P. S. Kandagal, 2019

Volume 4 Issue 3, pp.1466-1484

Date of Publication: 2nd February, 2019

DOI-https://dx.doi.org/10.20319/pijss.2019.43.14661484

This paper can be cited as: Kandagal, P. S., (2019). Impact of Royal Society of Chemistry-Yusuf Hamied Inspirational Chemistry Programme in the Development of Innovative and Eco-Friendly Micro-Scale Experiments for Secondary School Education in India. PEOPLE: International Journal of Social Sciences, 4(3), 1466-1484

IMPACT OF ROYAL SOCIETY OF CHEMISTRY-YUSUF HAMIED INSPIRATIONAL CHEMISTRY PROGRAMME IN THE DEVELOPMENT OF INNOVATIVE AND ECO-FRIENDLY MICRO-SCALE EXPERIMENTS FOR SECONDARY SCHOOL EDUCATION IN INDIA

P.S.Kandagal
Department of Chemistry, S.V.M. Arts, Science and Commerce College, IlkalRani Channamma University, Karnataka, India
drpskilk@gmail.com

Abstract

Science education in India faces many challenges today. Teaching practical sessions through demonstrations is one of the biggest challenges in secondary school education. Practical work in chemistry is a vital component of teaching and learning process. It is an effective way to enhance students' understanding of science concepts and the process of scientific investigation. But most of the secondary schools in India don't have the advantage of well-equipped labs. Specific science activities like chemistry practical may take more time than the teacher would like to spend on them. To overcome these challenges, eco-friendly micro-scale chemistry experimental kits have been developed to effectively perform the practical in secondary schools based on the existing curriculum. This paper explores the way in which the practical activities can be carried out at micro level and how the chemistry activities mentioned in secondary school NCERT textbooks can be modified using low cost and no cost materials for effective class room demonstrations.These innovative and eco-friendly micro-scale chemistry experimental kits developed through RSC-YHIC programme have been *proven to be more effective in handling practical sessions, developing practical skills and empowering secondary school science teachers in India.*

Keywords

RSC- YHIC, Micro-Scale, Eco-Friendly, Chemistry Kits, NCERT, Secondary School, Practical Skills, Science Education in India

1. Introduction

India is the second most populated country in the world with the population of 1.32 billion(UNDSA,2017). Every year around 28 million students are enrolled in secondary and higher secondary education in the country representing a Gross Enrolment Ratio (GER) of 35 percent(PritiChaudhari,2016).In Indian education system, the secondary education servesas a bridge between the primary and higher education.The secondary education spreads over the age of 14 to 16 years. These years of transition and adolescence are the most crucial years in the students' life. The type of education, a child receives at the secondary level, is the deciding factor in shaping the future of a child. This stage of education can plant a seed of passion and interest in the minds of childtowards learning a particular subject of their choice at higher secondary level.The impact of globalisation, liberalisation and rapid growth of technologiesdemands more technical, skilled and innovative manpower to remain competitive at global level.Education has all through been considered a key driver of national development and an essential condition for building a humane society. The new Indian education policy-2016 clearly states thatcore objectives of education in the coming years should encompass four essential components: building values, awareness, knowledge and skills (National Policy on Education, 2016).

The National Council of Educational Research and Training (NCERT) is an autonomous body set up in 1961 by the Govt. of India to assist and advise the central and state governments on policies and programmes for qualitative improvement in school education. Thirteen states in India have already been adopted NCERT textbooks for secondary school education.

