It is our great pleasure to host the 53rd International Chemistry Olympiad (IChO2021), a competition so rich in history since the first one in 1968, and to welcome very talented young students from 79 countries and regions around the world.

As important as it is as an academic subject, chemistry is also the basis for creating materials and substances with a vast range of functions that constantly supports our daily lives.

The COVID-19 pandemic is still plaguing the world. Chemistry is playing a vital role in the fight against COVID-19 by being applied for PCR and antigen testing to detect infection and its history and for the manufacture of COVID-19 treatment drugs.

Moreover, we expect chemistry to greatly contribute to achieving the Sustainable Development Goals, including the stable supply of food, the recycling of waste, and so on.

All the students participating in IChO2021 have the potential to address these various shared problems of the world and to open up a new path for humankind. It is a crucial issue for governments around the world to discover their talents and create an environment to develop fully these capabilities.

The International Science Olympiads, including IChO, have provided various opportunities for talented students to challenge, and contributed to discovering such students and fostering their capabilities. As the host country, Japan will make its utmost efforts to support this mission.

Because of COVID-19, like the previous Olympiad, IChO2021 will be held online. The organizers are planning to make full use of VR technology and avatar technology to provide remote tours to both state-of-the-art and traditional science and technology facilities, which large groups of people cannot usually visit. Unfortunately you will not be able to have direct interaction, however, with the creative use of these technologies, you will be able to overcome the barriers of distance and space to connect with your peers.

We hope that all of you representing your countries at this Olympiad will fully demonstrate your real abilities and the results of your efforts, improve yourselves through competitions, and make lasting friendships with peers.

It is our sincere wish that you all continue your self-improvement and make the most of your experiences to play active roles in leading your countries and the world.

HAGIUDA Koichi
the Minister of Education, Culture, Sports, Science and Technology
Dear students, now I would like to ask you to keep the following three things in mind, as you are about to enjoy a once-in-a-lifetime valuable experience.

First, you have been given hope and courage to overcome difficulties through your participation in this remote IChO2021 Japan.

Second, the unprecedented difficulties we have been facing can only be overcome by international friendships and trust. Thus, you should show gratitude and respect to your mentors, teachers, invigilators, and all others who have contributed to make this major international event a reality, despite the obstacles faced.

Third, I want you to remember that chemistry, the central science, is all around us. Chemistry must therefore play a key role in finding solutions for many global challenges, including energy, environmental, and resource-related issues that humanity is now facing.

I hope that IChO2021 Japan helps to foster many talented young people who will go on to play roles as future world leaders. While you do not have the opportunity to meet each other in person this time, I am convinced that one day you may meet each other somewhere in the world when you go to university or graduate school. I sincerely hope that you take the opportunities given to you as participants in this remote IChO2021 to create strong networks of international friendship, with the slogan “Chemistry! It’s Cool!” as your watchword.

Finally, I would like to thank the Ministry of Education, Sports, Science and Technology (MEXT Japan) and the Japan Science and Technology Agency (JST) for their meaningful support, and the more than 180 chemical companies and trading companies in Japan as our sponsors for their substantial financial assistance, as well as numerous personal donations.

My special thanks are also due to all the members of the Japan Committee and Organizing Committee for IChO2021 Japan, as well as our secretariat and KNT Corporate Business Company, Ltd., as represented by the Vice President of the Japan Committee and Chair of the Fundraising Committee Dr. Kohei Takahashi, Chairs of the Finance Committee the late Dr. Tadao Kondo and Dr. Teiji Koge, Chair of the Executive Committee Professor Yoshiki Chujo, Chair of the Scientific Committee Professor Hiroshi Nishihara, and member of the International Steering Committee Professor Nobuhiro Kihara.

Without their remarkable support and endeavors, this remote IChO2021 Japan would not be possible.

Now, it is my great pleasure to officially declare remote IChO2021 Japan open.

Thank you very much for your kind attention.

Dr. Kohei Tamao
President, IChO2021 Japan Committee Chairman, Organizing Committee for the 53rd IChO2021, Japan
How do chemical reactions occur? For chemistry students, the frontier orbitals called HOMO (Highest Occupied Molecular Orbital) and LUMO (Lowest Unoccupied Molecular Orbital) are extremely important. This concept of frontier orbitals was conceived by Kenichi Fukui, who in 1952 proposed that electrophilic substitution reactions in aromatic hydrocarbons occur at the position with the highest coefficient of HOMO, while nucleophilic reactions are determined by the coefficient of LUMO. This was an epoch-making concept, completely different from the conventional theory of organic electronics, which was based mainly on electron density.

