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UNIVERSITY OF BUCHAREST
VIRTUTE ET SAPIENTIA

Inform ART

International Chemistry Tournament
8th Edition

PROBLEM SET

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Problem 1. Blue Irises

Irises (original title in French: *Les Iris*) is a fairly well-known painting by Vincent van Gogh, portraying a landscape of flowers, predominantly of blue irises. However, up until recently one question has been boggling art historians regarding this particular piece of work; contemporary descriptions wrote about violet irises, despite the painting featuring blue flowers today.

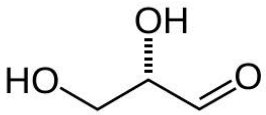
Spectroscopic and chemical analysis have shown that the flowers were indeed violet originally, only that the red pigment of the paint has degraded and faded over time, resulting in the flowers' blue colour that we can see today.

Your task is to read up on its literature, identify the chemical formula of the red pigment in question, and the chemical reaction involved in its degradation. Finally, and most importantly, propose a chemical synthesis route for the original pigment molecule, from the most likely end-product of the degradation process. The synthesis route is in no way confined to the conditions that are compatible with an oil painting, you can start from a pure compound, and your solution may use any suitable laboratory techniques and equipment.

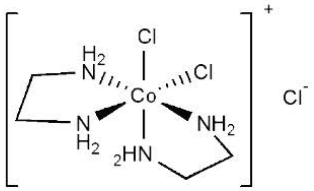
Problem 2. Ethereal for Eternity

In today's world, digital cameras dominate photography, pushing the magic of analog photography into the background of everyday life. Its final stronghold now lies with artists who use this unique medium to create their pieces. While the use of light-sensitive silver halides is one of the most well-known analog techniques, it is by no means the only one. Throughout the 19th century, various alternative photographic processes emerged, including tintypes, daguerreotypes, cyanotypes, the chlorophyll process, and anthotypes, each offering its own unique approach to capturing the world around us. While the most common silver-halide based photography is briefly mentioned in high school chemistry curricula, the rest has a chemical background just as interesting if not more.

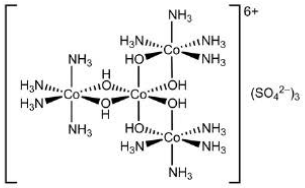
Anthotypes, one of the most extraordinary techniques of analog photography, only require plant extracts and some patience to create these beautiful ethereal images, making them a perfect candidate for a kitchen-suitable experiment. With analog photos, the use of an appropriate fixer is essential to make the image permanent. It is straightforward in the case of most processes, silver-halides requiring a bath of ammonium thiosulphate, cyanotypes only water, and the chlorophyll process having copper ions as a proposed fixer. However, there is no such method to preserve anthotypes that could help make the image permanent. Your task is to propose a possible treatment, or to find an appropriate starting material, that could keep anthotypes from disappearing due to light exposure. In your solution, you should also estimate the durability of your fixing process.



chiral organic molecules



chiral metal complex
chirality not based on carbon



chiral metal complex
no carbon atoms

?

chiral compound with:
no carbon atoms
no metal atoms

Problem 3. Chirality without carbon or metals

When thinking about chirality, probably the first thought would be “asymmetric carbon atom”. It was believed that chirality was restricted to organic chemistry, but it was proved that metal complexes could also be chiral, without asymmetric carbon atoms. Even purely inorganic optically active compounds have been identified, also based on metal ions. What about an inorganic molecule (not polymeric structure) that contains neither carbon atoms nor metal atoms, but presents chirality? Your task is to propose such a molecule, explain how it could be synthesized and characterized and discuss the origin of its chirality.

Problem 4. Laser vision!

