affected by** the temperature change. 7) It is the state of water but not its composition that can be **affected by** the process of heating or cooling.

3. Translate the following sentences into Russian, mind the various meanings of the word ”effect”.

Effect, v – осуществлять
Effect, n – результат, влияние
In effect – в сущности
To this effect – для этой цели

1) **In effect**, we would rather attempt to present only a general idea of organic chemistry and **to this effect** a classification of organic compounds and their important physical and chemical properties is given without going into details. 2) The light pressure produces an opposite **effect** and tends to force the molecules closer together. 3) Heavy water differs from ordinary water in its physical **effects**. 4) There are many uses of oxygen that require the substance in a high degree of purity so that to eliminate the **effect** of the presence of other gases.

4. Translate the following sentences paying attention to the word ”involve”.

Involve, v	включать в себя
Noun + involved	данный, рассматриваемый
Involving	с, связанный с …
Not involving	без …

1) Water takes part in hydrogen reactions **involving** coordination of water molecules with metallic ions and with various elemental and gaseous substances. 2) The rules **involved** will be considered as “rules of thumb” (эмпирические правила). 3) The part of the atom that is directly **involved** in the process of chemical change is the electron. 4) The chemical equation also tells how much of each substance is **involved**. 5) Other known nuclear reactions **involve** a proton, a neutron, an alpha particle or a photon, interacting with the nucleus of an atom. 6) The compounds **involving** radicals are often ionic because of the transfer of electrons. 7) At higher base concentrations complexes **involving** two molecules are formed. 8) The material **involved** possesses a rather complex structure. 9) The result **involved** was obtained when we used solutions of single sugars and not mixtures.

SELF-CHECK

1. Translate the following sentences into English by using the indirect questions.

- *Интересно было бы узнать, проводит ли эта группа исследования в области аналитической химии.*
- *Хотелось бы мне знать, работают ли они в вычислительных центрах нашей страны.*
- *Я не уверен, есть ли в этой области какие-то нерешенные вопросы.*
- *Было бы интересно знать, опубликовали ли они какие-то интересные работы за последние годы (lately).*

- *Хотелось бы мне знать, занимаются ли они исследованием той же проблемы, что и мы.*
- *Хорошо было бы посмотреть, достигли ли они каких-то успехов в экспериментах.*

UNIT 4
Electrochemical Cells
Galvanic Cells
Grammar: Participle;
Polysemantic Auxiliary Words

1. Warm-up

- *When did you hear the term "Galvanic cell" for the first time?*
- *Did you use a galvanic cell when you studied at school?*
- *Do you know who invented the galvanic cell?*
- *What's it used for?*

2. Before reading the text, study the meanings of the following words and think of examples with these words.

galvanism, n	electricity produced by chemical action.
neighboring, adj.	Situated nearby
anode, n	positive pole
cathode, n	negative pole of electric current.
electrode, n	[i'lektrəud], either of two points by which an electric current enters or leaves a battery.
anion, n	['ænaiən], electro-negative ion
cation, n	['kætaiən], positive ion
potential, n	amount of potential energy or work.
joule, n	unit of work or energy.
ohm, n	unit of measuring electric resistance.
coulomb	['kuləm], practical unit of quantity in measuring electricity.
transport, v	convey from one place to another.
involve, v	include
measure, n	size, quantity, unit of size
condition, n	the present state of a thing.

symbol, n	thing representing or typifying something; sign
strength, n	power
arbitrary, adj.	not bound by rules

3. Match each word in "A" with its synonym in "B".

A. Drive, generate, refer to, surface, flow, wire, eventually, identity, species, partial, involve, obtain, arbitrary.

B. Ultimately, plane, push, produce, conductor, pass on, stream, sort, fractional, uniqueness, random, get, engage.

4. Match antonyms and translate them into Russian.

A. Bore, logical, inside, fractional, external, below, firstly.

B. Surface, complete, random, involve, above, finally, internal.

5. Skim the passage as fast as you can; pay attention to the words in bold type.

ELECTROCHEMICAL CELLS

This chapter is devoted to cells in electrochemistry. The thing is that there are two kinds of electrochemical cells, *galvanic (voltaic) and electrolytic.* In the former, a chemical reaction spontaneously occurs to produce electrical energy. The lead storage battery and the ordinary flashlight battery are common examples. In electrolytic cells, on the other hand, electric energy is used to force a nonspontaneous chemical reaction to occur, that is, to go in the reverse direction. An example is the electrolysis of water. In both types of these cells, the electrode at which oxidation occurs is the anode, and that at which reduction occurs is the cathode.

Electrochemical cells that use an oxidation-reduction reaction to generate an electric current are known as **galvanic** or **voltaic cells.** Because the potential of these cells to do work by driving an electric current through a wire is measured in units of *volts*, we will refer to the cells that generate this potential from now on as *voltaic cells*.

Lets' have another look at the **voltaic cell** in the figure below.

Within each half-cell, reaction occurs on the surface of the metal electrode. At the zinc electrode, zinc atoms are oxidized to form Zn^{2+} ions, which go into solution. The electrons liberated in this reaction flow through zinc metal until they reach the wire that connects zinc electrode to the platinum wire. They then flow through the platinum wire, where they eventually reduce an H^+ ion in the neighboring solution to a hydrogen atom, which combines with another hydrogen atom to form an H_2 molecule.

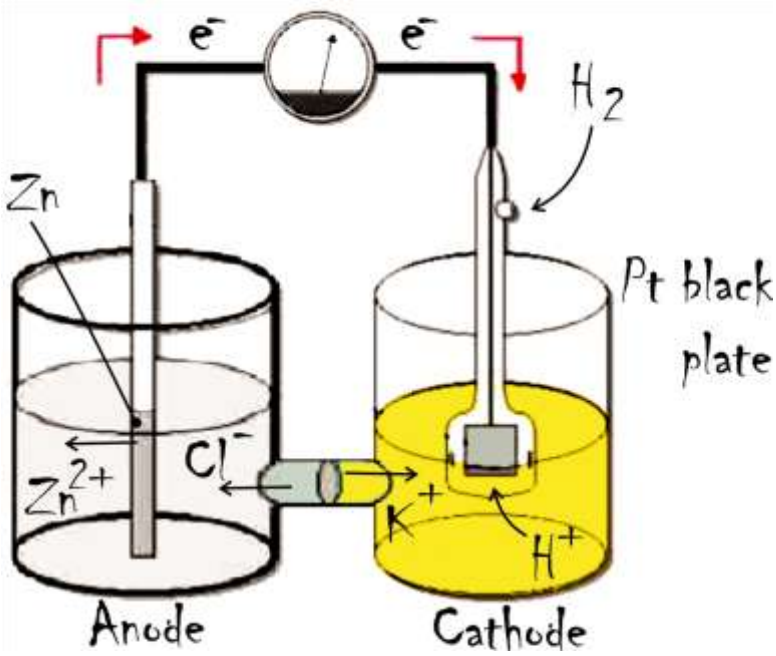


Fig. 2. Galvanic cell

The electrode, at which oxidation takes place in the electrochemical cell, is called the **anode.** The electrode at which reduction occurs is called the **cathode.** The identity of the cathode and anode can be remembered by recognizing that positive ions, or **cations,** flow toward the cathode, while negative ions, or **anions,** flow toward the anode. In the voltaic cell shown above, H^+ ions flow toward the cathode, where they are reduced to H_2 gas. On the other side of cell, Cl^- ions are released from the salt bridge and flow toward the anode, where the zinc metal is oxidized.

6. Answer the following questions:

- *What is a galvanic cell?*
- *What is the difference between a galvanic cell and electrolytic one?*
- *Would you describe the electrolytic cell operation?*
- *What is called the anode?*
- *What is called the cathode?*

7. Complete the following sentences:

- *Cations are ………*
- *Anions are ……..*

8. Look through the text again and correct these statements. There is a sense mistake in each of them.

1. The electrode, at which oxidation takes place in the electrochemical cell, is called the cathode. 2. The electrode at which reduction occurs is called the anode. 3. The identity of the cathode and anode can be remembered by recognizing that positive ions, or anions, flow toward the cathode, while negative ions, or cations, flow toward the anode.

9. Look at Fig. 2 and describe the galvanic cell design.

10. Read next information and carry out the following task.

Sometime electro chemical cells can be represented schematically as, for example, electrochemical cell composed of zinc anode and copper cathode:

Zn / Zn^{2+} (1M) // Cu^{2+} (1M) / Cu.

Remember!!! Anode is always on the left.

/ – boundaries;

// – salt bridge.

Other conditions like concentration are listed just after each species.

Write oxidation and reducing processes and the general reaction based on schematic representations of the following electrochemical cells:

$Ti/Ti^{2+}//Cu^{+}/Cu$	
Oxidation process	
Reduction process	
General reaction	
Ni/Ni2+//Ce4+, Ce3+/Pt	
Oxidation process	
Reduction process	
General reaction	

La3+/La//Pt2+/Pt	
Oxidation process	
Reduction process	
General reaction	

GRAMMAR REVISION

1. Remember Forms of Participle

		Active	**Passive**
Participle	**I Indefinite**	testing	having tested
	I Perfect	having tested	having been tested
	II	–	tested

2. In the following sentences define forms and functions of the Participle and translate sentences into Russian.

A

1. The beta particles are electrons moving with high velocity. 2. Returning to the equation, it will be noted that the sum of atomic numbers on one side of the reaction equals the sum of those on the other, and ditto (то же самое) for the atomic weight. 3. Translating the article a student used a dictionary. 4. This is the situation discussed in this paper. 5. The piece of ice placed into water began to melt. 6. The work done by these research-workers resulted in many new discoveries.

B

1. Having turned out the light we left the house. 2. Having carried out a great number of experiments we made a very interesting discovery. 3. Having found the composition of water the scientists could investigate its properties. 4. Having done the work they went home. 5. Having located the position at which these ions fall, and knowing the velocity with which the gas is moving along the apparatus, the transverse velocity imparted to the ion by the known electric field can be calculated. 6. Having been tested, this substance was found to be a good conductor. 7. Having been translated into many languages the book became known everywhere. 8. Having been written the translation was given to the teacher. 9. Having been typed the report was handed to the engineer.

C

1. Being asked he answered that he had used this device. 2. The new houses being built in this town will have from 5 to 9 floors. 3. All gases being poor conductors of electricity can be used as insulators. 4. Being treated for several hours the compound turned dark red. 5. Any neutrons and protons left over after the formation of maximum number of alpha-particles are looked upon simply as being present in the nucleus. 6. Being shown this document, she said that it belonged to the fifteenth century. 7. Material being studied by this student is very interesting.

3. In the following sentences choose the correct forms of Participles.

1. Much could be *(writing, written)* about the application of nuclides. 2. Many experiments have been *(carrying out, carried out)* in the field of radioactivity. 3. The work *(doing, done)* by the scientists was of great significance. 4. Many of the above-mentioned applications of radioactive nuclides or of the radiation *(emitting, emitted)* by them are directly or indirectly connected with industry. 5. A mechanical method was *(substituting, substituted)* by a new one. 6. This type of radiation consists of a current of positively *(charged, charging)* particles. 7. This discovery *(following, followed)* by many experiments was of great use to chemists. 8. The two substances *(investigating, investigated)* were homogeneous. 9. The man *(speaking, spoken of)* was the first to discover this phenomenon. 10. A positively *(charging, charged)* particle having the mass of the electron was discovered in 1932. 11. The scientist found that X-rays *(produced, producing)* were complex. 12. According to this theory *(dealt with, dealing with)* atomic structure the nucleus is a very small, compact, central part of an atom. 13. Oppositively *(charged, charging)* particles exert forces of attraction on one another.

4. Explain the words with "-ed" suffix (the Participle II as a function of a part of predicate, an attribute, or the Past Simple Tense). Translate the sentences into Russian.

1. In mass spectroscopy a beam of ionized atoms is sent through a combination of electric and magnetic fields. 2. Relative atomic weights may be used to form a table of chemical atomic weight. 3. The relative weight of elements may be determined by measuring the chemical combining weights. 4. From special relativity theory $E = (\Delta m) c^2$, where E is the energy released or absorbed in the reaction, c is a fundamental constant (the velocity of light), and Δm is the difference between the total mass before and after the reaction. 5. The discovery of Becquerel in 1896, of that property of matter now termed radioactivity opened up a new and important field of inquiry. 6. The number of predicted and confirmed experiments was overwhelming. 7. He tried other fluorescent materials, and whenever they contained uranium, he found his rays, but when they were made with calcium or zinc he did not.

5. Open the brackets translating the Russian words into English:

1. An iron rod *(нагретый)* in the fire increases in energy content. 2. *(При охлаждении)* to the original temperature the substance becomes solid. 3. The question *(рассмотренный, о котором шла речь)* was discussed at the last meeting. 4. The new experiment *(о котором говорили)* so much will be carried out again very soon. 5. The piece of ice *(помещенный)* in the water began to melt. 6. *(При нагревании)* ice melts. 7. The text *(переписанный)* by him was very useful in our work. 8. The new device *(показанный)* by our professor was very interesting. 9. *(При выпаривании)* a mass of greenish crystals will be obtained. 10. The work *(выполненная)* in time was very important.

6. Replace the subordinate clauses by the Perfect Participle according to the model:

Model: *When they had finished their work, they left the lab.*
Having finished their work, they left the lab.

- *When the composition of the substance had been determined, the scientists compared it with some other substances.*
- *When they had investigated all the properties, they could state that these gases were harmful.*
- *After they had separated nitrogen from other gases, they obtained it in nearly pure condition.*
- *When he had found the needed solvent, he could continue his experiment.*

7. Open the brackets choosing the correct forms of the Participles:

1. When *(heating, having heated)* this substance, one should be very careful. 2. *(Investigated, having investigated, investigating)* all the properties of new water, they could understand the mystery of silvery clouds. 3. The *(dissolving, dissolved, having dissolved)* materials may be soluble solids, liquids or gases. 4. Water *(using, used, having used)* in steam boilers, should be free from substances that cause corrosion. 5. *(Purified, having purified, purifying)* the water from the substance that cause corrosion, we can use it in steam boilers. 6. The reactions of non-metal oxides with basic hydroxides are closely related to the two types of reactions of acidic substances with basic substances already *(considering, considered).* 7. The partial pressure *(exerting, exerted)* by each gas in the mixture depended on the per cent of its molecules, i.e., upon the relative value of the molecular concentration of the gas. 8. Elements *(composed, composing)* of atoms containing only one or two valence electrons usually form positive ions. 9. *(Investigated, investigating, having investigated)* this phenomenon the scientists can come to some important conclusions. 10. The work *(doing, done)* by these research-workers resulted in many new discoveries. 11. The ions *(involving, involved)* can be used as a highly sensitive detector of radiation.12. The investigation *(followed, following)* by many experiments was of great importance. 13. The nuclei *(formed, forming)* in this reaction are unstable.

Polysemantic Auxiliary Words

1. Remember the following:

as, conj.	*как, в качестве, чем; так как, в то время, как*
as, adj.	*как (например)*
as well as	*так же, как и*
as well	*также*
as far as	*насколько, поскольку, постольку*
as follows	*в результате*
as early as, as late as	*еще*
as long as	*пока*
because, conj.	*так как, потому что*
because of, prep.	*из-за*

2. Translate the following sentences into Russian.

1) One can see that gases expand **as** the temperature rises. 2) The arrangement for accomplishing this experiment is **as follows**.3) **As early as** the beginning of the 19^{th} century Dalton laid the scientific foundation of the atomic theory.4) Aluminium **as well as** copper are the best conductors of electricity. 5) **As far as** these machines are inefficient, they must be replaced by new ones. 6) The existence of neutrons in nuclei was discovered **as late as** in 1932. 7) Information **as to** the fate of strontium in the animal and plant organisms is of particular interest at the present time. 8) **As to** its chemical behavior oxygen is very reactive. 9) Any oxidation reduction reaction can be expressed **as** the sum of two separate equations, one involves only oxidation and the other only reduction. 10) **As** gases pass through the regenerator they give up the greater part of the heat to the top layer. 11) The compounds involving radicals are often ionic **because of** the transfer of electrons. 12) **Because** carbon monoxide is odorless, the presence of this gas is not easily detected. 13) Phosphorous is never found free in nature **because of** its strong affinity for oxygen. 14) Argon, helium, neon, krypton and xenon are called the inert gases **because** they are chemically inactive.

3. Translate the sentences into Russian, mind the following meanings of "but".

but, conj.	*но, а*
but, prep.	*лишь только, кроме*
but for	*если бы не*
nothing but	*ничего кроме, лишь*
the next but one	*следующий через один*
the last but one	*предпоследний*

1) Oxygen will combine with each of the elementary substances **but** fluorine. 2) It should be known for many years that light is able to bring about chemical changes **but** the systematic study of photochemistry was only commenced in the middle of the last century. 3) **But for** the air no life on the Earth could have developed. 4) A substance, which has varying composition, is considered to be nothing **but** a mixture. 5) Carbon occurs principally in combination with various elements **but** is found uncombined as, for example, graphite, diamond and coal. 6) Helium gas contains **but** one atom of the element. 7) **The last but one** element in the Periodic Table is mendelevium. 8) We could not **but** stop the experiment, and all **but** he left the laboratory.

SELF-CHECK

Variant 1
Translate the following sentences in writing.
Pay attention to the Participle (for 30 minutes).

1. This behavior can be understood in the light of the formation reaction in which the electric fields of completed molecules or ions interact with adjacent ions or molecules, thus forming compounds of a higher order. 2. Based on the laws of conservation we can formulate chemical equations with a somewhat greater measure of justification. 3. The pressure exerted on the walls of a container by a gas is entirely due to collisions that take place between the moving molecules and the walls given below. 4. When considering the stability of equilibrium, we should start from some definition and, using this, investigate the given system, the investigation might proceed in two ways. 5. Some of the compounds involved have not been reported previously, additional data being reported in the appendix referred to in this report. 6. The results obtained for the analyses of a group of synthetic mixtures were as satisfactory as those obtained from other group methods. 7. All the processes described above take place more or less simultaneously, the hydrolysis of acetylchlorine resulting from a combined action of all the functional groups. 8. The temperature having been raised, the vapor began forming again.

Variant 2
Translate the following sentences in writing.
Pay attention to the Participle (for 30 minutes).

1. Having replaced some of the details of the new device they could get better results which were of great importance for the research concerned. 2. The results obtained were in good agreement with the values involved. 3. A small amount of common salt when added to water will be taken up by the water and become invisible. 4. Having examined the new work carried out by our research workers we could say that various lines of technological progress, ranging from the invention of new devices to the development of some industrial chemical processes were characterized by a steady improvement. 5. The terms insisted on in this statement are

to be discussed again. 6. Surrounding the nucleus were electrons, their number depending upon the atom. 7. The experiment spoken of is to be carried out again. 8. Substances thought of as radioactive should be treated carefully. 9. The conference attended by our students was devoted to the pollution problem. 10. When solving a non-linear problem described by differential equation, we must first design the computing diagram of the machine.

Variant 3
Translate the following sentences in writing.
Pay attention to the Participle (for 30 minutes).

1. A consideration of the equilibria involved in a solution of potassium cyanide illustrates the relationships upon which the degree of hydrolysis depends. 2. The increased concentration of the ions of water increases the effects caused by these ions. 3. The change in solubility resulting from the rise in temperature causes the completion of some hydrolytic reactions which are normally incomplete. 4. A very porous product used as a heat insulator is produced by preparing a mixture of this substance with asbestos. 5. Many of the metallic products, used extensively, are not single metals but alloys. 6. Salt can be obtained from salt mines, sea water. The impure salt thus obtained may be purified by recrystallization. 7. A solution containing no excess of either the acid or the basic hydroxide is known as a neutral solution. 8. Equations are known to show the proportions, in which the substances concerned react; consequently, the quantity of one of the substances involved establishes the quantities of all the rest. 9. A salt is a compound resulting from the replacement of the hydrogen of an acid by a metal or a metallic radical.

UNIT 5
Electrolytic Cells
Grammar: The Absolute Participial Construction;
Polysemantic Words.

