

**ADVANCED SUBSIDIARY GCE****CHEMISTRY B (SALTERS)****F332/ADVANCE NOTICE**

Chemistry of Natural Resources: Advance Notice article

For issue on or after:

13 MARCH 2009**Wednesday 3 June 2009
Morning****Duration: 1 hour 45 minutes****NOTES FOR GUIDANCE (CANDIDATES)**

- 1 This leaflet contains an article which is needed in preparation for a question in the externally assessed examination F332.
- 2 You will need to read the article carefully and also have covered the learning outcomes for Unit F332 (*Chemistry of Natural Resources*). The examination paper will contain questions on the article. You will be expected to apply your knowledge and understanding of the work covered in Unit F332 to answer these questions. There are 20 marks available on the paper for these questions.
- 3 You can seek advice from your teacher about the content of the article and you can discuss it with others in your class. You may also investigate the topic yourself using any resources available to you.
- 4 You will **not** be able to bring your copy of the article, or other materials, into the examination. The examination paper will contain a fresh copy of the article as an insert.
- 5 You will not have time to read this article for the first time in the examination if you are to complete the examination paper within the specified time. However, you should refer to the article when answering the questions.

This document consists of **8** pages. Any blank pages are indicated.

Origin of the Earth's atmosphere

adapted from 'Origin of the Earth's Atmosphere' by Dr John Stimac (Eastern Illinois University)

Introduction

Early Earth would have been very different and inhospitable compared to the Earth today.

Most scientists think that the earliest atmosphere would have been completely different in composition from the one we have now, probably being composed mainly of hydrogen (H₂) and helium (He).

Cooling of the Earth could have happened as primordial heat dissipated into space. This would have resulted in the condensation of water (to form rain) and the subsequent accumulation of surface water.

Evolution of the atmosphere

Our atmosphere is the envelope of gases that surrounds the Earth. It provides a reservoir of some of the chemical compounds needed for living systems. The atmosphere has no outer

boundary; it just fades into space. The dense part of the atmosphere (97% of its mass) lies within 30km of the Earth's surface (i.e. it is about the same thickness as the continental crust).

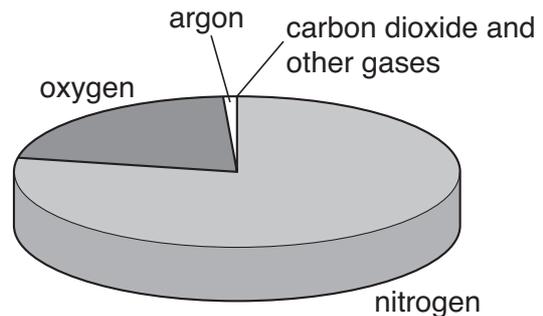


Fig. 1 Chemical composition of the Earth's atmosphere today

The atmosphere's chemical composition today is nitrogen, N₂ (~78%), oxygen, O₂ (~21%), argon, Ar (~1%), carbon dioxide, CO₂ (~0.03%), plus other gases, as shown in **Fig. 1** and **Table 1**.

constituent	percentage by volume	composition in parts per million (ppm)
Nitrogen (N ₂)	78.084	
Oxygen (O ₂)	20.948	
Argon (Ar)	0.934	
Carbon dioxide (CO ₂)	0.0314	
Neon (Ne)		18.18
Helium (He)		5.24
Methane (CH ₄)		2.00
Krypton (Kr)		1.14
Hydrogen (H ₂)		0.50

Table 1 Principal gases in dry, unpolluted tropospheric air

(data from CRC Handbook of Chemistry and Physics, edited by David R. Lide, 1997)

Earth's first atmosphere

The Earth's first atmosphere probably had a composition of nearly all hydrogen and helium. These gases are relatively rare on Earth compared to other parts of the Universe and were probably lost to space early in Earth's history because Earth's gravity is not strong enough to hold lighter gases.

Today, Earth's core comprises a solid inner and liquid outer core. This is referred to as a differentiated core and creates Earth's magnetic field which allows heavier gases to be retained. Very early Earth probably did not have a differentiated core and so gases were lost.

Once the core differentiated, the heavier gases could be retained.

Addition of O₂ to the atmosphere

Today, the atmosphere is approximately 21% free oxygen. How did oxygen reach these levels in the atmosphere? To answer this question, we need to revisit the oxygen cycle:

- Processes causing oxygen production:
 - **photochemical dissociation** causing the break-up of water molecules by UV radiation. This produced oxygen levels at approximately 1–2% of current levels. At these levels O₃ (ozone) can form to shield the Earth's surface from UV radiation,
 - **photosynthesis** occurred in cyanobacteria and eventually higher plants, using carbon dioxide, water and sunlight to produce organic compounds and oxygen, which supplied the rest of the O₂ to the atmosphere;
- Processes that consumed oxygen were:
 - **chemical weathering**, through the oxidation of surface materials (an early consumer),
 - **animal respiration** (which happened much later),
 - **burning of fossil fuels** (which started much, much later).