Have you ever read any Marvel comics or watched any of their movies? If so, you may have heard of Cyclops, a well-known superhero capable of producing high intensity red beams which he uses to defeat his enemies. Imagine you are like him and have the ability to produce high intensity monochromatic beams (not necessarily red) from your eyes. However, you're unable to control them, which could result in damage to your surroundings, so, like him, you have to wear special glasses. What material(s) should these glasses be made of so that in case you unintentionally produce a beam, it is absorbed but not transmitted? Design such glasses that can also be used to see through them within some domains of the visible light spectrum. Propose the process for synthesizing the material(s). In addition, explain the mechanism behind the absorption, as well as how you would prevent damaging yourself and the people around you.

Problem 5. "Bonfireworks"

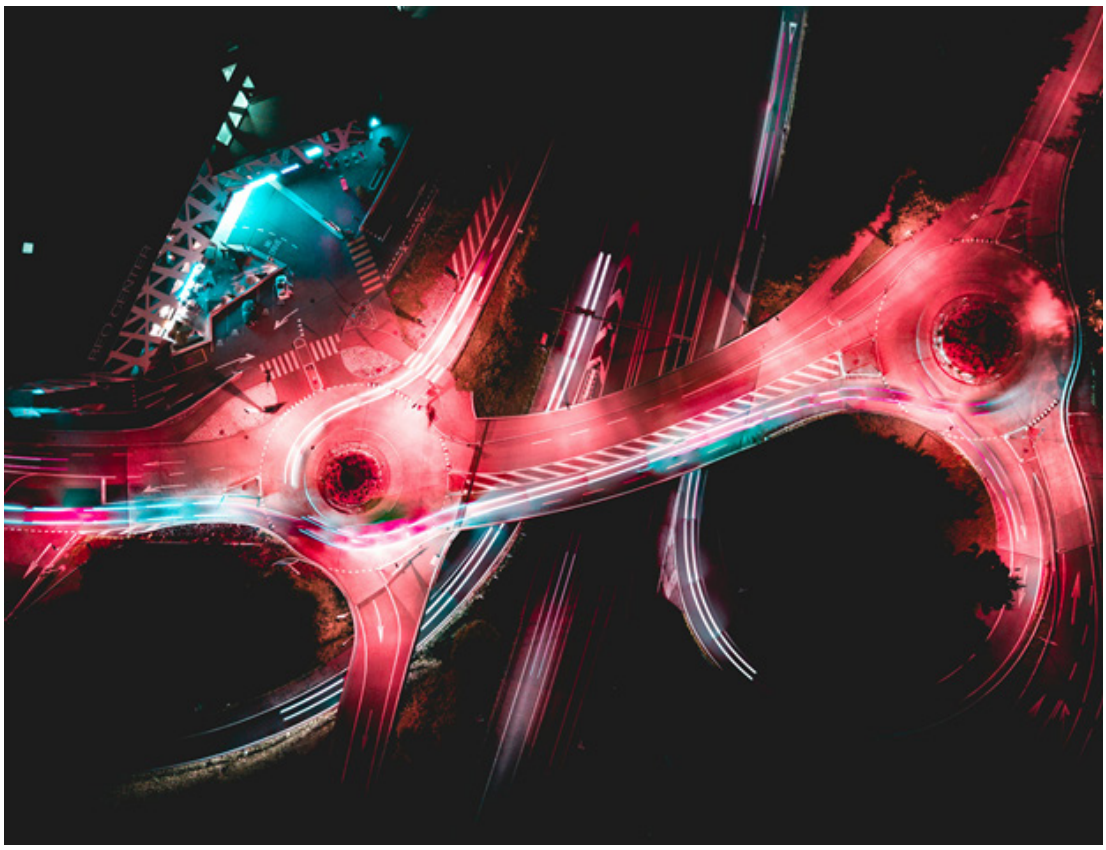
Fireworks originated from China at the end of the first millennium while bonfires are as old as humanity itself. They are used to mark special occasions, both historically as part of various traditions and folk festivities but are also quite popular even today. Despite serving a similar function there are some differences between them. While fireworks are usually colourful, awe-inspiring, loud and spectacular, the more subtle bonfires exude warmth, a sense of familiarity and community. Regardless of which form, it is no question that humans are fascinated by these magnificent displays of fire and light.

