SAMPLE

Introduction to Environmental Chemistry

Lesson Aim

Describe the nature, importance and scope of environmental chemistry and advance an understanding of basic chemistry including atoms and their components, elements, compounds and chemical reactions.

INTRODUCTION

Chemistry is the science of matter. It is defined as the science that is concerned with the composition and properties of substances and the changes that they go through.

Environmental chemistry (biogeochemistry) is a branch of chemistry that deals with the origins, movement, reactions, and effects of chemicals in the air, water, earth, and living environments. It often focuses particularly on the influence of human activities on chemicals in our world.

Environmental chemistry is a vast subject so this course concentrates on important influences of chemistry on:

- horticulture,
- agriculture,
- resource management,
- environmental management
- human health.

As concerns grow about the toxic effects of chemicals in our world, you will learn about new trends which strive to introduce eco-friendly chemicals and improve sustainability in their production.

As humans devised ways to make the world safer, healthier, or more productive by introducing new and/or increased use of existing chemicals and resources, very often these same chemicals have caused unforeseen problems pf enormous concern later down the line. Thus, there is a swing towards reduced use of resources and adoption of eco-friendly lifestyles, sustainable and organic production, green chemistry and engineering.

Environmental chemistry affects the world in diverse ways (both beneficial and detrimental) at scales ranging from **global to microscopic**. Global examples include climate change and global warming occurring mostly due to changes in the chemical composition of atmospheric gases (greenhouse gases) largely caused by humans. Global warming is the long-term trend of a rising average global temperatures, whereas climate change is a broader term referring to changes mostly brought about by global warming such as extreme rainfall events, increased prevalence of drought, heat waves and so on.

At a microscopic scale, chemicals are used to control or prevent outbreaks of diseases caused by microorganisms in crops. This includes fungal diseases such as mildews, rots and wilts which may be treated using chemicals called fungicides. These fungicides may contain inorganic copper or sulphur compounds; synthetic organic compounds (such as dithiocarbamates) as well as 'natural' compounds such as clay. The fungicides have a beneficial effect in that they increase food production for an ever-expanding population. However, some of these fungicides also have effects on the environment at a much larger scale than the intended microscopic one, due to their persistence in the environment (i.e. they do not break down with time and can accumulate). They can be toxic to soil organisms such as earthworms and to aquatic organisms such as fish or even to humans. Thus, chemicals have many interacting influences on the environment at many different scales.

Chemicals have also had many beneficial effects on the world in which we live. For example, water has been made safe to drink by treatment with chlorine. This is called 'disinfection'. Chlorine kills many water-borne pathogens and has no doubt saved millions of lives from devastating infections such as cholera, typhoid and salmonella. On the negative side, it is now known that when chlorine is added to water, it mixes with organic products in the water to form toxic by-products called trihalomethanes, which can cause cancer. Safer ways to disinfect water are therefore being explored such as ozonation.

ENVIRONMENTAL CHEMISTRY THROUGH TIME

Humans have manipulated the environment for thousands of years. This has implications for the chemistry of the environment, both in how it impacts our health and lifestyle as well the broader impact on the world we live in.

To study how the environment has been affected, human development through time can be placed into five broad periods:

1. Pre-human history
2. Hunters and gatherers
3. Agricultural revolution
4. Industrial revolution
5. The modern age

Pre-Human History

Prior to any human influence, only natural chemical changes occurred in the environment such as weathering of rocks; dissolving of substances into water, atmospheric, soil, water, plant and biotic changes through phenomena such as volcanic activity and tectonic movements, and burial of organic material in sediments.

Hunters and Gatherers

In the hunters and gatherers period, starting around 80 000 years ago, there were very few people on the planet, so their impact on environmental chemistry was low. Small influences such as use of fire, cutting of trees, killing of animals, harvesting of plants and production of human waste may have introduced small localised changes. When the ecosystem remained relatively undisturbed, as in this period, all their waste substances were processed through an intricate network of biogeochemical and physical cycles. During these cycles, waste decomposed on the soil and substances were taken up by the plants. The substances then moved through the food chain to larger and more complex organisms. When these larger organisms died, they decomposed into simpler forms and they were used again when they were taken up by the plants. These substances which can be broken down by the biological systems of the environment are called biodegradable substances.

Agricultural Revolution

When the environment becomes overloaded beyond the capacity of its normal processing systems, pollution starts occurring. This started in the third period, where there was a rapid expansion in agricultural activities. The greater amount of food produced and the more secure production and storage of grains allowed the population to grow. The production of food and increased population started to have consequences including increased waste, burning or clearing of land, increased use of water resources and so on. Agricultural development may have started as early as 12 000 BC in several regions. Examples include China (domestication of rice and millet); the Mediterranean countries (grains, legumes and fruit trees cultivated) and South America (domestication of the potato and squashes) among others. Animals such as sheep, pigs and cattle were also domesticated and used as food during these periods. Changes escalated when ploughing, burning, clearing of wetlands and crop rotations became more common in the middle ages, impacting the carbon cycle amongst other elements.

