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English for Chemistry

Английский для химиков

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Настоящее учебно-методическое пособие предназначено для студентов-бакалавров, обучающихся по направлению подготовки 04.03.01 Химия. Целью данного пособия является формирование и развитие навыков работы с профессионально-ориентированными текстами, совершенствование навыков устной речи на основе чтения и пополнение словарного состава за счёт специальной лексики.

Задания к текстам направлены на контроль понимания прочитанного, усвоение новой лексики, совершенствование фонетических, грамматических навыков и навыков учебного перевода.

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Предисловие

Учебно-методическое пособие предназначено студентам-бакалаврам, обучающимся по естественнонаучному направлению подготовки: химия. Целью настоящего учебно-методического пособия является формирование и совершенствование у студентов навыков работы с профессионально-ориентированной лексикой, навыков научно- технического перевода литературы и употребления специальных терминов в устной речи.

Пособие состоит из 10 разделов, каждый раздел заканчивается блоком лексических заданий, направленных на закрепление полученных навыков работы с профессионально-ориентированным текстом по специальности.

Для формирования и совершенствования лексических навыков в пособие включены упражнения на соответствие химических терминов и их определений, подстановочные упражнения и др. Для отработки коммуникационного навыка, студентам предложены творческие задания: дискуссия, разработка проекта или ролевая игра, презентация.

Далее предложены дополнительные неадаптированные тексты для перевода с английского на русский язык.

Текстовый материал в основе учебно-методического пособия, взят из различных источников: отечественных и зарубежных учебников и энциклопедий и открытых интернет источников, некоторые тексты адаптированы и подвергнуты переработке.

Оригинальность и новизна пособия заключается в том, что материал подобран с учетом лексических трудностей, которые снимаются по мере изучения темы, и на основании таких принципов, как информативность, предметная связность, доступность. Соблюдение данных принципов будет способствовать расширению профессионального кругозора, развитию навыков перевода научно- технической литературы, а также усвоению определенного запаса профессиональных терминов.

Использование пособия в учебном процессе позволит ускорить формирование у студентов навыков и умений, необходимых для работы с научно-технической литературой, будет способствовать повышению качества перевода литературы по специальности.

Unit1
Chemistry

An introduction

1. Read and translate. Give a title to each paragraph.

Chemistry is often said to be the central science, as it connects all other sciences. While mathematicians calculate the world, physicists explain it and biologists say what lives in it, chemistry looks at everything in the world and explains how it is made and what it can do.

Chemistry began with fire. Burning changes things and ancient man must have wondered what happened to the wood he burnt. It was by burning things that ancient man discovered iron and glass, combining different substances in the fire and seeing how they combined. Once gold was found, the false science of alchemy was born. People believed they could change ordinary metals like iron into gold. Though the idea was wrong, the alchemists discovered many of the chemical processes that are in use today. The origin of modern chemistry comes from the work of Antoine Lavoisier, an 18^{th} century Frenchman who was executed in 1794 during the French Revolution. He formulated the idea of the conservation of mass: that is, even though substances can be changed, their quantity of mass remains the same always. Although Lavoisier was the first to publish his ideas, in Russia, Mikhail Vasilyevich Lomonosov had reached the same conclusions some years earlier. Both men were interested in the nature of combustion - what happens when things burn and this was the first breakthrough in our understanding of chemistry.

The second great development in chemistry came later and concerned the nature of matter itself: how it was made up and what its parts were. In the early part of the 19^{th} century, the British scientist, John Dalton stated that all matter was made up of atoms of different elements and that these could not be broken down into smaller parts. We know now that atoms exist and that they do have parts which can be broken down, but at the time his ideas divided chemists into those who accepted his ideas and those who did not. There was a whole century of research to be done before the work of Marie Curie on radioactivity and of Ernest Rutherford and Niels Bohr on atomic structure finally proved that Dalton was correct after all.

Even while chemists were divided on atomism, it became necessary for someone to make sense of the growing list of elements that were being discovered. That someone was Dmitri Mendeleev. He took Dalton's theory of atomism and arranged the elements by their atomic weight and by their chemical properties. So accurate was his classification of the elements, that he was able to predict the properties of undiscovered ones to fill the gaps in the table. Mendeleev's table is one of the most useful and important generalizations of chemistry and of all science. These three developments give us the definition of chemistry. It is the science of the composition, structure and properties of substances and how they can be transformed.

2. Complete the sentences below with the words: *conversation of mass, combustion, accurate, alchemists, matter, quantity, breakthrough, properties.*

1.It is a fact that substances cannot change their ….
2. ……means that no matter how a substance is changed, what it is made up of will always stay the same.
3. When scientists make a ………. they succeed after trying very hard.
4. Without oxygen there cannot be………-things cannot burn.
5. ……….is what physical objects are made of.
6. All classifications in chemistry need to be……..

7………. believed that they could turn iron into gold.
8. Mendeleev's table classifies the elements found in nature according to their……

3. Find all the synonyms in each line. Explain your choice giving examples:

1.matter a). science; b). subject; c). substance; d). structure
2.property a). quality; b). characteristic; c). quantity; d). feature
3.definition a). attribute; b). rule; c). determination; d). explanation
4.composition. a). mixture; b). combination; c). compound; d). blend

5. via a). through; b). though; c). opposite; d). over
6. essential a). utmost; b). ultimate; c). main; d). important
7.to convert. a). to transform; b). to change; c). to turn into; d). to make
8.complicated. a). complex; b). hard; c). uneasy; d). difficult

4. Translate the word combinations and make your own sentences:

composition of matter, list of properties, essential fact, complicated structure, formal definition, intimately involved, utmost importance, undeserved reputation, to use indirectly, integral part of science, study of matter, reactions that involve electrons, subatomic realm, two sides of the same coin, diverse areas of study, ultimate science of materials, fundamental character of materials, complicated definition, composition and properties of substances, as a matter of fact...

5. Complete the text about chemistry using the words in the box.

bind	charge	science
nucleus	interactions	shape
mass	particles	matter
density	substances	amounts
ions	molecules	

Chemistry is the _____________ that systematically studies the composition, properties and activity of ________________ and various elementary forms of_________________ . Chemistry is the study of matter and energy and interactions between them. Energy has no ____________ or form. Matter is everything that occupies space and has

____________ . _____________ refers to the amount of matter in a given amount of space and is defined as the mass per unit of a substance.

The fundamental building block of matter is the atom. It has a ____________ at its centre consisting of protons, which have a positive electrical ___________, and neutrons which are uncharged. Negatively charged electrons circle around nuclei. There are super-small _______________ inside the protons and neutrons called quarks.

Chemical reactions involve ___________________ between the electrons of one atom and the electrons of another atom. Atoms which have different ______________ of electrons and protons have positive or negative electrical charge and are called ___________. When atoms __________ together, they can make larger building blocks of matter called _____________.

6. Answer the following questions.

1. How would you define chemistry?
2. What was your first encounter with chemistry?
3. What is/isn't interesting about chemistry for you?
4. Which branch of chemistry would you like to specialize in?
5. Name some branches of applied chemistry.
6. Which sciences are closely connected to chemistry?
7. Do you know any Nobel laureate in chemistry?
8. Which skills should a chemist have?
9. Where can you find a job as a chemist?
10. Name some products which would not exist without chemistry.
11. What does organic/inorganic chemistry study?

7. **Look the text through and prepare the monologue "What makes Chemistry so special to me":**

We're all chemists using chemicals daily and performing chemical reactions without thinking much about them. Chemistry is important because everything you do is chemistry! Even your body is made of chemicals. Chemical reactions occur when you breathe, eat, or just sit there reading. All matter is made of chemicals, so the importance of chemistry is that it's the study of everything.

Everyone can and should understand basic chemistry, but it may be important to take a course in chemistry or even make a career out of it. It's important to understand chemistry if you are studying any of the sciences because all of the sciences involve matter and the interactions between types of matter. Students wanting to become doctors, nurses, physicists, nutritionists, geologists, pharmacists, and (of course) chemists all study chemistry. You might want to make a career of chemistry because chemistry- related jobs are plentiful and high-paying. The importance of chemistry won't be diminished over time, so it will remain a promising career path.

Unit 2
Three States of Matter

1.Read and translate.

That matter may exist in three physical states (solid, liquid and gas) is a 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 vapor, 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 vapor. 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 behavior 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.

2. Translate into Russian, make your own sentences:
be a common knowledge, be composed of, behaviour, carbon, change, common salt, convert, definite, degree, essential, evaporate, exist, extraordinary, however, ice, law, liquid, liquefy, like, matter, means n, melt, obtain, produce, quantity, relative, shape, solid, still, thorough, usually, vapor, vaporize.

3. Answer the following questions:
1. How is it usually possible to change matter from one state to the other?
2. Can all kinds of matter be obtained in each of the three states?
3. What do solids have?
4. What characterizes gases?
5. Why should a chemist know the states of matter?
6. What other substances besides water can be obtained in the three states?

4. Fill in the blanks: ***thorough, various, neither... nor, as, among, relative, possess, a common knowledge, never, govern, both... and***
1. That matter exists in three physical states is ...
2. A piece of ice may melt and form a liquid ... it evaporates.
3. Carbon has ... been liquefied.
4. Solids have ... a definite volume ... a definite shape.
5. Gases have ... a definite shape ... a definite volume.
6. A chemist must have ... knowledge of the physical laws which ... the behavior of matter in ... states.
7. The essential difference ... the three states of matter is the ... quantities of energy molecules ... in different state

5. Read the article about solids, water and gases.
Water is the only common substance that is naturally found as a solid, liquid or gas. Solids, liquids and gases are known as states of matter. Before we look at why things are called solids, liquids or gases, we need to know more about matter.

Matter is everything around us

Matter can be a confusing word because it has several meanings. We often hear phrases like "What is the matter?" or "It doesn't matter". Scientists have a different meaning for matter – matter is anything that occupies space and has mass.

Matter is made up of tiny particles. These can be atoms or groups of atoms called molecules. Atoms are like individual LEGO blocks. They are the smallest unit that anything can be broken down into without doing something extreme (like hitting a LEGO block with a hammer or smashing atoms in the Large Hadron Collider.) If atoms are like LEGO blocks, molecules are the structures you build with them. The physical characteristics of atoms and molecules decide the form or state the matter is in.

Solid

Right now, you are probably sitting on a chair, using a mouse or a keyboard that is resting on a desk – all these things are solids. Something is usually described as a solid if it can hold its own shape and is hard to compress (squash). The particles in most solids are closely packed together. Even though the particles are locked into place and cannot move or slide past each other, they still vibrate a tiny bit.

Ice is water in its solid form or state. Ice keeps its shape when frozen, even if it is removed from its container. However, ice is different from most solids: its molecules are less densely packed than in liquid water. This is why ice floats.

Liquid

The simplest way to determine if something is a liquid is to ask this question: If I try and move it from one container to another (i.e. by pouring), will it conform to (take on the shape of) the new container?

If you have a glass of water and pour it into another glass, it clearly conforms – it takes on the shape of the glass. If you spill the water, it will go everywhere. Because it isn't in a container, it conforms to the shape of the floor, making a big puddle!

In most liquids, the particles are less densely packed, giving them the ability to move around and slide past each other. While a liquid is easier to compress than a solid, it is still quite difficult – imagine trying to compress water in a confined container! Water is an example of a liquid, and so are milk, juice and lemonade.

The atoms and molecules in gases are much more spread out than in solids or liquids. They vibrate and move freely at high speeds. A gas will fill any container, but if the container is not sealed, the gas will escape. Gas can be compressed much more easily than a liquid or solid. (Think about a diving tank – 600 L of gas is compressed into a 3 L cylinder.) Right now, you are breathing in air – a mixture of gases containing many elements such as oxygen and nitrogen. Water vapour is the gaseous form or state of water. Unlike ice or water, water vapour is invisible. We exhale water vapour whenever we breathe out. We cannot see the water vapour as we exhale, but if we hold our eyeglasses or smartphone to our mouths, we can see the water vapour condensing (becoming liquid) on these objects.

Other states of matter

We've known about solids, liquids and gases for hundreds of years, but scientists have discovered other states. One state is plasma, which naturally occurs in lightning, and we create it in fluorescent light bulbs and plasma TVs. Another state of matter is Bose-Einstein condensate, but this state only occurs with super-low temperatures.

6. Answer extreme thinking questions:

1.Can two (or more) types of matter occupy the same space at the same time?

2.What is hardest state of matter?

3. What is the softest state of matter?

4. What is the state of matter that is most fun? (To you) Why?

5. What are odor, color, weight, shape, sound and hardness?

7. Put the following materials and objects into the column of their natural state of matter.

Rock.	Smell of popcorn.	Spoon
Fire Flames.	Rope	Pepsi
Electric sparks	Tomato juice	Carbon dioxide
Hydrogen	Vacuum cleaner	Lightining
Milk.	Steam	Blood
Chicken.	Football	Bad breath
Sand.	Laser light	
Spit.	Wire	
Rain	Smoke	
Crayola	Sweat	

solid	liquid	plasma	gas

Unit 3
The atom

1. Read and translate.

The ancient Greeks coined the term meaning the smallest possible separation of matter. In ancient times, both the Greeks and Indians had philosophised about the existence of the atom but, it was first hypothesised scientifically by the British chemist John Dalton (1766-1844) in the early years of the 19^{th} century, when he suggested it was the smallest particle that could exist. Since then, smaller subatomic particles have been discovered and the part they play as the basic building blocks of the universe is clear.
We now know that atoms are made up of differing numbers of electrons, neutrons and protons, and these too are made up of even smaller particles.

Dalton's theory about atoms was not immediately accepted by chemists, though one reason for this was Dalton's well-known carelessness in experimental procedures. However, we know now that Dalton was correct in almost everything he said in his theory of the atom. He described an atom, even though he had never seen one, as a particle that cannot change its nature. It could, he observed, combine with the atoms of other chemical elements to create a compound. Almost a century later the first subatomic particles were discovered.

By the 1930s, physicists were working with new ideas which allowed them to investigate the parts of the atom in great detail. In turn, these developments helped them to develop quantum mechanics - the basis of both modern chemistry and physics.

In chemistry, the atom is the smallest part of an element that can still be recognized. An example will explain best of all. Each element is identified by the number of protons it has. An atom of carbon has six protons. Those six protons without the neutrons and electrons, or the electrons without the other subatomic particles are simply subatomic particles; they are not carbon. A carbon atom can be combined with two atoms of oxygen to give the compound carbon dioxide, or C02. It is this difference in the number of subatomic particles that makes one atom different from another.

Subatomic particles also have another purpose. If there is the same number of electrons and protons in the atom, then the atom will be electronically neutral. A difference between the two means the atom has an electrical charge, in other words, it produces electricity. This electricity means the electrons can become attracted to each other. In this way, atoms can bond together to form molecules, and when enough molecules are joined together, we have matter that we can see.

The most recent theories of the origins of the universe say that all the atoms in the universe were formed in the first few minutes of the universe coming into existence. The most common element is the simplest, hydrogen, which has the atomic number 1. Seventy-five per cent of all atoms are hydrogen atoms.

The next most simple is the next most common, helium, atomic number 2 making twenty-four per cent of all atoms. All the other atoms add up to just one per cent of everything that exists in the universe.

2. True or False, give the right answer:

1 Dalton believed the atom to be an element.
2 Dalton's theories were not tested very carefully.
3 The number of protons in an element is always six.
4 Electrons help atoms to form molecules.
5 Hydrogen is as common as helium.

3. Match these words with their definitions.

1 subatomic	A part of an atom which has no charge
2 electron	B two or more atoms
3 neutron	C smaller than an atom
4 molecule	D part of an atom that has a negative charge
5 proton	
	E a theory developed by physicists to explain the atom
6 quantum mechanics	F part of an atom which has a positive charge
7 carbon	G pulled together
8 attracted	H a chemical element
9 helium	I a chemical element that is lighter than air
10 universe	J the whole cosmos

4. Read the text, give a title to each paragraph:

Dalton's Atomic Theory

Although the concept of atoms is now widely accepted, this wasn't always the case. Scientists didn't always believe that everything was composed of small particles called atoms. The work of several scientists and their experimental data gave evidence for what is now called the atomic theory.

In the late 1700's, Antoine Lavoisier, a French scientist, experimented with the reactions of many metals. He carefully measured the mass of a substance before reacting and again measured the mass after a reaction had occurred in a closed system (meaning that nothing could enter or leave the container). He found that no matter what reaction he looked at, the mass of the starting materials was always equal to the mass of the ending materials. This is now called the law of conservation of mass. This went contrary to what many scientists at the time thought. For example, when a piece of iron rusts, it appears to gain mass. When a log is burned, it appears to lose mass. In these examples, though, the reaction does not take place in a closed container and substances, such as the gases in the air, are able to enter or leave. When iron rusts, it is combining with oxygen in the air, which is why it seems to gain mass. What Lavoisier found was that no mass was actually being gained or lost. It was coming from the air. This was a very important first step in giving evidence for the idea that everything is made of atoms. The atoms (and mass) are not being created or destroyed. The atoms are simply reacting with other atoms that are already present.

In the late 1700s and early 1800s, scientists began noticing that when certain substances, like hydrogen and oxygen, were combined to produce a new substance, like water, the reactants (hydrogen and oxygen) always reacted in the same proportions by mass.

In other words, if 1 gram of hydrogen reacted with 8 grams of oxygen, then 2 grams of hydrogen would react with 16 grams of oxygen, and 3 grams of hydrogen would react with 24 grams of oxygen. Strangely, the observation that hydrogen and oxygen always reacted in the "same proportions by mass" wasn't special. In fact, it turned out that the reactants in every chemical reaction reacted in the same proportions by mass. This observation is summarized in the law of definite proportions. Take, for example, nitrogen and hydrogen, which react to produce ammonia. In chemical reactions, 1 gram of hydrogen will react with 4.7 grams of nitrogen, and 2 grams of hydrogen will react with 9.4 grams of nitrogen. Can you guess how much nitrogen would react with 3 grams of hydrogen? Scientists studied reaction after reaction, but every time the result was the same. The reactants always reacted in the same proportions.