Today,science education in India faces many challenges. The most basic problem that has persisted and resisted solution since independence is the inability to provide schools with labs and equipment. The 8thAll India School Education Survey(AISES) conducted by NCERT reveals that out of the total 117,257 secondary schools in the country, only 49,278 (42.03%) schools are having facility of science laboratory (NCERT Report, 2016). Scienceis the knowledge about the material and natural world. It is the knowledge produced from systematic observation, measurement, experimentation, exploration, speculation and theorisation about natural objects, their properties and their interactions. The science classes are no different from geography or language classes. The textbooks talk about things, experiments and processes and show pictures. The teachers often take the route of not only describing the experiment, but also teaching children what to observe and what to conclude.Chemistry has always been an experimental science. In schools, it is desired that teaching of every chapter of theory inchemistry must involve simultaneous confirmation by commensurate experiments in the laboratories. The mainreason for this lapse is large-scale operation of the experiments.Whenever students work in the laboratories they perform thetests on a large scale involving cumbersome assemblies of apparatusand large amounts of chemicals. Therefore,the present education system needs serious reforms.

The Royal Society of Chemistry-Yusuf Hamied Inspirational Chemistry Programme (RSC-YHICP) was launched in India in 2014 by the Royal Society of Chemistry Cambridgewith the following objectives:

- To equip 8,000 teachers across India with the specialist knowledge and skills to deliver exciting and engaging chemistry lessons, and to share their knowledge with their colleagues.
- To provide 1,600 of the brightest chemistry students from all the background with places at chemistry camps to motivate and inspire them to reach the necessary standards to study chemistry at university.

The teacher training under RSC-YHInspirational Chemistry Programme which is supported by Dr.Yusuf Hamied, Chairman of Cipla, has reached new milestone in the number of teachers trained till date; more than 16,000 teachers have been trained from over 5000 secondary schools in the last four years across twenty one different states in India. Fortunately,I had the pleasure towork with RSC as a teacher developer for RSC-YH Inspirational Chemistry Programme from India. Through this programme,I have trained around1,800 secondary school science teachers and visited more than40 secondaryschools across Karnataka State in the last four years. During my visit I found that:

- Majority of the science teachers use rote learning technique for teaching and learning.
- Teacher's emphasismore on theory part than practical.
- Teachers lack practical skills and are resistant for doing chemistry experiments.
- Schools lackwell equipped science labs.

- Teachers find it difficult to perform chemistry experiments as described in the textbooks due to lack of equipment and chemicals.
- Financial constraints for purchasing chemicals and apparatus.
- Time constraints.

To overcome these challenges, I have made anattempt to develop micro-scale chemistryexperimental kits using locally available resources. Around40 curriculum-based, ready-to-use and eco-friendly micro-scale chemistry kits have been developed and these have been tested and proved to be effective methods in demonstrating chemistry experiments. Microscale Chemistry and well-ordered teaching sequences reduce cognitive overload (David Paterson 2017). This paper explores the way in which the practical activities could be performed at micro-scale.The chemistry activities mentioned in the Secondary School NCERT Textbooks have been modified using low cost and no cost materials for effective class room demonstrations.The developed micro-scale chemistry experiments consume small quantities of chemicals, involve simple equipment, and reducepreparation time and costs. Thus, it helps to develop practical skills and understand the process of scientific investigation throughlearning by doing. On the whole, the developed micro-scale experimental kits proved to be effective tools for empowering the secondary school science teachers in India.

2. Materials and Methods

2.1.Experiment 1: Extraction of Iron on a Matchstick Head

The head of a matchstickwas dipped in water to make it wet. It was respectively rolled in sodium carbonate powder, coke powderand iron(III) oxide powder.It was then put intoflame; match flared and burnt half way along its length. The matchstick was allowed to cool for about 30 seconds and the charred part of the matchstick was crushed in a small paper boat. When a magnet was moved around and under the paper boat, some of the small particles of iron weremoved in the paper boat (www.rsc.org/learn-chemistry).The micro-scale kit of this experiment is shown in Figure 1.

PEOPLE: International Journal of Social Sciences
ISSN 2454-5899

Figure 1: *Micro-scale kit forextraction of iron on amatchstick head*

2.2. Experiment 2: Graham's Law of Diffusion

A drop of liquidammonia (NH_3) was placed on a coloured plastic plate. A drop of concentrated hydrochloric acid (HCl) was placed nearer to the ammonia drop. White fumes of ammonium chloride (NH_4Cl) appeared nearHCl droplet.The micro-scale kit of this experiment is shown in Figure 2.

