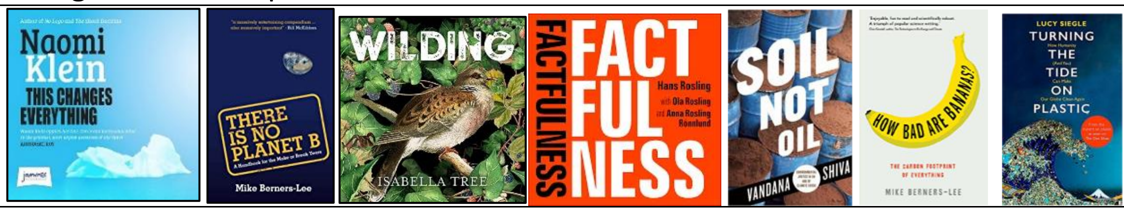
Environmental Science Hereford Sixth Form College

Welcome to **Environmental Science**. We would like to help you to prepare for your new A level course over the coming weeks and months. Below are some suggestions of books, news, films, podcasts, TV shows, citizen science activities and websites, which will keep you up to date with environmental knowledge and development.



	Overheard - National Geographic Podcast Science weekly - The Guardian Podcast BBC Costing the Earth BBC the Documentary Podcast	The Living Planet Podcasts BBC 30 animals that have made us smarter BBC Science Hour BBC Putting science to work - Air Pollution
	BBC Climate forcing BBC Climate Change BBC Science and Nature playlist BBC Sustainable Thinking Colchester Zoo Live at 11am and 1pm BBC Countryfile at 7pm on Sundays Any David Attenborough series	iPlayer Seven Worlds One Planet iPlayer dynasties iPlayer climate-change-the-facts
	Citizen Science penguin-watch Citizen Science rainfall-rescue The Big Butterfly Count	https://earthchallenge2020.earthday.org/ Transcribing old climate data Air quality surveys
	Bioethics Education project JNCC wwf CITES list of endangered species IUCN Red list of endangered species	Environment Agency air quality guide by region Living Planet Report

Pre-course work

Essential Science knowledge from GCSE for A level Environmental Science

You must understand the implications of basic science principles from your GCSE course

Biology

- Understand the processes of **photosynthesis** and **respiration** and their implications for life
- Be able to write word equations for photosynthesis and respiration

Chemistry

- Understand what an **element** is, and the properties of the most common elements found in biological compounds
- Be able to write a paragraph using all these words in correct context: -
  solution, solute, solvent, dissolve, temperature, precipitate. (Use NaCl as an example)

Physics

- Physical **properties of water**
- **Electromagnetic spectrum**, especially ultra violet, visible light and infra-red radiation
- 1^{st} & 2^{nd} laws of **thermodynamics**
- **Energy efficiency**

Geography (from Key Stage 3)

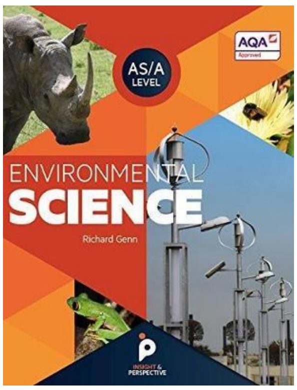
- The **water cycle**
- **Latitude** related to climate, latitudes of the **equator & the tropics**, latitudes of UK and Europe

Geology (covered in GSCE Science/ Chemistry)

- The three main **types of rock** and how they are formed

Mathematics

- Calculating %
- Calculating proportions (scaling down/up)
- Calculating mean



At A-level you will be following the **AQA Specification** and will study the following topics:

- The Living Environment
- The Physical Environment
- Energy and Pollution
- Biological Resources
- Sustainability
- Scientific Methods

The text book will be issued on loan to you from College, or can be purchased from the publisher, Amazon or sometimes eBay.

Publisher: Insight & Perspective
ISBN: 9781912190072

Pre-course work

1.