1. Warm up
- *Look at the title of this section and say what you know about this problem.*
- *Do the terms "Galvanic cell" and "Electrolytic cell" have the same meaning?*
- *If there is any difference between them, explain it.*

2. Before reading the text, match the words in "A" with their definitions in "B".

A	B
1. Electrolyte	a) It is a finally divided coating for platinum
2. Gain	b) It is a liquid where electrolysis takes place
3. Ignore	c) Obtain, acquire

4. E.m.f.	d) Disregard, leave out of account
5. Arrangement	e) Electromotive force
6. Platinum black	f) Order, disposition, plan

3. Skim the passage and answer the following questions using the information from the text or from any other sources.

- *What is called the electrolytic cell?*
- *What is the operating principle of a galvanic cell?*
- *What is the operating principle of an electrolytic cell?*
- *What is produced by means of a galvanic cell?*
- *For what methods are electrolytic cells very important?*

ELECTROLYTIC CELLS

The apparatus in which electrolysis is carried out is known as an *electrolytic cell*. The direct current is supplied by a battery or power pack. Graphite electrodes carry the current into and out of the liquid electrolyte. Graphite is chosen because it is quite unreactive (inert). It will not react with the electrolyte or with the products of electrolysis. Electrons flow from the negative terminal of the battery around the circuit and back to the positive terminal.

In electrolytic cells electric energy is used to force a nonspontaneous chemical reaction to occur, that is, to go in the reverse direction. The example is the electrolysis of water. In this type of cells the electrode, at which oxidation occurs, is the anode and that, at which reduction occurs, is the cathode.

Electrolytic cells are important in the electrochemical methods such as electrogravimetry in which a metal such as copper is deposited onto an electrode (cathode) for weighing by applying an appropriate potential to get this nonspontaneous reaction to occur. Let’s consider the following redox reaction:

$$Fe^{2+} + Ce^{4+} \Leftrightarrow Fe^{3+} + Ce^{3+}$$

If a solution containing Fe^{2+} is mixed with one containing Ce^{4+}, there is a certain tendency for the ions to transfer electrons. Assume the Fe^{2+} and Ce^{4+} are in separate beakers connected by a salt bridge. (A salt bridge allows charge transfer through the solutions but prevents mixing of the solutions.) No reaction can occur, since the solutions do not make contact. A salt bridge is not always needed only when the reactants or products at the anode or cathode react with each other so that it is necessary to keep them from mixing freely. Now put an inert platinum wire in each solution and connect the two wires. The setup now constitutes a galvanic cell. If a microammeter is connected in series, it indicates that a current is flowing. The Fe^{2+} is being oxidized at the platinum wire (the anode):

$$Fe^{2+} \Rightarrow Fe^{3+} + e^{-}$$

In a galvanic cell, a spontaneous chemical reaction produces electricity. This occurs only when the cell circuit is closed. The cell voltage (e.g., in a battery) is determined by the potential difference of the two half reactions. When the reaction has gone to completion, the cell runs down, and the voltage is zero (the battery is "dead").

In an electrolytic cell, the reaction is forced the other way by applying an external voltage greater than and opposite to the spontaneous voltage.

4. Look through the text again and correct these statements. There is a technical mistake in each of them.

1) The apparatus in which electrolysis is carried out is known as an electrolysis. 2) The alternating current is supplied by a battery or power pack. 3) Graphite is chosen because it is quite reactive. 4) It will react with the electrolyte or with the products of electrolysis. 5) Electrons flow from the positive terminal of the battery around the circuit and back to the negative terminal.

5. Look through these statements. Where are technical mistakes? Explain your choice.

1. In the feed element the electrode is made of graphite in connection with its high chemical activity. 2. The chemical energy permits the spontaneous chemical reaction to proceed in the electrolytic cells. 3. The oxidation-reduction reactions always proceed in the electrolytic and galvanic cells. 4. The salt bridge is necessary not only to transfer electrons from one half-cell to another, but also to prevent agitation of an electrolyte in different parts of a galvanic cell. It is possible to register the electric current flow in a circuit by means of the ammeter connected in series. 6. Reduction of iron will proceed on the anode. 7. Galvanic cells transform the chemical energy in the electrical one.

Oral Practice

6. In groups of two prepare the following topics: the first group describes the electrolytic cell, the second group – the galvanic cell. While describing cells follow the plan below. The winners are the group that answers the most questions correctly in five minutes.

- *What are the main parts of each cell?*
- *The operating principle;*
- *For what problem solving it is applied.*

- *The main difference between these cells.*
- *What methods of the physicochemical analysis based on the application of the given type of cells do you know?*

7. Read the following information.

Let's view the electrochemical cell in which the following reaction proceeds.

$$Cu^{2+} + Zn_{(s)} \rightarrow Cu_{(s)} + Zn^{2+}$$

You can see the galvanic cell in the figure below.

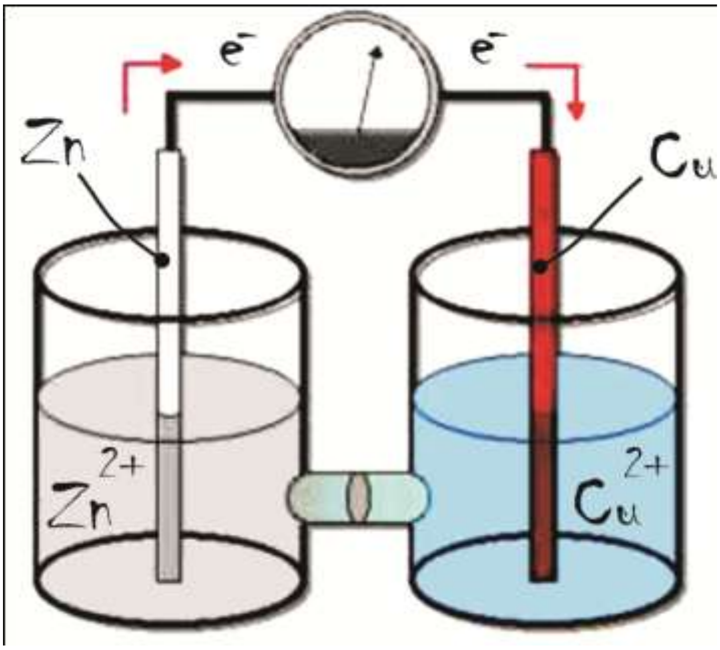


Fig. 3. Galvanic Cell

Each half reaction proceeds in a separate half-cell which is connected electrically. It permits to control the system better.

Salt bridge allows ion migration in a solution but prevents extensive mixing of electrolytes. It can be a simple porous disk or a gel saturated with a non-interfering salt like KCl. Cl^- is released to Zn side as Zn^0 is converted to Zn^{2+}. K^+ is released to Cu side as Cu^{2+} is converted to Cu^0.

Standard potential

The potential of a cell acting as a cathode compared to the standard hydrogen electrode. Values also require other standard conditions. Standard potentials are defined using specific concentrations.

- *all dissolved species are at 1 M;*

- *slightly soluble species must be at saturation;*
- *any gas is constantly introduced at 1 atm;*
- *any metal must be in the electrical contact;*
- *any other solids must also be in contact with the conducting electrode.*

The standard potential for $Cu^{2+} + 2e \rightarrow Cu_{(s)}$ is + 0.334 V. It means that if a sample of copper metal is placed in a 1 M Cu2+ solution, we'll measure a value if 0.334 V is compared to $2H^+$ (1 M) + 2e → $H_{2(g)}$ (1 atm).

One thing that we would like to know whether the spontaneous direction for a reaction is. This is necessary to determine the cell potential (E_{cell}). Since our standard potentials (E^0) are commonly listed as reductions, the following formula is used for our definitions:

$$E_{cell} = E_{forward} - E_{reverse}$$

One of your half reaction must be reversed. The potential E_{cell} of the spontaneous or galvanic direction for a reaction is positive. The half reaction with the largest E value will proceed as a reduction. The other will be reversed (oxidation).

For our copper-zinc cell at standard conditions:

$Cu^{2+} + 2e \rightarrow Cu^0$	+ 0.334 V
$Zn^{2+} + 2e \rightarrow Zn^0$	- 0.763 V
E_{cell}	1.097 V

The E value will vary if any of the concentration vary from standard conditions. This effect can be experimentally determined by measuring E versus a standard (indicating) electrode. Theoretically, the electrode potential can be determined by the Nernst equation.

$$E = E^0 + \frac{RT}{nF} Ln \frac{a_{Ox}}{a_{Red}},$$

Where: E^0 – standard electrode potential; R – gas constant (8.314 J/°mol); T – absolute temperature; F – Faraday's constant – 96000 coul; *n* – number of electrons involved; $a_{Ox/Red}$ – activity of oxidated/reduced compound.

8. Calculate the electromotive force (e.m.f.) [potential] of the following electrochemical cells:

Schematic representations of the electrochemical cells:

- *$Ni/Ni^{2+}//Cl^-/Cl_2$, Pt;*
- *$Mo/Mo^{3+}//Hg^{2+}, Hg^+/Pt$;*
- *$K/K^+//Pt^{2+}/Pt$;*
- *$Ti/Ti^{2+}//Au^{3+}/Au$;*
- *$Au/Au^{3+}//OH^-/O_2$, Pt;*
- *Cl_2/Cl^-, $Pt//Li^+/Li$*

9. Make up schematic representations of galvanic cells in which the following chemical reactions proceed:

- $Cu + 2I^{-} \rightarrow I_2 + Cu^{2+}$;
- $Ni + Hg^{2+} \rightarrow Ni^{2+} + Hg$;
- $Tl + 2H^{-} \rightarrow Tl^{+} + H_2$;
- $Cd + Ni^{2+} \rightarrow Cd^{2+} + Ni$;
- $La + Pb^{2+} \rightarrow La^{3+} + Pb$

GRAMMAR REVISION

1. Before doing exercises read and remember the charts of the Absolute Participial Construction.

1. S + Participle; S + Predicate Так как, когда, если, после того как…..

2. S + Predicate; S + Participle …. причем, а, и

2. Read and translate sentences into Russian, mind the Absolute Participle Construction.

1) Surrounding this nucleus are electrons, the actual number depending upon the atom being considered. 2) The mass of electrons being smaller, they reach the higher velocities necessary for evaporation at low temperatures. 3) Alternatively, the re-radiation may be delayed, the material storing the energy for a time, which may be as large as several seconds before radiating. 4) Sometimes the target was comparatively small piece of metal embedded in the surface of a lump of copper, advantage being taken of the high-thermal conductivity of the latter metal to dissipate the heat. 5) The temperature remaining constant, the volume of a given mass of a gas is inversely proportional to the pressure to which it is subjected. 6) There are several different types of alloys, some being homogeneous and others heterogeneous. 7) This indicates that the carbon dioxide evolved on heating results solely from the decomposition of carboxyl groups referred to earlier, one carboxyl group giving one mole of carbon dioxide. 8) The data derived are to be found in table 5, they being reliable. It’s obvious from the results given above. 9) Depending on their chemical compositions, solvents are divided into polar and non-polar solvents, and intermediary types, non-polar solvents being organic hydrocarbons.

3. Change the sentences according to the given models:

M o d e l I: As my work is very difficult, he helps me.
– My work being very difficult, he helps me.

- *As this machine works well, we can use it at our plant.*
- *As their lectures begin in the morning, they are free at five o'clock.*
- *As the range of application of stable isotopes is very wide, the scientists are greatly interested in it.*
- *Since the speed of light is extremely great, we cannot measure it by ordinary means.*
- *If the book is interesting, we read it with pleasure.*
- *The professor walked into the lecture hall, the students following him.*

M o d e l II: When radioactivity had been discovered, science made great progress in atomic physics.
Radioactivity having been discovered, science made great progress in atomic physics.

- *When all the properties of the element had been discovered, it was much easier to use it.*
- *After the new computer had been built, they could calculate the acceleration of the particles.*
- *When the solution had been evaporated, they began to examine the residue left.*
- *When the temperature of water had been raised, the steam began forming again.*
- *When X-rays had been discovered, science made great progress in medicine.*
- *When investigations had been carried out, scientists made a very interesting discovery.*
- *After the new house had been built, the family could move to it.*
- *After the work had been completed, we went home.*
- *After the assistant professor had finished his lecture, students began to discuss it.*

Polysemantic Words

1. Translate the following sentences into Russian, mind polysemantic pronoun 'it'.

1) **It** is the crystal structure of diamond as determined by X-rays which gives an explanation for this contrast of properties.

2) Those who study chemistry know that the law of conservation of mass makes **it** possible to write chemical equations.
3) Petroleum is a natural mixture of many liquid hydrocarbons such as gasoline, kerosene and heavy lubricating oil, but chemists have found **it** possible to separate these liquids from the mixture.
4) **It was not until** 1930 that the 3rd type of particles that make up atoms was discovered.
5) **It** would be difficult to find another element of the many we know which is more widely distributed in nature than oxygen.
6) Because of the partial decomposition of the carbide grey-cast iron is softer than white-cast iron, it has a higher melting point and it is much more suitable for castings.

2. Translate the following sentences into Russian. Pay special attention to the word "provide".

Provide, v – обеспечивать, давать, снабжать
To provide for – предусматривать
Provided (that), conj. – при условии, что …, если только
Providing, conj. - при условии, что …, если только

- ***Provided*** *we use the necessary instruments, the measurement will always be correct.*
- *Automation* ***provided*** *the control of not only individual machines but also of whole factories.*
- *Sometimes graphical representation of data can* ***provide*** *you with a particularly valuable piece of information.*
- *This laboratory* ***provided*** *with* ***up-to-date*** *equipment solves many important chemical problems.*
- *As an outstanding advantage, polyesters* ***provide*** *a good combination of mechanical and electrical properties at relatively low cost.*
- *The volume of a given quantity of a gas varies directly with the absolute temperature,* ***provided*** *that there is no change in pressure.*

3. Translate the following sentences into Russian, mind the word "until".

1) Reactions that have products interacting in such a way as to reform the original reactants **until** a balance is reached are called equilibrium reactions.
2) Atoms could not be 'seen' **until** the 20th century.
3) There are some elements, which do not catch fire **until** they are heated.
4) **Until** recently the Periodic Table showed four vacant places: numbers 43, 61, 85, 87.
5) One should take great care never to light a supply of hydrogen **until** it is known to be free of air.

6) **Until** recently the technical uses of selenium and tellurium have been of little importance.
7) Phosphorous does not ignite in the air **until** it is heated to a temperature of 240ºC.
8) It was not **until** the 18th century that steel began to replace wrought (чугун ковкий) iron in the making of tools and weapons.
9) Although the compounds of silicon have been used for many centuries the element was not prepared **until** the beginning of the 19th century.
10) It was not **until** 1896 that scientists found that compounds of uranium emitted rays that affected a photographic plate covered with black paper.
11) Not **until** the 17th century did man begin to understand pressure.
12) The phenomenon of electricity was discovered quite early but not **until** the end of the last century was it known that electricity is nothing but a flow of charged particles, which scientists name electrons.

UNIT 6
Electrolysis
Grammar: Gerund;
Polysemantic Words

1. Warm up

- *Look at the title of this section and say what you know about this problem.*

2. Match the words in "A" with their definitions in "B"

A	B
1. Solvent	a) Long narrow piece, take covering
2. Arbitrary	b) Strongly effectively
3. Species	c) Gloomy, tedious, dark, dim
4. Steam	d) Resisting wear, lasting
5. Perpetual	e) Vapour
6. Durable	f) Random, casual
7. Dull	g) Continuous, lasting for ever
8. Drastically	h) Sort, kind, sub-division
9. Strip	i) Liquid with power of dissolving

3. Read the passage, then write out the key words and find the facts supporting your ideas.

ELECTROLYSIS

An *ionic compound* is dissolved with an appropriate *solvent*, or otherwise melted by heat, so that its *ions* are available in the liquid. An electrical current is applied between a pair of inert *electrodes* immersed in the liquid. The negatively charged electrode is called the *cathode*, and the positively charged one the *anode*. Each electrode attracts ions which are of the opposite *charge*. Therefore, positively charged ions (called *cations*) move towards the cathode, while negatively charged ions (termed *anions*) move toward the anode. 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 probes, *electrons* are absorbed or released by the ions, forming a collection of the desired element or compound.

The amount of electrical energy that must be added equals the change in *Gibbs free energy* of the reaction plus the losses in the system. The losses can (theoretically) be arbitrarily close to zero, so the maximum thermodynamic efficiency equals the *enthalpy* change divided by the free energy change of the reaction. In most cases the electric input is larger than the enthalpy change of the reaction, so some energy is released in the form of heat. In some cases, for instance in the electrolysis of *steam* into hydrogen and oxygen at high temperature, the opposite is true. Heat is absorbed from the surroundings, and the *heating value* of the produced hydrogen is higher than the electric input. In this case the efficiency can be said to be greater than 100%. It is worth noting that the maximum theoretic efficiency of a fuel cell is the inverse of that of electrolysis. It is thus impossible to create a *perpetual motion* machine by combining the two processes.

In electrolysis, the anode is the positive electrode, meaning it has a deficit of electrons; species in contact with the anode can be stripped of electrons (i.e., they are *oxidized*). The cathode is the negative electrode, meaning it has a surplus of electrons. Species in contact with the cathode tend to gain electrons (i.e., they are *reduced*).

A higher current flow through the cell means it will be passing more electrons through it at any given time. This means a faster rate of reduction at the cathode and a faster rate of oxidation at the anode. This corresponds to a greater number of moles of product. The amount of current that passes depends on the conductance of the electrodes and electrolyte, though it also depends on how much current the power source itself can generate. The processes in an electrolytic cell with just two or three reactants can become very, very complex. For instance, metals plated at a certain current density might form a durable and shiny coating on the substrate, while some other current density might form an excessively grainy, dull coating.

A higher potential difference (voltage) applied to the cell means the cathode will have more energy to bring about reduction, and the anode will have more energy to bring about oxidation. Higher potential difference enables the electrolytic cell to oxidize and reduce energetically more "difficult" compounds. This can drastically change what products will form in a given experiment. On a practical level, both current and voltage determine what will form in a cell.

4. Explain the meanings of the words given in italics in the text.
Put questions using these words and ask your partner.

5. Read the following passage and translate the sentences marked with an asterisk.

ELECTROLYSIS OF WATER

One important use of electrolysis is to produce hydrogen. The reaction that occurs is:

$$2H_2O_{(aq)} \rightarrow 2H_{2(g)} + O_{2(g)}$$

This has been suggested as a way of developing society toward using hydrogen as an energy carrier for powering electric motors and internal combustion engines. Electrolysis of water can be achieved in a simple hands-on project, where electricity from a **battery** or low-voltage DC power supply (e.g. computer power supply 5 volt rail) is passed through a cup of water (in practice a saltwater solution or other electrolyte will need to be used otherwise no result will be observed). Using platinum electrodes, hydrogen gas will be seen to bubble up at **the cathode**, and oxygen will bubble at **the anode**. If, however, any other metal is utilized for the anode the oxygen will react with the anode instead of being released as a gas. For example using iron electrodes in a sodium chloride solution **electrolyte**, iron oxide will be produced at the anode, which will react to form iron hydroxide. When producing large quantities of hydrogen, this can significantly **contaminate** the electrolytic cell. That is why iron is not used for commercial electrolysis.

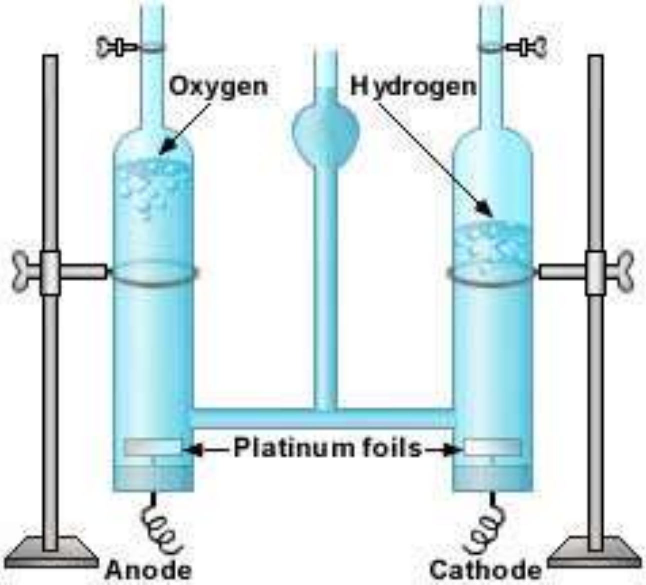


Fig. 4. Hoffman electrolysis apparatus used in electrolysis of water

The energy **efficiency** of water electrolysis varies widely. The efficiency is a measure of what fraction of electrical energy used is actually contained within the hydrogen. Some of the electrical energy is converted to heat, a useless **by-product**. Some reports quote efficiencies between 50–70%. This efficiency is based on the lower heating value of hydrogen. The lower heating value of hydrogen is thermal energy released when hydrogen is **combusted**. This does not represent the total amount of energy within hydrogen, hence, the efficiency is lower than a more strict definition. Other reports quote the theoretical maximum efficiency of electrolysis. The theoretical maximum efficiency is between 80–94%. The theoretical maximum considers the total amount of energy **absorbed** by both the hydrogen and oxygen. These values only refer to the efficiency of converting electrical energy into hydrogen's chemical energy. The energy lost in generating the electricity is not included. For instance, when considering a power plant that **converts** the heat of nuclear reactions into hydrogen via electrolysis, the total efficiency is more like 25–40%.

