UNIT 13

CHEMISTRY IN THE WORLD

Teacher Version

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Contents

a) Science, Technology and Development
b) Industry and Development
c) Environmental Chemistry
d) Careers in Science and Technology

Key words: technology, integrated science, hypothesis, law, technology, endogenous, exogenous, industry, rutile, bauxite, haematite, limonite, kaolin, fine chemical, heavy chemical, biotechnology, troposphere, stratosphere, mesosphere, thermosphere, greenhouse effect, ozone, ozone layer

Units which must be completed before this unit can be attempted:

Unit 1 – Atoms and the Periodic Table
Unit 2 – Particles, Bonding and Structures
Unit 3 – Amount of Substance and Measurement
Unit 4 – Introduction to Physical Chemistry
Unit 5 – Acids, Bases and Salts
Unit 6 – Redox Reactions
Unit 7 – Introduction to Organic Chemistry
Unit 8 – Solubility and Precipitation Reactions
Unit 9 – Metals and Their Compounds
Unit 10 - Radioactivity and Nuclear Chemistry
Unit 11 – Further Organic Chemistry
Unit 12 – Non-metals and their Compounds

Estimated Teaching Time: 5 hours

UNIT 13 – CHEMISTRY IN THE WORLD

UNIT 13 SUMMARY AND SYLLABUS REFERENCE

Lesson	Title and Syllabus Reference
1	**Science, Technology and Development** ***ISA1.1 concept of integrated science*** *(explanation of science as an interrelated body of knowledge);* ***ISE9 endogenous technology*** *(explanation of endogenous technology, effects of modern technology on the development of endogenous technology, inter-dependence of science and technology, distinction between science and technology, significance of science and technology to the development of society)*
2	**Industry and Development** ***CA12a chemistry in industry*** *(natural resources in candidate's own country, chemical industries in candidate's own country and their corresponding raw materials, distinction between fine and heavy chemicals, factors that determine siting of chemical industries, effect of industries on the community);* ***CA12bi extraction of metals*** *(raw materials, processing, main products);* ***ISA11 exploitation of minerals*** *(exploitation of the following minerals in Ghana: bauxite, diamond, gold, crude oil and kaolin, negative impact of exploitation of minerals mentioned and how to minimize the effect);* ***ISA13.1 classification of chemicals as organic and inorganic*** *(importance of organic chemistry in industrialization);* ***ISA13.3 petrochemicals*** *(sources, application and effects of petrochemicals on the environment, the refinery of crude oil, uses of petrochemical such as plastics, pharmaceuticals and agrochemicals)*
3	**Small-Scale Industries in West Africa; Industrial and Community Hazards** ***CA12d biotechnology*** *(food processing, fermentation including production of kenkey/gari, bread and alcoholic beverages e.g. local gin);* ***ISE6.3 hazardous substances*** *(possible hazards that can occur in working environment e.g. dust, fumes, toxic substance, corrosive substances, fire, food contamination, harmful radiation (X-rays), poisonous substances from heated or frozen plastics, effects of hazardous substances on human body, e.g. blindness, burns, nausea, vomiting, and allergies);* ***ISE6.4 common hazards in the community*** *(appraisal of the adequacy of the various hazards, warning labels on containers and other places, techniques involved in preventing fire due to electrical and chemical causes, community hazards: traffic problems in towns and cities, pollution problems and waste generation);* ***ISE9.1 small scale industries*** *(small scale industries: raw materials and equipment, scientific principles underlying the following small scale industries: soap production, salt making, palm oil production, bread making, and yogurt production);* ***ISE10 biotechnology*** *(explanation of biotechnology, examples of industries based on biotechnology)*
4	**Environmental Chemistry – Air Pollution** ***CA11eii alkanes – uses*** *(pollution effects of haloalkanes);* ***CA12c air pollution*** *(sources, effects and control, greenhouse effect and depletion of the ozone layer);* ***ISE2.1 regions of atmosphere*** *(layers of the atmosphere: troposphere, stratosphere, mesosphere, and thermosphere, description of the characteristics of each layer in terms of thickness, temperature, air quality and composition, pressure and support for human activities);* ***ISE2.2 human activities and their effects on the atmosphere*** *(effects of human activities on the atmosphere: air transport, defence, industrialization and agriculture);* ***ISE2.3 atmospheric pollutants*** *(sources and effects of the following major pollutants: oxides of lead, nitrogen and sulphur; ozone, halons (carbon and halogen compounds));* ***ISE2.4 greenhouse effect*** *(explanation of 'greenhouse' and its effect: global warming and climate change, possible factors to address the problem of global warming. greenhouse gases e.g. carbon (IV) oxide and methane);* ***ISE2.5 ozone layer*** *(ozone layer and how it protects living organisms, causes and effects of the depletion of the ozone layer, sources and effects of CFCs on the ozone layer);* ***ISE2.6 acid rain*** *(identification of acidic pollutants which cause acid rain, the effects of acid rain on the environment (damage to buildings, paints forests etc));* ***ISE6.4 common hazards in the community*** *(community hazards: traffic problems in towns and cities, pollution problems)*
5	**Environmental Chemistry - Soil and Water Pollution; Careers in Science and Technology; Unit 13 Revision and Summary** ***CA12c water and soil pollution*** *(sources, effects and control, biodegradable and non-biodegradable pollutants);* ***ISA1.1 concept of integrated science*** *(careers in science and technology);* ***ISE6.4 common hazards in the community*** *(community hazards: traffic problems in towns and cities, pollution problems and waste generation)*

