KITCHEN CHEMISTRY: PRACTICAL CHEMISTRY WITH SIMPLE EQUIPMENT AND READILY AVAILABLE MATERIALS

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ABSTRACT

The Kitchen Chemistry Science Show uses readily available materials and unsophisticated equipment. The development of the show is outlined and each of the demonstrations is described in detail. For each demonstration there is an explanation of the demonstration and, where appropriate, a suggestion for an extension to a whole class activity. Indications of safety precautions are also discussed. Further development of the Kitchen Chemistry Outreach Project is then outlined with a description of future plans. *[African Journal of Chemical Education—AJCE 8(2), July 2018]*

INTRODUCTION

The original Kitchen Chemistry Science Show was developed in partnership with Scifest Africa: South Africa's National Science Festival [1]. In 2006 I was collaborating with Prof. Mike Cook, a colleague at UEA on the photophysics of phthalocyanines.[2,3] Prof. Cook was simultaneously collaborating with Prof. Tebello Nyokong from Rhodes University in South Africa. Prof. Nyokong was at that time on the Advisory Committee of the National Science Festival – Scifest Africa. When she learned of my various demonstration lectures I was invited to take part.

I performed at Scifest in 2008 and 2009 using demonstration lectures developed with a grant from the Engineering and Physical Sciences Research Council (EPSRC), part of a pilot program to encourage EPSRC funded researchers to communicate their research to the public. I my application was for a grant to develop portable demonstration lectures which would illustrate aspects of my research.

After my appearances at these Festivals the then Director of Scifest Africa encouraged me to develop a chemistry show using readily available materials and unsophisticated equipment. This took inspiration from Lorelly Wilson's "Chemistry with Cabbage" [4] and other science shows that I had seen. The show was first performed as "Kitchen Chemistry" at Scifest Africa 2011 but elements had been already performed in front of audiences as "The Chemistry Show", such as part of the Mauritius Science Week in 2010 at the Rajiv Gandhi Science Centre.

Kitchen Chemistry was not only performed at Scifest in 2011 it was also taken on tours of the Western Cape in South Africa funded by the Embassy of the Kingdom of the Netherlands in South Africa. The Systemic Extra-Mural Education Development and Support (SEEDS) project, of which this was a small part, was made up of eleven different partners each with different interventions in rural and township schools throughout the Western Cape over a four-year period [5,6].

In 2013 I was awarded a sabbatical from teaching and from early January until mid-April I toured South Africa giving shows and workshops in schools and science centers. The whole event was coordinated by Scifest Africa as part of its outreach offering. Not only was I able to demonstrate directly to learners, I had the opportunity to train both educators and science centre staff. Travel, accommodation and consumables were covered by charging science centres for the science shows and workshops that I provided. Appearances at schools, however, were free.

During the 100 days I spent in South Africa, which included the week of Scifest, I was involved in over 120 events and drove over 11,000 km. The shows were not just Kitchen Chemistry, I also had a couple of physics demonstration lectures ("The Sound of Science" and "Lasers: the light fantastic") along with a version of the Royal Society of Chemistry's Spectroscopy in a Suitcase [7].

Since 2011 I have contributed Science Shows and workshops to Scifest Africa every year, and have also served on the Advisory Committee.

Figure 1: The Kitchen Chemist surrounded by his equipment.

KITCHEN CHEMISTRY: THE ACTIVITIES

The original Kitchen Chemistry show itself is made up of a number of different demonstrations linked by a narrative about what a chemist might end up doing. The first part serves to illustrate that the molecules a chemist works with are very small, but they influence the properties of the matter around us. From there we look at simple color changes to indicate something about the nature or contents of a solution. Where possible one or more new substances are made, and then we look at how materials can be decomposed into their components.

For the shows I have specially built one or two pieces of equipment. This is generally so that they are a suitable size for a large audience to see well. In all cases there is a readily available alternative which can be used instead. Equally, the quantities used are relatively large, again to enable the experiments to be visible to a large audience. These quantities can often be scaled down if one is adapting a demonstration to turn it into a classroom activity or to use as a demonstration in front of a small group.

This is a science show and the demonstrations are chosen and practiced so that they are slick and they are put together so that there is a certain pace to the show. It will not take too much to adapt some of these to involve the whole class in a practical activity. The show runs with the demonstration as follows.

