Program outline for the

Interactive chemistry summer school by Imperial College London graduates 2025

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1 Aim

Our aim is to provide a quality one week learning experience to Slovenian students. Since we have studied at Imperial, we aspire to provide an insight into teaching at this world-class institution. We have constructed a curriculum based on our experience that we believe is both interesting and useful. We hope to invoke appreciation of the advances that have been made in science so far and encourage participants to contribute in their own way.

2 Structure

The emphasis of the summer school is on hands-on experience, delivered through five comprehensive labs, each focusing on a different branch of chemistry. The *Computational lab* is an introduction to molecular simulation and presents molecular dynamics simulation, lays down its foundations and discusses its role in the context of drug discovery. *Chemical kitchen lab* is a novel concept in teaching that was recently introduced at Imperial College London and numerous other universities. It aims to teach relevant practical skills that are needed in a laboratory setting using harmless ingredients we all known from our daily lives. *Chemical kinetics lab* focuses on studying a chemical reaction using conductivity to decipher the reaction mechanism and strongly emphasises data analysis. *Build your own spectrometer* is a lab focusing on the construction of a simple spectrometer that is used to validate the Beer-Lambert law and discuss its shortcomings. Arguably the most conventional lab is the *Synthesis lab*, wherein a number of compounds are synthesized, and the underlying chemistry discussed. Each lab includes an introductory theoretical background lecture to equip the students with the required knowledge needed for successfully completing the lab. In addition to the labs, this summer school includes so-called *Keynote lectures*, whose purpose is to introduce an interesting topic, discuss best practices, etc. Speakers are from academia and industry.

* The program structure could be subject to change.

3 Labs

3.1 Computational

The ideal gas equation, $PV = nRT$, is part of any high school chemistry curriculum. But what does it mean exactly? And how did scientists come up with its functional form? The ideal gas law combines the empirical Boyle's, Charles', Avogadro's and Gay-Lussac's laws. Interestingly, the same conclusions can be reached from purely theoretical considerations. In this lab, we will look at these laws in more detail and consider the assumptions that are made in deriving the ideal gas law. Furthermore, we will account for some deviations from "ideal" behaviour and derive the van der Waals equation.

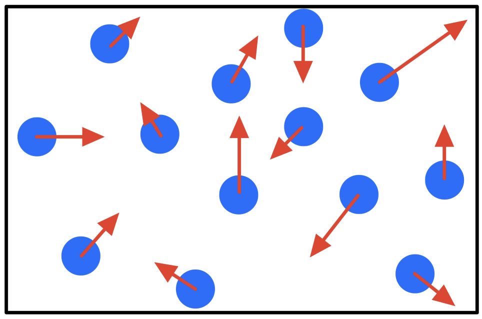

Figure 1: Schematic of a 2D ideal gas simulation.

A program to simulate a 2D gas is provided. Essentially, it is a simple molecular dynamics simulation engine that can be used to assess the validity of the assumptions made in the ideal gas Statistical mechanical properties will be extracted from the simulation and compared with theoretical predictions.

3.2 Chemical kitchen

Chemistry is truly an expansive realm. From the fascinating world of atoms to delicious food and life-saving drugs and all the way to the essence of life, chemistry is quite literally a way of life and a way of thinking. In this fun activity, we will utilize its power to process common raw ingredients and convert them into food. We will explore the properties of complex substances such as gelatine, natural gums, egg yolks, and more, and we will have the opportunity to fashion them into modern garnishes. How does milk turn into cheese and what happens down to the molecular level? What about frying or boiling eggs? Why do apples and bananas turn brown, and why do we throw them away? How does that compare with potatoes turning brown when baked? These are some of the questions we will be tackling throughout this hands-on chemical kitchen.

More often than not, people tend to forget chemistry is our ally in the kitchen, too, even though it may seem otherwise when we accidentally toast a slice of bread into charcoal or when we overheat anything. Regardless, chemistry is arguably the best utensil a chef has, and, as we will see, we can explain all these day-to-day experiences by resorting to the concept of chemical changes. More broadly, this chemical kitchen is designed to give you not only a gentle introduction to chemistry, but to teach you the skills and the mentality of a professional chemist, and by the end of it, you will have a greater appreciation of what chemistry can do for you, and you will acquire transferable skills that will surely serve you well in your future endeavours.