Conditions for life on Earth

Planet Earth is about 4.5 billion years old. About 3.9 billion years ago, life evolved and has continued to evolve. Life exists in the oceans, in the soil, on the surface, in rocks extending to several kilometres below the surface and (at least temporarily) in the air to an altitude of several kilometres. The question is: Why is Earth the only planet in our Solar System with life on it ?

The key factors are:

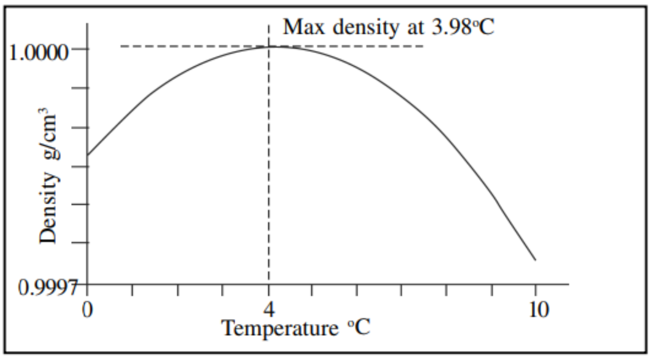
- liquid water near the surface;
- an atmosphere that filters incoming radiation, allowing just the right amount through;
- a stable planetary orbit around the Sun;
- our current position relative to the Sun, which provides our heat and energy;
- enough internal heat from the planet's molten core to allow plate tectonics (which are important for maintaining the balance of the carbon cycle);
- having Jupiter as a neighbour which protects us from comets and asteroids;
- the presence of a large moon that stabilizes tilt (keeping the seasons mild) and the tides;
- the evolution of photosynthetic microbes that released oxygen into the atmosphere

Water

Liquid water exists on Earth because we are just the right distance from the Sun and the natural greenhouse effect maintains a moderate surface temperature. Water acts as the solvent for all metabolic reactions in living organisms and is essential for internal transport.

Water has the very unusual property that its solid form (ice) floats on the liquid (Fig 1).

Fig 1 Density of water



This is because it is most dense at about 4°C - so ice is less dense than cold water. Thus water freezes from the top down. The ice crust that forms on a body of water insulates the water beneath from cooling and allows life to survive.

Water has a high specific heat capacity i.e. it takes a lot of energy to raise the temperature of water or conversely, a lot of energy can be lost before the temperature of water starts to fall. This is crucial for living organisms which need to maintain particular temperatures in order to optimise enzyme activity. The high water content of cells and tissues helps them to maintain a constant temperature. In this way water acts as a **temperature buffer**.

Conversely, when water molecules do escape from the water surface during evaporation, a lot of energy is released with them. As a result, evaporation (e.g sweating or panting) is an efficient cooling mechanism, allowing living organisms to maintain a constant body temperature. The biological importance of water is summarized in Table1.

Table 1 Biological importance of water

Function	Examples/Explanations
Transport	Uptake of minerals by plants from soil Transpiration stream and water-based movement of sugars and amino acids, hormones etc. in phloem occurs in solution. All transport fluids used in animals (e.g. cytoplasm, blood, plasma and tissue fluid) are water-based.
Chemical reactions (metabolism)	Combination of thermal stability and excellent solvent properties makes water an ideal environment for chemical reactions. All enzyme reactions of photosynthesis, respiration, excretion etc. occur in solution.
Temperature control	High specific heat capacity allows water to act as a buffer; essential in endothermic organisms that need to maintain a constant body temperature in order to optimise enzyme activity and thereby regulate metabolism. High incidence of hydrogen bonding also makes at it difficult for water molecules to evaporate. When they do so, much energy is released and this is involved in cooling mechanisms. Water remains a liquid over a huge temperature range - essential for metabolism and useful for aquatic organisms which avoid freezing.
Support & movement	In plant cells water confers turgidity. This is essential for example, in: 1. Maintaining maximum leaf surface area, hence light absorption, hence photosynthesis. 2. Maintaining aerial parts of the plant to maximise seed dispersal or pollination. Loss of water in very hot conditions may lead to leaves wilting. This decreases their surface area, hence light absorption, temperature and water loss. In animals, water-filled tissues also contribute to skeletal support. In organisms which possess a hydrostatic skeleton (e.g. annelids), water is the major component of the fluid in the coelom against which muscles can act. For aquatic organisms, water provides support through buoyancy. Organisms such a earthworms and leeches use their hydrostatic skeletons to move around. Longitudinal and circular muscles are able to contract against the incompressible watery fluid of the coelom.
Reproduction	Organisms which employ sexual reproduction use water to bring the male and female gametes together in the process of fertilisation.

