

# THE ATMOSPHERE EVOLVES

4.6 billion years ago, Earth's surface had a limited atmosphere. Volcanoes emitted gases from inside the Earth, primarily sulfur dioxide, carbon dioxide, and water. Comets originating between Jupiter and Neptune collided with Earth to contribute primarily carbon dioxide and water, but also carbon monoxide, methane, and ammonia. Gases were collecting on the surface, but high solar winds were also stripping much of it away, blowing it to the outer solar system. Once Earth's magnetic field formed, it deflected most of the by-then-diminished solar wind, protecting Earth's atmosphere and allowing it to accumulate in greater amounts. This first atmosphere was hot and rich in carbon dioxide, nitrogen, and water vapor. It had little to no oxygen and would be toxic to us today.

Earth's atmosphere today is mostly nitrogen and oxygen. Carbon dioxide was a major component in the early atmosphere. Now it exists as only 0.04% and increasing. Where did it go? And where did the oxygen come from? Blame life. When photosynthesis evolved (3.5 billion years ago), it removed carbon dioxide and added oxygen. What happened to all the water vapor that existed in the early atmosphere? When Earth's surface cooled enough for liquid water to be stable, water vapor precipitated to form the oceans! To this day, Earth remains unique in the solar system for its high content of water, both inside and outside its surface. Finally, why did nitrogen become so abundant? It doesn't react with much at Earth's surface, so it simply accumulates over time, as the other materials disappear.

## GAS COMPOSITIONS OF VARIOUS PLANETS AND OBJECTS

### Mars Atmosphere

Pressure: ~0.003 bar

96% carbon dioxide (CO<sub>2</sub>)

3.4% nitrogen (N<sub>2</sub>)

0.1% argon (Ar)

### Venus Atmosphere

Pressure: ~80 bar

96% carbon dioxide (CO<sub>2</sub>)

3.5% nitrogen (N<sub>2</sub>)

0.1% argon (Ar)

### Volcanic Gases

water (H<sub>2</sub>O)

carbon dioxide (CO<sub>2</sub>)

sulfur dioxide (SO<sub>2</sub>)

### Comets

water (H<sub>2</sub>O)

carbon dioxide (CO<sub>2</sub>)

carbon monoxide (CO)

methane (CH<sub>4</sub>)

ammonia (NH<sub>3</sub>)

### Early Earth Atmosphere

in decreasing abundance:

### carbon dioxide (CO<sub>2</sub>)

nitrogen (N<sub>2</sub>)

water vapor (H<sub>2</sub>O)

methane (CH<sub>4</sub>)

ammonia (NH<sub>3</sub>)

carbon monoxide (CO)

sulfur dioxide (SO<sub>2</sub>)

hydrogen sulfide (H<sub>2</sub>S)

### Earth Atmosphere Today

Pressure: 1 bar

78% nitrogen (N<sub>2</sub>)

21% oxygen (O<sub>2</sub>)

<1% argon (Ar)

Comet Hyakutake NASA ©

Gases from Halemaumau vent, June 2008, Hawaii (K. Wiese) ©

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