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Interview

THE AVOGADRO CONSTANT WAS RECALCULATED AND CONNECTED TO THE DEFINITION OF THE MOLE

THE IMPORTANCE OF THE AVOGADRO PROJECT FOR THE NEW DEFINITION OF THE MOLE AND THE KILOGRAM

***Bernd Güttler** studied mineralogy at Leibniz University Hannover, Germany, and received his Ph.D. in crystal physics in 1988 also at Hannover with a dissertation on the electronic transport properties of transition metal oxides. During this time he moved to Cambridge University in England and worked as a research scientist mainly on phase transition phenomena in the Department of Earth Sciences and the Cavendish Laboratories between 1987 and 1989. He joined PTB* (Physikalisch-Technische Bundesanstalt, the National Metrology Institute of Germany) *in 1990, initially focusing on metrology in solid state chemistry. He was responsible for the Department for Metrology in Chemistry at PTB between 2002 and 2016. Since 2015 he has been Head of Division for Chemical Physics and Explosion Protection at PTB. Bernd Güttler represents PTB at the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology of the Meter Convention and is Chairman of the Working Group on the Mole. He is also the German contact person at the Technical Committee for Metrology in Chemistry (TC-MC) of the European Association of National Metrology Institutes (EURAMET) and chaired this committee between 2007 and 2011. He also holds a teaching position in Metrology in Chemistry at the University of Braunschweig.*

Dear Dr. Güttler, could you please inform us on PTB and your division, briefly?

The Physikalisch-Technische Bundesanstalt, the National Metrology Institute of Germany, is a scientific and technical higher federal authority falling within the competence of the Federal Ministry for Economic Affairs and Energy (BMWi).

PTB is Germany's highest authority when it comes to correct and reliable measurements. It is the supreme technical authority of the BMWi and employs a total of approx. 1900 staff members.

The tasks of division 3 "Chemical Physics and Explosion Protection" include metrology in chemistry, i.e. the development of primary methods in analytical chemistry and the dissemination of the related unit mole, the measurement of thermodynamic quantities, as well as physical and electrical explosion protection.

You are head of the redefinition of mole project. I have read the "mise en pratique" of the definition of the mole. It is a very nice information sheet also about the result of the Avogadro project. What was the aim of the project? Why did you need to do this project?

The redefinition of the mole was part of a general endeavor to redefine the SI base units in terms of natural constants. This included the removal of practical realizations of the units from their definition.

For example, the kilogram was realized by a prototype made from a platinum-iridium alloy. It acted as the international kilogram prototype since 1889 and is located at the International Bureau for Weights and Measures (BIPM) in Paris. It is compared with its copies that are used as national measurement standards for mass in most countries in regular intervals. Such a prototype - no matter how stable it is and how well it is kept- is exposed to changes over time. This might be surface reactions, damages and, in the worst case, a destruction of the body. What we see in practice is a relative increase in the mass of many national copies of the prototype when compared to the prototype itself. This situation required a new primary realization of the kilogram that is independent of a prototype and can be fully described and reproduced at any time – at least in principle - and it should be accurate enough to replace the prototype kilogram. This requires a relative standard uncertainty of 2×10^{-8}. This goal was set by the consultative committee for mass and related quantities (CCM) as a minimum requirement for a redefinition of the units in order to safeguard continuity with the current system for the dissemination of the unit kilogram.

One of the experiments conducted to achieve this ambitious goal was the so-called "Avogadro-Project". In simple terms, it aimed at counting the atoms of silicium in a single crystalline Si-Sphere of extremely high quality by measuring the volume of the sphere and the crystal lattice constant of the silicium used.

This experiment was used to redefine the (interrelated) defining constants for the kilogram (Planck constant h) and the mole (Avogadro-constant N_A) within the old system with sufficient accuracy and such that the consistency of the units between the old and the new definition is maintained.

After the redefinition, these spheres are also primary (most accurate) realizations of the unit kilogram and mole. A "mise en pratique" [1] is a description of such a primary realization of a unit and accompanies the new definition. Consequently, the "mise en pratique" of the definition of the mole and also that of the kilogram contain a principle description of the work on the silicium spheres produced and measured in the Avogadro-Project.

Could you please mention the partners of the project?