Industrial Revolution

In the fourth period between 1750 to the late 1800s, the industrial revolution introduced new technologies to increase production. Transport between areas was improved through use of trains and steam powered boats.

Humans could grow, extract, process, and manufacture products much more easily. This included both renewable and non-renewable resources. As resources were used, so the production of waste also increased, with impacts on air, water, soil and living organisms. More of the population lived in cities, resulting in increased use of resources and more waste crammed into smaller areas. Mother Nature can only deal with so much waste by natural break-down, surplus waste therefore remained as a pollutant and was transported around the environment by air, water and human movement.

The Modern Age

In the modern age, there was a rapid rise in population growth, needing increased resources to provide their daily requirements. Humans are ingenious and have developed answers to many of their problems. This includes development, manufacture and distribution of synthetic chemicals/medicines for increased food production and improved health. This did indeed improve nutrition, lifestyle and longevity in many places. However, many of these chemicals have been used with limited knowledge of their potential consequences on health and the environment or knowledge of their persistence in the environment.

There was increased waste. Societies became' throw away' ones with little recycling, leading to huge amounts of household and industrial waste to deal with, particularly non-degradable plastics and e-waste.

More fossil fuels were burned. Since 1970, carbon dioxide emissions increased by about 90%, with emissions from fossil fuel combustion and industrial processes contributing about 80% of the increased greenhouse gas emissions. Agriculture, deforestation, and other land-use changes have been the second-largest contributors. Increased greenhouse gases are generally believed to have caused global warming and climate change.

Agriculture increasingly relies on artificial fertilisers, more water, pesticides, herbicides, fungicides, growth regulators, additives and antibiotics. Excess agro-chemicals are lost by leaching, runoff and volatilisation into the air, resulting in pollution of air, land and water resources. Toxins are found in food chains impacting human health and that of other organisms and affecting biodiversity.

The good news is that through education and the efforts of many environment conservation and protection agencies, humans have become increasingly aware of the negative effects of pollutants in the environment and the excessive use of resources. There has been a big increase in 'green' initiatives to reduce consumption of resources and to increase reuse and recycling. This includes reduction of vehicle emissions and up-cycling of waste products. Likewise, there are greater moves towards sustainable practices in farming, industry, construction, mining and lifestyle practices, where less chemicals are manufactured and used, waste products are recycled and natural products are substituted for synthetic products. There are myriad ways in which fast and slow, small and large improvements are being made. Some important examples of these are covered in later lessons.

GLOBAL WARMING, GREENHOUSE GASES AND CARBON SEQUESTERING

Earth's climate has changed throughout history. There have been several glacial (ice ages) periods followed by warmer periods. However, scientific evidence for the present warming of the climate system is now considered unequivocal by the Intergovernmental Panel on Climate Change.

The current **global warming** trend is very significant because much of it is likely caused by humans and it is proceeding at an unprecedented rate, much faster than previously studied periods. The 10 hottest years on record since 1880 have occurred in the period 1998-2015. As noted previously, this warming is causing **climate change** with more extreme weather events

This is generally attributed to increase in the **chemistry of the atmosphere**, namely accumulation of **greenhouse gases** caused by human activities, which in turn, create what we call the 'greenhouse effect'. As half of the atmosphere's solar radiation is transmitted as short wave radiations (UV) and absorbed by the earth surface, a part of it is radiated back into the atmosphere as long wave radiation (infrared or IR) and absorbed by suspended air particles, such as clouds and air pollution, rather than being re-emitted through the atmosphere. This 'trapping' of heat causes a rise of temperature in the atmosphere and the surface of the earth.

There are many different greenhouse gases, but the most abundant greenhouse gases in Earth's atmosphere are water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and chlorofluorocarbons (CFCs). Carbon dioxide concentrations now exceed 400 parts per million, the highest in about the last 800 000 years. Nitrogen, oxygen and argon exist naturally in the atmosphere but are not included as greenhouse gases. This is because they have symmetrical molecules which are 'transparent' to IR light.

A great part of these greenhouse gases come from natural sources. For example, more than half of the nitrous oxide in the atmosphere originates from the ocean and soil; marshlands and swamps as well as grazing cattle and termites are responsible for at least one-fourth of the world's methane emissions. Conversely, mining, the burning of fossil fuels, deforestation, industry growth, agricultural projects and other human activities account for approximately 75% of the increase in greenhouse gases.

Global warming affects the level and volume of the ocean ('thermal expansion'). The melting of glaciers has caused a rise in sea levels (approximately 20 centimetres in the last 100 years) with the potential of swamping low lying coastal areas.

There are worldwide efforts to reduce emissions of carbon dioxide and other green gases, ranging from international and national programs to community and household efforts. These include increased use of renewable energy forms instead of burning fossil fuels, changes in agricultural, mining and industrial process, carbon neutral housing and so on. **Carbon sequestration** is also being pursued – this is where carbon dioxide is captured and stored, to reduce its accumulation in the atmosphere.