Cartesian Diver

To attract the audience’s attention and get them a little off balance to start with I have a Cartesian Diver in a 2 L soda bottle. I divide the audience in two and each half has an opportunity to “push” the diver to the bottom of the bottle using their minds alone. Of course, the first group does not manage, where the second group does. If appropriate I explain the principle of action, or simply suggest that it might be a good question for later.

The diver itself must float but it is best to ensure that it only just floats. The demonstrator may then manipulate the bottle in such a way that it is not obvious the bottle is being squeezed. I usually use a vinegar packet from a fast food outlet for my diver for visibility. There are, however, many alternatives – a plastic pipette or a straw blocked at one end. If a diver is used that is open at one end and it is transparent or translucent the compression of the air inside the diver is easy to observe. This could then be carried out as a whole class activity and the class encouraged to observe the compression of the air.

Number of molecules

To get across the mind-boggling size of the number of molecules in my Cartesian Diver bottle I have a series of laminated cards which make up the number. I invite members of the audience to join me on stage to hold up the cards, and make a play of how big the number is.

An alternative method is to write the number on a long strip of paper which can then be slowly unrolled. In this way it would be possible to have indicators of other big numbers, such as the population of a capital city, the population of China, the world population, the number of seconds since the Universe began etc.

Newspaper ripping

Having established that molecules are very small we then see that their size and shape dictates the properties of materials around us. How these molecules interact and fit together determines whether a material is hard, or soft.

A newspaper, or any other sheet of paper can be used for this. In one direction a tear is neat and relatively clean, a tear in the perpendicular direction is more ragged, and often ends up tearing in the other direction. This comes about because the fibers that make up paper are composed of long thin molecules. This, in turn, means that the fibers are long and thin – just like fibers that make up cloth. In the process of making paper the fibers are aligned – they tend to be brushed in one direction. Tearing the paper in a direction parallel to these fibers gives a clean, straight tear, but in the perpendicular direction the tear is jagged and not at all clean.

This could be used in class to start an investigation of materials, what properties they have and whether they are the same in all directions.

Dissolution

I then usually move on to describe a "magic trick" that I have been practicing. I tell the audience that I have been trying to make people disappear, but when I do they do not return (at least not uninjured). So what I do instead is show how I practice, with salt. Having made a big show with magical "passes" I take a glass of water and dissolve the salt.

Of course the salt has not "gone away" it is still in the water. This could be a way to start a class discussion on dissolution which might range as far as weathering of rocks and the change in the pH of the ocean as carbon dioxide is absorbed.

Evaporation

The salt has dissolved and not gone away, so this is the time to talk about evaporation. If we left the water for long enough the salt could be recovered as the water will evaporate. This I demonstrate using expanded polystyrene balls as "water" and colored solid polystyrene balls as "salt". The expanded polystyrene may be blown out (and a show made of an imaginary piece of polystyrene being stuck in one's mouth) or alternatively a hairdryer could be used to generate a stream of air for the same effect. This demonstration makes rather a mess, but is a very visual demonstration of evaporation, and the particulate nature of matter.

Dissolution

I continue the dissolution theme by showing that expanded polystyrene may be "dissolved" in acetone. It might be possible to use nail polish remover for this, but the high water content of some formulations prevents them from working. I like to use long thin polystyrene sheets. The length means that the effect is particularly impressive, however, any expanded polystyrene will do.

The material one often finds in packaging will work, but take care to use polystyrene as packaging also comes with starch “popcorn” these days. Polystyrene cups work too, which lends itself to a demonstration where two unsuspecting volunteers are asked each to fill a polystyrene cup to see how quickly they can do it. One, however, is given acetone, and the other water. Obviously the cup disintegrates when acetone is poured in so some care must be taken to ensure that any spillage is contained.

Density – water and air

Figure 2: The final state of the density demonstration

After a short description of the particulate nature of solids, liquids and gases there is a demonstration of the effect of density using hot (coloured) and cold (not coloured) water. Again a great deal is made of the need to turn one of the glasses upside down on the other, until two offset CDs are used to make a lid / seal that enables one glass to be inverted without too much spillage. When slid together to line up the holes allow liquid to pass from one glass to the other. A good example of the final state of this demonstration can be seen in Figure 2. On the left the cold water was in the lower glass and on the right the cold water was in the upper.

This does take some practice and care should be taken when handling hot liquids. The CDs do not always slide smoothly, and that is when liquid tends to be lost.

