

The Olympic Flame

CHEMISTRY HELD HIGH

By Brian Rohrig

This past summer, the best athletes in the world gathered in Beijing to participate in the 2008 Summer Olympic Games. Today's games have come a long way since the first Olympic games of 776 B.C. Back then, there was only one event—a 400-meter sprint. To participate, you had to be a free Greek man. The prize for winning was not a precious medal, but typically an olive branch. You didn't have to spend much money on uniforms, either, as the athletes often ran naked!

One similarity between those early games and ours is the tradition of the Olympic flame. During the ancient games, a fire burned throughout the competition. The lighting of the flame has always signaled that the games are ready to be played.

Flame, torches, and lanterns

Today's Olympic flame is lit in the same way as it was in ancient Greece. Every four years, an elaborate ceremony is held at the site of the first Olympics in Olympia, Greece. An actress representing a high priestess holds an unlit torch above the center of a large, bowl-like mirror. The sun's rays are reflected off the curved surface of this mirror, converging at a single point on the torch. This generates enough heat to ignite a flame on the torch.



An actress in the role of the High Priestess gives the Olympic torch to the first runner in the torch relay.

After its lighting, the flame is passed on to the first torchbearer, beginning the torch relay, which symbolizes peace and brotherhood throughout the competition. The relay is a modern invention, beginning with the 1936 Berlin Olympic Games. At the Beijing Olympic Games, the relay was the longest so far, covering five continents over 137,000 km (85,000 miles) in 135 days. Part of the journey even included a trip to the top of Mount Everest!

The torch relay started on March 24 in Olympia, Greece. From there, it traveled within Greece for five days and then was flown to Beijing, where it continued its journey around the world, including Mount Everest on May 8. The relay culminated in the lighting of the Olympic flame in Beijing on August 8, ushering in the start of the competition. There were a total of over 21,000 torchbearers. Just like any relay race, each torchbearer ran only a small leg of the journey—at least 400 meters—before lighting the torch of the next runner.

"It is a great honor to be selected as a torchbearer, but it's an even greater honor to be the final torchbearer, whose task is to light up the Olympic flame," says Sam Shelton, a professor at the Georgia Institute of Technology. This honor is given to an individual who personifies the Olympic spirit by extraordinary athletic or humanitarian efforts.

Although there is only one Olympic flame, there are thousands of Olympic torches. The members of the torch relay team can purchase their torch at the conclusion of their leg of the journey.

The Olympic flame is carried in a lantern. Additionally, backup lanterns are carried inside guarded vehicles along the parade route and can be used to relight the torch if it is accidentally or intentionally extinguished. Because much of the flame's journey is done by air, the torch itself is extinguished most of the time, but the flame is kept alive thanks to the lanterns.



One of the members of the Mount Everest climbing team ignites the torch for the first torchbearer of a 30-meter relay on the tallest peak in the world.



Left: 1988 Seoul Olympics Cauldron. Right: Lantern carrying the 2008 Beijing Olympic torch.

Chemical composition

The Olympic torch is a marvel of chemistry, engineering, and art. The 2008 Beijing Olympic torch was made of a mixture of aluminum and magnesium. These metals were chosen because they are very lightweight, yet durable. Also, both metals have relatively low densities, yet are exceptionally strong. Weighing about one kilogram (two pounds), the torch was also designed to withstand 65 kilometers/hour winds, rainfall, and temperatures as low as -40°C !

In past Olympic torches, substances used for fuel have included ammonia, formaldehyde, olive oil, gunpowder, and naphthalene (the active ingredient in moth balls). Many of these early components were smoky, smelly, and downright dangerous. During the 1956 torch relay, burning bits of magnesium and aluminum erupted from the torch, no doubt thrilling the spectators yet severely burning one runner's arms.

Many of these early torches were intentionally designed to release soot, producing a more visible, yellow flame. Unfortunately, the soot that forms is made of carbon particles that can produce a lot of smoke.

