HL IB Environmental Systems & Societies (ESS)

Your notes

6.1 Introduction to the Atmosphere

Contents

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Atmospheric Composition & Function

- The atmosphere forms the boundary between Earth and space
- It is the outer limit of the biosphere
- The atmosphere **supports life** on Earth

Atmospheric gases and their redistribution

- The atmosphere is mainly composed of **nitrogen** (about 78%) and **oxygen** (about 21%)
  - These two gases make up the majority of the atmosphere and play vital roles in supporting life on Earth
- The atmosphere contains smaller amounts of other gases, including:
  - **Carbon dioxide**
  - **Argon**
  - **Water vapour**
  - **Various trace gases**
- Carbon dioxide, although present in relatively low concentrations (around 0.04%), is essential for:
  - **Photosynthesis** in plants
  - Maintaining the **greenhouse effect**
- Argon is an inert gas that does not participate in chemical reactions but contributes to the overall composition of the atmosphere
- Water vapour plays an important role in:
  - **Photosynthesis** in plants
  - The Earth's **weather patterns**
  - The formation of **clouds** and **precipitation**
- Trace gases, such as methane, ozone, and nitrous oxide, are present in even smaller quantities
  - However, they still have significant impacts on climate and atmospheric chemistry

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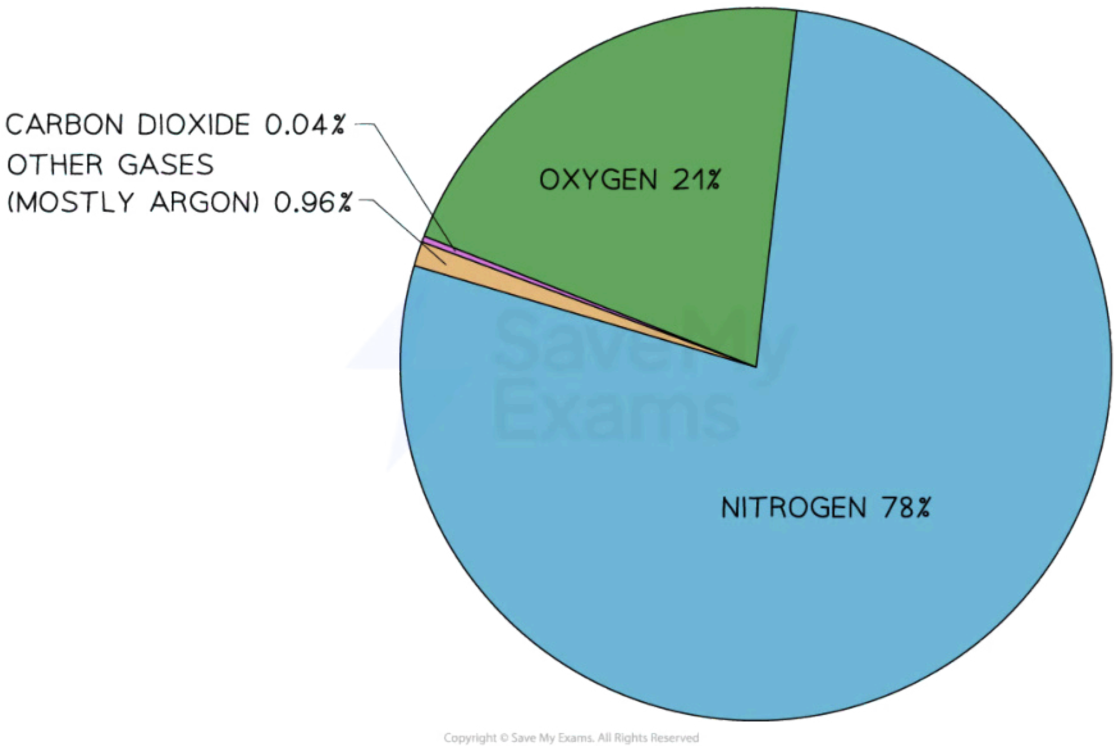

