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THE CHEMICAL THEATRE - EDUCATION, ENTERTAINMENT

TEATR CHEMICZNY - EDUKACJA, ROZRYWKA

Abstract: Seven simple demonstration experiments are described in this article, which can be used by teachers of chemistry for a wide variety of audiences. In addition to detailed instructions for each experiment, important background information is given, thus enabling the demonstrations to become part of a profound learning experience, which is the primary aim of the chemical theatre.

Keywords: experiment, learning by experiment, chemical theatre

Every chemical demonstration constitutes a chemical theatre. It is a unique teaching medium, since chemical changes are often accompanied by spectacular and surprising visual effects. These effects are numerous and varied, and teachers have thus been able to draw on a wide repertoire of material to enhance their lessons. Indeed, so remarkable are many of these processes, that they can be used to form the basis of magic shows. In his celebrated book *Chemical Magic*, Johnson [1] has described not only a wide variety of most interesting experiments, but he has also given first class examples of how to mislead the audience, which of course is the object of magic shows! There is a certain moral justification for an odd "tall story" during a science lesson, since this serves to stimulate an audience reaction: an air of suspense, doubt, mystery and incredulity is a fundamental prerequisite for a wholesome educational experience.

The following story is based on an actual event, in which the lead actor - the "Magic Medicine Man" used the chemical theatre to fraudulently extract money from members of the audience. The present author was there (for several performances!) and it was as a result of the experience, that his lifelong passion for chemistry was ignited.

"When I was 10 years old, I lived in West London, in Shepherd's Bush. Every Saturday afternoon, I used to go to Shepherd's Bush Market, to see what people were selling, buying, or throwing away. This is because frequently among other people's rubbish, I could find something useful. However, there was a certain strange man at the market every Saturday afternoon, who was selling medicine. It came in the form of purple tablets, and the man claimed that it could cure any disease. Be it a painful muscle, a headache, toothache, neuralgia or even nostalgia - this medicine would cure all of them. The reason why his

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medicine was supposedly better that many others was that, unlike other medicines which contain ACID (and everyone knows that acids BURN), his medicine did not contain any acid, so it could NOT BURN. To prove his point, he had some examples: Seidlitz Powders (used to cure constipation) contain tartaric acid - "acids BURN!", he would shout. Andrews Liver salts (used for indigestion) contain citric acid. "Acids BURN!", he would scream. Finally he showed some aspirin tablets. These contain acetyl salicylic acid. To prove his point about burning, he placed a couple of aspirins on some shiny crystals on a tin lid, and added some cough syrup (containing glycerol) and water. Within a few seconds the whole mass burst into flames, thus showing in a convincing manner, that acids can BURN your stomachs.

This spectacular demonstration achieved the desired effect: members of the audience delved deep into their pockets for half a crown, and purchased the tablets.

As a ten year old, I was very fortunate however, for I was never ill and I had no money. Thus I had no interest in his medicine. However, since a very early age, I had developed a secret and passionate obsession with fire, and even though my parents had bought me a chemistry set when I was 8 years old, I had never managed to make fire, like the "medicine" man at the market. So it became my great ambition to try and repeat the experiment at home. With appropriate research (*ie* reading a book on "Chemical Magic" which I borrowed from the library), I discovered the identity of the unknown crystals (potassium permanganate) and thus, to my great surprise and delight, I was able to repeat the experiment at home. My passion for chemistry has continued to evolve ever since that historic day in 1960."

This story also illustrates how, by a most unlikely set of circumstances, a profound and long lasting effect was achieved.

Below are given instructions for carrying out 7 chemical demonstrations, which employ simple apparatus, and readily available reagents.

It is the responsibility of the demonstrator to carry out an appropriate risk assessment for all experiments.

Experiment 1. Spontaneous combustion [2]

Aim: To demonstrate an example of a spontaneous chemical reaction. **Apparatus/reagents**: fireproof mat, aspirin tablets, potassium permanganate, glycerol, spatula, water.

Method: Two aspirin tablets are placed into an indentation in a small pile (about 25 grams) of potassium permanganate crystals. About 5 cm^3 of glycerol ("cough syrup") is poured onto the aspirins, followed by a few drops of water from a drink bottle.

Observations: After about 15 seconds the mixture begins to smoulder, and then bursts into flame. The flame burns for about 15 seconds.

Experiment 2. Reversible colour changes

Aim: To show that colour changes frequently occur in chemical reactions. This is linked to the most important idea that: "**Chemistry is the science of substances and how they change into different substances**".

Apparatus/reagents: Five 250 cm^3 conical flasks, 5M NaOH (aq), 5M HCl (aq), phenolphthalein indicator, teat pipette.

