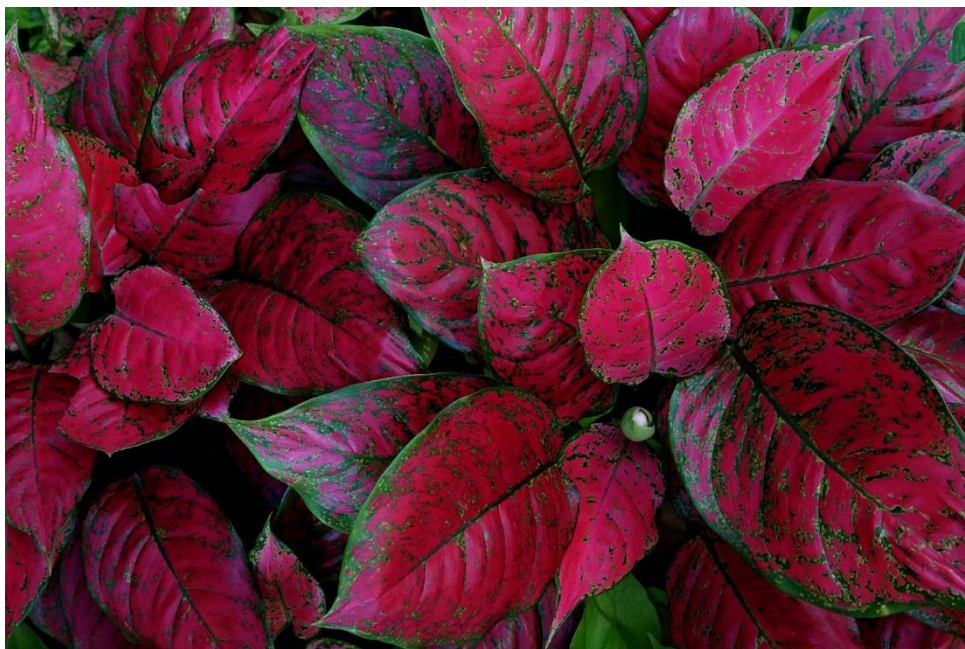




# International Chemistry Tournament 2022

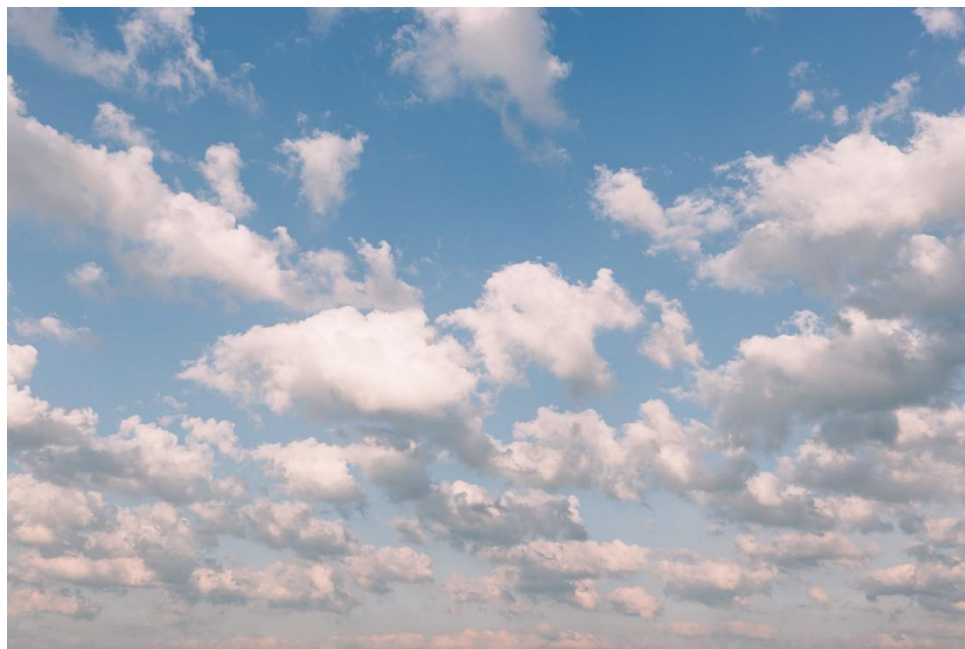
Problem Set



## 1. Feels and Logs

Many plant owners struggle to understand the needs of their flowers, even though chemical communication between individual plants is well known. Is it possible to listen to what they say?