Sequestration can be achieved in biological, physical and chemical ways. The **biological capture** of carbon dioxide by plants for photosynthesis is well known. However, if plants decompose (e.g. through harvesting, burning, consumption or natural decay), the carbon dioxide can be returned to the air. Sequestration therefore involves long-term storage in forests, through afforestation projects. Subsequently, wood should not be burnt in air e.g. used for furniture, turned into biochar etc. **Physical** methods include storage of captured carbon dioxide underground e.g. in old gas or oil reservoirs. **Chemical** methods include conversion from carbon dioxide gas to carbonate solid mineral forms using catalysts.

So, in summary, though our intentions in using chemicals may initially be good, in many cases there are subsequent unforeseen problems and side effects. Only by gaining a clearer understanding of chemicals, how and why we use them, their behaviour in the environment and their short and long term effects on living and non-living things, can we hope to manage them better and live in a healthier, more sustainable way.

Environmental Chemistry in global systems

Environmental chemistry is important in all systems of the globe. These interconnected systems operating on earth are commonly divided into four 'spheres' as indicated in the list and diagram below:

1. **Atmosphere**—the layer of gases surrounding the earth (air).
2. **Hydrosphere**—all the water on earth in rivers, sea, lakes, underground etc.
3. **Geosphere**—the solid parts of the earth such as soil, rocks, core.
4. **Biosphere**—all the living organisms on earth (biotic as opposed to non-living or abiotic things); the sum of all ecosystems

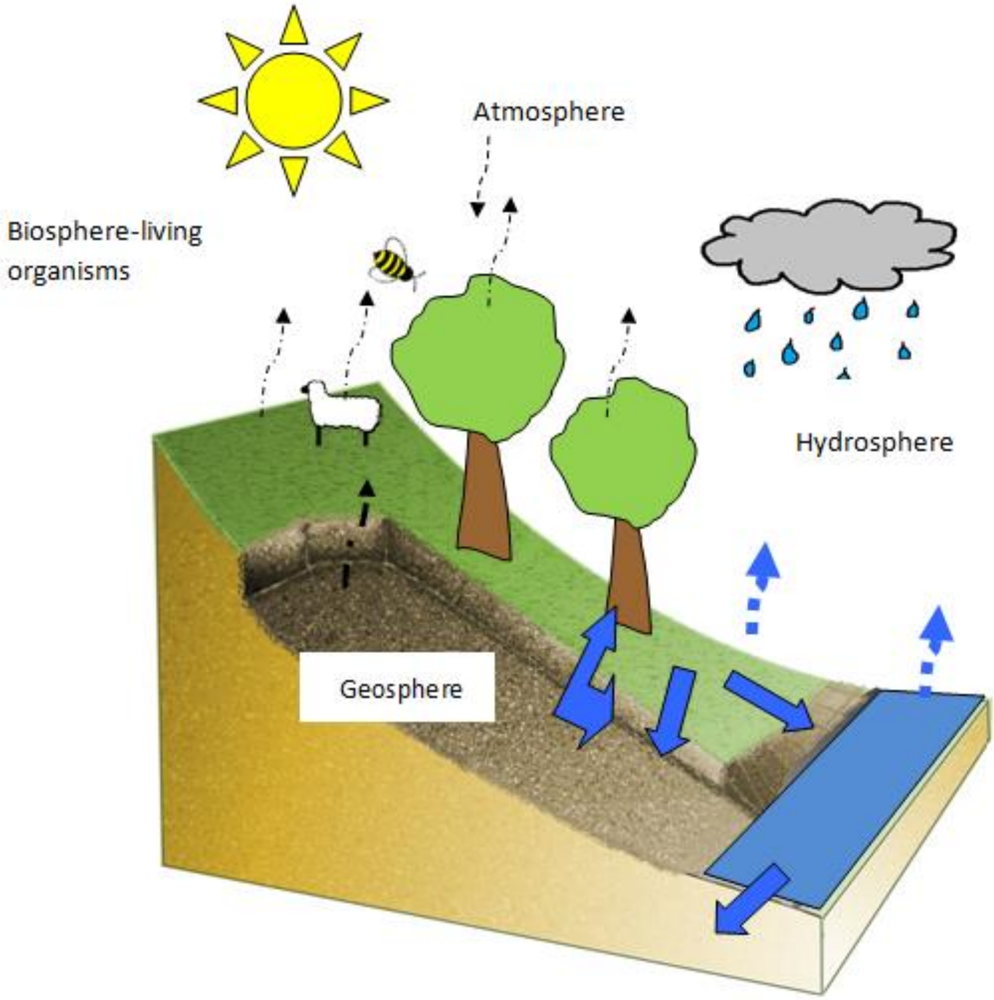


Diagram illustrating parts of the four traditional earth spheres or subsystems

A fifth sphere is sometimes included —the **Anthrosphere**. The anthrosphere is the ‘system of humanity’. It includes all things humans have built such as buildings, roads, dams, farms, mines and so on as well as humans themselves.

By studying the chemistry that occurs in these interconnected and related spheres, we can begin to truly understand how, why, what, when and where changes occur and how we can better manage these.

As an example, let us consider a chemical called cadmium. It is a metal and occurs naturally in soil/rocks, water and air. It is however classified as a human carcinogen (causes cancer). When inhaled, it can also cause severe problems such as bronchial and lung damage and it can also cause kidney problems. If ingested in significant amounts it can cause severe damage to the liver and kidneys.