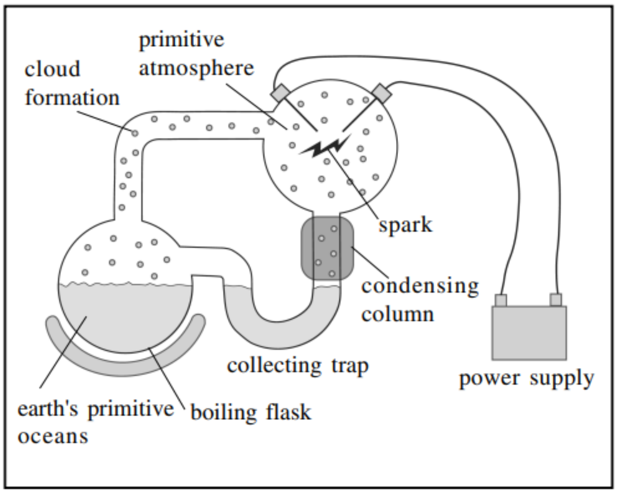
Water vapour in the atmosphere contributes to the greenhouse effect and helps raises the average surface temperature of the planet. Both atmospheric clouds and surface snow and ice are highly reflective; without them the Earth would absorb much more of the sunlight that strikes our planet, and this would raise the temperature even without a greenhouse effect. Water also plays a key role in the energetics of the atmosphere, since it can store or release energy as it changes from vapour to liquid (clouds) and back again.

The beginning of Life on earth

In the 1950s many scientists were trying to work out how the building blocks of life –amino acids, simple sugars etc – could have formed in the first place. Stanley Miller, an American scientist carried out an ingenious experiment. He put the gases that were believed to have made up the Earth's early atmosphere - methane (CH_4), ammonia (NH_3), hydrogen (H_2), and water (H_2O) and zapped them with an electric current to simulate lightning (Fig 2)

He used chromatography to identify the products. At the end of one week, 10% of the carbon was now in the form of organic compounds. Two percent of the carbon was in the form of amino acids which are used to make proteins. Thus, Miller showed that organic compounds such as amino acids, which are essential to cellular life, could be made easily under the conditions that scientists believed to be present on the early Earth.