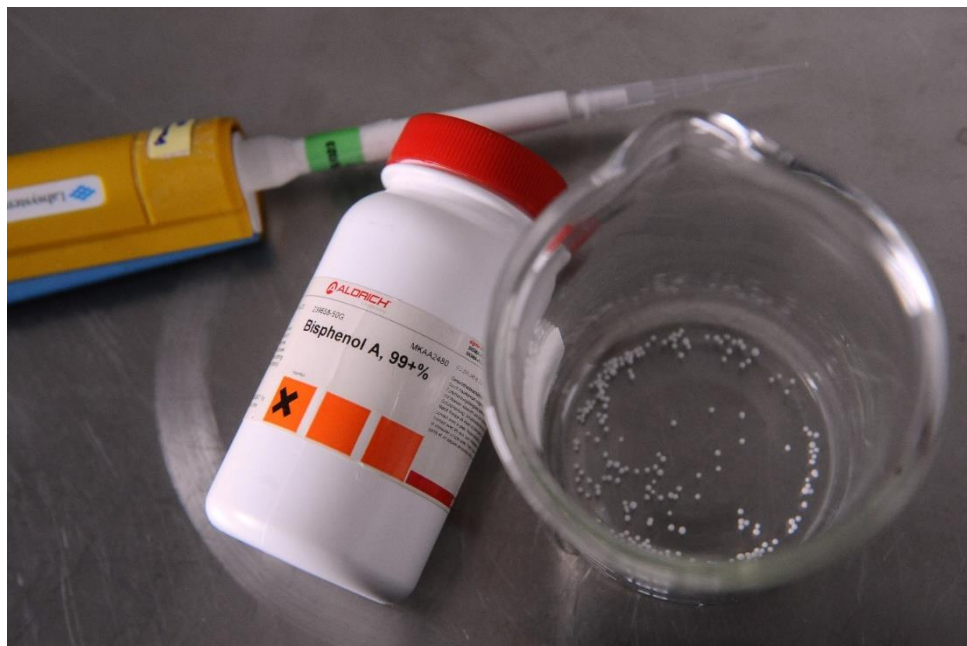
Design a tool that can translate chemical signals originating from plants into visual information using chemical reactions, similarly to how mood rings claim to reflect the wearer's feelings with different colours. The reactions must be reversible so that the kit may be reused multiple times.



## 2. Cloud Neutralisation

Since the industrial revolution, human activities have increasingly affected the composition of the atmosphere. One consequence of this is the higher incidence of acid rain, which is mainly caused by the release of nitrogen and sulfur oxides. While acid rain is highly damaging to the environment, it is also corrosive to buildings and other artificial structures. To combat the release of these pollutants, multiple effective preventative measures have been implemented worldwide, which are part of international treaties and protocols. However, acid rain is still an ongoing issue and after a cloud has already formed it is more difficult to handle the problem.