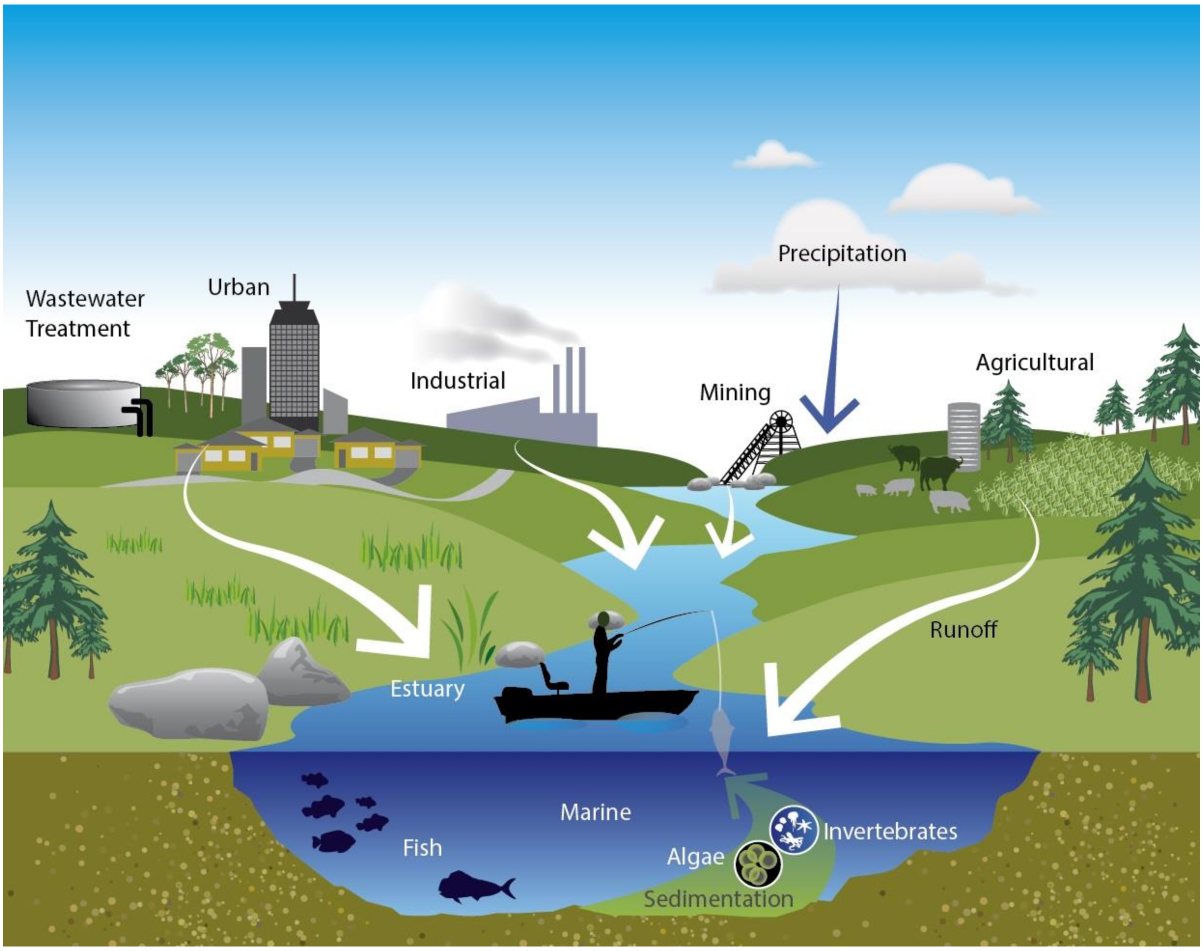
However, cadmium is used in many products such as alloys, metal plating, paints, plastics, batteries and electronic products as well as phosphate fertilizers. Cadmium has therefore been increasingly released into the environment from many sources, as illustrated in the diagram below.

These include:

- smelter emissions
- or tobacco smoke into the atmosphere;
- from fertilisers and waste into soils (geosphere),
- into the hydrosphere from runoff, wastewater disposal, leaching to groundwater or deposition from the atmosphere into water sources.

- Into the biosphere as it becomes incorporated in the food chain. Cadmium remains in the environment once released, as it is not broken down i.e. it is persistent. Once in the food chain, it can become toxic to living organisms including humans, aquatic species, micro-organisms and plants.

As it became clear that increased levels of cadmium were causing numerous problems in many spheres, people have worked towards limiting or removing this toxicity. Many nations have moved to limit cadmium use, release and exposure by different means. This includes control of emissions from factories, mines and waste management sites; control limits to concentration of cadmium in water sources, public education and government taxes to reduce tobacco smoking, reducing used of nickel-cadmium batteries and so on.



BASIC CHEMISTRY CONCEPTS

This course will introduce you to basic chemistry concepts, so that a deeper understanding of various chemicals, their properties, reactions and effects can be easily understood in later lessons.