At the same time that scientists were finding this pattern out, a man named John Dalton was experimenting with several reactions in which the reactant elements formed more than one type of product, depending on the experimental conditions he used. One common reaction that he studied was the reaction between carbon and oxygen. When carbon and oxygen react, they produce two different substances – we'll call these substances "A" and "B." It turned out that, given the same amount of carbon, forming B always required exactly twice as much oxygen as forming A. In other words, if you can make A with 3 grams of carbon and 4 grams of oxygen, B can be made with the same 3 grams of carbon, but with 8 grams oxygen. Dalton asked himself – why does B require 2 times as much oxygen as A? Why not 1.21 times as much oxygen, or 0.95 times as much oxygen? Why a whole number like 2?

The situation became even stranger when Dalton tried similar experiments with different substances. For example, when he reacted nitrogen and oxygen, Dalton discovered that he could make three different substances – we'll call them "C," "D," and "E." As it turned out, for the same amount of nitrogen, D always required twice as much oxygen as C. Similarly, E always required exactly four times as much oxygen as C. Once again, Dalton noticed that small whole numbers (2 and 4) seemed to be the rule. This observation came to be known as the law of multiple proportions.

Dalton thought about his results and tried to find some theory that would explain it, as well as a theory that would explain the Law of Conservation of Mass (mass is neither created nor destroyed, or the mass you have at the beginning is equal to the mass at the end of a change). One way to explain the relationships that Dalton and others had observed was to suggest that materials like nitrogen, carbon and oxygen were composed of small, indivisible quantities which Dalton called "atoms" (in reference to Democritus' original idea). Dalton used this idea to generate what is now known as Dalton's Atomic Theory which stated the following:

1.Matter is made of tiny particles called atoms.
2. Atoms are indivisible (can't be broken into smaller particles). During a chemical reaction, atoms are rearranged, but they do not break apart, nor are they created or destroyed.
3.All atoms of a given element are identical in mass and other properties.
4.The atoms of different elements differ in mass and other properties.
5. Atoms of one element can combine with atoms of another element to form "compounds" – new, complex particles. In a given compound, however, the different types of atoms are always present in the same relative numbers.

5. Summarize the text Dalton's Atomic Theory.

6. Translate into Russian, make your own sentences:

widely accepted, experimental data, measure, occur, look at, contrary, rust, gain, evidence, create and destroy, combine, produce, first step, reactants, definite proportion, pattern, turn out, multiple, suggest, indivisible quantities, generate, tiny particles, relative numbers.

Unit 4
The Periodic Table Turns 150

1. Read and translate.

The periodic table of elements is one of the most recognizable icons of science. You probably have one hanging on your chemistry classroom wall. If you google it, you'll see versions in rainbow colors, or with tiny photos in every box representing each element. There's even a periodic table of moles! You could almost call the table mundane, except really, it's anything but. The periodic table has been perhaps as foundational to chemistry as the discovery of DNA has been to biology. It is 150 years old this year and is holding up well under the test of time—and science. In celebration of the table, the United Nations proclaimed 2019 as the International Year of the Periodic Table of Chemical Elements. Time to break out the helium balloons, iron-based sparklers, and calcium-rich ice cream!

And whom do we have to thank for the exquisite arrangement of elements? While many scientists contributed to the formation of the table, Russian chemist Dmitri Mendeleev is most often credited for the periodic table's creation. He found that there was a periodicity to their organization, a repetition of particular chemical properties at regular intervals as atomic weight increased. In 1869, Mendeleev published his vision in an early form of the periodic table. It included the 63 elements that were known at the time, with holes to account for elements that hadn't yet been discovered. And while the table has been fleshed out over the past century and a half—including the addition of four new elements in 2016—the essence of Mendeleev's original idea remains. But who knows, future discoveries could lead to materials that even Mendeleev couldn't have dreamed of.

Before Mendeleev came along with his approach, other scientists were attempting to organize the elements. As early as 1789, French chemist Antoine Lavoisier had categorized elements into metals, nonmetals, "earths," and gases, based on their physical and chemical characteristics. By 1829, German chemist Johann Döbereiner had noticed patterns among triplets of elements. In 1865, British chemist John Newlands noticed the periodicity of chemical properties and likened the phenomenon to musical octaves, in which the same tone repeats after an increase or decrease of eight notes. In Germany, chemist Julius Lothar Meyer was developing his own periodic table that was published in 1870. But Mendeleev beat Meyer to the punch a year earlier.

What sort of chemical properties did Mendeleev have in mind when he developed his table? To get a better idea of the patterns he noticed, let's start with the metal lithium (Li). Mendeleev knew the hydride—a compound of hydrogen with another element—that Li formed had the formula LiH. **$2\ Li(s) + H_2(g) \rightarrow 2\ LiH(s)$.** In contrast, the next element by weight, beryllium (Be), formed the hydride BeH_2. **$Be(s) + H_2(g) \rightarrow BeH_2(s)$.** Each successively heavier element formed different kinds of hydrides until he got to sodium (Na). Sodium behaved like lithium in its reactions with hydrogen, forming NaH. **$2\ Na(s) + H_2(g) \rightarrow 2\ NaH(s)$.** Thus, a pattern started to emerge.

But Mendeleev’s most insightful decision was to let properties sometimes trump atomic weight when he placed elements. For example, if you look at the periodic table, you’ll notice that nickel follows cobalt in the fourth row even though nickel is lighter. Mendeleev placed them this way because nickel’s properties aligned with palladium’s (on the next row, same column) and cobalt’s with rhodium.

This approach allowed him to skip slots in the table that corresponded to chemical properties and atomic mass ranges that did not match any elements known at the time. For each open slot, Mendeleev predicted the existence of a yet-to-be discovered element.

He turned out to be right most of the time. For example, Mendeleev had left spaces for yet-to-be discovered elements that he called eka-aluminum, eka-manganese, and eka-silicon—eka is the Sanskrit word for “one.” These spots were ultimately taken by gallium, technetium, and germanium.

That’s not to say Mendeleev’s table was perfect from the beginning, or even the only way to organize elements. He himself revised it within two years of introducing it. Mendeleev’s 1869 periodic table had the elements with increasing mass moving down in columns, while elements with similar chemical properties lined up horizontally in rows. In 1871, however, he reversed this idea. He lined up elements with similar properties vertically, and the periods appeared in horizontal rows.

Changes to the periodic table continue to this day and will likely keep surprising us in the future. As recently as 2016, the four final gaps in period 7—elements 113, 115, 117, and 118—were officially filled. In order of increasing atomic number, these elements are named nihonium, moscovium, tennessine, and oganesson. So, it would seem that the periodic table is complete with period 7 filled in. Now what? Some scientists have hypothesized that period 7 might not be the last one in the table.

2. True or False:

1. The periodic table of elements is one of the most interesting icons of science.
2. In 1861, Mendeleev published his vision in an early form of the periodic table.
3. As early as 1789, French chemist Antoine Lavoisier had categorized elements into metals, nonmetals, “earths,” and gases, based on their physical and chemical characteristics.
4. In 1865, German chemist John Newlands noticed the periodicity of chemical properties and likened the phenomenon to musical octaves, in which the same tone repeats after an increase or decrease of eight notes.
5. In Germany, chemist Julius Lothar Meyer was developing his own periodic table that was published in 1870.
6. Mendeleev had left spaces for yet-to-be discovered elements that he called eka-water, eka-iron, and eka-cobalt—eka is the Sanskrit word for “two.”
7. In 1871, Mendeleev lined up elements with similar properties vertically, and the periods appeared in horizontal rows.
8. As recently as 2016, the four final gaps in period 10—elements 113, 115, 117, and 118—were officially filled.
9. These elements are named nihonium, moscovium, tennessine, and oganesson.

3. Questions:

1. What is the atomic symbol for silver?
2. What is the atomic mass of mercury?
3. Ni is the symbol for what element?
4. The element that has the atomic number 17 is?
5. List the symbols for two transition metals.
6. Cu, Ag, and Au are all in what group .
7. Name two noble gases.
8. Give the symbol for two halogens.

9. What is the symbol for element with atomic number 74?
10. What is the atomic mass of copper?
11. What is the last element in period 4?

4. Discuss elements.

a. Describe one element to your partner and let him/her guess which one it is. Focus on the following points: physical and chemical properties, occurrence in nature, laboratory preparation, industrial production, use of the element and its compounds

b. Which element/s do you consider the most important and why?

c. Pronounce the following elements and think of their symbols: bromine, calcium, carbon, chlorine, iodine, lead, magnesium, manganese, mercury neon, nitrogen, oxygen, potassium, radium, sodium, uranium, xenon

d. Circle the following element that is a metalloid
Argon Germanium Bismuth Zinc

e. Circle the following element that is not a transition metal
Osmium Titanium Gold Radon Hydrogen Copper

f. Circle all of the following elements that are representative elements
Sulfur Cerium Sodium Aluminum Iron

g. Circle the following element that is an inner transition metal
Nitrogen Hassium Californium Mercury Lithium

j. Write the symbol of the element that is in the 3rd period and group 13

k. Write the symbol of the element that is in the 5th period and group 11

5. Reading

Dmitri Ivanovich Mendeleev was born in Tobolsk, in Siberia, on 7th February 1834. As a child he showed a great interest in Mathematics and Physics and was a talented student. Despite the hardships experienced by his family while he was growing up. his mother was determined to see him educated and to help him achieve his dreams. After the family moved to St Petersburg, she managed to enrol him as a student science teacher on a full scholarship. Despite many more problems, Mendeleev earned his degrees and eventually, in 1863, was appointed Professor of Chemistry at the Technological Institute and the University of St Petersburg.

Probably his greatest scientific achievement was the discovery" of the periodic law and the development of the periodic table of elements, lie left gaps in his table for undiscovered elements and predicted the properties of the elements that would fit these gaps. His predictions were confirmed when, during his lifetime, three predicted elements; gallium, germanium and scandium, which he had named eka-aluminium, eka-silicon and eka-boron respectively, were discovered. These discoveries gave him great respect among members of the scientific community.

However, Mendeleev made other important contributions to science. He was involved in many areas including hydrodynamics, agricultural chemistry, mineral recovery, meteorology and chemical technology. One particular contribution involved solutions. He spent a lot of time studying how the nature of solutions could be determined, adding greatly to our understanding in that field.

In addition, he was involved in physical chemistry, looking at the expansion of liquids because of heat. He spent time in Paris with Henri Victor Regnault studying the densities of gases and came up with a formula to explain how gases are uniform when expanding; in other studies, he defined the absolute boiling point of a substance. His studies of gases at high and low pressures, moreover, allowed him to develop an accurate barometer and while working for the Russian navy, he came up with pyrocollodion, a smokeless powder based on nitrocellulose. The list of his achievements is endless!

Despite his international reputation as one of the world's most important scientists, the Tsar at the time did not approve of Mendeleev's politics, resulting in his resignation from the University of St Petersburg in 1900. He died on 20^{th} January, 1907, from pneumonia.

6. Read the text again and answer the questions in your own words.

1 What position did Mendeleev achieve at the University of St Petersburg?

2 Why did Mendeleev leave gaps in the periodic table of elements?

3 How were Mendeleev's predictions proven correct?

4 What contributions did Mendeleev make in the area of solutions?

5 What did Mendeleev's formula concerning gases explain?

7. Writing . Write 200-250 words.

Write a magazine article for your school magazine about the history of the periodicity of elements. Use these notes to help you.

PARAGRAPH 1
Introduction
Briefly explain what periodicity is, and where the concepts of electrons and atoms were first developed. Vocabulary: *In ancient times ... , during the 18th century ...*
PARAGRAPH 2
Write about the work of Mendeleev; arrangement by atomic weight.
Vocabulary: *organised according to ... , grouped by ...*
PARAGRAPH 3
The role of electrons; how electrons are the basis of the modern periodic table.
Vocabulary: *the function of... ,is based on ...*
PARAGRAPH 4
Conclusion
If you think new elements will be discovered in the future; the expansion of the periodic table. Vocabulary: *In the years to come, I would imagine ...*

Unit 5
Organic chemistry

1. Read and translate.

In the 17th century chemistry was divided into three branches: animal, vegetable, and mineral. It was believed that organic compounds were formed as the result of the so-called “vital force” in living things, and that they could not be produced by the chemists. In 1828, however, Wöhler discovered that ammonium cyanate, a so-called inorganic compound, could be transformed into urea, a typical organic substance.

As the study of organic compounds advanced, it was found that many of them could be prepared in the laboratory from the elements of which they are composed. The sharp distinction between inorganic and organic compounds based on the vital force disappeared. The term organic chemistry has survived, however. Organic chemistry may be defined as the chemistry of the carbon compounds and their reactions because the element carbon is present in all these so-called organic compounds.

Carbon compounds are of two types: inorganic and organic. The compounds that have a mineral origin fall under the category of inorganic compounds. The compounds having plant or animal origin are classified as organic compounds. Lavoisier showed that nearly all compounds of plant origin are composed of carbon, hydrogen and oxygen. While those of animal origin also had other substances like nitrogen, sulphur or phosphorus. Organic chemistry studies the properties of organic carbon compounds.

Carbon (C) is a very special element. It appears in the second row of the periodic table and has four bonding electrons in its valence shell. Similar to other non-metals, carbon needs eight electrons to satisfy its valence shell. Carbon, therefore, forms four bonds with other atoms (each bond consisting of one of carbon’s electrons and one of the bonding atom’s electrons). Every valence electron participates in bonding, thus carbon atom’s bonds will be distributed evenly over the atom’s surface. These bonds form a tetrahedron (a pyramid with a spike at the top).

Carbon has the ability to bond with itself to form long chains and ring structures; hence it can form molecules that contain from one to an infinite number of C atoms.

The number of different design possibilities for organic molecules is endless. In order to enable classification of such a large number of molecules, organic chemists have employed the principle of classifying all organic compounds into families according to their functional groups.

The behavior of any molecule in a particular chemical environment is determined by the stability or reactivity of its bonds. Each different type of bond shows different levels of reactivity. Generally, in a molecule there is a group of more reactive bonds that all the others. This group tends to determine how the whole molecule behaves in a particular chemical environment regardless of the structure of the rest of the molecule. Chemists call these dominant groups of atoms and bonds functional groups. They are used to classify organic compounds into families. Understanding the types of reactions that functional groups under- go will enable an understanding of how an organic molecule interacts with the environment.

A carbon-carbon double bond is an example of a functional group. Organic compounds that contain a carbon-carbon double bond and no other functional group are called alkenes (a family name used to classify these compounds). All alkenes react with bromine to yield dibromo alkanes.

Hence if you know a functional group reacts in one molecule you can predict how it will react in almost all other molecules.

It is possible to get more than one functional group in a single molecule, but the generalization stated above still applies.

Physical properties of an organic substance In addition to reactivity, the physical properties of an organic substance, such as melting point, boiling point and solubility, are among its most important traits. The physical properties of an organic substance can often be predicted from its structure. In most cases, a substance's molecular weight and the functional groups are sufficient in- formation to estimate the melting point, boiling point, and solubility. Comparing molecules of similar size, the greater the strength of intermolecular force, the more equilibrium will favor the condensed phase at a given pressure and temperature.

Organic compounds Millions of carbon compounds have been described in chemical literature, and chemists synthesize many new ones each year. All organic compounds, such as proteins, carbohydrates, and fats, contain carbon, and all plant and animal cells consist of carbon compounds and their polymers. (Polymers are macromolecules consisting of many simple molecules bonded together in specific ways.) With hydrogen, oxygen, nitrogen, and a few other elements, carbon forms compounds that make up about 18 percent of all the matter in living things. The processes by which organisms consume carbon and return it to their surroundings constitute the carbon cycle.

Study of organic chemistry is important for the simple reason that, organic compounds find applications in almost all aspects of our daily life and properties of organic compounds are distinctly different from those of inorganic compounds.

All living systems obtain their energy from organic compounds like carbohydrates (sugars) and fats, using amino acids and proteins (organic) to grow. They transmit genetic information from one generation to the next through organic compounds called nucleic acids. The clothes we wear are of natural fibres like cotton, while wool or silk or synthetic materials like polyester are organic compounds. Most of the drugs and pharmaceuticals are also organic compounds. In agriculture too, organic chemistry is well represented. Fertilizers like urea, pesticides like DDT, malathion and gammaxene, and plant growth regulators are all organic chemicals. Among various energy sources, fossil fuels like coal, lignite, petroleum and natural gas are of organic origin. Commonly used polymers natural and synthetic like wood, rubber, paper and plastics are again organic compounds.

Organic chemists at all levels are generally employed by pharmaceutical, biotechnical, chemical, consumer product, and petroleum industries.

Biotechnology (“biotech” for short) is a field of applied biology that involves using living organisms and bioprocesses to create or modify products for a specific use. The cultivation of plants has been viewed as the earliest example of biotechnology and the precursor to modern genetic engineering and cell and tissue culture technologies. Virtually all biotechnology products are the result of organic chemistry.

Biotechnology is used in health care, crop production and agriculture, nonfood uses of crops and other products (e. g., biodegradable plastics, vegetable oil, biofuels), and environmental applications.

The chemical industry is crucial to modern world economies and works to convert raw materials such as oil, natural gas, air, water, metals, and minerals into more than 70,000 different products. These base products are then used to make consumer products in addition to manufacturing, service, construction, agriculture, and other industries.

Over three-fourths of the chemical industry's output worldwide is polymers and plastics. Chemicals are used to make a wide variety of consumer goods, as well as thousands of products that are inputs to the agriculture, manufacturing, construction, and service industries. The chemical industry itself consumes about a quarter of its own output. Major industrial customers include rubber and plastic products, textiles, petroleum refining, pulp and paper, and primary metals.

Consumer products companies make consumer products for everyday use, such as soaps, detergents, cleaning products, plastic goods, and cosmetics.

The petroleum industry includes the global processes of exploration, extraction, refining, transporting, and marketing petroleum products. The largest volume products of the industry are fuel oil and gasoline. Petroleum is also the raw material for many chemical products, including pharmaceuticals, solvents, fertilizers, pesticides, and plastics. The industry is usually divided into three major components: upstream (exploration and production), midstream (transportation), and down- stream (refining crude oil, processing and purifying natural gas, creating petrochemicals).

The pharmaceutical industry develops, produces, and markets drugs licensed for use as medications for humans or animals.

Organic chemistry is the most important branch of chemistry – but of course, it would be nothing without the many other areas of chemistry – in fact all branches of chemistry should not be viewed in isolation.

2. Questions:

1. What does organic chemistry study? 2. What did Wöhler discover in 1828? 3. Why can carbon form molecules that contain an infinite number of C atoms? 4. What is a functional group? 5. What are the physical properties of an organic substance? 6. What are polymers? 7. Are there many of carbon compounds in the world? 8. What is the carbon cycle? 9. Why are organic compounds worth being studied? 10. Why are organic chemists generally employed by different industries related to chemistry? 11. Is organic chemistry the most important branch of chemistry?