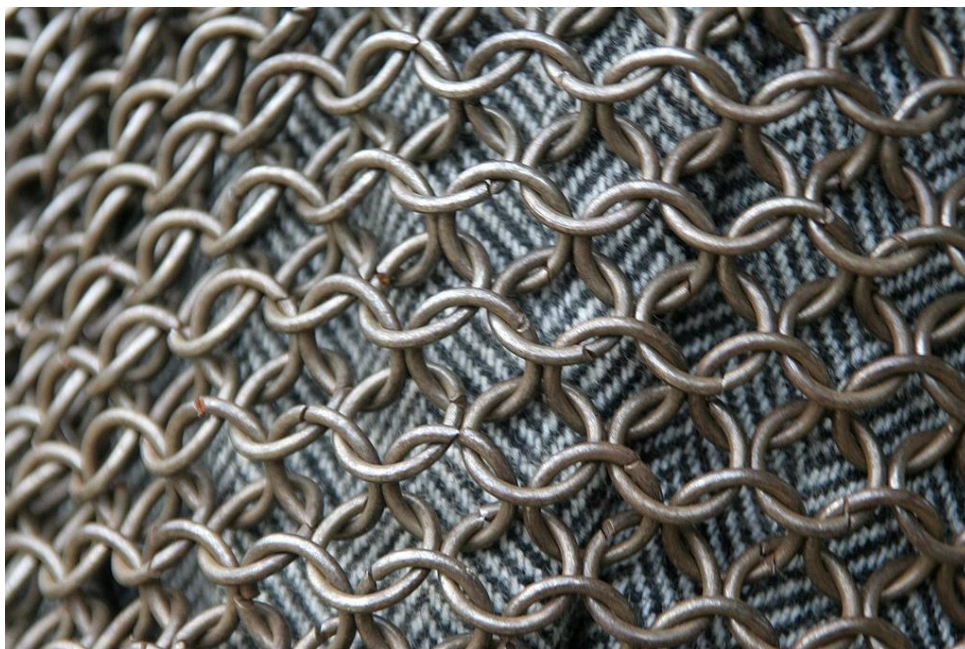
Devise a chemical treatment procedure to neutralise acid rain before it reaches the ground, without causing further environmental damage.



### 3. Polluted Water

Clean freshwater is becoming an increasingly valuable resource in the 21st century. Pollutants from various sources are infiltrating the water supply, posing serious health hazards. Some of the most important of these are phthalates and bisphenols. These organic compounds mostly originate from plastics and can cause a variety of issues over time, including hormonal disruptions. While the use of these compounds is highly regulated in certain products, it is still a major concern, especially in developing countries.

Devise a protocol for testing water samples for phthalate and bisphenol contamination at the site of sampling. Your method must only utilise portable field equipment with sufficient sensitivity and selectivity. It should be reasonably affordable and quick to perform.



#### 4. Molecular Chainmail

Ever wondered if a molecule with the formula  $C_nH_{2n}$  can have two rings? The answer is yes, such molecules are called catenanes and consist of two mechanically interlocked rings. These kinds of bonds allow “knotting” of molecules, and one can imagine what is the limit of complexity that can be achieved with such tools.

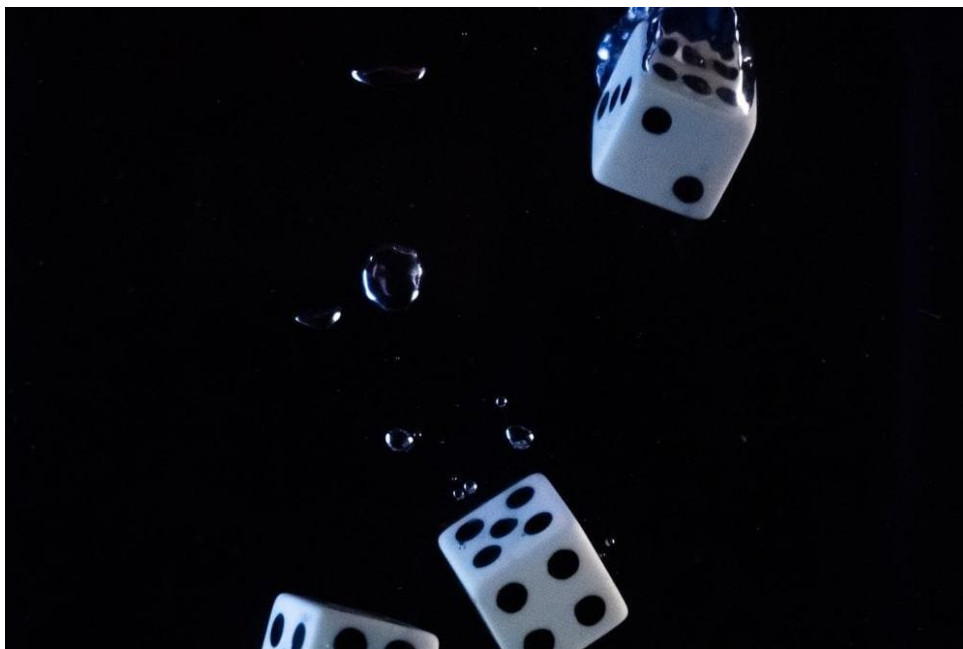
Your task is to propose a synthesis of a 2-dimensional polymer with monomers connected via mechanical bonds. What are the physical properties of such a compound going to be?