If your knowledge of basic chemistry is limited, or you need to refresh; the following pages will be important to ensure you have a sufficient grasp of chemistry fundamentals, to deal with the remainder of the course. If you find these pages very familiar though; please move on to the later part of this lesson.

As chemistry is the science of matter, we start by looking at the building blocks of matter. All matter (millions of substances) is made up of ~100 plus kinds of matter called **elements**. Each element comprises minute entities called atoms.

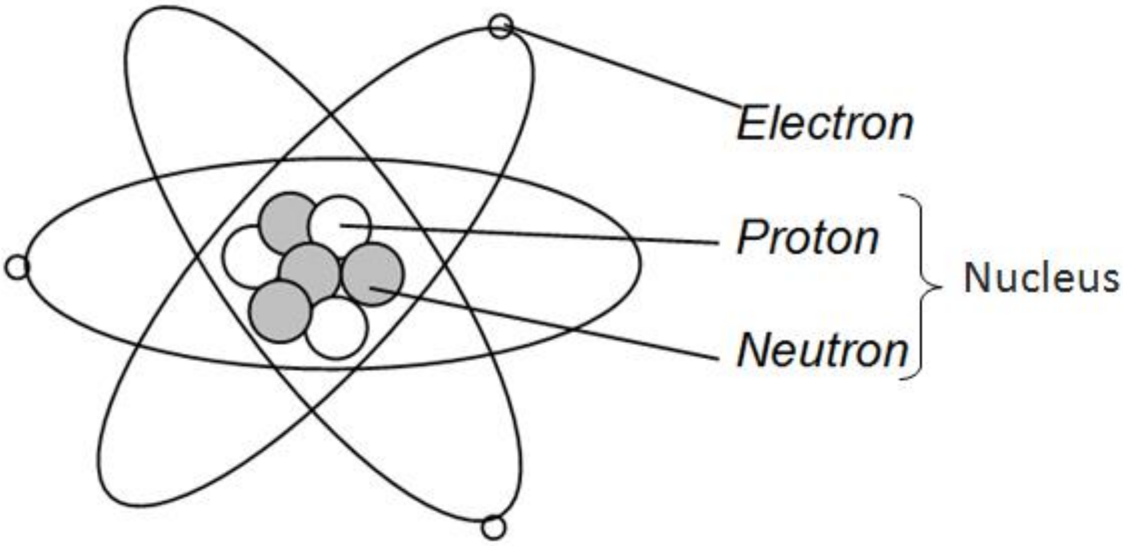
Atoms

An atom is like a microscopic solar system, composed of a centre like the sun (called the **nucleus,** which contains a characteristic number of subatomic particles called **protons** and **neutrons**, and other parts which orbit in a cloud around the centre called **electrons**. The protons and neutrons have relatively high masses compared to electrons.

The diagram below shows a Lithium atom, with protons in white, neutrons in grey and the small white electrons orbiting about the centre core or nucleus. The electrons are often depicted orbiting the nucleus in shells which are at different distances from the nucleus, similar in idea to the planets orbiting the sun in our solar system. These shells and their sub-shells may be show as ellipses, or sometimes they are simply represented as circles.

The particles which make up an atom can have electrical charges.

- Protons have a positive charge (+),
- Electrons have a negative charge (-) and,
- Neutrons are uncharged or neutral.



A simplified diagram of a Lithium (Li) atom

If the amount of positive and negative charge is balanced, the atom as a whole is neutral (i.e. the negative and positive cancel out the effect of each other). If an atom has no charge (i.e. is neutral) it appears stable, but in fact there are other factors that can also influence its stability (i.e. chemical stability is a measure of the tendency of an atom or group of atoms to resist change).

Each atom of element contains the same number of protons in the nucleus. The number of protons in the element is called the '**atomic number'** and this ranges from 1 for Hydrogen up to 118 for Oganesson. The atomic number of Lithium shown above is therefore, 3 (i.e. it has 3 protons). However, the number of neutrons can vary slightly in an element, giving rise to **isotopes**. For example, Lithium has 2 isotopes, one with 3 protons and 3 neutrons (called Lithium 6) and one with 3 protons and 4 neutrons (called Lithium 7). Note that the number of protons in an element always **stays the same,** even if the number of neutrons or electrons change.

In addition to atomic numbers, each element has a **name** and a **chemical symbol**. The chemical symbol is usually only one or 2 letters long and is usually an abbreviation of the full name. Examples are C for carbon; Na for sodium (from its Latin name Natrium) and Li for Lithium. In addition to atomic number, name, and chemical symbol, each element has an **atomic mass** (atomic weight). The atomic mass is calculated as the sum of the protons and neutrons of each element and if the element has isotopes, the average mass of the element is used. For example, the atomic mass of Lithium is 6.94

CHARGES ON ATOMS AND BONDS

An electron can be moved from one atom to another. This makes the first atom have a positive charge (loses an electron), and the second then has a negative charge (gains an electron). When an atom develops a charge, it is called an **ion.**

- Positively charged ions are called **cations.**
- Negatively charged ions are called **anions.**

Ions are not very stable due to their charges. They generally seek a partner of opposite charge to bind to, thus forming an overall neutral molecule, becoming stable again.