Method: A 250 cm^3 flask is filled with about 200 cm^3 water, containing a few drops of phenolphthalein indicator. 1 drop of HCl is added to the water. Into successive empty flasks are added: 3 drops of NaOH, 5 drops of HCl, 6 drops of NaOH and 8 drops of HCl. The water in the first flask is poured successively from one flask to the next, leaving behind about 40 cm^3 solution in each flask.

Observation: As water is poured from one flask to the next, the colour changes from colourless to pink, to colourless, to pink, and finally back to colourless (see flasks on the left - photo 1).

Photo 1. **"**Rainbow Water", Koscielisko, Poland, October, 2013

Experiment 3. Rainbow water

Aim: To illustrate the same idea as above, but in a more spectacular manner.

Apparatus/reagents: 5 litre flask, universal indicator solution (available from Griffin Education - 500 cm^3 for £16.76), 5M HCl (aq), 5M NaOH (aq), 2 teat pipettes, 7 small beakers or glasses.

Photo 2. "Rainbow Water - 1 ", Wachock, Poland, October 2013

Method: To approximately 2.5 dm^3 of water in a 5 dm^3 flask, add about 5 cm^3 of universal indicator solution. The water in the flask will turn green (pH 7). Using a teat pipette, add a few drops of 5M HCl to the flask and swirl it vigorously (photo 2).

Successive additions of HCl will cause the colour to change from green to yellow to orange to red. Once red has been reached, small amounts of 5M NaOH are added to the flask, swirling between each addition. This will reverse the above colour sequence, and also give blue, indigo and violet. Small samples of each coloured solution can be decanted into the beakers, which highlight the effect of the changes. The complete range of colours is shown in photo 1.

Observation: In the space of 2-3 minutes, all the colours of the rainbow are made in one flask, thus illustrating once again, how colour changes can occur in chemical reactions.

Experiment 4. The Iodine Clock Reaction [3]

Aim: To illustrate the principle that energy is always involved in chemical processes. To achieve this, a "tall story" is told, along these lines: there are many forms of energy which can be associated with chemical processes *eg* heat, light, electrical, kinetic. Explain also, that in this most curious reaction, musical energy (produced by a tune played on a violin for example), can cause a chemical reaction to take place.

Apparatus/reagents: 600 cm^3 beaker, 400 cm^3 beaker, glass stirring rod, two 100 cm^3 measuring cylinders, 500 cm^3 of freshly prepared: 0.01M KI (A), 0.01M $Na_2S_2O_3$ (B), 1M/1.5% HCl/H_2O_2 (C) , starch solution, teat pipette, musical instrument.

Method: To be completed **before** the talk. Into the 600 cm^3 beaker, using one measuring cylinder, pour 100 cm^3 solution (A), followed by 100 cm^3 solution (B) and about 1 cm^3 of starch indicator. Into the 400 cm^3 beaker place 100 cm^3 of solution (C). After the introduction about various forms of energy, mix the solutions together, and stir for a few seconds. Play a tune until the colour changes suddenly. (Although the tune has no relevance to the experiment, the effect is greeted with awe and amazement from the audience, and frequently prompts profound questions. It is worth noting that the iodine clock reaction has been used for decades by chemical demonstrators and magicians, and is also very popular on various "Youtube" versions. A particularly effective clock reaction, not involving iodine, is the "Formaldehyde-Bisulphite time reaction" [4]).

Observation: After about 45 seconds (at about 20ºC), the colour suddenly changes from colourless to blue/black.

Experiment 5. Internal combustion engines

Aim: To show how our understanding of the role of air (oxygen) in combustion processes has enabled scientists/technologists to exploit efficiently the combustion of fuels.

Apparatus/reagents: Small candle burning in holder, large (about 1 litre) glass jar/beaker, fireproof mat, tripod, teat pipette, petrol, 2.5 litre tin can with lid and with 1 cm diameter hole in the bottom, matches, splints.

Method: Start by demonstrating the well-known experiment, in which a burning candle is slowly extinguished when enclosed in an inverted glass container. Explain that this effect was first noted by the Greek engineer Philo of Byzantium, about 2000 years ago. He was unable to explain it, since air at that time was considered to be an element. Explain also that it took natural scientists 2000 years to finally establish that air is a mixture of gases, and that oxygen, which supports combustion and respiration, constitutes about 20% of air. Once this fact had been established towards the end of the 18^{th} century, it sparked off a whole new wave of chemical research into the combustion of fuels. This research had a momentous effect on human history - it initiated the Industrial Revolution.

