Earth's atmosphere - step by step evolution
Using a physical model to show the development of our current atmosphere

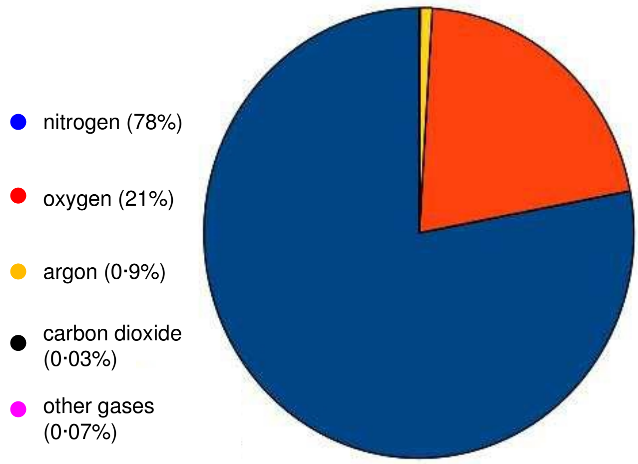
Preparation: Using whatever materials are available, prepare balls of approximately 2cm diameter. This can be time-consuming but, once made, or assembled, they can be re-used many times. Suggestions are given in the Resources list on page 4. You will need the following:-
- 74 green balls - water vapour
- 12 black balls - carbon dioxide
- 9 yellow balls - sulfur oxides
- 5 blue balls - nitrogen
- 3 red balls - oxygen
- 1 brown ball - argon
- 1 white ball - hydrogen

Ask the pupils: Why is Earth's atmosphere important? You could develop the discussion by using the following suggestions:-
- show that water is in the atmosphere by taking a glass bottle or jar from a refrigerator or boiling a kettle and holding a tile in the steam, to show that condensation is occurring;
- show that carbon dioxide is in the atmosphere by blowing into limewater to precipitate calcium carbonate turning the water milky;
- show a plant to prompt considerations of photosynthesis.

By the end of the discussion, students should realise that the atmosphere is critical to life on Earth as we know it.

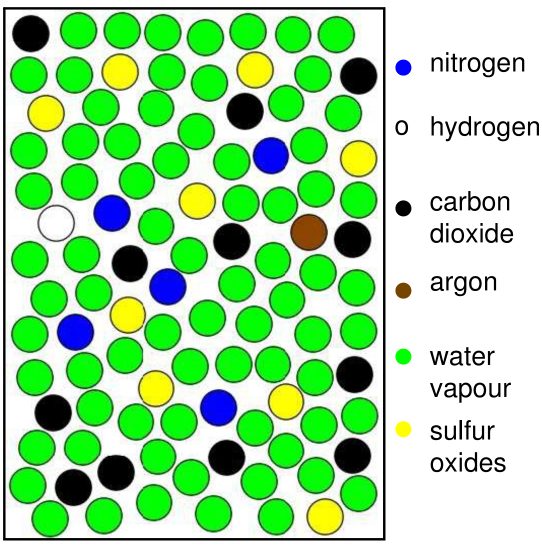
Discuss the composition of the atmosphere today, as shown in the pie chart opposite. The 0.07% of 'other gases' consists of hydrogen, ozone, neon, helium, krypton and xenon. Water vapour is not shown in this diagram because its amount in the atmosphere is variable.

Ask the pupils: How will the atmosphere in the room change if the room is sealed with everyone inside?
Through respiration, oxygen will diminish and carbon dioxide and water vapour will increase.