For example, if the sodium atom (Na) loses a negative electron (e), it now has a positive charge and is called a sodium cation, shown as Na^+:

$$Na \longrightarrow Na^+ + e$$

This sodium ion can bond with a negatively charged ion such as the chloride anion (formed by chlorine Cl gaining 1 electron to form Cl^-). This produces a compound called sodium chloride or salt.

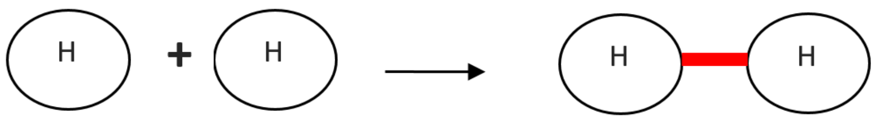
$$Na^+ + Cl^- \longrightarrow NaCl$$

A bond can therefore develop between a cation and anion (i.e. a positively charged cation will always be attracted to a negatively charged anion), and the bond between them is called an **ionic bond**. Ions can be formed from a single atom or from groups of atoms.

The chemical formula for sodium chloride is therefore made by placing the 2 element symbols together, as **NaCl.**

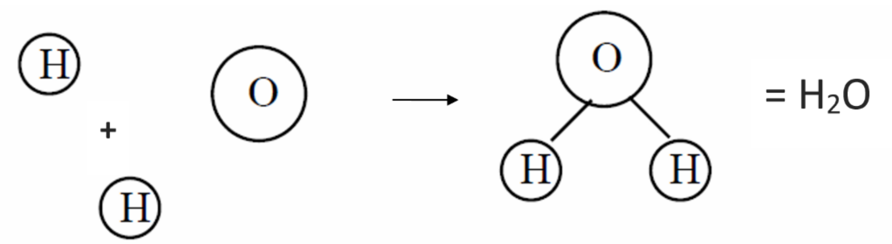
If, however, two uncharged atoms join and share electrons, the bond between them is called a **covalent bond**. A group of two or more atoms covalently bonded together is called a **molecule.** The atoms in a molecule are held together by these bonds. Some elements (e.g. oxygen) do not normally exist as single atoms but they do exist as molecules (O_2) in the form of 2 oxygen atoms joined by a covalent bond. Such groups of atoms can also lose, gain or share atoms.

For example, the diagram below shows two hydrogen atoms (H) joining together (they share two electrons), thus forming with a covalent bond (shown as a single line in red) and forming the hydrogen molecule H_2:



Bonds between two atoms or ions may be stronger or weaker depending on how much charge (or how many electrons) are involved and the distance between the atoms.

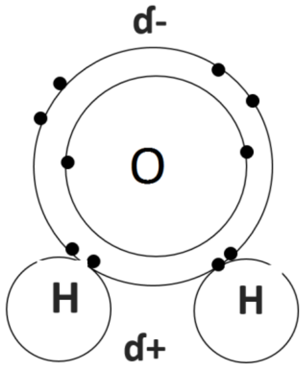
When different elements are joined together they form molecules which are called **compounds**. For example, one oxygen (O) atom joins 2 hydrogen (H) atoms to form water H_2O. The hydrogen atoms are bonded to the oxygen atom, but not to each other. We represent the water molecule by drawing a structural formula showing the bonds, where they exist in the molecule, as follows:



We can also draw the water molecule showing how the atoms are bonding through sharing of electrons. Hydrogen has 1 electron and Oxygen has 8 electrons in total, in two shells. By sharing the two electrons where the shells touch each hydrogen atom can count 2 electrons in its outer shell and the oxygen atom can count 8 electrons in its outer shell.

These full outer shells with their shared electrons are now stable. Note that 2 pairs (4 electrons) are shared between the atoms. Each electron pair is one bond, called a single covalent bond.

Water thus has two single covalent bonds (as illustrated by the two single lines in the previous diagram). **The chemical formula** for water is shown as **H_2O**, as 2 hydrogens bond to 1 oxygen.



The water molecule however is unusual in that it has polarity. Due to the arrangement of the atoms, electrons and bonds, the oxygen end of the molecule is slightly negatively charged **(ɗ-)** and the hydrogen ends are slightly positively charged **(ɗ+).** This polarity makes water a very good solvent (substances dissolve easily in it) and the polarity also affects some of its physical properties such as surface tension, freezing temperature etc.

When two atoms share two electrons (i.e. contributing one each), the bond is represented by a single line and is called a single bond. When two atoms share four electrons (i.e. contributing two each), this is referred to as a double bond, and two lines are drawn between the two. The double bond is stronger than the single bond.

Elements

Atoms are the smallest complete units of elements, of which there are more than 100 different types.

To help understand the properties and relationship between of elements, they are arranged in a table called the **Periodic Table of Elements (PT)**, in order of increasing atomic number. The PT lists all know elements. The elements are often grouped in the PT -these have similar chemical properties. For example: lithium, sodium, potassium, rubidium, cesium and francium are called the Alkali metals. This group of metals is very reactive with water and they have low melting points.

