JAMES DYSON FOUNDATION UNDERGRADUATE BURSARY – OUTREACH ACTIVITY

Development of a miniature water CPC

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Introduction

My project focused on the development of a new aerosol measurement instrument which has the potential to improve the monitoring of local air quality. A temperature gradient along the device creates a region of supersaturation, prompting water vapour to condense on the surface of particles as small as a few nanometres. Condensational growth finally yields droplets measuring a few micrometres in diameter, which are detectable by optical means. The outreach activity was therefore designed to deepen the students' knowledge on the topic of condensation. The activity was planned in three parts: first, the students were given an online quiz, introducing the topic of the experiment which was carried out next; finally, a physical explanation of the results of the experiment was given, with reference to practical applications of these concepts, including my final year project.

Part I: introductory quiz

The students were asked to take part in a live quiz hosted on a website: the questions and possible answers were shown on the screen and each student joined individually, submitting answers from their laptop. The quiz was timed and the leaderboard showing the top performers appeared after each question, engaging the students.

The quiz started from familiar concepts, such as the changes of state of matter, and gradually built up to more advanced questions. A brief explanation of some phenomena caused by condensation (e.g., clouds) was given following the questions. The quiz ended with a "food-for-thought" slide, asking the students to think about how a plastic bottle could be use to form a small, contained cloud.

Part II: cloud-in-a-bottle experiment

This is a simple experiment requiring readily available materials:

- Empty (colourless) plastic bottles with caps;
- Some water
- Matches

The students were asked to work in pairs and carried out the experiment in two steps. At first, the students were asked to fill the bottles with water to about half, screw the cap on tightly, give the bottle a shake and wait for a minute. They were then prompted to squeeze and release the bottle a few times. Probably to no surprise, the students observed that nothing was happening.

The more interesting part of the experiment involved using the matches. Again working in pairs, the students were asked to loosen the cap on the bottle, without removing it. One student then had to light up a match and drop it (still lit) in the bottle, while the other person in the pair removed the cap from the bottle and quickly screw it back on tightly. Again, the students were prompted to squeeze and release the bottle a few times. In this case, the air at the top of the bottle became cloudy.

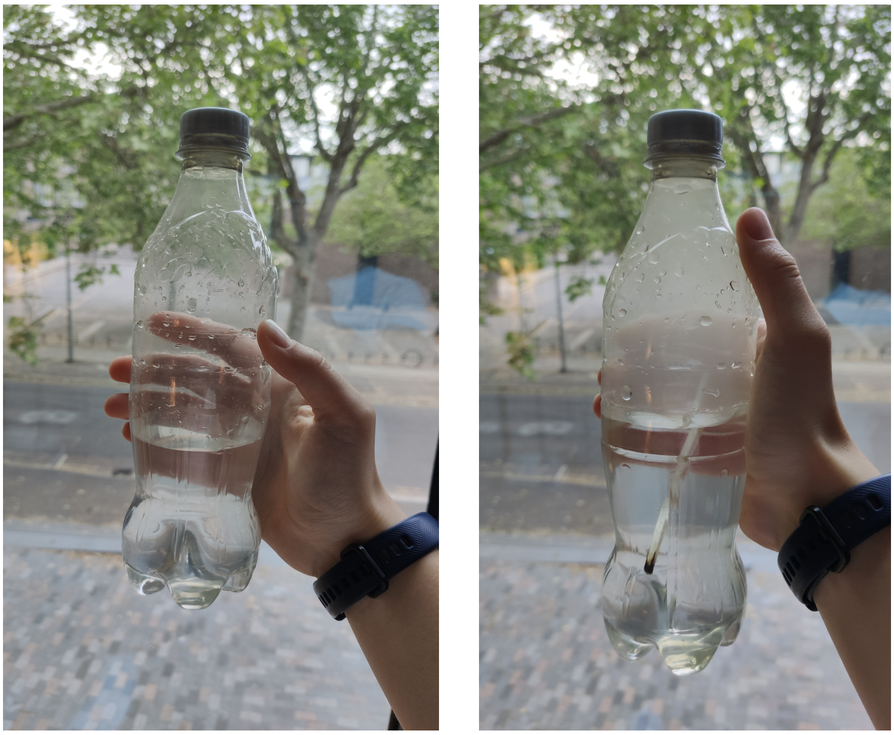

Figure 1: Results of the experiment: nothing happens in the bottle before adding the match (left); the air in the bottle becomes cloudy upon squeezing and releasing after the match has been dropped (right).

A video showing the experiment and a brief explanation can also be found at the following link: `https://www.youtube.com/watch?v=G70y90BVes4`.

Part III: explanation of the results and practical applications

The formation of the "cloud" in the bottle was explained by introducing the students to more advanced concepts in condensation.

Saturation, homogeneous condensation, and heterogeneous condensation were described in simple terms through a PowerPoint presentation. These concepts were then used to justify the formation of small droplets (a "cloud") in the air trapped in the bottle: upon adiabatic expansion, the presence of small particles released in the air by the burning match enabled heterogeneous condensation of the water vapour, due to the lower energy required for the phase transition.

A few words were spent at the end giving an overview of how controlled condensation on airborne particles is used to monitor air quality. The students were introduced to the idea that health-threatening particles in the nanometre range (e.g., soot and viruses), can be grown to an optically detectable size using condensation, thus allowing them to be detected and their concentration to be monitored.

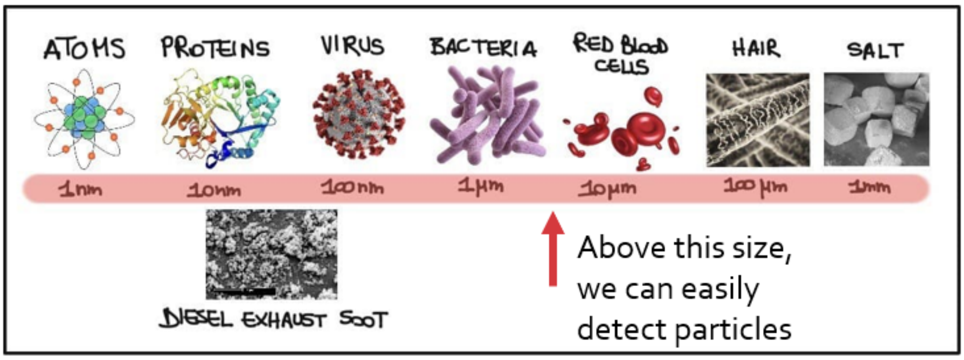

Figure 2: Typical dimensions of a range of particles and optical detection limit.

Retrospective and risk assessment

The students were eager to engage in the online quiz and seemed curious about the quick science experiment, with some being surprised to discover that it is indeed possible to make a "cloud" at home.

The interactive activities (both the quiz and the experiment) took a bit longer than anticipated: this was due to the slowed-down internet connection at the school during the quiz, as well as to the moving around and set-up of the experiment (the smoke alarm had to be adjusted before matches could be used).

As the students had laptops on their desks, they were moved to the end of the room to perform the experiment, such that it was difficult to keep track of the progress and to attract their attention. However, the activity was still successful, and a pre-recorded video of the cloud forming in the bottle had been included in the slides for those students who did not manage to complete the experiment first-hand.

The risks entailed by this activity were correctly managed: water and flames were kept away from the laptops, and the students worked in pairs during the experiment to mitigate the hazards involved in dropping the lit match into the bottle.