Composition of the atmosphere today

Primeval atmosphere

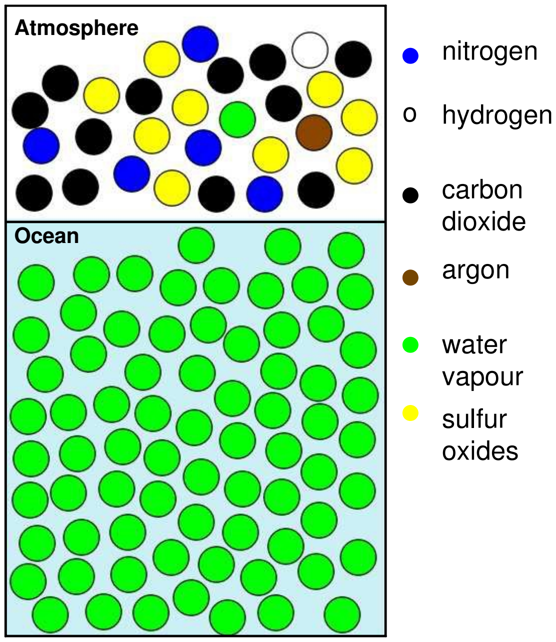


Ask the pupils to model the primeval atmosphere on Earth. Tell them that the gases in this early atmosphere are likely to be similar to those produced by present day volcanoes.
On a sheet of A3 white paper, or in a tray, whichever is most appropriate, place the following:-
- 74 green balls - 74% water vapour
- 12 black balls - 12% carbon dioxide
- 9 yellow balls - 9% sulfur oxides
- 5 blue balls 5% - nitrogen
- 1 white ball (representing 0·4% hydrogen)
- 1 brown ball (representing 0·2% argon)

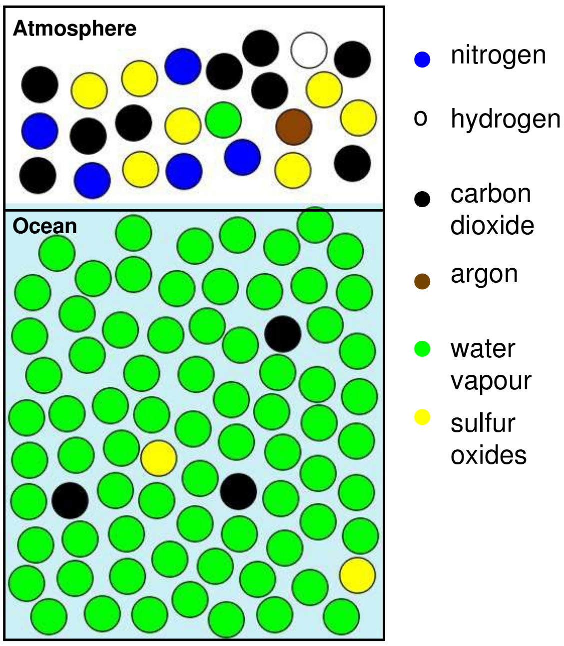
Ask the pupils to think about the composition of the current atmosphere and to suggest how the primeval atmosphere evolved into it. Give them a sheet of A3 white paper divided into two sections, atmosphere and ocean, as shown in the diagram Evolving atmosphere 1.
The following questions will help the pupils to place the coloured balls on the paper:-

• **What happened to the water vapour?** Clue - rainfall.
The Earth became cool enough for most of the water vapour to condense as rain by 4000 million years ago. The primeval ocean was formed.
The pupils should move all but one of the water vapour green balls into the ocean.

