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Кафедра иностранных языков естественно-научных факультетов

Английский язык для химиков

Активная лексика и устная речь

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Целью практикума является обучение студентов различным видам чтения, основам учебного реферирования и информационному поиску. Практикум содержит аутентичные материалы, позволяющие студентам понимать тексты по специальности и активно употреблять как общенаучную лексику, так и узкоспециальную терминологию в своей профессиональной деятельности.

Предназначен для студентов-химиков 1–2 курсов, обучающихся по дисциплине «Иностранный язык» на факультете биологии и экологии.

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INTRODUCTION TO SCIENCE

Almost everything we do depends on science – science is involved somewhere and somehow, truly changing the world and the way we live.

There are hundreds of different areas, or branches, of science. Scientific research has been going on for centuries and now our modern world is packed with the results of scientific discoveries and developments. The list is almost endless and growing day by day.

Scientific work has also given us greater understanding of natural phenomena which take place around us. We have knowledge about how substances and materials join together, react or combine, to produce different substances and materials. And that's what chemistry is doing!

We live in the age of chemistry. Nowadays chemistry solves many vital problems and one of these problems is the creation of new materials. Natural materials do not possess all properties we require and the present great progress in the production of artificial materials is due to synthetic polymers, to chemistry.

In the future, science, and chemistry in particular, will continue to make our lives more rewarding and enjoyable, and increase our knowledge and understanding.

UNIT 1
STUDYING SCIENCES

The Way We Study Sciences

My friend Dima and I study at Yaroslavl State University. We are first-year students, or freshmen, as they put it in America. We enjoy sciences. Do you know that all disciplines are divided into sciences and humanities? Sciences study the natural world around us. Humanities learn the human culture. At school my friend and I enjoyed biology and chemistry. They are sciences. Now we are students of the faculty of biology and ecology. I am doing biology and ecology. Dima has chosen another speciality. He is doing chemistry. Our faculty is located far from the center of the city. So we have to take a bus to get to the university. It usually takes us half an hour to get there.

The academic year begins, as a rule, on the first of September and ends in June. It lasts ten months: September, October, November, December, January, February, March, April, May and June. The academic year has two terms: the autumn term and the spring term. The autumn term begins in September and ends in December. It lasts four months or eighteen weeks. The spring term begins in the second week of February and ends, as a rule, in June. Each term ends with credit tests and examinations, or exams. They take place in January and in June, sometimes in July.

We have two holidays a year: winter holidays and summer holidays. The winter holidays are short. They last only two weeks. The summer holidays are long. They last two months. During the holidays we do not study, we have a rest.

We go to the university on week-days: Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday. We do not go there on Sundays. On Sundays we have a rest.

My classes begin at eight-thirty, or at half past eight, in the morning and end at about two or four in the afternoon. As for Dima, his classes begin at nine and end at about the same time. So almost every day we leave the university together.

We are never late. We always come to our classes in time. As a rule, we have four lectures or seminars or practical classes a day, sometimes three of them. Between classes we have short breaks and a long lunch break after the second period when we usually have lunch in the dining-hall.

Also, at the university all students learn some foreign languages: English, German or French. We have one English lesson a week. At the lesson we check up on our assignment, ask and answer questions, read English texts and translate them into Russian. We listen to English speech and learn to understand it. We also write English.

At the end of each lesson we are given our assignment, or homework. I am very attentive in class and always prepare my assignments because I want to know English well. It is not difficult for me: I work at this language regularly. I do my homework together with Dima. It usually takes us about three hours. As we are not from Yaroslavl, we live in the hall of residence (*British*) / in the dorm (*American*). We are roommates.

P.G. Demidov Yaroslavl State University as the Centre of Research

Yaroslavl State University is one of the youngest and at the same time one of the oldest universities in Russia. The history of Yaroslavl State University began in 1803. The emperor of Russia Alexander I founded the School of Higher Sciences on the money of the famous landlord, scientist-naturalist and the Councillor of State P.G. Demidov. It was later transformed into Demidov Law Lyceum.

In 1918 Yaroslavl State University was established. Six years later it stopped its activity because of the money problems. But in 1970 it began to work again. In 25 years it was given the name of Pavel Grigoriyevich Demidov.

Today P.G. Demidov Yaroslavl State University is one of the best higher educational institutions with more than 7000 students. It has about 70 bachelor's and master's programmes. Students can continue education at a post-graduate school for a candidate's and doctor's degree. The university develops a multi-discipline approach to education and its graduates have good job opportunities.

In its structure the university has eleven faculties: the Law Faculty, the Mathematics Faculty, the Physics Faculty, the Economics Faculty, the History Faculty, the Faculty of Information and Computer Science, the Faculty of Social and Political Sciences, the Psychology Faculty, the Biology and Ecology Faculty, the Faculty of Philology and Communication, the Institute of Foreign Languages. Also the University College offers academic programmes in secondary professional education.

The teaching process is provided by a professional team of lecturers and instructors, most of them have the degree of candidates and doctors of science. The rector of Yaroslavl State University is Professor Alexander Ilyich Rusakov.

At the university research works are carried out in many fields of science. Students and instructors participate in different scientific conferences and workshops. Their scientific achievements are known not only in Russia, but also abroad. Together with their supervisors students do research on both fundamental and applied problems of various scientific branches.

A wide range of research is provided by a close creative cooperation with a number of leading research institutes and higher educational institutions. The university takes part in international exchange projects and has long-term partnerships with higher educational institutions of the USA, Finland, France, England.

Demidov Yaroslavl State University provides students with a great variety of facilities, such as libraries, well-equipped laboratories and rooms with Internet access, dorms, gyms.

The Biological Faculty and My Speciality

I am a student of the biological faculty. Our faculty is one of the largest faculties of the University. We study different subjects: inorganic chemistry, organic chemistry, chemical analysis and many others. Besides these subjects we study law, history, philosophy and English. We study English to be able to read scientific books on chemistry.

There are two departments at our faculty: of organic and biological chemistry and of general and physical chemistry. Besides there are research laboratories and museums. Every student has an opportunity to work in modern, well-equipped laboratories, where different problems of chemistry are under investigation.

Students are acquainted with all branches of chemistry. We are lectured in various subjects of natural science, namely organic chemistry, inorganic chemistry, physical chemistry, chemical analysis, biochemistry, nanochemistry and also chemical technology.

During the first two years we attend lectures on mathematics, physics, biology, social studies and foreign languages. In the third year more narrow specialization begins. We have several specialized courses and additional practical and research work in the subject we have chosen as our future speciality. Besides attending lectures we may join some scientific circle and choose a problem to work on according to our bents. All of us know that chemistry is the science of glorious past and great future. We do our best to acquire as much knowledge as possible.

Graduates of the biological faculty can work at laboratories, schools, research institutes and pharmaceutical companies. Those who have a bent for research work may apply for a post-graduate course of study to continue their education.

ACTIVE VOCABULARY TO BE MEMORIZED IN UNIT 1

academic year	It takes smb. … to do smth.
term	establish = found
take a credit-test in	higher educational institution
pass an exam in	secondary professional education
get a credit	achieve a goal
be attentive	scientific achievement
be late	access
come in time	bachelor
period	Bachelor of Arts
break	Bachelor of Science
prepare for classes	master

ask and answer questions write English listen to English speech do one's homework check up on one's assignment work at the language hard as a rule choose one's speciality continue education at different difficult enjoy first-year student (freshman) foreign language during the holidays have a rest on week-days attend classes discipline humanities sciences do chemistry know last end with want enter graduate from graduate get to leave take place way	bachelor's and master's programmes develop a multy-discipline approach field = branch both fundamental and applied problems post-graduate school post-graduate get a degree instructor supervisor offer academic programmes participate take part close cooperation long-term partnership international exchange projects provide students with facilities opportunity a wide range of research do research on carry out a research work be under investigation well-equipped laboratory be acquainted with besides there is/are department faculty narrow specialization according to do one's best acquire knowledge

UNIT 2
THE SCOPE OF CHEMISTRY

The History of Chemistry

Thousands of years ago people valued gold as a rare and beautiful substance. They also understood that gold had a unique ability to resist decay and corrosion. Since there was no known acid or other substance that could damage gold they thought that gold had a quality of performance that could be transmitted to humans. Therefore, every medicine that fought ageing contained gold as an essential ingredient and doctors urged people to drink from gold cups to prolong life.

This universal desire for gold made alchemy a formal discipline in the first century A.D. It first appeared among Greek scholars, then spread to eastern Mediterranean countries, and finally to Spain and Italy in the 12th century. Though the attempts to produce gold from other substances was the original and central purpose of alchemy, a number of physician-alchemists in Europe in the Middle Ages tried to produce medicines that were not dependent on gold or related to it.

They worked to produce medicines and spirits from raw materials, such as herbs, and in this way improved methods of separating elements by distillation. For example, as early as the 13th century, Thaddeus of Florence identified the medical benefits of alcohol distillates taken internally and applied locally. Paracelsus (1493-1541), the German-Swiss physician and alchemist, was the first person to unite medicine with chemistry through his use of remedies that contained mercury, sulphur, iron, and copper sulphate. This led to steam distillation and improved equipment.

The development of apparatus and the extensive efforts to break down or distil substances laid the foundation for modern chemistry, but as true science began to evolve during the Renaissance, the study of alchemy blocked the birth of modern chemistry. Some scientists tried to lead people toward reliance on empirical evidence (that is, what can actually be observed and/or measured), but the idea of four essential elements (earth, air, fire, and water) lived on and there was no recognition that these four substances are made up of a combination of basic elements.

Overview of Chemistry

What is chemistry? All definitions of chemistry include the study of *matter. Matter is defined as anything that has mass and occupies space*. All matter is arranged and organized. The way it is arranged is called its *structure*. The parts of the structure and the ratio in which they are organized are called its *composition*. In addition, all matter has characteristics or *properties*. That is, each *substance* has a set of properties that are characteristic of that substance and give it a unique or special identity. These physical or chemical properties are the "personality traits" of that substance. In brief, chemists study the properties, the composition, and the structure of matter. They also study changes in the composition and the structure as well as the *reactions* of matter, especially of atomic and molecular systems. Basically, *chemistry is a science that deals with the composition and properties of substances and with the reactions by which substances are produced from, or converted into, other substances*.

People have practiced chemistry since ancient times. The Egyptian, Arabic, Greek, and Roman cultures each contributed significant developments to chemistry. These early developments were *empirical*. That is, they were achieved by trial and error and were not based on any valid theory of matter. The alchemists (500-1600 A.D.) whose practical goal was to change base metals into gold and to prolong life, also contributed to the development of chemistry. However, it was not until the 17th and 18th centuries that modem chemistry began to develop through systematic experimentation rather than trial and error. In fact, this systematic experimentation, called the *scientific method*, is usually credited with being the most important single factor in the development of chemistry and its application to technology.

Chemistry is related to physics, another basic branch of science. It is also related to biology, the science of life, because life itself is basically a complicated system of interrelated chemical processes.

The range, or scope, of chemistry is very wide. In fact, it includes the whole universe and every animate (living) and inanimate (nonliving) thing in it. Chemistry may be broadly classified into two main branches: *organic* chemistry (the chemistry of living things) and *inorganic* chemistry (the chemistry of nonliving things). Through the study of chemistry we try to learn and understand the *principles* and *laws* that control the activity of all matter.

Chemists may try to observe and to explain natural situations, or phenomena, or they may invent experiments that will show the composition and structure of complex substances. They may look at methods to improve natural processes or, sometimes, create or combine substances that are unknown in nature.

Even though the total of chemical knowledge is so enormous that no one could learn all of it in one's lifetime, the basic *concepts* are not difficult. In fact, these fundamental concepts in chemistry have become part of the education required for many professionals in a wide variety of fields and they have contributed to the rapid growth of technology.

The Nature of Chemistry

What is chemistry? A popular dictionary gives this definition: Chemistry is a science of the composition, structure, properties, and reactions of matter, especially of atomic and molecular systems. Another, somewhat simpler dictionary definition, is: Chemistry is a science dealing with the composition of matter and the changes in composition that matter undergoes. Neither of these definitions is entirely adequate. Chemistry, along with the closely related science of physics, is a fundamental branch of knowledge. Chemistry is also closely related to biology, not only because living organisms are made of material substances but also because life itself is an essentially complicated system of interrelated chemical processes.

The scope of chemistry is extremely broad. It includes the whole universe and everything, animate and inanimate, in it. Chemistry is concerned not only with the composition of matter, but also with the energy and energy changes associated with matter. Through chemistry we seek to learn and to understand the general principles that govern the behaviour of all matter.

The chemist, like other scientists, observes nature and attempts to understand its secrets: What makes a rose red? Why is sugar sweet? What is occurring when iron rusts? Why is carbon monoxide poisonous? Why do people wither with age? Problems such as these — some of which have been solved, some of which are still to be solved — are part of what we call chemistry.

A chemist may interpret natural phenomena, devise experiments that will reveal the composition and structure of complex substances, study methods for improving natural processes, or, sometimes, synthesize substances unknown in nature. Ultimately, the efforts of successful chemists advance the frontiers of knowledge and at the same time contribute to the well-being of humanity. Chemistry can help us to understand nature, however, it is not necessary to be a professional chemist or scientist to enjoy natural phenomena. Nature and its beauty, its simplicity within complexity, are for all to appreciate.

The body of chemical knowledge is so vast that no one can hope to master it all, even in a lifetime of study. However, many of basic concepts can be learned in a relatively short period of time. These basic concepts have become part of the education required for many professionals including agriculturists, biologists, dental hygienists, dentists, medical technologists, microbiologists, nurses, nutritionists, pharmacists, physicians, and veterinarians, to name just a few.

Alchemy

One of the most interesting periods in the history of chemistry was that of the alchemists (500-1600 A.D.). People have long had a lust for gold, and in those days gold was considered the ultimate, most perfect metal formed in nature. The principle goals of alchemists were to find a method of prolonging human life indefinitely and to change the base metals, such as iron, zinc, and copper, into gold. They searched for a universal solvent to transmute base metals into gold and for the "philosopher's stone" to rid the body of all diseases and to renew life. In the course of their labours they learned a great deal of chemistry. Unfortunately, much of their work was done secretly because of the mysticism that shrouded their activity, and very few records remained.

