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P-56

Space Chemistry Realization via SpaceMedChem

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1. Introduction

Presently two kinds of SpaceMedChem experimentations are available for human mankind. The International Space Station (ISS) allows direct human manipulation of the experimental materials or remote controlled instruments, that are satellites without human presence. Important components of the experimentation are initiating the experiments on the Earth, delivering them to satellites and then returning from the space.

2. International Space Station (ISS)

International Space Station (ISS) offers place for permanent chemical laboratories in space. These labs can be internal (on board) or external, the instruments are fully or semi automatized and mostly miniaturized. Since the ISS has limited space and laboratory staff formulation experiments need unique, state of the art equipments. A considerable example is the ICE Cubes platform,[1] which maintains and operates the crystallization and formulation process including the KIRARA cube[2]. It allows 100 individual experiments in 10 ×10 × 10 cm (so-called 1 U (unit)). The driving force of the crystal growth is the counter diffusion.

The external platforms of ISS are well-suitable for the stability investigation. Since no medicines survive in space longer than a year[3], novel formulation and packaging methods need to be developed and tested before the long-term space flights. Hessel and co-workers investigated the stability and the solar irradiation sending ibuprofen tablets to the external and internal platforms of the ISS [4] Beside the irradiation the permanent low temperature (-157 °C on the shady side) could also affect the experimental results.

Unfortunately, ISS is not a new construction. It can be operated safely until 2028-30 then space chemists need to find alternative ways to do they experiments.

3. Experiments on automatized/remote controlled satellites

Besides the ISS, satellites are also ideal platforms for chemistry and formulation studies in space. From a practical point of view two types of them can be distinguished: a) single use satellites, which never return to Earth; b) reusable ones for multiple missions.

For single use satellites the DIDO type (SpaceP-harma) miniaturized laboratories can be good examples.[5] This equipment can perform various lab-on-a-chip experiments such as crystallization, and enzymatic reactions.

The challenging opportunity to use unmanned, remote controlled and reusable satellites for space chemical experiments such as the Space RIDER[6] uncrewed robotic laboratory. Using novel flow chemistry methods we successfully developed an automatized reactor system, which will be able to carry out the synthesis of various active pharmaceutical ingredients (APIs). The reactor coupled with a complex in-line analytical tool enabling real time reaction monitoring. Using artificial intelligence-based quality control the system will be able to perform reaction optimization in space in order to produce as pure API as required for the pharmaceutical industry.

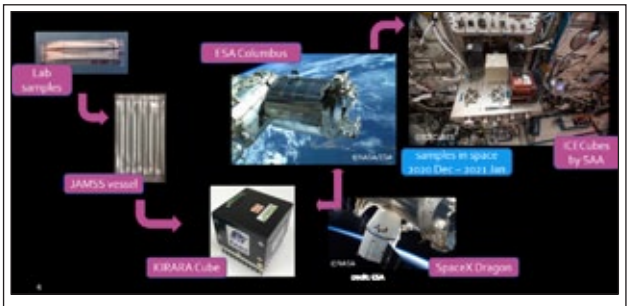

Figure 1 *A ground-space-ground formulation experiment pathway*

4. Route to the space and backwards

The most important experimental pathway from Earth to space, and space to Earth is shown in ***Figure 1***. In case of the anti-COVID experiments[7] it has started with lab experiment with sample preparation at the laboratories of the Cyclolab in Budapest with participation of Innostudio in 2020. Two identical sets of samples were prepared. The samples were delivered to Tokyo to the laboratory of JAMSS[2]when they inserted the samples to two identical sets of experimental vessels. The vessel were delivered to Europe Nordwijk hook (NL) to the center of the Space Applications Services Inc., where they packaged it to the ICE Cubes space experiment holding blocks (KIRARA cube on ***Figure 1***). The KIRARA cube was delivered by a flight to the launch station in Florida, where it was packed to SpaceX 19 rocket and sent to ESA ISS. The European Space Agency (ESA) provided working space (In ***Figure 1*** the ESA's space workspaces is demonstrated, together with KIRARA cube, where the chemical and physical transformations were performed[7]. After finishing the experimentations, the same route was provided to get back the samples for processing by Cyclolab[8] and Innostudio[9]. The control samples were kept on Earth[7].

5. Conclusions

Realization of medicinal chemistry experimentation needs one the widest collaborations of the human mankind including pharmaceutical research partners, several institutions servicing the space industry, furthermore owners of the satellites. The unpaved routes taken by the pioneers of space medicinal chemistry promise, on the other hand, unexpected and important results for those ones who are willing to take challenges and risks.

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