Evolving atmosphere 1

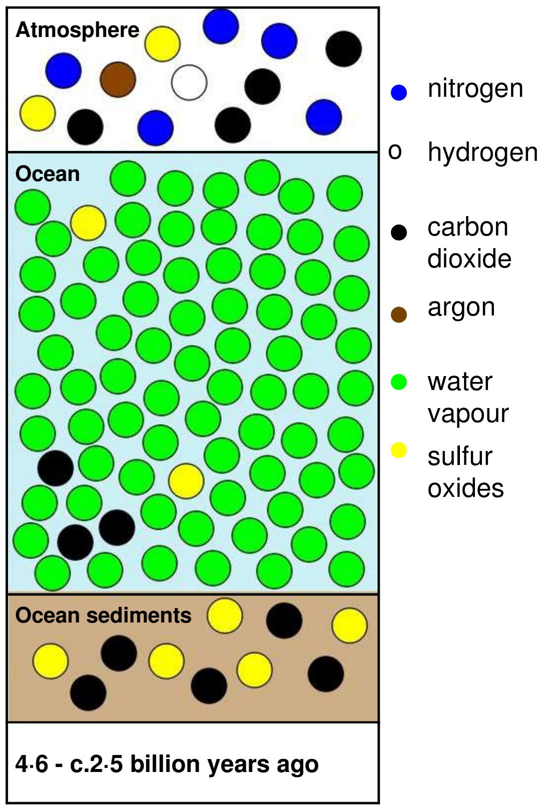


Evolving atmosphere 2



• **What happened to the carbon dioxide and sulfur oxides?**
Carbon dioxide and sulfur oxides are both soluble in rainfall so some dissolved in the oceans.
Add three carbon dioxide and two sulfur oxide balls to the ocean. The 'evolving atmosphere' should now look like the diagram Evolving atmosphere 2.

Evolving atmosphere 3



• **What effect did early bacteria have?**
They evolved soon after the oceans formed.
These early bacteria absorbed carbon and sulfur compounds from the ocean water as they grew. When they died, they sank to the ocean floor and the carbon and sulfur became locked up in ocean-floor sediments. Add 'Ocean sediments' to your diagram and move the balls as shown in Evolving atmosphere 3.

Ask the pupils to compare the Evolving atmosphere 3 with the composition of the current atmosphere.

• **What are the clear differences in the ratio of gases?**

• **What do they think happened?**

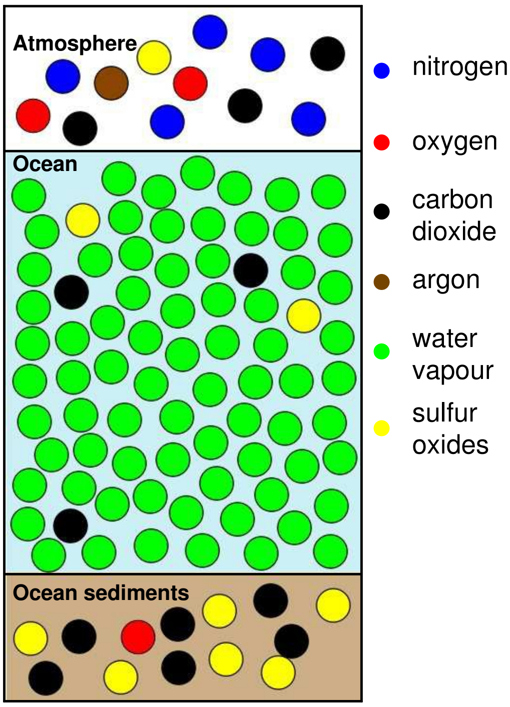
There is no oxygen in the evolving atmosphere. Photosynthesising algae evolved in the oceans. The early oxygen produced by photosynthesis reacted with iron dissolved in sea water and precipitated out to form sea floor sediments, (from about 2.2 billion years ago).
The pupils should now put one red oxygen ball into the sea floor sediments.

• Where did the hydrogen go?
Hydrogen is the lightest element; it rose into the upper atmosphere and was lost to space. ***The pupils should now remove the white hydrogen ball.***