Although the alchemists were not guided by sound theoretical reasoning and were clearly not in the intellectual class of the Greek philosophers, they did something that philosophers had not considered worthwhile. They subjected various materials to prescribed treatment under what might be loosely described as laboratory methods. These manipulations, carried out in alchemical laboratories, not only uncovered many facts of nature but paved the way for the systematic experimentation that is characteristic of modern science.

Alchemy began to decline in the 16th century when Paracelsus (1493-1541), a Swiss physician and outspoken revolutionary leader in chemistry, strongly advocated that the objectives of chemistry were directed toward the needs of medicine and the curing of human ailments. He openly condemned the mercenary efforts of alchemists to convert cheaper metals to gold.

Modern Chemistry

Modern chemistry was slower to develop than astronomy and physics. It began in the 17th and 18th centuries when Joseph Priestley (1733-1804), who discovered oxygen in 1774, and Robert Boyle (1627-1691) began to record and publish the results of their experiments and to discuss their theories openly. Boyle, who has been called the founder of modern chemistry, was one of the first to practice chemistry as a true science. He believed in the experimental method. In his most important book, *The Sceptical Chemist*, he clearly distinguished between an element and a compound or mixture. Boyle is best known today for *the gas law* that bears his name.

A French chemist, Antoine Lavoisier (1743-1794), placed the science on a firm foundation with experiments in which he used a chemical balance to make quantitative measurements of the weights of substances involved in chemical reactions. The use of the chemical balance by Lavoisier and others later in the 18th century was almost as revolutionary in chemistry as the use of the telescope had been in astronomy. Thereafter, chemistry became a quantitative experimental science. Lavoisier also contributed greatly to the organization of chemical data, to chemical nomenclature, and to the establishment of *the law of conservation of mass* in chemical changes.

During the period from 1803 to 1810, John Dalton (1766-1844), an English schoolteacher, advanced his atomic theory. This theory placed the atomistic concept of matter on a valid rational basis. It remains today as a tremendously important general concept of modern science. Since the time of Dalton, knowledge of chemistry has advanced in great strides, with the most rapid advancement occurring at the end of the 19th century and during the 20th century. Especially outstanding achievements have been made in determining the structure of atom, understanding the biochemical fundamentals of life, developing chemical technology, and mass production of chemicals and related products.

Empirical Chemistry

People have practiced empirical chemistry from the earliest times. Ancient civilizations were practicing the art of chemistry in such processes as wine-making, glass-making, pottery-making, elementary metallurgy and so on. The early Egyptians, for example, had considerable knowledge of certain chemical processes. Excavations into ancient tombs dated about 3000 B.C. have uncovered workings of gold, silver, copper and iron, pottery from clay, glass beads, and beautiful dyes and paints as well as bodies of Egyptian kings in remarkably well-preserved states. Many other cultures made significant developments in chemistry. However, all these developments were empirical, that is, they were achieved by trial and error and did not rest on any valid theory of matter.

Philosophical ideas relating to the properties of matter (chemistry) did not develop as early as those relating to astronomy and mathematics. The Greek philosophers made great strides in philosophical speculation concerning materialistic ideas about chemistry. They led the way to placing chemistry on an intellectual, scientific basis. They introduced the concepts of elements, atoms, shapes of atoms, and chemical combination. They believed that all matter was derived from four elements: earth, air, fire, and water. The Greek philosophers had keen minds and perhaps came very close to establishing chemistry on a sound basis similar to one that was to develop about 2000 years later. The main shortcoming of the Greek approach to scientific work was a failure to carry out systematic experimentation.

Greek civilization was succeeded by Roman civilization. The Romans were outstanding in military, political and economic affairs. They practiced empirical chemical arts such as metallurgy, enameling, glass-making, and pottery-making, but they did very little to advance new and theoretical knowledge. Eventually the Roman civilization was succeeded in Europe by the Dark Ages. During this period European civilization and learning were at a very low ebb.

In the Middle East and in North Africa, knowledge did not decline during the Dark Ages as it did in Western Europe. At this time Arabic cultures made contributions that were of great value to the development of modern chemistry. In particular, the Arabic number system, including the use of zero, gained acceptance; the branch of mathematics known as algebra was developed; and alchemy, a sort of pseudochemistry, was practiced extensively.

ACTIVE VOCABULARY TO BE MEMORIZED IN UNIT 2

define — definition	since ancient times
matter	the body of knowledge
have mass	govern the behaviour of matter
occupy space	be concerned with = be associated with
be arranged	concerning
arrangement	interpret
way	devise
structure	reveal
ratio	master
be composed of	ultimately
composition	significant
be decomposed by	vital
decomposition	invent
in addition	include
a set of properties	occur — occurrence
that is	rust
in brief	poison
undergo changes	poisonous
as well as	separate — separation
atomic and molecular systems	solve a problem
basically	synthesize — synthesis
deal with	through the study of chemistry

be produced from production be converted into contribute to — contribution to make a contribution to develop — development be based on base ≠ noble metals prolong life however rather than in fact scientific/experimental method apply to — application to technology fundamental branch = field of knowledge complicated = complex substance the range/scope of chemistry chemist animate ≠ inanimate thing be classified into organic ≠ inorganic chemistry principle law activity of matter observe — observation attempt explain natural phenomena improve natural processes create substances unknown in nature creation combine chemicals basic concepts require for a wide variety of trial and error a valid theory to be related to relation a closely related science interrelated processes to carry out = perform an experiment the rapid growth of	contribute to the well-being of humanity the whole universe natural ≠ artificial materials possess properties result in/from increase knowledge in be considered principle goal search for a universal solvent transmute = convert into rid the body of diseases cure ailments renew life in the course of unfortunately sound reasoning subject to prescribed treatment pave the way for the systematic experimentation discover — discovery practice chemistry as a true science practice empirical chemistry place the science on a firm foundation place the concept on a valid rational basis establish chemistry on a sound basis thereafter advance the frontiers of knowledge advance the theory advance in great strides rapid advancement make great strides in determine biochemical fundamentals of life introduce approach to scientific work eventually be at a low ebb in particular gain acceptance keep records make efforts be of great value to

UNIT 3
THE STATES OF MATTER

Matter and Chemistry

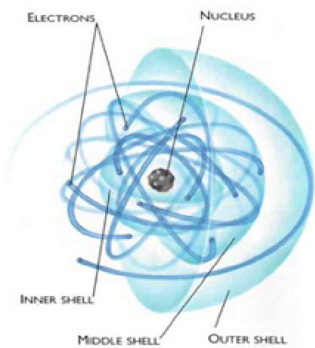
Chemistry is the study of matter, substances and chemicals. It investigates what matter is made of and how substances combine or react. Using this knowledge, chemists can create new, useful substances and materials – from medicinal drugs, to stronger metals, to long-lasting plastics.

Inside an atom

All substances are made of atoms. An atom has a central part called a nucleus, with even smaller parts, electrons, whizzing around it.

All matter is made of tiny particles called atoms. So far, scientists have discovered about 118 different types of atom. A substance made up of atoms which are all the same is called a chemical element. For example, the gas oxygen is an element. So is the metal iron.

A substance made up of different types of atoms joined together is called a compound. For example, water is a compound of the elements oxygen and hydrogen.



Molecules

When two or more atoms join together, or combine, they form a molecule. A molecule of the compound water has one atom of the element oxygen joined with two atoms of the element hydrogen. This can be written as the chemical formula H_2O.

Properties of matter

Scientists describe different substances in terms of their physical and chemical properties. At normal room temperature, substances like water are liquid, while oxygen is a gas, and iron is a solid.

Other properties include heaviness or density, strength, the temperatures at which they melt (turn from solid to liquid) and boil (change from liquid to gas), how well they conduct electricity and heat, and so on.

Matter in the Universe

That matter may exist in three physical states (solid, liquid and gas) is common knowledge. It is usually possible to change matter from one state to the other by changing its temperature. For instance, a piece of ice is called a solid; it may melt and form a liquid; as it evaporates, liquid water changes into a vapour, i.e. into the gaseous state.

Many kinds of matter, like water, can be obtained in each of the three states; for some, however, extraordinary means have to be used in order to produce one, or even two of the states; and for others, only two states are known or can be produced.

Common salt, for example, exists normally as a solid; at a temperature of several hundred degrees, it can be liquefied; and at still higher temperature it is converted into vapour. Carbon, a solid under normal conditions, can be vaporized, but it has never been liquefied.

Solids have both a definite volume and a definite shape. Liquids, too, have a definite volume, but they take the shape of their containers. Gases have neither a definite shape nor a definite volume. A chemist must have a thorough knowledge of the states of matter and of physical laws that govern the behaviour of matter in various states.

That all matter is composed of molecules is known to everybody. The question which must be answered, then, is: if all matter is composed of molecules, what is the essential difference between the states of matter? The answer to this question is that the essential difference between these states is the relative quantities of energy molecules possess in different states.

Molecules in Gases and Liquids

According to Avogadro's principle, equal volumes of gases regardless of composition, contain the same number of molecules at the same temperature and pressure. As a consequence of the principle, the gram-molecular weight of any gaseous substance occupies 22.4 litres at standard temperature (0°C) and pressure (760 mm of mercury). The number of molecules per gram-mole has been calculated by different methods of increasing refinement through the years, and is now considered to be 6.023x1023 atoms per gram-atom, or molecules per gram-mole, and it is accurate within 0.1%. For example, one mole of ammonia gas (NH_3 — weighs 17.073 grams, occupies a volume of 22.4 litres at standard temperature and pressure, and contains 6.023x1023 molecules).

At the same temperature, molecules of a liquid move at the same rate as those in a gas. In a liquid, however, the extent of motion must be more restricted. Liquids flow as a stream and tend to form drops to a greater or less extent, thus giving evidence of the importance of the force of cohesion between the molecules in a liquid. Heating liquids, as a rule, results in their expansion, an effect explained by the tendency of the molecules to occupy more space when they move at a faster rate. Also, increase in pressure has but slight effect on the volume compressible. From this evidence it is argued that molecules in a liquid are adjacent, close enough to flow in a continuous stream.

The molecules in a liquid, like those in a gas, are not all moving at the same velocity, but at the same average velocity at a given temperature. The molecules at the surface of a liquid, unlike those below the surface layer, have no force of attraction from molecules above. Some of the more rapidly moving molecules overcome the cohesive force of their neighbour and leave the surface. The tendency to leave the surface or to evaporate varies from liquid to liquid, and it increases when the temperature is raised.

The pressure caused by the evaporation of molecules from a liquid, measured at equilibrium with the returning molecules at a given temperature, is called the vapour pressure. In general, vapour pressure increases when the temperature rises. With continued addition of heat the vapour pressure rises still more until the vapour pressure reaches the vapour pressure of the atmosphere above the liquid. The evaporation goes on throughout the liquid, and the liquid is boiling. Obviously the act of boiling can be accomplished either by raising the temperature of the liquid or by reducing the pressure of the atmosphere above the liquid.

Molecules in Solids

Having their own shape is a characteristic feature of solids since they have their own shape rather than that of the container (as for liquids and gases) and generally do not flow, the extent of molecular motion in a solid is even more limited than that in a liquid. True solids are crystalline, bounded by plane surfaces that meet in a definite dihedral angle, and have a characteristic melting point. The molecules in a solid have the same temperature, and if they are molecules of the same substance, they are moving at the same average velocity. The motion of molecules in a solid must be confined, and, probably, it is a vibration or oscillation about a fixed point.

Crystals composed of molecules may evaporate in a manner similar to that of liquids. This phenomenon is called sublimation, and it may be noticed in solid carbon dioxide (dry ice), paradichlorobenzene, camphor, and many odorous solids. Non-molecular solids show little tendency to sublime. The Van der Waals force between the particles in molecular solids is, apparently, less in general than the coulomb forces between ions in non-molecular solids. As with liquids, solids vary greatly in their tendency to sublime, and the rate of sublimation varies with the temperature and inversely with the pressure. In some solids the crystal is composed of molecules in a pattern that repeats.

Solids, Liquids and Gases

Imagine a glass half-full of water. This shows substances existing in the three different forms — solid, liquid and gas. These are called the three states of matter. The glass is a solid. The water in the glass is a liquid. The air above the water (and all around us) is a gas.

All substances are made of atoms, or atoms joined together into molecules. The way that these atoms and molecules can move about determine whether the substance is a gas, liquid or solid.

Gases

In a gas, the particles are widely spaced. They can also whizz about at high speed. This means a gas expands to fill the container it is in, because its particles are always free to move. If the container changes its size or shape, the gas does so too, and still fills the space available.

Liquids

In a liquid, the particles are packed closer together, but they can still move. A liquid flows so that it takes the shape of the container it is in. Gases and liquids are both known as fluids, because they can flow. But liquids cannot be squashed or compressed, unlike gases.

Solids

In a solid, the particles are packed even closer together, and they are fixed so they cannot move. This means solids cannot flow. Most solids also have a fixed shape. They can be squashed, stretched and bent, but they return to their original shape when the forces are removed.

Changes of state

Most substances change from one state to another when they are heated or cooled. For example, when water is heated, it turns to gaseous water vapour. When cooled, it becomes solid ice. These alterations are changes of state.

FACTS ABOUT CHANGING STATES

► ***Melting Points***

The lightweight metal aluminium melts at 660°C.

The common metal iron melts at 1,535°C.

The metal titanium, used in jet engines, melts at 1,660°C.

► ***Boiling Points***

Aluminium boils at 2,467°C.

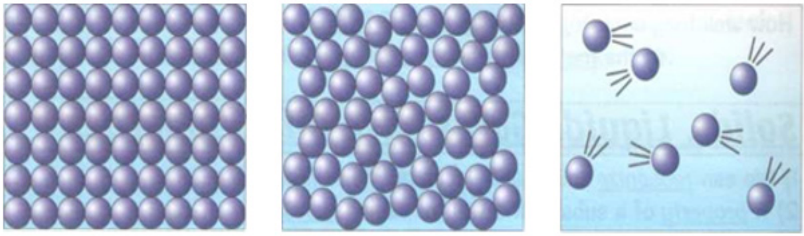
Iron boils at 2,750°C.