3. Match the words with their definitions:

1) DDT
2) gasoline
3) variety
4) bond
5) regardless
6) amino acids
7) exploration
8) vital forces
9) pulp
10) compound

a) mysterious, metaphysical energies that inhabit "organic" matter and which keep
organisms alive and functional
b) to join with each other, to become firmly fixed together

c) a substance containing atoms from two or more elements
d) a chemical used to kill insects that harm crops
e) one of the substances that combine to form proteins
f) a liquid obtained from petroleum, used mainly for producing power in the engines of cars, trucks
g) the act of travelling through a place in order to find out about it or find something such as oil or gold in it
h) without being affected or influenced by something
i) a lot of things of the same type that are different from each other in some way
j) a very soft substance that is almost liquid, made by crushing plants, wood, vegetables etc.

4. Say whether the following statements are true or false:

1. In the 17^{th} century it was believed that the organic compounds cannot be synthesized in the laboratory.
2. Carbon compounds don't have any mineral origin.
3. Wöhler showed that nearly all compounds of plant origin are composed of carbon, hydrogen and oxygen.
4. Carbon can form molecules that contain an infinite number of C atoms.
5. Carbon atom's bonds form a pyramid with a spike at the top.
6. Functional groups are used to determine the molecular weight of the compound.
7. Study of organic chemistry is important because organic compounds are very rare and unique and can hardly be found anywhere.
8. Carbohydrates and fats are sources of energy for all living systems.
9. Biotechnology is used in production of biodegradable plastics, vegetable oil, biofuels.
10. Organic chemists at all levels are generally employed by pharmaceutical, biotechnical, chemical, consumer product, and petroleum industries.

5. Insert the necessary words: *infinite number, ring structures, carbon atoms, endless, contain, inorganic compounds, functional groups, organic compounds*

1. The vast majority of organic compounds are typically chains or rings of ... that contain other elements such as O, N, P, S, Cl, Br and I.
2. There are over five million of these compounds known today and an almost ... of new compounds could possibly be synthesized.
3. This can be compared to the total number of ..., which is approximately half a million.
4. Carbon has the ability to bond with itself to form long chains and ....
5. It can form molecules that ... from one to an infinite number of C atoms.
6. The number of different design possibilities for organic molecules is ....
7. In order to enable classification of such a large number of molecules, organic chemists have employed the principle of classifying all organic compounds into families according to their ....
8. This greatly simplifies the study of ... as molecules with the same functional groups behave the same in most chemical reactions.

Unit 6
Chemical Reactions, Equations and Formulas.

1. Read and translate.

In a chemical change, new substances are formed. In order for this to occur, the chemical bonds of the substances break, and the atoms that compose them separate and re- arrange themselves into new substances with new chemical bonds. When this process occurs, we call it a chemical reaction. A chemical reaction is the process in which one or more substances are changed into one or more new substances.

Reactants and Products

In order to describe a chemical reaction, we need to indicate what substances are present at the beginning and what substances are present at the end. The substances that are present at the beginning are called reactants and the substances present at the end are called products.

Sometimes when reactants are put into a reaction vessel, a reaction will take place to produce products. Reactants are the starting materials, that is, whatever we have as our initial ingredients. The products are just that, what is produced or the result of what happens to the reactants when we put them together in the reaction vessel. If we think about baking chocolate chip cookies, our reactants would be flour, butter, sugar, vanilla, some baking soda, salt, egg, and chocolate chips. What would be the products? Cookies! The reaction vessel would be our mixing bowl.

Flour + Butter + Sugar + Vanilla + Baking Soda + Eggs + Chocolate Chips =Cookies

Writing Chemical Equations

When sulfur dioxide is added to oxygen, sulfur trioxide is produced. Sulfur dioxide and oxygen, $SO_2 + O_2$, are reactants and sulfur trioxide, SO_3, is the product.

$$2\,SO_{2(g)} + O_{2(g)} \longrightarrow 2\,SO_{3(g)}$$

reactants **products**

In chemical reactions, the reactants are found before the symbol "→" and the products and found after the symbol "→". The general equation for a reaction is: Reactants → Products There are a few special symbols that we need to know in order to "talk" in chemical shorthand. In the table below is the summary of the major symbols used in chemical equations. You will find there are others but these are the main ones that we need to know.

(→) Used to separate reactants from products; can be read as "to produce" or "yields.

example: $2\ H_2 + O_2 \rightarrow 2\ H_2O$

(+) Used to separate reactants from each other or products from each other; can be read as "is added to" or “also forms”.

example: $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

(s) in the solid state

example: sodium in the solid state = Na(s)

(l) in the liquid state

example: water in the liquid state = $H_2O(l)$

(g) in the gaseous state

example: carbon dioxide in the gaseous state = $CO_2(g)$

(aq) in the aqueous state, dissolved in water

example: sodium chloride solution = NaCl(aq)

Chemists have a choice of methods for describing a chemical reaction:

1. They could draw a picture of the chemical reaction.
2. They could write a word equation for the chemical reaction:

“Two molecules of hydrogen gas react with one molecule of oxygen gas to produce two molecules of water vapor. “

3. They could write the equation in chemical shorthand.

$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$

How to read chemical elements, compounds, names and formulas

Letters of Latin alphabet symbolizing chemical elements are to be read as the appropriate letters of English alphabet.

\+ should be read as “plus”, “and”, “together with” or “react with”.

- shows one bond and it shouldn't be read.

= should be read as "give", "form" or "produce".

→ should be read as "give", "pass over" or "lead

↔ should be read as "forms" and "is formed

Figure (at the bottom) after the symbol of the element shows the number of atoms in the molecule and has to be read as a number.

Figure before the element's symbol shows the number of molecules and should be read as a number and word combination "molecules of".

reacts with   producing   and

↓   ↓   ↓

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

one atom of zinc   one molecule of sulphuric acid.   one molecule zink sulphate   one molecule of hydrogen

Or: "z" "n" "plus" "h" "two" "s" "o" "four" "give" "z" "n" "s" "o" "four" "and" "h" "two"
[΄zed΄ən΄plʌs΄əɩtʃ΄tu:΄əs΄əu΄fɔ:΄gɩv΄zed΄ən΄əs΄əu΄fɔ:΄ənd΄əɩtʃ΄tu:]

2. Match each term and its definition:

1. Chemical formula
2. Compound
3. Empirical
4. Molecule
5. Valence
6. Atom

a). A combination of chemical symbols that shows the composition of a compound.
b). A substance that contains two or more elements combined in a fixed proportion.
c). Based on observation or experimentation.
d). The tendency of an atom to gain or lose electrons in reacting with other atoms.
e). The smallest particle of which an element can exist.
f). A particle formed by the combination of two or more atoms

3. Read and translate the text. Subdivide it onto parts, according to the main information given:
Chemical formulas.

A chemical formula is a combination of chemical symbols that represents the chemical composition of a compound. At a minimum, a formula tells which elements are present in the compound and the relative amount of each element. The chemical formula most familiar to people is probably H_2O, the formula for water. This formula says that water consists of two elements, hydrogen (H) and oxygen (O). Further, it says that the ratio of the two elements is two parts hydrogen and one part oxygen. On a submicroscopic scale, the formula says that a molecule of water contains two atoms of hydrogen and one atom of oxygen.
A chemical formula can be determined in one of two ways: by experimentation or by prediction. For example, imagine that an entirely new compound has been discovered whose formula must be determined. That compound can be broken down in the laboratory and the elements present determined. Also, the ratio of the elements can be found. The formula obtained in this way shows the simplest possible ratio of the elements present and is known as the compound's empirical formula. The word empirical means "obtained by means of experimentation".

The empirical formula of a compound may not be its true or correct formula. Consider three different chemical compounds made of carbon and hydrogen only. The first compound contains one carbon atom and one hydrogen atom in each molecule. A molecule of the second compound consists of three carbon atoms and three hydrogen atoms joined to each other. And a molecule of the third compound contains six atoms of carbon and six atoms of hydrogen joined to each other The empirical formula for all three compounds is CH because the ratio of carbon to hydrogen is 1:1 in each. But the true formula is different for the three compounds. It is CH for the first compound, C_3H_3 for the second, and C_6H_6 for the third. The true, correct, or molecular formula for most chemical compounds also can be determined experimentally.

A second way of writing the chemical formula of a compound is by making intelligent guesses. When sodium reacts with chlorine to form sodium chloride, for example, each sodium atom loses one electron and each chlorine atom gains one electron. It makes sense to assume that the formula for sodium chloride is NaCl. To form the compound, every sodium atom needs one chlorine atom, so their final ratio should be 1:1.

Chemists now know enough about the chemical elements to use this method with confidence. The tendency of any given element to lose or gain electrons in forming a compound is called its valence. The valence of sodium, for example, is +1, and the valence of chlorine, −1. Using valences, chemists can write the formulas for most chemical compounds with a high degree of accuracy.

Molecular formulas are the simplest kind of formulas to write because they tell only the minimum amount of information: the kind and number of atoms present in a compound. Structural formulas are a more complex type of formula because they also show how the atoms in a molecule are arranged in space.

The structural formula for water is H—O—H. The dashed lines (—) in this formula are called bonds. They stand for the electrons that hold each hydrogen atom to the oxygen atom.

Another example of a structural formula is the expanded structural formula. It shows not only the elements present (for example, hydrogen, carbon, and oxygen) and the ratio of those elements in the compound (for example, CH_4O), but also the arrangement of those atoms in comparison to each other. Thus, in an expanded structural formula you can see that three hydrogen atoms are attached to the carbon atom and one hydrogen atom is attached to the oxygen atom.

The only disadvantage of an expanded structural formula is the time and space required to write it out. Because of this disadvantage, chemists have developed an abbreviated kind of structural formula known as a condensed structural formula. The condensed structural formula for methanol can be written as:

CH_3 —OH or CH_3OH

When students are first beginning to study chemistry, they generally have to write expanded structural formulas. With practice, however, they soon develop the ability to write condensed formulas.

Other kinds of chemical formulas contain even more information about the structure of a molecule. For example, the structure of the water molecule shown above (H—O—H) is not quite correct. The hydrogen atoms in a water molecule do not really stick out in opposite directions from each other. Instead, the O—H bonds are bent slightly at an angle to each other.

More sophisticated formulas may be necessary for compounds whose three- dimensional shape is important. The compound known as 1,3-dichlorocyclobutane is an example. The compound consists of four carbon atoms connected to each other in a ring. The ring can be thought of as a square piece of cardboard with one carbon atom at each corner. Attached to two carbon atoms at opposite corners are two chlorine atoms. This molecule can be represented in two different ways, with both chlorine atoms on the same side of the carbon ring or on opposite sides of the ring. The two molecules look different from each other, and two different kinds of 1,3- dichlorocyclobutane can actually be found in the laboratory. Formulas that show special three-dimensional shapes are sometimes known as conformational formulas.

4. Complete the sentences:

1. A chemical formula is a combination of...
2. A chemical formula can be determined in one of two ways...
3. The word “empirical” means...
4. Molecular formula for most chemical compounds also can be determined...
5. Structural formulas are a more complex type of formula because...
6. The only disadvantage of an expanded structural formula is...

5. Read the formulas: H_2O, HNO_3, $AgNO_3$, $C + O_2 \rightarrow CO_2$
$CH_4 + 2O_2 \rightarrow CO + 2H_2O$ 4HC1 + O2 → 2CI2 + 2H2O,
$Na_2CO_3 + CaSO_4 \rightarrow Na_2SO_4 + CaCO_3$, $N_2 + 3H_2 \leftrightarrow 2NH_3$

6. Classify each type of reaction *as synthesis, decomposition, single replacement, double replacement or combustion.*

1) $Cu + O_2 \rightarrow CuO$
2) $H_2O \rightarrow H_2 + O_2$
3) $Fe + H_2O \rightarrow H_2 + Fe_2O_3$
4) $AsCl_3 + H_2S \rightarrow As_2S_3 + HCl$ 5) $Fe_2O_3 + H_2 \rightarrow Fe + H_2O$
6) $CaCO_3 \rightarrow CaO + CO_2$
7) $H_2S + KOH \rightarrow HOH + K_2S$
8) $NaCl \rightarrow Na + Cl_2$
9) $Al + H_2SO_4 \rightarrow H_2 + Al_2(SO_4)_3$
10) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

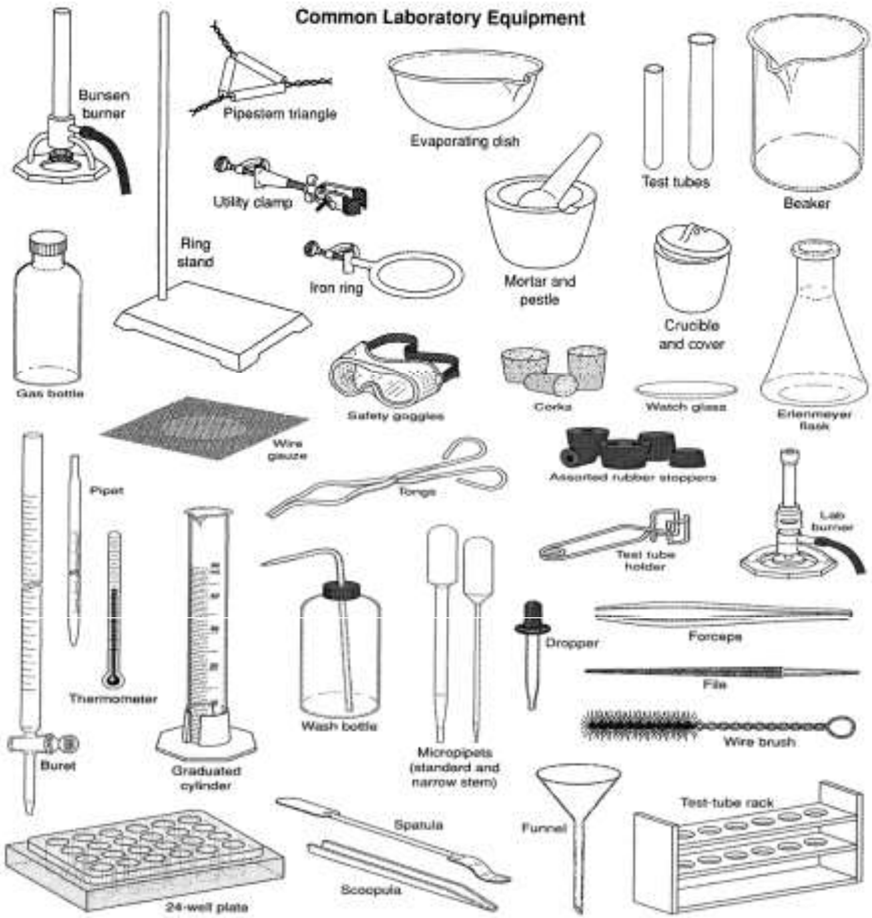
7. Draw a chemical reaction.
Write a word equation for the chemical reaction.
Write the equation in chemical shorthand.

8. Match the chemical formulae with the correct name and give your own definition:

MgO	citric acid
HCL	accytelene
$CaCl_2$	sodium chloride
CO_2	sodium sulphate
C_2H_2	trioxygen
NaCl	magnesium oxide
Na_2SO_4	ethanol
O3	hydrogen chloride
C_2H_5OH	calcium chloride
$C_6H_8O_7$	carbon dioxide

Unit 7
Laboratory

1. Write out all the names of common laboratory equipment. Give their Russian equivalents. Learn them by heart



2. Sort this laboratory equipment into the columns:

goggles	lab tongs	pestle	test tube
Petri dish	thermometer	cylinder	watch glass

mortar desiccator centrifuge burner conductivity tester magnetic stir bar	polarograph furnace crucible flint lighter clay triangle	spot plate balance funnel flask evaporating dish stirring rod hydrometer wash bottle filter paper	ring clamp hood stopper beaker pipet wire gauze spatula hose

glassware	**porcelain**	**tools and utilities**	**apparatuses**

3. Work with a dictionary: find expressions concerning the laboratory equipment that you still miss in the previous table and add them to the list.

4. Reading

In the Chemical Laboratory

Working in the laboratory, chemists use a variety of tools, vessels and other equipment. The following synthetic procedures will make you familiar with some of them.

Cobalt(II) (cobaltous) nitrate hexahydrate $Co(NO_3)_2 \cdot 6H_2O$
Properties:

Red, monoclinic crystals. Density 1.883 g cm^{-3}. Melting point 55.5^{o}C (dissolves in its own water of crystallization). Further heating results in loss of water of crystallization and nitrogen oxides with gradual colour change from red through blue, green to black cobalt(II) oxide CoO. Solubility in water (per 100 g H_2O, anhydrous salt): 84 g at 0^oC, 161 g at 55^oC and 339 g at 91^oC. Fairly soluble in ethanol. Prepared by dissolving cobalt (III) oxide in warm nitric acid solution.

Preparation:

150 ml distilled water was measured in a measuring cylinder (graduated cylinder) and poured into a 500 ml beaker. Then 105 ml concentrated (conc.) nitric acid HNO_3 were added, and the components mixed carefully with a glass rod.

The beaker was placed on a magnetic stirrer equipped with a hot plate, set up in a well-ventilated fume cupboard (fume hood). The solution was stirred and heated until the temperature reached 75^oC. Then 60 g of finely powdered cobalt (III) oxide Co_2O_3 was added in small portions using a laboratory spoon or a spatula. The mixture was stirred continuously, and the temperature maintained at 75 – 85^oC.

When the addition of cobalt oxide was complete, 3 ml saturated methanal (formaldehyde) solution HCHO was added dropwise using a Pasteur pipette, to ensure that all the cobalt (III) had been reduced to cobalt(II). The mixture was stirred and heated for another 30 minutes to produce an almost clear, dark pink solution.

The stir bar was then removed from the beaker and its contents passed through a fluted paper filter placed in a glass funnel. The resulting solution (filtrate) was transferred to a large evaporating dish and the excess water was evaporated until the onset of crystallization. The mixture was cooled to 5 – 10^oC and the separated crystals removed by filtration on a sintered (fritted) glass filter. The crystals were washed with 10 ml ice-cold water, transferred to a Petri dish or large watch glass and air-dried, the temperature being gradually raised from 35 to 45^oC. The yield of pure crystalline cobalt(II) nitrate hexahydrate $Co(NO_3)_2 \cdot 6H_2O$ was 100 g (about 50%).