The International Union of Pure and Applied Chemistry (IUPAC) approved the name and symbols for four new elements in 2016 which have been added into the PT: nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og), respectively for elements 113, 115, 117, and 118.

You will revisit the PT later in the lesson in your Set Task.

Significant elements

The table below shows some significant elements and their properties. The elements are listed alphabetically rather than by consecutive atomic number. This list includes elements called metals such as gold, non-metal gases such as oxygen and hydrogen, and the inert (non-reactive) gases such as helium.

NAME	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT	NAME	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
Aluminium	Al	13	26.98	Magnesium	Mg	12	24.31
Antimony	Sb	51	121.75	Manganese	Mn	25	54.94
Arsenic	As	33	74.92	Mercury	Hg	80	200.59
Boron	B	5	10.81	Molybdenum	Mo	42	95.94
Bromine	Br	35	79.91	Neon	Ne	10	20.18
Cadmium	Cd	48	112.40	Nickel	Ni	28	58.71
Calcium	Ca	20	40.08	Nitrogen	N	7	14.01
Carbon	C	6	12.01	Oxygen	O	8	16
Chlorine	Cl	17	35.45	Phosphorus	P	15	30.97

Chromium	Cr	24	52	Potassium	K	19	39.10
Cobolt	Co	27	58.93	Selenium	Se	34	78.96
Copper	Cu	29	63.54	Silicon	Si	14	28.09
Fluorine	F	9	19	Silver	Ag	47	107.87
Gallium	Ga	31	69.72	Sulfur	S	16	32.06
Gold	Au	79	196.97	Sodium	Na	11	23
Helium	He	2	4.00	Tin	Sn	50	118.69
Hydrogen	H	1	1.01	Titanium	Ti	22	47.90
Iodine	I	53	126.90	Tungsten	W	74	183.85
Iron	Fe	26	55.85	Uranium	U	92	238.03
Lead	Pb	82	207.19	Zinc	Zn	30	65.37
Lithium	Li	3	6.94				

Note: not all elements are listed in the above table; only those you are more likely to encounter in this course.

COMPOUNDS

As discussed previously, atoms group together in small OR very large numbers to make chemical compounds. These are made up of various individual atoms or groups (within which the chemical bonds are very strong), joined together by bonds which are weaker.

Two different compounds can have the same number of atoms of each of their constituents, but be considered different compounds with different characteristics. They are different because the arrangement of the atoms and/or bonding is different.

A Hypothetical Example:

If a compound has three different atoms, joined together in a straight line it might look like this:

A. . . .B. . . .C (NB: The dotted line represents chemical energy bonds.)

A therefore is joined to "B"; and "B" is joined to "C":

BUT "A" and "C" are not joined together in any way.

Another compound also has one each of A, B and C atoms but in this case the arrangement is:

```
    A
   . .
  .   .
 .     .
B. . . .C
```

Here "A" is joined to both "B" and "C"

"B" is joined to both "A" and "C"

"C" is joined to both "A" and B"

This difference in arrangement of atoms and bonds give rise to different physical and chemical properties of the resultant compounds

ORGANIC AND INORGANIC COMPOUNDS AND BIOCHEMISTRY

Organic compounds always contain carbon (C), usually with many carbon-hydrogen bonds involved. The molecules range from simple to extremely complex large ones. **Organic chemistry** is the study of these and is often focussed on chemicals in living things, or affecting living things. Examples include sucrose, fructose, ethanol, DNA and benzene. Organic compounds can have **chain structures** and/or **ring structures**, sometimes describes as aliphatic and aromatic respectively. There are also natural and synthetic (man-made) categories of organic compounds. There is more on organic compounds in following lessons.

Biochemistry is exclusively the chemistry of living things and focuses on the study of chemical changes and properties in living cells.

Inorganic compounds do not usually contain carbon and are often much smaller, simpler molecules or atoms. Examples include metals such as gold, lead and mercury and salts such as sodium chloride (salt) and calcium hydroxide (slaked lime).

Common organic chemistry groups:

Group Name	Simplified Representation of Structure and formula
Methyl	CH_3---
Ethyl	CH_3CH_2---
Propyl	$CH_3CH_2CH_2$---
Butyl	$CH_3CH_2CH_2CH_2$---
Isopropyl	CH_3CH_3CH---
Isobutyl	$CH_3CH_3CH_2CH$---
Amino	---NH_2
Hydroxyl	---OH
Carbonyl	CO---
Aldehyde	---COH
Carboxyl	---COOH

An example of a compound containing the ethyl group is ethanol (alcohol) = CH_3CH_2OH and acetic acid (vinegar) has a carboxyl group joined to a methyl group (CH_3COOH).

Basic Chemical Reactions

A **chemical reaction** occurs when one chemical species reacts with another. This causes the formation of chemical compounds (or their decomposition) through breaking and/or formation of bonds. A **chemical equation** shows what reaction has occurred—it is like a sentence of chemistry, explaining what has happened and the quantities of each component.

The equations have to follow certain chemistry ‘rules’, just as sentences have to follow grammar rules. A correctly written chemical equation has equal numbers of each kind of atom on both sides of the equation, i.e. the atoms on each side must be balanced.