Throughout the Archean (before 2.5 billion years ago), there was little to no free oxygen in the atmosphere (<1% of present levels). What little was produced by cyanobacteria was probably consumed by the weathering process. Once rocks at the surface were sufficiently oxidised, more oxygen could remain free in the atmosphere.

During the Proterozoic (between around 540 million and 2.5 billion years ago), the amount of free O₂ in the atmosphere rose from 1 to 10%. Most of this was released by cyanobacteria, which increase in abundance in the fossil record about 2.3 billion years ago. Present levels of O₂ were probably not achieved until about 400 million years ago.

Evidence from the rock record

- Iron (Fe) is extremely reactive with oxygen. If we look at the oxidation state of Fe in the rock record, we can infer a great deal about atmospheric evolution;
- In Archean sediments we find the occurrence of minerals that only form in non-oxidising environments, *e.g.* Pyrite (Fools gold; FeS₂). These minerals are easily removed from rocks by oxidation under present atmospheric conditions;
- The presence of **Banded Iron Formation (BIF)** – Deep-water deposits in which layers of iron-rich minerals alternate with iron-poor layers, primarily chert. These iron minerals include iron oxide, iron carbonate, iron silicate and iron sulfide. BIFs are a major source of iron ore, because they contain magnetite (Fe₃O₄) that has a higher iron-to-oxygen ratio than hematite. These are common in rocks 2.0–2.8 billion years old, but do not form today;
- **Red beds** (continental siliciclastic deposits) are never found in rocks older than 2.3 billion years old, but are common during the Phanerozoic time (between now and around 540 million years ago). Red beds are red because of the highly oxidised mineral hematite (Fe₂O₃), which probably forms secondarily by oxidation of other iron minerals that have accumulated in the sediment.

The conclusion is that the amount of oxygen in the atmosphere has increased with time.

Atmospheric structure

Not only does the atmosphere have a relatively stable composition, but it also has a structure to it.

The Earth's outermost atmosphere, the part above a few hundred kilometres, is a region of extremely low density. Near sea level, an atom or molecule, on the average, undergoes about 7×10^9 collisions each second; near 600 km, this number is about one each minute!

Not only does the pressure change with altitude, but temperature does as well.

Originally, scientists thought that temperature decreased continuously with increasing height until reaching absolute zero (-273.15°C). This decrease of temperature with increasing altitude is known as the environmental lapse rate and is approximately 6.5°C per km. In **Fig. 2**, the environmental lapse rate can be seen graphically as the decrease in temperature with increasing height throughout the troposphere.

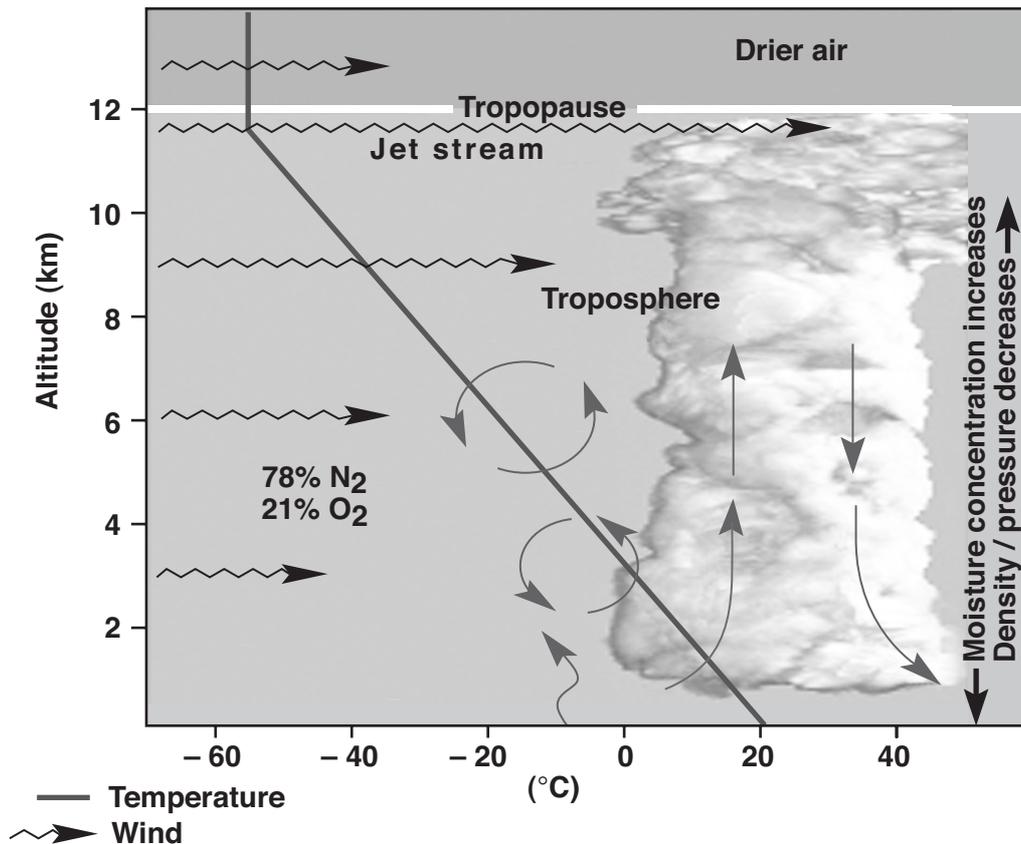


Fig. 2 Environmental lapse rate and the tropopause

Vertical structure of the atmosphere

After many balloon flights and temperature measurements, we know that temperature does not decrease continuously with increased height and the atmosphere can be divided into four regions, as shown in **Fig. 3**.