6. Explain the meanings of the word combinations given in bold.

7. Quote the text to prove that:

- *Electrolysis of water can be achieved in a simple hands-on project.*
- *Large quantities of hydrogen can significantly contaminate the electrolytic cell.*
- *The energy efficiency of water electrolysis varies widely.*

Oral Practice

8. Describe the operating principle of Hoffman electrolysis apparatus.

9. Read the information about Faraday's laws of electrolysis, then derive formulas and explain them.

FARADAY'S LAWS OF ELECTROLYSIS

The 1st Faraday's Law of Electrolysis

The mass of a substance produced at an electrode during electrolysis is proportional to the number of moles of electrons (the quantity of electricity) transferred at that electrode.

The 2nd Faraday's Law of Electrolysis

The Faraday's number of the electric charge required to discharge one mole of substance at an electrode is equal to the number of "excess" elementary charges on that ion.

In the modern form, Faraday's law states:

$$m = \frac{Q}{qn} \cdot \frac{M}{N_A} = \frac{1}{qN_A} \cdot \frac{QM}{n} = \frac{1}{F} \cdot \frac{QM}{n} = \frac{1}{96.485C} \cdot \frac{QM}{n},$$

where:
m is the mass of the substance produced at the electrode (in *grams),*
Q is the total electric charge that passed through the solution (in *coulombs),*
q is the electron charge = 1.602×10^{-19} coulombs per electron,
n is the valence number of the substance as an ion in solution (electrons per ion),
$F = qN_A = 96.485C$ is *Faraday's constant,*
M is the molar mass of the substance (in grams per *mole),* and
N_A is *Avogadro's number* = 6.022×10^{23} ions per mole.
In practice, the total charge *Q* is calculated by integrating the electric current *I*(*t*) over time *t*:

$$Q = \int_0^T I(t)dt$$

where *T* is the total amount of time of the electrolysis.

10. Fill in the gaps with corresponding words from the box below.

An ionic …….. is dissolved with an appropriate………, or otherwise melted by heat, so that its ……..are available in the liquid. An electrical current is applied between a pair of inert …….immersed in the liquid. The negatively charged electrode is called the………, and the positively charged one the…….... Each electrode attracts ions which are of the opposite……….. Therefore, positively charged ions (called……..) move towards the cathode, while negatively charged ions (termed………) move toward the anode. 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 probes,………. are absorbed or released by the ions, forming a collection of the desired element or compound.

anode	**ions**	**electrodes**	**cations**	**electrons**
anions	**cathode**	**compound**	**solvent**	**charge**

GRAMMAR REVISION

1. Before doing exercises read and remember forms of Gerund

Forms of Gerund	**Active**	**Passive**
Indefinite	solving	being solved
Perfect	having solved	having been solved

2. Define functions of Gerund and translate sentences into Russian.

1. After melting, the average speed of the molecules remains the same as before but the molecules are now free of each other. 2. The process of overcoming the attractive forces between the molecules of a substance is called melting. 3. Instead of increasing the temperature of the ice, the energy is used in decreasing the attraction between the ice molecules. 4. In the process of boiling heat is constantly added to the liquid. 5. By increasing the pressure, however, the substance can be obtained in a liquid state, provided the change from liquid to solid is accompanied by an expansion. 6. As we have seen, adding heat to a substance will not always cause a rise of its temperature. 7. When a liquid starts boiling at a certain temperature and under a given pressure, the heat causes the liquid to vaporize. 8. They succeeded in getting good results after a number of tedious investigations. 9. This resulted in increasing the temperature greatly. 10. Adding heat to a piece of ice or increasing the

pressure upon means to change it to water. 11. The cooling of a gas which occurs when it expands without doing external work is known as the Joule-Thompson effect.

3. Instead of the Infinitive put the Gerund in the necessary form.

1. Alloys are usually prepared by *(to melt)* metals together and allowing the melt to cool. 2. By *(to cool)* the solution a temperature is reached at which the solid pure ice and the liquid solution have the same vapor pressure. 3. After *(to make)* a number of experiments, the soviet scientists and engineers succeeded in *(to create)* an automatic interplanetary station. 4. We have learned of his *(to finish)* a number of new laboratory experiments. 5. Hydrogen chloride is usually prepared by (to heat) a mixture of concentrated sulphuric acid and the appropriate salt. 6. Iron is the most useful of metals, partly because of its extreme abundance, but largely because of the ease with which its properties may be altered by *(to add)* small amounts of other elements. 7. Water gas is obtained mainly by *(to pass)* steam over coke. 8. Ethylene is a material which is widely available in refining gases. 9. After *(to reach)* the boiling point, the temperature of water could not be increased any more in spite of our adding more heat.

4. Open the brackets. Use the necessary form: Participle I, II, Gerund, Verbal Noun.

1. A pattern *(to make)* of metal may be used longer that one *(to make)* of any other material. 2. The *(to pass)* of electricity through the conductor heats it. 3. The reflector *(to make)* of *Be* and *BeO* depends on temperature. 4. Several radiator concepts *(to use)* numerous heat pipes as fins have been proposed and built. 5. The problems *(to relate)* to this fuel have already been mentioned. 6. *(To decrease)* the temperature to 2,800 *K* would increase the lifetimes. 7. *(To have made)* all the necessary calculations the engineers began *(to design)* a new reactor. 8. The first metals *(to use)* by men were gold, silver and copper.

5. Point out sentences in which the subject is expressed by the Gerund or Gerundial Construction.

1) My friend having finished their research work, the results were published in a scientific magazine. 2) My friend’s having finished his work enabled him to visit me. 3) His being sent abroad was quite unexpected. 4) Bombarding atoms often results in unstable atoms. 5) Studying experiments with ice one can show that pressure causes ice to melt. 6) Adding more turns makes the magnetic field stronger. 7) Measuring resistance is necessary in many experiments.

6. Define sentences in which the object is expressed by Gerund or Gerundial Construction.

1) There were other ways of applying high voltage. 2) This results in burning the valves. 3) The neutral position depends on the setting of the gear change hand lever. 4) The expansion lies in the product being more stable. 5) We insisted on their being offered favorable terms of payment.

7. Translate sentences into Russian, pay special attention to the word "account".

Account, n — *объяснение, отчет*
Account (for), v — *объяснять*
On account of , prep. — *из-за, вследствие*
On this account — *в связи с этим*
To take into account — *принимать во внимание*

1) The electron was discovered in 1895 but the first attempts **to account for** chemical bonding were made only some twenty years later. 2) All atoms in diamond are firmly linked together forming a crystal acting as a giant molecule and this **accounts for** its extreme hardness, its high melting point and its failure to dissolve in any solvent. 3) This article gives an **account for** the structure and characteristic activity on the Sun. 4) **On account for** its inertness it is difficult to make nitrogen combine with other elements. 5) Each nucleus contains enough protons **to account for** the positive charge of the nucleus. 6) "Classical physics" fully **accounted for** everything from the motion of planets to the Brownian movement; in general, it **accounted for** all natural phenomena. 7) White phosphorous is very poisonous; on this **account** care should be taken when working with it.

SELF-CHECK

Translate the following sentences
into Russian in writing.
(for 30 minutes)

1. Some metals are remarkable for being very light. 2. Your having carried out this work under this professor helped you greatly in your research work. 3. Physical properties are those that may be expressed without considering the possibility of transforming the given material into materials of other kinds. 4. The capacity of material for being dissolved in water or in some other solvent is also commonly listed as a physical property. 5. Iron has the chemical property of being transformed into other materials. 6. Adding heat to a piece of ice or increasing the pressure upon it means to change it to water. 7. The cooling of a gas which occurs when it expands without doing external work is known as the Joule-Thompson effect.

UNIT 7
Classification of Electrochemical Methods
Grammar: Infinitive: Forms and Functions
Complex Subject

1. Warm up

- *What methods of analytical analysis do you know?*
- *Have you ever used one of these methods in your practice?*

2. Before reading the text study the following words and think of sentences with these words.

Develop, v	evolve, bring to maturity
Current, n	transmission of electricity through a conductor
Deplete, v	to empty
Cause, n	[kO:z], reason, motive, purpose
Drop, v	to fall; **n** – descent
Law, n	rule, general principal deduced from facts
Inert, adj.	without power of action or resistance
Null, adj.	of no effect
Estimate, v	form opinion of; n – approximate judgment of amounts
Response, n	Reply
Convection, n	transfer of heat in a liquid or gas
Oscillate, v	swing to and fro
Plateau, n	tableland (on a curve)
Contribute, v	[kqn'trIbju:t], give, pay to common fund, help to common result
Growth, n	increase, extend
Substantial, adj.	big, important
Consequence, n	result, effect, outcome, what follows as a cause
Throughout, prep.	in every part of
Indicator electrode	the electrode whose potential is a function of the analyte's concentration (also known as the working electrode)
Reference electrode	an electrode whose potential remains constant and against which other potentials can be measured
Auxiliary electrode	the third electrode in a three-electrode cell that completes the circuit.
Ohm's law	the statement that the current moving through a circuit is proportional to the applied potential and inversely proportional to the circuit's resistance ***(E=I·R)***
Potentiometer	a device used for measuring the potential of an electrochemical cell without drawing a current or altering the cell's composition
Galvanostat	a device used to control the current in an electrochemical cell
Potentiostat	a device used to control the potential in an electrochemical cell

3. Match each word in "A" with its synonym in "B".

A. Specific, category, response, diffusion, experiment, substantial, diminish, rapidly, interface, detection, determine.

B. Class, reply, dispersion, particular, significant, define, trial, fast, revealing, boundary, weaken.

4. Match each word in "A" with its antonym in "B".

A. Detection, increase, inert, approximately, connect, alternating current, specific, continuously.

B. Diminish, vague, concealment, direct current, moving, disconnect, intermittently, exactly.

5. There is a presented diagram of the electrochemical methods. Think what you know about each method. Then read the information and find the ideas, which were not known to you before reading.

CLASSIFICATION OF ELECTROCHEMICAL METHODS
1. POTENTIOMETRY It measures **electrical potential** developed by an **electrode** in an electrolyte solution at **zero current flow**. It uses NERNST EQUATION relating **potential** to **concentration** of some ion in solution.
2. VOLTAMMETRY It determines concentration of an ion in dilute solutions from **current flow** as a function of voltage when POLARIZATION of ions occurs around the electrode. *POLARIZATION = depletion of concentration caused by electrolysis. If using a dropping mercury electrode, method is termed POLAROGRAPHY.*
3. COULOMETRY It is **electrolysis** of a solution and use of **Faraday's law*** relating quantity of electrical charge to amount of chemical change. [* essentially states that it takes 9.65×10^4 Coulombs of electrical charge to cause electrolysis of 1 mole of a univalent electrolyte species.]
4. CONDUCTIMETRY It measures **conductance** of a solution using INERT ELECTRODES, ALTERNATING CURRENT, AND AN ELECTRICAL NULL CIRCUIT – thereby, ensures **no net current flow** and **no electrolysis**. The concentration of ions in the solution is estimated from the conductance

NOTES:

a) Methods 1 and 4, NO ELECTROLYSIS of solution. Sample is recoverable, unaltered by analysis.

b) Methods 2 and 3 should cause ELECTROLYSIS OF THE SAMPLE.

6. Read passages attentively and get ready to talk about each method.

Classification of Electrochemical Methods

Although there are only three principal sources for the analytical signal – potential, current, and charge a wide variety of experimental designs are possible. The simplest division is between *bulk methods,* which measure properties of the whole solution, and *interfacial methods,* in which the signal is a function of phenomena occurring at the interface between an electrode and the solution in contact with the electrode. The measurement of a solution's conductivity, which is proportional to the total concentration of dissolved ions, is one example of a bulk electrochemical method. A determination of pH using a pH electrode is one example of an interfacial electrochemical method. Only interfacial electrochemical methods receive further consideration in this text.

Interfacial Electrochemical Methods

Interfacial electrochemical methods are divided into *static* methods and *dynamic* methods. In static methods no current passes between the electrodes and the concentrations of species in the electrochemical cell remain unchanged, or static. *Potentiometry,* in which the potential of an electrochemical cell is measured under static conditions, is one of the most important quantitative electrochemical methods.

The largest division of interfacial electrochemical methods is the group of *dynamic* methods, in which current flows and concentrations change as the result of a redox reaction. Dynamic methods are further subdivided by whether we choose to control the current or the potential. In controlled current *coulometry,* we completely oxidize or reduce the analyte by passing a fixed current through the analytical solution. Controlled-potential methods are subdivided further into controlled-potential coulometry and amperometry, in which a constant potential is applied during the analysis, and voltammetry, in which the potential is systematically varied.

7. Answer the following questions.

- *What are the principal sources for the analytical signal?*
- *How many varieties of experimental designs are possible?*
- *What can we measure using bulk and interfacial methods?*
- *Would you give an example of an interfacial electrochemical method?*
- *What methods are interfacial electrochemical methods divided into? Describe each method.*

8. Draw the diagram of interfacial electrochemical methods and ask your partner about each method.

9. Skim the passage as fast as possible and find answers to the questions below, then divide the text into logical parts and entitle each part and make an appropriate comment on each part.

- *What do electrochemical methods include?*
- *What are potentiometric methods based on?*
- *What are coulometric methods based on?*
- *What is called polarography?*
- *What is amperometry?*
- *What is called the ion-selective electrode?*
- *What forms of polarography are described here?*

SUMMARY

Electrochemical methods include **potentiometry, coulometry, and voltammetry.** Potentiometric methods are based on the measurement of an electrochemical cell's potential when only a negligible current is allowed to flow. In principle the Nernst equation can be used to calculate the concentration of species in the electrochemical cell by measuring its potential and solving the Nernst equation; the presence of liquid junction potentials, however, necessitates the use of an external standardization or the use of standard additions.

Coulometric methods are based on Faraday's law that the total charge or current passed during an electrolysis is proportional to the amount of reactants and products in the redox reaction. If the electrolysis is 100% efficient, in that only the analyte is oxidized or reduced, then the total charge or current can be used to determine the amount of analyte in a sample. In controlled-potential coulometry, a constant potential is applied and the current is measured as a function of time, whereas in controlled – current coulometry, the current is held constant and the time required to completely oxidize or reduce the analyte is measured.

In voltammetry we measure the current in an electrochemical cell as a function of the applied potential. Individual voltammetric methods differ in terms of the type of the electrode used, how the applied potential is changed, and whether the transport of material to the electrode's surface is enhanced by stirring.

Polarography is a voltammetric experiment conducted at a mercury electrode under conditions in which the solution is not stirred. Normal polarography uses a dropping mercury electrode (or a static mercury drop electrode) and a linear potential scan in an unstirred solution. Other forms of polarography include *normal pulse polarography, differential pulse polarography, staircase polarography, and square-wave polarography,* all of which apply a series of potential pulses to the mercury electrode.

In hydrodynamic voltammetry the solution is stirred either by using a magnetic stir bar or by rotating the electrode. Because the solution is stirred, a dropping mercury electrode cannot be used and is replaced with a solid electrode. Both linear potential scans or potential pulses can be applied.

In stripping voltammetry the analyte is first deposited on the electrode, usually as the result of an oxidation or reduction reaction. The potential is then scanned, either linearly or by using potential pulses, in a direction that removes the analyte by a reduction or oxidation reaction.

Amperometry is a voltammetric method in which a constant potential is applied to the electrode and the resulting current is measured. Amperometry is most often used in the construction of chemical sensors that, as with potentiometric sensors, are used for the quantitative analysis of single analytes. One important example, for instance, is the Clark O_2 electrode, which responds to the concentration of dissolved O_2 in solutions such as blood and water.

Note:**In voltammetry the working electrode's surface area is significantly smaller than that used in coulometry.*

10. Fill in the blanks with the necessary words given in the box

In hydrodynamic …………. the solution is stirred either by using a…… …… bar or by rotating the electrode. Because the solution is stirred, a dropping mercury electrode cannot be used and is replaced with a ……electrode. Both linear potential scans or potential pulses can be applied.

In stripping voltammetry the …….. is first deposited on the electrode, usually as the result of an ………or reduction reaction. The potential is then scanned, either linearly or by using potential……, in a direction that removes the analyte by a reduction or oxidation reaction.

Voltammetry	magnetic stir	pulses	analyte	solid	oxidation

11. Write the annotation of the text "Summary" with the algorithm given in Appendix 3.

GRAMMAR REVISION

1. Remember the Infinitive forms.

	Active Voice	*Passive Voice*
Simple	*To solve*	*To be solved*
Continuous	*To be solving*	–
Perfect	*To have solved*	*To have been solved*

2. Study and remember the following chart, mind the functions of the Infinitive:

1. **To repeat** the words is very useful. It is important **to solve** this question.	*Subject*
2. The main task *is* **to examine** this substance. He *has to (must, may...)* **solve** this problem. The substance *began* **to melt**.	*Predicative*
3. He tried to **finish** his work in time. He is sorry **to have been late**.	*Object*
4. The material **to be used** was examined. He was the first **to examine** this material. Here is the student **to examine** this material.	*Attribute*
5. To understand this phenomenon well one must know the structure of the material.	*Adverbial modifier of purpose*
6. He knew me too well **not to believe** me.	*Adverbial modifier of result*

3. Define functions of the Infinitive and translate sentences into Russian.

A

1. Chemical reactions that change the concentration of hydrogen ions **to become** the same as in pure water are called neutralization reactions. 2. Ammonium ions interact with water **to form** hydronium ions in equilibrium with molecular ammonia. 3. No special regulation of concentration is required **to effect** a separation between the chlorides of these ions. 4. The purpose of these experiments was **to observe** properties of the element involved. 5. The aim of these research-workers is **to find out** the required element. 6. As a result of many experiments involving combining weights, chemists have been able **to determine** the relative weights of different elements. 7. The substance **to be extracted** should be more soluble in the extracting solvent than in the initial solution.

B

1. Some of the metals are not active enough **to react** with water at ordinary temperature. 2. **To establish** the molecular weight of oxygen means to find the number of atoms in the oxygen molecule. 3. The apparatus **to be used** in our work was constructed in our laboratory. 4. Where is the mixture **to be heated**? 5. E. Rutherford was the first **to change** nitrogen to oxygen by bombarding nitrogen atoms with alpha particles. 6. **To determine** the relative weights of different elements we were **to use** the relative system of atomic weights. 7. A slight addition of pressure at this temperature should cause liquefaction **to take place**, but beyond this temperature no amount of pressure would enable the gravitational attraction **to exceed** the energy of motion. 8. In order **to liquefy** a gas at a temperature below its critical temperature, it is practically necessary only **to compress** the gas.

4. Paraphrase the following sentences according to the given models:

Model I: The problem which is to be solved by us *is very interesting.*
The problem ***to be solved by us*** *is very interesting.*

1. Many ores which are to be found in our region will be used in industry. 2. The report which will be made by this scientist deals with very important problems in the field of atoms. 3. The solution which is to be filtered was poured into a flask. 4. The article which is to be translated is published in our journal. 5. The experiment which will be carried out will help us in our investigation.

Model II*: He was* ***the first who passed*** *all his exams. He was the* ***first to pass*** *all his exams.*

1. Dalton was the first who deduced scientifically the atomic theory from experimental data. 2. She was the last who learned the news. 3. Alpha radiation was the first that was studied in detail at that time. 4. He was the third who translated the article so well. 5. This student was the last who left the laboratory.