This lesson has in fact already shown several chemical reactions. If you refer to the formation of sodium chloride (NaCl), a reaction between Na^+ and Cl^- was presented.

A more complex reaction is shown below for when methane (a gas) is burnt in oxygen (in the air).

The methane molecule has one carbon and 4 hydrogen atoms joined by covalent bonds, with a formula, CH_4.

The oxygen molecule has 2 oxygen atoms joined with a covalent bond, O_2.

The reaction is:

$$CH_4\,(g) + 2\ O_2(g) \text{ -> } CO_2(g) + 2\ H_2O(g) + \text{energy}$$

Thus 1 molecule of methane reacts with 2 molecules of oxygen to form 1 molecule of carbon dioxide (CO_2) and 2 molecules of water (H_2O) as vapour plus energy is released from the breaking of bonds (this results in a release of heat).

The symbol (*g*) refers to the fact that all reactants are gases. If components were solid, they would have the symbol (*s*). The symbol -> shows the direction of the reaction. A double-sided arrow would indicate a reversible reaction (one that goes in either direction).

Chemical Terms

The following terms indicate some important concepts in chemical reactions and chemical behaviour that affect environmental chemistry.

- An **acid** is a molecule that has the capacity to donate a proton or receive an electron during a chemical reaction. An example is hydrochloric acid, HCl.
- A **base** can accept a proton or donate an electron during a chemical reaction. An example is magnesium hydroxide, MgOH.
- **A salt** is a compound that is created by a reaction between a base and acid; usually a molecule with a positive ion from a metal and negative ion from a non-metal. An example is potassium chloride KCl.
- A **solution** is a homogeneous (uniform) mixture of one or more **solutes** dissolved in a **solvent.** Note that the solvent is the substance that is present in the greatest amount.
- A **solvent** is the substance in which solute dissolves in to produce a homogeneous mixture. Water is an excellent solvent.
- A **solute** is the substance that dissolves in a solvent, such as salt.

An example of a solution could therefore be a salty solution used to gargle a sore throat e.g. ½ tsp of salt dissolved in a glass of water.

USED IN ENVIRONMENTAL CHEMISTRY

In environmental chemistry, quantities, weights, concentrations, volumes etc. of various chemicals are expressed using a number and a unit. It is important to define these amounts for monitoring and mitigation measures.

An important unit is **Moles**. A mole is the amount of pure substance containing the same number of chemical units as there are atoms in exactly 12 grams of carbon-12 (i.e., 6.023×10^{23} atoms). It is calculated using the atomic masses of the component substances. A mole of water thus weighs 18 g (16 g from 1 oxygen atom and 2 x 1 g from the 2 hydrogens, giving a total of 18 g).

Molar concentration, also called **molarity**, is a measure of the concentration of a solute in a solution. A commonly used unit for molar concentration used in chemistry is mol/L. A solution of concentration 1 mol/L is also denoted as 1 molar (1 M). For example, if 40 g NaOH was dissolved in 1 Litre of water, this solution would have a molarity of 1 (i.e. its concentration would be 1 mol/L or 1 M)

Mass is usually measured in units ranging from very small ones like micrograms to large ones such as tonnes. Examples are shown in the table below

Name	Number of grams	Symbol
tonne	1,000 000	t
kilogram	1,000	kg
gram	1	g
milligram	0.001	mg
microgram	0.000 001	µg

Volumes (e.g. of liquids) are measured in units ranging from microlitres (µL) through litres (L) to metres cubed (m^3).

Concentrations of chemicals (e.g. of salts in solution or nutrients in soil) are measured in units having a mass and a volume component. Examples are g/L; µg/L; kg/m^3. The units are sometimes expressed with super and subscripts instead of using the / symbol.

For example, kg/m^3 could be written as $kg\ m^{-3}$.

Concentrations or other measurements of quantity may range from very low ones (for example ug/L commonly measured for organic toxins in water) to large ones such as the amount of carbon dioxide in gigatonnes released annually from burning of fossil fuels. In environmental chemistry, concentrations of pollutants in water and soil are often measured by laboratories in mg/L, mg/kg, and μg/L.

SET TASKS

Set Task 1

Locate some information in local newspapers, magazines, books or on the internet about environmental chemistry. Choose two of the news items- one that is important globally or country-wide and one that is important within your own community or household. Make some notes about these issues: describe how the issue has come about, if it is causing problems and if so, what is being done to stop, contain or reduce or these problems. Spend up to 1 hour doing this task.

Set Task 2

Do some research and find a recent copy of the Periodic Table of the Elements. This could be through an internet search, through your local library, asking a friend or colleague etc.

a) Study the Table and take note what the different rows and columns of the elements signify. Can you name them what group of elements is found in the last column of the Table? Can you name some common ways in which these elements may be used in households or businesses? What elements are found in the third row?

b) Locate at least 5 of the different elements discussed in this lesson and note down their chemical symbol, name, atomic number and atomic mass. Is there any other information shown in the Table about these elements? Identify at least 4 chemical or physical properties of these 5 elements. Spend up to 1 hour doing this task.