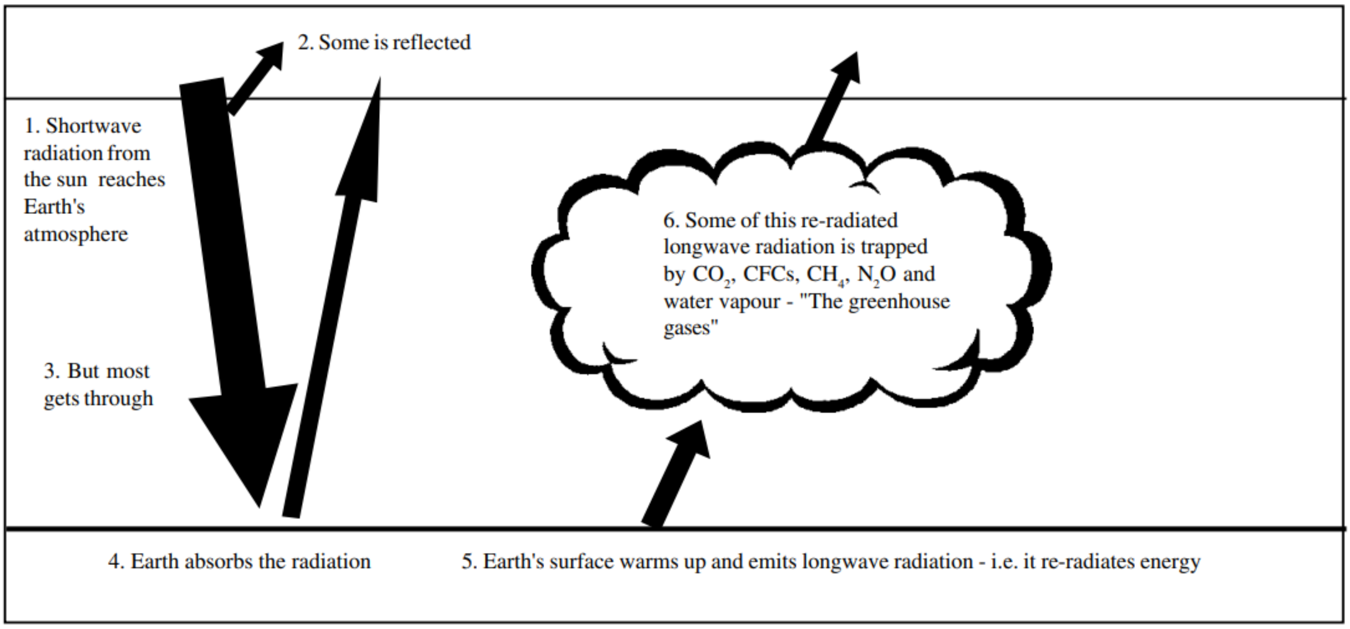
Fig 2 Miller's How did Life begin? experiment



The atmosphere

The greenhouse effect – the trapping of heat in the lower atmosphere – is a natural process and is essential for life on Earth. Without it, temperatures would be below 0°C (Fig3).

Fig 3. The Greenhouse Effect



The greenhouse effect ensures that most of our planet has a temperature range that permits life. These temperatures also ensure that the gases that all life depends upon – oxygen and carbon dioxide – exist in a gaseous state.

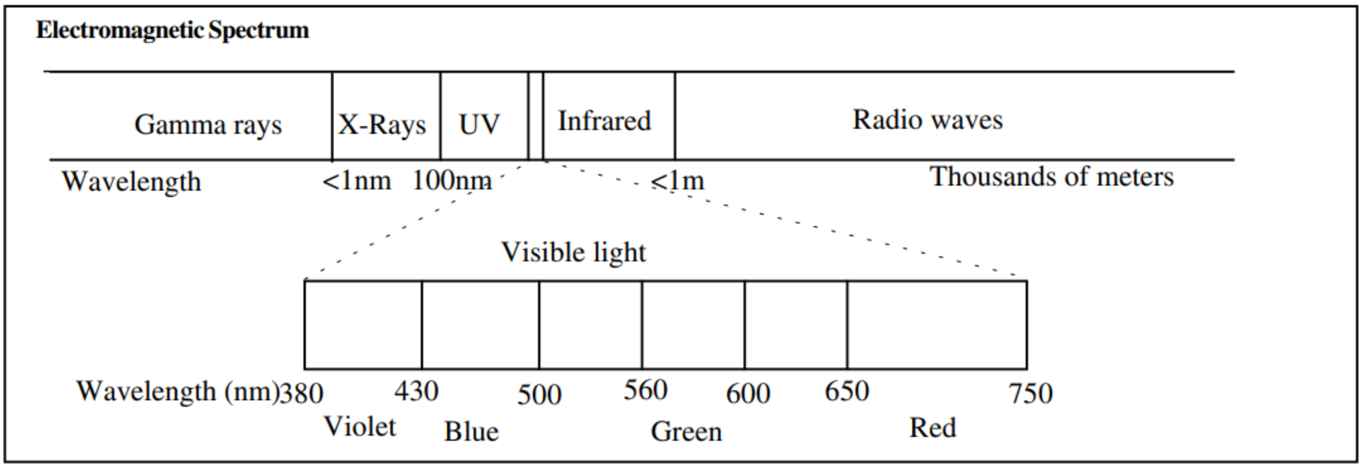
The gaseous composition of our atmosphere allows photosynthesis and aerobic respiration, two processes that actually help to maintain that composition. Although there is only 0.035% carbon dioxide, that is sufficient for photosynthesis and, if that percentage was higher, we would run the risk of a runaway greenhouse effect. The 21% of the atmosphere that is oxygen allows plants and animals to carry out aerobic respiration – the efficient release of energy from chemical stores.