The Avogadro Project would have not been possible without an international collaboration that aimed at the redetermination of the Avogadro constant with sufficient accuracy to permit the redefinition of the SI system based on this constant. The International Avogadro Coordination (IAC) started in 2004 among the BIPM, INRIM (Italy), the IRMM (Belgium), NIST (United States), the NMIA (Australia), the NMIJ/AIST (Japan), the NPL (United Kingdom), and the PTB (Germany). The collaboration was renewed in 2012 among the BIPM, INRIM, the NMIA, the NMIJ, and the PTB.

Could you please inform me about the work package of the project? Which parts were done by which partners?

The accurate determination of the Avogadro constant was made using a ^{28}Si enriched spherical shaped single crystal of silicium. A range of measurements was required for that purpose. This

Dr. Ahmet C Goren and Dr. Bernd Güttler in Braunschweig included the interferometric determination of the volume of the sphere (NMIJ, PTB, NMIA), the mass of the sphere (BIPM, PTB, NMIJ), its lattice constant based on x-ray interferometry (INRIM, NIST), the crystal density (PTB, NMIJ), the surface layer that covers the sphere (PTB, NMIJ), the impurities in the single crystal (PTB, INRIM) as well as its isotopic composition (to calculate its molar mass) using mass spectrometry (PTB, NIST, NMIJ).

Silicium 28 sphere (photo from PTB)

The ^{28}Si enrichment of the silicium used for the crystal sphere was made in Russia. Single crystals were grown at Leibniz-Institute for Crystal Growth (IKZ) in Berlin. The crystals were cut and polished into spheres at NMIA in Australia and at PTB in Germany.

Some work is still ongoing even after the redefinition of the mole and the kilogram in the new SI and the fixing of the Avogadro constant. It aims at reducing the measurement uncertainty of the primary realisation of the mole and the kilogram.

In your opinion what was the most problematic part of the project in the past? How did you solve it?

All those measurements had to be carried out with utmost precision to achieve the aspired relative accuracy of 2 x 10^{-8}. It was a challenge for all measurements involved and often required dedicated instrumentation for this specific purpose. Many years of work went into any of these experiments.

A breaking point was certainly a new method for the determination of the molar mass of silicium with sufficient accuracy. This was considered as the key problem for many years and almost stopped the entire project. It is related to silicium isotope ratio measurements as elemental impurities are small. This problem was overcome by an entirely new measurement concept that considered the Si isotopes ^{29}Si and ^{30}Si as an independent element in a matrix of ^{28}Si. This so-called virtual element approach led to an improvement of the measurement uncertainty of the molar mass by more than two orders of magnitude. This was decisive for the success of the project.

What is the benefit of the redefinition of a mole in our scientific life?

As mentioned before, the idea behind the redefinition is a general concept for the SI units that aims for definitions that are based solely on natural constants. Any artifacts should be removed from the definitions – the most obvious one being the kilogram prototype.

The new definition will be more robust and stable as the defining constants are independent of time.

The benefit for chemistry is a solution for an uncomfortable situation: The value of a natural constant, the Avogadro constant, depended previously on the stability of an embodiment of a unit – the kilogram prototype. Any damage to this prototype changes the Avogadro constant – this is very unsatisfying!

Now, as a result of this project, the Avogadro constant and the Planck constant are fixed. Mole and kilogram were realized using those numbers and will be stable over time. Finally, the following new definition is now valid since 20 May 2019 and available on the website of BIPM:

"The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly 6.022 140 76 x 10^{23} elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number" [2].

References

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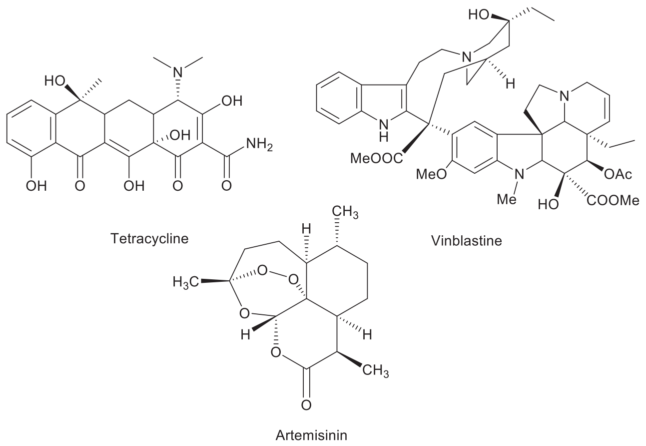
2. Chemistry and Biology: SI base unit (mole). https://www.bipm.org/metrology/chemistry-biology/units.html