Titanium boils at 3,287°C.

The Particle Theory

The state of a substance – gas, liquid or solid – depends on how its *particles* can move about.

*Particles in a **SOLID** cannot move*	*Particles in a **LIQUID** move more slowly*	*Particles in a **GAS** move fast and freely*



The particles in a substance stay *the same* whether it's a solid, a liquid or a gas. What changes is the *arrangement* of the particles and their *energy*. The particle theory explains all the *different properties* of solids, liquids and gases.

SOLIDS — Particles are Held Very Tightly Together

1. There are *strong* forces of *attraction* between particles.
2. The particles are held *closely* in *fixed positions* in a very regular *arrangement*. But they do *vibrate* to and fro.
3. The particles *don't move* from their positions, so all solids keep a *definite shape* and *volume*, and *can't flow* like liquids.
4. Solids *can't* easily *be compressed* because the particles are already packed *very closely together*.
5. Solids are usually *dense*, as there are *lots* of particles in a *small* volume.

LIQUIDS — Particles are Close Together but They Can Move

1. There are *some* forces of *attraction* between the particles.
2. The particles are *close* but free to *move* past each other, but they do *stick together*. The particles are *constantly* moving in *all* directions.
3. Liquids *don't* keep a *definite shape* and can form puddles. They *flow* and *fill the bottom* of a container. But they do keep *the same volume.*

4. Liquids *won't compress* easily because the particles are packed *closely together*.

5. Liquids are *quite dense*, as there are *quite a lot* of particles in a *small* volume.

GASES — Particles are Far Apart and Whizz About a Lot

1. There are *very weak* forces of *attraction* between the particles.

2. The particles are *far apart* and free to *move* quickly in *all* directions.

3. The particles move *fast* so *collide* with each other and the container.

4. Gases *don't* keep a *definite shape* or *volume* and will always *expand to fill* any container. Gases *can be compressed easily* because there's a lot of free *space* between the particles.

5. Gases all have *very low densities*, because there are *not many* particles in a *large* volume.

Properties of Solids, Liquids and Gases

Materials come in three different forms – solid, liquid and gas. These are called the *Three States of Matter*. All materials are made up of *tiny particles*. Which *state* you get (solid, liquid or gas) depends on how *strongly* the particles *stick together*. How well they stick together depends on *three things*: a) the *material* b) the *temperature* c) the *pressure*.

We can *recognize* solids, liquids and gases by their different *properties*. A *property* of a substance is just a way of saying *how it behaves*.

Property	***SOLIDS***	***LIQUIDS***	***GASES***
Volume	Solids have a *definite volume*	Liquids have a *definite volume*	Gases have *no* definite volume – they always *fill the container* they're in

Shape	Solids have a *definite shape*	Liquids *match the shape* of the container	Gases become *the same shape* as the container
Density	Solids have a *high density* (heavy for their size)	Liquids have a *medium density*	Gases have a very *low density*
Compres-sibility	Solids are *not* easily *squashed*	Liquids are *not* easily *squashed*	Gases are easily *squashed*
Ease of Flow	Solids *don't flow*	Liquids *flow easily*	Gases *flow easily* (and *diffuse*)

Why Is Water So Important?

Three-quarters of the Earth's surface is covered in water. This makes water the most common material on Earth. Like other substances, water can exist as a liquid, as a gas, or as a solid. Water in the form of a gas (water vapour) is commonly called *steam*. Solid water is *ice*. We can change one form into another form by simply changing the conditions, for example, by heating it up or cooling it down. The change from one form to another is usually called a *change of state*. Changes of state are examples of a physical change. They don't involve making new substances.

Single substances are either compounds or elements. What about water? From the chemical point of view water has many points of interest, because it enters into chemical reactions which are of fundamental importance. Water not only reacts with many substances but it also has a marked influence upon many chemical reactions.

Well, water can be decomposed. So it can't be an element, can it? Decomposition of water can be made by electric current. In this way two volumes of hydrogen and one volume of oxygen are obtained. So we can say that water is a *compound of hydrogen and oxygen*. The chemical name for water is *hydrogen oxide*. Is it possible to make water from its elements? The answer is – yes! In fact, it's quite easy to do (but rather dangerous).

Hydrogen's the water former, remember? When it's burnt in air, water is formed. The "artificial water" formed in this way is exactly the same as "natural water". The experiment can be made in the laboratory, but only by the teacher, and with strict safety precautions.

Chemical and Physical Properties of Water

Water is hydrogen oxide, a compound of hydrogen and oxygen. It can be made if hydrogen or a hydrogen-containing substance is burnt in air or oxygen.

Most of the world's water is liquid, but an important fraction is solid as ice and snow.

Many mineral substances contain water of crystallization (e.g. copper sulphate) and in the atmosphere there are millions of tons of water vapour. Clouds consist of minute droplets of water or crystals of ice.

Water dissolves a very large number of substances and is the most important solvent. It does not dissolve greasy, fatty substances or most plastics.

After they had found the composition of water, the scientists could investigate its properties. It was stated that ordinary water is impure, it usually contains dissolved salts and dissolved gases, and sometimes organic matter.

For chemical work water is to be purified by distillation. Pure water is colourless, tasteless, and odourless. Rain water formed by condensation of water in the air is nearly pure water, which contains only small proportions of dust and of dissolved gases.

After the examination of the water properties the chemists found that physical properties of water can be used to define many physical constants and units.

The freezing point of water (saturated with air at 1-atm pressure) is taken at 0°C and the boiling point of water at 1 atm is taken as 100°C.

The unit of volume in the metric system is chosen so that 1 ml of water at 3.98°C (the temperature of its maximum density) weighs 1,000 g/cm.

So water is one of the most important of all chemical substances. It is a major constituent of living matter and of the environment in which we live.

Water Purification

The abundance of water in liquid, solid and gaseous state is a matter of common observation. Water is not only the most abundant compound, but it is also very important for life. To be sure life would be impossible without water.

For many purposes water must be pure. The purest natural water is rain. But we can't say that it is really pure. The same can be said about ground water. It contains a great deal of impurities which fail to settle. Dissolved substances do not settle and don't evaporate with water, and this makes their removal difficult.

One of the most important problems is to obtain water sufficiently pure to meet our needs. The choice what process is to be used for purification of water depends upon the uses for which it is intended as well as the impurities it contains. Water used for steam boilers should be free from substances that cause corrosion and scale formation. Water for washing should not contain substances that react with soap. When water is to be used for drinking, it is necessary to kill the microbes it may contain. To achieve this, water which is to be purified is thoroughly filtered. Another way to purify water is to boil it. None of these methods is fit for producing pure water in the chemical sense, because most of the soluble salts are unaffected by the treatment.

To remove these and to prepare chemically pure water suitable for scientific use, we take advantage of the fact that water is usually changed to steam while most of the dissolved substances as have already been mentioned are not volatile. If we condense the steam, we are thus able to remove all the impurities except volatile ones. This process is called distillation. Distilled water has many uses, both in the laboratory and in industry, when even small quantities of impurities are undesirable.

ACTIVE VOCABULARY TO BE MEMORIZED IN UNIT 3

be made up of = consist of exist states of matter obtain convert form change from one state to the other turn into under normal conditions at a temperature of at standard temperature and pressure heat up ≠ cool down water vapour (steam) solid water (ice) evaporate — evaporation vaporize liquefy solidify sublime — sublimation be called govern the behaviour of matter attract — attraction force of attraction force of cohesion / cohesive force available collide vibrate — vibration oscillation diffuse combine = join together in different ways compound property conduct electricity — conductivity dense density high / medium / low strong ≠ weak strength heavy heaviness depend on describe determine expand — expansion	liquid solid crystal melt the freezing/boiling/melting point be adjacent be packed closely together be held tightly together stick together be widely spaced fill the container take/match the shape of the container stretch squash compress bend be formed by condensation of colourless / tasteless / odourless purify be purified by distillation water purification pure ≠ impure a great deal of impurities settle fraction minute droplet from the chemical point of view have many points of interest for chemical purposes for scientific use the most important solvent dissolve — solution soluble ≠ insoluble volatile be burnt with strict safety precautions the most common material commonly the most abundant substance abundance enter into a chemical reaction influence many chemical reactions be decomposed by electric current a matter of common observation treat — treatment

definite volume fixed shape flow as a stream be free to move move fast — motion be restricted = be limited = be confined at high speed at a faster rate at the same average velocity	prepare chemically pure water remove — removal size nucleus whizz around inner/middle/outer shell increase ≠ decrease to meet needs investigate — investigation

U N I T 4
PHYSICAL AND CHEMICAL CHANGES

Physical and Chemical Change

Change is happening all around us all of the time. Just as chemists have classified elements and compounds, they have also classified types of changes. Changes are either classified as physical or chemical changes.

Chemists learn a lot about the nature of matter by studying the changes that matter can undergo. Chemists make a distinction between two different types of changes that they study – physical changes and chemical changes.

Physical changes are changes in which no bonds are broken or formed. This means that the same types of compounds or elements that were there at the beginning of the change are there at the end of the change. Because the ending materials are the same as the beginning materials, the properties (such as colour, boiling point, etc.) will also be the same. Physical changes involve moving molecules around, but not changing them. Some types of physical changes include:

• Changes of state (changes from a solid to a liquid or a gas and vice versa).

• Separation of a mixture.

• Physical deformation (cutting, denting, stretching).

• Making solutions (special kinds of mixtures).

When we heat the liquid water, it changes to water vapour. But even though the physical properties have changed, the molecules are exactly the same as before. We still have each water molecule containing two hydrogen atoms and one oxygen atom covalently bonded. Similarly, if you have a piece of paper, you don't change it into something other than a piece of paper by ripping it up. What was paper before you starting tearing is still paper when you've done. Again, this is an example of a physical change.

For the most part, physical changes tend to be reversible – in other words, they can occur in both directions. You can turn liquid water into solid water through cooling; you can also turn solid water into liquid water through heating. However, as we will later learn, some chemical changes can also be reversed.

Chemical changes occur when bonds are broken and/or formed between molecules or atoms. This means that one substance with a certain set of properties (such as melting point, colour, taste, etc.) is turned into a different substance with different properties. Chemical changes are frequently harder to reverse than physical changes.

One good example of a chemical change is burning paper. In contrast to the act of ripping paper, the act of burning paper actually results in the formation of new chemicals (carbon dioxide and water, to be exact). Another example of a chemical change occurs when water is formed. Each molecule contains two atoms of hydrogen and one atom of oxygen chemically bonded.

One more example of a chemical change is what occurs when natural gas is burned in your furnace. This time, at the beginning we have a molecule of methane, CH_4, and two molecules of oxygen, O_2, while at the end we have two molecules of water, H_2O, and one molecule of carbon dioxide, CO_2. In this case, not only has the appearance changed, but the structure of the molecules has also changed. The new substances do not have the same chemical properties as the original ones. Therefore, this is a chemical change.

Chemical Reactions

When ice melts to make water, the ice changes its physical form from solid to liquid. But it is still the same chemical substance – water, as molecules of H_2O. A chemical change is where a substance changes into another one which is chemically different, with molecules that have different atoms.

When a chemical change happens, a substance's molecules are altered. For example, if the gases hydrogen (H) and oxygen (O) are mixed at high temperature, the hydrogen and oxygen atoms join, or combine, to make water molecules (H_2O). This is called a chemical reaction.

Some of the processes we see every day are chemical reactions. Burning things, cooking foods and rusting metals all involve chemical reactions. In the laboratory, chemical reactions are used to create new and useful substances from raw materials.

Breaking and making

The atoms in substances are joined together by links called bonds. When a chemical reaction happens, some of the bonds are broken. The atoms become free. Then they join together in new, different combinations, to make molecules of the new substance.

There are various types of bonds, shown below. Some are harder to break than others. The usual way of breaking them is by increased temperature, or heating.

Solutions

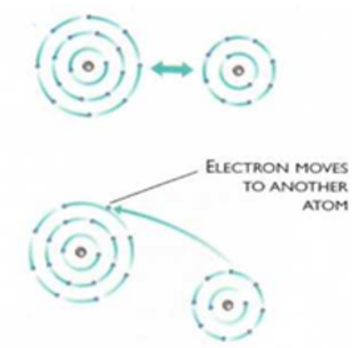
When you stir sugar into water, what happens to the sugar? It seems to disappear. Yet you can taste its sweetness in the drink.

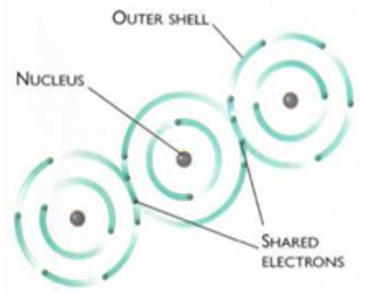
The answer is that the sugar has broken up into its particles or molecules, which are too small to see, and which mix in among the water molecules. This is called *dissolving*. The water is known as the *solvent*. The substance which dissolves in it, in this case sugar, is the *solute*. The two together are known as a *solution*.

Water is an extremely good solvent. Many substances, from salt crystals to instant coffee granules, dissolve in it. Gases and liquids can also dissolve in water. In rivers, lakes and seas, creatures such as fish breathe by taking in the oxygen which is dissolved in the water.

Ionic bond
One atom loses an electron from its outer shell. The electron moves to the outer shell of the other atom, creating the link or bond.

Covalent bonds
The outer shells of two atoms 'share' an electron between them. Sometimes the electron is more attached to one of the atoms. At other times it moves to the other atom.





Physical Changes

Physical changes are ones which *re-arrange* particles without altering any *chemical bonds*.

Physical changes don't involve a change in mass. Look at this easy example. If you *melt* a certain amount of *ice*, you get *the same amount* of water — and then if you *boil* that, you get *the same amount* of *steam*. No mass is lost as it's still *the same* substance just a *different* state.

