Earth's Formation: How to explain the Formation of the Earth's Atmosphere

It is very poetic to say that the water we drink is as old as the planet. Amazingly, it's also true! Much of the materials found on our planet, are made of elements that were combined to form the planets. Let's examine how the Earth formed from these elements into the planet we know and love!

First Atmosphere Composition - Probably H_2, He

These gases are relatively rare on Earth compared to other places in 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. Also Earth still did not have a differentiated core (solid inner/liquid outer core) which creates Earth's magnetic field (magnetosphere = Van Allen Belt) which deflects solar winds. Once the core differentiated the heavier gases could be retained

Second Atmosphere produced by *volcanic out gassing.*

Gases produced were probably similar to those created by modern volcanoes (H_2O, CO_2, SO_2, CO, S_2, Cl_2, N_2, H_2) and NH_3 (ammonia) and CH_4 (methane).

- No free O_2 at this time (not found in volcanic gases).
- *Ocean Formation* - As the Earth cooled, H_2O produced by out gassing could exist as liquid in the Early Archean, allowing oceans to form.
    - Evidence - pillow basalts, deep marine beds in greenstone belts.

Third and Current Atmosphere Addition of O_2 to the Atmosphere

Today, the atmosphere is ~21% free oxygen. How did oxygen reach these levels in the atmosphere? Revisit the oxygen cycle:

- **Oxygen Production**
    - **Photochemical dissociation** - breakup of water molecules by ultraviolet
        - Produced O_2 levels approx. 1-2% current levels
        - At these levels O_3 (Ozone) can form to shield Earth surface from UV
    - **Photosynthesis** - $CO_2 + H_2O$ + sunlight = organic compounds + O_2 - produced by cyanobacteria, and eventually higher plants - supplied the rest of O_2 to atmosphere. Thus plant populations
- **Oxygen Consumers**
    - **Chemical Weathering** - through oxidation of surface materials (early consumer)
    - **Animal Respiration** (much later)
    - **Burning of Fossil Fuels** (much, much later)

Evidence from the Rock Record

- *Iron* (Fe) i s 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.
- ***Banded Iron Formation (BIF)*** - Deep water deposits in which layers of iron-rich minerals alternate with iron-poor layers, primarily chert. Iron minerals include iron oxide, iron carbonate, iron silicate, iron sulfide. BIF's are a major source of iron ore, b/c they contain magnetite (Fe_3O_4) which has a higher iron-to-oxygen ratio than hematite. These are common in rocks 2.0 - 2.8 B.y. old, but do not form today.
- *Red beds* (continental silica-clastic deposits) are never found in rocks older than 2.3 B. y., but are common during Phanerozoic time. Red beds are red because of the highly oxidized mineral hematite (Fe_2O_3), that probably forms secondarily by oxidation of other Fe minerals that have accumulated in the sediment.

Conclusion - amount of O_2 in the atmosphere has increased with time.

Biological Evidence

- Chemical building blocks of life could not have formed in the presence of atmospheric oxygen. Chemical reactions that yield amino acids are inhibited by presence of very small amounts of oxygen.
- *Carbon Dioxide allowed for growth of the most primitive living bacteria such as photosynthetic bacteria (cyanobacteria) and Oxygen production resulted in methane-producing bacteria that derive energy from fermentation*. Conclusion - Since today's most primitive life forms are anaerobic, the first forms of cellular life probably had similar metabolisms.
- Today these *anaerobic* life forms are restricted to anoxic (low oxygen) habitats such as swamps, ponds, and lagoons.

Atmospheric oxygen built up in the early history of the Earth as the waste product of photosynthetic organisms and by burial of organic matter away from surficial decay. Current atmosphere consists of 78% nitrogen, 21% oxygen and 1% lesser gases (carbon dioxide, sulfur dioxide, argon, nitrous oxide, water vapor)

You will draw an illustration that shows the formation of our Earth's atmospheres. Explain through comic images or diagrams how the 1st, 2nd and current atmospheres may have looked on Earth. Then from the details include information that shows how these different atmospheres changed over time. Be sure to include all stages that are bolded and include call outs from what is happening at each phase (these are *italicized*.) Make this a creative exercise!