In 1964, he further developed this theory by pointing out that the symmetry and phases of the HOMO and LUMO of the reacting molecule play important roles in cycloaddition reactions such as the Diels–Alder reaction. In 1981, he was awarded the Nobel Prize in Chemistry for “the theories concerning the course of chemical reactions,” together with Roald Hoffmann, who separately published the Woodward–Hoffmann rules in 1965. Fukui was the first Japanese chemist and Asian person to be awarded the prize, which had until then been won by researchers from Europe and the United States. Today, the concept of HOMO–LUMO is widely used not only in chemical reactions and physical properties of molecules themselves, but also in molecular electronics, organic electroluminescence, enzymatic reactions, and electron transfer in interactions in biomolecules such as proteins.

Frontier orbitals of naphthalene. a) HOMO. b) LUMO. The arrows show locations where reactivity is higher.
For certain infectious diseases, it is empirically known that once a person is infected they will not contract the disease again. This is due to the function of the immune system, which remembers the disease they have been infected with and can quickly eliminate the pathogen on the second infection. Vaccines make use of this biological function. Less virulent viruses or bacteria, as well as a portion of the pathogen (protein or polysaccharide), can be administered as a vaccine. This allows the immune system to remember the pathogen and prevent infection. Vaccines against COVID-19, a new type of coronavirus, which has had a major impact on our lives since 2020, are being vigorously developed around the world, resulting in the development of mRNA vaccines. Unlike conventional vaccines, mRNA vaccines deliver mRNA, the gene for the pathogen protein, into the human body. Although mRNA vaccines have been studied since the 1990s, they have not been put to practical use due to a number of drawbacks, including the following: 1) mRNA is not stable in vivo, 2) mRNA is not very efficient in the production of proteins, and 3) it is not easy to deliver mRNA into cells. Development of effective mRNA vaccines proceeded by solving these issues one by one. This was done through introducing artificial structures into the mRNA to prevent degradation by metabolism, and optimizing the RNA sequence to increase the efficiency of conversion into protein. Furthermore, by encapsulating the mRNA in lipid nanoparticles, researchers succeeded in efficiently delivering it into the cell. As a result, an extremely effective vaccine against coronaviruses has been developed.

How vaccines work

Conventional vaccine

1. Culture
2. Inactivation (Loss of infectivity)
3. Preparation
4. Injection

mRNA Vaccines

1. Synthesized coronavirus surface protein
2. Lipid coating to promote delivery to the target cells
3. Packaged as a vaccine
4. Injection

Protein on the virus surface is analyzed and stable and efficient mRNA is synthesized

The next time the real virus invades the body, it is rapidly eliminated

Doshomachi "Medicine Town" and Sukunahikona Shrine

In the era of Toyotomi Hideyoshi (1537 to 1598), drug wholesalers were concentrated in the Doshomachi area of Osaka in accordance with the government’s commercial policy. During the isolationist period of the Tokugawa shogunate (1603 to 1687), exchange with foreign nations was restricted to China and Holland. Drug wholesalers who imported drugs from those two countries established their businesses in Doshomachi, forming an officially approved guild, or Kabunakama, called the Yakashunakagaiinakama. In 1721, the Tokugawa government established an agency in Doshomachi for checking the quality of medicinal products made in Japan (Wayakusha aratame kaisho). Hence, all medicines commercially traded throughout Japan passed through Doshomachi first. All these historical connections led to Doshomachi being home to many pharmaceutical companies, making it Japan’s first “medicine town,” followed later by Nihonbashi Honcho in Tokyo.

The Doshomachi Pharmaceutical and Historical Museum (Kasurinomachi Doshomachi Shiryoukan) is a great place to see exhibits of prescription medicines, instruments, equipments, and other related items used by medical wholesalers. The Sukunahikona Shrine, a Shinto shrine that is dedicated to medical deities, can also be found in Doshomachi.

Participating Teams

[List of countries]
Students doing experiments in the lab and standing in front of the chemistry department gate.

The Swedish team with the elements. Good luck with the Catalyser!

This picture was taken during the IChO training session on July 5 2021.

We are glad to participate in 2021 Remote IChO competition. Regards from Nigeria.
A neodymium magnet, known as the world’s strongest permanent magnet, is made of three elements. Which of the following is the correct combination?

1. (Nd, Pb, B)  
2. (Nd, Pd, Fe)  
3. (Nd, Fe, Co)  
4. (Nd, Fe, B)

A Papier-mâché Tiger

In ancient Asia, tigers were considered to be messengers from the Gods, and their bones were used as a medicine and in lucky charms. In 1822, when Osaka was hit by the cholera epidemic that was sweeping the world at the time, an apothecary in Doshomachi, Osaka, created a Japanese herbal medicine containing tiger skulls and distributed it with a tiger-shaped charm made of paper called Hariko-no-tora, meaning a papier-mâché tiger. Although the medicine itself became obsolete, Hariko-no-tora are still handmade as traditional crafts. They are popular in the Kansai region as lucky charms that protect people from disease and express the wish for healthy growth of children.