5. Study and remember the following chart, pay attention to the Passive Infinitive:

Active Infinitive	***Passive Infinitive***
1. She doesn't want **to ask** you. 2. My friend was glad **to have given** you this book. 3. He had **to translate** this article without a dictionary.	1. She doesn't want **to be asked**. 2. My friend was glad **to have been given** this book 3. The article had to **be translated** without a dictionary.

6. Find the sentences with the Complex Subject and translate them into Russian:

1. The new method appeared to be very tedious and time-consuming. 2. The atoms of unconfined elements proved to be electrically neutral. 3. Elements composed of atoms containing only one or two valence electrons prove to form positive ions by giving up electrons during their reactions. 4. This new element has been discovered to be very useful. 5. They knew this new element to have been discovered and used. 6. The concentration of the solute particles seems to be less than an integral multiple of the molecular concentration. 7. The question known to be very important will be discussed very soon.8. Many of the substances determined to be soluble will be carefully investigated. 9. Zinc and cadmium are used widely to protect iron and steel from rust. 10. The concentration of chromate ions required to establish this condition may be secured through the use of a weakly acidic solution of potassium chromate. 11.During the burning of coal there appears to be a loss of weight. 12. No single set of properties is sufficient to serve for the definition of

matter. 13. The changes reported to take place are shown in this table. 14. These changes were found to follow certain rules.

7. Change the subordinate clauses into sentences with the Complex Subject:

Model: *a) It is known that hafnium is used for making special glasses.*

b) Hafnium is known to be used for making special glasses.

1. It was proved that the boiling point of hafnium was 5,400 ºC. 2. It is considered that hafnium is hot-rolled in air at 840 ^{o}C. 3. It is known that zircons from granite rocks have higher *Hf/Zr* ratios than a mineral from alkalic rocks. 4. It has been estimated that the ratio of hafnium to zirconium is 0.02. 5. It is reported that the main problem in the production of hafnium is its separation from zirconium.

8. Translate the following sentences into Russian. Pay attention to the Complex Subject.

1. This situation is likely to occur at very high temperatures. 2. This point is not likely to be clarified because of the absence of an exact theory of irreversible processes. 3. In this case there seems to be no discrepancy between the experimental data and theory. 4. The ratio of the internal and gravitational mass was always found to be the same. 5. The electrons seem to be required to pick their way through a dense collection of ions whose own electric fields scatter and deflect them. 6. A tachyon whose energy is positive for one observer, however, might appear to be negative to other observers in motion with respect to the first. 7. Simple capture is said to be a resonance process; it can occur only if there is resonance between the energy of the incident neutron and the energy of one of the states of excitation of the new composite nucleus.

9. Change the subordinate clauses into sentences with the Complex Subject:

Pattern: It is known that he is a good engineer. – He is known to be a good engineer.

1. It is known that heat is a form of energy. 2. It is known that the delegation has left for home. 3. It is believed that he is one of the best students of our group. 4. It is reported that copper and silver are the best conductors of electricity. 5. It is known that Oxford and Cambridge are the most famous Universities in Great Britain. 6. It appeared that this phenomenon was of great importance. 7. It is unlikely that he will come back in a week. 8. It appeared that gamma rays were true waves like X-rays, but of much shorter wave-lengths. 9. It was found that beta rays consisted of negative electrons.

10. Define sentences with the Complex Subject.

1) Natural uranium has been stated to consist mainly of two isotopes. 2) Only a limited number of reactions is known to be influenced by light. 3) Forests are planted to stop dry winds. 4) To be fully effective control must start with the prediction of raw material. 5) To understand the procedure we must consider the following analogy. 6) To give a true picture of the surrounding matter is the task of natural

science. 7). The particles shown to be negatively charged were used in this device. 8) The beta rays were shown to be negative particles. 9). The element helium is known to have been discovered in the sun. 10) Organic chemistry is known to be defined as the chemistry of compounds containing carbon. 11) The experimenter knew this substance to be absolutely pure. 12) The procedure to be used for this work must be very accurate.

SELF-CHECK

1. Translate sentences into English, use the Complex Subject.

1. Известно, что цинк – это серебристо-белый метал с относительно низкими точкой плавления *(419,5 ºC)* и точкой кипения *(907 ºC).* 2. Известно, что научные сотрудники нашего института провели серию экспериментов по расщеплению урана. 3. Этот метод, по-видимому, старый и не дает хороших результатов. 4. Оказалось, что стоимость производства этих веществ очень велика. 5. Известно, что ядерное деление – один из новых типов трансмутации. 6. Считается, что уран и торий являются важными источниками тепла в мире. 7. Оказалось, что их дочерние ядра содержат несколько нейтронов, первоначально присутствующих в ядре урана 236.

2. Read the Russian variant and choose the necessary form in the English sentence:

1. Сообщают, что делегация уже приехала. The delegation is reported (to come, to have come). 2. Известно, что он работает над этой проблемой много лет. He is known (to be working, to have been working) at this problem for many years. 3. Утверждают, что этот закон был открыт Ломоносовым. This law is stated (to be discovered, was discovered, to have been discovered) by Lomonosov. 4. Оказывается, что эта сила действует на плоскость. This force seems (to have acted, to be acting) on the plane. 5. Считают, что этот студент изучает физику очень давно. This student is considered (to have been studying, to be studying) physics for a long time. 6. Законы движения, которые надо рассмотреть в этом тексте, как известно, были сформулированы Ньютоном. The laws of motion to be analyzed in this text are known (to have been formulated, to be formulated) by Newton. 7. Ожидают, что этот опыт будет проведен завтра. This experiment is expected (will be made, to be made, to have been made) tomorrow.

UNIT 8
Voltammetry
Grammar: Complex Object
«For + to» Infinitive Construction
Polysemantic Words.

1. Warm up

- *What do you know about voltammetry?*
- *What devices are used in this method of analysis.*

2. Study the definitions of the following words

Ramp, n	slope, incline
Total, n	whole amount; adj. – complete, entire
Sweep, v	extend in continuous curve, carry impetuously, brush off
Scan, v	look at carefully, measure, look into, examine
Rate, n	degree of speed, tempo
Plot, n	plan, scheme
Magnitude, n	greatness; size; importance, value
Amplitude, n	spaciousness, width
Dislodge, v	drive out especially from the place of hiding, remove, dislocate
Step, n	footstep, measure in paces

3. Match each word in "A" with its synonym in "B".

A. General, apply, vary, include, rotate, replace, minimize, duration, eliminate, return, occur, rate, experiment, magnitude, scale.

B. Use, differ, comprise, speed, range, reinstate, common, turn around, value, lessen, come back, happen, test, remove, period.

4. Look through the passage carefully and answer the following questions:

- *What is called a voltammogram?*
- *What is voltammetry?*
- *Do you often use a voltammetric method of analysis in your work?*
- *What can you analyze by this method?*
- *What electrodes are used in this method?*

VOLTAMMETRY

Voltammetry is an electrochemical method in which we measure current as a function of the applied potential.

Voltammetry is essentially an electrolysis on a microscale, using a micro working electrode (e.g., a platinum wire). As the name implies, it is current-voltage technique. The potential of the microworking electrode is varied (scanned slowly) and the resulting current is recorded as a function of applied potential. The recording is called a voltammogram. If an electroactive (reducible or oxidizable) species is present, a current will be recorded when the applied potential becomes sufficiently negative or positive for it to be electrolyzed. [By convention, a cathodic (reduction) current is + and an anodic (oxidation) current is -]. If the solution is dilute, the current will reach a limiting value, because the analyte can only diffuse to the electrode and be electrolyzed at a finite rate, depending on its concentration. We will see below that the limiting current is proportional to the concentration of the species. The microelectrode restricts the current to a few microamperes or less, and so in most applications the concentration of the test substance in solution remains essentially unchanged after the voltammogram is recorded.

5. Fill in the gaps with corresponding words from the box below.

The Voltammetric Cell

A voltammetric cell consists of the microworking electrode, the auxiliary electrode, and a reference electrode, usually an SCE. A …*(A device used to control the potential in an electrochemical cell)* is employed to control the potential. The current of the working electrode is recorded as a function of its potential measured against the …   …, (*whose potential remains constant and against which other potentials can be measured)* but the voltage is applied between and the current passes between the working and auxiliary electrodes.

In this manner, the current-voltage curve is not disturbed by an appreciable solution resistance, which creates an *iR* drop (voltage drop) between the working and auxiliary electrodes, as in nonaqueous solvents. The recorded potential is that between the working electrode and the reference electrode, with essentially no flow of current.

reference electrode	potentiostat

6. Skim the text below and choose the answers that suit the following questions best.

- *What is called faradic current?*
- *What is nonfaradic current?*
- *What is cathodic current?*
- *What is anodic current?*

Currents in Voltammetry

When an analyte is oxidized at the working electrode, a current passes electrons through the external electric circuit to the auxiliary electrode, where reduction of the solvent or other components of the solution matrix occurs. Reducing an analyte at the working electrode requires a source of electrons, generating a current that flows from the auxiliary electrode to the cathode. In either case, a current resulting from redox reactions at the working and auxiliary electrodes is called a **faradic current.** In this section we consider the factors affecting the magnitude of this faradic current, as well as the source of any nonfaradic currents.

Since the reaction of interest occurs at the working electrode, the classification of current is based on this reaction. A current due to the analyte's reduction is called a **cathodic current** and, by convention, is considered positive. **Anodic currents** are due to oxidation reactions and carry a negative value.

Influence of Mass Transport on the Faradic Current

There are three modes of **mass transport** that influence the rate at which reactants and products are transported to and fro the electrode surface: **diffusion**, **migration,** and **convection. Diffusion** from a region of high **concentration** to a region of low concentration occurs whenever the concentration of an ion or molecule at the surface of the electrode is different from that in bulk solution. The volume of solution in which the concentration gradient exists is called the **diffusion layer.** Without other modes of mass transport, the width of the diffusion layer, 8, increases with time as the concentration of **reactants** near the electrode surface decreases. The contribution of diffusion to the rate of mass transport, therefore, is time-dependent.

Note: **In voltammetry the working electrode's surface area is significantly smaller than that used in coulometry. Consequently, very little* *analyte undergoes electrolysis, and the analyte's concentration in bulk solution remains essentially unchanged.*

7. Explain the words given in bold.

8. What is the main idea of the last text?

9. Before reading the passage, read its headline and say what you know about this problem. Discuss it with your partners. Then read the passage and find the facts supporting your ideas.
Pay attention to the following definitions:

Faradic current *–*	*Any current in an electrochemical cell due to an oxidation or reduction reaction*
Cathodic current *–*	*A faradic current due to a reduction reaction*
Anodic current *–*	*A faradic current due to an oxidation reaction*
Mass transport *–*	*The movement of material toward or away from the electrode surface*
Diffusion *–*	*The movement of material in response to a concentration gradient*
Diffusion layer *–*	*The layer of solution adjacent to the electrode in which diffusion is the only means of mass transport*

POLAROGRAPHY

Polarography is an ***voltammetric*** measurement whose response is determined by ***combined diffusion/convection*** mass transport. Polarography is a specific type of measurement that falls into the general category of ***linear-sweep voltammetry*** where the electrode potential is altered in a linear fashion from the initial potential to the final potential. As a linear sweep method controlled by convection/diffusion mass transport, the current vs. potential response of a polarographic experiment has the typical sigmoidal shape. What makes polarography different from other linear sweep voltammetry measurements is that polarography makes use of the ***dropping mercury electrode*** **(DME).**

A plot of the current *vs.* potential in a polarography experiment shows the current oscillations corresponding to the drops of Hg falling from the capillary. If one connected the maximum current of each drop, a sigmoidal shape would result. The limiting current (the plateau on the sigmoid), called the ***diffusion current*** because diffusion is the principal contribution to the flux *c* electroactive material at this point of the Hg drop life, is related to analyte concentration by the Ilkovic equation:

$$i_d = 708nD^{1/2}m^{2/3}t^{1/6}c,$$

where D is the diffusion coefficient of the analyte in the medium (cm^2/s), n is the number of electrons transferred per mole of analyte, m is the mass flow rate of *Hg* through the capillary (mg/sec), and *t* is the drop lifetime is seconds, and *c* is analyte concentration in *mol/cm*^{3}.

There is a number of limitations to the polarography experiment for quantitative analytical measurements. Because the current is continuously measured during the growth of the Hg drop, there is a substantial contribution from ***capacitive current.*** As the Hg flows from the capillary end, there is initially a large increase in the surface area. As a consequence, the initial current is dominated by capacitive effects as charging of the rapidly increasing interface occurs. Towards the end of the drop life, there is little change in the surface area which diminishes the contribution *c* capacitance changes to the total current. At the same time, any redox process, which occurs, will result in the farad current that decays approximately as the square root of time (due to the increasing dimensions of the ***Nernst diffusion layer****)*. The exponential decay of the capacitive current is much more rapid than the decay of the faradic current; hence, the faradic current is proportionally larger at the end of the drop life. Unfortunately, this process is complicated by the continuously changing potential that is applied to the working electrode (the *Hg* drop) throughout the experiment. Because the potential is changing during the drop lifetime (assuming typical experimental parameters of a *2mV/sec* scan rate and a 4 sec drop time, the potential can change by *8 mV* from the beginning to the end of the drop), the charging of the interface (capacitive current) has a continuous contribution to the total current, even at the end of the drop when the surface area is not rapidly changing. As such, the typical signal to noise of a polarographic experiment allows detection limits of only approximately 10^{-5} or 10^{-6} M. Better discrimination against the capacitive current can be obtained using the ***pulse polarographic techniques***.

Qualitative information can also be determined from the ***half-wave potential*** of the polarogram (the current vs. potential plot in a polarographic experiment). The value of the half-wave potential is related to the standard potential for the redox reaction being studied.

10. Write the outline of the text and choose the key words on the subject.

11. What is the difference between polarography and other linear sweep voltammetry measurements?

12. Explain the meaning of the word combinations given in bold.

13. Quote the text to prove that:

- *A polarographic experiment has the typical sigmoidal shape;*
- *The initial current is dominated by capacitive effects;*
- *The exponential decay of the capacitive current is much more rapid than the decay of the faradic current;*

14. Fill in the blanks with the necessary words given in the box.

Potentiomentry measures … developed by an … in an electrolyte solution at zero … .

It uses the Nernst equation relating … to … of some ion in solution.

Electrical potential	**electrode**	**zero current**
flow concentration	**potential**	

15. Read the following information and answer the following questions

- *What is this text about?*
- *How is polarogram obtained?*
- *What is the advantage of the normal pulse polarography method?*

Normal-Pulse Polarography (NPP)

Pulse polarographic techniques are voltammetric measurements, which are variants of the polarographic measurement, which try to minimize the ***background capacitive contribution*** to the current by eliminating the continuously varying potential ramp, and replacing it with a series of potential steps of short duration. In Normal-pulse polarography (NPP), each potential step begins at the same value (a potential at which no faradic electrochemistry occurs), and the amplitude of each subsequent step increases in small ***increments***. When the *Hg* drop is dislodged from the capillary (by a ***drop knocker*** at accurately timed intervals), the potential is returned to the initial; value in preparation for a new step.

For this experiment, the ***polarogram*** is obtained by plotting the measured current *vs*. the potential to which the step occurs. As a result, the current is not followed during Hg drop growth, and normal pulse polarogram has the typical shape of a ***sigmoid.*** By using discrete potential steps at the end of the drop lifetime (usually during the last 50-100 *ms* of the drop life which is typically 2-4 *s*), the experiment has a constant potential applied to an electrode with nearly constant surface area. After the initial potential step, the capacitive current decays exponentially while the faradic current decays as the square root of time. The diffusion current is measured just before the drop is dislodged, allowing excellent discrimination against the background capacitive current. In many respects, this experiment is like conducting a series of ***chromoamperometry*** experiments in sequence on the same ***analyte solution.*** The normal pulse polarography method increases the analytical sensitivity by 1 - 3 orders of magnitude (limits of detection 10^{-7} to 10^{-8} M, relative to normal *dc* polarography.

16. Explain the words given in bold.

17. Write the abstract of one of the articles. They are given at the end of the book. See Appendix 4.

GRAMMAR REVISION

1. Translate the following sentences into Russian paying attention to the Complex Object.

1. We know A.V. Shubnikov to have made the first systematic measurements of the properties of Type II superconductors. 2. In solids, molecules have fixed lattice sites but their thermal motion causes them to vibrate around these equilibrium positions. 3. We now know the subatomic particles to be created or destroyed easily. 4. No one expected this problem to be solved. 5. No scientist could suppose this estimation to be true. 6. No one doubted us to have done the job well.

2. Make up simple sentences using the Complex Object:

Model: *We believe that this flight is an outstanding event.*
We believe this flight to be an outstanding event.

1. They supposed that this test will be carried out next month. 2. We know that the first atomic power station has been built in Obninsk. 3. Our professor wants that we should make use of these data. 4. I saw that they were testing this device. 5. I heard that she spoke English. 6. We think that this research work will be completed in a month.

3. Work in pairs.
Use the Complex Object answering the questions.

Pattern: *The doctor was examining the patient. Robert saw it.*
What did Robert see?
- Robert saw the doctor examine the patient.

- *They were discussing the question. George heard it. What did George hear?*
- *The telegram was delivered at seven o'clock. Robert saw it. What did Robert see?*
- *He announced the news loudly. Everybody heard it. What did everybody hear?*
- *Alice mentioned it, and he heard it. What did he hear?*
- *The teacher explained the rule. We heard it. What did we hear?*

- *The mechanic was repairing the car and everybody was watching him. Whom was everybody watching?*
- *The engineer was examining the motor. Peter saw it. What did Peter see?*
- *The secretary typed the paper and the manager saw it. What did the manager see?*

4. Point out sentences in which the predicate has a direct object (simple or complex).

- *We like reading and translating technical texts from English into Russian.*
- *They found the substance to be a compound of two gases.*
- *One may safely expect this prediction to be quite reliable.*
- *By this method they could increase the number of molecules escaping from the surface of the liquid.*
- *These figures indicate the expansion of the American economy.*

5. Translate sentences with «For + to» Infinitive Constructions into Russian.

1. It is the question too difficult for her to answer. 2. Here is the book for you to read in the train. 3. It is important for them to fulfil this task in time. 4. He waited for her to speak. 5. He asked for her papers to be brought. 6. He stepped aside for me to pass. 7. There's nobody here for him to play with. 8. We waited for the director to finish his conversation over the telephone. 9. These are the books for you to read in summer. 10. Everybody waited for the meeting to start. 11. It was late for us to begin discussing this question.

6. Translate the following sentences into Russian paying attention to the word ”make”.

Make, v – *делать*
To make use of – *использовать*
To make up – *составлять*
To make up for – *компенсировать, восполнять*

Make + Infinitive without the particle "to" – заставлять
If the verb "make" is used in the Passive Voice, it has the particle "to".

1. All in the earth and atmosphere is **made up** of atoms and molecules. 2. There are other processes in nature by which nitrogen is **made up for**. 3. The question is what **makes** a chemical reaction go. 4. When Mendeleyev reached iron he had to **make** an eighth column with the three elements – iron, cobalt and nickel in it. 5. The laboratory assistant was **made** to repeat that experiment. 6. We **made** that test to **make** you realize that it was necessary to raise the pressure by three atmospheres. 7. No plans were **made** to analyze the new substance. 8. Each nucleus contains enough

protons to account for the positive charge of a nucleus, the balance in the weight is **made up** of neutrons.

SELF-CHECK
Translate the following sentences into Russian paying attention to the Infinitive and Infinitive Constructions.

1. I want you to explain theory to him. 2. We heard our scientist speak on the radio. 3. We expected the delegation to arrive soon. 4. Scientists are known to have worked for a long time to find an answer to the last question. 5. At present, we know heat to be a form of energy. 6. We know the electric charges to be positive and negative. 7. I saw the water boil. 8. We suppose him to work at this plant. 9. He seems to know English well. 10. He is supposed to work at this plant. 11. I wish you to come again. 12. At present we know heat to be a form of energy. 13. The doctor was the first person to be sent for. 14. He wanted me to visit his friend and to be introduced to him. 15. Our students were happy to have been sent to the international students' camps. 16. The helium atom was found to have two electrons. 17. We are supposed to graduate from the Academy in four years. 18. Everybody expected you to give this information. 19. I saw her switch off the light and go out of the room. 20. A computer is a suitable machine for them to use in their research work. 21. He is unlikely to take one of the first prizes. 22. This test is supposed to be carried out next month. 23. We know them to have graduated from the institute. 24. Their plans are likely to change in the future. 25. The first man to fly into space was Y. Gagarin.