> ***Learn these seven definitions:***
>
> *1. <u>Solute</u> – is the solid being dissolved.*
> *2. <u>Solvent</u> – is the liquid it's dissolving into.*
> *3. <u>Solution</u> – is the solute and the solvent.*
> *4. <u>Soluble</u> – means it will dissolve.*
> *5. <u>Insoluble</u> – means it will NOT dissolve.*
> *6. <u>Saturated</u> – a solution that won't dissolve any more solute at that temperature.*
> *7. <u>Solubility</u> – how much will dissolve.*

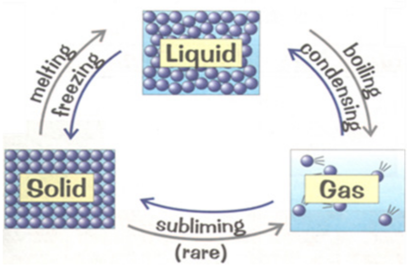
Dissolving isn't disappearing. Remember, when salt *dissolves* it *hasn't vanished* – it's still there – *no mass* is lost. If you *evaporated* off the *solvent* (the water), you'd see the *solute* (the salt) again.

Solubility increases with temperature. Water particles tend to *bump* into the lump of salt and *knock* the particles *apart*. The *free* salt particles then *mix* and *fill* the spaces between the water particles – this makes a *solution*. At *higher* temperatures *more solute* will dissolve in the *solvent* because particles move *faster*. However *some* solutes won't dissolve in *certain* solvents. E.g. salt won't dissolve in petrol.

As it has been mentioned before, physical changes don't change the particles — just their *arrangement* or their *energy*. For example:

1) Changes of State – i.e. changing from one *state of matter* to another.

1. When a solid *is heated*, its particles *gain* more *energy*.
2. This makes the particles *move more* which *weakens* the *forces* which hold the solid together. This makes the solid *expand*.
3. At a *certain temperature*, the particles have *enough* energy to *break free* from their positions. This is called *MELTING* and the *solid* turns into a *liquid*.
4. When a liquid *is heated*, again the particles get even *more* energy.
5. This energy makes the particles move *faster* which *weakens* and *breaks* the *bonds* holding the liquid together.
6. At a *certain temperature*, the particles have *enough* energy to *break* their *bonds*. This is called *BOILING* and the *liquid* turns into a *gas*.



It is worth noting that substances *change state* at *different temperatures*. Water *melts* at 0°C and *boils* at 100°C. Iron *melts* at 1540°C and *boils* at 2750°C. In water, the *forces* that *hold* the particles *together* are *weak*, so they *don't take* much *heat energy* to *loosen* or *break*. In iron, the *forces* that *hold* the particles *together* are *strong*, so they take *lots* of *heat energy* to *loosen* or *break*.

2) Gas Pressure is due to Particles Hitting a Surface.

1. When you *increase* the *temperature*, it makes the particles move *faster*. This has *two* effects: they *hit* the walls of the container *harder*, they *hit more often*. *Both* these things *increase* the *pressure.*

2. If you *reduce* the *volume* it makes the *pressure increase*. This is because when the particles *are squashed up* into a *smaller space* they'll *hit* the walls *more often*.

3) Diffusion is just Particles Spreading Out.

1. *Diffusion* is a *slow process* – like when a *smell spreads* slowly through a room.

2. The smell particles *move away* from where there are *lots* of them to everywhere else where there's only *a few* of them – but remember, diffusion is always slow.

3. This is because the *smell* particles *keep bumping* into *air* particles which stops them making forward progress and often *sends* them *off* in a completely *different direction*.

Chemical Changes

Chemical reactions are pretty important. Without them there would only be about 100 different substances – i.e. 100 or so elements. All the other *materials* in the world are created by *chemical changes* (chemical reactions). And all living things *are made* and *kept alive* just by chemical reactions.

Basic Facts about Chemical Reactions

1) In a chemical reaction *no mass* is lost when the *reactants* turn into the *products*.

2) A *word equation* is used to show what's going on.

3) Chemical reactions involve a *permanent* change not just a *temporary* one.

4) They always involve a change in *energy*, i.e. reactions always *give out* or *take in* energy. This is usually *heat energy* and this means the *temperature* in a reaction will *go up* or *down*.

5) *Visible changes* can occur in the reaction mixture. These show that a reaction has taken place. For example – a *gas* comes off; a *solid* is made; or the *colour* changes.

Two Handy Types of Chemical Reaction

1) NEUTRALISATION – *acidity* or *alkalinity* is destroyed.

1. *Acids* react with *bases*, *alkalis*, *reactive metals*, and *carbonates*.

2. Acids have *a low pH* – *neutralisation* raises the pH, which *destroys* the acidity.

Examples:

ACID + BASE	→	**SALT + WATER**
ACID + ALKALI	→	**SALT + WATER**
ACID + METAL	→	**SALT + HYDROGEN**
ACID + CARBONATE	→	**SALT + WATER + CARBON**

2) DISPLACEMENT REACTIONS – one metal *kicks out* a *less reactive* one.

1. A *more reactive* element *displaces* a *less reactive* element from its *compound*.

2. Reactive elements *join* to other elements with *strong bonds*.

3. Elements with *low reactivity* join to other elements only with *weak bonds*.

Example:

ZINC + COPPER SULPHATE	→	**ZINC SULPHATE + COPPER**

Reversible and Irreversible Changes

Changes can be reversible or irreversible. An irreversible change *lasts forever*. In an *irreversible change*, a material turns into a *completely new* and *different material*. The new material *can't be changed back* into what it was before. These changes are all irreversible:

1. *Burning* fuel – e.g. burning wood to form ash.
2. *Cooking* food – e.g. making bread from flour, water and yeast.
3. *Decay* – e.g. dead plants and animals *decomposing* to form humus.
4. *Firing* – e.g. making a pot out of a lump of clay.

So, you can't change the materials back to how they were before.

Some changes are reversible. In a *reversible change*, a material turns into something that looks and feels different, but it isn't changed forever. The material *can be changed back* so it looks and feels the same as it did before.

These are examples of reversible changes:

1. *Changes of state* – e.g. water *freezing* to form ice, then *melting* back to water.
2. *Dissolving* – e.g. salt *dissolving* in water, then the water *evaporating* off to leave the salt behind.
3. Many *simple chemical reactions* – e.g. hydrogen and nitrogen *reacting* to form ammonia, while at the same time ammonia *decomposes* back into hydrogen and nitrogen.

Therefore, the materials can be changed back to how they were before.

The Air

The layer covering the Earth like a blanket is called the atmosphere. It is made of very thin stuff called air. Air is so thin you hardly know it's there. But it's all around us. Really, we live at the bottom of a very deep "ocean of air".

Air gets thinner and thinner as you go up. There's enough air to breathe at the top of Mt. Everest (five miles above sea level), but getting there is hard work! Most climbers have used breathing apparatus on their way up. By the time you get to 50 miles above sea level, there's practically no air left. The air doesn't stop suddenly, however, so it's impossible to say exactly how deep the atmosphere is.

Air is not a single substance. It's made of a number of gases all mixed together. It's impossible to stop gases mixing together. They mix together spontaneously. So a gas that escapes from the Earth becomes a part of the atmosphere. Scientists believe that the atmosphere has changed a very great deal since the Earth was first formed. At first, the atmosphere may have been made up of gases like ammonia, methane, carbon dioxide and water vapour. Later, the first early forms of life developed and gradually more and more oxygen was added to the atmosphere. Nowadays the main gases in the air are oxygen and nitrogen.

You can easily perform experiments in the laboratory to find out about the air, for example, to prove that it's a mixture rather than a single substance, or find out how much oxygen there is in it. These experiments usually involve getting the oxygen to combine with another substance. In other words, to get rid of the oxygen altogether a chemical reaction is used.

There are plenty of ways to do this because oxygen is a very reactive gas. For instance, burning and rusting are two kinds of chemical change that use up oxygen.

The main gas left after removing oxygen is nitrogen. In fact, nearly all of the remainder (about four-fifths) is nitrogen. To put this another way, 78 percent of the air is nitrogen.

Apart from oxygen and nitrogen, there are only small amounts of other gases in the air. One of them is carbon dioxide. Another of the minor constituents of the air is water vapour. Ordinary air always contains some of it. The best way to show that there is water vapour in the air in the laboratory is to condense the water. This can be done by cooling the air. Altogether there's not much of either water vapour or carbon dioxide in the air, both of them are very important.

So far we've mentioned oxygen, nitrogen, carbon dioxide and water vapour. Are these the only gases in the air? The answer is "no", but it's hard to prove.

Evidence for other gases in the air came towards the end of the 19th century (a long time after oxygen and nitrogen had been sorted out). The work leading to their discovery was an investigation into the density of nitrogen.

Unlike oxygen, nitrogen is very unreactive. So it's difficult to do experiments to remove nitrogen from the air. But it's quite easy to take the oxygen, carbon dioxide and water vapour out of the air practically leaving nitrogen alone. This nitrogen might be called "atmospheric nitrogen".

The main gas that "contaminates" the atmospheric nitrogen is argon. Being a very inert gas, it's used for filling electric light bulbs.

Reactions of Oxygen

No other element is more important to life than oxygen. It is not only the most widely distributed element on the surface of the globe, but it is absolutely necessary *to the maintenance of life/to maintain life*. To be sure, air breathing animals would die within a few minutes if the supply of oxygen in the atmosphere stopped suddenly. After we have learned the methods of oxygen's preparation, let us study its main reactions.

When oxygen combines with an element, it forms a product called an oxide. The process is called oxidation. There are only a few elements attacked by oxygen. Among the substances unaffected by it we should mention inert gases.

Combinations with oxygen often liberate heat and light in which case the process is known as combustion. There are some elements which do not catch fire unless they are heated. Some substances will ignite even if they are very slightly heated; others have to be heated before taking fire. The temperature at which a substance ignites is called its kindling point.

Once these reactions are started, they liberate heat and light. The heat which is liberated maintains the substance at or above the kindling temperature. The amount of heat liberated by very slow oxidation, such as rusting of metals and the decay of wood, is the same as that liberated by rapid combustion, but there is no rise in temperature because the heat is radiated to the surrounding air. The difference between combustion, on the one hand, and corrosion and decay, on the other, is one of the rates of reaction and temperature at which these reactions take place.

Oxidation and Reduction

Generally speaking, the simple meanings of these terms are that *oxidation is the addition of oxygen to a substance* and *reduction is the removal of oxygen*. Needless to say, hydrogen seems to be the chemical opposite of oxygen (the two elements combine readily, and are evolved at opposite electrodes during electrolysis). Removal of hydrogen is, therefore, similar to the addition of oxygen, and addition of hydrogen is similar to the removal of oxygen. Fuller meanings of the two terms are therefore:

Oxidation is the addition of oxygen to, or removal of hydrogen from, a substance. Reduction is the removal of oxygen from, or addition of hydrogen to, a substance.

$2SO_2 + O_2 \leftrightarrow 2SO_3$	(oxidation of SO_2; addition of oxygen)
$PbO + H_2 \rightarrow Pb + H_2O$	(reduction of PbO; removal of oxygen)
$Cl_2 + H_2 \rightarrow 2HCl$	(reduction of Cl_2; addition of hydrogen)
$H_2S + Cl_2 \rightarrow S\downarrow + 2HCl$	(oxidation of H_2S; removal of hydrogen)

The terms now are applied to reactions in which neither oxygen nor hydrogen is involved. To take an example, the change of ferrous oxide to ferric oxide is, obviously, an oxidation; similarly, we can regard the change of any ferrous compound to a ferric compound as an oxidation (and a change of ferric to ferrous as a reduction): $4FeO + O_2 \rightarrow 2Fe_2O_3$; $FeCl_2 + Cl_2 \rightarrow 2FeCl_3$. Note that the valency of the metal increases during oxidation.

Metals and hydrogen form positive ions (e.g. Na^+ and H^+) and are, therefore, called electropositive. Non-metals and acid radicals are electronegative as they form negative ions (e.g. O^{2-}, SO_4^{2-}). Putting it another way, more complete definitions of the two terms are the following:

Oxidation is the addition of any electronegative element or radical to, or removal of any electropositive element or radical from, a substance. Reduction is the opposite.

An oxidizing agent is a substance which brings about oxidation; a reducing agent is a substance which brings about reduction.

Oxidizing agents include: oxygen, hydrogen peroxide, nitric acid, sulphuric acid, chlorine, potassium permanganate, potassium dichromate.

Reducing agents include: hydrogen, carbon, carbon monoxide, sulphur dioxide, hydrogen sulphide, ammonia, and most metals and non-metals.

The equations for the oxidation of ferrous chloride are:

$$2FeCl_2 + Cl_2 \rightarrow 2FeCl_3;$$

$$\text{ionically: } 2Fe^{2+} + Cl_2 \rightarrow 2Fe^{3+} + 2C1^-.$$

As already mentioned, the oxidation involves a change of ferrous ion to ferric, it occurs by loss of an electron (*e*). And oxidation of chlorine to chloride ions takes place by gain of electrons:

$$Fe^{2+} - e \rightarrow Fe^{3+} \text{ (oxidation);}$$

$$Cl_2 + 2e \rightarrow 2C1^- \text{ (reduction).}$$

To summarize, *oxidation is the removal of electrons from a substance. Reduction is the addition of electrons to a substance.*

In this case, an oxidizing agent is a substance that accepts electrons. A reducing agent is a substance that supplies electrons.

Remember the word ORE – Oxidation is Removal of Electrons.

Original Meanings of Oxidation and Reduction

Prior to the discovery of oxygen independently by Scheele of Sweden in 1771-1772 and by Joseph Priestley of England in 1774, combustion had been regarded to be a loss of phlogiston. Roughly speaking, phlogiston was conceived to be a sort of *materia* of fire. Lavoisier used the new knowledge to show more extensively and systematically that combustion is the combination of the combustible substance with Priestley's "dephlogisticated air". Knowing that several products of combustion, notably those formed from sulphur, phosphorus and carbon are acidic substances, Lavoisier named the element *oxygen*, from the Greek for *acid-former*.

