INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

The beginning of life on Earth

It may not be widely known, but life's very existence is directly connected to molybdenum. As one of a handful of essential elements, molybdenum helps the human body – and all other living things – perform key life-supporting processes. Molybdenum even played an important role in the very beginnings of life on Earth, billions of years ago.

Molybdenum is essential for life. It plays a critical role in the production of several enzymes in humans and animals that help to remove toxins and waste products, and it helps cells to produce energy. It is an essential micronutrient for plants, enabling them to extract nitrogen from the air and soil.

Nitrogen is also essential to all life. It is largely present in the air and soil in an inert form that cannot be readily used. Strong chemical bonds hold the nitrogen atoms together in pairs, and they must be broken to release the single atoms used in biological processes. Nitrogen atoms combine with other chemicals to form life-sustaining biological compounds. This conversion process is known as nitrogen fixation.

There are many theories about exactly how life on Earth began and evolved – but a common factor is the presence of molybdenum.

The breath of life

One theory postulates that life started in the seas. The Earth's atmosphere was very different from the oxygen-rich one we breathe today, consisting largely of nitrogen, carbon dioxide and water vapor. The seas were also relatively oxygen-free, although some oxygen would have been produced from the first photosynthesis by early forms of bacteria called cyanobacteria, living in the shallow seas. These early organisms used abundant soluble iron present in the seas to 'fix' nitrogen for growth.

As these organisms grew, photosynthesis led to the oxygenation of the shallow seas, which turned the iron insoluble and inhibited further nitrogen fixation. A period of stagnation began in the development of the earth's atmosphere that scientists refer to as the "boring billion" years from 1.85 to 0.85 billion years ago.

The 'boring' period ended with a sudden growth in organic life and the increasing oxygenation of the Earth's atmosphere. Scientists have argued that a dramatic increase in the amount of soluble molybdenum in the sea at the end of the "boring billion" years led to the development of the molybdenum-containing enzyme *nitrogenase*. ›

Life on earth would not be possible without molybdenum. © shutterstock/sdecoret

A powerful nitrogen-fixing enzyme, nitrogenase greatly increased the amount of available nitrogen, leading to faster growth. As organisms grew, their increased photosynthesis produced more oxygen, creating the oxygen-rich atmosphere that has supported life ever since.

Rock of ages

Another theory asserts that life began not in the sea, but on land. In a paper published in 2015, a team from the University of Washington found evidence of nitrogen fixation in some of the oldest rocks on Earth. Stüeken and her co-authors chemically analyzed more than 50 rock samples from what is now southern Africa and Australia. The results were consistent with a pattern caused by nitrogen-fixing by microbes using nitrogenase. Because some of the rocks are more than three billion years old, researchers have suggested that early life may have existed as a single-celled layer of oxygen-producing slime. This oxygen would have reacted with molybdenum in rock, turning it into a soluble form much more suitable for nitrogen-fixing. Thus, it is possible this process could have contributed to the increase in available molybdenum in the sea, "kick-starting" large-scale marine photosynthesis.

A stabilizing influence

There is yet another, more intriguing, theory surrounding the beginnings of life on Earth – one that suggests terrestrial life actually began on Mars! And according to Professor Steve Benner, who presented his theory in 2013, molybdenum proves it. The idea of panspermia, the transfer of life between planets, is not new. However, Professor Benner's work takes the idea a stage further by looking at the availability of boron and molybdenum oxides. He states that simply adding energy to the organic compounds present on the early Earth would have only resulted in a tarlike 'gloop', not the beginnings of life. This problem has puzzled scientists for many years.

Benner proposed that borate and molybdate acted as catalysts to produce the correct formation of RNA, the precursor to DNA. RNA is widely accepted by scientists to be the first genetic molecule to form and be capable of self-replication. His theory postulates that borate and molybdate stabilized and rearranged the sugar molecules in carbon compounds to make ribose – the 'r' in RNA. Crucially, however, he asserts this could only happen when the boron and molybdenum were themselves stabilized – in their oxidized forms. Because there was very little oxygen on Earth three billion years ago, Benner concludes that this must have taken place somewhere else – somewhere with plenty of oxygen, like Mars.

Another aspect supporting this theory is that the early Earth was awash with water, which would have both prevented boron from developing in the necessary quantities and attacked RNA as soon as it was formed, posing the second problem for theories arguing that life began on Earth.

By contrast, scientists believe that the surface of Mars three billion years ago had very little surface water, but abundant oxygen. The theory proposes that life began in the more welcoming cradle of the Martian surface before being transported to Earth by a meteorite, where it continued to flourish. By providing plausible explanations for key questions that have shaped debate on the terrestrial origins of life, Benner's theory has gained many followers and looks set to become firmly established as another possible explanation of how life began.

Molybdenum's essential role in sustaining modern life is well documented and understood. There will always be a discussion about the origins of life, and of course scientific discoveries are adding to our understanding continually. However, molybdenum is an essential factor in all the current major theories regarding life's origins and evolution, so it seems likely that it was just as important to life billions of years ago as it is today. (Alan Hughes)