5. Reading comprehension:

1. How does cobalt (II) nitrate hexahydrate behave on heating?
2. What equipment can be used for stirring mixtures?
3. What glassware would you use to measure out a specified volume of liquid?
4. How is the crystallization of the reaction product achieved?
5. What are the final steps for recovering the product?

6. Read the text:

Butyl benzoate $C_6H_5COOC_4H_9$

Properties

Colourless, oily liquid of balsamic, fruity smell. Melting point -22^{o}C, boiling point 249^{o}C, flashpoint 115^{o}C, density 1.00 g cm^{-3}. Insoluble in water, soluble in most organic solvents. It is prepared by direct esterification of benzoic acid with butanol in the presence of conc. sulphuric acid as catalyst.

Preparation

In a 500 ml round-bottomed flask place a mixture of 30 g (0.246 mol) of benzoic acid, 37 g (46 ml, 0.5 mol) of dry butanol, 50 ml of sodium-dried toluene and 10 g (5.4 ml) of conc. sulphuric acid.
Add a few boiling stones (or small chips of porous porcelain), attach a reflux condenser and boil the mixture gently for 4 hours.
Pour the reaction product into about 250 ml water contained in a separating funnel, rinsing the flask with few ml of water. Add 50 ml diethyl ether, shake the mixture in the funnel vigorously and allow to stand. Run off the lower aqueous layer, collect the upper organic layer and repeat the extraction of the water layer with another portion of ether. Wash the combined ethereal extracts with saturated sodium bicarbonate solution and then with water.
Transfer the extracts to a conical flask containing about 5 g anhydrous magnesium sulphate. Cork the flask, shake for about 5 minutes, and allow to stand for at least half an hour with occasional shaking.

Pass the solution through a fluted paper filter directly into a small round- bottomed flask. Distil off excess solvent using a rotary evaporator and a warm water bath.
Fit the flask with a two-necked adapter, a capillary ebulliator, a short fractionating column and a Liebig condenser. At the end of the condenser attach a rotating distillation receiver that allows at least two fractions to be collected in separate flasks. Distil the residue under reduced pressure, using a water aspirator pump. Collect the forerun separately, then the main fraction boiling at 119 – 120 ^{O}C/11 mm Hg (1.46 kPa). The yield of pure butyl benzoate is 35 g (80%).

7. Reading comprehension

1. How can butyl benzoate be prepared?
2. What equipment is used for carrying out the esterification reaction?
3. How is the crude ester purified from the residual reactants – butanol, benzoic acid
and sulphuric acid?
4. How are ether and toluene removed?
5. What setup is used for the final purification of the product?

8. Which of the following statements concerning the preparation of butyl benzoate are true (T) and which are false (F).

1. Sulphuric acid is used as a catalyst in the esterification of benzoic acid with butanol.
2. This reaction is not sensitive to the presence of water.
3. Boiling stones are used to ensure the smooth, gentle boiling of the reaction mixture.
4. When an aqueous solution is extracted with ether, the reaction product is contained in the lower layer in the separating funnel.
5. Washing ether extracts with sodium bicarbonate solution removes residual butanol from the product.

6. Toluene is removed from the product at a temperature far below its boiling point at normal pressure.
7. The final purification step involves crystallization of the product.

9. Work in small groups and decide which of the Lab Safety Rules are of the utmost importance. Make a TOP TEN list and reason your choice. Then report to the rest of the class.

1. When first entering a science room, do not touch any equipment, chemicals, or other materials in the laboratory area until you are instructed to do so.
2. Never work alone in the laboratory. No student may work in the science classroom without the presence of the instructor.
3. Perform only those experiments authorized by your teacher. Carefully follow all instructions, both written and oral. Unauthorized experiments are not allowed.
4. Do not eat food, drink beverages, or chew gum in the laboratory. Do not use laboratory glassware as containers for food or beverages.
5. Be prepared for your work in the laboratory. Read all procedures thoroughly before entering the laboratory. Never fool around in the laboratory.
6. Always work in a well-ventilated area.
7. Observe good housekeeping practices. Work areas should be kept clean and tidy at all times.
8. Proceed with caution at all times in the laboratory. Notify the teacher immediately of any unsafe conditions you observe.
9. Dispose of all chemical waste properly. Never mix chemicals in sink drains. Sinks are to be used only for water. Check with your teacher for disposal of chemicals and solutions.
10. Labels and equipment instructions must be read carefully before use. Set up and use the equipment as directed by your teacher.

11. Keep hands away from face, eyes, mouth, and body while using chemicals or lab equipment. Wash your hands with soap and water after performing all experiments
12. Experiments must be personally monitored at all times. Do not distract other students or interfere with the laboratory experiments of others.
13. Know the locations and operating procedures of all safety equipment including: first aid kit(s) and fire extinguisher. Know where the fire alarm and the exits are located.
14. Know what to do if there is a fire drill during a laboratory period; containers must be closed, and any electrical equipment turned off.
15. Any time chemicals, heat, or glassware are used, students will wear safety goggles. NO EXCEPTIONS TO THIS RULE!
16. Contact lenses may not be worn in the laboratory.
17. Dress properly during a laboratory activity. Long hair, dangling jewellery, and loose or baggy clothing are a hazard in the laboratory. Long hair must be tied back, and dangling jewellery must be secured. Shoes must completely cover the foot. No sandals allowed on lab days.
18. A lab coat or smock should be worn during laboratory experiments.
19. Report any accident (spill, breakage, etc.) or injury (cut, burn, etc.) to the teacher immediately, no matter how trivial it seems. Do not panic.
20. If you or your lab partner is hurt, inform the teacher immediately. Do not panic.
21. If a chemical splashes in your eyes or on your skin, immediately flush with running water for at least 20 minutes.
22. All chemicals in the laboratory are to be considered dangerous. Avoid handling chemicals with fingers. Always use tweezers. When making an observation, keep at least 1 foot away from the specimen. Do not taste, or smell any chemicals. If you need to identify a smell, cup your hand and waft.

23. Check the label on all chemical bottles twice before removing any of the contents. Take only as much chemical as you need.
24. Never return unused chemicals to their original container. 25. Never remove chemicals or other materials from the laboratory area.

Unit 8
Oxygen and Hydrogen

1. Read the texts, compare properties, facts and discovery of two elements

a) Oxygen

Breathe in … breathe out. Ahh. Hooray for oxygen, the element that keeps much of life on Earth humming.

Element No. 8 on the Periodic Table of the Elements is a colorless gas that makes up 21 percent of Earth's atmosphere. Because it's all around, oxygen is easy to dismiss as dull and inert; in fact, it's the most reactive of the non-metallic elements.

Earth has been oxygenated for about 2.3 billion to 2.4 billion years, and levels began to creep up at least 2.5 billion years ago, according to a 2007 NASA-funded study. No one knows quite why this lung-friendly gas suddenly became a significant part of the atmosphere, but it's possible that geologic changes on Earth led to oxygen produced by photosynthesizing organisms sticking around, rather than being consumed in geologic reactions, according to the study researchers.

Breath of life

Oxygen is the third most abundant element in the universe, according to the Thomas Jefferson National Accelerator Facility. However, its reactivity made it relatively rare in early Earth's atmosphere.

Life today depends heavily on oxygen, but the initial build-up of this element in the atmosphere was nothing short of a disaster. The new atmosphere caused a mass extinction of anaerobes, which are organisms that don't require oxygen. Anaerobes that were unable to adapt or survive in the presence of oxygen died off in this new world.

Fast forward — way forward. The first inkling humans had of the existence of oxygen as an element was in 1608, when Dutch inventor Cornelius Drebbel reported that the heating of saltpeter (potassium nitrate) released a gas, according to the Royal Society of Chemistry (RSC). The identity of that gas remained a mystery until the 1770s, when three chemists converged on its discovery more or less at the same time. English chemist and clergyman Joseph Priestly isolated oxygen by shining sunlight on mercuric oxide and collecting the gas from the reaction. He noted that a candle burned more brightly in this gas, according to the RSC, thanks to oxygen's role in combustion.

Priestly published his findings in 1774, beating out Swiss scientist Carl Wilhelm Steele, who had actually isolated oxygen in 1771 and written about it, but not published the work. Oxygen's third discoverer was Antoine-Laurent de Lavoisier, a French chemist who gave the element its name. The word comes from the Greek "oxy" and "genes," meaning "acid-forming."

Oxygen has eight total electrons — two orbit the nucleus in the atom's inner shell and six orbit in the outermost shell. The outermost shell can hold a total of eight electrons, which explains oxygen's tendency to react with other elements: Its outer shell is incomplete, and electrons are thus free for the taking (and giving).

Just the Facts:

-Atomic Number (number of protons in the nucleus): 8
-Atomic Symbol (on the Periodic Table of Elements): O
-Atomic Weight (average mass of the atom): 15.9994
-Density: 0.001429 grams per cubic centimeter
-Phase at Room Temperature: Gas
-Melting Point: minus 361.82 degrees Fahrenheit (minus 218.79 degrees Celsius)
-Boiling Point: minus 297.31 degrees F (minus 182.95 degrees C)

-Number of isotopes (atoms of the same element with a different number of neutrons): 11; three stable
-Most common isotopes: O-16 (99.757 percent natural abundance)
-As a gas, oxygen is clear. But as a liquid, it's pale blue.
-If you've ever wondered what swimming in a pool of liquid oxygen would be like, the answer is: very, very cold, according to Carl Zorn of the Thomas Jefferson National Accelerator Facility. Oxygen must get down to minus 297.3 F (minus 183.0 C) to liquefy, so frostbite would be a problem.
-Too little oxygen is problematic. So is too much. Breathing 80 percent oxygen for more than 12 hours irritates the respiratory tract and can eventually cause deadly fluid build-up, or edema, according to the University of Florida and the company Air Products.
-Oxygen is one tough cookie: A 2012 study published in the journal Physical Review Letters found than an oxygen molecule (O2) can survive pressures 19 million times higher than atmospheric pressure.
-The lowest levels of oxygen ever recorded in human blood were measured near the summit of Mount Everest in 2009. Climbers had arterial oxygen levels of 3.28 kilopascals on average. Compare that to the normal value of 12 to 14 kilopascals, and the mountaineering term "death zone" makes plenty of sense. The findings were published in the New England Journal of Medicine.
-Thank goodness for an atmosphere of 21 percent oxygen. About 300 million years ago, when oxygen levels reached 35 percent, insects were able to grow super-large: Think dragonflies with the wingspans of hawks.

b) Hydrogen

The most abundant element in the universe, hydrogen is also a promising source of "clean" fuel on Earth.

Named after the Greek words *hydro* for "water" and *genes* for "forming," hydrogen makes up more than 90 percent of all of the atoms, which equals three quarters of the mass of the universe, according to the Los Alamos National Laboratory. Hydrogen is essential for life, and it is present in nearly all the molecules in living things, according to the Royal Society of Chemistry. The element also occurs in the stars and powers the universe through the proton-proton reaction and carbon-nitrogen cycle. Stellar hydrogen fusion processes release huge amounts of energy as they combine hydrogen atoms to form helium, according to Los Alamos.

Pure hydrogen gas is scarce in Earth's atmosphere and any hydrogen that actually enters the atmosphere rapidly escapes Earth's gravity, according to the Royal Society. On our planet, hydrogen occurs mainly in combination with oxygen and water, as well as in organic matter such as living plants, petroleum and coal, Los Alamos reports.

Hydrogen discovery

Robert Boyle produced hydrogen gas in 1671 while he was experimenting with iron and acids, but it wasn't until 1766 that Henry Cavendish recognized it as a distinct element, according to Jefferson Lab. The element was named hydrogen by the French chemist Antoine Lavoisier.

Hydrogen has three common isotopes: protium, which is just ordinary hydrogen; deuterium, a stable isotope discovered in 1932 by Harold C. Urey; and tritium, an unstable isotope discovered in 1934, according to Jefferson Lab. The difference between the three isotopes lies in the number of neutrons each of them has. Hydrogen has no neutrons at all; deuterium has one, while tritium has two neutrons, according to Lawrence Berkeley National Laboratory. Deuterium and tritium are used as fuel in nuclear fusion reactors, according to Los Alamos.

Hydrogen combines with other elements, forming a number of compounds, including common ones such as water (H_2O), ammonia (NH_3), methane (CH_4), table sugar ($C_{12}H_{22}O_{11}$), hydrogen peroxide (H_2O_2) and hydrochloric acid (HCl), according to Jefferson Lab.

Hydrogen is typically produced by heating natural gas with steam to form a mixture of hydrogen and carbon monoxide called syngas, which is then separated to produce hydrogen, according to the Royal Society.
Hydrogen is used to make ammonia for fertilizer, in a process called the Haber process, in which it is reacted with nitrogen. The element is also added to fats and oils, such as peanut oil, through a process called hydrogenation, according to Jefferson Lab. Other examples of hydrogen use include rocket fuel, welding, producing hydrochloric acid, reducing metallic ores and filling balloons, according to Los Alamos. Researchers have been working on developing the hydrogen fuel cell technology that allows significant amounts of electrical power to be obtained using hydrogen gas as a pollution-free source of energy that can be used as fuel for cars and other vehicles.
Hydrogen is also used in the glass industry as a protective atmosphere for making flat glass sheets, while the electronics industry, it is used as a flushing gas in the process of manufacturing silicon chips, according to the Royal Society.

Just the facts

-Atomic number (number of protons in the nucleus): 1
-Atomic symbol (on the Periodic Table of Elements): H
-Atomic weight (average mass of the atom): 1.00794
-Density: 0.00008988 grams per cubic centimeter
-Phase at room temperature: Gas
-Melting point: minus 434.7 degrees Fahrenheit (minus 259.34 degrees Celsius)
-Boiling point: minus 423.2 F (minus 252.87 C)
-Number of isotopes (atoms of the same element with a different number of neutrons): 3 common isotopes, including 2 stable ones
-Most common isotope: 1H, natural abundance 99.9885 percent
-Hydrogen is the main component of Jupiter and the other gas giant planets, according to Los Alamos.

-The first gas balloon flight was launched in Paris in 1783 and the gas used in the balloon was hydrogen, according to the National Balloon Museum. Its use in filling airships ended when the Hindenburg caught on fire, according to the Royal Society.
-NASA uses hydrogen as rocket fuel to deliver crew to space.
-Liquefied hydrogen is extremely cold and it can cause severe frostbite when it comes into contact with skin.
-Hydrogen is about 14 times lighter than air, according to "The Principles of Chemistry."
-Lavoisier, the French chemist who gave hydrogen its name, served as a financier and public administrator before the French Revolution and was executed during the revolution, according to Encyclopedia Britannica.
-About 3 billion cubic feet of hydrogen are produced in the United States per year, according to Los Alamos.
-Hydrogen has the lowest density of all gases, according to the Royal Society.
-Hydrogen is the only element whose three common isotopes – protium, deuterium and tritium – have been given different names, Los Alamos reports.

2. True or False

1. Oxygen is the most reactive of the non-metallic elements.
2. Oxygen is the second most abundant element in the universe, according to the Thomas Jefferson National Accelerator Facility.
3. English chemist and clergyman Joseph Priestly isolated oxygen by shining sunlight on mercuric oxide and collecting the gas from the reaction.
4. Oxygen's third discoverer was Antoine-Laurent de Lavoisier, a French chemist who gave the element its name.
5. The word *oxygen* comes from the Greek "oxy" and "genes," meaning "metal-forming."
6. The lowest levels of oxygen ever recorded in human blood were measured near the summit of Mount Everest in 2009.

7. Robert Boyle produced hydrogen gas in 1671 while he was experimenting with iron and acids.
8. The element was named hydrogen by the French chemist Antoine Lavoisier.
9. On our planet, hydrogen occurs mainly in combination with oxygen and carbon.
10. Hydrogen has three common isotopes: protium, deuterium, and tritium.

3. Read the text: 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 be sure, air breathing animals would die within a few minutes if the supply of oxygen in the atmosphere stopped suddenly. When oxygen combines with an element, it forms a product which is called an oxide. The process is called oxidation. There are only a few elements which are attacked by oxygen. Among the substances which are unaffected by it we should mention inert gases.

Combinations with oxygen often liberate heat and light in this 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 they take 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 which is liberated by very slow oxidation such as rusting of metals and the decay of wood is the same as that which is 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.

4. Match English words and word combinations with Russian equivalents.

1.the most widely distributed element	a. передаваться
2. we should mention	b. подача кислорода
3. to liberate heat	c. температура воспламенения
4. have to be heated	d. быстрое сгорание
5. to be necessary to the maintenance of	e. наиболее распространенный элемент
6. supply of oxygen	f. гниение древесины
7. kindling point	g. коррозия металлов
8. rusting of metals	h. нам следует упомянуть
9. rapid combustion	i. быть необходимым для поддержания
10.decay of wood	j. следует нагреть
11. to be radiated	k. выделять тепло

5. Fill in the gaps with the words given below:

a. attacked b. unless c. combining d. inert gases e. to maintain f. supply g. oxygen h. called i. liberate

1. ____1____ is the most widely spread element on the surface of the globe, and it is
necessary ____2_____ life.)
Air breathing animals would die very quickly, if the ___3____ of oxygen in the
atmosphere stopped.
_____4______ with an element, oxygen forms a product ____5____ an oxide.
Only a few elements are ____6_____ by oxygen.
Among the substances unaffected by oxygen____7______ should be mentioned.
Combinations with oxygen often ____8_____ heat and light.
There are some elements not catching fire ___9_____ heated.

6. Read the text : Reactions of Hydrogen

Hydrogen (H_2) is a diatomic gas that is tasteless, colourless, and odourless. The element hydrogen (H) has the lowest atomic weight (1.008 amu), and is the least dense of any known substance. Because of hydrogen's low density ($1/14^{th}$ the density of air), balloons filled with hydrogen will float. Because of the hydrogen molecule's small size, it will diffuse through many substances. Hydrogen gas is extremely flammable and will react with oxygen to form water with a release of a great deal of heat. The Hindenburg Zeppelin was destroyed in 1937 because of this reaction. Helium is used nowadays because of its inert behavior. The element hydrogen is the ninth most abundant element on earth, but is the third most common element found in all known compounds. The sun is made up almost entirely of hydrogen gas, which is continually undergoing fusion. Hydrogen gas can be generated in the laboratory by various chemical means.

