Brown Ring Experiment in Virtual Reality

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Abstract—Brown Ring Experiment is a very popular test to detect the presence of Nitrate in salts commonly performed in chemical laboratories with supplies of required chemicals. Our work clears out the need for a chemical laboratory and chemicals in order to understand the experiment practically. We have used the technology of Virtual Reality to fulfil this requirement. Our research work can be extensively utilised to create virtual environments for conducting other chemical processes in a virtual environment hence, eliminating the need for a chemical laboratory. This can help students in remote areas with minimal resources to fill in the void of practical experiments they have in their learning process due to space constraints.

Index Terms— Virtual worlds, virtual environments, unity3d, HTC Vive, Education, Chemistry, Virtual Reality

INTRODUCTION

There is a considerable crunch in the availability of Chemical laboratories in remote parts. So, students lack the resources to gain practical knowledge of the concepts they learn in class. So, our initiative is to provide that practical experience using virtual reality so that students don't require the presence of an actual chemical laboratory to gain practical knowledge. For demonstrating this, we have taken up a very popular chemical experiment to detect the presence of Nitrate in salts called Brown Ring Experiment.

To start with, let's see what wikipedia has to say about the Brown Ring Experiment. Wikipedia says, A common nitrate test, known as the **brown ring test**[1] can be performed by adding iron(II) sulfate to a solution of a nitrate, then slowly adding concentrated sulfuric acid such that the acid forms a layer below the aqueous solution. A brown ring will form at the junction of the two layers, indicating the presence of the nitrate ion.[2] Note that the presence of nitrite ions will interfere with this test.[3].

The overall reaction is the reduction of the nitrate ion by iron(II) which is oxidised to iron(III) and formation of a nitrosonium complex where nitric oxide is reduced to NO^{+}.[4]

$2HNO_3 + 3H_2SO_4 + 6FeSO_4 \text{--->>} 3Fe_2(SO_4)_3 + 2NO + 4H_2O$
$(\text{Remaining})[Fe(H_2O)_6]SO_4 + NO = [Fe(H_2O)_5(NO)]SO_4 + H_2O$

This test is sensitive up to 2.5 micrograms and a concentration of 1 in 25,000 parts.[5]

This article will demonstrate a way to set up equipments and chemicals needed to conduct this experiment on to a scene in the virtual environment and the user can conduct the experiment by picking up stuff and dropping them according the demands of the experiment.

RELATED WORK

In 2006, Kerawalla, Luckin, Seljeflot & Woolard[6] have suggested four design requirements that need to be considered for AR to be successfully adopted into classroom practice in the future. These requirements according to the authors are: Flexible content that teachers can adapt to the needs of their children; guided. exploration so learning opportunities can be maximized in a limited time; and attention to the needs of institutional and curricular requirements. In 2013, a paper by P. Maier and G. Klinker[7] also used Augmented Reality to support Chemistry students in learning and researchers in developing and understanding new chemical molecular structures and their spatial relations.

METHOD

Our method comprises carrying out chemical experiments by mixing virtual chemicals. We use VR device controllers to move the equipments, containing chemicals in chemistry lab. In this experiment we have glass bottles comprising the Ferrous Sulphate solution, Sulphuric acid and Nitrate solution. The glass bottle consisting of Ferrous Sulphate is picked using the HTC Vive controller and its contents are passed into the test-tube by tilting the glass bottle above the mouth of the test tube. Then we add the Nitrate solution (salt) the same way. After this, the dropper is picked up with the controller and placed inside the glass bottle containing Sulphuric acid. Small quantity of Sulphuric acid is sucked in by the dropper. This is later dropped into the same test tube through the sides of the test tube. On contact with the Sulphuric acid particles, the mixture undergoes a chemical reaction and a thin brown ring is formed around the test-tube slightly above the middle point of the solution.

IMPLEMENTATION DETAILS

The liquid particles were simulated via transparent spheres. Models for the experiment were designed by ourselves using the 3D modelling/sculpting software Maya. The table upon which the experiments are setup is downloaded for free from free3d.com[8]. The glass bottles had a mesh collider in the inside to prevent the particles from falling through. Each of the particles had their own sphere collider attached to themselves and hence, they were stuck within the mesh. It was also required to have a collider for the HTC Vive controller to grab onto. This was achieved by creating an empty

Fig 1. Glass bottles with Chemicals

object collider as a sibling to the original glass bottle. They are then given a common parent and this parent gets attached to the controller when the controller grabs the collider. This way we can grab and move the entire bottle and its contents towards the test tube[9] or any other position desired.

The test tube contains a collider on the inside that would prevent the objects from moving out of it once fallen inside so they are not impacted by the movement of the object they have fallen from. While the particles are being transferred from the glass bottle into the test tube, we are changing the parent of the particle from the glass bottle to the test tube to attain that functionality. This is done only for the particles that have fallen into the test tube. During the pouring process, we calculate the distance between the particle and the test tube and the glass bottle. If the test tube is within a threshold, then the test tube becomes the parent of the particle. The same check is performed between the particle and the glass bottle. If there are particles that are outside the threshold for both of them, then those are the particles that must've slipped though the edges of the test-tube while pouring. For such particles we set their parent to be null.