The Periodic Table of the Elements

Key

relative atomic mass
symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	96.0 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La** * lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac** † actinium 89	[267] **Rf** rutherfordium 104	[268] **Db** dubnium 105	[271] **Sg** seaborgium 106	[272] **Bh** bohrium 107	[270] **Hs** hassium 108	[276] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[280] **Rg** roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

* **58 – 71** Lanthanides	140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	[145] **Pm** promethium 61	150.4 **Sm** samarium 62	152.0 **Eu** europium 63	157.3 **Gd** gadolinium 64	158.9 **Tb** terbium 65	162.5 **Dy** dysprosium 66	164.9 **Ho** holmium 67	167.3 **Er** erbium 68	168.9 **Tm** thulium 69	173.1 **Yb** ytterbium 70	175.0 **Lu** lutetium 71
† **90 – 103** Actinides	232.0 **Th** thorium 90	231.0 **Pa** protactinium 91	238.0 **U** uranium 92	[237] **Np** neptunium 93	[244] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[247] **Bk** berkelium 97	[251] **Cf** californium 98	[252] **Es** einsteinium 99	[257] **Fm** fermium 100	[258] **Md** mendelevium 101	[259] **No** nobelium 102	[262] **Lr** lawrencium 103

UNIT 13 – CHEMISTRY IN THE WORLD

Lesson 1 – What is the difference between science and technology?

a) Science, Technology and Development

(i) Science and Scientific Method

- **Science** is the study of the physical and natural world with the purpose of developing a systematic body of facts and general laws through experimentation and observation; the purpose of science is to develop a knowledge and understanding of the material world

- There are three main branches of science:
  - physics is the study of the matter and energy
  - chemistry is the study of the substances of which matter is composed and how they interact
  - biology is the study of living organisms

- There is significant overlap between the three branches; the study of biology requires the understanding and application of many principles of chemistry, and the study of chemistry requires the understanding and application of many principles of physics; the three branches are very dependent on each other and science is best regarded as a single **integrated** body of knowledge; the study of all branches of science as an integrated body of knowledge is known as **integrated science**

Test your knowledge 1.1: Understanding science and scientific enquiry

(a) Give one example of how Biology relies on an understanding of Chemistry
(b) Give one example of how Chemistry relies on an understanding of Physics
(c) Define the term "science"

(a) Eg amino acids joining together to make proteins and proteins breaking up into amino acids etc
(b) Eg attraction between opposite charges (electrostatic law), conservation of energy etc
(c) Experimental and observational study of physical and natural world with the purpose of obtaining a systematic body of facts and general laws

(ii) Science, Technology and Development

- The application of scientific knowledge for useful and practical purposes is called **technology**; technological developments are, by definition, underpinned by science; in turn, many technological developments are used by scientists for the study of science (eg microscopes, Bunsen burners, computers) and so scientific development is dependent on technology; science and technology are therefore inter-dependent

- Science and technology contribute in many ways to the development of society:
  - the study of science helps humans understand the nature of the world they live in, which should in turn provide insight as to how best to live in it; to maximise the quality of life whilst managing natural resources in a sustainable way for the benefit of all
  - the study of science and information in general allows individuals to become more empowered, as educated people are more difficult to take advantage of and better placed to make informed decisions which benefit themselves and others

  - technology allows us to live and operate more efficiently, to access information quickly and easily and to avoid spending time on manual tasks; this in turn allows people to be more economically productive and/or enjoy more leisure time; technology is therefore a significant contributor to higher living standards

- Science and technology can also be harmful to the development of society:
  - science can be used to create technology which harms people and the environment, deliberately or inadvertently
  - technology can be used by people to do bad as well as good
  - the desire for technology and a better quality of life can drive people to use the earth's natural resources in an unsustainable way

- To ensure that the development of science and technology does as much good and as little harm as possible,
  - scientific and technological research should be carried out in the public domain as far as possible
  - all scientific and technological developments should be subject to peer review in an open and transparent manner
  - as many people as possible should be highly educated in science as technology so that technology and those who develop and use it can be held accountable by as many people as possible
  - the citizens of the world should consider themselves a single global community, rather than as competing families, nations or races, to encourage people to act for the benefit of all as far as is possible

- Technology which is developed within the same context in which it is used is known as **endogenous technology**; technology endogenous to Sierra Leone, for example, is technology developed in Sierra Leone for use in Sierra Leone; these can include agricultural tools, fishing tools, small-scale mining tools and cooking tools as well as some other industrial tools; technology which is developed in a different context from that in which it is used is **exogenous technology**; all imported technologies such as TVs and motor vehicles are exogenous technologies in Sierra Leone

- Generally speaking, societies develop most sustainably through the use of endogenous technologies, for the following reasons:
  - technologies developed in a certain context to meet a certain need are likely to work most effectively in that context, and will often work well when exported to a different context without consideration of how the contexts might be different
  - technologies are developed by people with skills, and generally need to be repaired and maintained by the same people; societies who rely on imported, exogenous technologies remain reliant on the importer for skilled labour and spare parts and often do not develop the skills to maintain and reproduce the technology; this can be expensive and time-consuming; it also creates inequality of skills and income between exporter and importer
  - the development of endogenous technologies happens alongside the study of science in that society and the application of science to meet local needs; endogenous technologies both rely on and help produce an educated population able to meet its own needs

