



International
Chemistry
Tournament

HUNGARIAN QUALIFIERS



2027
Problem Set



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<https://www.tinyurl.org/huhto>



<https://www.kemiaitorna.mke.org.hu>



Problem 1 – Penguinone

3,4,4,5-tetramethylcyclohexa-2,5-dienone is an organic molecule, also known as penguinone, named humorously for its resemblance to a penguin. And similarly to the term 'unionized', attempting to pronounce it for the first time could reveal a lot about one's exposure to chemistry as a reading material. It's a lesser-known fact that penguins are widely distributed throughout the Southern hemisphere, with many species inhabiting temperate or even warm environments, such as the coastlines of South Africa or Australia. Nonetheless, these birds are mostly associated with the endless world of snow and ice that is Antarctica, where temperatures can regularly reach as low as $-60\text{ }^{\circ}\text{C}$.

Your task is to propose a synthetic pathway for penguinone starting from simple molecules, with the additional restriction that the temperature of the reaction mixture can never exceed $5\text{ }^{\circ}\text{C}$, keeping it cold throughout the process.



Problem 2 – Out of the Blue

The word 'bleach' generally refers to any whitening agent used to remove stains from clothing. However, most products rely on an aqueous solution of sodium hypochlorite (NaOCl) for its whitening properties. While bleach works well for brightening white items like napkins, it can be problematic if it accidentally drips onto coloured fabrics, leaving a stain by destroying the dye molecules. At the intersection of arts and science, the colour-removing effect of bleach can be harnessed to create unique, personalised designs on dark-coloured T-shirts. The final appearance of these designs depends on the fabric's base colour, as different dyes respond to bleach in varying ways.

It would be interesting to use other chemicals to modify the pigment molecules, and achieve a different colour, similarly how bleaching turns garments white. Your task is to find a chemical or mixture of chemicals that could be used to "recolour" traditionally indigo-dyed blue jeans in this way. In your solution, please explain the working mechanism and treatment conditions of your design. The final product should remain functional as a garment; your treatment must not damage the fabric beyond its utility, the colour must be permanent, and the modified fabric must be safe to wear.



Problem 3 – Titrating Taurine

Taurine is the third most common 'active' ingredient in energy drinks after caffeine and sugar. And unlike these latter two, there is little evidence regarding taurine's supposed effects on cognition and mental performance. Nonetheless, it could be found in the products of most popular brands. Interestingly, humans naturally produce taurine, similarly to many other animals like oxen, the species from which this compound was first isolated – hence the name. Interestingly, not all animal species are capable of this, for example, felines must source their taurine exclusively from their diets instead, which makes for an important consideration in cat food formulations.

Your task is to come up with a titrimetric protocol for quantifying the taurine content in energy drinks, suitable for a high school lab. In your solution, you must start out with a commercially available regular energy drink, explain any necessary pre-treatment to the beverage that you may need to conduct, your titration reaction, end-point identification, and the sensitivity of the process with regard to the concentrations typical to energy drinks.