One might consider combining the two to create "bonfireworks" - a bit of the best of both worlds. Propose a method that can be used to make the flames of a traditional bonfire colourful. The materials you use must not be harmful to people observing the event, and they must not be polluting to the environment, nor can they produce substances that can leach from the remaining ash.

Problem 6. Inorganic candle

Not long-ago candles were the default choice for indoor lighting. However, limited access to bee's wax made late night reading and writing a privilege for the rich. Although kerosene lamps and electric lightbulbs made candles obsolete, candles still retain a significant cultural role. Modern candles use hydrocarbons for wax, but petroleum products are also on their way of being phased out.

Propose an inorganic compound or mixture that could function like a normal candle or spirit lamp, capable of producing a sustained flame with a wick. Your candle should not pose any danger to the user if used properly.



Problem 7. Molecular roundabout

The discovery of catenanes and rotaxanes has opened the doors towards the astonishing field of mechanically interlocked molecular architectures. Chemists have managed to control the position of a mechanically bonded ring on a dumbbell between two or even three stations. This means that we could control the position of one ring in a catenane by placing stations on the other one and the motion could be continuous. However, could we ensure a unidirectional motion? Your task is to design a catenane for which the motion of one ring could be controlled to be unidirectional and the sense of this rotation could be switched by changing the stimuli used or their order. Propose the synthesis of your compound and think of a possible application.

Problem 8. Mysterious Monasteries

The Voronet Monastery, known for its beauty as the Sistine Chapel of the East, is a gem of late medieval architecture, and is the most famous amongst the painted churches of Bucovina located in northern Romania. Inside or out, almost every square inch of the building's walls is covered with finely detailed frescoes depicting religious scenes.

One of the most striking things about the frescoes is their prominent featuring of a vibrant shade of blue. It is so characteristic to the building, that this particular shade of blue in art is known as Voronet blue. It is still somewhat a mystery how the paintwork remained in this good of a condition despite the passing of several centuries.

The blue pigment behind the colour is mainly azurite, which was not produced in the region at that time. Several locations have been proposed as the potential source of azurite, but its exact origin remains a mystery too.

Propose a non-destructive, non-invasive technique, which would be suitable for analysing the blue azurite in 'Voronet blue' to yield information about its geographical origin via its measured properties. How would the method work, what data could it potentially yield, and how would you connect your data to the potential source locations?

Problem 9. Acid or base? Beyond the pH scale

The pH scale that we commonly use is based on the equilibrium of water since it is a substance that can self-ionize. This scale is of great importance because water is a polar solvent that can dissolve a wide variety of substances, both inorganic and organic, and multiple chemical and biological phenomena occur in aqueous media. Could a different scale be developed? Propose an alternative acid-base scale based on a substance other than water. Include the autoionization reaction of the chosen substance and explain which acid-base theory best supports your proposal, specifying which chemical species would act as “acid” and “base”. Develop the new scale by doing calculations using equilibrium constants. Additionally, propose some compounds that could act as acid and bases in the solvent and the kind of reactions that could happen in this medium.

Problem 10. Kinetics of fermentation!

Alcohol has many applications in our current society: as a fuel, disinfectant, solvent, reagent in many chemical reactions, or simply as a drink. One of the more well-known methods to obtain alcohol is through fermentation, a simple yet sensible process in which a microorganism metabolizes glucose to convert it into ethanol. Fermentation has been so widely used that all the materials and reagents necessary for it are easily accessible, allowing anyone to investigate it at home.

Using only materials and equipment that can be found in a conventional house, design and execute an experiment capable of giving you information on how the fermentation process is carried out through time. Study what kind of factors influence the rate of fermentation, and how microorganisms switch between respiration and fermentation. Is there a set of optimal conditions for maximising fermentation?