UNIT 9
Voltammetric Methods of Analysis
Grammar: Subjunctive Mood;
Composite Prepositions

1. Warm up

- *What was the earliest voltammetric technique?*
- *Who was the father of polarography method?*

2. Before reading the text, pay attention to the definitions of the following words:

voltammetry

An electrochemical method in which we measure current as a function of the applied potential.

voltammogram

A plot of current as a function of applied potential.

Then read the text and tell about the steps of developing voltammetry.

Voltammetric Methods of Analysis

In voltammetry a time-dependent potential is applied to an electrochemical cell, and the current flowing through the cell is measured as a function of that potential. A plot of current as a function of applied potential is called a voltammogram and is the electrochemical equivalent of a spectrum in spectroscopy, providing quantitative and qualitative information about the species involved in the oxidation or reduction reaction. The earliest voltammetric technique to be introduced was polarography, which was developed by Jaroslav Heyrovsky (1890-1967) in the early 1920s, for which he was awarded the Nobel Prize in chemistry in 1959. Since then, many different forms of voltammetry have been developed. Before examining these techniques and their applications in more detail, however, we must first consider the basic experimental design for making voltammetric measurements and the factors influencing the shape of the resulting voltammogram.

3. Fill in the gaps with words given in the box.

Hydrodynamic Voltammetry

In polarography a limiting current is obtained because each falling drop of mercury returns the solution near the electrode to its initial composition. As noted earlier, a limiting current is also obtained whenever the solution is ...*(mixed)* during the analysis. The simplest means of stirring the solution is with a magnetic stir bar. More commonly, however, stirring is achieved by rotating the electrode.

In hydrodynamic… (*An electrochemical method in which we measure current as a function of the applied potential)* current is measured as a function of the potential applied to a solid working electrode. The same potential profiles used for polarography, such as a linear scan or a differential pulse, are used in hydrodynamic voltammetry. The resulting… *(A plot of current as a function of applied potential)* are identical to those for polarography, except for the lack of current oscillations resulting from the growth of the mercury drops. Because hydrodynamic voltammetry is not limited to *Hg* electrodes, it is useful for the analysis of analytes that are reduced or oxidized at more positive potentials.

Voltammograms	stirred	voltammetry

4. What is the difference between polarography and hydrodynamic voltammetry?

5. Read the following information and put questions to this text, then ask your partner.

Stripping Voltammetry

It is a form of voltammetry in which the analyte is first deposited on the electrode and then removed, or "stripped," electrochemically while monitoring the current as a function of the applied potential.

One of the most important quantitative voltammetric techniques is stripping voltammetry, which is composed of three related techniques*: anodic, cathodic, and adsorptive stripping voltammetry*. Since anodic stripping voltammetry has found the widest application, we consider it in the greatest detail. Anodic stripping voltammetry consists of two steps. The first is a controlled potential electrolysis in which the working electrode, usually a hanging mercury drop or mercury film, is held at *a cathodic potential* sufficient to deposit the metal ion on the electrode. This step essentially serves as a means of preconcentrating the *analyte* from the larger volume of the solution to the smaller volume of the electrode. The solution is stirred during electrolysis to increase the rate of deposition. Near the end of the deposition time stirring is stopped, eliminating convection as a mode of mass transport. Deposition times of 1-30 *min* are common, with longer times being used for analytes at lower concentrations.

In the second step, the potential is scanned anodically toward more positive potentials. When the potential of the *working electrode* is sufficiently positive the analyte is stripped from the electrode. The current during the stripping step is monitored as a function of potential, giving rise to peak-shaped.

The peak current is proportional to the analyte's concentration in the solution.

Anodic stripping voltammetry is very sensitive to experimental conditions, which must be carefully controlled if results are to be accurate and precise. Key variables include the area of the mercury film electrode or the size of the Hg drop when using a hanging mercury drop electrode, the deposition time, the rest time, the rate of stirring, and the scan rate during the stripping step. Anodic stripping voltammetry is best used for metals that form amalgams with mercury.

The experimental design for *cathodic stripping voltammetry* is similar to that for anodic stripping voltammetry with two exceptions. First, the deposition step involves the oxidation of the Hg electrode to Hg_2^{2+}, which then reacts with the analyte to form an insoluble film at the surface of the electrode. For example, when Cl^- is the analyte the deposition step is

$$2Hg(l) + 2Cl^-(aq) \rightarrow Hg_2Cl_2(s) + 2\bar{e}$$

Second, stripping is accomplished by scanning cathodically toward a more negative potential, reducing Hg_2^{2+} back to Hg and returning the analyte to solution.

$$H_{g2}Cl_2(s) + 2\bar{e} \rightarrow 2Hg(l) + 2Cl^-(aq)$$

The table below lists several analytes that have been analyzed successfully by cathodic stripping voltammetry.

In adsorptive stripping voltammetry the deposition step occurs without electrolysis. Instead, the analyte adsorbs to the electrode's surface. During deposition the electrode is maintained at a potential that enhances adsorption. For example, adsorption of a neutral molecule on a Hg drop is enhanced if the electrode is held at -0.4 V versus the SCE, a potential at which the surface charge of mercury is approximately zero. When deposition is complete the potential is scanned in an anodic or cathodic direction depending on whether we wish to oxidize or reduce the analyte. Examples of compounds that have been analyzed by absorptive stripping voltammetry also are listed in Table below.

Stripping Voltammetry

Anodic Stripping Voltammetry	Cathodic Stripping Voltammetry	Absorptive Stripping Voltammetry
bismuth	bromide	bilirubin
cadmium	chloride	codeine
copper	iodide	cocaine
gallium	mercaptans (RSH)	digitoxin
indium	sulfide	dopamine
lead	thiocyanate	heme
thallium	-	monensin
tin	-	testosterone

6. Explain the way you understand the italicized words and phrases in the passage and answer the questions:

- *What is called the stripping voltammetry?*
- *What techniques is stripping voltammetry composed of?*
- *What is called anodic stripping voltammetry?*
- *What is called cathodic stripping voltammetry?*

7. Skim the text "Voltammetric Measurements", choose the key words on the subject and write the outline of the text.

Voltammetric Measurement

Although early voltammetric methods relied on the use of only two electrodes, modern voltammetry makes use of a three-electrode potentiostat. A time-dependent potential excitation signal is applied to the working electrode, changing its potential relative to the fixed potential of the reference electrode. The resulting current between the working and auxiliary electrodes is measured. The auxiliary electrode is generally a platinum wire, and *the standard hydrogen electrode (SHE) and Ag/AgCl electrode* are common reference electrodes.

Several different materials have been used as working electrodes, including mercury, platinum, gold, silver, and carbon. The earliest voltammetric techniques, including polarography, used mercury for the working electrode. Since mercury is a liquid, the working electrode often consists of a drop suspended from the end of a capillary tube.

In the *hanging mercury drop electrode, or HMDE,* a drop of the desired size is formed by the action of a micrometer screw that pushes the mercury through a narrow capillary tube. In the *dropping mercury electrode, or DME,* mercury drops form at the end of the capillary tube as a result of gravity. Unlike the HMDE, the mercury drop of a DME grows continuously and has a finite lifetime of several seconds. At the end of its lifetime the mercury drop is dislodged, either manually or by gravity, and replaced by a new drop. The *static mercury drop electrode, or SMDE*, uses a solenoid-driven plunger to control the flow of mercury. The SMDE can be used as either a hanging mercury drop electrode or as a dropping mercury electrode. A single activation of the solenoid momentarily lifts the plunger, allowing enough mercury to flow through the capillary to form a single drop. To obtain a dropping mercury electrode the solenoid is activated repeatedly. A mercury film electrode consists of a thin layer of mercury deposited on the surface of a solid carbon, platinum, or gold electrode. The solid electrode is placed in a solution of Hg^{2+} and held at a potential at which the reduction of Hg^{2+} to Hg is favorable, forming a thin mercury film.

Mercury has several advantages as a working electrode. Perhaps its most important advantage is its high overpotential for the reduction of H_3O^+ to H_2, which allows the application of potentials as negative as –1 V versus the SCE in acidic solutions, and –2 V versus the SCE in basic solutions. A species such as Zn^{2+}, which is difficult to reduce at other electrodes without simultaneously reducing H_3O^+, is easily reduced at a mercury working electrode.

8. Answer the following questions.

- *What does modern voltammetry rely on?*
- *How does the auxiliary electrode look like?*
- *What materials have been used as working electrodes?*
- *What did the earliest voltammetric techniques use for working electrode?*

Oral Practice

9. Work in pairs. Ask for the information, like this:

- *What does the HMDE mean?*
- *HMDE stands for …*
- *What does the DME mean?*
- *DME stands for …*
- *What does the SMDE mean?*
- *SMDE stands for …*

10. Retell the text according to your outline.

Grammar

GRAMMAR REVISION

1. Translate the following sentences into Russian, mind the Subjunctive Mood.

1.We suggested that the project should be discussed in detail. 2. Whatever the nature of the tube and the arrangement of the electrode be, an emitting electrode should be present. 3. He proposed that this fact be used to define a temperature scale, which would be independent of the properties of any particular substance. 4. The new technique suggests that a similar method might be used in color television. 5. It is necessary that the plates of a condenser be well insulated from one another. 6. It is desirable that the student should know another definition of radioactive elements. 7. It is important that all machinery should be always in good order. 8. In many operations it is important that the frequency of the oscillator be constant.

2. Insert the verbs in the forms of the Subjunctive Mood instead of the Infinitives.

1. So that an electric current may flow through a circuit, it is necessary that there (to be) an electromotive force acting in the circuit. 2. It was suggested that the machine parts (to be tested) under very severe conditions. 3. It is theoretically possible that a part of the nuclear energy (to be liberated) by transforming either the lightest or the heaviest of the elements into others of medium weight. 4. Mendeleyev found it is necessary to alter some atomic weights in order that the elements (to fall)

into positions in the periodic table assigned to them by their chemical properties. 5. The concept of a fundamental particle requires that we (to have) also precise knowledge about their rest mass, their spin, as well as the statistics they obey. 6. The crystal acts as if it (to be compressed) by a great pressure. 7. The whole weight of a body acts as though it (to be concentrated) at a single point, this point being called the centre of gravity. 8. When an electromagnetic wave propagates through uniform plasma it behaves as though the plasma (to be) a homogeneous dielectric medium. 9. He found that such an object casts a shadow, as though the glow (to be produced) in the glass by rays proceeding in straight lines from the cathode.

3. Translate the following sentences into Russian, concentrate on words "should" and "would".

1) It is not necessary that there should be two coils of wire in order to observe the phenomenon of inductance. 2) If the human eye were uniformly sensitive to radiation of all wavelengths, the radiant power expressed in watts would provide an adequate method of evaluating the flux. 3) Nuclear energy should be used for peaceful purposes only. 4) Since it is a scalar, it should be the same for any orientation of the spin. 5) First we should consider the arrangement of atoms in metals, i.e. in substances having thermal and electrical conductivities. 6) Since a liquid-crystal device does not emit light, it should require relatively little power. 7) If negative-energy tachyons were emitted by the unexcited atoms of ordinary matter, this would cause the emitting atoms to be unstable. 8) If it were not for the ionosphere, radio waves would propagate like light waves, only within the limits of the visible horizon. 9) If at this moment the charged rod were removed all the original charges in the electroscope would return to their original positions.

4. Translate sentences into Russian, pay attention to the paired conjunctions

Either … or – или … или; либо … либо

The … the – чем …, тем (в сочетании с прилагательными в сравнительной степени)

Whether … or – будь то … или; независимо от того … ли

1. The more carbon the steel contains, the harder it becomes. 2. The stronger the magnet, the more magnetic lines of force pass through a given space. 3. The more surface of the material is exposed to the air, the more rapidly burning takes place. 4. The higher the energy of the bombarding electrons, the greater the number of secondary electrons to be emitted. 5. The lower the electronegativity of the metal, the higher the reactivity of its organometallic compounds. 6. The method is used whether the product is pure or contaminated. 7. In any element whether it is gold, copper, mercury, hydrogen or any other element electrons are always in motion. 8. In each salt crystal whether large or small the ions of chlorine and sodium are arranged in regular order. 9. Oxidation may be either slow or rapid, in both cases the same

amount of heat is liberated provided that the same kind and quantities of substances undergo oxidation. 10. Acids may be either gases, liquids or solids.

5. Remember well these composite prepositions.

According to	
In accordance with	согласно
Aside from	
Apart from	помимо, кроме
Because of	
On account of	
By virtue of	
Owing to	из-за; в силу; благодаря
Thanks to	
Due to	
To be due to	быть вызванным, обусловленным
By means of	при помощи, посредством
Compared to/with	по сравнению с
Depending upon/on	в зависимости от
Except for	кроме, исключая
In spite of	несмотря
Instead of	вместо
Regardless of	независимо от
In terms of	на основе, в виде, исходя из
Parallel with	наряду
With respect to	в отношении
With regard to	принимая во внимание

6. Translate the following sentences into Russian.

1) Radiant energy is described in this paper **in terms of** the electromagnetic spectrum. 2) Iron is usually used when hydrogen is prepared **by means of** the reaction between water and a metal. 3) **Due to** its greater energy content ozone is more reactive than oxygen. 4) The difference between the two kinds of product is largely **due to** the amount and nature of impurities. 5) The electrons and the nucleus are very small **as compared** to the size of the atom. 6) Gases, unless highly compressed, are characterized by extreme lightness **compared to** liquids and solids, while compared to gases the former are highly incompressible. 7) The property **by virtue of** which a body offers resistance to a change in its motion is called inertia. 8) The liquids were selected **with regard to** their degree of polarity and the temperature range, which permits them to remain in the liquid state. 9) The elements are arranged in the Periodic Table **in accordance with** their atomic number. 10) **On account of** its inertness it is difficult to make nitrogen combine with other elements and its compounds are unstable.

SELF-CHECK

1. Translate the parts of the sentences given in Russian into English.

Model: *In general, it may be desirable* ***that the transmitted pulse (should) make some mark on the oscilloscope to serve as a zero time-of-flight reference****.*

- In this case it is desired that … антенны имели бы несколько меньшее усиление.
- It is required that … отношение “сигнал–шум” было бы удовлетворительным.
- It is necessary that … передаваемый сигнал был бы очень большой силы.
- It is impossible that … отраженный импульс вернется через короткое время.
- It is unnecessary that … радар имел бы точный стабилизатор частоты.

UNIT 10

Potentiometry

Grammar: Conditional Sentences;
Negation in the English Sentence;
Composite Verbs

1. Warm up

- *What do you know about potentiometry and potentiometric methods of analysis?*

2. Active Vocabulary

Study the meaning of the following words.

Proceed, v	go forward, continue, be carried on
Equilibrium, n	state of balance
Conduct, v	lead, direct, escort
State, n	condition
Allow, v	permit, acknowledge
Calculate, v	compute, consider, think
Explicit, adj.	statement clearly and fully expressed
Permeable, adj.	admitting of passage of fluids
Semi-, pref.	forms compounds with the meaning of ‘half’ as in ‘semiconductor’

Membrane, n	thin flexible material
Selective, adj.	choice, picked, exclusive
Discrepancy, n	contradiction, difference , disagreement

3. Match each word in "A" with its synonym in "B".

A. Measure, determine, concentration, component, occur, proceed, condition, satisfy, concept, introduce, difference, allow, standard, generate, permeable.

B. Porous, designate, quantify, part, create, arise, circumstance, focus, nation, discrepancy, agree to, continue, make happy, normal, bring in.

4. Match each word in "A" with its antonym in "B" and translate them into Russian.

A. Permeable, allow, difference, proceed, concentration, anode, standard, initial, typically, involve.

B. Forbid, recede, watertight, cathode, similarity, destruction, unusual, bore, final, uncharacteristically.

5. Match the following word combinations in "A" with Russian equivalents in "B".

A.	B.
1. Measured potential 2. Standard state 3. Redox reactions 4. Potentiometric phenomena 5. Semi-permeable membrane 6. Potential difference	a) полупроницаемая мембрана b) окислительно- восстановительная реакции c) потенциометрические явления d) разность потенциалов e) измеряемый потенциал f) стандартное состояние

6. Read the following information and put the questions to the words given in italics.

Potentiometry

Potentiometry is the field of *electroanalytical chemistry* in which potential is measured under the conditions of no current flow. The measured potential may then be used to determine the analytical quantity of interest, generally the concentration of some component of the analyte solution. The potential that develops in the *electrochemical cell* is the result *of the free energy change that* would occur if the chemical phenomena were to proceed until the *equilibrium condition* has been satisfied.

This concept is typically introduced in quantitative analysis courses in relation to *electrochemical cells that* contain an *anode* and a *cathode.* For these electrochemical cells, *the potential difference* between the cathode *electrode potential* and the anode electrode potential is the potential of the electrochemical cell.

If the reaction is conducted *under standard state* conditions, this equation allows the calculation of the standard cell potential. When the reaction conditions are not standard state, however, one must utilize the *Nernst equation* to determine the cell potential.

Physical phenomena which do not involve explicit redox reactions, but whose initial conditions have a non-zero free energy, also will generate a potential. An example of this would be ion concentration gradients across a semi-permeable membrane. This can also be potentiometric phenomenon, and is the basis of measurements that use *ion-selective electrodes.*

7. Read the following information and say a few words about each of the problems posed by the authors and their importance for analytical chemistry.

TYPES OF ELECTRODES

Let's consider only some types of electrodes.

Reference Electrodes

Potentiometric electrochemical cells are constructed such that one of the half-cells provides a known reference potential, and the potential of the other half-cell indicates the analyte's concentration. By convention, the reference electrode is taken to be the anode.

The ideal reference electrode must provide a stable potential so that any change in *E* cell is attributed to the indicator electrode, and, therefore, to a change in the analyte's concentration. In addition, the ideal reference electrode should be easy to make and to use. Three common reference electrodes are discussed in this section.

Standard Hydrogen Electrode

The standard hydrogen electrode (SHE) is rarely used for routine analytical work, but is important because it is the reference electrode used to establish standard-state potentials for other half-reactions. The SHE consists of a Pt electrode immersed in a solution in which the hydrogen ion activity is 1.00 and in which H_2 gas is bubbled at a pressure of 1 Atm. A conventional salt bridge connects the SHE to the indicator half-cell. The shorthand notation for the standard hydrogen electrode is

$$Pt(s), H_2 \text{ (g, 1 Atm) / } H^+ \text{ (aq, } a = 1.00) \text{ //}$$

The S.H.E. consists of hydrogen gas bubbling over a platinum electrode immersed in a solution of hydrochloric acid. At standard conditions, the hydrogen must be at a pressure of 1 Atm (101.325 kPa) and the acid must be 1 mol per liter, but we can ignore the difference. The temperature should be 25°C (298 K). The platinum electrode is usually coated with finely divided platinum called platinum black. This acts as a catalyst to allow equilibrium between the gas and the solution to be established quickly. Standard Hydrogen Electrode is shown in Fig. 5.

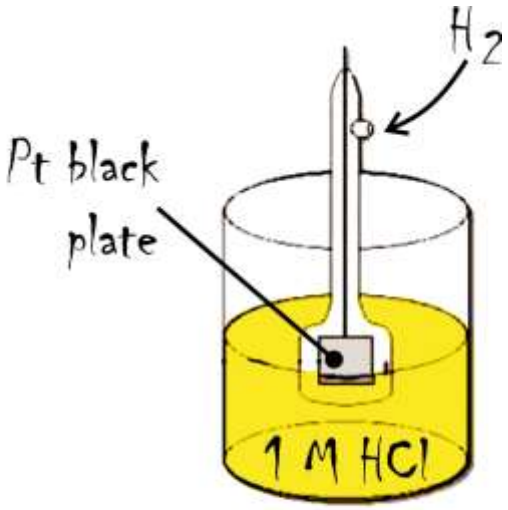


Fig. 5. Standard Hydrogen Electrode (SHE)

Calomel Electrodes

Calomel reference electrodes are based on the redox couple between Hg_2Cl_2 and Hg (calomel is a common name for Hg_2Cl_2). $Hg_2Cl_2(s) + 2\bar{e} \rightarrow 2Hg(l) + 2Cl^-(aq)$. The Nernst equation for the calomel electrode is E = 0.244 V.