Lavoisier called the product formed by addition of oxygen an *oxide*. Therefore, it was natural to refer to the process as *oxidation*.

To tell the truth, long before the introduction of the term "oxidation" the term "reduction" had been used in a technical sense. Primitive man had used charcoal to win iron from ores which we call oxides. During the development of this and other metallurgical processes *reduction* was used, perhaps in the dual sense of bringing down the bulk of an ore to that of the metal and of a *restoration*. In the latter sense it was used by Paracelsus in describing the restoration of iron from rust.

With de Morveau, Berthollet and de Fourcroy – to mention only a few – Lavoisier devised the nomenclature used today. Oxides were distinguished by the name of the element combined with oxygen and by the degree of oxidation.

ACTIVE VOCABULARY TO BE MEMORIZED IN UNIT 4

happen = occur = take place	believe
either…or… / neither…nor…	mention
form or break bonds	perform an experiment
involve — involvement	find out
be involved in	prove
separate — separation	proof = evidence
mix — mixture	get rid of
alter — alteration	for instance = for example
similarly	remainder
in other words	to put this another way
turn = transform into	apart from
in contrast	minor constituent
to be exact	condense water by cooling the air
in this case	so far
therefore	unlike
raw materials	be widely distributed = be widely spread
link	maintain life — maintenance of life
bond	prepare — preparation
ionic bond	the supply of oxygen
lose an electron — loss	be affected ≠ unaffected by

move to covalent bond share an electron be attached to rearrange particles dissolve solvent solute solution solubility soluble ≠ insoluble saturated disappear = vanish changes of state supply heat gain energy weaken the force hold together break free from one's positions due to hit reduce diffusion spread out smell reactant product permanent ≠ temporary change give out or take in energy neutralisation destroy acidity or alkalinity displace — displacement reversible ≠ irreversible changes last forever change back into what it was before burning fuel cooking food decay = decomposition firing really = in fact	inert gas liberate heat and light combustion ignite = catch fire = take fire be heated the kindling point the amount of heat rusting of metals / corrosion be radiated to the surrounding air on the one hand / on the other hand oxidation add — addition of … to … reduce — reduction remove — removal of … from … needless to say be similar to similarly to take an example regard valency an oxidizing/reducing agent bring about oxidation/reduction loss of an electron gain of an electron to summarize accept electrons supply electrons prior to roughly speaking combustible substance acidic substance to tell the truth introduce — introduction of the term in a sense win iron from ores during the development of restore — restoration devise the nomenclature distinguish

UNIT 5
ELEMENTS, COMPOUNDS, MIXTURES

Chemical Elements

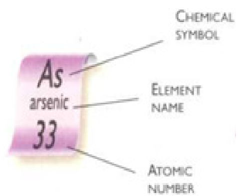
One of the basic sets of information in all of science is the list of chemical substances, called elements. The list can be drawn as a large chart known as the periodic table of chemical elements. There are about 118 elements so far discovered. Of these, about 90 are natural, occurring on and in planet Earth, or among the planets and stars in space. The rest have been made, or synthesized, in chemistry and physics laboratories.

All matter in the Universe is composed of the basic substances known as chemical elements. The periodic table groups the elements according to their similarities and differences. These are physical, both in the way their atoms are made up of smaller particles, and in the physical features of an element, such as its weight and density. They are also chemical, in the way that the element reacts or combines chemically with other substances.

Each element has its own name, such as carbon, iron, aluminium, boron, lithium or zinc. Some names are taken from ancient Latin, Greek or other languages. Other elements are named after their discoverers or generally famous scientists. Arsenic, a very poisonous element, gets its name from *arsenikon*, the old Greek name for the yellow mineral "orpiment", which is rich in arsenic.

The chemical symbol for each element is one or two letters, usually taken from a shortened version of the full name. It is an international symbol, recognized by scientists all over the world.

The atomic number of an element is the number of the particles called protons inside the nucleus of each atom of the element. This number of protons is the same as the number of electrons whizzing around the nucleus of the atom.



Atoms and Elements

Elements consist of only one type of particle. Elements can't be split up into anything simpler by chemical methods. They only contain *one type* of *atom*. *Now* there are *118* different elements. Each one has a *name* and a shorthand *symbol*, e.g. *Carbon, C*. *Everything* on Earth *is made up of elements*.

The Periodic Table lists all the elements. The elements are *specially arranged* so that every *column* contains elements with very *similar properties*. These columns of elements are called *groups*. The *horizontal rows* are called *periods*. There's always a gradual *change* or "trend" in *properties* across a period. Elements are listed in order of *atomic number* – this is just the number of *protons* in the *nucleus* of the atom.

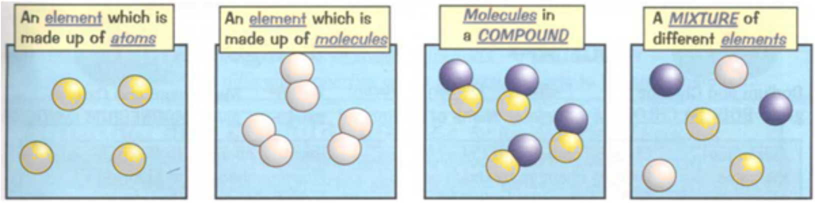
GROUP NAMES

Group 1: The alkali metals
Group 2: The alkaline earth metals
Group 7: The halogens
Group 0: The noble gases
The block of elements between groups 2 and 3 are called the transition metals.

The atom is the smallest stable part of an element. The *atoms* in an *element* are all *identical*. All atoms are *real tiny*. Atoms are the basic building blocks of all *materials*. Atoms have a *nucleus* in the middle which contains *protons* and *neutrons*. Protons *are positively charged*. Neutrons are *neutral*. Atoms have even *smaller* bits called *electrons* which *whizz* around the nucleus. Electrons *are negatively charged*. They go real fast.

Compounds

Compounds contain two or more elements joined up. The *particles* in a *compound* are called *molecules* – formed when atoms *join*. To make a *compound*, the atoms must be from *different elements* and the *"join"* is known as a *chemical bond*. E.g. CO_2



The particles are all the same and not joined up — it must be an ***element****.*

The atoms may be joined, but there's still only one type, so it's still an ***element****.*

Here we have different atoms joined together — that's a ***compound*** *alright.*

This is not a compound because the elements aren't joined up — it's a ***mixture.***

In chemical reactions elements combine together. A *chemical reaction* involves *two* or *more* chemicals (called the *reactants*) combining together to form one or more *new* substances (called the *products*). The *new compounds* produced by any chemical reaction are always totally *different* from the *original elements* (or reactants). We sometimes say a new compound is *synthesized*.

The *classic example* of this is *iron* reacting with *sulphur*. Iron is *magnetic*. It reacts with *sulphur* to make *iron sulphide*, a totally new substance which is *not magnetic*.

When elements *undergo* a *chemical reaction* like the one above, the products will always have a *chemical formula* – e.g. H_2O for *water* or FeS for *iron sulphide*.

Compounds *can be split up* back into their *original* elements but it won't just happen by itself – you have to *supply* a lot of *energy* to make the reaction go in *reverse*.

Mixtures

Mixtures are substances not chemically joined or bonded together. Sea water and air are good examples of mixtures – they have *constituents* which are *not combined*. The mixture has *properties* of *all its parts*. We can *separate* them very easily using *physical methods* (i.e. not chemical). This is done to *obtain* useful substances from the mixture, or to *find out* what constituents are in it.

There are *four separation techniques* we need to be familiar with: *filtration, evaporation, chromatography, distillation*. All four make use of the *different properties* of the *constituent parts* to *separate* them out.

FILTRATION AND EVAPORATION are used to separate a mixture of a *liquid* and a *solid*, e.g. for the separation of rock salt.

Rock salt is simply a *mixture* of *salt* and *sand*. Salt and sand are both *compounds* – but *salt dissolves* in water and *sand doesn't*. This *vital difference* in their *physical properties* gives us a great way to *separate* them.

Learn the *four steps* of the method:

1. *Grinding – grind up* the rock salt with a *pestle* and *mortar*.
2. *Dissolving – dissolve* in a *beaker* and *stir*.
3. *Filtering – filter* through *filter paper* in a *funnel*.
4. *Evaporating – evaporate* in an *evaporating dish*.

The sand doesn't dissolve (it's *insoluble*) so it stays as *big grains* and obviously these *won't fit* through the *tiny holes* in the filter paper – so it *collects on the filter paper*.

The salt is dissolved in *solution* so it does go through – and when the water is *evaporated*, the salt forms as *crystals* in the *evaporating dish*. This is called *crystallization*.

CHROMATOGRAPHY is used to separate a mixture of a *liquid* and *several different substances*. The mixture *is passed* through a chromatography *medium*. The substances *get trapped* in *different layers* in the medium.

As an example, this method is ideal for separating out the *dyes* found in *inks*. *Different dyes* in ink will *wash* through paper at *different rates*. Some will *stick* to the *paper* and others will *dissolve* and travel through it *quickly*.

Two other exciting uses of chromatography are: identifying *blood samples* and investigating *chlorophyll*.

SIMPLE DISTILLATION is used for separating out a mixture of a *liquid* and a *solid*, e.g. for separating *water* from *ink*.

The liquid *is heated* and *boils off*. It's then *cooled, condensed* and *collected*, leaving the *solid* behind. Simple distillation is great for getting *pure water* from something like *sea water* or *suspect tap water*.

FRACTIONAL DISTILLATION is used for separating *mixed liquids* or a *mixture of liquids*.

Different liquids will boil off at *different temperatures* around their *own boiling point*. The *fractionating column* ensures that the "wrong" liquids *condense* back *down*, and only the liquid properly *boiling* at the temperature on the thermometer will make it to the top. When each liquid *has boiled off*, the temperature reading *rises* until the *next fraction* starts to boil off. This means the fractions are obtained *pure*.

Real life examples include: *distilling* whisky and *purifying* organic chemicals.

Organic Chemistry

Non-chemist can't help being surprised to learn that many chemical compounds are obtained from living things. For example, sugars, ethanol, methane, urea, etc.

What all these compounds have in common are the elements carbon and hydrogen. Thus, it can be said that nearly all compounds obtained from living things are carbon compounds.

In the early days of chemistry no one ever thought of obtaining compounds from living things in the laboratory. The idea was that there were special processes going on inside the organism (living thing). The special processes were believed to be essential for the formation of the compounds. So, chemists considered the compounds from organisms to be somehow special and different from "ordinary" chemicals that could be made in the laboratory. They called chemicals from living things *organic chemicals* and the others *inorganic chemicals*.

However, in 1828 a chemist called Wohler showed organic chemicals to be just ordinary chemical substances. He did this by converting an inorganic chemical into an organic one simply by heating it in the laboratory. Gradually, more and more organic chemicals were shown to be just like ordinary chemicals. But we still use the terms "organic" and "inorganic" to divide chemicals into two classes. Nowadays, however, we use the term "organic compounds" to mean *carbon compounds*, there being some exceptions to the rule.

Most of the organic chemicals we have nowadays are man-made and are obtained directly from organisms. However, the main raw material for manufacturing organic chemicals is *petroleum*, it having been formed in the past from marine organisms.

Why do we have to separate a branch of chemistry just for carbon compounds? Couldn't its compounds be included with those of other elements?

There's a simple reason for keeping carbon compounds separate: there are just too many of them. *There are more compounds of carbon than compounds of all the other elements put together.* Organic chemistry is therefore to be a very large branch of chemistry. It includes millions of compounds. Most of these are compounds of carbon involving just a few other nonmetallic elements, for example, hydrogen, nitrogen, oxygen and the halogens.

Why does carbon have so many more compounds than other elements? What is special about it? The answer to these questions is: carbon atoms have the special property of being able to join together to form chains of atoms. The chains may be short, or they may be hundreds or even thousands of atoms long.

Since the carbon chain can be practically any length, the number of possible hydrocarbons is enormous.

Carbon

Carbon is to be ranked along with hydrogen and oxygen as one of the most important of all the elements to man. Carbon occurs in nature as a free element and in many compounds. It constitutes only about 0.03 percent of the Earth's crust, but this relatively small amount of the element is of great importance. Its importance is indicated by the 300,000 or more compounds of the element which exist naturally or which have been prepared. It is proved that this number is approximately ten times the number of compounds of all the other elements put together. For a long time it was believed that these compounds might have never been produced except with the aid of organic life, in other words, by living plants and animals. For this reason they were called organic compounds.

It is known that carbon occurs in two crystalline forms which differ strikingly by their properties. Graphite is black, soft, a good conductor of electricity. Diamond, on the contrary, is colourless and transparent, the hardest of known substances, a non-conductor of electricity. It is the crystal structure, as determined by X-rays, which gives an explanation of this contrast of properties.

The four valence electrons of each carbon atom enable it, by sharing electrons with four of its neighbours, to be linked with them in a covalent union. It may be shown by X-rays examination that in the diamond the four nearest neighbours of each carbon atom are symmetrically arranged about it in space. All atoms in a diamond are thus firmly linked together, hence the whole crystal acts as a giant molecule. Thus we account for the extreme hardness of the diamond, its high melting point, and its failure to dissolve in any solvent.

On the other hand, it is found that graphite possesses parallel planes of atoms, and each is at a considerable distance from its neighbours. Each carbon atom in graphite has three nearest neighbours and they all are present in its own plane. Only three of the four valence electrons of each atom are needed for furnishing bonds with these nearest neighbours and the fourth is available for producing a bond with a neighbouring plane. A certain portion of the electrons in graphite are relatively free to move as it is true of metals. Hence, graphite is a conductor of electricity.

The Carbon Cycle

It is known, that carbon, like water, cycles from the Earth into the atmosphere and back again. Green plants and algae use the sun's energy to convert carbon dioxide (and water) into carbohydrates. The plants are eaten by animals, including people and fish, who exhale carbon dioxide. It was discovered that carbon dioxide is also formed by decomposition of dead animals and animal wastes by microorganisms. The carbon dioxide passes into the atmosphere and is again used for photosynthesis. An equilibrium also exists between carbon dioxide in the atmosphere and dissolved carbon dioxide and H_2CO_3 in oceans and lakes. In addition it was estimated that much carbon is stored in the Earth's crust in the form of fossil fuels – coal, petroleum, and natural gas – and in the form of limestone and coral.