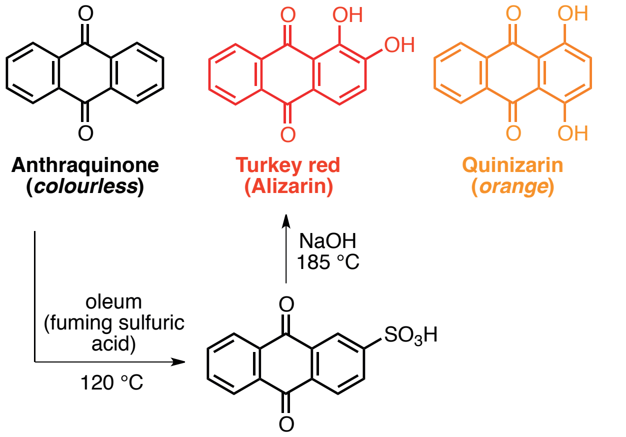
Ahmet C Goren

Variety of orange color fruits and vegetables, which are a good source of beta-carotene.

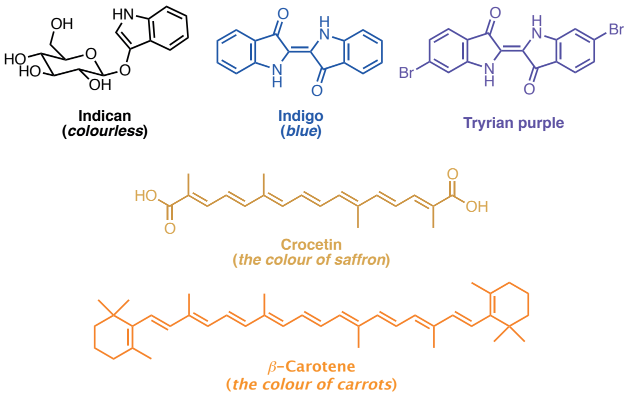
TURKEY RED AND ALIZARIN

As chemists, we all have a certain level of knowledge on natural products (secondary metabolites) mostly due to their fascinating biological activity profiles. While some natural products such as vinblastine and taxol are used as highly potent anti-cancer drugs, many other natural products including penicillins, cephalosporins, tetracyclines, and vancomycin were discovered to be extremely useful antibiotics. Another famous example is artemisinin, which was isolated and studied by the Nobel laureate Tu Youyou [1]. Artemisinin is currently one of the most effective drugs against malaria.





In addition to their biological activities, natural products have found widespread use in other areas as well throughout history. Before the advent of synthetic dyes, plants and, to a lesser extent, animals were used as main sources of dyes. For instance, indigo, which is famous for its blue color, was prepared from naturally occurring indican via alkaline treatment followed by oxidation. Interestingly, the dibromo analogue of indigo, isolated via a similar procedure from snails, exhibits a purple color, and is named Tyrian purple [2]. Moreover, a variety of organic molecules are responsible for the characteristic colors of certain fruits and vegetables. Crocetin forms the core polyene skeleton of crocin, which is responsible for the color of saffron, whereas the characteristic orange color of carrots is due to a similar polyene molecule, beta-carotene.



Historically, one of the most important dyes obtained from plants was Turkey red, which was produced from madder, the root of *Rubia tinctorum* (kökboya in Turkish). The procedure for the production of Turkey red was a lengthy process and involved the use of alum as a dye mordant [3]. The structure of alizarin, which is responsible for the bright color of Turkey red, was elucidated by the German chemists Carl Graebe and Carl Liebermann from BASF in 1868 [4]. After this discovery, synthetic routes to alizarin starting from anthracene and anthraquinone were developed. An efficient synthesis of alizarin involves the conversion of anthraquinone to anthraquinone-2-sulfonic acid by a sulfonation reaction and its subsequent treatment with NaOH at high temperature under oxidative conditions [5]. Interestingly, the infantrymen of the French army wore trousers dyed with Turkey red until World War I [2,6]. The production of Turkey red from madder declined after the commercial production of synthetic alizarin. Finally, it should be noted that 1,4-dihydroxyanthraquinone, which is a constitutional isomer of alizarin, is named quinizarin and has an orange color.

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Yunus Emre Türkmen

TURKEY'S HIGHEST MOUNTAIN, MOUNT AGRI

Ayfer Kalkan Burat

Mount Ağrı, Turkey's highest mountain, is located in the country's Eastern Anatolia Region. The mountain has won the admiration of those who have seen both its geological location and spectacular view. For Mount Ağrı, Marco Polo mentioned in his writings that "it is a mountain that will never be able to be climbed", but according to records, the first ascent of the mountain was carried out in 1829 by Prof. Friedrich Parrot, and the second one in 1970, many years after the first. Nowadays, it is a place frequented by many climbers.