Figure 2: *Micro-scalekit for Graham's law of diffusion*

2.3. Experiment 3: Reaction between Acids and Bases (Neutralisation)

About 2 ml of 0.5 N HClsolution was taken in a small glass bottle with the help of a syringe and two drops of phenolphthalein indicator were added to it. While stirring, standard (0.5N) sodium hydroxide (NaOH) solution was then added to the above solution drop bydropby using 2 ml syringe until a pale pink colour appeared. The volume of standard NaOH consumed was recorded.The micro-scale experimental kit is shown in Figure 3.

Figure 3: *Micro-scale kit for acid-base titration*

2.4. Experiment 4: Preparation of Sodium Hydroxide bythe Electrolysis of Sodium Chloride Solution

A pinch of sodium chloride (NaCl) crystals was placed in a watch glass. A few ml ofrain water (distilled water) was added to dissolve NaCl. To this, a drop of phenolphthalein indicator was added. Thegraphite electrodes (pencil electrodes) were placed in the solution in such a way that two electrodes did not touch each other. The electrodes were then connected to a battery using crocodile clips and electric current of 9V was passed for few seconds. Pink colour appeared atthe anode due to the formation of NaOH.The micro-scale experimental kit used for this experiment is shown in Figure 4.

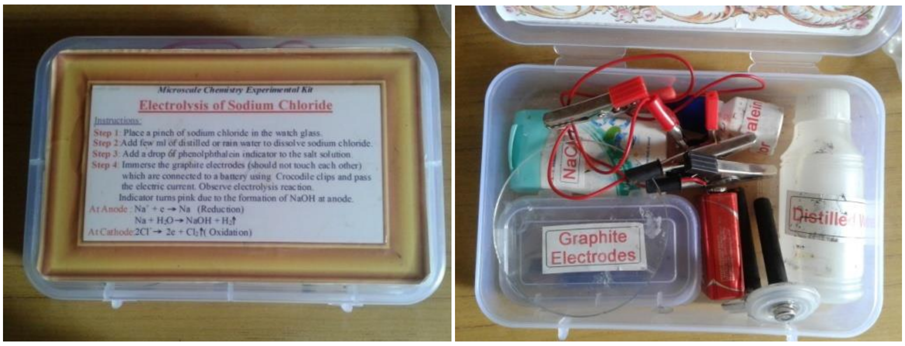


Figure 4:*Micro-scale kit forthe preparation of NaOHby the electrolysis of NaCl*

2.5.Experiment 5: Burning of Magnesium in Air (Redox Reaction)

Magnesium ribbon about 1-2 cm long was cleaned and the oxide layer was removed by washing it with dilute hydrochloric acid. A sparkler was lighted by a gas lighter and then magnesium metal was held onto the sparkler flametill magnesiumcatches fire.Magnesium burnt with dazzling white flame and formed white residueof magnesium oxide whichwas collected on a paper.The micro-scale kit of this experiment is shown in Figure5.

Figure5:*Micro-scale kit for burningof magnesium in air*

2.6.Experiment 6: Double Displacement Reaction

About 10 -15 mlof rain water was taken in a watch glass. A few crystals of lead nitrate and potassium iodide werecarefully placed simultaneously at the opposite ends in water. A golden yellow precipitate of lead iodide appeared after some time nearlead nitrate(RSC, The Particle Nature of Matter, Teacher Book, 2014).Figure 6shows the micro-scale kit of this experiment.

Figure6:*Micro-scale kitfordouble displacement reaction*

2.7.Experiment 7:Formation of Hydrogen Gas by the Action of dil.H_2SO_4 on Zinc

A small piece of zinc metal was placed in the cavity of a tablet wrapper (blister pack).A few drops of dilutesulphuric acid (H_2SO_4) were added to cover the zinc metal.The evolved hydrogen gas was collected in a test tube by the downward displacement of air. A glowing splint was brought near the mouth of thetest tube. The hydrogen gas burnt witha pop sound. The micro-scale kit of this experiment is shown in Figure 7.