Using the bottle of hydrogen, various experiments will be conducted to demonstrate the properties of hydrogen gas (H_2). Remember that hydrogen in its pure form will NOT BURN. It will only burn if it is mixed with oxygen.

REMEMBER SAFETY PROCEDURES FOR WORKING WITH HYDROGEN AND ACIDS

1. Wear protective goggles at all times.

2. Keep open flames away from hydrogen generators. 3. If acid gets on your skin, flush the skin with water. 4. Do not touch sodium metal with your skin

Unless instructed otherwise, do all the experiments with the mouth of the gas-collecting bottle pointed downward.

1. Grasp a wood splint with a pair of tongs and light the splint.
2. Remove the gas-collecting bottle containing the air- hydrogen mixture (1st bottle), and at arms length, insert the burning splint to the bottom of the bottle. Remember to keep the mouth of the bottle face down.
3. Using the second bottle of hydrogen (H_2), insert the burning splint to the bottom of the bottle for three seconds.
4. Bring the splint to the mouth of the bottle.
5. Reinsert the splint to the bottom of the bottle.
6. Take the third gas collecting bottle and place on the lab bench with the mouth of the bottle upward. Let stand for one minute.
7. Bring a burning splint to the mouth of the third bottle.
8. Place a glass plate underneath the fourth bottle of hydrogen and remove from the water.
9. Turn mouth upward with the glass plate on top. Place the empty third gas- collecting bottle on top of the gas plate mouth downward.
10. Quickly remove the glass plate so that mouth of both bottles are connected.

11. After two minutes, reinsert the glass plate between the two bottles. Raise the top bottle straight up and apply a burning splint into the mouth of the bottle.
12. Invert the bottom bottle so that the mouth is downward. Remove the glass plate and insert a burning splint into the mouth.

7. What information does the text "Reactions of hydrogen" include?

1. Occurrence of H on the Earth.
2. Description of an experiment.
3. Production of Hydrogen.
4. Safety rules while working with H in the laboratory.
5. Physical properties of Hydrogen.
6. The discovery of Hydrogen.
7. Chemical properties of Hydrogen.

8. Answer the following questions:

1. How many atoms does a molecule of hydrogen gas consist of?
2. What element has the lowest atomic weight?
3. Why does Hydrogen diffuse through many substances?
4. When does Hydrogen burn?
5. Why must the mouth of the gas-collecting bottle be pointed downward?

9. State which of the following statements are true (T), false (F) or not mentioned (NM) in the text:

1. There are many elements that are more important than oxygen.
2. Oxygen is very reactive.
3. Oxygen is a bluish coloured gas.
4. The reaction of oxygen and hydrogen results in formation of water.
5. Combinations with oxygen seldom liberate heat.
6. Liquid oxygen boils at -185.5°C.
7. The amount of heat liberated on oxidation doesn't depend on the rate of oxidation.

8. The combination of an element and oxygen is called an acid.
9. Hydrogen gas is extremely flammable.
10. The formation of water through the combination of oxygen with hydrogen is not
accompanied with heat liberation.

Unit 9
Branches of chemistry

1. Read and translate.

Today, chemistry has become a very diverse subject with large numbers of branches. Modern chemistry can be categories into five main branches which are discussed below.

Main Branches of chemistry

The five main branches of chemistry are Physical chemistry, Analytical chemistry, Inorganic chemistry, Organic chemistry, and Biochemistry.

Physical Chemistry

As from the name Physical Chemistry is the combination of Physics and Chemistry. Physical Chemistry has a good overlap with some of the branches of Physics. It is a sub-branch of science that deals with the study of macroscopic properties like pressure, volume etc.; atomic properties like ionization energy, electronegativity, valency etc. It also deals with the structure of matter and energy.

Some of the areas of study in Physical Chemistry are mentioned below:

Chemical Kinetics: It is the study of rates of chemical reaction.

Thermochemistry: It is an area pertaining to thermodynamics which deals with heat in the chemical system and its relation to work.

Surface Chemistry: It is an area of the study of chemical processes at surfaces of materials.
Photochemistry: It is the study of chemical reactions which take place in the presence of light.
Spectroscopy: It concerns with electromagnetic radiations and how they interact with atoms and molecules.
Statistical Mechanics: It is the statistical study of large numbers of atom and molecules. Statistical Mechanics is one of a subject where Physics and Chemistry overlap each other.
Quantum Chemistry: It is an application of Quantum Mechanics to the chemical system.
Electrochemistry: It is a branch of physical chemistry which deals with chemical changes involving the movement of electrons between the electrodes.
Femtochemistry: It is the study of chemical reactions in femtoscale (10^{-15} seconds). It helps us to understand each and every movement of molecules.

Analytical Chemistry

It is a branch of Chemistry that focusses on qualitative and quantitative methods to analyse properties of matter. In short, it deals with the analysis of chemicals. It has huge applications in chemical industries to maintain the quality of the final finished product. In real life, the steps in the analysis are separation, identification and finally quantification. In separation, we separate the constituents from the mixture. After isolating the desired sample, we identify its constituent by qualitative analysis. And finally, we estimate the concentration of analytes by quantitative analysis.
There are two classical methods used in Analytical Chemistry: *qualitative and quantitative*. The qualitative method involves identification of chemical constituents (atoms, molecules, ions etc.) in the substances. In the quantitative method determines the concentration of a substance in a given sample. With progress in

science and technology, we are able to develop various instruments which can give better accuracy and precision.
Analytical Chemistry is not only about the analysis of substances, but also improving the existing analysis techniques and developing new ones.

Some of the common analysis methods are as follows:
Flame tests: The test involves subjecting a given sample to the flame (reducing or oxidizing) and then observing the colour of the flame. The colour of the flame gives us an idea of a constituent present in the sample. This test is hardly used in industries or in a professional world.
Chemical tests: It is used to identify functional groups in a given sample by conducting a series of chemical reaction on the sample.
Titrations (or Volumetric analysis): It involves the addition of a known titrant in the solution until the equivalence point is reached.
Gravimetry: It is a quantitative technique that is used to estimate the amount of substance present based on the difference of mass after a change.
Chromatography: It is a separation technique that consists of mobile phase (a fluid carrying a given sample) which flows on the stationary phase. Based on the affinity of the mobile phase ingredients towards the stationary phase, the retention of ingredients on the stationary phase takes place.
Spectroscopy: It is the study of how atoms and molecules interact with electromagnetic radiations.
Electrochemical analysis: It is a method of analysis in which the analyte is studied by passing electricity and measuring voltage and current over time.
Electrophoresis: It is a separation method in which dispersed particles are separated under the influence of an electric field.

Inorganic Chemistry
It is a branch of Chemistry which deals with the study of inorganic compounds. Inorganic compounds are compounds which do not

contain carbon-hydrogen bond. Inorganic compounds largely found beneath the earth surface: rocks and minerals, and others are produced in chemical industries. Inorganic chemicals have applications in paint, pigment, coating, fertilizer, surfactant, disinfectant, solar power industries. The largest inorganic chemicals produced in the world are sulphuric acid, hydrogen, nitrogen, ammonia, chlorine, phosphorus pentaoxide, nitric acid, hydrochloric acid, sodium hydroxide.

Some of the areas in Inorganic chemistry are as follows:

Coordination Chemistry: It consists of the study of coordination complexes. Coordination complexes are composed of a centre atom typically a metal surrounded by ligands or complexing agent.

Organometallic Chemistry: It is the study of organometallic compounds which consist of compounds having a metal-carbon-hydrogen bond (organometallic bond). This field is included in both organic as well as inorganic chemistry.

Bioinorganic Chemistry: This covers the interaction of inorganic species like metals in cells and tissues.

Solid-State Chemistry (or Material Chemistry): It is the study of properties, structures of solid-state phase. It is a part of Solid-State Physics.

Organic Chemistry

It is a branch of Chemistry which deals with the study of organic compounds. organic compounds are compounds which contain carbon-hydrogen bond. Carbon is capable of forming long C-C chains (called catenation). It is because of this property of carbon, it forms a tremendous number of compounds. This is a reason why organic compounds exceed inorganic compounds. Other than carbon and hydrogen, the elements widely found in organic compounds are oxygen, nitrogen, sulphur, phosphorus, and halogens (fluorine, chlorine and iodine). Organics compounds are used in agriculture, food, medicine, polymer, textile, insecticide, pharmaceutical, rubber, fuel, and consumer good industries. Some of the industrial important organic chemicals are methane, ethylene, propylene, 1,2-dichloroethylene, methanol, isopropyl alcohol, butane, acetylene, polystyrene, glycerol, acetone, acetic acid, acetic anhydride, urea, toluene, phenol, aniline. glucose, fructose, starch etc.

Important areas in Organic Chemistry are mentioned below.

Polymer Chemistry: It deals with the synthesis and properties of polymers.
Organometallics Chemistry: It is the study of organometallic compounds which consist of compounds having a metal-carbon-hydrogen bond (organometallic bond). This field is included in both organic as well as inorganic chemistry.
Physical Organic Chemistry: It is the study of reactivity and structure of organic chemicals.
Stereochemistry: It is a chemistry that studies stereoisomers. It focusses on the spatial arrangement of atoms.
Medicinal Chemistry: It involves the application of chemistry for medicine and drug development.
Bioorganic Chemistry: It is the combination of Organic and Biochemistry.

Biochemistry

Biochemistry is the field of science that emphases on the study of chemical processes inside the biological system. Biochemistry is a new field compare to the above branches of chemistry. Professionals in this arena of Chemistry are called Biochemist. Biochemistry focusses on uses of chemistry to better understand biological systems like respiration, digestion, cellular metabolism etc. Biochemists work on diseases like cancer to develop better treatment; they also study molecular genetics to improve genes.
The important areas of study in Biochemistry are as follows:
Molecular Genetic: It involves the studies of genes. It is closely related to genetic engineering.
Agricultural Biochemistry: It focusses on the implementation of biochemistry to improve agriculture production.

Molecular Biochemistry: It deals with the study of macromolecules like proteins, membranes, enzymes, nucleic acids, amino acids, viruses etc.
Clinical Biochemistry: It is all about diseases and related topics.
Immunochemistry: It is a branch of biochemistry that concerned with chemical reaction associated with the immune system.

Other Disciplines of Chemistry

Chemistry is not limited to the above five branches, but there are many other specialized branches of chemistry developed over a period of time.

Astrochemistry

It is the study of chemical reactions in outer space. Astrochemistry is closely related to Astronomy.

Geochemistry

It is the study of chemical systems in the geological environment. Geochemists works on studying activities like mining, oil extraction, the formation of rocks, petroleum formation.

Food Chemistry

Food chemists study the various biological constituents of food. The main constituent in any biological system are carbohydrates, fats and proteins. Food chemists ameliorate the quality of food. The quality of food can be improved by increasing the lifespan of food, by proper storage and maintaining the sensory aspects like odour, colour, the taste of food.

Chemical Engineering

Chemical Engineers work can be divided into two main categories: innovating new products and industrial applications. In industries, they work to process chemicals, troubleshoot the problems, maintain the daily production quantity. This is a mostly field job. They also work in developing and improving new methods for better production of chemicals. While in a lab, they mostly spend time on developing new materials.

Forensic Chemistry

Forensic Chemistry is an application of Analytical Chemistry. It involves the analysis of various samples by analytic methods to identify criminals. Forensic chemists work in labs and are mainly employed by government agencies.

Nuclear chemistry

This branch of chemistry deals with the study of reactions at the atomic level like fission, fusion. Nuclear scientists work in developing nuclear bombs, nuclear power. The conversion of nuclear power into electricity is one of the main achievements of nuclear scientists.

Neurochemistry

It is the study of chemicals associated with the nerves system (also called as neurochemicals). Neurochemicals include glutamate, glycine, dopamine, norepinephrine, adenosine, histamine etc.

Cosmochemistry

It is the study of chemical components of matter in the universe.

Atmospheric Chemistry

It focusses on the understanding of the complex chemical processes in the atmosphere of a planet. It is a very important area to understand climate change.

Phytochemistry

It is closely connected to botany. It is the study of Phytochemicals which chemicals obtained from plants.

Ocean Chemistry

It is also called Marine Chemistry which deals with the study of chemical processes in oceans.

Petrochemistry

The branch of Chemistry dealing with crude oil, petroleum, natural gas and its processing and refining. Petrochemistry is a very important segment since most of our energy requirements are fulfilled by end crude oil products like gasoline, diesel, LPG etc.

Mathematical Chemistry

It is an implementation of Mathematics to model various chemical processes. It is a combination of Mathematics and Chemistry.

Mechanochemistry

In Mechanochemistry, chemical reactions are brought by applying mechanical energy to molecules. It is an emerging field. It is a combination of chemistry and mechanical engineering.

Radiochemistry

It deals with the use of radioactive substances to study ordinary chemical reactions.

Sonochemistry

It is a branch of science that focusses on how ultrasonic waves (high-frequency sound) affect chemical systems.

Supramolecular Chemistry

This branch involves the study of intermolecular forces formed by non-covalent bonds like Van der Waal forces, hydrogen bonds, metal coordination etc.

Industrial Chemistry

It is the study of industrial processes to convert raw materials into products. It comes between lab-based research and industrial scale production. An industrial chemist and a chemical engineer are closely related. an industrial chemist is focused more on the chemistry aspect of the process. While a chemical engineer is more concerned with up-scaling the process in an economical way.

Environmental Chemistry

Environment Chemistry deals with the study of chemical interactions in air, soil and water environment. Environmental chemists apply the knowledge of chemistry to understand the environment.

Green Chemistry

Green Chemistry aims to reduce the harmful substances in the environment by improving chemical processes and developing alternative routes. It is also called Sustainable Chemistry; It should not be confused with Environment Chemistry.

2. Choose one branch of chemistry and expand the information.

3. Read the following article about environmental chemistry and fill the gaps with appropriate forms of the words in brackets. Use prefixes and suffixes.

Environmental chemistry is the______________(science) study of the________________(chemistry) and __________________(biochemistry) phenomena that occur in _______________ (nature) places. It can be defined as the study of the sources, reactions, transport, effects, and fates of _______________ (chemistry) species in the air, soil, and water environments; and the effect of human activity on these. Environmental chemistry is an ____________________(discipline) science that includes ___________________(atmosphere), ______________ (aqua) and soil chemistry, as well as ____________________ (heavy) relying on _________________(analysis) chemistry and being related to ___________________(environment) and other areas of science.
Environmental chemistry involves first _________________(understand) how the uncontaminated environment works, which chemicals in what concentrations are present, and with what effects. Without this it would be _______________(possible) to __________________(accurate) study the effects humans have on the environment through the release of chemicals.

4. What branches of chemistry are essential for environmental chemistry?

5. What is the meaning of the following terms? Match them with their definitions.

a) pollutant
b) contaminant
c) biochemical-oxygen demand (BOD)

d) CFCs
e) pH
f) dissolved oxygen (DO)

_______________ a class of volatile compounds consisting of carbon, chlorine, and fluorine. Commonly called **freons**, which have been in refrigeration mechanisms, and, until banned from use several years ago, as propellants in spray cans.
_______________ a substance that has a **detrimental impact** on the environment it is in
_______________ a substance present in the environment as a result of human activity, but without **harmful** effects. However, it is sometimes the case that toxic or harmful effects from contamination only become apparent at a later date.
_______________ one of the most important **indicators** of the condition of a water body, necessary for the life of fish and most other aquatic organisms.
_______________ the amount of oxygen, expressed in **milligrams per liter**, that is removed from aquatic environments by the life processes of micro-organisms. It is used in water quality management and **assessment**, ecology and environmental science.
______________ the measure of the **acidity** or **alkalinity** of a solution

6. Discuss in pairs or in small groups the following statements.

- 10 ways how to save our planet
- What is your greatest environmental concern, and why?
- Common types of alternative energy – definitions and resources (e.g. solar power,
wind power, offshore wind power, hydro-electric power, geothermal energy, tidal
power, hydrogen, biofuel, ethanol, biomass, ...)
- What should governments do to tackle pollution?

- Nuclear energy plants are the most sophisticated and complex energy systems ever
designed.

7. Prepare some interesting news connected with environmental protection. Use different sources e.g. the latest news , the Internet, newspaper articles or professional magazines. Present the news briefly and discuss it in the class.

Unit 10
A Career in chemistry

1. Read and translate.

The career options in chemistry are not limited to teaching chemistry or working as lab assistants.
Want to enrol in a course that will open doors to jobs that you never imagined? Then a Chemistry qualification could be just for you. Think of it - whatever we eat, wear, the technology we use - depends on Chemistry! A chemist can play multiple roles – they can protect our environment and food supply, develop medicines that combat diseases, assist in developing technology to make our lives easier and do much more.
When it comes to careers in chemistry, there isn't enough awareness of the large number of options available. About one-third of chemistry graduates pursue traditional lab work. You can find a number of possibilities in research laboratories, especially in those owned by petroleum companies. By specializing in Biochemistry, you can widen your scope by availing conservation, environmental and medical opportunities.
A chemist gets to transform mundane, everyday stuff into incredible things. Some discover cures for AIDS, a few keep check of the ozone activity and there are chemists who help create

utilities that make life easier by implementing concepts such as induction, hydration and malleability.

Who do you think ensures the smell and taste of chocolates or roses? – Chemists! – They are the ones who check if your deodorants and antiperspirants are operating properly and evaluates yours perfumes. Sounds much better than a boring desk job?

How tasty was what you ate for breakfast? Chemists play a major role in creating foods that are tempting to our palette. Chemists also ensure that food items you buy from supermarkets are well-preserved and safe for consumption.

Forensic chemists analyse evidences that are brought in from crime scenes. Their findings can help solve crimes. If a case goes to court, giving evidence is a vital part of a forensic chemist's job. The forensic chemist impartially explains the evidence to the jury and aids the jury in reaching a verdict.

If you love science and have a passion for writing, why not combine the two? Science journalism is a field, which enables you to write for specialist magazines or public communications universities and government departments.

As an environmental engineer, you can solve environmental problems and work in different avenues, such as pollution control, public health issues, climate change and wildlife conservation. What about contributing to help make a greener city, perhaps by creating greener cars?

Now that does sound quite interesting. Let’s delve into the details of the career options in chemistry.

What are the career opportunities in the field of chemistry?