The same effect can be obtained with a bag of air. The best bags to use are thin, crinkly bin liners. The air inside can be warmed above a toaster. Care must be taken to ensure that the bag does not melt or drop into the toaster. This can also be done with large black bin bags but it will take considerably longer to warm up the air inside than a smaller bin liner. It is good practice to trim excess plastic from the bottom and add some tape to the opening to weight it a little. This helps to prevent the bag inverting when it starts to float.

This demonstration might be made into an investigation to determine the lifting power of air. There are many interesting questions that arise. How would one determine the force produced? How might the temperature of the air in the bag be determined? What is the volume of the bag? If one was simply determining the lifting power of air all of these questions would have to be answered. More interesting still is to transfer the scenario to a hot air balloon. Then the gas mixture in the balloon envelope is no longer simply air: it will contain water and carbon dioxide from the combustion of the fuel.

Indicators – vinegar and washing soda

Many colored materials act as acid-base indicators. One of the best is red cabbage water, but this can be difficult to keep for long periods, especially in warm climates, as it tends to develop a variety of bacterial cultures. When I am on the road my choice is either grape juice, which involves no preparation, or fruit teas, such as blackcurrant, cranberry etc. as they may be stored dry and made up on site. The active ingredient in all of these are anthocyanins which turn green in a basic (alkaline) solution, purple at neutral pH and pink when acidic.

My chosen base is washing soda (sodium carbonate) and the acid is distilled, or spirit vinegar. The absence of color in the vinegar enables the color changes to be observed more readily. It is, of course, possible to use other bases with these indicators.

These simple indicators allow a variety of analytical experiments to be carried out. First, there is the qualitative determination of whether a substance, which might be a substance found in the house, such as toothpaste, were acidic or basic (alkaline). Second, one might consider using the indicators to show the endpoint of a titration, where either an acid or base is neutralized. If burettes are not available for these sorts of experiments the number of drops from an eye-dropper, or pipette could be counted and calibrated.

Indicators – milk of magnesia

I then use milk of magnesia (a suspension of magnesium hydroxide) to demonstrate the use of an indicator. I explain that we might ask whether this material is acidic or basic. The milky solution when a little milk of magnesia is added to water turns the indicator green, so it can be seen to be a basic (alkaline) mixture.

This mixture may also be used to demonstrate equilibria, because when acid is added the mixture turns the indicator back to pink. The concentration of dissolved hydroxide ions has thus gone down. The result is that more magnesium hydroxide dissolves and over time the indicator regains its green color. The equilibrium will continue to be re-established on addition of acid until all the solid has dissolved. A process which I liken to using up the charge in a battery.

Indicators – iodine starch and vitamin C

Not all indicators need to be highly colored. A few drops of tincture of iodine in water produces a pale yellow solution. When starch indicator is added to this a deep blue color forms.

The starch indicator should be prepared in advance. I take a small amount (half a teaspoon) of cornstarch (Maizena) and pour a small amount of boiling water onto it. I then boil that for a while. At home I do it in the microwave, and at a venue I mix it in a polycarbonate glass and put the glass in a kettle that is one third full of water and let that boil (with the lid open) for a little while. Care must be taken when taking the glass out of the kettle unless everything is allowed to cool first.

Having made the deep blue color, addition of vitamin C will remove the color. The vitamin C is an anti-oxidant, or reducing agent. It reduces the iodine to iodide. This is a quantitative reaction and can be used for analyzing the amount of vitamin C in a solution. This was the basis of the Royal Society of Chemistry's global experiment in 2013 [8].

Water into wine

At this point I often step away from the readily available chemicals and do a classic "Water into Wine" demonstration. I pour myself a large "gin" or "vodka" from a suitably labelled bottle, then explain how I was not meant to drink hard liquor on stage, so I pour it into another glass to turn it into "juice". Then it occurs to me that that white wine is not hard liquor so by pouring into a third glass I produce some white wine. I go to drink this (but do not, of course) and realise that it should be chilled, so I decide that red wine can be drunk at room temperature, and produce this by pouring into another glass. Before I get to drink that I "remember" that I should not be drinking alcohol as I have to drive, so take my bottle and a final glass, and produce some "milk".

The mixture in the bottle is water, phenolphthalein and salt. In the first glass I have nothing (gin), the second glass contains a few drops of sodium carbonate solution to turn the phenolphthalein pink (juice), the next glass has a few drops of concentrated iron (III) chloride, which is acidic (to remove the color of the phenolphthalein) and produces a yellow solution (white wine), and the next glass has some ammonium thiocyanate, which reacts with the iron to produce a deep red color. For my "milk" I have a few drops of silver nitrate solution in the glass, which reacts with the sodium chloride in the gin bottle. It is best to use wine glasses for this as the liquid tends to be disguised by the glass where the bowl joins the stem.