Since the middle of the nineteenth century, it has been observed that the production of carbon dioxide by the combustion and the decomposition of limestones is increasing rapidly. In addition, it has been proved that destruction of tropical forests is reducing the quantity of carbon dioxide used up by photosynthesis. Human activities have now reached a scale where interference with the natural carbon cycle may well be significant. The longest continuous records of the concentration of CO_2 in the atmosphere unfortunately were made only in 1958, and therefore it's hard to be sure how harmful human activities have been since that time.

ACTIVE VOCABULARY TO BE MEMORIZED IN UNIT 5

the periodic table	identify blood samples
so far	simple/fractional distillation
occur on and in planet Earth	be heated
be synthesized in the laboratory	boil off
be composed of = be made up of	be cooled/condensed/collected
be known as	leave the solid behind
group chemical elements	fractionating column
according to similarities/differences	fraction
similar/different properties	be obtained pure
physical and chemical features	obtain from living things
weight	have in common
combine with other substances	thus
discoverer	carbon compound
be recognized by scientists	be essential for
all over the world	consider
the atomic number	organic/inorganic chemicals
inside the nucleus of the atom	be just ordinary chemical substances
the number of protons/electrons	convert an inorganic chemical into
whizz around	an organic one by heating
neutron	divide into
be neutral	man-made
be positively/negatively charged	manufacture
the same = identical	join together to form chains of atoms
be split up into = be broken down into =	the enormous number of

be decomposed into	hydrocarbons
shorthand symbol	occur in nature as
the smallest stable part of an element	be of great importance
form a compound — formation	exist naturally
be made up of molecules	be prepared
a chemical bond	be produced
be joined up	for this reason
undergo a chemical reaction	two crystalline forms
combine together	differ by properties
reactant	a good conductor of electricity
product	a non-conductor of electricity
original elements	on the contrary
supply a lot of energy	transparent
go in reverse	be determined by X-ray examination
mix — mixture	give an explanation
constitute — constituent	be symmetrically arranged
have properties of all its parts	be firmly linked together
separate — separation	hence
separation techniques	a giant molecule
be familiar with	account for
filtration	the extreme hardness
evaporation	possess parallel planes of atoms
grind — grinding	at a considerable distance from
pestle	be relatively free to move
mortar	neighbour
dissolve — dissolving	cycle from…into…and back
beaker	exhale carbon dioxide
flask	decomposition of dead animals by
stir	microorganisms
filter — filtering	pass into the atmosphere
filter paper	be used for photosynthesis
funnel	in addition
evaporate — evaporating	be stored in the Earth's crust
evaporating dish	fossil fuels
collect on the filter paper	combustion
crystallization	destruction of tropical forests
chromatography	reduce the quantity of
wash/go through the paper	interference with the natural carbon cycle
stick to the paper	significant
at different rates	harmful human activities

UNIT 6
THE PERIODIC TABLE AND PERIODIC LAW

The Periodic System of Elements

The story of how D.I. Mendeleyev established the Periodic System of Elements has long been a matter of great interest to research workers.

When Mendeleyev began to teach at St. Petersburg University, chemistry was still far from being the well-ordered and harmonious branch of science that we know today.

The great majority of scientists were firmly convinced that atoms of different elements were in no way connected with each other, and that they were quite independent particles of nature. Only a few advanced scientists realized that there must be a general system of laws which regulates the behaviour of atoms of each and every element. However, the few attempts made by Beguyer de Chancourtois, Newlands, Lother Meyer and others to find a system of laws controlling the behaviour of atoms were unsuccessful and exercised no influence on Mendeleyev, the future founder of the Periodic System of Elements.

"Mendeleyev was a man who could not bear any kind of disorder and chaos," writes Academician A.A. Boikov. "This is why at the beginning of his course in chemistry at St. Petersburg University, where he had been appointed to the department of chemistry, D.I. had to establish order in the chemical elements."

By comparison of chemical properties of different elements researchers had long ago discovered that elements could be placed in several groups according to similarity in their properties.

Mendeleyev applied in his system the principles that he developed and included in his table listing the elements according to increasing weights.

Because he had the insight to see that many elements had not yet been discovered, he left open spaces in the Periodic Table. For example, he predicted that an unknown element with atomic weight of 44 would be found for the space following calcium. And in 1879 the Swedish chemist Lars Fredric Nilson discovered scandium.

Mendeleyev's table developed into the modern Periodic Table, one of the most important tools in chemistry. The vertical columns of the modern Periodic Table are called groups and the horizontal rows are called periods. The atomic number of an element is the number of protons in the nucleus of the atom of that element. The modern Periodic Table not only clearly organizes all the elements, it lucidly illustrates that they form "families" in rational groups, based on their characteristics.

The History of the Periodic Table

The final and most important step in the development of the periodic table was taken in 1869, when the Russian chemist Dmitry Ivanovich Mendeleyev (1834-1907) made a thorough study of the relation between the atomic weights of the elements and their physical and chemical properties, with special attention to valence. Mendeleyev proposed a periodic table containing seventeen columns, resembling in a general way the present periodic table without the noble gases. In 1871 Mendeleyev revised this table and placed a number of elements in different positions, corresponding to revised values of their atomic weights.

The "zero" group was added to the periodic table after the discovery of helium, neon, argon, krypton and xenon by Lord Rayleigh and Sir William Ramsay in 1894 and the following years.

The periodic law was accepted immediately after its proposal by Mendeleyev because of its success in making predictions with its use which were afterward verified by experiment. In 1871 Mendeleyev found that by changing seventeen elements from the positions indicated by the atomic weights which had been accepted for them into new positions, their properties could be better correlated with the properties of the other elements.

Most of the elements occur in the periodic table in the order of increasing atomic weights. There still remain, however, four pairs of elements in the inverted order of atomic weight; argon and potassium (the atomic numbers of argon and potassium are 18 and 19, respectively, whereas their atomic weights are 39.948 and

39.098), cobalt and nickel, telluruim and iodine, and protactinium and thorium. The nature of the isotopes of these elements is such that the atomic weight of the naturally occurring mixture of isotopes is greater for the element of the lower atomic number in each of these pairs than for the element of higher atomic number; thus, argon consists almost entirely (99.6%) of the isotope with mass number 40 (18 protons, 22 neutrons), whereas potassium consists largely (93.4%) of the isotope with mass number 39 (19 protons, 20 neutrons). This inversion of the order in the periodic system, as indicated by the chemical properties of the elements, from that of atomic weight caused much concern before the atomic numbers of the elements were discovered, but has now been recognized as having little significance.

A very striking application of the periodic law was made by Mendeleyev. He predicted the existence of six elements which had not yet been discovered, corresponding to vacant places in his table. Three of these elements were soon discovered (they were named scandium, gallium, and germanium by their discoverers), and it was found that their properties and the properties of their compounds are very close to those predicted by Mendeleyev.

After helium and argon had been discovered, the existence of neon, krypton, xenon, and radon was clearly indicated by the periodic law, and the search for those elements in air led to the discovery of the first three of them; radon was then discovered during the investigation of the properties of radium and other radioactive substances.

The Periodic Table of Elements

One of the most valuable parts of chemical theory is the periodic law. In its modem form this law states simply that the properties of the chemical elements are not arbitrary, but depend upon the electronic structure of the atom and vary with the atomic number in a systematic way. The important point is that this dependence involves periodicity that shows itself in the periodic recurrence of characteristic properties.

For example, the elements with atomic numbers 2, 10, 18, 36, 54, and 86 are all chemically inert gases. Similarly, the elements with atomic numbers one greater – namely 3, 11,19,37,55, and 87 are all light metals that are very reactive chemically. These six metals – lithium (3), sodium (11), potassium (19), rubidium (37), caesium (55) and francium (87) – all react with chlorine and form colourless salts that crystallize in cubes and show a cubic cleavage. The chemical formulae of these salts are similar: LiCl, NaCl, KC1, RbCl, CsCl, and FrCl. The composition and properties of other compounds of these six metals are correspondingly similar, and different from those of other elements.

The horizontal rows of the periodic table are called periods: they consist of a very short period (containing hydrogen and helium, atomic numbers 1 and 2), two short periods of 8 elements each, two long periods of 18 elements each, and two very long periods of 32 elements, containing lanthanides or the lanthanide series (in the first case) and actinides or the actinide series (in another case).

The vertical columns of the periodic table, with connections between the short and long periods as shown, are the groups of chemical elements. Elements in the same group are sometimes called congeners; these elements have closely related physical and chemical properties.

The Periodicity of Elements

The history of the periodicity of elements began with the first ideas concerning substances and particles. It had been noticed by the earliest thinkers that things (different substances) are different from each other, and that each can be reduced to very small parts of itself (the beginnings of the atomic theory).

Over the course of history, more and more elements were discovered, and scientists were naturally curious about the relationships between them. Lavoisier divided the elements known in the 1700s into four classes, the first formal attempt at grouping the elements. In 1869, unknown to each other, Julius Meyer and Dmitri Mendeleyev devised periodic tables in which the elements were arranged by atomic weight. However, on the basis of his table, Mendeleyev was able to do something that Meyer could not; he predicted the properties of elements that had not been discovered yet. Chemists were highly impressed when these elements were later discovered.

Mendeleyev noticed that when all the elements were arranged in order of their atomic weight, a certain repetition of properties was obvious. He had organized the chemical elements according to their atomic weights because he believed that the properties of the elements would gradually change as the atomic weight increased, but in composing his periodic table, he found that the properties of the elements suddenly changed at very clear stages, or periods. To show where the changes were happening, Mendeleyev grouped the elements in a table that had both rows and columns.

The modern periodic table of elements is based on Mendeleyev's, but instead of being arranged by atomic weight, the modern table is arranged by atomic number (the number of protons in the nucleus of the atom). Rows in the periodic table are known as periods. The chemical properties of the elements in each period slowly change, but at the end of each row, a sudden change in these properties is observed. The columns in the periodic table are known as groups. Elements within the same group have many similar properties.

The periodicity that Mendeleyev discovered is directly related to the arrangement of an atom's electrons around its nucleus. Electrons are located in specific electron shells (in simple terms this means that the electrons make a kind of a shell around the nucleus of the atom) and each shell can contain only a certain number of electrons. The first shell can hold two electrons, the second shell can hold up to eight electrons, and so on. For example, neon has ten electrons, two in the first shell, and eight in the second shell. Next is sodium, with eleven electrons, and here is one of the places in the table where a sudden change occurs. Sodium has three shells because it has eleven electrons, two in the first shell, eight in the second, and one in the third. This extra shell is the reason for the big change in chemical properties. It is the electrons in the outer shell that determine the chemical properties of the elements because it is these atoms which interact with other atoms.

Reactive Metals and Rare Earths

In the periodic table the elements in the far left column are called the *alkali metals*. They combine or react very readily with other elements.

The table of elements is known as the periodic table because the chemical features of the elements in each column, one below the other, are similar. They occur with a periodicity – that is, in a regular cycle.

For example, the elements in the far left column include lithium, sodium, potassium, rubidium and caesium. These are all metallic elements, and they are all very reactive. This means they join or react easily with other substances. So in nature they are rarely found on their own, in pure element form.

FACTS ABOUT ALKALI METALS

► *Many alkali metals and other metals are used in alloys. An* ***alloy*** *is a mixture or a compound of two or more metals, or of a metal and a non-metal.*

► ***Lithium*** *is used in some very lightweight alloys of aluminium or magnesium. It is also used in certain medical drugs for mental conditions such as severe depression.*

► ***Rubidium*** *is used in tiny amounts in photo-electric or "solar" cells, which generate electricity when light shines on them. It also works as a "getter" for combining with and removing impurities in chemical processes.*

► ***Caesium*** *is also used in photo-electric cells.*

This first column of elements is called the alkali metals. This is because they react with other substances to form alkalis, which are the opposite of acids. Sodium joins with oxygen and hydrogen to form sodium hydroxide, NaOH. This is better known as caustic soda. It is a powerful alkali that can burn skin. It is used as a drain-cleaner and in the manufacture of paper, artificial fibres, soaps and detergents.

Rare earth elements

The two sets of elements do not quite fit into the main periodic table. They are known as the *lanthanide series* and the *actinide series*, after the first element in each group. They are also called "rare earths" because the lanthanides occur only rarely in the rocks of the Earth.

All the elements in the lanthanide series are very similar to each other. They are also similar to a more familiar element, the shiny metal called aluminium.

The elements in the actinide series are also similar to the lanthanides and to each other. But they are synthetic elements – they have been created in science laboratories.

Metals and More Metals

Most elements are *metals*. This means they are generally hard and shiny, tough and strong, and they conduct or carry electricity and heat well. They have thousands of uses in daily life, often mixed or combined with each other to form *alloys*.

Almost any machine or device has at least one metal in it. Iron is one of the most widely-used metals. It is combined with small amounts of the non-metal carbon, to form the group of alloys known as steels.

There are hundreds of kinds of *steels*. Each one has been carefully developed to have different qualities of hardness, stiffness, lightness, resistance to corrosion and other features. In most steels, the proportion of carbon is less than one-twentieth.

Iron makes steel

Metallurgists (metal experts) are continually developing new combinations and mixtures of metals, to produce better alloys for a range of uses. Steel plate forms the large sheets in washing machines, cars, trains and ships. The stainless steel used for making cutlery and cooking utensils is an alloy with at least one-tenth of the extremely hard, shiny metal known as chromium.