## 5. The Silver Lining

Hungary is famous for the hot springs and thermal spas, some of which are situated in the capital city. Besides relaxation, people often visit these facilities for the favourable medical properties of the water, constituted by their mineral composition. However as good as it might do to your health, spa water can turn jewellery made of silver black.

Your task is to propose a water treating additive that could prevent the aforementioned unfortunate effect. It must not alter the properties of the water such as the mineral composition, temperature, or pH, and it should not be toxic if it is to be used in spas.



## 6. Roll the Dice

All people who have tried making a demonstrative experiment knows that a reaction very often does not happen as it should, or expected. Its outcome must depend on some mysterious forces such as planetary constellation or no one knows what... So, from this, one thing is clear, that reactions can have different outcomes, and might result in different observations as the experiment is repeated. Thus for once, instead of being annoyed by this phenomenon, one can exploit it to design a chemical dice, which works as the following:

Upon mixing two solutions in a beaker, there can be six visually different possible outcomes that one can observe, with the different outcomes having an equal chance of happening.

Your task is to design the system described above.

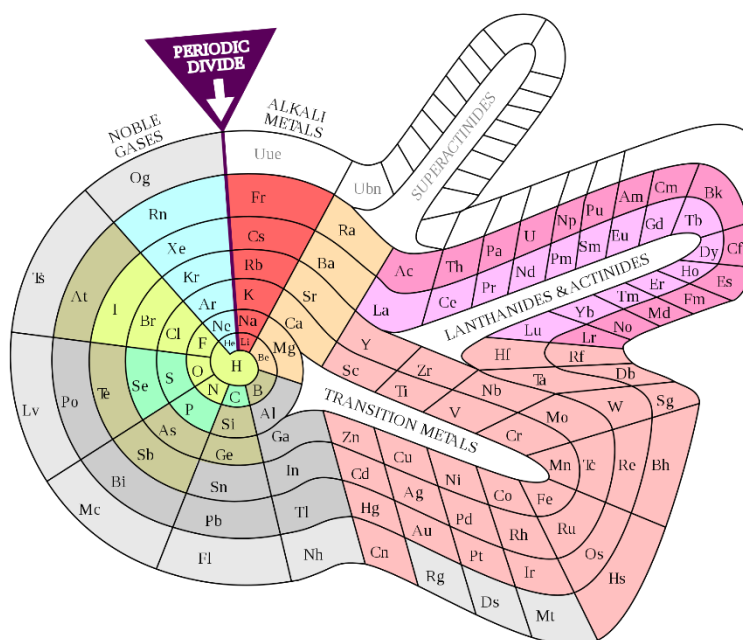


## 7. Spy Gadgets 101

Many people saw the scene. Our hero is on the run with henchmen shooting guns all around him in the middle of a top-secret terrorist hideout. He is running towards a bridge that suddenly collapses right in front of him. The gap is too wide to jump, what is he going to do? Being the crafty secret agent, he swiftly points his luxury watch to the ceiling roughly halfway through the gap and a small rope shoots out from the watch. The end of the rope secures itself into a concrete wall, rolls up around a pipe or just gets stuck between two pieces of metal and our hero can swing across the gap to successfully flee from the base.

Behind every successful agent, there is a successful quartermaster who makes these gadgets come to life. We invite you to be a quartermaster and make this ultra-tough and thin cable a reality. It has to be strong enough to hold the weight of two people. (You cannot leave a beautiful companion behind.) Also, it has to be thin enough to fit inside a commercially available, operational watch while having a length of at least 5 meters.