"There is one advantage to a dirty yellow flame, though," says Shelton, who was the chief designer of the 1996 Atlanta Olympic torch. "A yellow flame is much more visible than a blue flame, especially from a distance." The soot particles produce the very visible flame through incandescence, which is the emission of light due to heating.

The 1996 Olympic torches were especially visible, because they used a mixture of propylene (C_3H_6) and propane (C_3H_8). The unique fuel mixture produced a bright yellow smokeless flame clearly visible in sunlight and under windy conditions.

Since 1972, liquid hydrocarbons have been exclusively used as the Olympic torches' fuel because they are relatively safe and produce little odor when burning. The Beijing Olympic torches used pure propane (C_3H_8) as a fuel. Propane is the bottled gas used in gas grills that burns very cleanly. The only drawback is that it is not as bright as previous flames. But the flame can burn yellow by adjusting the fuel-to-oxygen ratio. Propane reacts with oxygen by producing carbon dioxide (CO_2) and water (H_2O) as follows:



Inside Beijing's Olympic torch

The burning system of this year's Olympic torch was designed by the state-owned China Aerospace Science and Industry Corporation. Within the handle of the torch is a small canister of liquid propane. When the torch is turned on, the sudden pressure drop causes the propane to vaporize.

The propane gas flows through tiny holes at the top of the torch that ensure that the gas comes out. Then, once the propane hits the atmosphere, it combines with oxygen and burns. Each torch has a 25- to 30-centimeter flame under good conditions and can stay lit for about 15 minutes, which is more than enough time for a typical 400-meter journey.

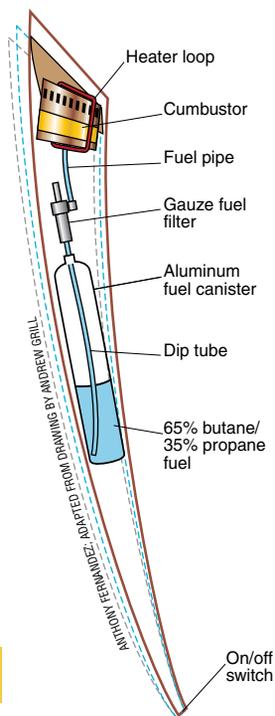
Recent Olympic torches worked on the same principle as the 2008 Beijing torch. For example, the inside structure of the 2000 Sydney Olympic torch is shown in Fig. 1.

But for the journey up Mount Everest—the tallest peak in the world—solid fuel instead of propane was used. The combustion of propane relies entirely on outside oxygen. But on top of Mount Everest, the atmospheric pressure is only about one-third of that at sea level. To burn effectively, the oxygen is supplied by a compound called an internal oxidizer that releases oxygen during combustion.

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Figure 1. The inside structure of the 2000 Sydney Olympic torch (left) works on the same principle as the 2008 Beijing torch.



Marine biologist Wendy Craig-Duncan carries the 2000 Olympic torch under water at Agincourt Reef, Queensland, Australia.

and a lecture demonstrator at Purdue University, West Lafayette, Ind. "An oxidizer was also used for the 2000 Sydney Olympic torch, which was taken under water by a SCUBA diver to cross Australia's Great Barrier Reef!"

The solid fuel used in the torches is similar to the solid rocket boosters used to launch the space shuttle. These rocket boosters use ammonium perchlorate (NH_4ClO_4) as the internal oxidizer and aluminum as the fuel. The oxygen comes from the decomposition of ammonium perchlorate at 200°C as follows:



The Olympic flame is one of the most enduring symbols of the Olympic Games. The torches that carry the flame leading up to the games serve to heighten the anticipation for athletes and spectators alike. "By being lit directly from the sun, the Olympic flame vividly shows that the sun is an important source of energy for life on Earth," Shelton says. "The same energy that ignites the flame fuels the body of each Olympic athlete." ▲

Brian Rohrig teaches at Jonathan Alder High School in Plain City (near Columbus), OH. His most recent *ChemMatters* article, "The Chemistry of Arson Investigation," appeared in the April 2008 issue.

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