FACTS ABOUT METALS

▶ *Most pure metals are, surprisingly, not that hard or tough. This is why the science of* ***alloys****, combining metals with each other or with different non-metal substances, is so important.*

▶ *One of the earliest alloys was* ***bronze****, a mix of copper and tin. It has been in use for thousands of years and was the first widely-used substance for tools, after rocks and stones.*

▶ ***Brass*** *is another common alloy, made from copper and zinc.*

▶ *Perhaps the most famous metal is* ***gold****. It has been valued and cherished since ancient times because it stays bright and shiny, yet is also easy to work with.*

▶ ***Silver*** *is another long-valued metal. It is the best conductor of electricity of any metal, and is also used in jewellery, photographic film and for coins.*

Steels with titanium in them form the light but stiff structural sheets in high-speed aircraft where friction creates enormous heat. Steels with chromium and vanadium are exceptionally tough, suitable for pipes that must resist wear and corrosion.

Non-metals

There are well over 100 chemical elements. Only about 20 are non-metals. But they include some of the most widespread and important of all elements. For example, oxygen is vital for life, while carbon is the basic element in all living things, and silicon is essential for electronic devices like microchips.

The two most abundant elements on our planet are non-metals. Oxygen accounts for almost one-half of all the substances in the Earth's crust. Silicon accounts for about one-quarter.

Oxygen makes up one-fifth of the air we breathe. It combines with hydrogen to form water (H_2O). It is also found in all kinds of rocks, combined in the form of oxides.

Silicon is also found in combined forms in most kinds of rocks, as oxides such as silica. Ordinary sand on the beach is almost pure silica, SiO_2.

FACTS ABOUT NOBLE GASES

► ***Helium*** *is the second-lightest element, after hydrogen. It is used in balloons and airships since it does not catch fire, like hydrogen.*

► ***Neon*** *is used in red "neon" lights and in lasers.*

► ***Argon*** *is also used in light bulbs and tubes, and as a "blanket" to prevent metals combining with oxygen during high-temperature welding.*

► ***Krypton*** *is another gas used in lighting tubes, and in photographic flash units.*

Carbon is another vital non-metal. It forms long chains of atoms linked together, -C-C-C-. This feature has allowed it to form the "backbones" of the molecules in living things. Carbon is so important, and joins with so many other elements, in so many different ways, that it has its own branch of science. This is called organic chemistry.

Noble gases

On the far right of the periodic table is the column of elements known as "noble gases". They include helium, neon, argon, krypton, xenon and radon. They are the opposite of the alkali metal elements in the far left of the table, in that they hardly react or join with any other elements. They are known as "inert". Most occur in tiny quantities in the air around us.

Properties of Metals

You need to know all about metal elements – learn all these 14 properties.

1. Metals can be found in the Periodic Table.

There are over *90 metal* elements in the Periodic Table.

2. Metals conduct electricity.

Metals all allow *electrical charge* to pass through them *easily*. The moving charges are in fact *electrons*. Moving charge is otherwise known as *electric current*.

3. Metals conduct heat.

They let *thermal energy* pass through. The *"hot"* particles *vibrate strongly*. This is *passed on* through the metal.

4. Metals are strong and tough.

They have high *tensile strength*. This is due to the *strong bonds* which exist between the metal particles. They make good *building materials*.

5. Metals are shiny when polished or freshly cut.

Metals give strong *reflection* of light from their *smooth surface*. This makes them look *shiny*.

6. Metals are malleable.

Metals are easily *shaped*. The bonds inside metals are *strong* and they can *withstand* stresses and *movement*.

7. Metals are sonorous.

This means they make a nice "donnnnggg" sound when they're hit. If you think about it, it's *only metals* that do that – you *could* make a gong out of plastic, but it wouldn't be much good .

8. Metals are ductile.

This means they can be drawn into *wires*. The *bonds* in the metal *don't break* easily. This means metals *aren't brittle* like non-metals are. They just *bend* and *stretch*.

9. Metals have high melting and boiling points.

A *lot* of *heat energy* is needed to *melt* metals. This is because their *atoms* join up with *strong bonds*.

10. Metals have high densities.

Density is all to do with how much *stuff* there is squeezed into a certain *space*. Metals feel *heavy* for their *size* (i.e. they're *very dense*) because they have a lot of *atoms* packed into a *small volume*.

11. Some metals are magnetic.

Only *certain metals* are magnetic. In the periodic table only i*ron, nickel* and *cobalt* are magnetic. *Alloys* made with these three metals will also be magnetic – e.g. *steel* is made mostly from *iron* and is also *magnetic*.

12. Metals make alloys when mixed with other metals.

A *combination* of different metals is called an *alloy*. The *properties* of the metals get *jumbled up* in the new *alloy*. So *light, weak metals* can be *mixed* with *heavy, strong metals* and the *result* is, hopefully, an *alloy* which is *light and strong*.

13. Metals make oxides when reacted with oxygen.

Metals react with *oxygen* to make *metal oxides*.

E.g. Magnesium + Oxygen → Magnesium Oxide.

14. Metallic oxides are basic.

Metal oxides have a *pH* which is *higher than 7* – i.e. they're *alkaline*. So *metal oxides* react with *acids* to make *salts* and *water*.

Properties of Non-metals

The properties of non-metal elements vary quite a lot. As you will slowly begin to realise…

1. Non-metals can be found in the Periodic Table.

There are *22 non-metal* elements.

2. Non-metals are poor conductors of electricity.

Non-metals are all *insulators* which means that charges *can't flow* through them. If charges can't move then *no electric current flows*. This is *very useful* – non-metals combine to make things like *plugs* and electric cable *coverings*.

3. Non-metals are poor conductors of heat.

Heat does not travel very well at all through non-metals. This makes non-metals really good *insulators*. *"Hot"* particles *don't pass on* their *vibrations* so well.

4. Non-metals are not strong or hard-wearing.

The *bonds* in most *non-metals* are strong but the *structure* and *arrangement* of the molecules is *weak* – this means they *break* easily. It's also easy to *scrub* atoms or molecules off them – so they *wear away* quickly.

5. Non-metals are dull.

Most non-metals don't *reflect* light very well at all. Their surfaces are not usually as *smooth* as metals. This makes them look *dull*.

6. Non-metals are brittle.

Non-metal structures are held together by *weak forces*. This means they can *shatter* all too easily.

7. Non-metals have low melting and boiling points.

The *forces* which hold the particles in non-metals together are *very weak*. This means they *melt* and *boil* all too *easily*. Most non-metals are *gases*, one is liquid. *Very few* are solid.

8. Non-metals have low densities.

Obviously the non-metals which are *gases* will have very *low density*. Some of these gases will even *float* in *air* – ideal for party balloons. Even the liquid and solid non-metals have *low densities*. This means they don't have very many *particles* packed into a certain *space*.

9. Non-metals are not magnetic.

Remember only *iron, nickel* and *cobalt* are *magnetic*. These are all metals. So *all non-metals* are most definitely *non-magnetic*.

10. Non-metals react with oxygen to make oxides.

Non-metals will *burn in oxygen* to make *oxides*.

E.g. Sulphur + Oxygen → Sulphur dioxide.

11. Non-metal oxides are acidic.

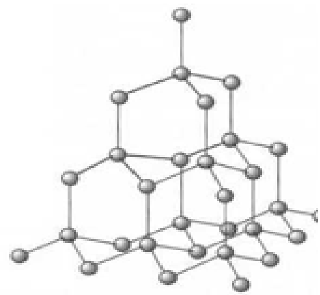
The oxides of non-metals have a *pH below 7*. This means they're *acidic*. So non-metal oxides will react with a *base* to make *salts* and *water*.

Four Exceptions to the Rule

The previous texts have listed all the *normal properties* of *metals* and *non-metals*. There are *four main exceptions* to those general rules which you need to know about:

1. Diamond is a non-metal – but it's seriously hard.

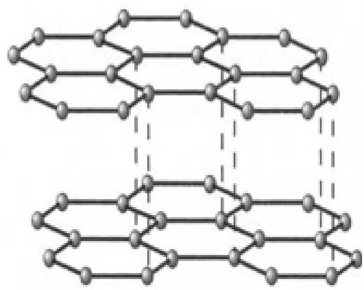
Diamond is made *purely* from *carbon atoms* – so it's a *non-metal*. Being a *non-metal* it should be *soft* or *brittle* – but in fact it's *very hard*. This is because the carbon atoms *are* all *bonded* very *strongly* to each other in a *special arrangement* as shown →



This arrangement of atoms makes it *very, very strong*. It therefore has a very *high melting point* – 3500°C in fact. Being so *hard* makes it ideal for *drill tips* and for *cutting glass*.

2. Graphite is a non-metal – but it conducts electricity.

Graphite is also made *purely* from *carbon atoms*. But it has a very *different structure* from diamond. It's made up of *layers* as shown →



It's a *non-metal* so it *shouldn't conduct electricity*, but it *does* – because *electrons* can move around in *between* its *flat layers*. These layers also make graphite *soft* and *slippery* because the layers can *slide easily* over each other. It's therefore a good *lubricant* too.

3. Mercury is a metal – but it's liquid (at rm. temp.).

Mercury is a *меtal*. All other metals are *solid* at room temperature, but mercury is *liquid* at room temperature – it only goes solid down at *–39°C*. This is because mercury atoms *aren't held together* quite as *strongly* as the atoms in other metals – hence a bit of *thermal energy* soon *breaks* the *bonds.* Mercury *expands* on heating – this makes it ideal for use in *thermometers*.

4. Sodium is a metal – but it's very soft and it floats.

Sodium is a *metal*. Most metals are *hand* and *strong*. But sodium is *very soft* – so soft that you can easily cut it with a knife. Sodium is also *not* very *dense*. In fact its density is so *low* it even *floats on water*. Sodium metal is also *very reactive* – don't touch it because it'll *burn* your skin.

ACTIVE VOCABULARY TO BE MEMORIZED IN UNIT 6

establish the periodic system of elements	be arranged by atomic weight/atomic number
be a matter of great interest	on the basis of — be based on
research worker = researcher	notice
well-ordered branch of science	certain repetition of properties
the great majority of	change gradually/suddenly
be firmly convinced	alkali metal
be independent particles of nature	combine = join = react readily with
advanced scientists	other substances
realize	be rarely found in pure element form
regulate/control the behaviour of atoms	detergent
make a few attempts	the lanthanide series
exercise no influence on	the actinide series
founder	rare earths
order ≠ disorder	occur rarely
that is why	be created in laboratories
compare — comparison of properties	form alloys
develop and apply the principle	resistance to corrosion
according to increasing weights	stainless steel
discover an unknown element	vital = essential non-metal
leave open spaces in the periodic table	feature

predict the existence — prediction	conduct electricity and heat
the most important tool in chemistry	electrical charge
vertical column	pass/flow through
horizontal row	electric current
the atomic number of an element	vibrate strongly
the number of protons in the nucleus	pass on vibration
organize all the elements	poor conductors of electricity and heat
take a step in the development of	insulator
make a thorough study of	plug
the relation/relationship between	electric cable covering
valence	strong and tough
propose — proposal	tensile strength
contain	strong bonds
resemble	building materials
revise the table	shiny ≠ dull
corresponding to revised values	reflect light
add the "zero" group	give strong reflection of light
lead to the discovery of noble gases	smooth surface
accept the periodic law	be malleable
be verified by experiment	withstand stresses and movement
be correlated with	sonorous
occur in the order of	ductile
remain	be drawn into wires
the inverted order of atomic weight	be brittle
the inversion of the order	bend
respectively	stretch
whereas	hold together by weak forces
consist of the isotope with mass number	high ≠ low melting/boiling point
be indicated by	high ≠ low density
cause much concern	feel heavy for their size
have little significance	float in air
a striking application	be packed into a small/certain volume
the search for	be magnetic ≠ non-magnetic
during the investigation	make oxides
state	burn in oxygen
be arbitrary	be basic/alkaline

depend on the electronic structure	react with acids
dependence on	be acidic
vary with the atomic number	react with a base
in a systematic way	hard-wearing
involve periodicity	weak structure and arrangement of molecules
occur with periodicity	break easily
periodic recurrence of properties	scrub atoms or molecules off
inert gas	wear away quickly
show a cubic cleavage	exceptions to the rule
be correspondingly similar — similarity	hard ≠ soft
incomplete period	be bonded strongly
with connections between	be made up of layers
congener	slippery
closely related/similar properties	slide easily
devise/compose the periodic table	lubricant
be related to the arrangement of	be held together
be located in electron shells	break the bonds
determine chemical properties	expand on heating
interact with other atoms	float on water

SUPPLEMENTARY MATERIALS

Chemical Elements

Ac	actinium	[æk'tiniəm]	актиний
Ag	argentum = silver	[a:'dʒentəm] = ['silvə]	серебро
Al	aluminium	[ˌælju'miniəm]	алюминий
Am	americium	[ˌæmə'risiəm]	америций
Ar	argon	['a:gɔn]	аргон
As	arsenic	['a:snik]	мышьяк
At	astatine	['æstəti:n]	астат
Au	aurum = gold	['ɔ:rəm] = [gould]	золото
B	boron	['bɔ:rɔn]	бор
Ba	barium	['beəriəm]	барий
Be	beryllium	[bə'riliəm]	бериллий
Bi	bismuth	['bizməθ]	висмут
Bk	berkelium	[bə'кi:liəm]	беркелий
Br	bromine	['broumi:n]	бром
C	carbon	['кa:bən]	углерод
Ca	calcium	['kælsiəm]	кальций
Cd	cadmium	['kædmiəm]	кадмий
Ce	cerium	['siəriəm]	церий
Cf	californium	[ˌкælə'fɔ:niəm]	калифорний
Cl	chlorine	['klɔ:ri:n]	хлор
Cm	curium	['kjuəriəm]	кюрий
Co	cobalt	['koubɔ:lt]	кобальт