It consists of two major volcanic cones: Greater Ağrı, the highest peak in Turkey, with an elevation of 5137 m, and Lesser Ağrı, with an elevation of 3896 m. The Ağrı massif is about 40 km (25 mi) in diameter. The summit of the mountain is covered with a snow and ice cap glacier (10 km^2) that remains throughout the year. This glacier is Turkey's largest. A total of 11 glacial tongues hanging from the ice caps and varying in length from 1 to 2.5 km have reached 4200 m on the southern skirts and 3900 m on the northern skirts.

Digital depiction of Noah's ark in a stormy ocean.

Many people who believed that Noah's ark was located on Mount Ağrı attempted to climb this mountain [1-3]. Moreover, the fact that the view of some dents in the mountain resembled a ship further reinforces this idea. Therefore, many adventurers visit the mountain every year. In 2007, Turkish and Chinese explorers claimed to have found seven large wooden compartments buried at 13,000 feet (4000 m) above sea level, near the peak of Mount Ağrı. After this announcement many explorations have been mounted for the ark. However, no confirmable physical proof of the ark has been found yet.

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What many people believe are the remains of Noah's Ark (centre right) near the town of Doğubayazıt in the far east of Turkey near the border with Iran.

DIYARBAKIR GREAT MOSQUE

Cultural Heritages

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The Great Mosque of Diyarbakır is the oldest and one of the most significant mosques in Mesopotamia, Turkey.

Located in the city center of Diyarbakır, the building was designed as a mosque in 639. It is understood from the inscription on the northern façade that it underwent a major repair upon the command of Malik Shah, the Great Seljuk ruler, in 1091.

The mosque was badly damaged in an earthquake and fire in 1115-16 and was entirely rebuilt. During this construction process, the decorated columns were taken outside and used in two-storey porticos in the east and west. Diyarbakır Great Mosque, which provides the architectural features of Umayyad Mosque in Damascus in Anatolia, is the most magnificent and decorated structure of the early Islamic period and is regarded as one of the holy places of the Islamic world after Mecca, Medina, and Jerusalem.

Evliya Çelebi said, "*It is such a perfect structure that it is impossible to make it smoother and stronger than it already is*." The mosque has three naves parallel to the mihrab and has a plan created by cutting these naves with a vertical one in front of the mihrab.

The Zinciriye and Mesudiye Madrasas are located to the northeast and west of the mosque courtyard. The minaret in the southwest is representative of the square-bodied minarets in North Africa and Syria.

The mosque has entrances on three sides. A fighting lion and bull, shown on the portal on the eastern side and considered a reflection of the Central Asian ornamentation style, adds importance to this façade.

The decorations and inscriptions of the Great Mosque from different periods are presented in harmony on the inner walls of the courtyard.

Hüseyin YURTTAŞ, Esra HALICI, Burak Muhammet GÖKLER, Muhammed Emin DOĞAN

View of the Grand Mosque (Ulu Cami), the center of Diyarbakır

The Great Mosque (dates back to 7th century) of Diyarbakır is considered by some to be the fifth holiest site in Islam.

TODAY'S PROBLEM AND YESTERDAY'S ANSWER

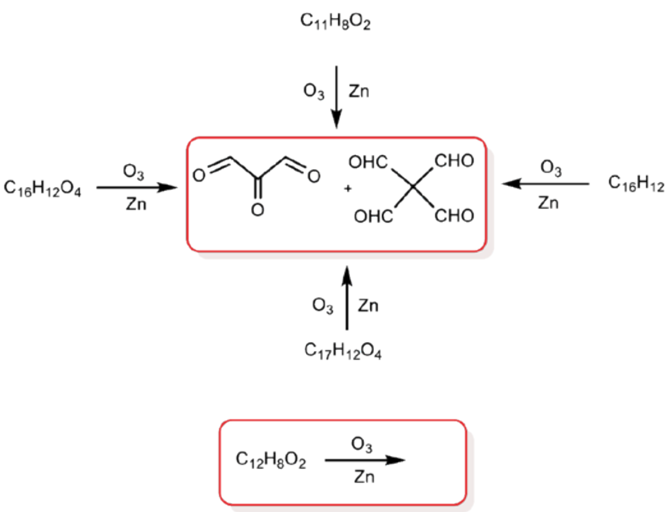
Problem 6.