The dropper pipette is designed to have particle attractor in the interior that gets activated only upon pressing the dropper's bulb at the top. For this we have invisible plane at the mouth of the dropper that open and closes upon the press of a button. Once this plane is open, the contents inside the dropper falls out due to gravity. They then become the child of the object they are falling into. If they fall on the ground, their parent becomes null. Once inside a glass bottle, we open the mouth of the dropper and enable suction of the particles by transforming the particles into the magnet that is contained inside the dropper

The mouth closes when sufficient number of particles goes in. The particles that are transferred into the dropper, then drops towards the mouth of the dropper and stays there until the mouth is opened.

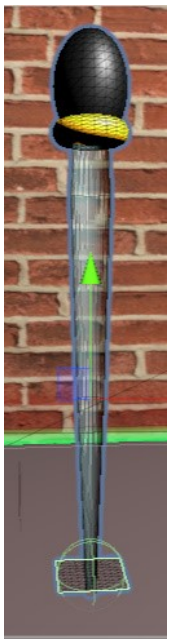

Fig. 2 Dropper Pipette

Once the contents inside the dropper pipette is dropped into the test tube, the reaction commences. A brown ring is formed inside the test tube about 4/5th of the way from the bottom of the test tube. This is accomplished by first figuring out the total height of the particles inside the test tube along the axis of the test tube and dividing them into 5 and picking the 4th layer. We then colour all the particles in this layer that are closer to the test tube. One thing that has to be maintained is the order of the chemicals when added to the test-tube. At first iron sulphate must go in, followed by salt solution and lastly the concentrated sulphuric acid is to be added by the dropper through the sides to see the results.

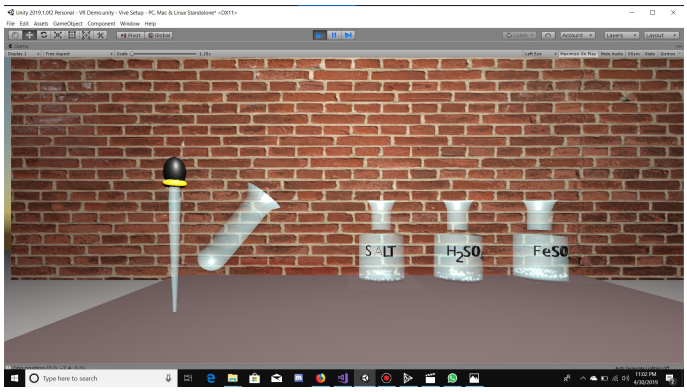

Fig. 3 - Full Scene

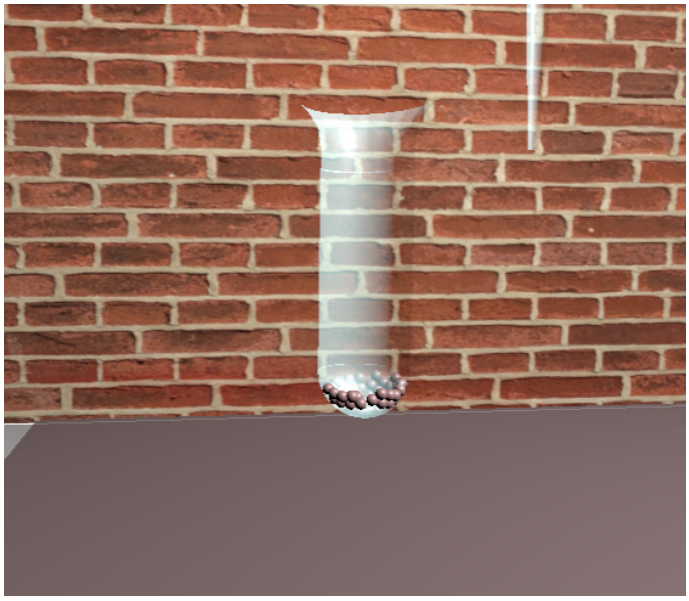

Fig 4. Final Result - Brown Ring Formation

RESULT

The experiment was completed successfully except for the functioning of the controller. When the glass bottles are moved fast, the contents inside sometimes tend to fall off. This happens only when the controller is used. However, this cannot be reproduced if the glass bottles are moved using keyboard controls.

Another issue associated with the same bug is that once a particle. move outside the glass bottle, it stays there indefinitely.

DISCUSSION

We have demonstrated here that you can perform chemical experiments in a virtual reality environment successfully. Further

experiments can be conducted by adding new scenes and creating a user control on which experiment the user want. //TODO.

The boundaries of this observation is not limited to Chemistry alone and can be used to successfully conduct experiments in other subjects also.

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