The ozone layer in the stratosphere absorbs UV radiation which would otherwise destroy living organisms by causing mutations and cancers.

Photosynthesis

Green plants are the basis of almost all food chains. Plants trap light energy in the pigment chlorophyll. This light energy is converted into chemical energy – carbohydrates,fats, proteins etc. Plants use only a small part of the electromagnetic spectrum – the part that is visible light (Fig4).

Fig 4. The Electromagnetic Spectrum

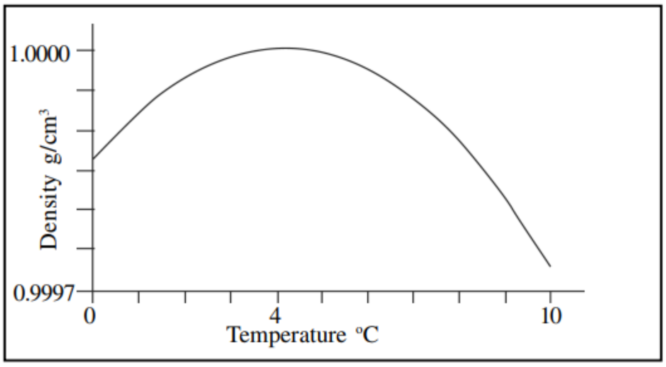


Chlorophyll is actually a mixture of different pigments, each of which absorbs a slightly different part of the visible spectrum. The two wavelengths that are most useful in photosynthesis are those that correspond to red and blue light – most green light is reflected from leaves, which is why they appear green to us. No animal is capable of converting light energy into chemical energy in this way – so the animal Kingdom depends upon the plant Kingdom, and both depend upon the Sun!

As far as we know, no other planet supports life.

Practice Questions

1. The graph shows the effect of temperature on the density of water.



(a) State the temperature at which water reaches maximum density; 1 mark

(b) Outline the environmental significance of the relationship between water temperature and density. 4 marks

2. Outline the importance of each of the following for life on Earth:

(a) the ozone layer; 2 marks

(b) the natural greenhouse effect. 4 marks

2.

Is Earth the only living planet?

This Factsheet:
- Describes the composition of Earth's early atmosphere
- Explains how life changed Earth's atmosphere
- Discusses the possibility of life on Venus and Mars

Scientists estimate that Earth was formed about 5 billion years ago. The actual process of formation took tens of millions of years. Fig.1 shows a timeline of events on early Earth.

Fig.1 Early Earth

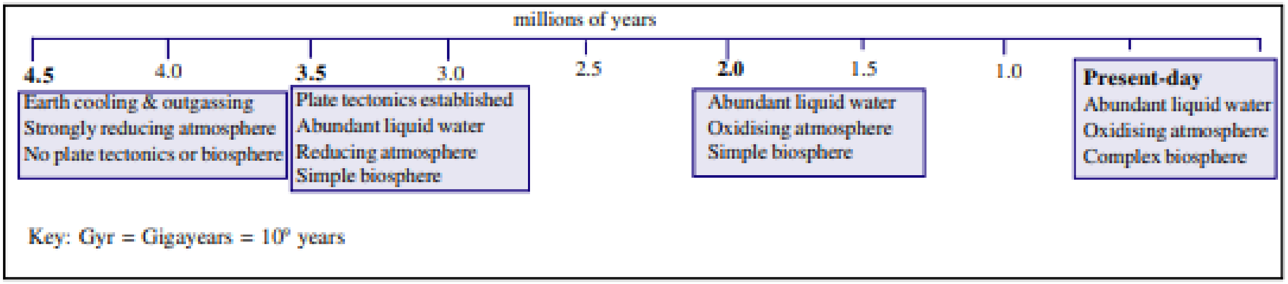


Table 1 shows the composition of the Earth's atmosphere before life began and today.