- This does not mean that societies should never use exogenous technology; in some cases it is necessary to import technologies in order to facilitate development, as the resources and skills may not be available locally at that time; however societies should always be working towards the development of endogenous technologies; for example, there are currently no motor vehicles produced in Sierra Leone; this means that the country is reliant on imported motor vehicles which causes a number of problems:
  - the cost of importing each vehicle makes the vehicle more expensive
  - it may also be difficult to get spare parts or find skilled labour to maintain the vehicle
  - there is no incentive for the manufacturers of the vehicle to educate or train the local labour force and so the technology does not create any jobs in Sierra Leone
  - the vehicle has not been built for the road conditions or climate in Sierra Leone and so may not work as effectively
  - as a result, capital is transferred out of Sierra Leone

  This does not mean that Sierra Leone should not import cars; the country needs cars, but the country would benefit greatly by developing its own automotive industry, to reduce the cost of cars, build cars better suited to the needs of Sierra Leoneans, make vehicles easier to maintain, create jobs and develop skills

Test your knowledge 1.2: Understanding technology and development

(a) State the difference between science and technology and explain how they both depend on each other
(b) State two ways in which technology can raise living standards
(c) Explain the difference between endogenous and exogenous technology
(d) Explain why endogenous technology is more likely to create sustainable development than exogenous technology

(a) Science: study of the natural and material world; technology: application of scientific knowledge for useful purposes; science is used in technology and technology is used in science
(b) Greater automation allows people to be more productive; technology allows information to be shared more quickly and openly
(c) Endogenous technology is developed in the same context in which it is used; exogenous technology is developed in a different context from that in which it is used
(d) Using endogenous technology reduces import costs, creates local employment and skills; endogenous technologies are usually quicker and easier to maintain

Lesson 2 – What are the different types of industry in West Africa?

b) Industry and Development

- Industry is defined as "economic activity associated with the processing of raw materials and manufacturing of goods in factories"

- Industry can provide important income for communities as a result of job creation and investment in infrastructure; it can also be an important source of government revenue through local and export taxes, and reduce reliance on imported goods

- Industry can also, however, have an adverse impact on the community as a result of the environmental changes and damage caused by the industry; working in industry also has safety risks; the challenge for governments and communities is to maximise the benefits of industry whilst minimising its adverse effects

- There are a number of industries in West Africa, the most significant of which, in economic terms, involve mining; there are also some smaller-scale manufacturing industries operating in Sierra Leone; these include food processing, the manufacture of building materials, the brewing of alcoholic and non-alcoholic drinks, the manufacture of fabrics and the generation of renewable energy

Summary Activity 2.1: Extraction of Metals and Refining of Crude Oil

- How is iron extracted from its ore?
- How is aluminium extracted from its ore?
- How is gold extracted from its ore?
- What is a petrochemical? How is crude oil converted into petrochemicals?

- By chemical reaction using carbon as a reducing agent
- By electrolysis
- By concentration, then dissolving in cyanide ions, then reforming on a carbon surface
- A useful chemical made from crude oil; by fractional distillation, then by cracking and reforming the different fractions

(i) Mining and Drilling

- Sierra Leone has significant deposits of diamonds, titanium ore (rutile), aluminium ore (bauxite), iron ore (haematite and limonite) and aluminium ore (bauxite); the commercial value per kilogram of the raw materials rutile, bauxite, haematite and limonite is fairly low; these minerals are mined in Sierra Leone but are mostly exported before significant processing takes place; extraction of aluminium, titanium and gold from its ore is mostly carried out outside Sierra Leone (for the extraction of iron, aluminium and gold see Unit 6 – Redox Reactions and Unit 9 – Metals and their Compounds); diamonds have a high value even without processing, but the fine cutting and polishing of diamonds is mostly carried out outside Sierra Leone

- Ghana has significant deposits of crude oil, aluminium ore (bauxite), diamonds, gold and kaolin (a type of clay with medicinal properties); some of these raw materials are processed into higher value products before they are exported or sold inside Ghana; Nigeria has large deposits of crude oil; some of this crude oil is refined inside Nigeria (see Unit 7 – Introduction to Organic Chemistry) but much is exported as crude oil and refined in other countries; Nigeria also has significant deposits of other minerals, most of which are exported before they are processed

- If the processing of these raw materials were to take place inside the country in which they are mined, the value of the exports would be much higher; lack of transport infrastructure, lack of skilled labour and lack of energy security are reasons why these raw materials are not, but if Sierra Leone and other countries in West Africa were able to attract investment for such processing plants, the benefits to the economy would be significant in terms of job creation and increased export revenues

- Mining provides Sierra Leone, Nigeria and Ghana with significant revenues but there are also significant downsides to mining; the presence of mines can be damaging to the local landscape, reducing tourism; mines can also cause air and water pollution, which harms local residents and the environment; in addition, people are often displaced as a result of the building of mines; in addition, mining can be dangerous work and miners can be killed in mines or become unwell as a result of exposure to toxic materials; the extra traffic and noise in an area can also be a problem