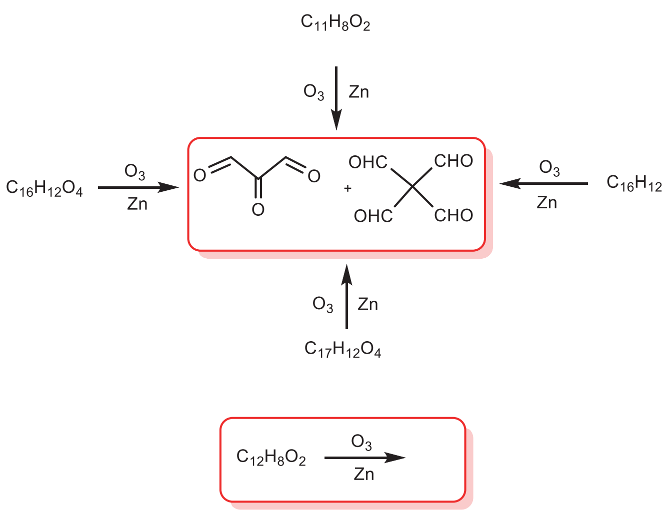
Structural Analyses by Ozonolysis Reaction: An Old Method

Before the development of modern spectroscopy methods, ozonolysis was used as a method for the structure determination of unknown molecules for many years. By analyzing the fragments of the ozonolysis reaction, it is then possible to deduce what the original structure was, through "binding" together with the fragments.

Let's go back to the past and guess molecular structures with this old method. The reductive ozonolysis reaction of A, B, C, and D resulted in the formation of products 1 and 2. On the other hand, the reaction of E gave only compound 1. Suggest a possible structure for compounds A-E.

Arif Daştan





The smallest possible value of n is 103.

Alaaddin can divide the sticks into 97 groups containing 2 sticks and 2 groups containing 3 sticks each. Since there are 100 magic sticks, at least one of these groups contains a pair of magic sticks. Therefore, by trying all stick pairs in at most 103 trials Alaaddin will activate the enchanted lamp. If the total number of trials is 102 then some stick, assumed not magic, is used at least twice. Then the number of trials without this stick is at most 100 and it can be easily shown that these 100 trials are not sufficient to activate the enchanted lamp.

