International Chemistry Tournament

PROBLEMS SET

AUGUST 25-30, 2024
GUADALAJARA, JALISCO
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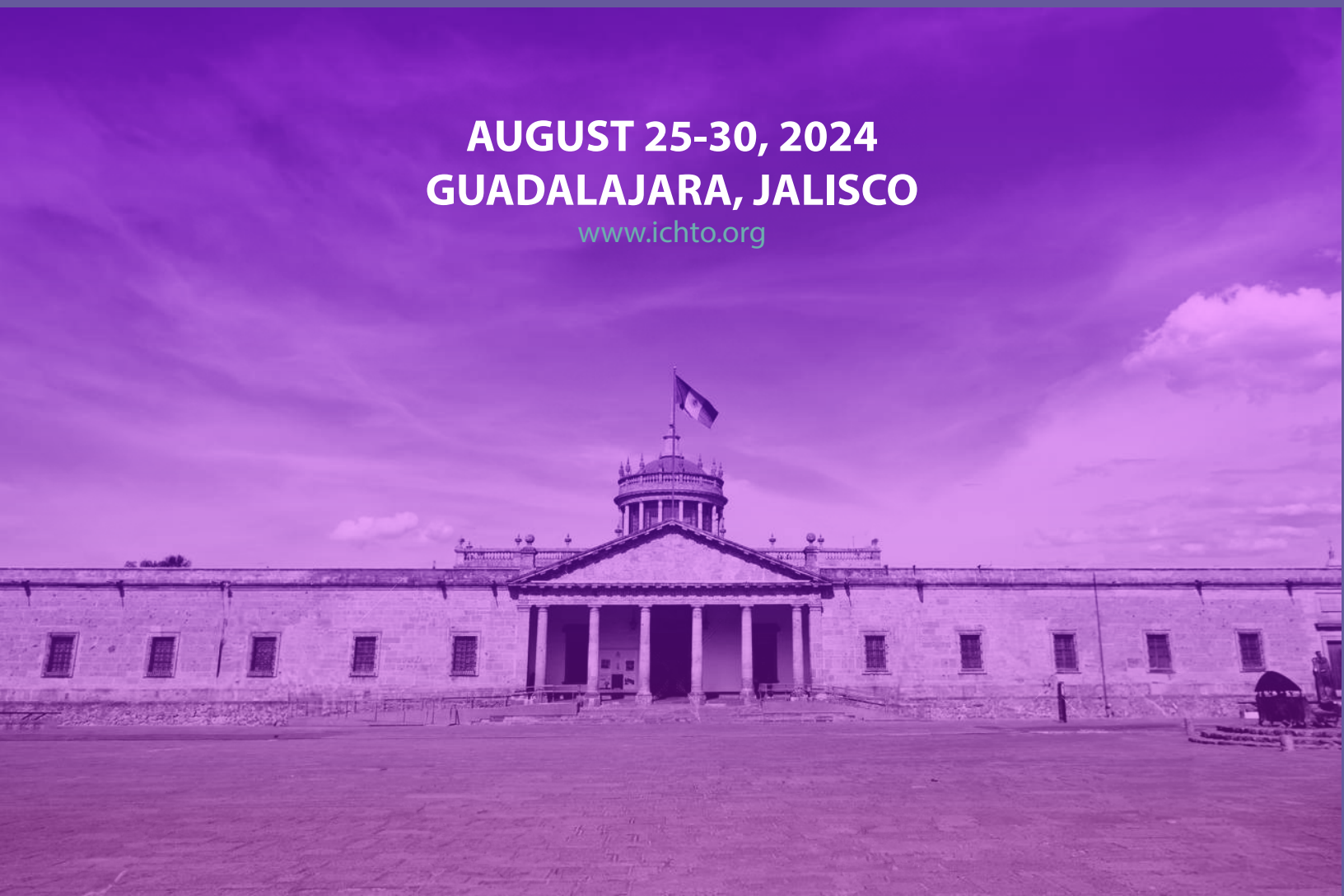

7TH INTERNATIONAL CHEMISTRY TOURNAMENT

GUADALAJARA, MEXICO
25–30 August 2024

International Chemistry Tournament

UNIVERSIDAD DE GUADALAJARA
Red Universitaria e Institución Benemérita de Jalisco

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Q-NOTE

Problem 1

Shrinking solutions

Consider aqueous solutions of inorganic salts. It is often assumed that dissolving the salt in water doesn't change the volume of solution. But as with all assumptions, it has its limitations. Most salts (like NH_4NO_3) increase the total volume of the resulting solution while others (e.g. $Al_2(SO_4)_3$) shrink the overall volume of the final solution. What is the physical limit of this shrinkage? Explain your calculations and design a salt that provides a maximal shrinking effect on water.

Problem 2

The power of boron

It is commonplace that every 'out of the box' chemistry competition and B-category science fiction features silicon-based lifeforms. However, boron has a similar or even more interesting reactivity. It can create boron-boron bonds, has multiple oxidation states, and has some 'wacky' chemistry due to the empty p orbital. Now we invite you to imagine how would chemistry look like if it was based on boron.