Given the length of the show, I use this demonstration less frequently now. It also simplifies the logistics and transport, as I do not have to worry about my solutions leaking in transit.

Holey bottle

I then show a bottle of water which I "discover" has two wooden kebab skewers stuck through it. The audience is asked to predict, just like a scientist would, what will happen when the skewers are removed. I then "do the experiment" and remove the skewers and explain that everything is balanced, air pressure, water pressure etc. By opening the lid of the bottle very satisfying streams of water can be produced.

I have found the key to making this successful is to have the holes at the same height in the bottle. It does mean that the skewers have to be distorted a little when setting the bottle up, but bamboo kebab skewers are sufficiently flexible, especially if they have been immersed in water for a while.

It would be possible to involve the whole class in this if the effect were not explained, but set as an open-ended problem. There are a number of factors which contribute, the reduced pressure of air inside the bottle, the external air pressure balancing the hydrostatic pressure and the surface tension of the water. Depending on the level of study one might also consider the effects of increasing the size of the holes – is there any hole size at which the effect would no longer work?

Three cup trick

Finally, I get my drink of water, but I use three identical polystyrene cups for this. One has been prepared with some super-absorber (sodium polyacrylate). This I usually buy from a garden center. It is slightly slower to absorb water than the material found in nappies, but much easier to handle and less hazardous: the crystals in nappies are very fine and easy to inhale.

This I frame as a test of the power of observation of the audience members. I ensure that they know where some water is to start with, then proceed to swap cups round. Having done this, I ask the audience which cup contains the water. I generally pour the water into the cup with the absorber for the third set of swaps. I can prolong this sufficiently that the water has been absorbed nicely and when the cup chosen by the audience appears to be empty I am careful to say that the water does not “come out” of the cup.

This can be made very theatrical but I always try to make the point that not only should a scientist be able to make accurate observations, but they should also be very precise with language. When I said the water did not "come out" of the cup, it did not mean that the water was no longer in the cup.

New material

The absorbent material is a new material made by chemists, so at this point I generally make a new material. If the washing soda (sodium carbonate) solution is nice and clear it may be added to a solution of Epsom salts at which point it forms a precipitate. The milky appearance of this mixture may be linked back to the milk of magnesia. Both are milky because of finely divided solids scattering light, because they are suspensions, not solutions.

If it is possible to get some borax, another new material may be made by adding borax to PVA glue. I generally dilute the glue with some water and emphasize how runny it is. Then add a few drops of a borax solution to produce slime.

This can form a great class experiment. Slime can be made in small batches and tested. There are a variety of tests that are possible on slime. One is to see how far a sample will stretch under its own weight without breaking. Another is to see how quickly it will flow through a funnel (which can be made out of the top of a drinks bottle). Another is to measure how quickly it flows from one concentric circle to another. It is best to put the paper with the concentric circles inside a clear plastic wallet for this. The participants can then determine how to modify their recipe to make their slime quicker or slower, for example.

Fire extinguisher

Having put some things together to make new materials I then take a look at taking things apart. The first thing to try is sodium bicarbonate (bicarbonate of soda, sodium hydrogen carbonate) and acid. I explain that any carbonate material plus an acid will liberate carbon dioxide. Once the audience has confirmed for me that carbon dioxide is a gas I then ask them what we might observe. My analogy here is that if a solid (me) is sitting in a bath full of water (a liquid) and I produced a gas, what would I observe? In this case the solid is the bicarbonate, the liquid is vinegar and we should see bubbles – which we do.

This gas can then be used to extinguish a candle, by pouring it from one container into another container where there is a lighted candle. This can be made more impressive by using an intermediate container. We can explain this as carbon dioxide is denser than air so displaces air from the bottom of our containers. This can be related back to the earlier experiment with density. This is a nice, low cost, reaction that can be used to experiment to find reliable ways to measure gas release from a reaction. You might use the gas to produce a foam by adding a little dishwashing liquid (washing-up liquid). The time it takes your foam to move between two marks on a standard container (say a drinks bottle) would give an approximate idea of the speed at which the gas has been evolved and thus how quickly the reaction is taking place.

It may also be used to look at the concept of a limiting reactant, and is a nice example of an endothermic reaction.