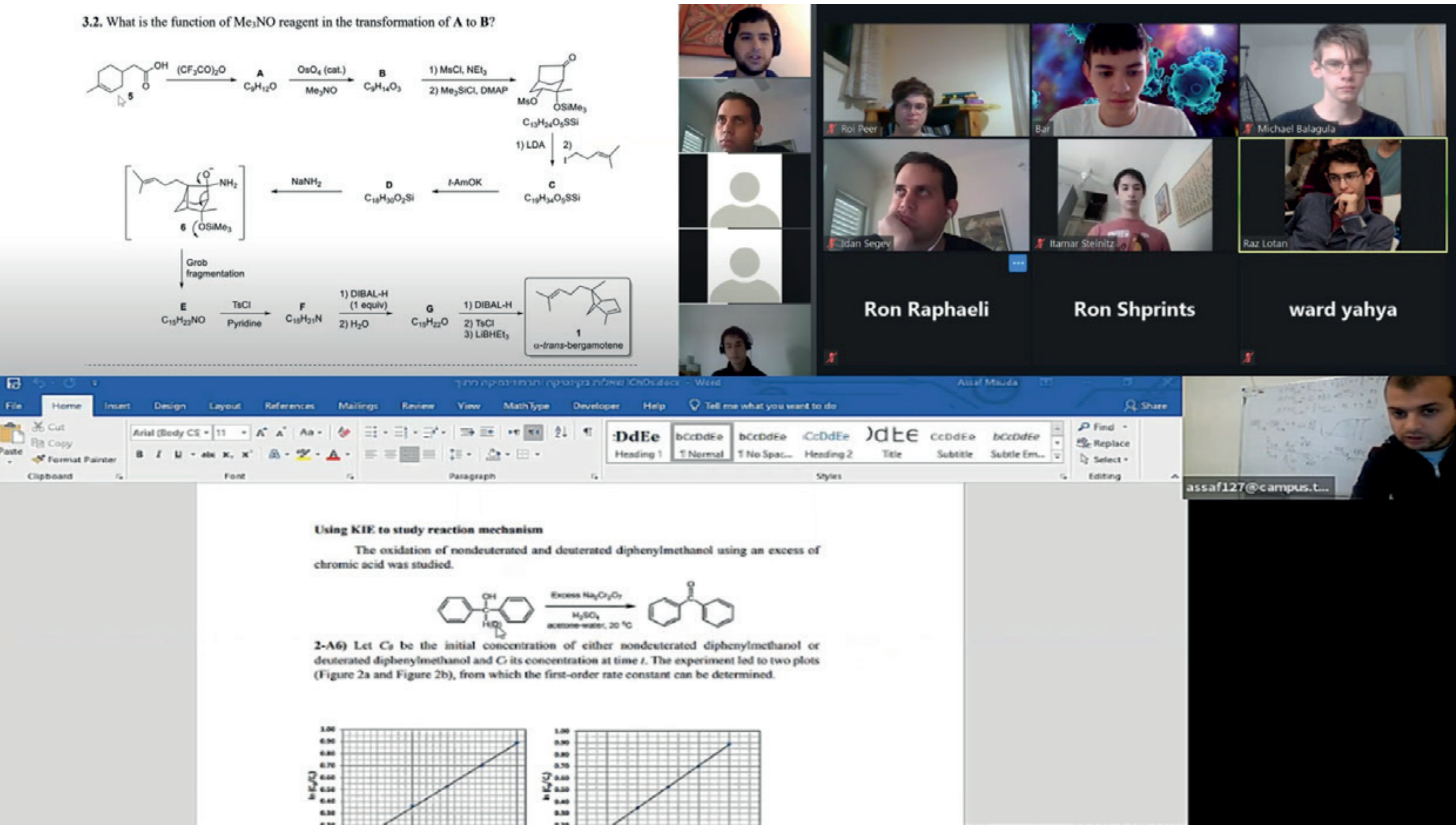
INDONESIA

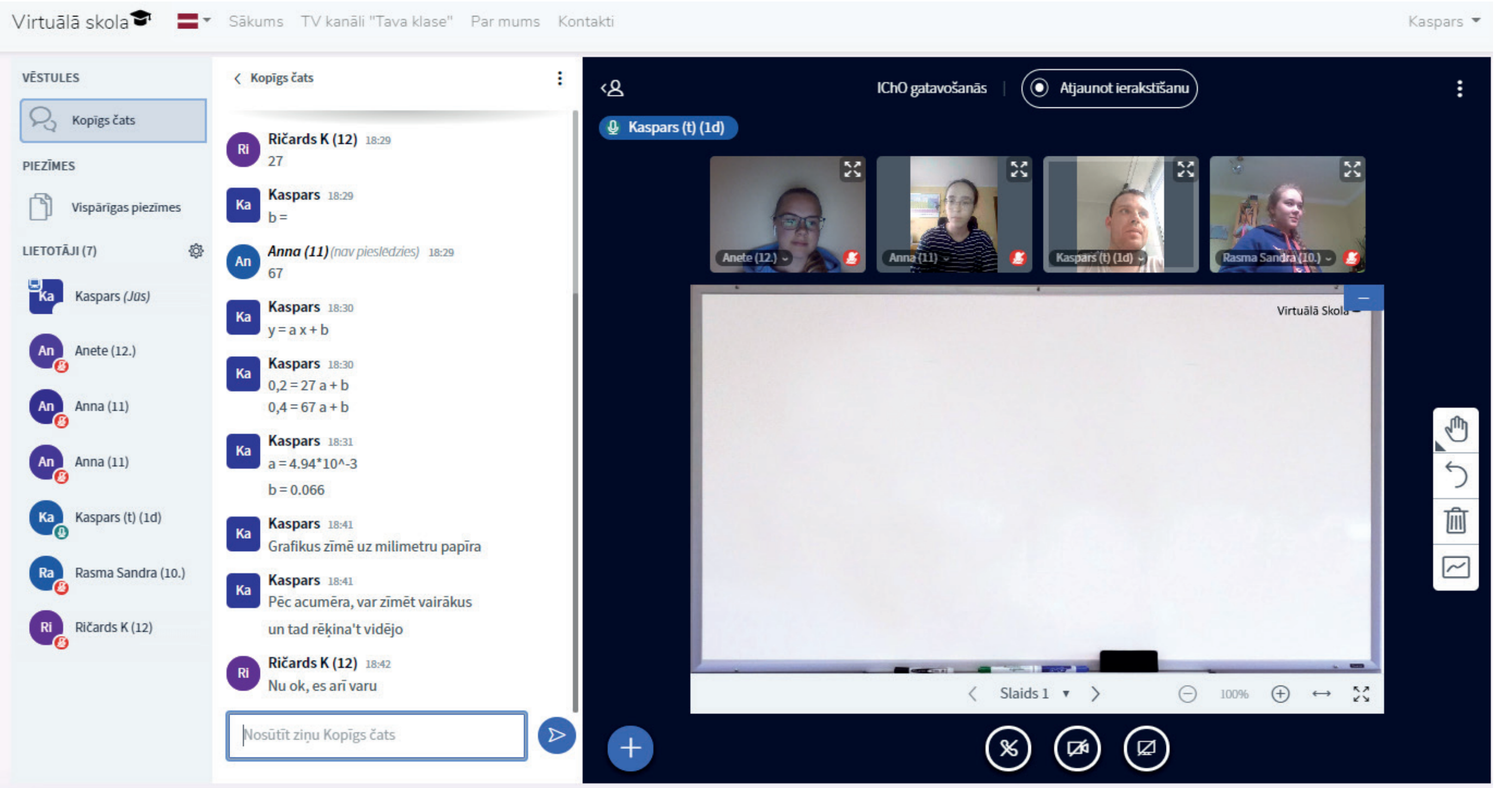
The Journey of Indonesia Team to IChO 2020: From Offline to Online