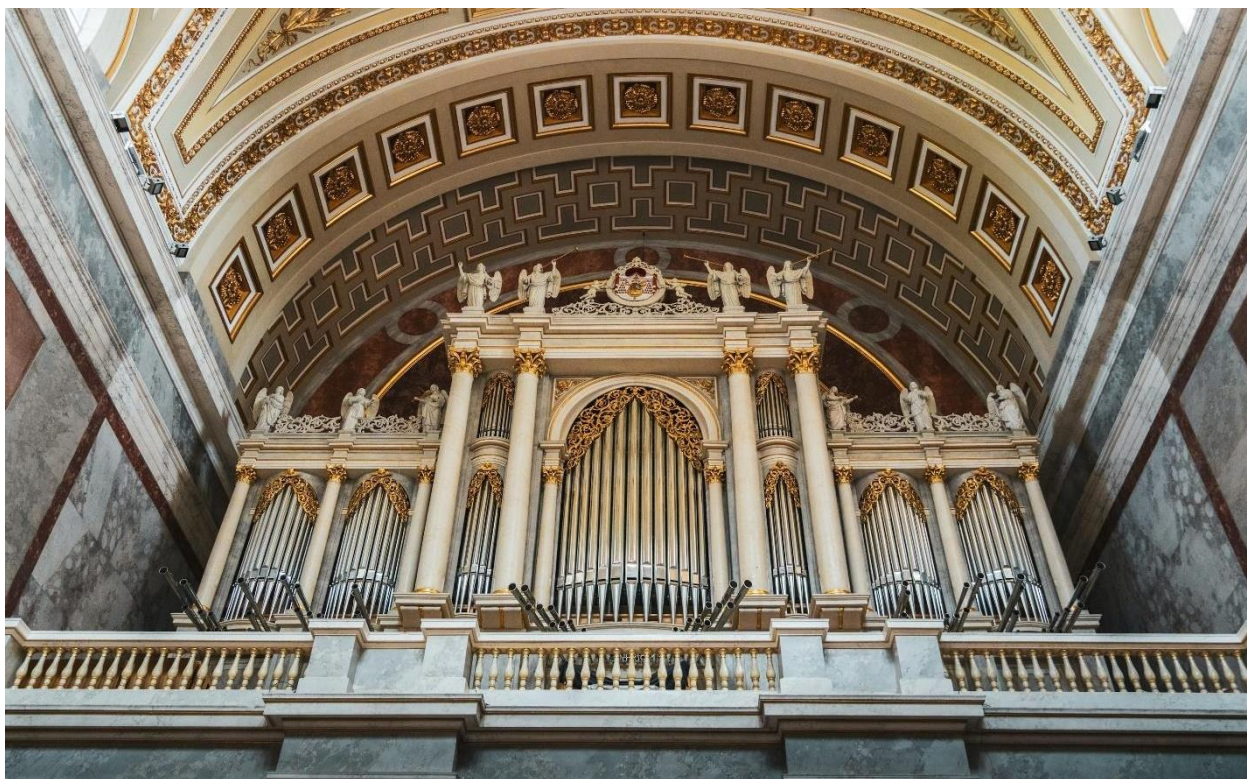


Problem 4 – Chemical Combination Lock

Combination locks are a lot like chemistry. You can only unlock a device using the correct sequence of numbers, similarly to how some serial chemical reactions can have a strictly defined order of reactant addition. The final outcome of a reaction may strongly depend on which reagent was added first, even if the same substances are eventually present.

Design a chemical ‘combination lock’ consisting of a starting system and three chemical ‘keys’, A, B, and C. The keys may represent any compound or mixture of compounds, excluding biological macromolecules. All three keys must eventually be added one at a time in a specified order to the same initial system, but only one of the six possible orders of addition should produce a unique, clearly detectable signal, such as a colour change or fluorescence. The other five orders may produce other observable changes, but it must not produce the signal characteristic of the correct sequence.

The quantities of A, B, and C added must be identical across all different sequences, and no material may be removed from the system between additions. Explain the reactions responsible for producing the signal associated with the correct sequence and identify the important intermediate products. Discuss the kinetics and thermodynamics of any potential competing reactions and estimate how reliably the correct and incorrect sequences could be distinguished.



Problem 5 – Organ Failure

Allotropy is defined as the property of elements to exist in several stable forms with different chemical structures. Well-known examples include the diamond-graphite-fullerene trio for carbon, red and white phosphorus, or molecular oxygen and ozone. A bit lesser-known example is the case of white and grey tin. These two solid forms have very different physico-chemical properties. While white tin is metallic, characterised by good malleability, grey tin is non-metallic and brittle. This presented some interesting historical problems in past centuries, related to their chemistry. The transformation of white tin to grey tin can occur at low temperatures, and objects made out of metallic tin all of a sudden became brittle and started falling apart. Most famous examples include church organ pipes, and the buttons of Napoleon's soldiers in the harsh Russian Winter. And to make matters worse, the transformation process is autocatalytic, once it starts, it slowly takes over the whole object, just like some mysterious disease. Thus, the term 'tin pest' was coined for it.

Your task is to come up with a treatment method or technology that could cause organ pipes made out of metallic tin to become more resistant against allotropic transformation, even at lower temperatures. As the pipes are already made, you must not re-cast them with some additives to the metal, your solution should work on the finished metallic product. Explain in detail how your proposed treatment would prevent the transformation via physico-chemical means.