The gaseous composition of the Earth's atmosphere

Redistribution through physical processes

- Gases in the atmosphere are moved around by various physical processes, including:
  - **Wind**: the main mover of gases, caused by differences in air pressure
  - **Convection**: warm air rises and cool air sinks, creating vertical movement
  - **Diffusion**: gases spread from areas of high concentration to areas of low concentration
  - **Turbulence**: irregular air flow caused by obstacles like mountains and buildings
  - **Jet streams**: fast-flowing, narrow air currents in the upper atmosphere

Atmospheric layers

- **Atmospheric stratification**:
  - The atmosphere is divided into layers based on **temperature changes**

- The key layers for living systems are the **troposphere** and the **stratosphere**
- **Troposphere**:
  - The **lowest layer**, extending up to about **10 km** from the Earth's surface
  - Weather phenomena, such as clouds, precipitation, and gas mixing, occur here
  - Contains the highest concentration of water vapour, carbon dioxide and other important trace gases
- **Stratosphere**:
  - Located **above** the troposphere, extending from about **10 to 50 km** above the Earth's surface
  - Contains the **ozone layer**, which **absorbs** and **blocks** most of the Sun's harmful **ultraviolet (UV) radiation**
- **Importance of inner layers**:
  - Various reactions in the troposphere and stratosphere are vital for maintaining the balance of gases, **regulating climate** and **supporting life**
  - In the troposphere, chemical reactions involving pollutants, greenhouse gases and particles impact **air quality** and **climate**
  - In the stratosphere, chemical reactions involving **ozone** maintain the ozone layer and protect organisms on Earth from harmful UV radiation

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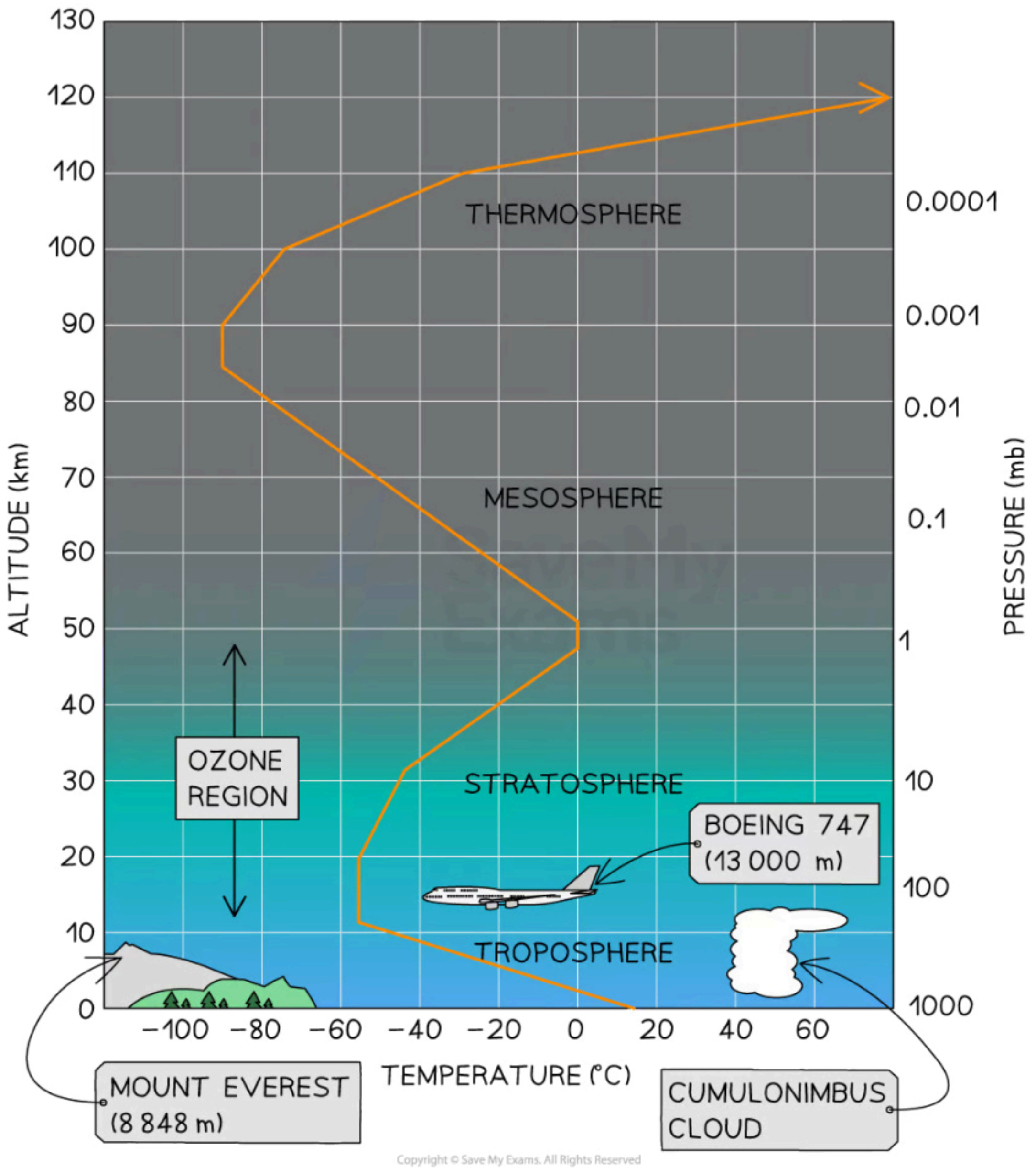