- Offshore crude oil drilling can be a particular environmental hazard, as if there is a significant leak, large quantities of crude oil will end up in the sea; this can be very damaging for marine wildlife and for industries which depend on the sea, such as fishing and tourism

- It is important to balance the economic benefits of mining for the community and the country against the adverse effects of mining, possible ways to do this include:
  - limiting the quantity that can be mined per day and the times of day during which the mine can operate
  - developing and enforcing strong environmental laws which control the amount of pollution produced by the mine
  - requiring the mining company to invest in the local community and to source as much of its labour locally as possible
  - developing and enforcing strong labour laws which protect workers from exposure to dangerous situations and chemicals
  - not mining in areas of outstanding natural beauty
  - process the minerals in-country to create higher value manufactured products

(ii) Chemicals

- The chemical industry is the manufacture of useful chemicals from raw materials; raw materials used in the chemical industry include air, water, minerals and metals as well as oil and natural gas

- Useful chemicals manufactured from oil or natural gas are known as **petrochemicals**; the crude oil is first refined using fractional distillation and cracking (see Unit 7 – Introduction to Organic Chemistry); this produces various fractions, many of which are used in the petrochemical industry and are widely used in the manufacture of plastics (see Unit 11 – Further Organic Chemistry), pharmaceuticals and agriculture; petrochemicals are non-renewable because they come from fossil fuels; petrochemicals can also contribution to the pollution of the atmosphere and water supplies

- Chemicals can be classified as **fine chemicals** or **heavy chemicals** depending on the production technique and the commercial value of the chemical per kilogram:
  - Fine chemicals are chemicals produced in limited quantity, usually with a high purity and a value of $10 or more per kilogram; they often use advanced technologies and rely on highly skilled labour and they send to be sold directly to retailers and consumers (eg drugs, perfumes)
  - Heavy chemicals are chemicals produced in large quantities, often with a relatively low purity and a value of less than $10 per kilogram; they tend to use less advanced technologies and less skilled labour (eg sulphuric acid, ammonia) and they tend to be sold to other industries

- Fine chemical industries generally bring more economic benefit to a community as they use more highly skilled labour, bring in more income and have less environmental impact due to the smaller scale of production; heavy industries can also bring economic benefits but tend to have a more adverse environmental impact

- Unlike mining and drilling industries, which need to be established at the point where the substance to be extracted exists, it is usually possible to choose the site of a chemicals factory; there are a number of factors to consider when choosing the site for a chemicals factory:
  - the area should have good transport infrastructure; ideally close to a sea port or rail network; this is especially important for heavy industries which involve transporting large quantities of chemicals
  - the area should be close to an urban area so there is a supply of labour and transport infrastructure, but not in an area of high population density or outstanding natural beauty; the outskirts of large cities is often a popular site for this reason
  - the site needs to have good access to energy and water; if water is only needed for cooling, sea water can be used
  - the cost of the land should be reasonably low

Test your knowledge 2.2: Understanding the role of heavy industry in West Africa

(a) State the four most valuable mineral exports from Sierra Leone
(b) Explain how the government of Sierra Leone could increase its revenue from these exports and suggest why it has not been able to do so
(c) State three important minerals exported from Ghana
(d) State the main source of income for Nigeria
(e) State three problems associated with the mining industry
(f) What is the difference between a heavy chemical and a fine chemical?
(g) State three factors which should be considered when deciding where to build a chemical plant

(a) Bauxite, rutile, diamonds, iron ore/haematite/limonite
(b) By processing the raw materials into higher value materials before exporting; problems with transport infrastructure, skilled labour and energy security
(c) Crude oil / bauxite / diamonds / gold / kaolin
(d) Crude oil
(e) Dangerous conditions for miners; loss of scenic beauty; increased pollution and traffic
(f) Heavy chemical: produced in large quantities, low purity, low cost per kg; fine chemical: produced in smaller quantities, high purity, high cost per kg
(g) Availability of sea or rail transport; availability of labour; not area of high population density or natural beauty

Lesson 3 – What are the main small-scale industries in West Africa?

(iii) Small-scale Industries

Summary Activity 3.1: Small-scale chemical industries in West Africa

- What is soap and what are the ingredients needed to make it?
- How can salt be extracted from sea water?
- How are alcoholic drinks made? Why are some drinks distilled?

- sodium salt of a fatty acid; it is made by breaking down a fat or oil with sodium hydroxide
- By evaporating off the water
- By fermentation of sugar, usually in fruit; distillation concentrates the alcohol

- Sierra Leone and other countries in West Africa are home to many small-scale industries; these are industries with a start-up cost of less than $150,000; small-scale industries common in West Africa include:

  - soap production: the production of **soap** was studied in Unit 11 (see Unit 11 – Further Organic Chemistry); it is a process called saponification and it can be carried out on a small scale with only cooking oil, sodium hydroxide and clean water; access to heat is also required

  - salt making: **salt** is sodium chloride and is found as a mineral in the ground and also in sea water; salt can be produced from sea water by evaporating off the salt; this process requires only sea water and heat; salt can be mined by direct excavation or by pumping water down into the salt deposits at high pressure; the water comes back to the surface as a saturated solution of sodium chloride (brine); the water can be evaporated off to leave the salt; this process requires access to clean water as well as access to a reliable pump and drilling equipment