## 8. 32-electron Rule

Commonly cited as a desire of atoms to reach noble-gas-electron-structure, the Lewis octet rule is a powerful guide to predict the valency of main block elements. A similar rule exists for coordination complexes of d-block metals, where having 18 valence electrons is often favoured.

Does a similar rule exist for actinoids or lanthanoids? Under what conditions would a 32-electron-structures be favourable? Give examples and justification. Describe the origins, generality, and limitations of the rule.



## 9. Metal Eating Foam

*Mission: Impossible III* features an outstanding action sequence on the Chesapeake Bay Bridge-Tunnel, a 23-mile crossing that is exciting enough without nefarious henchmen shooting rockets at you.

Ethan Hunt (Tom Cruise) has the ruthless black market trader Owen Davian (Phillip Seymour Hoffman) shackled up inside an armoured transport vehicle. Davian's posse comes to rescue him, but when the moment strikes, a bunch of goons approach the side of the van and...spray it with something. A moment later the metal shatters like glass and the bad guy gets away.

Your mission, should you choose to accept it is to recreate the foam from the movie. It has to produce the same effects seen on the screen, and be possible to store the potent canister on a shelf for an extended time.



## 10. Chemist's Gambit

Chess is one of the most popular board games currently, which is understandable due to its relatively simple rules and almost infinite combinations of moves. While it is certainly enjoyable using conventional pieces, one might wonder what a game of chess might look like using single cells instead. One of the key characteristics of motile cells is their ability to respond to external stimuli by transducing the signal and making movements by rearranging their cytoskeleton and using motor proteins. Theoretically, this can be utilised to play games like chess with these cells, and your task is to propose such a system.

The main questions are the following: What kind of external signal is used to control cells? How is the signal transduced on a molecular level, what kind of mechanisms are at play? What molecular characteristics enable control of the direction and duration of movements? How is the identity of different pieces determined? How would capturing the opponent's piece work?



## 11. Living Metal

In the popular computer game *Stellaris*, one of the finest technologies is ‘Living metal’. This strategic resource provides a self-healing solid material, which can heal itself after being subject to damage. The fascinating aspect is the ability to do so without human or robotic supervision. Although self-healing concrete is already on the market, self-healing metal is very much still science fiction.

Your duty is to invent such a metallic material that can heal wounds caused by bullets and knife cuts, close fractures and holes. What are the potential applications of your solution?

## 12. Cast your vote on the final problem when you register early bird

### A. Organic Battery

Energy storage is one of the most crucial challenges of the next century; necessary for the transition from fossil fuels to renewables, and also vital in operations conducted on alien planets. Currently, the market is dominated by lithium batteries, but they suffer from several drawbacks in terms of safety and cost.

Propose a rechargeable battery, where both the anode and the cathode are made of organic compounds that is practical to be mass-produced in environments where metals are scarce, such as on the cold surface of the moon Titan. Only utilise materials which are found there. Evaluate the performance of your battery.

### B. The Spice Must Flow

Saffron is a spice made from the plant *Crocus sativus*. It is difficult to cultivate, labour-intensive to harvest and has a highly unique fragrance. Due to these factors, it is one of the most expensive spices in the world. It is perhaps no surprise then that saffron has often been a subject of adulteration, especially in the powdered form. Related species are often mixed in and sold as authentic saffron, as well as others that can resemble the vivid red stigmas and styles of the original plant. Devise a simple test, or series of tests, which could be used to identify adulterated saffron on a chemical basis. The method must be reasonably low-cost, quick to perform, and should identify a wide range of adulterants.

### C. Local Rocket Science

In the famous movie *Martian*, the rocket launching the astronauts back to Earth uses hydrazine synthesized on the Red Planet. Can you make rocket fuel on Mercury and Venus in a similar manner, only incorporating substances found on the respective planet in a practical timeframe?

### D. Terraforming Mars

If we want to set foot on Mars, we will have to solve challenging problems never faced before. One of these will be the removal of toxic perchlorate salts from the martian soil to make growing plants possible. Propose a method that could be viable for an early colony on the red planet.

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