

Elements of Sports: From IYPT 2019 to Tokyo 2020¹

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Sports, one of the symbols of the global human culture and a unit of peaceful society, excite both competitors and audiences. During the game and even practice, athletes concentrate to choose not only a comfortable design but also high-performing materials of their shoes, rackets, uniforms, etc. Under the high demand of athletes, sports materials are evolving with the support of new chemical reactions and coordination chemistry. Here, we exhibit the role of elements in sports. The International Year of the Periodic Table (IYPT) will bring chemistry into the future as The Olympic & Paralympic Games in Tokyo in 2020.

“Ironmen” is an expression for strong athletes that originates in the tough image of iron (${}_{26}\text{Fe}$). We can easily find many places and parts at the sports stadium forged from iron. The majority of these materials combine iron with other elements to form alloys used for their flexibility or prevention of oxidation. The shotput, fencing sword and barbell are exceptions, being made from neat iron. In the past, many sports used neat iron as a tough metal, for applications such, the shaft of a golf club, or the frame of a bicycle or wheelchair. In recent decades, alloys of iron and aluminum (${}_{13}\text{Al}$), titanium (${}_{22}\text{Ti}$) or magnesium (${}_{12}\text{Mg}$) with CFRP (Carbon Fiber Reinforced Plastic) were developed for increasing performance and high scores in games. Here, we would like to enjoy the world of elements in sports.

No Iron, no games

Before starting to write, we checked and summarized materials which strongly support athletes as

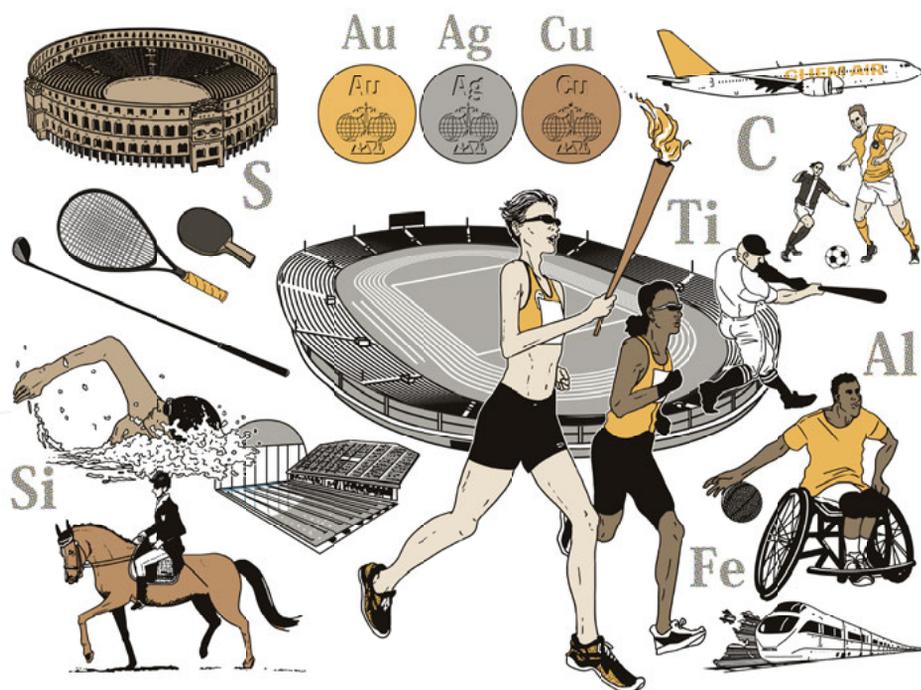


Illustration by Hayanon Science Manga Studio

shown tables on the website.² Then, we found that iron is one of the key elements in sports. Iron is one of the more abundant elements in the Earth's crust (4th; 5% of the crust). On the athletic field, athletes wear spikes in their shoes to run and turn with surety. These small spikes are made with iron, as well the starting-blocks that help sprinters launch themselves at the beginning of a race. The cannonball used in the shot put and the disc in the discus throw are also mainly made with iron. The Olympic & Paralympic Games have a long history as well as the iron which is one of the most traditional and historical materials to make shaped materials on demand. In fencing, iron is used for the supple swords and the stiff, protective masks. In gymnastics, parallel bars and iron bars are made of iron, the former contains GFRP (glass fiber reinforced plastics) as well. Similarly, the shooting guns and bullets contain iron. Finally, the stadium structures, the trains, and the automobiles are built by using metals beams and other parts that make use of iron and other elements such as nickel (${}_{28}\text{Ni}$), titanium, and others.