  - palm oil production: **palm oil** comes from the pulp of the fruit from palm trees; palm kernel oil comes from the kernel of the fruit of palm trees; no other ingredients are required and the only equipment required is an oil press

  - bread production: **bread** production is an example of **biotechnology** as it makes use of living organisms; bread consists of flour, water, oil, sugar and yeast; the yeast consumes the sugar in a process called fermentation (see Unit 11 – Further Organic Chemistry), converting it into ethanol and carbon dioxide; the carbon dioxide causes the dough to rise; the dough is then cooked, which causes the ethanol to evaporate away; **kenkey** is made in similar way (from maize flour) as is **fufu** (from cassava flour)

  - alcoholic beverage production: **beer**, **wine** and **gin** production are also examples of biotechnology**;** alcoholic drinks are made from fruit or vegetables, water and yeast; the yeast consumes the sugar in the fruit by fermentation (see Unit 11 – Further Organic Chemistry), converting it into ethanol and carbon dioxide; the longer the fermentation process and the less water, the greater the concentration of ethanol in the liquid; the presence of ethanol makes the drink alcoholic and affect your nervous system; the presence of carbon dioxide often makes the drink fizzy; the resulting mixture is sometimes concentrated by distillation; this removes much of the water and creates a type of more strongly alcoholic drink called a spirit (see Unit 11 – Further Organic Chemistry); the production of alcoholic beverages requires no equipment other than an air-tight container, although the production of sprits also requires distillation apparatus

  - yoghurt production: **yoghurt** production is another example of biotechnology; yoghurt is produced by adding a bacterium called lactobactillus or streptococcus to milk; the bacteria consume lactose in the milk; breaking it down into lactic acid in another example of fermentation (lactose → lactic acid); the acidity of the lactic acid causes the milk to clot, producing yoghurt; no equipment is required other than a clean container; the bacteria are usually obtained from existing yoghurt

Test your knowledge 3.2: Understanding the role of small-scale industries in West Africa

(a) Explain the meaning of the term "biotechnology" and explain how biotechnology is used to make:
(i) alcoholic drinks; (ii) bread; (iii) kenkey or fufu; (iv) yoghurt

(b) Explain how salt can be extracted from underground deposits without directly mining it

(a) Using microorganisms to make useful products; (i) fermentation of sugar by yeast into ethanol and carbon dioxide; (ii) fermentation of sugar by yeast into carbon dioxide, which make bread rise; (iii) same as with bread but with cassava flour and more yeast; (iv) fermentation of lactose by bacteria into lactic acid, which clots the milk
(b) Pump water down into the salt deposit and back up again; the water dissolves the salt; the water can then be removed by evaporation

(iv) Common hazards associated with working in industry

- Working in industry can be rewarding and lucrative but it can also be more hazardous than working in other environments; employees must be aware of the risks and employers must make reasonable efforts to reduce them; some typical hazards are below:

  - **dust** particles: this is a particular issue in the mining industry but can also be an issue in other industries; mining usually involves drilling through rock or breaking up rocks and this creates dust particles, which can be inhaled, causing damage to lungs and other allergies; suitable protective equipment is essential and techniques which restrict the quantity of dust produced are also important

  - **toxic and corrosive chemicals**: this is a particular issue in the chemical industry but it also an issue in mining, especially gold mining; toxic materials can be inhaled or ingested and cause blindness, nausea, vomiting and allergies; corrosive chemicals can cause blindness and burns; if a chemical industry involves the use of toxic or corrosive chemicals essential protective clothing is essential, as are practices which limit exposure to these chemicals; there are some claims that the repeated freezing or heating of plastics can release toxic chemicals but there is insufficient evidence to support this; all toxic and corrosive chemicals should be clearly labelled as such and the visibility of these labels should be monitored and reviewed

  - **fire:** many chemicals are flammable and many other industrial processes involve high temperatures; this creates a significant risk of fire; managers of industrial sites should be aware of all fire risks on the site, take measures to reduce them, keep all employees informed of the risks or fire, how to reduce them and what to do in the event of a fire; risk of fire is a particular issue in mining, as flammable gases can be released underground and it can be very difficult to escape from a mine

  - **food contamination:** industrial environments can contaminate food and drink; eating and drinking should not take place in industrial areas due to the presence of toxic or corrosive substance; catering on industrial sites needs to be well separated from production areas; in industries involving the production of food, aseptic and clean conditions are essential to prevent the product being contaminated

  - **radiation:** most industrial processes to not involve radiation but some use X-rays or gamma rays to kill bacteria, or in analysis and testing; some industries involve working with significant quantities of radioactive material, especially nuclear power plants; providing adequate protective equipment and limiting exposure to radiation is essential in such circumstances; levels of radiation should be constantly monitored and efforts made to reduce it

(v) common hazards in the community

- industrialization and economic growth is also associated with a variety of community hazards; most of which result from rapid population growth in urban areas; it is important that political and community groups work together to minimise these hazards, which can include:
  - increased traffic and hence increased congestion and pollution
  - pollution from household waste and inadequate sanitation facilities, including the accumulation of human waste and plastic waste

Test your knowledge 3.3: Understanding the hazards associated with working in industry

(a) Suggest two risks associated with the mining industry and suggest how the risk can be minimised
(b) Suggest how chemical industries should protect workers from exposure to dangerous chemicals
(c) Explain why there is a high risk of fire in chemical plants and suggest how this risk can be minimised
(d) In what industry are workers in danger of exposure to radiation? How can this risk be minimised?