Cr	chromium	['kroumiəm]	хром
Cs	c(a)esium	['si:ziəm]	цезий
Cu	cuprum = copper	['kju:prəm] = ['kɔpə]	медь
Dy	dysprosium	[dis'prouziəm]	диспрозий
Er	erbium	['ɜ:biəm]	эрбий
Es	einsteinium	[ain'stainiəm]	эйнштейний
Eu	europium	[ju:'roupiəm]	европий
F	fluorine	['fluəri:n]	фтор
Fe	ferrum = iron	['ferəm] = ['aiən]	железо
Fm	fermium	['fɜ:miəm]	фермий
Fr	francium	['frænsiəm]	франций
Ga	gallium	['gæliəm]	галлий
Gd	gadolinium	[,gædə'liniəm]	гадолиний
Ge	germanium	[dʒɜ:'meiniəm]	германий
H	hydrogen	['haidrədʒən]	водород
He	helium	['hi:liəm]	гелий
Hf	hafnium	['hæfniəm]	гафний
Hg	hydrargyrum = mercury	[hai'dra:dʒirəm] = ['mɜ:kjuri]	ртуть
Ho	holmium	['houlmiəm]	гольмий
I	iodine	['aiədi:n]	йод
In	indium	['indiəm]	индий
Ir	iridium	[i'ridiəm]	иридий
K	kalium = potassium	['keiliəm] = [pə'tæsiəm]	калий
Kr	krypton	['kriptɔn]	криптон

Ku	kurchatovium	[ˌkɜ:tʃə'touviəm]	курчатовий
La	lanthanum	['lænθənəm]	лантан
Li	lithium	['liθiəm]	литий
Ln	lawrencium	[lə'rensiəm]	лоуренсий
Lu	lutecium	[lu'ti: ʃəm]	лютеций
Md	mendelevium	[ˌmendə'li:viəm]	менделевий
Mg	magnesium	[mæg'ni:ziəm]	магний
Mn	manganese	[ˌmæŋgə'ni:z]	марганец
Mo	molybdenum	[mə'libdənəm]	молибден
N	nitrogen	['naitrədʒən]	азот
Na	natrium = sodium	['neitriəm] = ['soudiəm]	натрий
Nb	niobium	[nai'oubiəm]	ниобий
Nd	neodymium	[ˌni:ou'dimiəm]	неодим
Ne	neon	['ni:ɔn]	неон
Ni	nickel	[nikl]	никель
No	nobelium	[nou'bi:liəm]	нобелий
Np	neptunium	[nep'tju:niəm]	нептуний
Ns	nielsbohrium	[ni:ls'bɔ:riəm]	нильсборий
O	oxygen	['ɔksidʒən]	кислород
Os	osmium	['ɔzmiəm]	осмий
P	phosphorus	['fɔsfərəs]	фосфор
Pa	protactinium	[ˌproutæk'tiniəm]	протактиний
Pb	plumbum = lead	['plʌmbəm] = [led]	свинец
Pd	palladium	[pə'leidiəm]	палладий
Pm	promethium	[prou'mi:θiəm]	прометий

Po	polonium	[pə'louniəm]	полоний
Pr	praseodymium	[ˌpreiziou'dimiəm]	празеодим
Pt	platinum	['plætinəm]	платина
Pu	plutonium	[plu:'touniəm]	плутоний
Ra	radium	['reidiəm]	радий
Rb	rubidium	[ru:'bidiəm]	рубидий
Re	rhenium	['ri:niəm]	рений
Rh	rhodium	['roudiəm]	родий
Rn	radon	['reidɔn]	радон
Ru	ruthenium	[ru'θi:niəm]	рутений
S	sulphur	['sʌlfə]	сера
Sb	stibium = antimony	['stibiəm] = ['æntiməni]	сурьма
Sc	scandium	['skændiəm]	скандий
Se	selenium	[si'li:niəm]	селен
Si	silicon	['silikən]	кремний
Sm	samarium	[sə'meəriəm]	самарий
Sn	stannum = tin	['stænəm] = [tin]	олово
Sr	strontium	['strɔntiəm]	стронций
Ta	tantalum	['tæntələm]	тантал
Tb	terbium	['tɜ:biəm]	тербий
Tc	technetium	[tek'ni:ʃiəm]	технеций
Te	tellurium	[te'luəriəm]	теллур
Th	thorium	['θɔ:riəm]	торий
Ti	titanum	[tai'teiniəm]	титан
Tl	thallium	['θæliəm]	таллий

Tm	tullium	['tʌliəm]	тулий
U	uranium	[ju'reiniəm]	уран
V	vanadium	[və'neidiəm]	ванадий
W	wolfram = tungsten	['wulfrəm] = ['tʌŋstən]	вольфрам
Xe	xenon	['zi:nɔn]	ксенон
Y	yttrium	['itriəm]	иттрий
Yb	ytterbium	[i'tɜ:biəm]	иттербий
Zn	zinc	[ziŋk]	цинк
Zr	zirconium	[zɜ:'kouniəm]	цирконий

How to Read Chemical Formulae and Equations

Цифра перед обозначением элемента указывает число молекул; $2MnO_2$, например, читается следующим образом: ['tu: 'mɔlikju:lz əv 'em'en'ou'tu:].

Знаки + и –, стоящие в левом верхнем углу, обозначают положительную и отрицательную валентность иона:

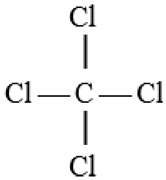
H^{+} — hydrogen ion ['haidrədʒən 'aiən] или univalent positive hydrogen ion [,ju:ni'veilənt 'pɔzətiv 'haidrədʒən 'aiən]

Cu^{++} — divalent positive cuprum ion [,dai'veilənt 'pɔzətiv 'kju:prəm 'aiən]

Al^{+++} — trivalent positive aluminium ion [,trai'veilənt 'pɔzətiv ,ælju'miniəm 'aiən]

Cl^{-} — negative chlorine ion ['negətiv 'klɔ:ri:n 'aiən] или negative univalent chlorine ion ['negətiv ,ju:ni'veilənt 'klɔ:ri:n 'aiən]

Знак "—" — обозначает одну связь и не читается:

 ['si:'si:'el 'fɔ:]

Знак "=" — обозначает две связи и также не читается:
O = C = O ['si:'ou'tu:]

Знак	+	читается: **plus, and** или **together with**
Знак	=	читается: **give** или **form**
Знак	–	читается: **give, pass over to** или **lead to**
Знак	↔	читается: **forms** или **is formed from**

For example:

1. $4HCl + O_2 = 2Cl_2 + 2H_2O$ ['f ɔ: 'mɔlikju:lz əv 'eitʃ 'si 'el 'plʌs 'ou 'tu: 'givz 'tu: 'mɔlikju:lz əv 'si: 'el 'tu: ənd 'tu: 'mɔlikju:lz əv 'eitʃ 'tu: 'ou]

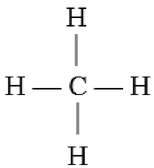
2. $H_2 + J_2 \leftrightarrow 2HJ$ ['eitʃ 'tu: 'plʌs 'dʒei 'tu: 'fɔ:mz 'tu: 'mɔlikju:lz əv 'eitʃ 'dʒei] или ['eitʃ 'tu: 'plʌs 'dʒei 'tu: iz 'fɔ:md frəm 'tu: 'mɔlikju:lz əv 'eitʃ 'dʒei]

3. $CH_4 + 2O_2 \rightarrow CO + 2H_2O$ ['si: 'eitʃ 'fɔ: 'plʌs 'tu: 'mɔlikju:lz əv 'ou 'tu: 'givz 'si: 'ou 'plʌs 'tu: 'mɔlikju:lz əv 'eitʃ 'tu: 'ou]

4. $H^+ + NaHCO_3 \rightarrow Na^+ + H_2CO_3 \rightarrow Na^+ + H_2O + CO_2$ ['haidrədʒən 'aiən 'plʌs 'en 'ei 'eitʃ 'si: 'ou 'θri: 'givz 'neitriəm 'aiən 'plʌs 'eitʃ 'tu: 'si: 'ou 'θri: givz 'neitriəm 'aiən 'plʌs 'eitʃ 'tu: 'ou 'plʌs 'si: 'ou 'tu:]

5. $AcOH \leftrightarrow AcO^- + H^+$ ['ei 'si: 'ou 'eitʃ 'fɔ:mz ənd iz 'fɔ:md frəm 'ei 'si: 'ɔksidʒən 'aiən 'plʌs 'haidrədʒən 'aiən]

6. AcO^- — acyloxy ion ['eisailɔksi 'aiən]

7.  ['si:'eitʃ 'fɔ:]

Naming Compounds

When elements combine their names often change slightly. Learn the *Three Simple Rules*.

Rule 1: When **TWO ELEMENTS** combine the ending is usually **-IDE**.

Sodium and Chlorine (NaCl) give SODIUM CHLOR**IDE**
Magnesium and Oxygen (MgO) give MAGNESIUM OX**IDE**
And in just the same way: Chlor**ine** changes to Chlor**ide**
Ox**ygen** changes to Ox**ide**
Sulph**ur** changes to Sulph**ide**
Brom**ine** changes to Brom**ide**
Fluor**ine** changes to Fluor**ide**
Iod**ine** changes to Iod**ide**

Rule 2: When **THREE** or **MORE** different elements combine – and one of them is **OXYGEN** – then the ending will be **-ATE**.

1 Copper, 1 Sulphur, **4 Oxygens** ($CuSO_4$) → COPPER SULPH**ATE**
1 Calcium, 1 Carbon, **3 Oxygens** ($CaCO_3$) → CALCIUM CARBON**ATE**
And in just the same way:
Sodium + Carbon + **3 Oxygens** makes SODIUM CARBON**ATE**
Potassium + Sulphur + **4 Oxygens** makes POTASSIUM SULPH**ATE**
Ammonia + Nitrogen + **3 Oxygens** makes AMMONIUM NITR**ATE**

Rule 3: When two **IDENTICAL** elements combine the name **DOESN'T CHANGE** at all.

H_2 = Hydrogen
N_2 = Nitrogen
O_2 = Oxygen
F_2 = Fluorine
Cl_2 = Chlorine
Br_2 = Bromine

Numerals

Числа (numbers)	*Количественные (Cardinal)*	*Порядковые (Ordinal)*
1	one	first
2	two	second
3	three	third
4	four	fourth
5	five	fifth
6	six	sixth
7	seven	seventh
8	eight	eighth
9	nine	ninth
10	ten	tenth
11	eleven	eleventh
12	twelve	twelfth
13	thirteen	thirteenth
14	fourteen	fourteenth
15	fifteen	fifteenth
20	twenty	twentieth
21	twenty-one	twenty-first
30	thirty	thirtieth
32	thirty-two	thirty-second
40	forty	fortieth
50	fifty	fiftieth

При чтении чисел после “hundred” произносится “and”:
563 — five hundred and sixty three
1,445 — one thousand four hundred and forty-five
100 — a hundred

300 — three hundred
1,000 — a thousand
5,000 — five thousand
1,000,000 — a million
10,000,000 — ten million

Даты:

1147 — eleven forty-seven
1493 — fourteen ninety-three
1900 — nineteen hundred
1905 — nineteen o [ou] five
1992 — nineteen ninety-two
2000 — two thousand
2004 — two thousand and four

Полные даты:

January 17, 1992 — on the seventeenth of January, nineteen ninety-two

Номера телефонов/автомобилей:

123-45-67 — one-two-three-four-five-six-seven

Математические операции:

x — times / multiplied by
: — divided by
= — equals / is equal to / is / makes

Например: 3x3 = 9 (three times three equals nine)
12:4 = 3 (twelve divided by four makes three)

Дроби (Fractional Numerals)

Простые (fractions):

1/2 — a (one) half
1/3 — one third
2/3 — two thirds
1 1/2 — one and a half
2 3/7 — two and three sevenths
24 1/8 — twenty-four and one eighth

Десятичные (decimal):

0.2 — o [ou] point two / zero ['zi:rou] point two / nought [nɔ:t] point two
0.002 — o [ou] point oo ['dʌblou] two
0.25 — nought point two five

1.15 — one point one five
12.75 — twelve point seven five
64.598 — sixty-four point five nine eight

Проценты:

3% — three per cent (*Latin* – pro centum)
2/5% — two fifths per cent
0.01% — o [ou] point o [ou] one per cent

Степень (power):

10^4 — ten to the fourth power
31^{-5} — thirty-one to the minus fifth power

Units of Measurement

The International System of Units (SI)

Length	kilometre (km)	metre (m)	centimetre (cm)
Area	square kilometre (km^2)	square metre (m^2)	square centimetre (cm^2)
Volume		cubic metre (m^3)	cubic centimetre (cm^3)
Velocity	kilometre per hour (km/h)	metre per second (m/sec)	
Mass	ton	kilogram (kg)	gram (gr)
Density		kilogram per cubic metre (kg/m^3)	gram per cubic centimetre (gr/cm^3)

American-British System

Length	mile (m)	yard (yd)	foot (ft) (*pl* feet)	inch (in)
Area		square yard (sq.yd.)	square foot (sq.ft.)	square inch (sq.in.)
Volume		cubic yard (yd^3)	cubic foot (ft^3)	cubic inch (in^3)
Velocity	knot (kt)	mile per hour (mph)	foot per second (fps)	
Mass	ton	hundredweight (cwt)	pound (lb)	ounce (oz)
Density			pound per cubic foot (lb/ft^3)	ounce per cubic inch (oz/in^3)

Temperature

Degree Fahrenheit (°F) ['færənhait]	Degree Celsius (°C) ['selsiəs]

The Words of Latin and Greek Origin

Singular	—	*Plural*	*Singular*	—	*Plural*
-a [ə]	—	***-ae*** [i:]	formul**a**	—	formul**ae**
-um [əm]	—	***-a*** [ə]	dat**um**	—	dat**a**
-on [ən]	—	***-a*** [ə]	phenomen**on**	—	phenomen**a**
-us [əs]	—	***-i*** [ai]	nucle**us**	—	nucle**i**
-is [is]	—	***-es*** [i:z]	hypothes**is**	—	hypothes**es**
-x [ks]	—	***-ces*** [si:z]	inde**x**	—	indi**ces**
The following nouns have the same forms of their singular and plural: **apparatus, means, news, series, species.**					

Other examples:

maximum, axis, analysis, quantum, bacillus, matrix, crisis, bacterium, criterion, phylum, thesis, momentum, synthesis, vacuum, genus, basis, focus, equilibrium, medium, stimulus, curriculum, symposium, spectrum, stratum, phasis, radius.

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