Table 1 Earth's atmosphere before & with life

Gas	Atmosphere / % by volume	
	Before life began	Present-day
Nitrogen	1.90	78.10
Oxygen	0.00	20.90
Carbon dioxide	98.00	0.04

Scientists still hotly dispute how life began on Earth but a widely-accepted theory is that water arrived on Earth from dust, rocks and comets and allowed life to begin. Before life began, there was no free oxygen. Any oxygen rapidly combined with other elements to form oxides. Thus, the earliest forms of life used **anaerobic respiration** to obtain their energy. Eventually, microorganisms capable of photosynthesis evolved. Through photosynthesis, oxygen levels increased and levels of carbon dioxide went down. This enabled aerobic respiration, which yields energy more efficiently than anaerobic respiration. The presence of oxygen in the atmosphere enabled an ozone layer to form (see Box). This was crucial for living organisms to move from the sea to land. The layer of ozone in the stratosphere filtered out highly damaging UV radiation which would otherwise have damaged the DNA of any organism that absorbed it.

Slowly, the number, diversity and complexity of organisms increased. As the biomass of photosynthetic organisms increased there was increased "locking up" of carbon dioxide by burial as the organisms died and were crushed into sediments.

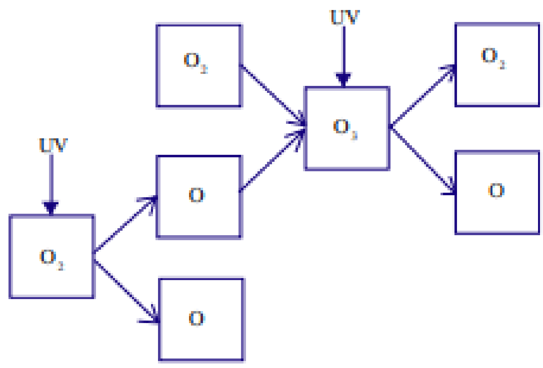
This also helped to reduce atmospheric levels of carbon dioxide. Sunlight broke down ammonia (NH_3) emitted from volcanoes, releasing nitrogen and levels of nitrogen increased to their present-day equilibrium.

Formation of the ozone (O_3) layer

1. UV is absorbed by an oxygen molecule (O_2)
2. UV energy is converted into chemical energy
3. The oxygen molecule is split into oxygen atoms (O) (photodissociation)
4. An oxygen atom combines with an oxygen molecule to form tri-atomic oxygen (ozone)
5. Some ozone is then split back into O and O_2 by UV and so is continuously made and destroyed = **dynamic equilibrium**

***Exam Hint:-** Explaning this dynamic equilibrium is a very common exam question!*

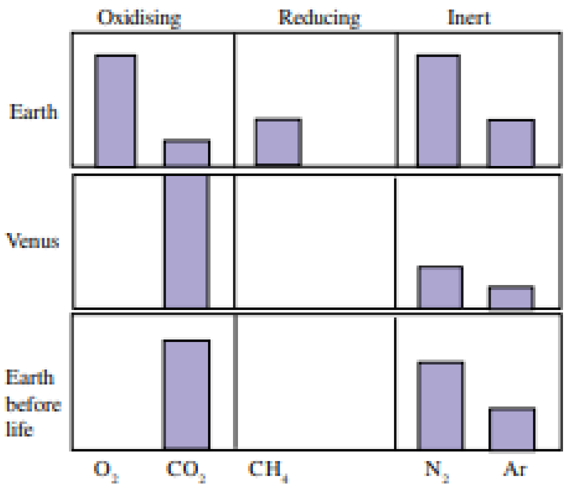
Formation and destruction of ozone



Present day Earth is the only planet we are aware of that has an atmosphere containing free oxygen. This free oxygen is produced continuously in photosynthesis in huge quantities and maintains oxygen levels which would otherwise fall through respiration and chemical reaction.