Approximate atmospheric temperatures and pressures up to an altitude of about 120 km—note the warmer temperatures in the troposphere, below the zone of maximum ozone concentration (in the stratosphere)

Differential heating and the tricellular model

- Differential heating of the atmosphere:
  - The Sun heats the Earth and its atmosphere **unevenly**
  - The equator receives more direct sunlight, making it warmer
  - The poles receive less direct sunlight, making them cooler
  - This results in an effect known as the tricellular model of atmospheric circulation
    - This model explains how heat is **distributed** from the **equator** to the **poles**

Atmospheric Systems

- The atmosphere is a highly **dynamic system**
  - It plays a crucial role in the Earth's climate and weather patterns
  - As with other systems, the atmospheric system is made up of storages, flows, inputs and outputs
- **Storages**:
  - The atmosphere acts as a storage for **gases**
  - These gases are present in different concentrations
  - These concentrations can vary over time due to natural and human activities
  - This includes greenhouse gases like carbon dioxide and methane
    - These gases contribute to the greenhouse effect and influence the Earth's temperature
- **Flows**:
  - Within the atmosphere, there are constant flows of gases and particles
  - These flows are driven by processes such as air currents, weather patterns and atmospheric circulation
  - These flows contribute to the movement and redistribution of gases and other substances within the atmosphere
- **Inputs**:
  - The atmosphere receives inputs from various sources
  - Natural inputs include:
    - Gases emitted from **volcanic eruptions**

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    - Gases emitted from **plants** and other **living organisms**
    - **Dust** particles from **desert regions**
  - Anthropogenic inputs, resulting from **human activities**, include:
    - Greenhouse gases (e.g. from fossil fuel combustion and livestock)
    - Air pollutants from industrial processes
    - Aerosols from combustion

Human activities such as emissions from industrial chimneys create inputs into atmospheric systems (Photo by Michal Pech on Unsplash)

- **Outputs**:
  - Gases maybe be removed from atmospheric systems through natural processes like **respiration** and **photosynthesis**
  - **Pollutants** and **aerosols** can be removed from the atmosphere through, e.g. **precipitation** and **dry deposition**

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- **Exchanges and interactions with other Earth systems**:
  - The atmosphere interacts with other components of the Earth system
    - This includes the **biosphere** (plants, animals, and microorganisms), **hydrosphere** (oceans, lakes, and rivers), and **lithosphere** (landmasses and rocks)
  - It exchanges gases and particles with these systems through various mechanisms
    - E.g. the exchange of carbon dioxide occurs through photosynthesis by plants and respiration by organisms
  - These interactions involve the exchange of gases, energy and particles
    - This shapes climate patterns, weather events and overall Earth system dynamics

EXAM TIP

You need to be familiar with the tricellular model of atmospheric circulation, as this is an important part of Topic 2.4 (Climate & Biomes).