NEWS FROM NATIONAL TEAMS OF COUNTRIES

ISRAEL

IChO and Covid-19 Preparations



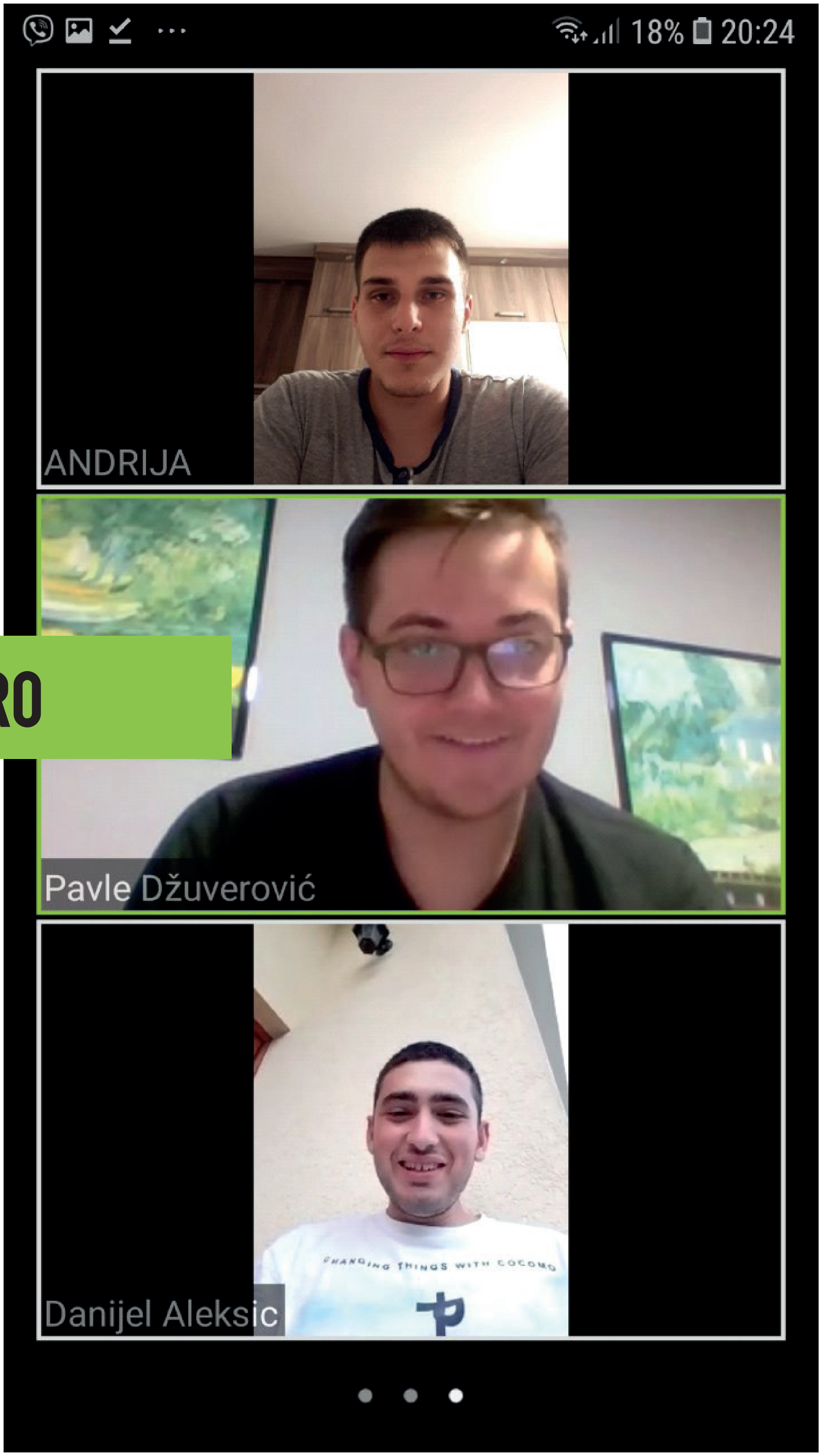


LATVIA

Preparations online @virtualaskola.lv

MONTENEGRO

Due to the COVID-19, Montenegrin national preparataions were organized online.

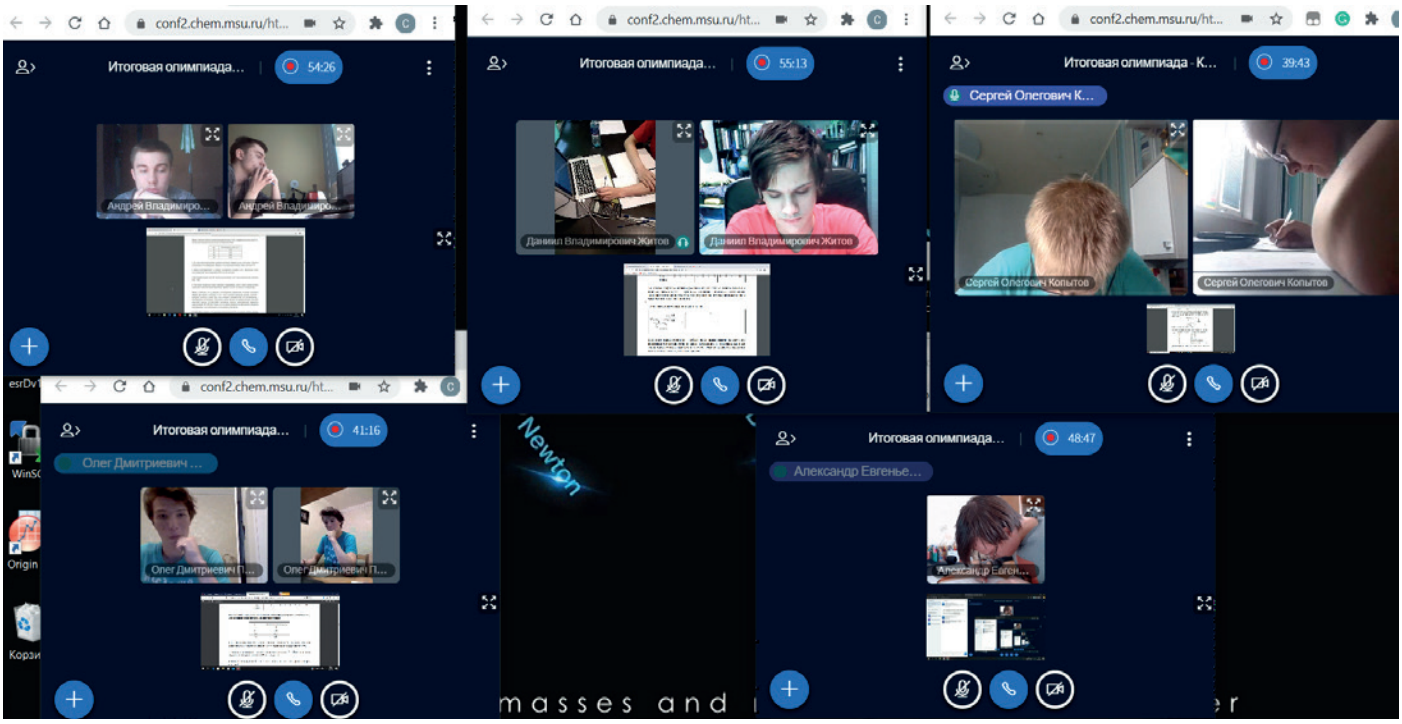


NEPAL

National Olympiad picture

NETHERLANDS

Theoretical exam of the Dutch team



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