A sea of career options, starting from in industry to academia, are available for Chemistry graduates. Pick the one that's your call:

1.Research & Development
2.Analytical Chemist
3.Forensic experts
4.Cheminformatics Data Scientist
5.Crystallographer

6.Chemical Engineer
7.Industrial Management
8.Chemical Health & Safety Professional
9.Quality Assurance officer
10.Regulatory Affairs Pharmacists
11.Toxicologist
12.Quality Controller
13.Technical Support Professional
14.Formulation Chemistry
15.Process Chemistry
16.Hazardous Waste Management chemists
17.Textile Chemist
18.Science Policy Analysts
19.Pharmacologists
20.Professor

2. Which of these characteristics should a good chemist have? Explain why.

patient, funny, good interpersonal and communication skills, optimistic, creative, flexible, talkative, punctual, ambitious, competitive, cooperative

3. Choose one profession and give more information.

4. Read the interview

Career Interview: Analytical Chemistry as a Mature Student

April 1, 2018
Author: Amelia Powell
Dr. Joy Bennett is a Doctor in Chemistry with aPh.D. in Organic/Inorganic Chemistry from Coventry University in the UK. Having previously graduated with a BSc in

Pharmaceutical Chemistry as a mature student, she now works as a chemist doing analytical chemistry.

Q: What does your job entail?

A: My job entails testing unknown hazardous waste chemicals to ascertain the safest method of disposal. The samples must be tested to ensure that *'it is what is says on the label*', as often it is not. Customers will sometimes say that their waste chemicals are non-hazardous to get a cheaper disposal rate. Sometimes the customer can have containers of chemicals that need disposing of and they have no idea what is inside. It is my job to find out what the chemical is and what concentration it is. To do this I have a number of analytical instruments to help determine what the chemicals are.

Q: What led you to decide to work in the field of analytical chemistry?

A:I always had an interest in science, and my preferred subject was chemistry – there was too much drawing in biology and too much maths in physics. After finishing university, most of the chemistry jobs seemed to be in analytical chemistry, specifically in the hazardous waste industry as this is a growing area of business.

Q: Could you briefly describe the academic journey you realised in order to become an analytical chemist?

A: My journey into higher education did not begin until I was 35 years old. I got divorced and had three small children to bring up (aged 3, 5 and 7).I saw an advertisement in the local paper with the header somewhere along the line of "Women, would you like a career in science?". The article was an invitation to an open day aimed at getting women interested in science careers by running a specially designed science course at the local college. It said that the course was designed around school hours and holidays to fit in with busy moms. I became interested and signed up. At enrolment day in the September, I discovered that it was actually part of the "Access

to higher education” course. At this time, I had absolutely no intention of going to university (that was something that clever rich people did). I did, however, want to do the college course as it looked interesting. It was a one-year course and it was fun and I made friends.
Towards the end of the course we had careers meetings and my tutor asked me which university I was going to. When I said I wasn’t, he said that it would be a waste of the course if I didn’t. A friend of mine from the course suggested that we go to university together and car share the journey. We both chose Analytical Chemistry at Coventry University, being the closest one to home as having children meant living in halls was not an option. This was still a thirty-five-mile journey to get there. My friend dropped out after six weeks but I continued. After graduating I needed to get a job with school hours/holidays so I started a Post Graduate Certificate in Education at Warwick University. I got half way through when I realised I wasn’t teacher material. I got a job as a lab technician instead. After about six months, I received a call from a lecturer at Coventry university, asking if I would consider doing a Ph.D.I said yes, and three and a half years later I graduated as a Doctor of Chemistry.It was now time to look for a job and earn some money. The big research companies wanted young graduates to train and were not within commuting distance anyway. I wanted to remain in a lab, so I chose analytical chemistry.

Q: You went to university as a mature student –did that come with any advantages or disadvantages in your opinion?

A: The advantage of being a mature student is that you tend to remain focused on your work no matter what. Not being able to participate in the clubs and societies or go out much socially with the younger students due to family commitments was a big disadvantage, although work-wise this was probably an advantage in disguise. One disadvantage was having to manage time for studying after the children were in bed and juggling childcare with coursework whilst living on a student loan. One big advantage was that I had a very generous maintenance grant from the university, which helped pay for my fuel and child care.

Q: Following your Ph.D., you decided to leave behind the field of research and work in industry instead. Why was this?

A:I had had enough of traveling every day and relocation was not an option. There are no research facilities nearby so I had to find a job. When I stared applying for jobs I found that a lot of companies preferred young ambitious graduates that could be trained and then work their way up in the business over a number of years. As a mature student my length of service would not be as long, i.e. I was too old to get a graduate position. Also, potential employers sometimes felt intimidated by my Ph.D. and would not employ me because they thought I would get bored and leave very soon.

Q: What skills gained during your Ph.D. help with your day to day work?

A: A Ph.D. is not necessary to do this job, but life experience as a mature person helps to determine how to deal with the various hazards that could come through the door.

Q: What are your most and least favourite parts of your job?

A: My least favourite part of the job is writing the reports for the sales team. My favourite part of the job is on a Friday all of the samples have to be cleared from the lab. The majority of the samples that are fairly low hazard can be smashed into a large drum ready for disposal through the process plant before going to landfill. There is something satisfying about hearing the glass smash inside the big drum.

Q: What is the most dangerous chemical you've come across in the lab, and have you ever had any dangerous incidents with the chemicals?

A: The most dangerous chemical I have seen in a lab was picric acid. It must be kept wet because if it's allowed to dry out it is explosive. Whilst at university doing my Ph.D. the waste chemical bottle exploded covering the lab with flammable liquid. This happened because the temperature in the lab was too high due to sun shining through the window into the Winchester full of waste chemicals. I have also had a condenser explode during an experiment covering the fume cupboard with blue liquid which unfortunately stained. Whilst at work I had to go to a company and empty and remove a metal tool box that had been filled with glacial acetic acid. I had to wear a respiratory mask and evacuate the building during the process. The acid had to be secured in a drum then the tool box washed out before it could be loaded onto the lorry for removal. Nerves of steel and a strong stomach were needed.

Q: Are there other pathways to job positions you have held, such as those taken by colleagues?

A: The Environment Agency specifies that chemists working at a hazardous waste plantare educated to undergraduate degree level, preferably with a chemistry degree. There are colleagues who have forensic degrees. One colleague who joined the company as an operative was then taken on as a chemist apprentice and was attending university part time to obtain his degree. The company were paying his fees but in return he had signed a contract of employment so that he could not leave for a certain number of years after completion of this training.

Q: What qualities do you think someone needs to have in order to be successful in this career pathway?

A: To work in an analytical laboratory a person needs to be very methodical and able to prioritise the order of work. It is also very important to have good housekeeping practice. Material and reagents must be ordered and the laboratory kept well stocked and clean and tidy. A clean laboratory is important to prevent cross contamination between samples.

Q: What advice would you give current undergraduate students who might wish to pursue a career in this field?

A: Get plenty of practical experience working in a laboratory. The knowledge of as many instruments as possible would be useful. Enquire about graduate positions that will allow a person to work in various departments so that they can get a taste for different jobs.

5. Roleplay. In pairs, act out a job interview which would be relevant to your field of study (e.g. an applicant for a place in a pharmaceutical company), where one of you will be an HR recruitment specialist and the other one a job applicant. Discuss the specifics of the post, requirements for the position etc.

6. Write a short essay discussing what field of chemistry you would like to specialize in and why.

Translation practice

Text 1
Chemistry: the Science of Molecular Transformations

What is the focus of modern chemistry? At first glance, the answer to this question seems quite simple. Indeed, chemistry deals with substances and their transformations. But let us analyze this statement. First, a few words about substances that are encountered. Take, for example, aluminium hydroxide and basic copper carbonate. These substances are of interest to geologists, because they are the main components of the minerals bauxite and malachite, respectively. Bauxite is used to obtain aluminium, while malachite is a good material for masonry work. Substances such as penicillin and haemoglobin are of interest not only to chemists but also to physicians and biologists. Second, what kind of transformations do substances undergo? Ice transforms into water, helium I transforms into superfluid helium H. These transformations have nothing to do with chemistry: they are the focus of physics, because the melting point of a substance is a physical property.

So what is then a chemical property? It is the ability of a substance to react with another substance. A chemical reaction is the transformation of one molecule into another. During chemical transformations, only molecules (which consist of atoms) are destroyed, while the atoms themselves remain unchanged. Transformations of atoms are studied by physics, or, more precisely, atomic and nuclear physics. We have already mentioned that physics also studies transformations in which neither atoms nor molecules are destroyed. So, it looks like physics borders chemistry on two sides, i.e. "below" (atomic level) and "above" (per molecular level).

Two comments should be made. The first concerns the fact that modem chemists are becoming less and less interested in the nonexcited state of a substance, in its composition and structure.

Of course, unsolved problems in this field still remain, but their solution is within the physicist's scope of interest. And second, branches intermediate to physics and chemistry exist: when chemical processes are studied by physicists, and, conversely, when chemists investigate physical phenomena. For instance, a chemical process, i.e. interaction of two or several molecules, can be interpreted from the physical viewpoint. A branch of science that studies the physical parameters of chemical transformations is called chemical physics. On the other hand, the physical properties of molecular clusters in a solution called a colloidal solution are investigated in colloid chemistry, a branch of physical chemistry.

Both chemical physics and physical chemistry deal with the properties of all types of substances. These sciences are classified according to me techniques used to initiate chemical reactions (e.g. electrochemistry, photochemistry, and radiation chemistry), or according to the investigation methods employed (e.g. magnetic or optical spectroscopy, and kinetic methods).

There is also another classification of the chemical sciences, which distinguishes between types of substances. All substances are divided into either inorganic or organic ones. Organic compounds are various hydrocarbon derivatives, all of them containing carbon atoms. Molecules of inorganic compounds may include any other elements in different combinations. Carbon atoms possess the peculiar feature of combining into chains, rings, and other configurations, so that one molecule may contain a hundred carbon atoms. It is therefore not surprising that the number of compounds comprising carbon atoms is much greater than the number of inorganic compounds. Organic compounds form the basis of living organisms, and a science that deals with the substances and processes occurring in organisms is called biochemistry. Recent years have seen the appearance of one more new branch of chemistry, i.e. bioorganic chemistry, which deals with the organic reactions pro-ceeding in a cell. |Ions of various metals can bind to organic molecules in a living organism to form enzymes (biological catalysts), hemoglobin (the carrier of oxygen), and other important substances. These are the compounds studied in bioinorganic chemistry, a science which appeared a few years ago. There are also other branches of chemistry related to biology, medicine, and agriculture, e.g. pharmaceutical, toxicological, and agricultural chemistries. It is also necessary to mention here a chemistry of high-molecular compounds (polymers). Molecules of these compounds, both organic and inorganic, consist of a large and indefinite number of identical units.

Text 2

In chemistry, what does it mean to be organic?

Out of 118 elements, only one has its own field of study: carbon. Chemists refer to most molecules that contain one or more carbon atoms as organic. The study of these molecules is organic chemistry.

Carbon-based molecules get special attention because no other element comes close to carbon’s versatility. More types of carbon-based molecules exist than all non-carbon ones put together.

Scientists generally define a molecule as organic when it contains not only carbon, but also at least one other element. Typically, that element is hydrogen, oxygen, nitrogen or sulfur. Some definitions say that a molecule must contain both carbon and hydrogen to be organic.

(By the way, in farming, “organic” refers to crops grown without certain pesticides and fertilizers. That use of “organic” is very different from the chemical definitions here.)

Living things are built with organic molecules and operate using organic molecules. Indeed, organic molecules perform the tasks that makes a living thing “alive.”

DNA, the molecular blueprint for our bodies, is organic. The energy we get from food comes from breaking down carbon-based — organic — molecules. In fact, until the 1800s, chemists thought that *only* plants, animals and other organisms could make organic molecules. Now we know better. Our oceans created organic molecules before life even existed. Organic molecules can also be made in the lab. Most medicines are organic. So are plastics and most perfumes. Still, organic molecules are seen as a defining feature of life-forms.

But living things also contain lots of molecules that are not organic. Water is a good example. It makes up about six-tenths of our bodyweight but is not organic. We must drink water to live. But drinking water doesn't satisfy hunger. A hamburger or beans, for instance, contains those organic molecules needed to fuel our bodies' growth.

In living things, organic molecules usually fall into one of four categories: lipids (such as fats and oils), proteins, nucleic acids (such as DNA and RNA) and carbohydrates (such as sugars and starches). These molecules can get big, though still too small to see with just our eyes. Some may even be organic molecules bonded to other organic molecules. The big ones, made by linking a lot of littler ones, are known as polymers.

Carbon: Molecule-maker supreme

Three things make carbon special.

Covalent bonds are those within a molecule where various atoms share an electron. Those tight linkages hold the atoms close to one another. Each carbon atom can form four covalent bonds at once. That's a lot. And it's not just that carbon can form four bonds, but rather that **it *wants* to form four bonds**.

Carbon's covalent bonds come in three types: single, double and triple bonds. A double bond is extra-strong and counts as two of carbon's four desired bonds. A triple bond is stronger still, and counts as three. All these bonds and bond types allow carbon to make many types of molecules. In fact, simply replacing any single bond with a double or triple bond will give you a different molecule.

Carbon atoms tend to link up with other carbon atoms to form chains, sheets and other shapes. Scientists call this ability catenation. Plastic is the name for a family of organic polymers. Their long carbon chains can either be straight or branch out like trees. Each trunk or branch of these polymers is made from a backbone of catenated carbons. Carbon can link into ring shapes, too. Caffeine, a molecule in coffee, is a compact, two-ring, spider-shaped molecule held together by the catenation of carbon atoms. Carbon atoms even connect to form perfectly spherical 60-carbon balls. These are known as buckyballs.

Hydrocarbons: The basis of fossil fuels

Crude oil and natural gas are fossil fuels made from a complex mix of natural organic chemicals, generally known as hydrocarbons. That term is a mash-up of hydrogen and carbon. These molecules are, too.

The simplest hydrocarbon is methane (METH-ain). It's made from a single carbon atom bonded (covalently) to four hydrogen atoms. A two-carbon version, ethane (ETH-ain), holds onto six hydrogen atoms. Add a third carbon — and two more hydrogens — and you get propane. Notice that the end of each name stays the same. Only the first part, or prefix, changes. Here, that prefix tells us how many carbons the molecule holds. (Peek at the back of a bottle of hair conditioner. Try to spot some of these prefixes hidden in the long chemical names.)

Once we reach four bound carbons, new hydrocarbon shapes become possible. Since carbon chains can branch, four carbon atoms (and their hydrogens) may bend and connect into unusual shapes. That results in new molecules.

Beyond hydrocarbons

Even more molecules become possible when something else stands in for one or more of a hydrocarbon's hydrogen atoms. Based on which atom takes hydrogen's place, scientists can predict how the new molecule will act — even before it's been tested.

For example, having just carbon and hydrogen atoms, a simple propane molecule won't dissolve in water. It will be hydrophobic

(Hy-droh-FOH-bik). That means water-hating. The same is true for other oils made of hydrocarbons. Try this: Pour canola oil into water. Watch the oil layer float atop the water. Even if stirred, the oil won't mix.

But if a scientist replaces a few of the hydrogens in those molecules with a bound pair of oxygen and hydrogen atoms — known as a hydroxyl (Hy-DROX-ull) group — the molecule suddenly dissolves in water. It has become water-loving, or hydrophilic (Hy-droh-FIL-ik). And the more hydroxyls added, the more water-soluble the former oil becomes.

So what is inorganic?

Not all carbon-based molecules are organic. Some, such as carbon dioxide (or CO_2), can be "inorganic." The lack of hydrogen is why many chemists classify carbon dioxide this way. To be "organic," these chemists argue, a molecule must combine its carbon with some hydrogens.

Diamonds are also inorganic. They are made solely of carbon atoms. So is graphene. (When stacked in sheets, graphene becomes graphite, the soft black stuff found inside pencils.) Diamond and graphene are made of the same atoms, just arranged differently. Diamond's carbon atoms connect up, down, and sideways to form three-dimensional crystals. Graphene's carbon forms sheets that stack like paper. But the size of those sheets is not standard; it depends solely on the amount of carbon used.

Most scientists argue that diamond and graphene are *inorganic* carbon because neither graphene nor diamond counts as a molecule. At least, not in the strict sense of the word. Molecules should be discrete assemblies of atoms. And though there are endless types of molecules, each type should "have a fixed molecular weight," explains Steven Stevenson. He's a chemist at Purdue University Fort Wayne in Indiana.

A true molecule has a fixed weight because it contains a specific number of atoms that are combined in a particular way. Diamond contains atoms arranged in a specific way — but not a specific

number of atoms. Big diamonds have more atoms than small diamonds. So diamond isn't a true molecule, Stevenson says.
Sugar, on the other hand, is a molecule. And it's organic. A cube of sugar may look diamond-like. But inside, sugar contains bazillions of separate sugar molecules all stuck together. When we dissolve sugar in water, all we do is unstick those true molecules.

And then there are the fullerenes

True molecules made entirely of carbon do exist. Known as fullerenes, these all-carbon molecules come in a variety of shapes, such as buckeyballs and tubes. Are these organic?
"I think it depends on which organic chemist you ask," Stevenson says. He's a fullerene specialist. In 2020, his lab discovered a new family of these molecules called fullertubes. Stevenson refers to the 100-carbon version as simply C_{100}. It shows a notable hue. "I cannot tell you how nice that is," he recalls, to suddenly realize "you're the first one in the world to know that this new molecule is purple."
Fullertubes count as molecules. But are they organic?
"Yes!" Stevenson argues. But he also acknowledges that some chemists would disagree. Remember, many typically define organic molecules as not just having carbon, but also hydrogen. And the new fullertubes? They're just carbon.

Text 3

CO_2 and other greenhouse gases

Carbon dioxide is just one of several chemicals that contribute to the greenhouse effect

Many different gases make up Earth's atmosphere. Nitrogen alone accounts for 78 percent. Oxygen, in second place, makes up another 21 percent. Many other gases comprise the remaining 1 percent. Several (such as helium and krypton) are chemically inert. That means they don't react with others. Other bit players have the ability to act like a blanket for the planet. These have come to be known as greenhouse gases.

Like the windows in a greenhouse, these gases trap energy from the sun as heat. Without their role in this greenhouse effect, Earth would be quite frosty. Global temperatures would average around -18° Celsius (0° Fahrenheit), according to the National Oceanic and Atmospheric Administration (NOAA). Instead, the surface of our planet averages around 15 °C (59 °F), making it a comfy place for life.