You should recall how this model explains the behaviour of atmospheric systems and the distribution of **precipitation** and **temperature** at **different latitudes**.

It also explains how these factors influence the structure and relative **productivity** of **different terrestrial biomes**.

Go back and have a look at this revision note again if you need to revise it!

The Greenhouse Effect

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Greenhouse Gases & the Greenhouse Effect

- Greenhouse gases (GHGs) and aerosols play an important role in Earth's climate by trapping heat in the atmosphere

Greenhouse gases and aerosols

- **GHGs**: gases in the atmosphere that trap heat
  - Key GHGs:
    - **Water vapour**
    - **Carbon dioxide**
    - **Methane**
    - **Nitrous Oxides**
- **Aerosols**: tiny particles or droplets in the atmosphere
  - Key aerosols:
    - **Black carbon**
      - A type of aerosol produced from incomplete combustion of fossil fuels, wood and other biomass
      - Found in emissions from, e.g. diesel engines, cooking stoves and open burning of vegetation
      - Absorbs sunlight and warms the atmosphere
      - Can darken snow and ice surfaces, reducing their reflectivity and accelerating melting

Key Greenhouse Gases

Name of GHG	Sources	Other Information

Water vapour	Evaporation from oceans, lakes and rivers Transpiration from plants Sublimation from ice and snow Combustion of fossil fuels	Most abundant GHG Concentration varies with temperature Amplifies effects of other GHGs Positive feedback loop: warmer atmosphere holds more water vapour, leading to more warming and greater evaporation It is often excluded from climate models due to its dynamic levels and essential role in life, meaning it cannot be mitigated against
Carbon dioxide	Burning fossil fuels: coal, oil and natural gas (e.g. vehicle emissions) Deforestation (when forests are cleared or burned, the carbon stored in trees is released back into atmosphere as carbon dioxide) Industrial processes (e.g. cement production)	Significant contributor to the greenhouse effect due to high concentration and long lifespan in the atmosphere
Methane	Agriculture: livestock digestion (e.g. from large-scale cattle farming) Landfills Natural gas extraction (methane leaks) rice paddies Wetlands	More effective at trapping heat than carbon dioxide (over 20 times more potent over 100 years) Found in much lower concentrations than carbon dioxide, so overall warming effect is less
Nitrous oxides	Agricultural practices (use of synthetic and organic fertilisers) Fossil fuel combustion Industrial processes	Potent GHG with a warming effect nearly 300 times that of carbon dioxide per molecule Found in much lower concentrations than carbon dioxide, so overall warming effect is less

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Rice paddies produce methane due to the anaerobic conditions created by flooded cultivation, which promote the growth of methane-producing microorganisms that decompose organic matter in the soil (photo by Steve Douglas on Unsplash)

The Greenhouse Effect

What is the Greenhouse Effect?

- The Sun emits energy in the form of solar radiation
  - This includes visible light and ultraviolet rays
- This solar radiation enters the Earth's atmosphere
- Some thermal energy is **reflected** from the Earth's surface
- Most thermal energy is **absorbed** and **re-emitted** back from the Earth's surface
  - This energy **passes through the atmosphere**

- Some thermal energy passes straight through and is emitted into **space**
- However, some thermal energy is **absorbed** by **greenhouse gases**
  - This causes thermal energy to be re-emitted in all directions
- These gases act like a blanket
  - They allow sunlight to pass through while preventing a significant amount of the infrared radiation from escaping back into space
- This reduces the thermal energy lost into space and **traps** it within the Earth's atmosphere
  - This keeps the Earth warm
- This process is known as the **greenhouse effect**
  - The greenhouse effect is a **naturally occurring phenomenon**
  - The greenhouse effect is important to ensure that Earth is warm enough for **life**
  - Without the greenhouse effect, the average temperature would be much **colder**, making the planet **uninhabitable**
    - For example, the average surface temperature of Earth is about 15 °C
    - Without the greenhouse effect, it would be about -18 °C