Photo 3. “Petrol vapour ignition”, Koscielisko, Poland, October, 2013

Using a teat pipette, squirt about 2 cm^3 of petrol onto a fireproof mat. Ignite the petrol with a burning splint, and then comment on the slow rate of combustion and on the smokiness of the flame. Explain to the audience that substances similar to petrol have been known for thousands of years, yet their exploitation as fuels has been limited on account of the slow smoky flame. Show the tin can to the audience, and explain that this is a model of a cylinder, which is found in every internal combustion (*ie* petrol and diesel) engine - this cylinder is known as the combustion chamber. It is here that the fuel is burnt. Using the teat pipette again, squirt about 1 cm^3 of petrol into the can, replace the lid tightly, and warm the can gently by holding it in your hands for about half a minute. Explain to the audience, that while you are holding the can in your hands, the petrol, being a volatile liquid, is evaporating and mixing with the air. It is thus forming an homogeneous system. Then place the can on top of a tripod, and ignite the vapour from under the can. Photo 3 shows the moment of ignition. A loud report is heard, and the lid flies off the can. A blue flame can also be momentarily seen.

This experiment illustrates that when a fuel is mixed with the correct (stoichiometric) proportion of oxidant (oxygen from air in this example), the combustion process is vastly more effective than when the same fuel is burnt as a liquid in air. It is this type of efficient (complete) combustion which underpins the technology of today's world.

Experiment 6. Enhancing the combustion of fuels

Aim: Two important methods are demonstrated for optimizing the combustion of fuels: (a) increasing its surface area - *eg* fuel injection systems, (b) adding pure oxygen - *eg* rocket fuels [5].

Increasing surface area

Apparatus/reagents: rectified spirit (95% ethanol), bucket, cup of tap water, paraffin, 1 steel poker with cloth soaked in paraffin, attached by wire to the poker, matches.

Method: Ignite the cloth soaked in paraffin at the end of the poker, then take a mouthful of ethanol and, using full lung power, spray the ethanol through the poker flame. As soon as the fireball has burned, rinse your mouth several times with tap water, spitting the washings into a bucket.

Observations: A large fireball is formed - shown in Photo 4 during a demonstration to 200 children in the Cultural Centre in Wachock, Poland.

Photo 4. "Ethanol combustion", Wachock, Poland, October 2013

Adding pure oxygen

Apparatus/reagents: two evaporating basins (100 cm^3 capacity), industrial methylated spirit, matches splints, potassium permanganate crystals, 50 cm^3 measuring cylinder, 20 vol. (6%) hydrogen peroxide solution, spatula, 1 litre beaker/conical flask, fireproof mat.

Method: Demonstrate the combustion of ethanol in air, by igniting about 25 cm^3 of it in an evaporating basin, which is placed on the fireproof mat. The flame is slow, quiet, and slightly yellow. Extinguish it by placing the fireproof mat over the basin, to exclude air. Then show how pure oxygen can be used to enhance the combustion of a glowing splint - into the 1 dm^3 beaker, pour about 50 cm^3 hydrogen peroxide solution. Place a glowing splint in the top of the beaker and show that it is not relit. Then add a spatula measure (about 5 g) of potassium permanganate to the peroxide, and lower the glowing splint into the beaker. This procedure with the splint can be repeated several times. Into a separate evaporating basin, pour about 25 cm^3 of ethanol, followed by about 25 cm^3 of peroxide solution. Ignite this mixture with a burning splint (if it does not inflame, add a little more ethanol), and then carefully add about 1 g of permanganate crystals.

Observations: When the permanganate is added to the peroxide, clouds of steam are produced, together with oxygen. When the glowing splint is lowered into the beaker, it immediately relights, and burns with a bright yellow flame. When the permanganate is added to the burning mixture of alcohol and peroxide, a loud series of reports is heard. The alcohol now burns fast, loudly, and with a colourless flame.

Safety

The chemical theatre is, and always will be an intrinsic part of our cultural heritage. In order for success to be achieved, it is imperative that the presenter has carefully practised all of the procedures. The important principle of “safety first” cannot be overemphasized.

Conclusion

The concept of a “chemical theatre” *ie* a lecture/demonstration, is not new - it forms part of the great tradition of chemistry teaching which has evolved during the past three centuries. Through the use of this medium, it is possible to create an atmosphere of learning and understanding which greatly enhances the educational process.

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TEATR CHEMICZNY - EDUKACJA, ROZRYWKA

Abstrakt: W niniejszym artykule autor opisuje siedem prostych doświadczeń chemicznych, które mogą być wykorzytywane przez nauczycieli chemii w różnych okolicznościach i dla różnych grup słuchaczy. Oprócz instrukcji do wykonywania doświadczeń, autor podaje szereg dodatkowych informacji, które umożliwiają podnoszenie poziomu spektaklu ze zwykłej lekcji chemii do głębokiego przeżycia - taki jest bowiem główny cel teatru chemicznego.

Słowa kluczowe: eksperyment, uczenie się poprzez wykonywanie doświadczeń, teatr chemiczny