Since about 1850, though, human activities have been releasing extra greenhouse gases into the air. This has slowly propelled a rise in average temperatures across the globe. Overall, the 2017 global average was 0.9 degree C (1.6 degrees F) higher than it had been between 1951 and 1980. That's based on calculations by NASA.

Stephen Montzka is a research chemist with NOAA in Boulder, Colo. There are four main greenhouse gases to worry about, he says. The best known is carbon dioxide (CO_2). The others are methane, nitrous oxide and a group that contains chlorofluorocarbons (CFCs) and their replacements. (CFCs are refrigerants that have played a role in thinning the planet's protective high-altitude ozone layer. They are being phased out as part of a global agreement begun in 1989.)

Climate-warming chemicals

Each greenhouse gas, once emitted, rises into the air. There, it helps the atmosphere hold onto heat. Some of these gases trap more heat, per molecule, than do others. Some also stay in the atmosphere longer than others. This is because each has different chemical properties, Montzka notes. They also are removed from the atmosphere, over time, by different processes.

Excess CO_2 comes mainly from burning fossil fuels — coal, oil and natural gas. Those fuels are used for everything from powering vehicles and generating electricity to manufacturing industrial chemicals. In 2016, CO_2 accounted for 81 percent of the greenhouse gases emitted in the United States. Other chemicals are more effective at trapping heat in the atmosphere. But CO_2 is the most abundant of the ones released by human activities. It also sticks around longest.

Some CO_2 gets removed each year by plants as they grow. However, much CO_2 is released during colder months, when plants aren't growing. CO_2 also can be pulled from the air and into the ocean. Organisms in the sea can then convert it into calcium carbonate. Eventually that chemical will become an ingredient of limestone rock, where its carbon can be stored for millennia. That rock-forming process is really slow. Overall, CO_2 can linger in the atmosphere for anywhere from decades to thousands of years. So, Montzka explains, "even if we stopped emitting carbon dioxide today, we would still see warming from that for a very long time."

Methane is the main component of natural gas. It's also released from a host of biological sources. These include rice production, animal manure, cow digestion and the breakdown of wastes put into landfills. Methane accounts for about 10 percent of U.S. greenhouse-gas emissions. Each molecule of this gas is much better at trapping heat than is one of CO_2. But methane does not remain in the atmosphere as long. It gets broken down as it reacts in the atmosphere with hydroxyl radicals (neutrally charged OH ions made from bound atoms of oxygen and hydrogen). "The timescale for methane removal is about a decade," Montzka notes.

Nitrous-oxide (N_2O) made up 6 percent of greenhouse gases emitted by the United States in 2016. This gas comes from agriculture, the burning of fossil fuels and human sewage. But don't let its small quantity make you disregard N_2O's impact. This gas is hundreds of times more effective than is CO_2 at trapping heat. N_2O also can linger in the atmosphere for nearly a century. Each year, only about 1 percent of airborne N_2O gets converted by green plants into ammonia or other nitrogen compounds that plants can use. So this natural N_2O removal "is really slow," Montzka says.

CFCs and their more recent replacements are all manufactured by people. Many have been used as refrigerants. Others are used as solvents for chemical reactions and in aerosol sprays. Together, these made up only about 3 percent of U.S. greenhouse gas emissions in 2016. These gases are only removed when they get locked up in a high layer of the atmosphere. In this stratosphere, high-energy light bombards the chemicals, breaking them apart. But that can take decades, Montzka says.

Fluorine-based chemicals, such as CFCs, he notes, "are potent greenhouse gases, on a per molecule basis." But releases of them are so low that compared to CO_2, their overall impact is quite small. Reducing emissions of methane, N_2O and CFCs will help slow climate change, Montzka notes. "But if we're going to solve this [greenhouse gas] problem, we need to take care of CO_2," he says. "It's contributing the most … and it has this extremely long residence time in the atmosphere."

Text 4
Describing Acids & Bases

We may not realize how much acids and bases affect our lives. Have you ever thought of drinking a can of soda pop and actually drinking acid? Have you looked at bottles of household cleaners and noticed what the main ingredients were? Have you ever heard a shampoo commercial and heard them say that the shampoo was "pH balanced" and wondered what this means and why it is so important for hair? Thanks to the beginning work of scientists in the latter part of the 19th century, we started to learn about acids and bases; our study continued and is constantly growing. Let's begin our study of this wonderful branch of chemistry.

Properties of Acids
Acids are a special group of compounds with a set of common properties. This helps to distinguish them from other compounds. Thus, if you had a number of compounds and you were wondering whether these were acids or otherwise, you could identify them by their properties. But what exactly are the properties? Think about

the last time you tasted lemons. Did they taste sour, sweet, or bitter? Lemons taste sour. This is property of acids. Another property of acids is that they turn blue litmus paper red. Litmus paper is an indicator, which is a substance that changes color depending on how acidic or basic something is. If blue litmus paper turns red when it is dipped into a solution, then the solution is an acid. Another property of acids that many people are familiar with is their ability to cause burns to skin. This is why it is a bad idea to play with battery acid or other acids.

Acids react with many metals to produce hydrogen gas. For some examples, look at the reactions below:

$Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

$Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

What do you notice that is the same for all three equations? In each case, the reactants are a metal (Zn or Mg) and an acid (HCl). They all produce hydrogen gas, H_2. This is another property of acids. Acids react with most metals to produce hydrogen gas.

Think about the last time you took an aspirin or a vitamin C tablet. Aspirin is acetylsalicylic acidwhile vitamin C is ascorbic acid; both are acids that can produce H^+ ions when dissolved in water. Acetic acid ($HC_2H_3O_2$) is a component of vinegar, hydrochloric acid (HCl) is stomach acid, phosphoric acid (H_3PO_4) is commonly found in dark soda pop, sulfuric acid H_2SO_4 is used in car batteries and formic acid HCO_2H is what causes the sting in ant bites. For all of these acids, the chemical formula of an acid begins with one or more hydrogen atoms. Acids dissolve in water to make H^+ ions. Because they make ions (charged particles) when they are dissolved, acids will also conduct electricity when they are dissolved in water.

We interact with acids on a daily basis so some knowledge of their properties and interactions is essential. Acids are present in our everyday lives.

Properties of Bases

There is one common base that some may have had the opportunity to taste: milk of magnesia, which is a slightly soluble solution of magnesium hydroxide. This substance is used for acid indigestion. Flavorings have been added to improve the taste, otherwise it would have a bitter taste when you drink it. Other common bases include substances like Windex, Drano, oven cleaner, soaps and many cleaning other products. Please note: do not taste any of these substances. A bitter taste is one property you will have to take for granted. Bases also tend to have a slippery feel. This matches what you have experienced with soaps and detergents. As with acids, bases have properties that allow us to distinguish them from other substances. We have learned that acids turn blue litmus paper red. Bases turn red litmus paper blue. Notice that the effect of the indicator is the opposite of that of acids.

Most acids have formulas that start with H. On the other hand, most of the bases we will be using in this course have formulas that end with –OH. These bases contain the polyatomic ion called hydroxide. When bases dissolve in water, they produce hydroxide (OH^-) ions. Because they dissolve into charged particles, bases will also conduct electricity when they are dissolved.

Although many people have already heard of the danger of acids at causing burns, many bases are equally dangerous and can also cause burns. It is important to be very careful and to follow correct safety procedures when dealing with both acids and bases.

Acids & Bases Defined

Although scientists have been able to classify acids and bases based on their properties for some time, it took a while to come up with a theory explaining why some substances were acidic and others were basic. Svante Arrhenius set the groundwork for our current understanding of acid-base theory. We will focus on his famous acid-base definitions. This was quite an accomplishment for a scientist in the late 19th century with very little technology, but with the combination of knowledge and intellect available at the time Arrhenius led the way to our understanding of how acids and bases differed, their properties, and their reactions. Keep in mind that Arrhenius came up with these theories in the late 1800's so his definitions came with some limitations. For now we will focus on his definitions.

Arrhenius Acids

Take a look at all of the following chemical equations. What do you notice about them? What is common for each of the equations below?

Hydrochloric acid: $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$ Nitric acid: $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$ Perchloric acid: $HClO_4(aq) \rightarrow H^+(aq) + ClO_4^-(aq)$

One of the distinguishable features about acids is the fact that acids produce H^+ ions in solution. If you notice in all of the above chemical equations, all of the compounds dissociated to produce H^+ ions. This is the one main, distinguishable characteristic of acids and the basis for the Arrhenius definition of acids. An Arrhenius acid is a substance that produces H^+ ions in solution.

Arrhenius Bases

In contrast, an Arrhenius base is a substance that releases OH^- ions in solution. Many
bases are ionic substances made up of a cation and the anion hydroxide, OH^-. The dissolving equation for the base sodium hydroxide, NaOH, is shown below:

$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

Barium hydroxide produces a similar reaction when dissociating in water:

$Ba(OH)_2(s) \rightarrow Ba^{2+}(aq) + 2\ OH^-(aq)$

The production of OH^- ions is the definition of bases according to the Arrhenius.

Summary

Acids turn blue litmus paper red, taste sour, and react with metals to produce hydrogen gases.

Common acids include vinegar ($HC_2H_3O_2$), phosphoric acid in soda pop (H_3PO_4) and stomach acid HCl.

Bases turn red litmus paper blue, have a bitter taste, and are slippery to the touch. Common bases include Drano (NaOH), soaps and detergents, milk of magnesia ($Mg(OH)_2$) and Windex (NH_4OH).

Arrhenius defined an acid as a substance that donates H^+ ions when dissociating in solution.

An Arrhenius base is a substance that releases OH^- ions in solution.

Text 5
Laws of chemical combinations

The combination of elements to form compounds is governed by the following five basic laws.

Law of Conservation of Mass

This law was put forth by Antoine Lavoisier in 1789. He performed careful experimental studies for combustion reactions and reached to the conclusion that in all physical and chemical changes, there is no net change in mass duting the process. Hence, he reached to the conclusion that matter can neither be created nor destroyed. This is called 'Law of Conservation of Mass'. This law formed the basis for several later developments in chemistry. In fact, this was the result of exact measurement of masses of reactants and products, and carefully planned experiments performed by Lavoisier.

Law of Definite Proportions

This law was given by, a French chemist, Joseph Proust. He stated that *a given compound always contains exactly the same proportion of elements by weight.*

Proust worked with two samples of cupric carbonate — one of which was of natural origin and the other was synthetic. He found that the composition of elements present in it was same for both the samples as shown below:

Thus, he concluded that irrespective of the source, a given compound always contains same elements combined together in the same proportion by mass. The validity of this law has been confirmed by various experiments. It is sometimes also referred to as Law of Definite Composition.

Law of Multiple Proportions

This law was proposed by Dalton in 1803. According to this law, *if two elements can combine to form more than one compound, the masses of one element that combine with a fixed mass of the other element, are in the ratio of small whole numbers.*

For example, hydrogen combines with oxygen to form two compounds, namely, water and hydrogen peroxide.

Hydrogen + Oxygen → Water 2g 16g 18g

Hydrogen + Oxygen → Hydrogen Peroxide 2g 32g 34g

Here, the masses of oxygen (i.e., 16 g and 32 g), which combine with a fixed mass of hydrogen (2g) bear a simple ratio, i.e., 16:32 or 1: 2.

Gay Lussac's Law of Gaseous Volumes

This law was given by Gay Lussac in 1808. He observed that when gases combine or are produced in a chemical reaction they do so in a simple ratio by volume, provided all gases are at the same temperature and pressure.

Thus, 100 mL of hydrogen combine with 50 mL of oxygen to give 100 mL of water vapour.

Hydrogen + Oxygen → Water

100 mL 50 mL 100 mL

Thus, the volumes of hydrogen and oxygen which combine (i.e., 100 mL and 50 mL) bear a simple ratio of 2:1.
Gay Lussac's discovery of integer ratio in volume relationship is actually the law of definite proportions by volume. The law of definite proportions, stated earlier, was with respect to mass. The Gay Lussac's law was explained properly by the work of Avogadro in 1811.

Avogadro's Law

In 1811, Avogadro proposed that *equal volumes of all gases at the same temperature and pressure should contain equal number of molecules.* Avogadro made a distinction between atoms and molecules which is quite understandable in present times. If we consider again the reaction of hydrogen and oxygen to produce water, we see that two volumes of hydrogen combine with one volume of oxygen to give two volumes of water without leaving any unreacted oxygen.
In fact, Avogadro could explain the above result by considering the molecules to be polyatomic. If hydrogen and oxygen were considered as diatomic as recognised now, then the above results are easily understandable. However, Dalton and others believed at that time that atoms of the same kind cannot combine and molecules of oxygen or hydrogen containing two atoms did not exist. Avogadro's proposal was published in the French *Journal de Physique*. In spite of being correct, it did not gain much support.
After about 50 years, in 1860, the first international conference on chemistry was held in Karlsruhe, Germany, to resolve various ideas. At the meeting, Stanislao Cannizaro presented a sketch of a course of chemical philosophy, which emphasised on the importance of Avogadro's work .

Text 6
Hydrocarbons

Simple Hydrocarbons. The simplest hydrocarbons are those that contain only carbon and hydrogen. These simple hydrocarbons come in three varieties depending on the type of carbon-carbon bonds that occur in the molecule. Alkanes are the first class of simple hydrocarbons and contain only carbon-carbon single bonds. The alkanes are named by combining a prefix that describes the number of carbon atoms in the molecule with the root ending *-ane*. The names and prefixes for the first ten alkanes are given in the following list.

1. Meth- Methane CH_4 CH_4
2. Eth- Ethane C_2H_6 CH_3CH_3
3. Prop- Propane C_3H_8 $CH_3CH_2CH_3$
4. But- Butane C_4H_{10} CH_3CH_2 CH_2CH_3
5. Pent- Pentane C_5H_{12} $CH_3CH_2CH_2CH_2CH_3$
6. Hex- Hexane C_6H_{14} $CH_3CH_2CH_2CH_2CH_2CH_3$
7. Hept- Heptane C_7H_{16} $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
8. Oct- Octane C_8H_{18} $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH$
9. Non- Nonane C_9H_{20} $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
10. Dec- Decane $C_{10}H_{22}$ $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

The chemical formula for any alkane is given by the expression C_nH_{2n+2}. The structural formula, shown for the first five alkanes in the table, shows each carbon atom and the elements that are attached to it. This structural formula is important when we begin to discuss more complex hydrocarbons. The simple alkanes share many properties in common. All enter into combustion reactions with oxygen to produce carbon dioxide and water vapour. In other words, many alkanes are flammable. This makes them good fuels. For example, methane is the principle component of natural gas, and butane is common lighter fluid:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

The combustion of methane. The second class of simple hydrocarbons, the alkenes, consists of molecules that contain at least one double-bonded carbon pair. Alkenes follow the same naming convention used for alkanes. A prefix (to describe the number of carbon atoms) is combined with the ending -*ene* to denote an alkene. Ethene, for example is the two-carbon molecule that contains one double bond. The chemical formula for the simple alkenes follows the expression

C_nH_{2n}. Because one of the carbon pairs is double bonded, simple alkenes have two fewer hydrogen atoms than alkanes. Alkynes are the third class of simple hydrocarbons and are molecules that contain at least one triple-bonded carbon pair. Like the alkanes and alkenes, alkynes are named by combining a prefix with the ending -*yne* to denote the triple bond. The chemical formula for the simple alkynes follows the expression C_nH_{2n-2}, e. g. ethyne.

Hydrocarbons. These are compounds composed of carbon and hydrogen. They are generally insoluble in water although those with lighter molecular masses are gases and are slightly soluble. Examples of hydrocarbons include methane – the gas we burn as natural gas, pro- pane (also called liquid petroleum gas) and petroleum jelly.

The carbon atoms join together to form the framework of the compound; the hydrogen atoms attach to them in many different configurations. Hydrocarbons are the principal constituents of petroleum and natural gas. They serve as fuels and lubricants as well as raw materials for the production of plastics, fibers, rubbers, solvents, explosives, and industrial chemicals.

Many hydrocarbons occur in nature. In addition to making up fossil fuels, they are present in trees and plants, as, for example, in the form of pigments called carotenes that occur in carrots and green leaves. More than 98 percent of natural crude rubber is a hydrocarbon polymer, a chainlike molecule consisting of many units linked together. The structures and chemistry of individual hydrocarbons depend in large part on the types of chemical bonds that link together the atoms of their constituent molecules.

Nineteenth-century chemists classified hydrocarbons as either aliphatic or aromatic on the basis of their sources and properties. Aliphatic (from Greek aleiphar, “fat”) described hydrocarbons derived by chemical degradation of fats or oils. Aromatic hydrocarbons constituted a group of related substances obtained by chemical degradation of certain pleasant-smelling plant extracts. The terms aliphatic and aromatic are retained in modern terminology, but the compounds they describe are distinguished on the basis of structure rather than origin.

Aliphatic hydrocarbons are divided into three main groups according to the types of bonds they contain: alkanes, alkenes, and alkynes. Alkanes have only single bonds, alkenes contain a carbon-carbon double bond, and alkynes contain a carbon-carbon triple bond. Aromatic hydrocarbons are those that are significantly more stable than their Lewis structures would suggest; i. e. they possess “special stability”. They are classified as either arenes, which contain a benzene ring as a structural unit, or non-benzenoid aromatic hydrocarbons, which possess special stability but lack a benzene ring as a structural unit.

This classification of hydrocarbons serves as an aid in associating structural features with properties but does not require that a particular substance be assigned to a single class. Indeed, it is common for a molecule to incorporate structural unit characteristic of two or more hydrocarbon families. A molecule that contains both a carbon-carbon triple bond and a benzene ring, for example, would exhibit some properties that are characteristic of alkynes and others that are characteristic of arenes.

Hydrocarbons cclassification

Hydrocarbons and compounds derived from them generally fall in-to three large categories.

Aliphatic hydrocarbons consist of chain of carbon atoms that do not involve cyclic structures. They are often referred to as open-chain or acyclic structures, e. g. propane, pentane, hexane.