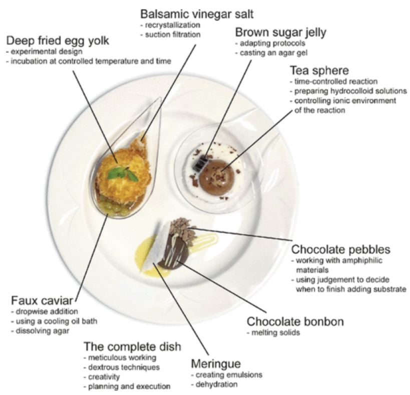

Figure 2: An example of a chemical kitchen experiment. Image credit: Radzikowski *et al.* *J. Chem. Educ.* 2021, **98**, 3, 710–713.

3.3 Chemical kinetics

Kinetics is a branch of chemistry concerned with how quickly chemical reactions occur and is crucial for developing new catalysts and for optimizing reactions in chemical industry and academia. In kinetic experiments, the reaction progress is monitored over time for example by UV-Vis or IR spectroscopy to generate data which can be analyzed to elucidate the reaction mechanism and evaluate rate constants.

In this kinetics laboratory experiment, we will investigate the classical S_N1 reaction in which an electrophile ionizes to give a halide ion as well as a carbocation which then reacts with the protic solvent to give an alcohol or an ether product. Since the reaction generates acid, the progress of the reaction will be measured by conductivity. A significant part of the lab will be dedicate to data analysis and result visualization in Python adjusted to the students' prior knowledge. This interactive experiment will give you the chance to explore how the solvent and temperature determine the rate of the reaction and is open for you to pursue your own ideas and curiosity.

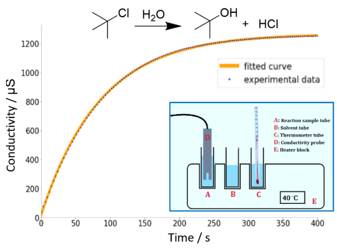

Figure 3: An example data gathering to elucidate the reaction mechanism.

3.4 Build your own spectrometer

Spectroscopic experiments are a powerful tool that can help elucidate the structure and function of various chemical species. While spectroscopic instruments are generally complicated and consist of a multitude of parts, a relatively accurate UV-Vis spectrometer can be constructed using simple equipment.

In this lab, a UV-Vis spectrometer will be built and used to study the absorbance of methylene blue as a function of concentration. In line with the other experiments and one of the overarching principles of this summer school, we will discover the range of conditions where the Beer-Lambert law is valid and discuss where the deviations arrive from.

Figure 4: A simple UV-Vis spectrometer.

3.5 Synthesis

Organic synthesis stands as the cornerstone of numerous industries, wielding immense significance particularly in pharmaceuticals, cosmetics, and chemical sectors. Within these domains, the creation of novel organic compounds holds the key to innovation, product development, and the pursuit of solutions to pressing challenges.

In the pharmaceutical industry, organic synthesis plays a pivotal role in the development of life-saving drugs and therapies. Chemists meticulously design and craft organic molecules to target specific biological pathways, combat diseases in the quest of alleviating human suffering. Whether it is the synthesis of complex active pharmaceutical ingredients (APIs) or the creation of simpler building blocks, organic chemistry laboratories serve as the birthplace of countless medicinal breakthroughs.

As we embark on our journey into the realm of organic chemistry laboratories, we embrace the fundamental principles and techniques that underpin organic synthesis. Through hands-on experimentation, we dive into the art and science of making molecules, culminating in the synthesis of simple products like poly-aromatic compounds, in conjunction with the appropriate methods of laboratory characterization. These laboratories serve as the fertile ground where theory meets practice, equipping students with the confidence and the skills needed to take any challenge head-on in the future.

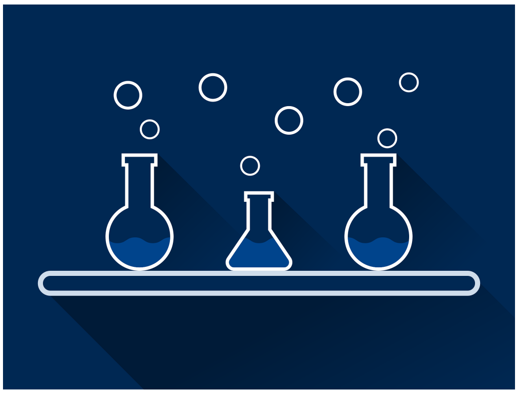

Figure 5: Chemical synthesis.

4 Keynote lectures

A number of *Keynote lectures* will be given by mentors as well as external speakers, from industry and academia, spanning chemistry, biotechnology and medicine.