The bottom layer, where temperature decreases with altitude, is known as the troposphere (from the Greek for 'turning layer'). The top of the troposphere is marked by the tropopause. This is the point at which the environmental lapse rate is

no longer observed and is the first major break in the atmosphere.

Above the tropopause lies the stratosphere, which gets its name from the Greek meaning 'stratified layer'. The layer is stratified with the denser, cooler air below the warmer, lighter air. This leads to an increase in temperature with height (see **Fig. 3**). The primary reason that there is a temperature increase with altitude is that most of the ozone is contained in the stratosphere. Ultraviolet light interacting with the ozone causes the temperature increase.

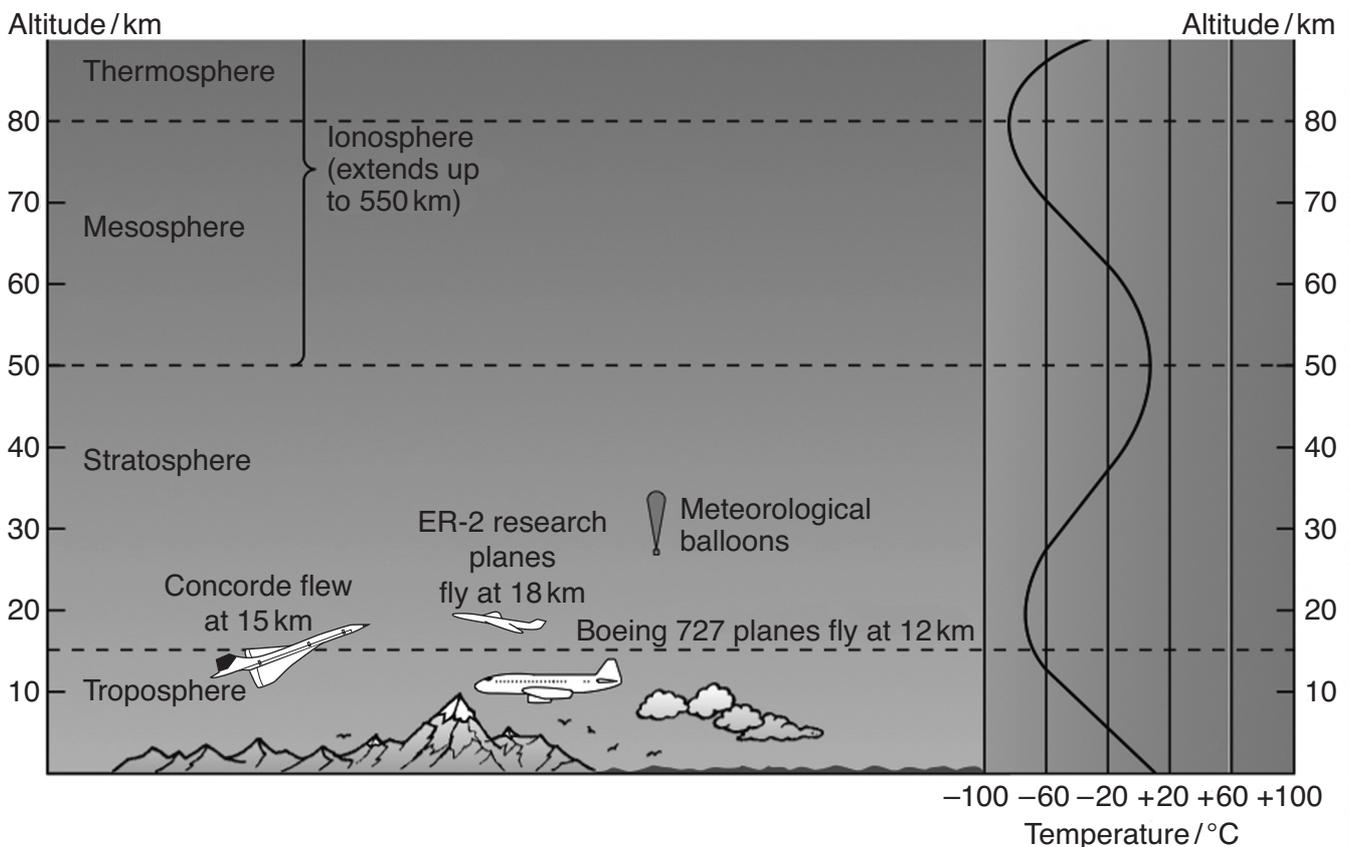


Fig. 3 Thermal structure of the atmosphere

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