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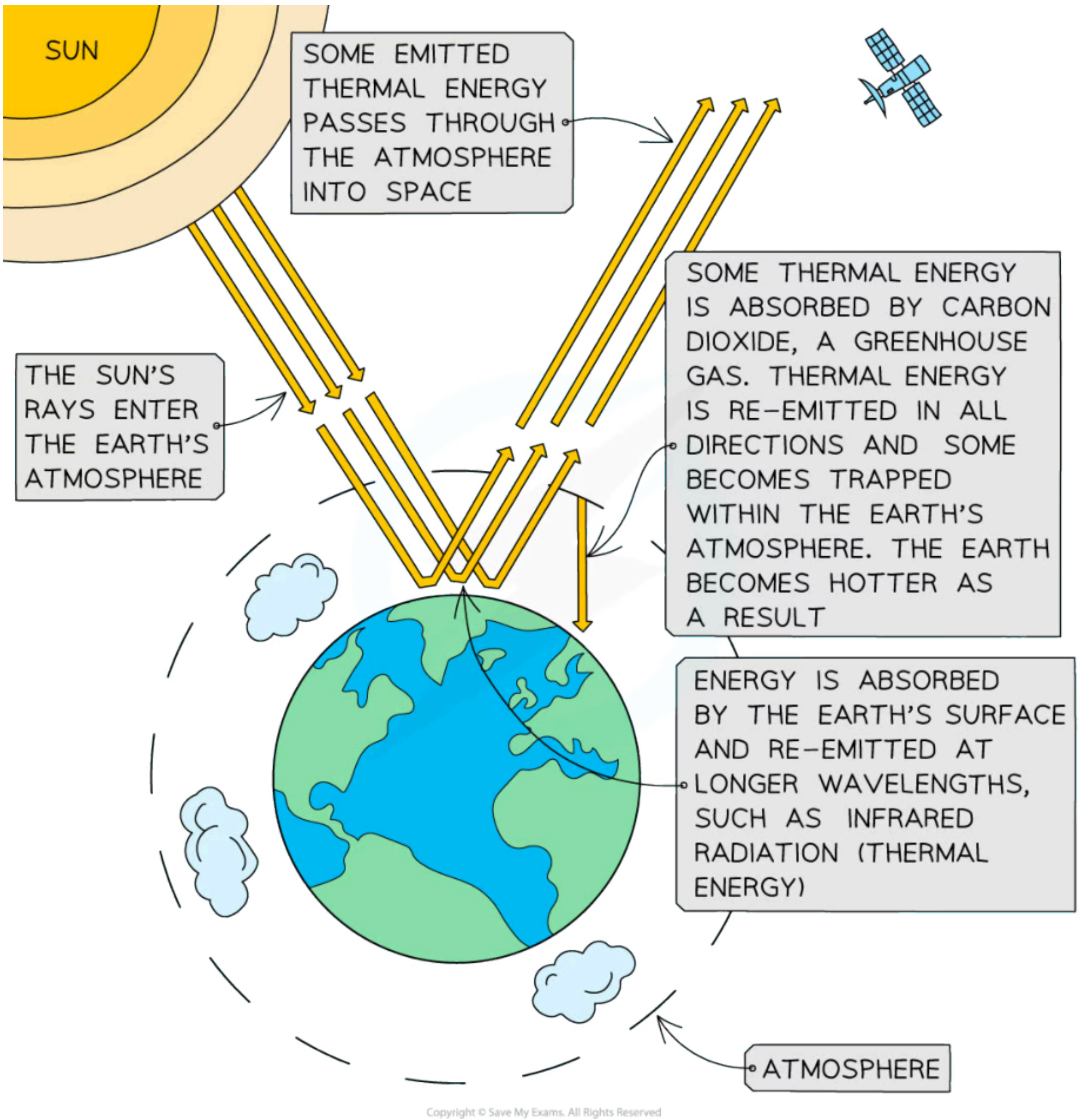

Greenhouse gases absorb the radiation that is re-emitted from the Earth's surface, trapping it in the atmosphere

EXAM TIP

Don't get confused—the greenhouse effect is a natural process and is necessary for life on Earth. The **accelerated** or **enhanced** greenhouse effect refers to the changes in the greenhouse effect (mostly due to human activity) that are commonly referred to as global warming. This is discussed further in Causes of Climate Change.

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