(a) Inhalation of dust – limit time working in mine and ensure miners wear protective filters; fire/toxic fumes – ensure mines are well ventilated and have more than one exit; have equipment to monitor level of toxicity in air
(b) Eye protection; protective clothing, limit time exposed to chemicals; access to emergency treatment
(c) Many chemicals are flammable and temperatures can be high; have good monitoring equipment; shut down production if temperature gets too high; train staff to reduce risk of fire; abundant fire extinguishers such as sprinkler systems
(d) Nuclear power generation; limit time workers can be on site; ensure good protective clothing (eg containing lead)

Lesson 4 – How are we polluting the environment?

c) Environmental Chemistry

Summary Activity 4.1: Burning crude oil

- Why is the amount of carbon dioxide in the atmosphere increasing? Why is it important that there is not too much carbon dioxide in the atmosphere?
- How does sulphur dioxide get into the atmosphere and why is it harmful?
- How do oxides of nitrogen get into the atmosphere and why are they harmful?
- What is meant by the term non-biodegradable? Give an example of a substance which is non-biodegradable

- Because more fossil fuels are being burned, which produce carbon dioxide; carbon dioxide is a greenhouse gas and too much of it can lead to global warming and climate change
- Many fossil fuels contain sulphur; when the fuel burns the sulphur also burns to form sulphur dioxide; it is acidic and dissolves in water to form acid rain, which damages trees, buildings and marine life
- The nitrogen in the air reacts with oxygen in the air in the conditions of a combustion engine, producing oxides of nitrogen; nitrogen dioxide is also acidic and dissolves in water to form acid rain
- Not broken down in nature; most addition polymers are non-biodegradable

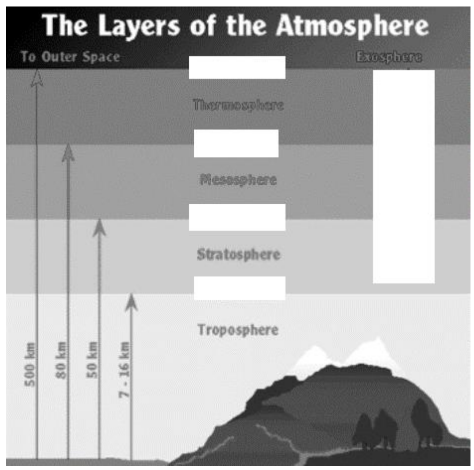
UNIT 13 – CHEMISTRY IN THE WORLD

- Environmental Chemistry is the study of the chemical reactions taking place in the environment, which mainly means the atmosphere, water and soil; it is mostly concerned with studying the effects of pollution and climate change and monitoring levels of different chemicals in the environment

- Pollutants can be classified as **biodegradable** or **non-biodegradable**; non-biodegradable pollution is considered more harmful as it remains in the environment for a long time as it is not broken down naturally

(i) the structure of the atmosphere

- the earth's atmosphere consists of four layers; the **troposphere** (up to 10 km from the surface), the **stratosphere** (10 – 50 km from the surface), the **mesosphere** (50 – 90 km from the earth's surface) and the **thermosphere** (90 – 500 km from the earth's surface); the chemical reactions taking place in each layer of the atmosphere are very different, due to the different temperatures, pressures and amounts of radiation from the sun



- the troposphere contains 75% of the earth's atmosphere and almost all the water vapour and dust; the pressure and temperature in the troposphere decreases as you move away from the surface and is around -30 °C at its outer edge; most clouds are in the troposphere; humans can only survive in the lower sections of the troposphere; above 6 km, the air pressure is too low and radiation levels too high

- the stratosphere contains most of the ozone in the atmosphere; ozone absorbs harmful ultraviolet radiation and prevents it from reaching the earth's surface; the temperature of the stratosphere increases you move away from the surface, rising to around 0 °C at its outer edge, as there is more solar radiation which the ozone absorbs; aircraft fly in the lower parts of the stratosphere

- the mesosphere contains a large number of ions (the top of the mesosphere is also called the ionosphere) because the solar radiation is strong enough to remove electrons from atoms; these ions absorb and reflect radio waves back to earth; the temperature in the mesosphere decreases with height, reaching a minimum temperature of -90 °C

- the thermosphere contains free atoms of oxygen and hydrogen which rarely collide with each other; temperatures vary depending on the position of the sun but the temperature can reach 1500 °C; space stations are often in this layer