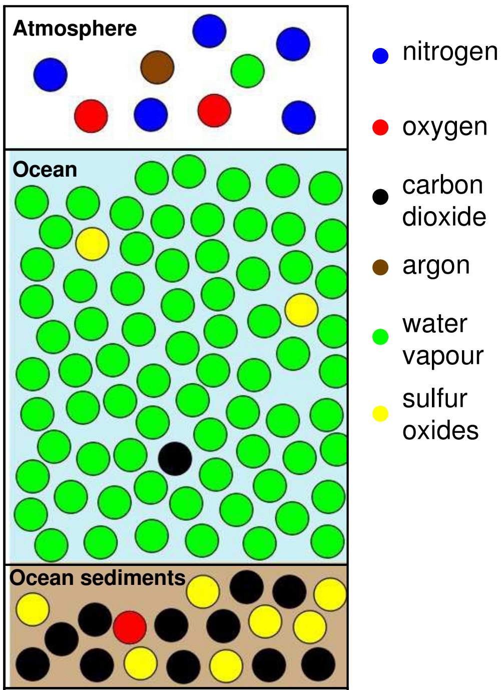
• How did oxygen get into the atmosphere?
By 2 billion years ago, the iron in the oceans had absorbed all the oxygen it could, so 'free' oxygen appeared in the atmosphere for the first time.
Add two red oxygen balls to the atmosphere - *Evolving atmosphere 4*

• What happened to the remaining carbon dioxide and sulfur oxides in the atmosphere?
More and more became dissolved in the ocean and were then locked up in the ocean floor sediments. Move the black and yellow balls from the atmosphere into 'Ocean sediments'.

Evolving atmosphere 4



Outer Earth today



Atmosphere developed over the last 1 billion years

The final A3 sheet of paper should look like the one opposite. The atmosphere is mostly nitrogen with oxygen and a little argon and has a similar ratio of gases to the current atmosphere. The ocean water has some dissolved carbon and sulfur oxides. The ocean floor sediments and the rocks that formed from them contain carbon, sulfur and oxygen compounds.

• What about water vapour in the atmosphere?
Consider the water cycle.
Move two green water balls from the ocean and return them to the atmosphere as water vapour. One could then condense and return to the ocean as rain.

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The back up:

Title: Earth's atmosphere - step by step evolution.

Subtitle: Using a physical model to show the development of our current atmosphere

Topic: This activity could be used in any lesson involving discussions about the atmosphere or climate change and greenhouse gases.

Age range of pupils: 14 - 18 years

Time needed to complete activity: 30 minutes, longer with full discussions.

Pupil learning outcomes: Pupils can:
- construct a model of the primeval atmosphere;
- suggest how our primeval atmosphere could have changed to become our current atmosphere;
- realise that the amount of atmosphere around the Earth today is considerably less than when there was a primeval atmosphere.

Context: This activity demonstrates the slow evolution from the primeval to today's atmosphere.

Following up the activity:
Pupils could investigate the atmospheres of our planetary neighbours, Mars and Venus.

Underlying principles:
- Our current atmosphere contains 78% nitrogen, 21% oxygen, 0.9% argon and 0·03% carbon dioxide. The remaining 0·7% consists of hydrogen, ozone, neon, helium, krypton and xenon. The amount of water vapour in the atmosphere is variable, with a maximum of about 4%.
- The primeval atmosphere is likely to have been composed of the same gases that are derived from modern volcanoes.
- Early water vapour condensed to form the oceans
- Carbon dioxide and sulfur oxides dissolved in water and with early bacterial activity, much of it became locked into ocean floor sediments.
- Photosynthesis evolved and after early oxygen had been absorbed by iron into ocean floor sediments, 'free' oxygen escaped to the atmosphere.

Thinking skill development:
A pattern of evolution from the primeval atmosphere to our current atmosphere is developed. Discussion at the various stages results in metacognition and using the model to explain today's atmosphere is bridging.

Resource list:
- blue, green, red, black, yellow, brown and white balls made of modelling clay, screwed up paper, Molymod™ balls, marbles, beads, counters - whatever is available
- sheets of A3 white paper (some labelled) or trays with separate labels

Useful links:
http://www.ux1.eiu.edu/~cfjps/1400/atmos_origin.html
YouTube videoclip of Evolution of the Atmosphere
http://www.youtube.com/watch?v=OaiAh-V0C2c

Source: This activity is adapted from the KS4 workshop 'Life, atmosphere and everything', Earth Science Education Unit, http://www.earthscienceeducation.com

Evolving atmosphere in action
Elizabeth Devon