Alicyclic or simply cyclic hydrocarbons are composed of carbon atoms arranged in a ring or rings, e. g. cyclopropane, cyclopentane, cyclohexane.
Aromatic hydrocarbons are a special group of cyclic compounds that usually have six-membered rings with alternative single and double bonds. They are classed separately from aliphatic and alicyclic hydrocarbons because of their characteristic physical and chemical properties, e. g. benzene, naphthalene.
Addition of hydrogen (hydrogenation) to a carbon-carbon double bond, reduces an alkene to an alkane. The process requires the presence of a metal catalyst, and for this reason, it is also called catalytic reduction. Catalytic reduction of alkenes is a very important reaction in the laboratory. In hydrogenation, both hydrogen atoms are added to the same side of the alkene molecule.
The addition of water to an alkene is called hydration. In the presence of an acid catalyst, often 60% aqueous sulfuric acid, water adds to alkenes to produce alcohols. Hydrogen adds to the carbon of the double bond with the greater number of hydrogen; OH adds to alkenes in accordance with Markovnikov's rule. Hydration of alkenes is a very important reaction both in the chemical industry and in biological systems.

Sources and uses of hydrocarbons. Petroleum and its associated natural gases are now the major source of hydrocarbons. Natural gas is composed principally of methane (CH_4). Ethane (C_2H_6) and propane (C_3H_6) typically represent 5 to 10 per cent of the total, along with traces of C_4 and C_5 hydrocarbons. The gas is freed of various unwanted contaminants and then it is utilized almost exclusively as fuel. Valuable side products of petroleum cracking provide raw materials for the petrochemical industry. Ethylene (C_2H_4) and propylene (C_3H_6) are principal starting points for the manufacture of chemicals, medicines, and polymers.

Text 7
Alcohols

The products of replacement of hydrogen in hydrocarbons by the hydroxyl group (hydroxyl group) are known as alcohols. The general formula for an alcohol is ROH, the R representing the aliphatic portion of the molecule, alcohols may be regarded as derivatives of water in which an alkyl group replaces one hydrogen atom. The alcohols bear some physical resemblance both to the hydrocarbons and water. The best known member of the class is ethyl alcohol, CH_3CH_2OH. It is soluble both in water and in gasoline. Its boiling point is lower than that of water, although its molecular weight is much greater.

The hydroxyl derivatives of aromatic hydrocarbons are called aromatic alcohols when the hydroxyl group is in the side chain and phenols when the hydroxyl group is attached directly to a benzene ring.

Aliphatic alcohols are divided into saturated and unsaturated ones in conformity with the nature of the hydrocarbon radical.

The characteristic functional group of alcohols is hydroxyl or –OH group. Depending on the number of –OH groups in the molecule the alcohols are classified into monohydric, dihydric, trihydric, and poly- hydric alcohols.

The isomerism of alcohols is caused by the structure of the radical (isomerism of the carbon skeleton) and the position of the hydroxyl (position isomerism). There are primary I, secondary II, and tertiary III alcohols in conformity with the position of the hydroxyl in the molecule, depending on the carbon (primary, secondary, or tertiary one) with which it is linked.

There are several general methods of alcohol preparation:

1. The hydration of olefins in the acid medium. This method is of great importance, because it allows us to obtain alcohols from gases of petroleum cracking. Primary alcohol, or ethanol, is obtained from ethylene, while only secondary and tertiary alcohols are obtained from other olefins. The method of direct hydration is

used industrially; it is carried out by passing a mixture of olefin and water vapour over a phosphate catalyst.

2. Another important industrial method is the fermentation of carbohydrates.

3. Hydrolysis of the halogen derivatives. This method is important in obtaining alcohols from hydrocarbons.

Physical properties of alcohols

The lower and middle members of the series of saturated monohydric alcohols (C_1–C_{11}) are liquids whose boiling points rise as the com- position becomes more complex. Higher alcohols from C_{12} are solids. Alcohols having an iso-structure boil at a lower temperature than those having a normal structure. The lower representatives have a characteristic alcoholic odour and a burning taste, the middle representatives C_4–C_6 have an unpleasant odour, and the higher ones are odourless. The density of alcohols is less than unity, and only that of some of aromatic alcohols is higher than unity. The first three members of the saturated alcohols mix with water in all proportions, but solubility di- minishes as the radical becomes more complex. Higher alcohols, like hydrocarbons are practically water insoluble.

The molecules of alcohols in solid and liquid state, like water molecules, are associated; in this case, the molecular mass of a substance considerably increases and consequently, its volatility decreases. Association is interrupted as alcohols pass over to a vapour state. Association is caused by hydrogen bonds which originate between molecules.

Chemical properties of alcohols

The functional group of alcohols, the hydroxyl, determines the main chemical properties of these compounds. Alcohols are characterized by great chemical activity.

Acid and basic properties. Formation of alkoxides. Alcohols are practically neutral substances: they do not change the colour of indicators and do not react with either aqueous solutions of alkalies or dilute acids. However, in certain reactions, alcohols exhibit properties of a very weak acids and bases, i. e. they are amphoteric, like water. When alkali metals act on alcohols in unhydrous medium, hydroxyl hydrogen is forced out and alkoxides are formed. Alkoxides have the nature of salts of a very weak acid with a base. The basic properties of alcohols are exhibited in their interaction with strong acids. In this case, alcohols like water yield oxonium salts.

Formation of ethers. Ethers are obtained when alkoxides react with alkyl halides.

Dehydration of alcohols. Alcohols are capable of losing water under definite conditions. Concentrated sulphuric or phosphoric acid can be used as dehydrating agent. Alcohols dehydrate when their vapours are passed over a heated solid catalyst (silica gel, aluminium oxide, etc.).

Oxidation of alcohols. Different products can be formed, depending on the nature of alcohols and reaction conditions. Primary alcohols yield at first aldehydes, and then acids having the same number of car- bon atoms. Ketones are formed from secondary alcohols. Tertiary alcohols are more stable towards oxidation.

Catalytic dehydrogenation of alcohols. Alcohols can be converted into aldehydes and ketones also by dehydrogenation, i. e. by passing alcohol vapours over a heated metallic catalyst such as copper or silver at 300°C. A typical dehydrogenation reaction is the conversion of ethyl alcohol into acetaldehyde. This reaction is endothermic.

Preparation of alcohols

Functional group transformation. Alcohols can be prepared by nucleophilic substitution of alkyl halides, hydrolysis of esters, reduction of carboxylic acids or esters, reduction of aldehydes or ketones, electrophilic addition of alkenes, hydroboration of alkenes, or substitution of ethers.

C–C bond formation. Alcohols can also be obtained from epoxides, aldehydes, ketones, esters, and acid chloride as a consequence of C–C bond formation. These reactions involve the addition of car- banion equivalents through the use of Grignard or organolithium reagents.

Text 8
Fats

Fats occur naturally in food and play a significant role in human nutrition. Fats are used to store energy in the body, insulate body tis- sues, cushion internal organs, and transport fat-soluble vitamins in the blood. Fats also play in an important role in food preparation: They enhance food flavor and food texture, make baked products tender, and conduct heat during cooking.
Fats are the most prevalent class of compounds (in living systems) referred to as lipids. Lipids are cellular compounds that are in- soluble in water. Fats are soft, low-melting solids, with a density less than that of water. They have a greasy feel and are slippery. Because fats are insoluble in water and less dense than water, after meat that has a lot of fat in it has been cooked, upon cooling a layer of fat often appears on top of the juices. Fats and closely related oils are mixtures of compounds consisting of fatty acids combined with glycerol (commonly known as glycerin) via ester linkages. Fatty acids are long, straight chain carboxylic acids. A fat (or oil) is formed when three fatty acid molecules react with a glycerol molecule to yield a triglyceride (and three water molecules). Fats in the body are trans- ported and stored as triglycerides.
Fat molecules are characterized as monoglycerides, diglycerides, or triglycerides, depending on whether there are one, two, or three fatty acid chains present in the molecules. Fatty acids in nature generally have an even number of carbon atoms because they are

synthesized in cells via successive additions of two-carbon acetate groups in a step- wise cyclic reaction.

Fats and oils

Dietary fats and oils are both triglycerides. Fats are generally solids and oils are generally liquids at ordinary room temperatures. The characteristics of fats and oils are related to the properties of the fatty acids that they contain. The larger the number of carbon atoms, the higher the melting point; the larger the number of double bonds, the lower the melting point. Oils contain a higher percentage of unsaturated fatty acids than fats. Fats from animal sources tend to be solids and fats from vegetable sources tend to be liquids. Thus fats are often referred to as “animal fats” and “vegetable oils”.

Saturated and unsaturated fatty acids

When the fatty-acid molecule contains the maximum of hydrogen possible, the acid is said to be a saturated fatty acid. It is saturated with respect to hydrogen. Myristic, lauric, palmitic, and stearic acids are such saturated acids. They are solids at ordinary temperatures. When, however, the fatty-acid molecule does not contain the maximum amount of hydrogen possible, the acid is said to be an unsaturated fatty acid. It is unsaturated with respect to hydrogen. Such unsaturated acids are oleic, linolic, and linolenic acids. They are liquids at ordinary temperatures. By chemical means these acids may be made to take up, i. e., combine with, hydrogen. This process is known as hydrogenation. It converts a more unsaturated fatty acid into a less unsaturated one, or, if the hydrogenation is carried to completion, into a saturated fatty acid. Thus by hydrogenation oleic acid is converted into stearic acid. Linolic acid when hydrogenated can be made to take up twice as much hydro- gen as oleic acid, and linolenic acid three times as much. Linolic acid is, therefore, a more highly unsaturated acid than oleic, while linolenic acid is more highly unsaturated than linolic.

Unsaturated fatty acids can be made to combine with other substances instead of with hydrogen. For example, they may be made to take up iodine or oxygen. Acids of a low degree of unsaturation, such as oleic acid, do not combine with oxygen with any great degree of acidity, but acids of a greater degree of unsaturation, such as linolic or linolenic, combine with it very readily; they do so merely upon exposure to the air.

Measures of unsaturation

It is obvious, then, that it is important for industrial users of fats to know the degree of unsaturation of a given parcel of fat. This might be ascertained by determining the amount of hydrogen required to convert it into a saturated fat. In practice this is a complicated procedure and so simpler methods are resorted to. The simplest of these is the determina- tion of the amount of iodine that can be made to combine with the fat. The percentage by weight of iodine absorbed by the fat in the natural state is known as the iodine number. It is an index to the degree of un- saturation of the fat. The fats with the highest iodine numbers are the drying oils par excellence, linseed and tung oil, with which must also be classified menhaden fish oil.

Text 9

Chemists look to mine silver from laundry wastewater

Laundering can release the toxic metal, which often is added to fabrics to retard bacterial growth

Believe it or not, laundry wash water can hold a mother lode of silver. And scientists are looking for ways to recover this precious metal. Their main goal is not to make big bucks selling it to people who make jewelry, coins or pricey flatware. Silver is toxic. So researchers want to catch it before it threatens wildlife. Now, two environmental engineers report preliminary success doing just that. They have developed a way to extract silver from wash water. If the technique proves affordable and reliable, that silver could be recycled for a host of uses. The researchers have just shared their innovation in the January 2 *ACS Sustainable Chemistry & Engineering*.

For years, companies have added nano-sized bits of silver to all types of products — especially fabrics. Their main aim has been to fight the growth of odor-causing bacteria. That's why this treatment has been especially popular for athletic wear, such as socks.

Studies soon showed, however, that nanosilver doesn't stay put. It soon starts washing away in the laundry. Because that wash water ultimately makes its way into rivers, lakes and the ocean, so can the silver. And that could pose risks to wildlife.

"[Researchers] are walking a fine line between silver's desirable properties and its potential toxicity to the environment," argues science journalist Silke Schmidt. "Products embedded with nano-silver," she notes, "tend to lose some of their silver coating every time they're laundered."

And stinky germs are not the only things that metal can poison. "Silver is harmful to humans, rats and aquatic species such as zebrafish and rainbow trout," notes Tabish Nawaz. He's an environmental engineer who works at the University of Massachusetts in Dartmouth. That same silver also can harm the growth of aquatic embryos, he notes, such as those of developing fish.

To protect all these creatures, he says, that silver needs to be removed from the laundry water *before* it spills out of a community's waste-treatment plant. With that in mind, Nawaz teamed up with Sukalyan Sengupta, also at the University of Massachusetts. Together they are fine-tuning a technique to mine that nuisance silver from the laundry.

The trick: Turn to chemistry

Ions are electrically charged atoms or molecules. This means they're missing electrons (making them positively charged) or have extra electrons (making them negatively charged). In the wash water, silver atoms exist as ions. These ions are positively charged.

Nawaz and Sengupta’s trick for harvesting silver is to trap those silver ions in a special type of *resin*. It, too, contains ions. That resin is made into beads and then packed into cylinders known as columns. Liquids, such as wash water, then get pumped through the columns.

When the liquid contacts the resin, something interesting happens. Ions in the liquid start swapping places with ions in the resin. As some ions are trapped, others are released. This process is known as ion exchange. (That’s why the resin is known as an ion-exchange resin.)

The idea is simple. Making it work, however, can be challenging.

The problem is that silver is not the only positive ion in the wash water. Laundry detergent, Nawaz points out, contains other types of positive ions, such as sodium ions. Any of these might bind to the resin in place of the silver.

What’s more, he notes, “several other detergent components react with silver.” They can do this through a range of other processes (known as complexation, precipitation, oxidation or reduction). The result? Those processes may make the silver unavailable to the resin.

But his team was able to overcome the challenge. How? Different ion-exchange resins contain different “functional groups.” These are particular group of atoms that perform particular roles in chemical reactions. Nawaz says that he and Sengupta used an ion-exchange resin with a functional group that targets silver. The functional group they chose is known as a thiol (THY-all).

To up their resin’s performance, the engineers did not just add thiol. They also changed some other conditions (such as pH and temperature). Afterward, they were able to trap and remove 84 percent of the silver that had been added to water in the lab.

But how much silver can wash water deliver? After crunching a few numbers, Nawaz estimates that it could run to “about 2 grams [0.07 ounce] per person per day.” Multiply that by the population of the United States, for instance, and you’ll find that’s an estimated 652,000 kilograms (1,437,414 pounds) of silver!

Recovering that much *before* it enters the environment would be much better for wildlife than trying to catch it later.

Some doubts remain

Denise Mitrano is a geochemist in Dubendorf, Switzerland. She works at the Swiss Federal Institute of Aquatic Science and Technology. There, she studies how to measure nanopollutants in the environment. Mitrano questions whether it's even necessary to trap silver from wash water. Many big cities run wastewater-treatment facilities. Their role is to clean up a community's dirty water. And in many of those plants, she argues, "silver is effectively diverted to the *sewage sludge*." That's a special goopy type of waste separated from the water.

Silver may sit trapped in that sludge, Mitrano says. And that could prevent large amounts of it from getting into the environment.

Cost is another issue to consider, she notes. Just because it's possible to do something does not mean it can be done affordably or conveniently. Those are big issues here, she says. For instance, she asks, would the benefits of ion-exchange trapping outweigh the potential cost to the environment (and launderers) of letting this silver continue to wash away?

Those are questions engineers will have to explore. For now, Nawaz would like to see people play a bigger role in managing the wastes they release. "To be successful, effective waste management requires that everyone get on board," he says. "We also need to inform people just how much our choices are affecting the environment."

But if society *is* successful in getting rid of this toxic metal from waste water, the only question left may be what to do with all that silver.

Text 10
Fingers leave tell-tale clues about you on your phone

Every time your fingers touch your cell phone, they leave behind trace amounts of chemicals. And each chemical offers clues to you and your activities. By analyzing them, forensic scientists might be able to piece together a story about your recent life, a new study finds. One day, police might use such data to help track down a phone's owner. Or they might figure out what a person had recently been up to.

A molecule is a group of atoms. It represents the smallest amount of some chemical. Your skin is covered in molecules picked up by everything you have touched. Those molecules might include traces of the chocolate bar you had snacked on. Or there might be small amounts of shampoo, cosmetics — even some medicine you took. And with each new thing your skin contacts, you leave behind some small share of what it had touched earlier.

Researchers at the University of California, San Diego (UCSD) recently analyzed such chemical leftovers on the phones of 39 volunteers. These residues helped the scientists analyze each phone user's behavior.

Amina Bouslimani led the study. As a biochemist, she studies the chemical processes that take place inside organisms.

Her team's new tests often could discover if a phone's owner liked spicy food, drank coffee or used deodorant. The tests could point to places someone had visited recently. They could even point to whether he or she was ill.

Bouslimani's team published its findings online November 14 in the *Proceedings of the National Academy of Sciences.*

"Like your skin, your phone also reflects who you are and what you do," she says. That's because the average person spends about five hours a day handling their cell phone, she notes.

Jack Gilbert is a microbial ecologist at the University of Chicago in Illinois. He studies how microbes relate to each other and their surroundings. The UCSD research is exciting, he says. That's because it allows scientists to reconstruct details of a phone owner's lifestyle.

Consider someone who has just lunched on a peanut butter and jelly sandwich. "A small amount of the jelly, the bread, the butter and even the peanut would be left on your hands," he says. (Some people's PB and J sandwiches also contain butter.) That would be true *"even* after you have washed them," he notes. In fact, washing would add traces of soap.

Residues from each recent activity would increase the complexity of the mix of molecules left behind.

What the scientists did

To probe those residues, the UCSD team wiped the surface of each volunteer's phone with a cotton swab. The scientists also swabbed each person's right hand. Then the researchers compared the chemicals found on each.

If the chemicals matched, it would suggest that those molecules from the skin had been transferred to a user's phone, says co-author Pieter Dorrestein. He's a UCSD pharmaceutical chemist. (That means he studies the composition, structure and properties of different types of medicines.)

The scientists identified as many of the molecules as they could. They then compared these to a database of chemicals. Dorrestein had helped set up that database a few years earlier.

It contains the profiles of various compounds, including spices, caffeine and medicines.

Traces of anywhere from hundreds to thousands of different molecules turned up on each phone. The molecules reflected what had been in the body, such as medications and food. They also reflected what each person had handled before touching the phone, such as soap or makeup. Indeed, the majority of molecules came from beauty products, medicines and food.

From all of this, Bouslimani says, "We could tell if a person is likely female, uses high-end cosmetics, dyes her hair, drinks coffee, prefers beer over wine or likes spicy food." These residues might also show whether someone wears sunscreen or bug spray. If so, that could point to someone who spends a lot of time outdoors.

Police already use molecular analyses to look for traces of explosives or illegal drugs. To date, Dorrestein says, he’s never heard of police using phone residues to narrow down behavioral clues to search for a suspect. But detectives might one day use such data to track down someone who left a phone behind at a crime scene.

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