(ii) sources of atmospheric pollution

- Human activity is having a significant impact on the composition of the atmosphere:
  - industrialisation has increased our use of energy and hence our burning of fossil fuels; this has caused levels of **CO_2** in the troposphere to rise; this causes global warming and can contribute to climate change (see Unit 7 – Introduction to Organic Chemistry); the destruction of rainforests reduces levels of photosynthesis, which also causes CO_2 levels to rise
  - the burning of fossil fuels has also increased levels of **SO_2** in the troposphere; this causes acid rain
  - engines which burn fossil fuels often also produce **NO** and **NO_2**, as well as **unburned hydrocarbons**; in the troposphere NO and NO_2 can contribute to acid rain; air transport also increases levels of NO and NO_2 in the stratosphere, where these gases can destroy ozone; in the troposphere unburned hydrocarbons and nitrogen oxides can react together to produce **ozone** at ground level, where it is a toxic gas which causes smog (see Unit 7 – Introduction to Organic Chemistry)
  - fridges and aerosol cans used to release **chlorofluorocarbon**s (CFCs) or **halons** into the atmosphere; these unreactive molecules would rise into the stratosphere, where they can destroy ozone
  - petrol/gasoline from cars used to contain **lead**, which improved its octane rating; when the fuel was burned, lead was released into the atmosphere, both as free lead atoms and as molecules of PbO and PbO_2; lead can accumulate in the organs of humans and cause organ failure
  - agriculture can also contribute to atmospheric problems; cows release large quantities of methane, which causes global warming

- The "**greenhouse effect**" is the warming of the temperature of the earth as a result of the accumulation of certain gases in the atmosphere, most notably carbon dioxide, water vapour and methane; these gases are known as "**greenhouse gases**"
  - a greenhouse is a house made from glass in which plants are grown, usually in cold countries; the glass absorbs the infra-red radiation (heat) emitted from the earth and returns it to earth; as a result not much heat escapes from greenhouses and they can become very warm
  - greenhouse gases have the same effect on the earth as glass does on a greenhouse; they absorb infra-red radiation from the earth, reflect it back down to earth and hence prevent heat from escaping
  - the greenhouse effect is essential to keep the earth warm enough to live on; however too much of greenhouse gases can warm up the earth too much; this can have a major effect on global temperatures and weather patterns; this effect is known as **climate change**
  - if climate change continues it may make the planet uninhabitable; the effects of climate change can be limited by releasing less carbon dioxide and methane into the atmosphere; this requires burning fewer fossil fuels and moving to alternative sources of energy; this requires international cooperation

- The **ozone layer** refers to the stratosphere, which contains almost all of the ozone (O_3) in the atmosphere; ozone is an allotrope of oxygen
  - ozone is produced when O_2 molecules are broken up by high energy radiation: $O_2 \rightarrow O + O$, $O + O_2 \rightarrow O_3$
  - ozone is constantly being converted back to oxygen $O_3 \rightarrow O_2 + O$; this maintains a constant level of ozone in the stratosphere
  - ozone is essential to the safety of the planet because it absorbs most of the harmful ultra-violet light which the sun radiates towards earth; UV light causes skin cancer
  - oxides of nitrogen (NO and NO_2) which are released into the stratosphere by aircraft, react with ozone and destroy it: $NO + O_3 \rightarrow NO_2 + O_2$; $NO_2 + O_3 \rightarrow NO_3 + O_2$
  - CFCs from refrigerators and aerosols are broken down by UV light in the stratosphere, releasing Cl atoms; these react with ozone and destroy it: $Cl + O_3 \rightarrow ClO + O_2$; CFCs are non-biodegradable and so are especially problematic
  - The destruction of the ozone layer has been mostly stopped due to the banning of CFCs; aircraft, however, still release NO and NO_2 into the stratosphere

- **Acid rain** is rainwater with a pH of below 4; it forms when rainwater absorbs acidic gases in the atmosphere such as NO_2 and SO_2; these produce weak acids in water such as HNO_2 and H_2SO_3; further oxidation of these acids by oxygen in the air produces even stronger acids, HNO_3 and H_2SO_4; acid rain can damage trees, crops, buildings and marine life

Test your knowledge 4.2: Understanding the atmosphere and how it can be polluted

(a) Identify the four main layers of the atmosphere
(b) What are the two most abundant gases in the troposphere?
(c) In which layer of the atmosphere is ozone found and why is ozone important?
(d) State two molecules which can destroy ozone and explain how they end up in the atmosphere
(e) What is a greenhouse gas? Name the two most significant greenhouse gases in the atmosphere
(f) Which pollutants cause photochemical smog and how do they end up in the atmosphere?
(g) How do oxides of lead end up in the atmosphere and why are they harmful?

(a) Troposphere, stratosphere, mesosphere, thermosphere
(b) Nitrogen (80%) and oxygen (20%)
(c) Stratosphere; absorbs harmful UV rays from the sun and stops them reaching ground level
(d) Halons (from refrigerators and aerosols) and oxides of nitrogen (from combustion engines)
(e) A gas which absorbs the IR radiation emitted by the earth and hence contributes to global warming
(f) Ozone, formed by the reaction of nitrogen oxides (released from combustion engines) with unburned hydrocarbons (released when petrol is burned)
(g) Lead used to be added to petrol to increase its octane number; it causes neurological damage, especially to children

Lesson 5 – What career paths are open to you if you study Chemistry?