Hydrogen peroxide with yeast

Another nice decomposition reaction is the so-called “elephant’s toothpaste”. I would normally have mixed some dried yeast with water prior to the start of the show and this is the source of the peroxidase enzymes that are required for this experiment. One can use blood, liver, celery, or some inorganic salts for this, but dried yeast is easy to store and transport. It also has the advantage that it will foam, which has been useful for me when I have forgotten to bring, or ask for, washing-up liquid, which helps to catch the bubbles of oxygen.

Not only is this a nice decomposition reaction, one can mention that we make hydrogen peroxide just by breathing, that it is breaking down slowly all the time and the yeast will simply speed up the reaction. At a suitable level one can use this to talk about enzymes and catalysts.

This can be used for a whole class investigation looking at the effect of particle size on reaction rate, and also on concentration on reaction rate, especially if a gas measuring technique has been developed.

In the first case one can use a piece of freshly cut potato to decompose the hydrogen peroxide. If this is large, like a fat French fry, the gas forms slowly as there is a relatively small amount of surface area in contact with the peroxide solution. If the same amount of potato is cut up, there is more surface area and the gas bubbles form more quickly. Finally mash up the same amount of potato and the gas should be produced more quickly again.

To look at reaction rates one can use potato, celery or yeast, to add to different concentrations of peroxide. Alternatively, different amounts of yeast added to the same concentrations of peroxide.

Of course when working with peroxide suitable safety precautions need to be taken. Even low concentrations of peroxide will bleach skin temporarily and cause a pricking sensation. Any spillage should be treated with copious quantities of water which should then be run to waste.

Whoosh bottle

I link this to the previous demonstration by noting that the “elephant’s toothpaste” generates some heat during the reaction. We can thus use chemistry to make heat and one of the simplest ways is to burn a fuel. In this case we take a water cooler bottle and add some methylated or surgical spirits. I make sure that the inside is fully coated with liquid, give it a bit of a cuddle to warm up the bottle, and pour away any excess liquid. Always use a splint on a stick or a long barbeque lighter to light the bottle. The results of this experiment can be seen in Figure 3.

Figure 3: *The "whoosh" bottle*

These bottles can be expensive to get hold of. I have found, however, that the water cooler companies are happy to supply bottles, which they are taking out of service, free of charge. These bottles would otherwise only have been sent for recycling. Even if they cannot be used to supply potable water for humans they are generally plenty good enough for this demonstration.

Immediately after the demonstration the bottle has depleted its reserve of oxygen. If the experiment is repeated without refreshing the air in the bottle the alcohol will only burn at the neck of the bottle which will discolor and melt the bottle. (Yes, it has happened to me.) This can be avoided by blowing into the bottle, or simply leaving the bottle with the neck down in an environment where the carbon dioxide can settle, and diffuse away. If the bottle is to be reused quickly the oxygen may also be replenished by half-filling the bottle with water, and tipping the water out. In this case, however, the bottle should be rinsed with excess fuel to ensure that any residual water has been removed.

Cornflour flame

The final flourish is a demonstration to show the energy there is in food. Cornflour (cornstarch, Maizena) may be blown out of a funnel and ignited with a variety of sources. My preference is to use a funnel on the end of a fairly rigid plastic tube. I blow in the end of the funnel and ignite the flame with a blowtorch as shown in Figure 4.

Figure 3: A cornflour flame

There are many alternative ways of setting this up. For example, the funnel can be clamped in place, as can the blowtorch and a stomp rocket pump may be used to expel the cornflour from the funnel. Instead of cornflour, custard powder may be used. This gives a markedly more intense flame, but the sugar and egg content of the custard powder means that it is slightly less straightforward to clear up.

HINTS, TIPS AND SAFETY

Many of these demonstrations benefit from practice. Sometimes this can be done in a kitchen or lab, other times there is no substitute for trying it out in front of an audience. There are a number of hints and tips on the Kitchen Chemistry website [9] and a forum [10] which I would encourage readers to use to exchange ideas and suggestions.

Please refer to the website safety page [11] and the pages for each individual experiment for specific details of safety advice.

All the glasses I have referred to here are polycarbonate glasses from an internet supplier. Not only are these rigid, and stand up to heat, they are also essentially unbreakable and, therefore, very useful when travelling. The large containers I use for the indicator experiments and other aqueous solutions are manufactured to be vases. Only colored or patterned vases seem to be available on the internet at the moment so I ordered in bulk from China. If you would like to purchase these containers, please contact me through the website or by email. They can easily be dispatched by post, but international postage might incur a surcharge.