Typical Exam Question

The bar charts show the present-day atmospheric composition of Earth and Venus and the predicted gaseous composition of Earth before life existed. The chemical behaviour of each gas is also shown.



(a) Explain why the development of life on Earth changed:
   (i) oxygen levels (1)
   (ii) carbon dioxide levels (1)
   (iii) methane levels (1)

(b) Suggest why the surface temperature of Venus is much higher than that of Earth (1)

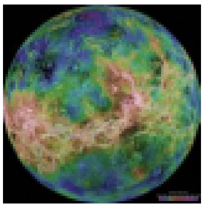
(c) Explain why the ozone layer in the stratosphere is important for life on Earth (2)

Remember: only plants photosynthesise, taking in CO_2 and releasing O_2, but both plants and animals respire, taking in O_2 and releasing CO_2

The conditions on Earth that enable life

- distance from sun just right
- gravity holds our atmosphere
- magnetic field protects Earth from solar wind
- moon controls tides
- water exists as a liquid over large temperature range
- water needed as a solvent for all metabolic reactions
- water needed as a transport medium
- water acts as a C sink
- water provides a habitat
- water is transparent so allows light to penetrate it
- carbon available as building-block
- wide range of elements/minerals available
- visible light for photosynthesis;
- appropriate temperature range for metabolic/enzyme activity
- temperatures > 40°C would damage/denature enzymes
- temperatures permit O_2, N_2 and CO_2 to exist as gases
- CO_2 for photosynthesis
- O_2 for respiration
- O_3 layer shields organisms from damaging UV radiation
- CH_4 and other greenhouse gases maintain warm atmosphere

Is there life on Mars or Venus?



There is evidence that, when the solar system was young, conditions on Mars and Venus may have been suitable for life. The surface of Mars has clearly been altered by water in the past and it may still exist deep underground. Venus is the nearest planet to Earth and is almost identical to Earth in both size and geological composition. Recent research has suggested that, long ago, Venus could have been Earth's sister planet, complete with rivers and life.

But the climates of both planets changed dramatically. Whatever water existed on Mars froze. Any life that existed on the surface could only have survived deep underground where the planet's heat kept water liquid. NASA continues to send probes to try to detect signs of life on Mars.

Any life on Venus faced the opposite problem as carbon dioxide and methane from huge volcanic eruptions led to a runaway greenhouse effect that scorched the surface. However Venus does have an atmosphere containing water and it is just possible that microorganisms live in it. Volcanic emissions provide a range of elements needed for life as we know it and there is plenty of sunlight. Scientists are becoming increasingly interested in investigating the possibility of life on Venus!

Typical Exam Questions

1. The table compares some features of Earth, Venus and Mars.

	Earth	Venus	Mars
Mean distance from the sun/10^6 km	152	109	249
Day length/hours	24	2,800	1,026
Mean diameter/miles	7,892	7,523	3,389.5
Maximum & minimum surface temperature/ °C	-88 to 58		-87 to -5
Mean surface temperature/ °C	15	462	-23
Surface gravity/ m/s²	9.81	8.87	3.71
Atmospheric composition/%	N_2 – 78 O_2 – 21 CO_2 – 0.04	N_2 – 3.4 O_2 – 0.0 CO_2 – 96	N_2 – 2.8 O_2 – 0.15 CO_2 – 95

(a) Use the information in the table to explain why some scientists do not believe that Venus can support life (3)

Both Earth and Venus experience the 'greenhouse effect'.
(b) Explain what is meant by the term 'greenhouse effect' (2)
(c) Explain why the 'greenhouse effect':
  (i) makes life possible on Earth (2)
  (ii) may make life impossible on Venus (2)
(d) Scientists predict that, if life had not developed on Earth, the surface temperature would be much higher. Suggest why (1)

2. Explain the importance of water for life on Earth (5)

3. Watch the TED talk.

https://www.youtube.com/watch?v=N-yALPEpV4w

We will be asking you questions in the first lesson about it.