The **saturated calomel electrode** (SCE), which is constructed using an aqueous solution saturated with KCl, has a potential at 25 °C of +0.2444 V. A typical SCE consists of an inner tube, packed with a paste of Hg, Hg_2Cl_2, and saturated KCl, situated within a second tube filled with a saturated solution of KCl. A small hole connects the two tubes, and an asbestos fiber serves as a salt bridge to the solution in which the SCE is immersed. The stopper in the outer tube may be removed when additional saturated KCl is needed. The shorthand notation for this cell is

$$Hg(l) / Hg_2Cl_2 \text{ (sat'd), KCl (aq, sat'd) //}$$

The SCE has the advantage that the concentration of Cl^-, and, therefore, the potential of the electrode, remains constant even if the KCl solution partially evaporates. On the other hand, a significant disadvantage of the SCE is that the solubility of KCl is sensitive to a change in temperature. At higher temperatures the concentration of Cl^- increases, and the electrode's potential decreases. For example the potential of the SCE at 35 °C is +0.2376 V.

Electrodes containing unsaturated solutions of KCl have potentials that are less temperature-dependent, but experience a change in potential if the concentration of KCl increases due to evaporation. Another disadvantage of calomel electrodes is that they cannot be used at temperatures above 80 °C. Calomel Electrode is shown in Fig.6.

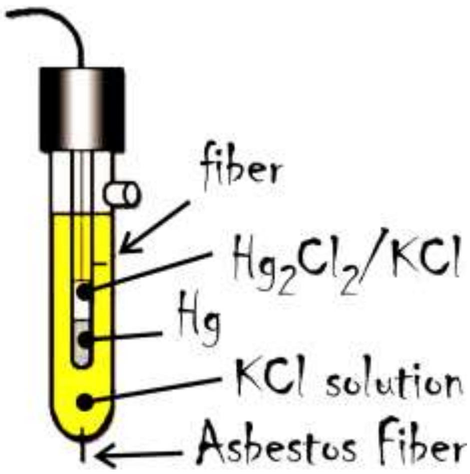


Fig. 6. Calomel Electrode (SCE)

Silver/Silver Chloride Electrodes

Another common reference electrode is the **silver/silver chloride electrode,** which is based on the redox couple between AgCl and Ag.

As with the saturated calomel electrode, the potential of the Ag/AgCl electrode is determined by the concentration of Cl^- used in its preparation.

When prepared using a saturated solution of KCl, the **Ag/AgCl** electrode has a potential of +0.197 V at 25 °C. Another common **Ag/AgCl** electrode uses a solution of 3.5 M KCl and has a potential of +0.205 at 25 °C. The Ag/AgCl electrode prepared with saturated KCl, of course, is more temperature-sensitive than one prepared with an unsaturated solution of KCl.

A typical **Ag/AgCl** electrode consists of a silver wire, the end of which is coated with a thin film of AgCl. The wire is immersed in a solution that contains the desired concentration of KCl and that is saturated with AgCl. A porous plug serves as the salt bridge. The shorthand notation for the cell is

Ag(s) / AgCl (sat'd), KCl (*x*M) //,

where *x* is the concentration of KCl. Ag/AgCl electrode is shown in fig. 7.

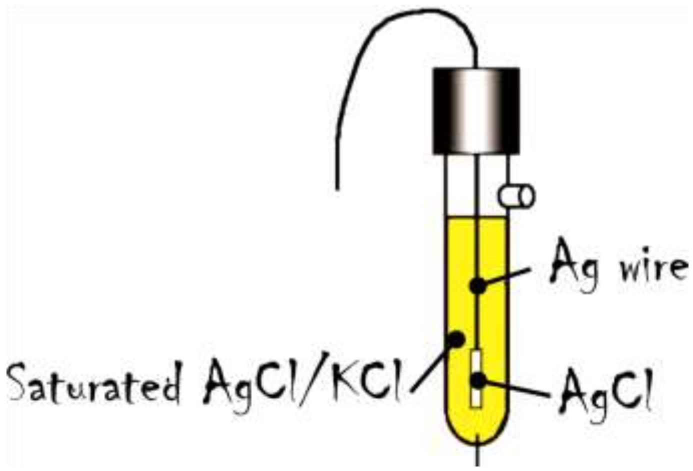


Fig. 7. Silver/silver chloride electrode

In comparison to the SCE the **Ag/AgCl** electrode has the advantage of being useful at higher temperatures. On the other hand, the **Ag/AgCl** electrode is more prone to reacting with solutions to form insoluble silver complexes that may plug the salt bridge between the electrode and the solution.

8. Why is "the reference electrode" called so?

9. Prove that the ideal reference electrode is easy to make and to use.

10. What kinds of electrodes are not mentioned here?

11. Read the information below and find the answers to the following questions.

- *What classes are potentiometric electrodes divided into?*
- *What is the membrane electrode?*

Potentiometric Electrodes

They are divided into two classes: *metallic electrodes and membrane electrodes*. The smaller of these classes are the metallic electrodes. *Electrodes of the first kind* respond to the concentration of their cation in solution; thus the potential of an *Ag* wire is determined by the concentration of Ag^+ in solution. When another species is present in solution and in equilibrium with the metal ion, then the electrode's potential will respond to the concentration of that ion. For example, an Ag wire in contact with a solution of Cl^- will respond to the concentration of Cl^- since the relative concentrations of Ag^+ and Cl^- are fixed by the solubility product for AgCl. Such electrodes are called *electrodes of the second kind*.

The potential of a *membrane electrode* is determined by a difference in the composition of the solution on either side of the membrane. Electrodes using a glass membrane respond to ions that bind to negatively charged sites on the glass membrane surface. A pH electrode is one example of a glass membrane electrode. Other kinds of membrane electrodes include those using insoluble crystalline solids and liquid ion exchangers incorporated in a hydrophobic membrane. The F^- ion-selective electrode, which uses a single crystal of LaF_3 as the ion-selective membrane, is an example of a solid-state electrode. The Ca^{2+} ion-selective electrode, in which a chelating ligand such as di-(n-decyl) phosphate is immobilized in a PVC membrane, is an example of a liquid-based ion-selective electrode.

Potentiometric electrodes also can be designed to respond to molecules by incorporating a reaction producing an ion whose concentration can be determined using a traditional ion-selective electrode. Gas-sensing electrodes, for example, include a gas-permeable membrane that isolates the ion-selective electrode from the solution containing the analyte. Diffusion of a dissolved gas across the membrane alters the composition of the inner solution in a manner that can be followed with an *ion-selective electrode. Enzyme electrodes* operate in the same way.

12. Fill in the blanks with the necessary words given in the box.

The **standard hydrogen electrode** (SHE) is rarely used for 1) …. …work, but is important because it is the reference electrode used to establish standard-state 2)…for other half-reactions. The SHE consists of a 3)…. …. immersed in a solution in which the hydrogen ion activity is 1.00 and in which H_2 gas is bubbled at a pressure of 1 Atm. A conventional 4)…. bridge connects the SHE to the indicator half-cell.

The S.H.E. consists of hydrogen 5)…. …… over a platinum electrode immersed in a solution of hydrochloric acid.

Gas bubbling	**Pt electrode**	**potentials**	**routine analytical**	**salt**

13. Before reading the passage, read its headline and say what you know about this problem. Discuss this problem with your partners. Then read the passage and find the facts supporting your idea.

Potentiometric Methods of Analysis

In potentiometry the potential of an electrochemical cell is measured under static conditions. Because no current, or only a negligible current, flows while measuring a solution's potential, its composition remains unchanged. For this reason, potentiometry is a useful quantitative method. The first quantitative potentiometric applications appeared soon after the formulation, in 1889, of the Nernst equation relating an electrochemical cell's potential to the concentration of electroactive species in the cell.

When first developed, potentiometry was restricted to redox equilibria at metallic electrodes, limiting its application to a few ions. In 1906, Cremer discovered that a potential difference exists between the two sides of a thin glass membrane when opposite sides of the membrane are in contact with solutions containing different concentrations of H_3O^+. This discovery led to the development of the glass pH electrode in 1909. Other types of membranes also yield useful potentials. Kolthoff and Sanders, for example, showed in 1937 that pellets made from AgCl could be used to determine the concentration of Ag^+. Electrodes based on membrane potentials are called ion-selective electrodes, and their continued development has extended potentiometry to a diverse array of analytes.

14. Look through the text, divide it into logical parts and entitle them.

15. Open the brackets choosing the suitable word and translate the sentences into Russian:

When first developed, potentiometry was restricted to *(redox/oxidation)* equilibria at metallic electrodes, limiting its application to a few *(atoms/ions)*. In 1906, Cremer discovered that a potential difference exists between the two sides of a thin ***(****steel/glass)* membrane when opposite sides of the membrane are in contact with solutions containing different concentrations of H_3O^+. This discovery led to the development of the glass electrode in 1909.

Potentiometric Measurements

Potentiometric measurements are made using a potentiometer to determine the difference in potential between a working, or indicator, electrode and a counter electrode. Since no significant current flows in potentiometry, the role of the counter electrode is reduced to that of supplying a reference potential; thus, the counter electrode is usually called the reference electrode. In this section we introduce the conventions used in describing potentiometric electrochemical cells and the relationship between the measured potential and concentration.

Potentiometric Electrochemical Cells

Note that the electrochemical cell is divided into two half-cells, each containing an electrode immersed in a solution containing ions whose concentrations determine the electrode's potential. This separation of electrodes is necessary to prevent the redox reaction from occurring spontaneously on the surface of one of the electrodes, short-circuiting the electrochemical cell and making the measurement of cell potential impossible. A salt bridge containing an inert electrolyte, such as KCl, connects the two half-cells. The ends of the salt bridge are fixed with porous frits, allowing ions to move freely between the half-cells and the salt bridge, while preventing the contents of the salt bridge from draining into the half-cells. This movement of ions in the salt bridge completes the electric circuit.

By convention, the electrode on the left is considered to be the anode, where oxidation occurs and the electrode on the right is the cathode, where reduction occurs $Ag^+(aq) + \bar{e} \rightarrow Ag(s)$. The electrochemical cell's potential, therefore, is for the reaction $Zn(s) + 2Ag^+(aq) \rightarrow 2Ag(s) + Zn^{2+}(aq)$.

Also, by convention, potentiometric electrochemical cells are defined such that the indicator electrode is the cathode and the reference electrode is the anode. A more useful representation is a shorthand, or schematic, notation that uses symbols to indicate the different phases present in the electrochemical cell, as well as the composition of each phase. A vertical slash (/) indicates a phase boundary where a potential develops, and a comma (,) separates species in the same phase, or two phases where no potential develops. Shorthand cell notations begin with the Shorthand Notation for Electrochemical Cells anode and continue to the cathode.

The double vertical slash (//) indicates the salt bridge, the contents of which are normally not indicated. Note that the double vertical slash implies that there is a potential difference between the salt bridge and each half-cell.

$$Zn(s) / ZnCl_2 (aq, 0.0167 M) // AgNO_3 (aq, 0.100 M) / Ag(s)$$

16. Write the shorthand notation for the electrochemical cell.

Oral Practice

17. Work in pairs.

- *Tell what you know about potentiometric electrodes.*

- *What discovery led to the development of the glass pH electrode?*
- *Prove that potentiometry is a useful quantitative method.*
- *Tell about schematic representation of electrochemical cells.*

18. Decide the following problems:

1. Identify the anode and cathode for the following electrochemical cells, and write the oxidation or reduction reaction occurring at each electrode.

Pt / $FeCl_2$ (0.015 M), $FeCl_3$ (0.045 M) // $AgNO_3$ (0.1 M) / Ag

Ag / AgBr(s) / NaBr (1.0 M) // $CdCl_2$ (0.05 M) / Cd

(c) Pb, $PbSO_4$ H_2SO_4 (1.5 M) // H_2SO_4 (2.0 M) $PbSO_4$, PbO_2

2. Calculate the potential for the electrochemical cells in problem 1.

3. What reaction prevents Zn from being used as an electrode of the first kind in an acidic solution? Which other electrodes of the first kind would you expect to behave in the same manner as Zn when immersed in acidic solutions?

GRAMMAR REVISION

1. State the types of the Adverbial Clauses of Condition. Translate the sentences into Russian:

1. A system will remain in equilibrium provided the temperature and pressure are maintained constant. 2. If the liquid phase underwent a slight change in composition at constant temperature, there would be changes in the partial vapor pressures p_1 and p_2. 3. If the second phase is solid instead of gaseous, we shall have, for example, a salt solution in contact with ice. 4. If an electric field could be applied to a perfect vacuum, there would be no separation of positive and negative electricity, because there would be no electrons and no positive ions or nuclei in the empty space. 5. Water vapor could be condensed into a liquid if we took away heat or if we decreased its volume. 6. If a vapor were superheated, it would behave approximately as a gas. 7. Unless the cathode C were cooled, it would overheat and emit gases.

2. Open the brackets translating the Russian words into English:

1. If you (пытались бы) to bend a glass rod when it is not heated, it (сломался бы). 2. If this glass (было бы) transparent, it (могло бы использоваться) in windows. 3. If you try (согнуть) this glass rod, it (сломается) as it is brittle. 4. If they (изучали) solids last year, it (было бы) not so difficult to understand these new phenomena. 5. This substance (можно было) used as an insulator. 6. This question (был бы решен) provided you (помогли) them. 7. If the electron transfer (имело бы место, произошел бы), the atom which has lost the electron (стал бы) a cation. 8. If a liquid (охлаждается), its molecules (теряют энергию). 9. If the cooling process (проводился бы) slowly enough, the particles which constitute the solid (могли бы располагаться) into definite positions with respect to each other.

3. Translate the following sentences into Russian. Concentrate on Conditional Sentences.

1) If hydrogen gas had been admitted to the discharge tube the single particles would be protons and the pairs would consist of molecular hydrogen ions. 2) If phase differences were measured in time, these curves would represent different values of time for each frequency. 3) If the velocity of light were to vary with the relative velocity of the star, certain irregularities in the motion of the stars would be observed. 4) If the reaction would proceed smoothly, the end product might increase. 5) If this were correct, the experiment would demonstrate the evaporation of the coolant. 6) If the power of the heaters increased, then the evaporation of the coolant would be higher. 7) If one impurity were present in greater amount, the electrons of holes it provided would become the principal carriers of electricity.

4. Open the brackets and put the verbs in the necessary forms.

1. If both impurities (to be) present in equal amounts, the excess electrons would just fill the excess holes. 2. If the electrode (to connect) to an electrometer, we should have measured the current in the gas. 3. If he (to use) this formula, he would not have made this mistake. 4. If the rod (to be removed), the charges would, of course, neutralize each other again. 5. If the rate of growth of cubic crystal (to be) isotopic, they would all be spheres! 6. If the two kinds of atoms (to have) the same scattering power for X-rays, the amplitude of their scattering waves would be the same and they would cancel each other.

5. Remember! There is only one negation in an English sentence.
Ways of negation:
Verb + not
No + noun

Never
None of
Nor
Neither … nor
Unless
Until
Fail + infinitive

6. Translate the following sentences into Russian.

1. **None of** the methods, either filtering or boiling, is good for producing water for chemical work, since most of the soluble salts are unaffected by the treatment. 2. **No** other element is more important to life than oxygen. 3. **No** other alkali metals (except Na) show any sign of radioactivity. 4. Ice can **never** exist at a temperature above 0 °C. 5. Many substances are better solvents for specific organic compounds but **none of** them approaches water as a universal solvent for many different classes of substances. 6. New elastomers do **not** have properties equivalent to those of natural rubber. 7. **None of** these nitrides except for lithium compound has been obtained in pure states in their experiment. 8. **Neither** of the oppositively detected reactions in a chemical equilibrium can ever become complete. 9. We do **not** consider rain water to be really a pure substance, **nor** is ground water free from impurities. 10. The substance **failed** to oxidize even when exposed to the air. 11. Each of these portions of fractions is redistilled and collected in separate flasks **until** the mixture is separated into portions, which may be regarded as pure.

7. Remember the most generally used composite verbs

1. to bring about – вызывать, осуществлять
2. to use up – расходовать
3. to make up for – восполнять
4. to make up – составлять
5. to give off – выделять, испускать
6. to give up – оставлять, бросить
7. to carry out – выполнять
8. to build up – образовывать

8. Translate the following sentences into Russian.

1). Iron makes up about four percent of solid rocks of the earth's crust. 2). The molecule of hydrogen is made up by the union of two hydrogen atoms. 3). Higher temperatures bring about more frequent collisions between molecules. 4). The process of making ordinary glass is carried out by using such raw materials as sand, limestone and sodium carbonate. 5). Reactions such as synthesis, decomposition, hydrolysis, oxidation, reduction, polymerization can be brought about by exposure to suitable light. 6). If we pass an electric current through water using platinum or gold electrodes we find two gases to be given off at the electrodes and the water to be used up. 7). Supersaturated solutions are unstable, they readily give up their excess solute if shaken. 8). Each of the sodium atoms gives off an electron and forms an ion which goes into solution.

SELF-CHECK

Open the brackets and put the verbs in the necessary forms of the Subjunctive Mood.

1. If they (use) another method, the results would have been different. 2. If the load (increase) the speed would decrease. 3. If one (know) the dimensions of the core liner he (calculate) easily its volume. 4. If all the people of the world (count) the atoms in a drop of water they would not be able to finish their work even in ten thousand years. 5. If he (know) the specific heat and the weight of the substance, he would have calculated its thermal capacity. 6. If the complete list of details had been prepared the engineer (finish) everything in time.

UNIT 11
Coulometry
Grammar: Inversion;
Recognition of Subjects,
Predicates, Objects and Attributes
in English Sentences

1. Warm up

- *What is the origin of the word "coulometry"?*
- *What kinds of coulometric techniques are known?*

2. If you want to find out about coulometry in details, read the information below.

Coulometry

Coulometry is the name given to a group of electroanalytical chemistry techniques that determine the amount of matter transformed during an electrolysis reaction by measuring the amount of electricity (in coulombs) consumed or produced. The technique is applicable to redox reactions, which are reactions in which electrons are transferred from one molecule to another. The reaction is controlled by applying an electrical potential and the amount of electricity (i.e, the number of electrons) needed to complete the reaction is the main measurement.

There are two basic categories of coulometric techniques. One category, *potentiostatic coulometry*, involves holding the electric potential constant during the reaction using a potentiostat. *(A potentiostat is a device that keeps the potential at the working electrode constant relative to the reference electrode. The circuit for the potentiostats works to keep the voltage constant by noticing changes in the resistance of the system and compensating inversely with a change in the current. As a result, a change to a higher resistance would cause the current to decrease to keep the voltage constant in the system. The cathode of a potentiostatic coulometry experiment is usually a platinum electrode with a large surface area or a mercury pool, although other particularly reactive electrodes can be used in rare circumstances).*

The other, called *coulometric titration* or *amperostatic coulometry*, keeps the current (measured in amperes) constant using an amperostat. *(An amperostat is used to maintain a constant current in coulometric titrations. It reacts to changes in the resistance of the cell by altering its output potential).*

Both techniques take place within an electrochemical cell and are explained in more detail below.

Coulometric techniques are as accurate as other analytical techniques used to carry out similar analyses, but are usually quicker and more convenient; Since coulometric methods do not measure directly the amount of matter transformed in the redox reaction, it is important that the reaction maintains a stoichiometrical relationship. Thus, each electron introduced or removed from the electrochemical cell must correspond to a known number of molecules in the reaction. When this is the case, standardization or calibration curves are not required for accurate analysis because the amount of current can be determined using the equation:

$$Q = I \cdot t,$$

where Q is the amount of electricity in coulombs, I is the current in amperes and t is the time in seconds. Q is then related to the reaction by the stoichiometric ratio. As the reaction progresses, the concentration of the molecule being converted will decrease. The electrical potential must be increased to maintain the direction of the reaction as the concentrations in the sample change. Eventually the electrical potential will be large enough that the solvent (usually water) begins to decompose. As a result, the system will have an excess of ions and will give an error in the calculation of the concentration of the reaction components, indicating that there are more molecules in the system than are actually present. To compensate for this error, an ion such as cerium (Ce^{3+}) that is oxidized at a lower potential than water, is added to maintain the efficiency of the system.

Oral Practice

3. Explain the formula *Q = It*.

4. Give the definitions of the following words:
redox reaction, coulomb, amperostatic coulometry, stoichiometrical relationship.