FURTHER DEVELOPMENT OF THE KITCHEN CHEMISTRY OUTREACH PROJECT

There is now a second show Kitchen Chemistry: Second helpings, which has a different set of demonstrations but maintains the theme of readily obtainable materials and unsophisticated equipment. If readers are interested I would be happy to describe those demonstrations as I have done here in a further publication. Many of them are already on the website. I am also gathering material and making preparations for there to be a third.

The variety of experiments that I have available now can be used to generate a selection for bespoke events. For example, I spent one week in January 2017 working with the British Council in France on their "Science in Schools" initiative. This was a combination of parts of the Kitchen Chemistry show and the RSC Global experiment [8]. The audience was able to experience part of the science show but also get some hands-on experience of chemistry experiments. All the sessions were delivered in English.

I have also used some of the demonstrations to put on a "Science of Santa"10 demonstration lecture, with a colleague, Maxine Rushton. This was first performed as the Christmas Lecture for Young Children at the UEA in 2014, and was chosen to be part of the UK delegation for the "Science on Stage" conference which took place in London in 2015. We use demonstrations to put forward the hypothesis that Santa is not a magician, he is simply a scientist. A link to the poster and a recording of the lecture are both available from reference [12].

I have recently extended my work in Southern Africa. The Kitchen Chemistry Outreach Project in South Africa is helping me put to extend my activities to Johannesburg and the Durban area, with the inaugural Umjikelezo We-Science festival [13,14] in 2017. I have also started visiting schools in the Maputo area of Mozambique with Kitchen Chemistry shows.

I am continually looking for opportunities to work with partners or to attract funding to extend the reach and impact of Kitchen Chemistry. The shows and educator workshops are especially useful in areas of the world where specialized chemicals and well-equipped laboratories are not readily available.

If you think that something from Kitchen Chemistry could work for you, then please go ahead, adapt it for your needs, and use it. Very few of the demonstrations I do are original, I have merely adapted them to fit with my own requirements. Often the same demonstration may be used in a variety of ways to illustrate different points. If you need help or advice then please contact me directly, or ask on the Forum.

If you would like Kitchen Chemistry to visit you, then please get in touch. I am happy to travel, and if we can come to some mutually convenient arrangement that fits around my day job, I will be happy to oblige.

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REFERENCES

1. Scifest Africa, http://www.scifest.org.za/, (Last Accessed 02/01/2018)
2. M. van Leeuwen, A. Beeby, and S. H. Ashworth, *Photochemical & Photobiological Sciences* **9** (3), 370 (2010).

3. M. van Leeuwen, A. Beeby, I. Fernandes, and S. H. Ashworth, *Photochemical & Photobiological Sciences* **13** (1), 62 (2014).
4. L. Wilson, http://www.lorellywilson.co.uk/, (Last Accessed 02/01/2018)
5. M. Erskine, http://blogs.sun.ac.za/seeds, (Last Accessed 02/01/2018)
6. Outsourced Insight, Systemic Education & Extra-Mural Development and Support (SEEDS) Initiative 2009-2013, Western Cape Province, South Africa - Mid-Term Review,http://tinyurl.com/yayojnbf (2011).
7. Royal Society of Chemistry, http://www.rsc.org/learn-chemistry/resource/res00001239/spectroscopy-in-a-suitcase?cmpid=CMP00002351, (Last Accessed 02/01/2018)
8. Royal Society of Chemistry, http://www.rsc.org/learn-chemistry/resource/res00001280/measuring-vitamin-c-in-food-a-global-experiment?cmpid=CMP00002712, (Last Accessed 02/01/2018)
9. S. H. Ashworth, http://www.KitchenChemistry.eu, (Last Accessed 05/04/2018)
10. S. H. Ashworth, http://www.kitchenchemistry.eu/forum/, (Last Accessed 05/04/2018)
11. S. H. Ashworth, http://www.kitchenchemistry.eu/topics/safety/, (Last Accessed 05/04/2018)
12. S. H. Ashworth, http://ScienceOfSanta.KitchenChemistry.eu, (Last Accessed 05/04/2018)
13. Centre for Advancement of Science and Mathematics Education, http://www.casme.org.za/news/umjikelezo-we-science-project-takes-the-message-of-science-to-rural-kzn, (Last Accessed 02/01/2018)
14. Centre for Advancement of Science and Mathematics Education, http://www.casme.org.za/umjikilezo-wescience.html, (Last Accessed 02/01/2018)