What would "B" organic molecules look like? Show some reaction mechanisms of such compounds. Choose a class of biomolecules, find their boron-based analogues and explain their properties.

Problem 3

Smart smoke alarm

Many of us are familiar with the dreadful situation of a smoke alarm going off in the morning, after someone burnt the toast. While this situation represents a false alarm, where no real fire or danger whatsoever was present, smoke alarms in general are highly useful devices in many buildings, notifying people to evacuate before it is too late. Ideally, smoke alarms should only be triggered by serious fires, not by minor kitchen accidents.

Design a smoke alarm which is capable of distinguishing between open fires and burnt or overcooked food on a chemical basis. It should be reasonably compact and reuseable, and should be able to make a distinction in a sufficiently quick timeframe, before a potential fire may grow out of control.

Problem 4

Roll-up material

In recent decades, the development of materials with unique molecular and supramolecular structures has been of significant interest. A variety of different chains, rings, tubes, sheets, ribbons, coils and many other interesting shapes can form, given the right starting molecule and conditions.

Suggest a material that can exist in two different structural states: one where it is formed of molecular sheets or strings, and another where it rolls up into a scroll or a spiral, without closing in on itself to make a tube/ring. The material should be able to switch between these states reversibly multiple times, given the right conditions to trigger the transition. How would the material's physical properties potentially change upon transition? Can you imagine any applications for it?

Problem 5

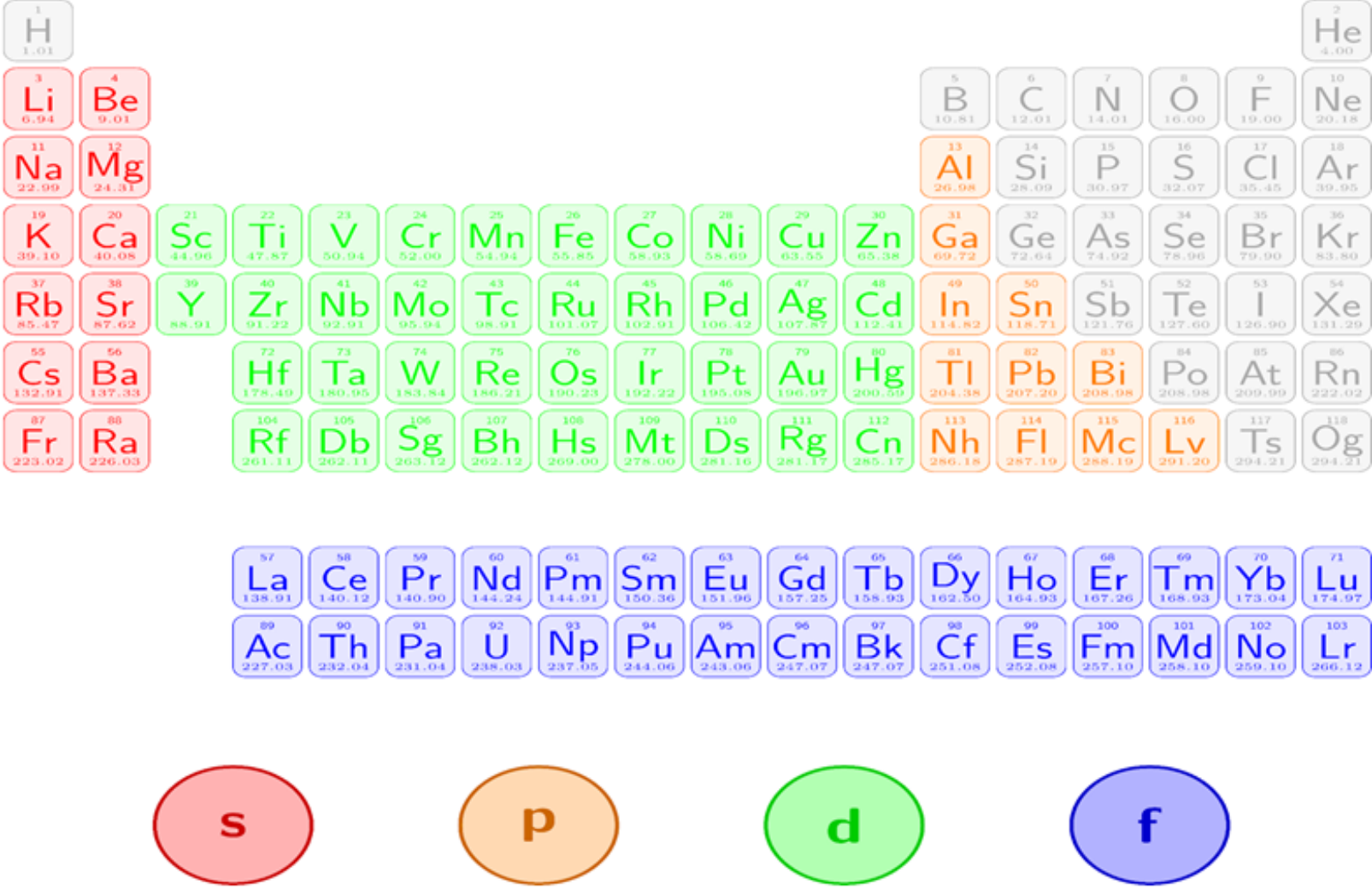
Library of Alexandria

The burning of the library of Alexandria was a great loss to both science and mankind. Many valuable papyrus scrolls have been lost forever to the flames. This could have been prevented if the scrolls were treated with something that made them fire resistant. Suggest such a treatment that could have been used back in antiquity, whilst not making the writing on the papers illegible.