5. Work in pairs.
Situation.
Both your friend and you work in the chemical laboratory. You practise with coulometric methods of analysis and your friend – with potentiometric methods of analysis. Prove that your method is more accurate, quicker and more convenient than the other methods. To support your idea find the arguments in the text.

6. Read the passage carefully and supply the answers for the following questions:

- *How many elements does the potentiostatic coulometry technique determine?*
- *Why are potentiostatic coulometry techniques frequently used for the determination of uranium and plutonium?*
- *Why is potentiometric coulomrtry useful for determining ozxygen?*
- *Can coulometric titrations be used for the neutralization of acids? Why?*
- *What electrodes are good counter electrodes for the reaction of neutralization of acids?*
- *What is the advantage of coulometric technique over the volumetric technique?*

Application

Potentiostatic coulometry techniques have been used to determine over 50 elements. They are used very frequently for the determination of uranium and plutonium since potentiostatic coulometry techniques do not interfere much with the sample. Another useful application is the determination of the amount of oxygen in a sample by using a cadmium electrode and a porous silver electrode. This system for determining oxygen is convenient because it does not require an external power supply or a potentiostat to control the reaction since it does not reach a potential that is high enough to oxidize other substances. In addition, potentiostatic techniques can be used to separate materials, to measure the diffusion current, and to determine and sometimes synthesize organic compounds.

Coulometric titrations can be used for the neutralization of acids, which contain H^+ ions, by producing hydroxide ions (OH^-) at an electrode to form water. Mercury, silver chloride, or silver bromide electrodes are good counter electrodes for this reaction. The coulometric technique has one real advantage over the volumetric technique, which is that the interference of carbonate ions is easily removed by bubbling a carbon-dioxide deficient gas through the sample. This removes carbon dioxide in the sample, which would otherwise form carbonate ions and interfere with the analysis. Other applications include:

Ions, such as halides and mercaptans can be determined by complex formation or precipitation in the presence of aniodically generated silver ions.

The oxidation of cerium, from Ce^{3+} to Ce^{4+}, in 1 N sulfuric acid can be used to characterize several systems including titanium, iron, and uranium. The electrodes used for such a system would be a polarized platinum electrode and a non-polarized reference electrode, such as a lead amalgam – lead sulfate electrode.

The reduction of Fe^{3+} to Fe^{2+} in acidic solutions can be used to determine the amount of permanganate ($Mn0_4^-$), chromate ($Cr0_4^{2-}$), or dichromate ($Cr_2O_7^{2-}$) ions in a sample. Coulometric titrations or potentiostatic coulometric techniques can be used for these systems. In the coulometric titration technique, the ratio of iron ions will change when the sample is added and the endpoint occurs when the ratio returns to its initial amount.

7. Look through the text about coulometric methods of analysis and find the sentences supporting the idea of the title and answer the following questions.

- *1. What is used to determine an analyte's concentration in potentiomery?*
- *2. What are the dynamic electrochemical methods?*
- *3. What are coulometric methods of analysis based on?*
- *4. How many forms of coulometry are given there?*
- *5. What is called coulometry?*
- *6. What is called amperometry?*
- *7. What is called voltammetry?*

8. Before reading the text pay attention to the definitions of the following:

Faraday's law *- The current or charge passed in a redox reaction is proportional to the moles of the reaction's reactants and products.*

Current efficiency *- The percentage of current that actually leads to the analyte's oxidation or reduction.*

Coulometric Methods of Analysis

In potentiometry, the potential of an electrochemical cell under static conditions is used to determine an analyte's concentration. As seen in the preceding section, potentiometry is an important and frequently used quantitative method of analysis. Dynamic electrochemical methods, such as **coulometry, voltammetry, and amperometry**, in which current passes through the electrochemical cell, also are important analytical techniques. In this section we consider coulometric methods of analysis.

Coulometric methods of analysis are based on an exhaustive electrolysis. There are two forms of coulometry: controlled-potential coulometry, in which a constant potential is applied to the electrochemical cell, and controlled-current coulometry, in which a constant current is passed through the electrochemical cell.

The total charge, Q, in coulombs, passed during an electrolysis is related to the absolute amount of analyte by Faraday's law $Q = nFN$, where n is the number of electrons transferred per mole of analyte, F is Faraday's constant, and N is the moles of analyte.

GRAMMAR REVISION

1. Read some highly doubtful suppositions not proved by science or experiment. Translate them into Russian.

Model: *Should theoretical research prove this, it would be the case. – Если бы теоретические исследования подтвердили это, то так бы и было.*

1. Should there be enough matter in the Universe, it would close on itself and be finite. 2. Should there be any invisible matter in the Universe, the latter would make up the difference needed for the Universe to close. 3. Should neutrinos have a small mass, they could provide energy density to close the Universe. 4. Should there be any other presently unknown subatomic particles, the same must be true. 5. Should the Universe be finite, its expansion would be eventually stopped and be replaced by a contraction. 6. Should the protons be unstable, their lifetime would be at least 10^{31} years on the average.

2. Translate the following sentences into Russian.

1. Had water been added to a mixture, more alcohol and acid would have been formed. 2. Had water been purified carefully, they wouldn't repeat the experiment. Had he finished the laboratory tests, he would have delivered the report. 3. Should this happen, the motor would continue to run as a single-phase machine. 4. Were the force applied greater, the body would move more rapidly. 5. Had they obtained the information required, they would have certainly made the decision. 6. Should he check the operation, he would find the mistake. 7. Had they investigated the properties of the substance, they would have been careful. 8. Were two bodies placed in contact with each other, the temperature of the hot body would fall while that of the cold one would rise. 9. Should we test the hypothesis in practice, we would get the results desired. 10. Had the gas been cooled instead of heated, the heat supplied would have become the heat given out by the gas.

3. Say if a certain condition is fulfilled, there will be the results achieved. Follow the model.

Model: Teacher: *We cannot reach an agreement on the problem and no results are obtained.*

Student*: Should you reach the agreement, the results would be obtained.*

1) They do not make any attempts to reconcile the two conflicting views and the situation does not change.
2) They do not put forward any working hypothesis and we cannot develop any sound approach.
3) They do not suggest any alternative interpretation of the phenomenon and we cannot obtain new information.
4) They do not present any convincing arguments in favour of their approach, and we cannot understand their view on the problem.
5) They do not take any measures to improve the situation and we don't know what to do.
6) We do not plan any new experiments and no studies are being undertaken.

4. Say, that if the conditions of Exercise 3 had been fulfilled, the results would have been obtained by now. Follow the model.

Model: Teacher: *We cannot reach an agreement on the problem, the results would have been obtained by now.*

Student: *Had you reached an agreement on the problem, the results would have been obtained by now.*

SELF-CHECK

1. Translate the following sentences into English. Begin each sentence with "should".

Model: *Если бы вы помогли мне, я был бы вам признателен. – Should you help me, I would be thankful to you.*

1) Если бы эта проблема обсуждалась на конференции, я выступил бы с докладом.
2) Если бы вы поверили нашему опыту, вы бы избежали бы многих затруднений.
3) Если бы вы провели наблюдение за температурами, результаты были бы совсем иными.
4) Если бы появились расхождения между нашими данными, мы могли бы обсудить их.
5) Если бы была разработана новая методика, вы могли бы воспользоваться ее преимуществами.
6) Если бы вы потерпели неудачу, мы могли бы помочь вам.

2. Define which words in bold type are subjects.

1) **His heating copper wire** from 0º to 100º increased its **resistance** about 40%. 2) **Falling** is **a case** of **motion** at constant **acceleration**. 3) For practical **reasons the influence** of space **charge** will be neglected. 4) **Many methods** for detection of uranium have been proposed for **use** under various conditions. 5) **It** takes **the rays** of the **sun 8 minutes** to get the earth. 6) **It** has become possible to modify the Periodic **Table** so as **to bring** out the structural features more clearly.

3. Define sentences in which the subject has the left attribute.

1) The automobile repair plant construction project is known to have been adopted. 2) Having been cooled for two hours, the mixture was examined. 3) In the radioactive bodies alpha, beta and gamma rays are emitted spontaneously. 4) You must aim at obtaining accurate results. 5) The efficiency of the process resulted in increasing the yield. 6) Laplace transportation properties enable us to solve many problems in engineering and physics. 7) The data processing equipment has been installed in our laboratory.

4. Define sentences in which the subject has the right attribute.

1) Radium whose properties are known to be of the greatest importance to the present day chemistry was isolated in 1910. 2) One may safely expect this prediction to be quite reliable. 3) The problem of making quantitative chemical analysis is to determine the amount of one or more constituents in a given substance. 4) The gas to be condensed formed discrete solid particles.

5. Define the beginning and the end of the subject-groups in the following sentences.

1) River and lake deposits contain remains of organisms which inhabited the waters. 2) Different substances used as leaching solutions are dealt with this article. 3) Our engineer having been awarded the prize was met with approval. 4) Using the terms just defined, the above examples of functional relations can be restated as follows. 5) The advances of modern sciences in the production of a wide range of experimental temperatures are not inconsiderable.

6. Define a subject and a predicate in the following sentences.

1) It is necessary to reduce the load on the battery to a minimum. 2) One has to liberate energy very rapidly to make a shock wave. 3) Supplying heat to the liquid so as to raise its temperature will assist the process of evaporation. 4) He ought to have been more careful when dealing with those chemicals. 5) Water was considered to be an element. 6) To explain this simple fact is not so easy.

7. Point out sentences in which the predicate has indirect object (prepositional or non-prepositional).

1) Now we can communicate with the remotest parts of the world. 2) Current starts flowing at the very moment when we close the circuit. 3) When we wish to add

together two alternating electromotive forces we have different problem. 4) We do not know how the control is accomplished but we have theories. 5) Let us now obtain a more general formula that simplifies heat-conduction problems.

8. From every line write out three words which can be “signals” of a predicate.

1) Could, never, should, often, as, makes
2) with, had, has, again, because, can
3) will, for, shall, done, being, does
4) is, must, need, always, surely, but

9. Arrange the following words in order to get a predicate.

a) have[1], investigated[2], been[3]
b) being[1], is[2], read[3]
c) will[1], been[2], have[3], discussed[4]
d) increased[1], should[2], been[3], have[4]
e) improved[1], be[2], could[3]

10. Define in which column all the groups of the words can be predicates.

A	B	C
Does not treat	Was advanced	Does not heat
Is being heated	Is being advanced	Is being heated
Can be heated	Can be said	Can be heated
Heats	Being discussed	It is heat
Has been heated	Heated salts	Has been heated

11. Point out sentences in which the predicate is expressed by one word.

1) A good many of the early electron diffraction results must be revised. 2) A number of scientists have recently adopted this method. 3) Mendeleyev arranged the elements in the order of their atomic weights. 4) Helium belongs to the same category as argon. 5) The arrangement of the elements corresponds with their so-called valencies.

12. Point out sentences in which the predicate consists of two components.

1) Have you to be in the laboratory every day? 2) I did say so and I do say so now. 3) Gold is often alloyed with copper. 4) This problem is dealt with in the most profound way. 5) In this case the substance does not lose its chemical properties.

13. Point out sentences in which the predicate is used in the Passive Voice.

1) The form of energy most required by us is mechanical energy. 2) Heat cannot be weighed. 3) Extracts from different books copied by hand were to be sent by post. 4) A rod of iron has been rubbed with flannel. 5) You should have been more careful.

14. An adverb can be involved in the group of a predicate. Write out such adverbs.

1) This conclusion does not always prove right. 2) The lower layer will gradually disappear. 3) The early division of chemistry into inorganic and organic chemistry is still maintained for convenience. 4) Under pressure vinyl acetylene is readily polymerized. 5) They had already discussed this problem.

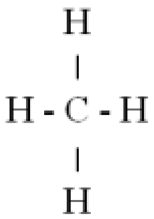
15. Find and write out predicates of the following sentences.

1) These springs may also be employed for leading the current in and out of the moving coil. 2) The wire used should have as large a cross-section as possible. 3) Your work is to observe the rise of temperature. 4) Burning changes the fuel into heat, light, gases and ashes. 5) Many experiments made after helped us to come to a conclusion that heat is a form of energy.

APPENDIX 1

Reading chemical elements and formulas.

O [ou], Al [‘ei ‘el], Hg [eiC ‘Gi:], HCl [‘eiC’sJ’el], CO_2 [‘ si:’ou’tu:],
2 KCl [‘tu:’molikjulz’əv’kei’si:’el]
The sign – designates one bond and is not to be read in formulas.
The sign = designates two bonds and is not to be read in formulas.
The sign $\rightleftarrows$ is to be read ‘give’, ‘pass over to’, ‘lead to’
The sign $\longrightarrow$ is to be read ‘forms’ and is formed from
The sign = is to be read ‘give’, ‘form’



[‘ si:'eC'fL]

$CO_2 + CaO \longrightarrow CaCO_3$ – [si:’ou’tu:’plAs’si:’ei’ou give ‘si:’ei’si:’ou’T ri:]
- in oral practice it is said as follows:
carbon dioxide plus calcium oxide form calcium carbonate.

$N_2 + 3H_2 \rightleftarrows 2NH_3$ – [‘en ‘tu:’plA s’Tri: mOlikju:lz əv’eiC ‘tu: fO:rm ənd α: ‘fO:md frqm tu: mOlikjulz əv ‘en’eiC ‘Tri:]
- in oral practice it is said as follows:
nitrogen plus three molecules of hydrogen give two molecules of ammonia.
$C_2H_4 + Cl_2 = C_2H_4Cl_2$ – [‘si:’tu:’eiC ‘fL’pl As’si:’el tu: giv si:’tu:’eiC ‘ fq:’si:’el’tu:]
- in oral practice it is said as follows:
ethylene plus chlorine give ethylene chloride.

APPENDIX 2

Reading mathematical symbols.

+	plus
–	minus
±	plus or minus
·	multiplication sign
:	1) ratio 2) is to
=	equals; is equal to
≠	is not equal to
~	approximately equal
>	greater than
<	less than
≥	equal or greater than
≤	equal or less than
∞	infinity бесконечность
√	square root (out) of
$\sqrt[3]{\ }$	cube root (out) of
$\sqrt[n]{\ }$	*n-th* root (out) of
[]	square brackets
( )	parentheses, round brackets
{ }	braces
||	parallel to
°	degree
′	minute foot, feet
″	second inch
∠	angle
∟	right angle
⊥	perpendicular
α^*	"α"-star
α'	a prime [ei`praim]
α''	a double prime
b_1	"b" sub one ("b" first)
$a_1^`$	a first prime
∑	summation [`sə`meiʃn]
dx	differential [`difə `renʃəl əv eks]
dy/dx	derivative of y with respect to x
∫	integral of

$\int_n^m$	integral between limits n and m
(x)	absolute value of x
%	percent [pɘ:`sent]
/	solidus
a/b	a solidus b ; a divided by b
: :	double colon
a:b=c:d (a:b::c:d)	*a* is to *b* as *c* is to *d*
$\frac{a}{b}$	*a* over *b*; *a* divided by *b*
a^n	*a* to the n^{th} power
$\frac{ab}{cd}$	*a* times *b* over *c* times *d*
$\uparrow\uparrow$ $a \uparrow\uparrow b$	*a* is parallel to *b*
$\uparrow\downarrow$ $a \uparrow\downarrow b$	*a* is antiparallel to *b* “
$\rightarrow a \rightarrow b$	*a* tends to *b* *a* approaches *b*

APPENDIX 3

The Algorithm of an Annotation

1. The title of the paper in the foreign language, translation of this title. Author's surname and initials in the foreign language.

↓

2. Publisher's data, the name of the journal in the foreign language, number and year of publishing, publication place, volume and the number of pages, number of drawings, tables.

↓

3. List of main problems dealt with in the paper.

↓

4. Description and estimation of the paper being reviewed

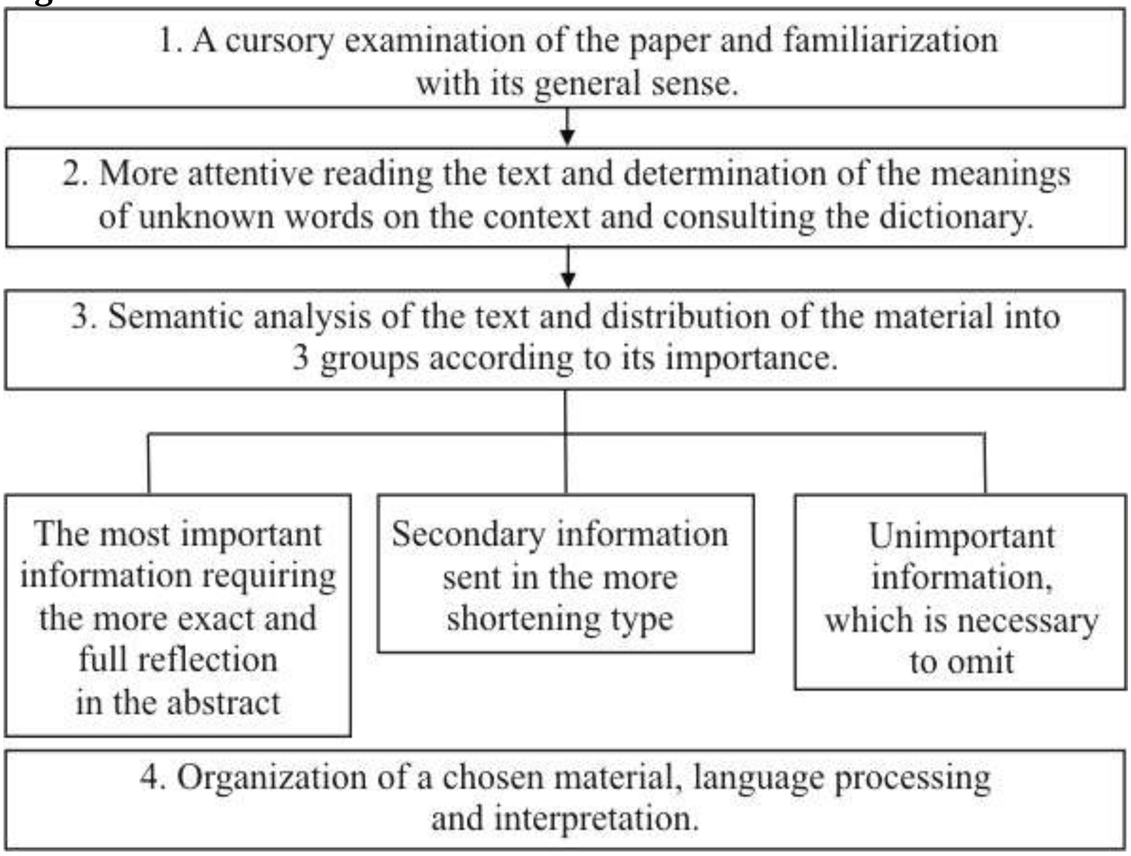
Remember

It is found that the main information is:

– In references, charts, tables;
– In last and in last but one passages of each section;
– In the first three passages;
– In subscriptions to drawings and tables.

APPENDIX 4

Algorithm of an abstract



Contents and Structure of an Abstract

I. The abstract title.
II. Bibliographic description of the article to be reviewed.
III. The abstract text.

The following data are given in the text of an abstract:

- *The problem, the objective, the main idea and contents of the article.*
- *Data about methods and their comparative accuracy.*
- *Findings of the author and instructions of the possibilities and ways of the practical application of the work.*
- *Reference to presence of the bibliographies and illustrations.*
- *Technology and applied equipment.*
- *Tables, schemes, graphs, formulas required for understanding the main contents of the document.*
- *The necessary reference given about (authors, histories, the problem, place of undertaking the study.*

Differences between an Abstract and an Annotation

An annotation is intended for information of the initial document only, but an abstract serves for interpretation of the main contents of the primary document.

Learn the words and expressions used in an abstract.

A.

Данная статья –	the present paper
Тема –	the theme (subject-matter)
Основная проблема –	the main problem
Цель –	the purpose
Проблемы, связанные с –	problems relating to
Основной принцип –	the basic principle
Аналогично –	similarly
Поэтому, следовательно, в результате этого –	hence, therefore
Наоборот –	on the contrary
Кроме того –	besides, also, again, in addition, furthermore
Сначала –	at first
Далее, затем –	next, further, then
Тем не менее –	nevertheless, still, yet
Наконец, итак –	finally
Вкратце –	in short, in brief

B.