Carbon is everywhere

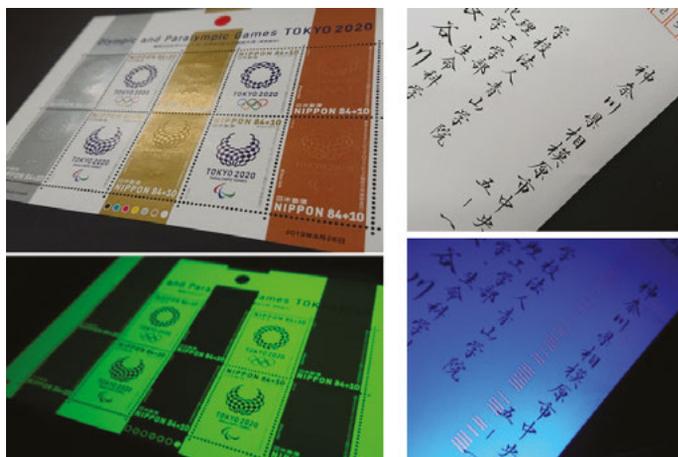
In sports, clothing has several roles, such as

1. This feature is the last one in a special collection published under the title of **Elements of X**, published in *Chem Int* Oct 2019. The chemical elements tiles (page 7) illustrating this feature are part of the IYPT Timeline of Elements project <https://uwaterloo.ca/chemistry/timeline-elements-image-gallery>
2. See supplementary materials at degruyter.com/ci or directly from <https://doi.org/10.1515/ci-2020-0102>

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identifying teammates, encouraging athletes, recognizing countries/regions, and ensuring participant safety. These clothes differ for each athlete with various raw materials, such as cotton, silk, polyester, polyurethane, and nylon, which are all mainly based on carbon (${}_{6}\text{C}$) and hydrogen (${}_{1}\text{H}$). These materials can be easily dyed with the colors of a team.

Like bamboo trees, polymer materials provide strength and elasticity for athlete's protection. Because of its high transparency, polycarbonate is used for swimming-goggles and the back-board behind the basketball hoop. Additionally, it's more impact resistant and lighter than the silicon oxide-glass materials usually used. In Japan, the Shinkansen's windows are also made with polycarbonate. Kevlar is a hydrogen bonds polymer and known as a highly resistant material with good elasticity properties. Therefore, this polymer is employed for the string of an archer's bow, fencing lamés, hockey sticks or sail boat rudders. CFRPs are known for having more elasticity behavior than previously described polymers. They are applied to bows and arrow of archers, rackets for badminton and tennis, and shafts for golf or hockey. Additionally, this unique property is suitable for the frame of wheelchairs and bicycles or the hulls of canoes, sailboats, or other competitive boats when combined with other



Luminescent stamps of Olympic & Paralympic Games for Tokyo 2020 (left) and red-barcode for transportation from Japan Post (right) under ambient (top) and UV (bottom) light.

elements. Glass Fiber Reinforced Plastics (GFRP, ${}_{14}\text{Si}$, ${}_{16}\text{O}$) are often mixed with CFRP and used in ship bodies or high jump sticks for their high rigidity.

Finally, carbon compounds can be used as an artificial coating for footballs, baseballs, volleyballs, basketballs, foot-covers in rhythmic gymnastics, and other small sports equipment. These artificial coatings are developed by polymer science using hydrocarbons.



Energy absorber gel, aGEL. Photos show a raw egg having no crack after falling from 18 m.

Function Diversity for Results on Athletes

The excitement of sports events universally make us happy. This has been supported by advanced materials for safety, efficiency, and comfort of players. Here, we focus on two elements, silicon (${}_{14}\text{Si}$) and sulfur (${}_{16}\text{S}$) in some of the latest advanced materials in sports.

Silicon, the second most abundant element in the earth's crust after oxygen, constitutes rocks as silicates and silicon dioxide. On one hand, amorphous silicon is widely used in semiconductor devices such as thin-film transistors (TFT) and solar cells. On the other hand, an organized compound in which an organic group is bonded to the main skeleton formed by a siloxane alternatively composed of silicon and oxygen is referred to as silicone. The physical properties of silicone can be freely controlled, from oil state to rubber state, depending on changes in the chain length of the siloxane bond. As a result, silicone is used in a wide range of fields including construction, electronics, and medicine.