Problem 6

Roadside riches

The dust of a busy highway is loaded with precious metals originating from vehicles' catalytic converters, and as traditional mines are getting depleted, their recycling has recently gained much interest. The main problem that remains is that the procedure requires handling large amounts of the material that contain the metals in relatively low concentration, thus rendering the process costly and polluting for the environment. One possible solution to this problem could be to selectively concentrate the metals on-site to localised objects or areas, thus making the recycling more effective, cheaper, and an overall better process. How would you envision this selective enrichment? What benefits would it provide compared to the traditional process? What material would you use? What metals could you obtain with it? Choose one of the metals and explain how it would fit into the overall recycling process. Do bear in mind when working on your solution, that the initial problems with the recycling process were high cost and environmental concerns, so the suggested solution must not worsen these.



Problem 7

Metals from all over the periodic table

A lot of organic molecules can act as ligands, binding to various metal ions. It is relatively easy to obtain a complex containing one metal ion, but the synthesis of a complex containing two different metal ions might be more challenging.

Your task is to design the synthesis of a complex (isolable in pure form) containing one metal ion from each block of elements – s, p, d and f (four metal ions in total, all bound to one ligand). You should explain how the complex containing four different metal ions is favored over complexes containing two or more identical metal ions (for example, two d-block metal ions and no f-block metal ion).

Problem 8

Keeping tortillas safe from frying

It is well known that the process of frying lowers the nutritional value of foods. However, we must admit that the flavor, aromas, and colors obtained as products of the Maillard reaction are really attractive. We wish there was a way to avoid the use of oil to not lower the nutritional value and high temperatures are also desirable to avoid to keep as many nutrients intact as possible. Luckily for us, the Mailliard reaction also occurs at room temperature, but slowly.

Propose the best catalyst to accelerate the Maillard reaction in tortillas and obtain edible tortilla chips as quickly as possible while maintaining the nutritional values as intact as possible, avoiding the use of oil and high temperatures.

Problem 9

Homebrew

Alcoholic beverages, such as beer, wine, spirits and cocktails and widely consumed drinks, and are enjoyed both for their flavor and their alcohol content. However, some people would prefer them without alcohol, and for this reason several non-alcoholic alternatives of them exist. Some are produced without alcohol in the first place, while others get de-alcoholised using different methods. Getting rid of the alcohol itself is not a tough task for the food industry, but could you do something similar at home, without the use of specialised equipment?

Suggest a procedure which could be used to substantially lower the alcohol content of a drink of your choice, without drastically altering the flavor and composition of it. The process should not utilise any tools other than those found in a well-equipped kitchen, although you can make use of any chemical compound you want.

Problem 10

Doublelectron Universe

Although there might be some physical limitations, one can imagine a fictitious universe which is similar to our own, with all the standard model particles, but having one small change: having leptons with double the amount of charge. How will that affect Chemistry? Will there be any atoms or molecules in such a Universe? Compose a Periodic table for such a magical world.

Problem 11

Wetlands dilemma

Wetlands are defined as environments where soils are covered by water either periodically or permanently. They include a variety of habitats such as marshes, swamps, floodplains and peat bogs. Awareness of these areas is growing not only due to biodiversity conservation efforts, but also because they emit a massive amount of methane into the air. Methane is quite a potent greenhouse gas, which accounted for about 30% of the temperature rise in recent centuries. Therefore, it is of great importance to understand the mechanisms by which methane gets into the atmosphere.

Explain why so much methane is generated in the wetlands, and suggest possible intervention measures that could reduce the net emissions of these environments. Solutions should be feasible to conduct on a large scale and should minimise the additional emissions produced and damage done to wetland ecosystems.

Problem 12

Reinventing corn

In the movie Interstellar, corn has almost become the only product that can be used to feed humankind. However, diets based on corn tend to produce pellagra which is the lack of niacin in the body. The existing niacin in corn is bound to complex carbohydrates and small peptides, which makes it unavailable for absorption in the body. Also, corn has leucine, which interferes with the conversion of tryptophan to niacin. The ancient Mexican civilizations created a method called nixtamalization which freed niacin and gave corn other properties. However, the movie occurs in an apocalyptic world and we will suppose that such a process was impossible for them or simply did not have the effect.

Your task is to create another chemical technique that could have been used in the movie. This method must also give an edible product that can raise the levels of niacin in the body but must not have an alkaline cooking step while maintaining its nutritional characteristics.