(iii) Water and soil pollution

- A clean water supply is important for life; we get most of our drinkable water from rain collected in streams, rivers and reservoirs; if this water becomes contaminated, it is not safe to drink and can harm animals and plants

- Much water pollution comes from agriculture; soluble fertilisers added to crops are washed away by rain and accumulate in rivers and streams; this starts a process called **eutrophication**:
  - as a result of high levels of fertiliser in the water, algae grow rapidly and cover the surface of the water (algal bloom)
  - this means that underwater plants cannot get any sunlight, so cannot photosynthesise and so cannot survive
  - the dead plants are broken down by bacteria, which in doing so use up the oxygen in the water
  - as a result fish cannot breathe and also die
  - farmers can reduce the problem of eutrophication by using organic fertilisers, which are less water soluble and so not washed away so easily, and by reducing the quantity of fertiliser used

- Industrial sewage is also a main cause of water pollution; if not properly treated; industrial sewage can contain a wide variety or harmful chemicals and bacteria which can contaminate the water supply; heavy metals such as lead are a significant problem; these are non-biodegradable and remain in the water for a long time; they are highly toxic; the effluent released from factories must be closely monitored for dangerous chemicals and the companies must follow strict laws on what they are allowed to release into the water supply

- Domestic sewage can also release harmful bacteria into the water supply

- A recent problem is the accumulation of large quantities of plastic in the water supply, especially in the sea; this causes major problems for marine life and plastic microparticles can also be harmful to humans; it is important for us to reduce our dependence on plastics, especially single-use plastics; plastics are non-biodegradable and so remain in the water supply for a long time

- Soil pollution is also a problem and has similar causes to air pollution and water pollution; soil pollution is both a cause and a consequence of water and air pollution; polluted soil cannot be safely cultivated and it is also dangerous to build homes on polluted soil unless the water supply can be isolated

Test your knowledge 5.1: Understanding water and soil pollution

(a) Give one example of how agriculture can contribute to water pollution and suggest how this problem can be prevented
(b) State three other ways in which human activity can contribute to water pollution

(a) Fertilisers run off into water supply causing eutrophication; problem can be reduced by using less fertiliser, or using organic fertilisers which are less water soluble
(b) Human sewage, industrial sewage, plastic

d) Careers in Chemistry, Science and Technology

- Studying Chemistry at Senior Secondary level can lead to a number of possible career pathways in the field of science and technology; this can include careers in Education, Health, Industry, Government or Non-Profit sectors

- Students who have studied Chemistry can work in the education sector as:
  - Science or Chemistry teachers or university lecturers
  - Science or Chemistry laboratory technicians
  - Research Scientists based at a university (receiving grants from industry or government or NGOs to carry out research); many research scientists are also lecturers

- Students who have studied Chemistry can work in the health sector as:
  - Doctors, Nurses, Midwives, Pharmacists (these careers require further study in the chosen field)
  - Medical laboratory technicians and analysts (analysing medical samples)

- Students who have studied Chemistry can work in industry (including petrochemicals and mining) as:
  - Research and Product Development Chemists (developing new chemical products or processes)
  - Manufacturing Chemists or Chemical Engineers (extracting, purifying or manufacturing chemical products)
  - Analytical Chemists (quality control of research, manufacturing or waste products)

- Students who have studied Chemistry can work in government or non-profit as:
  - Environmental Scientists (monitoring levels of pollution, monitoring the impact of industrial and other activities on the environment; developing and enforcing laws which control and regulate the behaviour of different industries in terms of their impact on the environment)

Test your knowledge 5.2: Understanding how studying chemistry can lead to a career

(a) State one career you can pursue in education by studying chemistry
(b) State one career you can pursue in health by studying chemistry
(c) State one career you can pursue in industry by studying chemistry
(d) State one career you can pursue in government by studying chemistry
(e) State three different courses other than Chemistry you can study at university level which require a pass in senior secondary Chemistry

(a) Chemistry teacher (or lab technician)
(b) Medical analyst/laboratory technician
(c) Research chemist; manufacturing chemist; quality control chemist
(d) Environmental scientist
(e) Medicine, Nursing, Chemical Engineering etc

5.3 END-OF-TOPIC QUIZ

UNIT 13 – CHEMISTRY IN THE WORLD

1. Explain the meaning of "technology"; distinguish between exogenous technology and endogenous technology, giving one example of each in your country
2. Distinguish between fine chemicals and heavy chemicals and suggest two reasons why a fine chemicals plant might be more beneficial to a community than a heavy chemicals plant
3. State two risks associated with working in a mine
4. Explain the meaning of "biotechnology" and identify two small-scale industries in West Africa which use biotechnology
5. Name two gases which contribute to the greenhouse effect and explain how they get into the atmosphere
6. Name two gases which destroy the ozone layer and explain how they get into the atmosphere
7. Describe a career in industry you could pursue with a degree in Chemistry

1. Application of scientific knowledge for useful purposes; exogenous technology is not developed in the society in which it is used (eg motor vehicles, refrigerators); endogenous technology is developed in the community in which it is used (fish smokers)
2. Fine chemicals are high purity, high value chemicals produced in limited quantities; heavy chemicals are low purity, low value chemicals produced in large quantities; fine chemicals use more highly skilled labour with higher salaries, and there is less environmental impact due to the smaller scale
3. Dust inhalation, toxic fume inhalation, risk of fire or explosion
4. Use of microorganisms to create a product; brewing and breadmaking use yeast to ferment glucose; yoghurt production uses bacteria to ferment lactose
5. Carbon dioxide (burning fossil fuels), methane (cows)
6. NO or NO_2 (from combustion engines) and halons (from refrigerators and aerosols)
7. Quality Control Analyst; Development Chemist; Manufacturing Chemist