The Purpose of Writing the Article

1. The object (purpose) of this paper is to present (to discuss, to describe, to show, to develop, to give) …

2. The paper (article) puts forward the idea (attempts to determine) …

Problems to be Discussed in the Article

1. The paper (article) discusses some problems relating to (deals with some aspects of, considers the problem of, presents the basic theory, provides information on, reviews the basic principles of) …

2. The paper (article) is concerned with (is devoted to) …

The Beginning of the Article

1. The paper (article) begins with a short discussion on (deals firstly with the problem of) …

2. The first paragraph deals with …

Transition to the Interpretation of theFollowing Article Part.

1. Then follows a discussion on …
2. Then the author goes on to the problem of …
3. The next paragraph deals with (presents, discusses, describes) …
4. After discussing the author turns to …

The End of the Interpretation

1. The final paragraph states (describes, ends with) …
2. The conclusion is that the problem is …
3. The author concludes that …
4. To sum up, to summarize, to conclude the emphasizes (point out) that …

Estimation of the Article

In my opinion (to my mind, I think) …

The paper (article) is interesting (not interesting), of importance (of little importance), valuable (invaluable), up-to-date (out-of-date), useful (useless) …

ARTICLES TO BE SUMMARIZED

1. Chromatography

Introduction

In 1906, the Russian scientist Tswet reported separating different colored constituents of leaves by passing an extract of the leaves though a column of calcium carbonate, alumina and sucrose. He coined the term **chromatography**, from the Greek words meaning "color" and "to write". Tswet's original experiments went virtually unnoticed in the literature for decades, but eventually other methods were developed and today there are several different types of chromatography. Chromatography is taken now to refer generally to the separation of components in a sample by distribution of the components between two phases – one that is stationary and one that moves, usually but not necessarily in a column. Probably no other technique has been more valuable in the separation and analysis of highly complex mixtures. The object of this paper is to discuss the principles of chromatography. The paper describes some of the different types of chromatography.

Types of chromatography discussed include

- size exclusion chromatography, in which molecules are separated based on their size by passage through a porous structure stationary phase;
- ion exchange and ion chromatography, in which ions are separated based on their charge;
- gas chromatography, in which gaseous substances are separated based on their adsorption on or solubility in the stationary phase.

The combination of gas chromatography and mass spectrometry is a very powerful identification tool. High performance liquid chromatography is described. This is modern development based on the above principles but using micrometer-sized particles for the stationary phase so that equilibrium is achieved rapidly and separations are performed rapidly.

Although there are several different forms of chromatography, this simplified model typifies the mechanism of each. That is, *there is nominally equilibrium between two phases, one mobile and one stationary.* (True equilibrium is never really achieved.) As pure solvent is added in the mobile phase, the substances will distribute between the two phases and eventually be eluted, and if the distribution is sufficiently different for the different substances, they will be separated.

Christian, Gary d. @Analytical Chemistry, 1994 545-dc 20, pages 384-385.
J. T. Stock, "Amperometric Titration",1995, pages 451-453.

2. Classification of Chromatographic Techniques

The first paragraph deals with types of chromatographic techniques. Chromatographic processes can be classified according to the type of equilibration process involved, which is governed by the type of stationary phase. Various bases of equilibration are: adsorption, partition, ion exchange and pore penetration.

Adsorption Chromatography

The stationary phase is a solid on which the sample components are adsorbed. The mobile phase may be a liquid (liquid – solid chromatography) or a gas (gas-solid chromatography); the components distribute between the two phases through a combination of sorption and desorption processes. Thin-layer chromatography (TLC) is a special example of sorption chromatography in which the stationary phase is a plane, in the form of a solid supported on an inert plate.

Partition Chromatography

The stationary phase of partition chromatography is a liquid supported on an inert solid. Again, the mobile phase may be a liquid (liquid – liquid partition chromatography) of a gas (gas – liquid chromatography, GLC). Paper chromatography is a type of partition chromatography in which the stationary phase is a layer of water adsorbed on a sheet of paper.

In the normal mode of operations of liquid-liquid partition, a polar stationary phase (e.g. methanol on silica) is used with a nonpolar mobile phase (e.g. hexane). This favors retention of polar compounds and elution of nonpolar compounds and is called *normal-phase chromatography*. If a nonpolar stationary phase is used with a polar mobile phase, then nonpolar solutes are retained more and polar solutes are readily eluted. This is called *reversed-phase chromatography*.

Ion Exchange and Size Exclusion Chromatography

Ion exchange chromatography uses an ion exchange resin as the stationary phase. The mechanism of separation is based on ion exchange equilibria. In size exclusion chromatography, solvated molecules are separated according to their size by their ability to penetrate a sieve-like structure (the stationary phase).

These are arbitrary classifications of chromatographic techniques, and some types of chromatography are considered together as a separate technique, such as “gas chromatography” for gas – solid and gas – liquid chromatography. In every case successive equilibria are at work that determine to what extent the analyte stays behind or moves along with the eluent (mobile phase). The individual types of chromatographic techniques mentioned under the above classifications will be described in more detail below.

Dean John A. “Analytical Chemistry” textbook, 1999.

3. Techniques of Column Chromatography

The next paragraph deals with typical chromatographic column. A column is prepared by carefully packing the solid material (small particles) in a column, usually by adding it to the column filled with a solvent or by pouring a slurry of it into the column and allowing this to settle. The column can be mechanically vibrated or the solid material tamped with a long plunger during packing. Care must be taken to keep out air bubbles or channeling will result in the column, rendering it less effective.

A column consists from sintered-glass frit or glass wool, which is placed in the bottom of the column to support the solid. A burette can be used as the column. The dimensions will depend on the separation efficiency required, the size of the sample, and the type of chromatography. A typical column may range from a few millimeters in diameter and a few centimeters in length.

The sample is placed in a small volume on top of the column. A solvent should be used in which the sample is readily soluble, so that the volume can be kept small.

The solvent is allowed to flow slowly from the column until all of the sample just reaches the top of the solid. Then, solvent is added at the top of the column at the same rate that it flows out, or else a given volume is added at once. The solvent must be eluted slowly, so that there is adequate time to establish continuous equilibrium.

The elution must not be so slow, however, that diffusion processes will set in; the sample components (solutes) will diffuse along the column even in the absence of solvent flow and cause the peak to spread. Again, the flow rate will depend on factors such as the type of chromatography and the column size. With a typical column about 1,5 cm diameter × 5 cm length, a flow rate of about 1 cm/min for different sized columns can be used.

The solvent (*eluent*) is collected as it emerges from the column. Usually, equal-volume aliquots of eluent are collected in individual test tubes. If the flow rate is constant, then samples may be collected at equal time intervals. There are automatic *fraction collectors* that will perform either type of collection. After a certain volume of sample has been collected in the intermediate sample collector, it is emptied into a test tube. The rack holding the test tubes rotates to the next tube. After various fractions have been collected, they are analyzed for the sample components, and the amount or concentration in each tube is plotted as a function of the tube number or volume of solvent collected.

Once the elution order has been established under a given set of conditions, all the tubes containing a certain substance may be combined and analyzed singularly for that substance. Or, if the contents of each tube are analyzed separately, the area under the peak is proportional to the amount of the solute. If two peaks overlap, as the last two of the figure do, it may be possible to extrapolate their bases to obtain the separate areas.

Often, all substances are not eluted from the column with a single solvent. After elution of part of the solutes a different solvent or solvent mixture is added that shows a greater eluting power for the remaining solutes. In solvent gradient analysis, mixed solvents are used, but their volume ratios are varied continuously throughout the elution, usually in a linear fashion. Or a concentrated salt or other reagent in the eluting solvent may be continuously diluted, as in salt gradient analysis. The salt may act as a salting-out agent (precipitating) for the solutes, and the salting-out ability decreases continuously. So, a combination of salting-out and chromatographic effects is achieved. Temperature gradient analysis is common in gas chromatography; the gas phase equilibria are greatly affected by the temperature.

Rogers, K. R.; Williams, L. R. Trends Anal. Chem. 1995,14, 289-294.

4. Paper Chromatography

Paper chromatography is a very simple form that is used widely for qualitative identification, although quantitative analysis can be done. A sample is spotted onto a strip of filter paper with a micropipette, and the chromatogram is “developed” by placing the bottom of the paper in a suitable solvent. The solvent is drawn up the paper by capillary action, and the sample components move up the paper at different rates, depending on their solubility and their degree of retention. Following development, the individual solute spots are noted or are made visible by treatment with a reagent that forms a colored derivative. The spots will generally move at a certain fraction of the rate at which the solvent moves, and they are characterized by the R_f value:

R_f =distance solute moves/distance solvent front moves,

where the distances are measured from the center of where the sample was spotted at the bottom of the paper. The solvent front will be a line across the paper. The distance the solute moves is measured at the center of the solute spot or at its maximum density.

The cellulose filter paper used is very hydrophilic and will normally have a thin coat of water adsorbed from the air. So the mechanism of separation is a form of liquid-liquid partition chromatography in which the sample distributes between the stationary water phase and the developing solvent. The developing solvent is usually a mixture of organic solvents with water that may be buffered at a certain pH. The water, as it moves up the paper, is adsorbed and causes the paper to swell. Other polar solvents will also be adsorbed by the paper. Sometimes a water-immiscible solvent is used to develop the chromatogram.

The conclusion is that the problem is detection of the spots.

If the solutes fluoresce (aromatic compounds), they can be detected by shining an ultraviolet light on the paper. Color-developing reagents are often used. Exposure to iodine vapor often produces a color with colorless solutes. After the spots are identified, they may be cut out and the solutes washed off (eluted) and determined quantitatively by a micromethod.

To sum up that paper chromatography is useful for the separation of very small amounts of substances and has proved extremely valuable in biochemistry, where small and complex samples are often found. Simple mixtures of amino acids can be separated by developing with water-saturated phenol. Almost any mixture of organic components can be separated. Inorganic substances are also easily resolved. Modified forms of paper are available impregnated with ion exchange resins, silica gel, alumina, and other substances, but the principle of the operation is the same.

Rechnitz, G. A. Controlled-Potential Analysis. Macmillan: New York, 1963, p. 49.

APPENDIX 5

1. In order to start the presentation, study the following:

The Overall Diagram of the Presentation

The Problem (the description of a key problem - 5 -10 %)
Investigation and Results (Ways of a problem decision- 80 - 85 %)
Conclusions (how the problem can be solved - 5 - 10 %)

Dimensionality of a Slide

1. 1 slide = one idea
2. One idea = the statement = one line
3. 5- 6 lines = one slide
4. 5 – 6 words = 1 line
5. One slide = one minute

Slide Design

1. Speaking heading for each slide.
2. Parallelism of grammatical constructions and parts of speech.
3. Picture contrast.
4. Choose the color plan and adhere to it
5. Number of a font - orientation to an audience at the last desks.

- *Heading - 48 font*
- *The Text - 24 - 28 font*
- *Working fonts - Tahoma, Arial, Times New Roman*

6. Number slides.
7. Do not take a great interest in special effects.
8. Do not overload a slide with the text.
9. The graphical information is more preferable.

2. Language Practice

INTRODUCTION

How you begin your presentation depends on how formal the situation is. Most audiences prefer a relatively informal approach.

FAIRLY FORMAL	MORE FRIENDLY
Perhaps we should begin.	*OK, let's get started.*
Good morning, ladies and gentlemen.	*Morning, everyone*
On behalf of … may I welcome you to…	*Thanks for coming.*
My name is…	*I'm …*
For those of you who do not know me already, …	*As you know …*
I am responsible for …	*I am in charge of ….*
This morning I would like to (discuss, report on, present)	*What I want to do this morning is …. (talk to you about…, tell you about…, show you)*
If you have any questions you would like to ask, I will be happy to answer them.	*Feel free to ask any questions you like as we go along*
Perhaps we can leave any questions you may have until the end of the presentation.	*And don't worry; there will be plenty of time left over for questions at the end.*

STATING YOUR PURPOSE

It is essential to state the purpose of our presentation near the beginning. To do this clearly and effectively you need a few simple presentation verbs.
To look at…, report on…. give an overview of …

OK, let's get started. Good morning, everyone. Thanks for your coming. I'm (your name).

This morning I am going:

- *to tell you about…*
- *to show you how to …*
- *to take a look at ..*
- *to report on the results of …*

… so I begin by:

- *making a few observations about …*
- *outlining….*
- *giving you an overview on the results of …*
- *bringing you up-to date on the latest findings …*

... and then I will go on to:

- *highlight what I see as…*
- *put the situation into some kind of perspective.*
- *make detailed recommendations regarding…*
- *discuss in more depth the implications of the data in the files in front of you.*

TEXT FOR PRESENTATION

Coulometric Titration

Coulometric titrations use a constant current system to perform the reaction. The only measurement required in these systems is the time it takes to complete the electrolysis. The product of this time and the current is then used to determine the total amount of electricity used. The endpoint of the titration can be determined analytically by using an indicator that is placed in the sample and signals when the system reaches equilibrium. Alternatively, the endpoint can be determined from data provided by potentiometric, amperometric or conductance measurements. This is similar to regular chemical titrations.

Since concentration polarization occurs in coulometric titrations, most (if not all) of the reaction must occur distant from the working electrode. Otherwise, the potential will need to constantly increase as the reaction progresses to maintain the production of products. Therefore, coulometric titration reactions usually have other ions in the sample that react directly with the electrode and then react with the sample molecules. Coulometric titrations can also be done by back-titration.

An amperostat is used to maintain a constant current in coulometric titrations. It reacts to changes in the resistance of the cell by altering its output potential. Both amperostats and potentiostats can be built relatively cheaply using operational amplifiers.

Applications

Potentiostatic coulometry techniques have been used to determine over 50 elements. They are used very frequently for the determination of uranium and plutonium since potentiostatic coulometry techniques do not interfere much with the sample. Another useful application is the determination of the amount of oxygen in a sample by using a cadmium electrode and a porous silver electrode. This system for determining oxygen is convenient because it does not require an external power supply or a potentiostat to control the reaction since it does not reach a potential that is high enough to oxidize other substances. In addition, potentiostatic techniques can be used to separate materials, to measure the diffusion current, and to determine and sometimes synthesize organic compounds.

Coulometric titrations can be used for the neutralization of acids, which contain H^+ ions, by producing hydroxide ions (OH^-) at an electrode to form water. Mercury, silver chloride, or silver bromide electrodes are good counter electrodes for this reaction. The coulometric technique has one real advantage over the volumetric technique, which is that the interference of carbonate ions (CO_3^{2-}) is easily removed by bubbling a carbon-dioxide deficient gas through the sample. This removes carbon dioxide in the sample, which would otherwise form carbonate ions and interfere with the analysis. Other applications include:

- Ions, such as halides, Zn, and mercaptans can be determined by complex formation or precipitation in the presence of aniodically generated silver ions.
- The oxidation of cerium, from Ce $^{3+}$ to Ce $^{4+}$, in 1 N sulfuric acid can be used to characterize several systems including titanium, iron, and uranium. The electrodes used for such a system would be a polarized platinum electrode and a non-polarized reference electrode, such as a lead amalgam - lead sulfate electrode.
- The reduction of Fe $^{3+}$ to Fe $^{2+}$ in acidic solutions can be used to determine the amount of permanganate (MnO_4^-), chromate ($Cr0_4^-$), or dichromate ($Cr_2O_7^{2-}$) ions in a sample. Coulometric titrations or potentiostatic coulometric techniques can be used for these systems. In the coulometric titration technique, the ratio of iron ions will change when the sample is added and the endpoint occurs when the ratio returns to its initial amount.

J. T. Stock, "Amperometric Titration",1995, pages 451-453.

APPENDIX 6

GLOSSARY

Anode

The electrode where oxidation occurs.

Anodic current

A faradic current due to an oxidation reaction.

Amalgam

A metallic solution of mercury with another metal.

Amperometry

A form of voltammetry in which we measure current as a function of time while maintaining a constant potential.

Asymmetry potential

The membrane potential when opposite sides of the membrane are in contact with identical solutions yet a nonzero potential is observed.

Auxiliary electrode

The third electrode in a three-electrode cell that completes the circuit.

Cathode

The electrode where reduction occurs.

Convection

The movement of material in response to a mechanical force, such as stirring a solution.

Current efficiency

The percentage of current that actually leads to the analyte's oxidation or reduction.

Cathodic current

A faradaic current due to a reduction reaction.

Counter electrode

The second electrode in a two-electrode cell that completes the circuit.

Coulometry

An electrochemical method in which the current required to exhaustively oxidize or reduce the analyte is measured.

Coulometric titrations

A titration in which the equivalence point is the time required for a constant current to completely oxidize or reduce the analyte.

Charging current

A current in an electrochemical cell due to the electrical double layer formation.

Diffusion layer

The layer of solution adjacent to the electrode in which diffusion is the only means of mass transport.

Dropping mercury electrode

An electrode in which successive drops of Hg form at the end of a capillary tube as a result of gravity, with each drop providing a fresh electrode surface.

Electrode of the second kind

A metallic electrode whose potential is a function of the concentration of X in an MXn/M redox half-reaction.

Enzyme electrodes

An electrode that responds to the concentration of a substrate by reacting the substrate with an immobilized enzyme, producing an ion that can be monitored with an ion-selective electrode

Faradic current

Any current in an electrochemical cell due to an oxidation or reduction reaction.

Faraday's law

The current or charge passed in a redox reaction is proportional to the moles of the reaction's reactants and products.

Galvanostat

A device used to control the current in an electrochemical cell.

Hydrodynamic voltammetry

A form of voltammetry in which the solution is mechanically stirred.

Hanging mercury drop electrode

An electrode in which a drop of Hg is suspended from a capillary tube.

Ion-selective electrode

An electrode in which the membrane potential is a function of the concentration of a particular ion in solution.

Ionophore

A neutral ligand whose exterior is hydrophobic and whose interior is hydrophilic.

Indicator electrode

The electrode whose potential is a function of the analyte's concentration (also known as the working electrode).

Liquid-based ion-selective electrode

An ion-selective electrode in which a chelating agent is incorporated into a hydrophobic membrane.

Membrane potential

A potential developing across a conductive membrane whose opposite sides are in contact with solutions of different composition.

Migration

The movement of a cation or anion in response to an applied potential.

Mediator

A species that transfers electrons from the electrode to the analyte.

Mass transport

The movement of material toward or away from the electrode surface.

Nonfaradaic current

A current in an electrochemical cell that is not the result of a redox reaction.

The interface between a positively or negatively charged electrode and the negatively or positively charged layer of solution in contact with the electrode.

Ohm's law

The statement that the current moving through a circuit is proportional to the applied potential and inversely proportional to the circuit's resistance ***(E=I·R).***

Overpotential

The difference between the potential actually required to initiate an oxidation or reduction reaction, and the potential predicted by the Nernst equation.

Potentiometer

A device for measuring the potential of an electrochemical cell without applying a current or altering the cell's composition.

Polarography

A form of voltammetry using a dropping mercury electrode or a static mercury drop electrode.

Potentiostat

A device used to control the potential in an electrochemical cell.

Residual current

The current in an electrochemical cell that is present even in the absence of an analyte.

Reference electrode

An electrode whose potential remains constant and against which other potentials can be measured.

Redox electrode

An inert electrode that serves as a source or sink for electrons for a redox half-reaction.

Salt bridge

A connection between two solutions that allows the movement of current in the form of ionic charge.

Saturated calomel electrode

Reference electrode based on the reduction of Hg_2Cl_2 to Hg in an aqueous solution saturated with KCl; that is,

$H_{g2}Cl_2$(s) + *2e-t2Hg(l) + 2Ct(aq).*

Silver/silver chloride electrode

Reference electrode based on the reduction of AgCl to Ag; that is,

AgCl(s) + *e-tAg(s) + Ct(aq).*

Static mercury drop electrode

An electrode in which successive drops of Hg form at the end of a capillary tube as the result of a mechanical plunger, with each drop providing a fresh electrode surface.

Stripping voltammetry

A form of voltammetry in which an analyte is first deposited on the electrode and then removed, or "stripped," electrochemically while monitoring the current as a function of the applied potential.

Voltammetry

An electrochemical method in which we measure current as a function of applied potential.

Voltammogram

A plot of current as a function of the applied potential.

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Основы аналитической химии
Basics of Analytical Chemistry

Учебное пособие
по профессиональному английскому языку

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