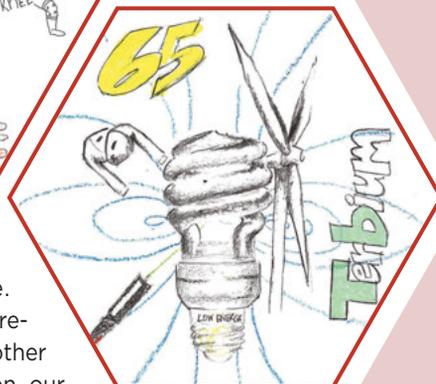
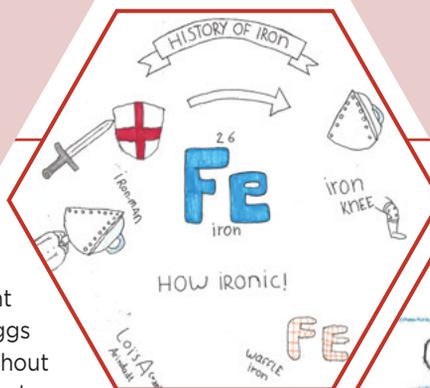
The silicone is cross-linked with an appropriate amount of silane or other reagents to form a silicone gel. Taica Corporation leads the world in the field of silicone gel and has released various products under the trade name of aGEL. In particular, as a vibration

isolation insulator, it is used in various situations that are not directly visible. A layer of shock absorbent α GEL only 2 cm thin can accept raw eggs dropped from a height of 18 m without cracking. This property of shock absorbency is used as a shock absorber in the sole of running shoes. While running, the runner is subject to an impact of three times the runner's weight. The α GEL absorbs the energy at the time of the ground collision to buffer the impact. Furthermore, the running speed is maintained by providing an appropriate modulus of resilience. α GELS are also used in mats for bouldering, which is one of the new sports adopted for the Olympic & Paralympic Games 2020 in Tokyo. The impact absorbency properties of the α GEL allow a thinner mat while reducing the impact on the body of the climber by about 41% compared to conventional urethane mats.

Sulfur is naturally present in sulfide and sulfate minerals. Sulfur is found in the amino acids cysteine and methionine and plays an important role in the formation of higher-order structures and functions in living organisms. In Japanese culture, some popular and famous hot springs are known as sulfur springs and contain sulfur compounds good for the skin and the body. Sulfur plays an important role in the production of rubber products. There are two types of rubber: the natural rubber which is harvested from the rubber tree and the synthetic rubber which is synthesized by polymerization of monomers such as isoprene and butadiene. Sulfur vulcanization is an important process to convert natural and synthetic rubbers into materials of a variety of hardness and elasticity. Many of these rubbers are used in automobile tires and tubes. In the field of sports, rubbers are used as a surface on a table tennis racket. The surface rubber is very important for players to demonstrate their skill. Top athletes can perceive the subtle changes in the rubber's coefficient of restitution. The makers provide rubbers required by athletes through rubber compounding technology.

Rare earths?

As you wonder why a series of rare earths makes its way out of ordinary boxes in the periodic table of elements, we just found the greenish luminescence of the Japanese stamps of Olympic & Paralympic Games, Tokyo 2020 under UV light. It looks like the typical emission from rare earths, such as terbium element (${}_{65}\text{Tb}$), doesn't it? But it is not Tb, since the spectral viewpoints observed at our laboratory can be assigned



to organic fluorophore. While we surely found another lanthanide on our mail, it is europium

(${}_{63}\text{Eu}$) as a red-barcode under UV light for the smooth operation of Japan Post. The luminescence of this element is assigned to f-f-transition localized on the inner core electronic transition of europium. The luminescence is accelerated by UV irradiation and known as a security ink for counterfeit prevention. It is not only used for beautiful design but also for high security. Rare earth elements were recently found in the Tokyo deep sea and we hope that some of the elements obtained from the Tokyo sea will become functional materials relating to Olympic & Paralympic Games in 2020 as a "Made in Tokyo" material.

Elements always support sports and athletes

The Olympics represent our ability to come together peacefully to enjoy sports. Every athlete has a target to win a gold (${}_{79}\text{Au}$) medal. Each event has its history, but each generation needs advanced materials in the combination of suitable elements. Every four-years the Olympic & Paralympic Games show distinguished players/athletes, and the important role of elements in sports. We are looking forward to watching the games and to seeing developments using essential elements. Anyway, there is not enough space to describe all of the elements in the Periodic Table in sports. We can only wonder what sorts of elements will be used in future games! 🏆

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