Figure 7: *Micro-scale kit for the formation of hydrogen gas by the action ofdil.H_2SO_4 on zinc*

2.8.Experiment 8: Liberation of Carbon Dioxide Gas during Respiration in Human Beings

About 10 ml of rain water was taken in a small beaker. 1-2 drops of universal indicator were added to it. The exhaled air was bubbled through the water using a straw for a few minutes. The colour of the indicator changed from pale green to yellow. The micro-scale kitof this experiment is shown in Figure 8.

Figure8:*Micro-scalekit for the demonstration of liberation of CO_2 during respiration*

2.9.Experiment 9: Photochemical Reaction

About 2 mlof0.1 N silver nitrate($AgNO_3$)was taken in the cavity of tablet wrapper. To thisadded about 2 mlof 0.1 N sodium chloride (NaCl). Awhite precipitate of silver chloride (AgCl) formed. This was filtered, dried and exposedto sunlight. White silver chloride turned grey after some time.The micro-scale kit of this experiment is shown in Figure 9.

Figure9:*Micro-scale kit for photochemical reaction of AgCl*

2.10. Experiment 10:Preparation and Properties of Chlorine

A pinch of manganese dioxide (MnO_2), a drop made of potassium iodide (KI) and starch mixture, a drop of silver nitrate ($AgNO_3$) and adrop made of NaOH and phenolphthalein mixture were placed in the respective labelled circles in apetri dish. A drop of conc.HCl was added to MnO_2 and the petri dish was closedwith a lid. The chlorine gas generated *in situ* diffused and reacted with other chemical reagents in the petri dish. The pink colour of NaOH solution disappeared; colourless $AgNO_3$turned into white curdy precipitate; KI and starch mixture changed from colourless to blue.The micro-scale kit of this experiment is shown in Figure 10.

Figure 10:*Micro-scale kit for preparation and properties of chlorine*

3. Results and Discussion

3.1.Experiment 1: Extraction of Iron on a Matchstick Head

Industrial extraction of iron from haematite ore in the blast furnace using coke and lime stonewas described in the Secondary Level NCERT Science Textbook.Figure 11 illustrates the industrial extraction of iron.

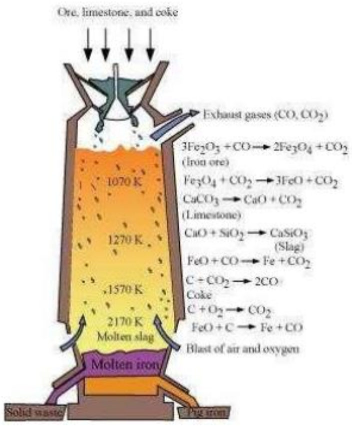


Figure 11: *Blast furnace*

This experiment is difficult to demonstrate. Hence,extraction of iron can be effectively demonstrated using the micro-scale kit. The results of the micro-scale experiment are in good agreement with macro-scale. The chemistry of the experiment is as follows:

All matchstick heads usually contain a phosphorus compoundand an oxidising agent which ignite easily.The iron(III) oxide is reducedby carbon to form metallic iron upon burning.The sodium carbonate fuses easily and brings the iron(III) oxide in close contact with the carbon. The carbon is oxidised as it gains oxygen and reduces iron(III) oxide into metallic iron.The chemical equation of the reaction is given below:

$$2Fe_2O_{3(s)} + 3C_{(s)} \rightarrow 4Fe_{(s)} + 3CO_{2(g)}$$

Although complete reduction ofiron(III) oxide from the haematite to metallic iron is difficult, but howeverit could be possible to reduce a few iron(III) oxide particles.

Theseresulting metallic iron particles can be easily separated with the help of a bar magnet. Thus, this micro-scale kit proves to be an effective tool to understand the basic principles involved in extraction of iron.

3.2.Experiment 2: Graham's Law of Diffusion

Graham's law of diffusion was illustrated in the Secondary Level NCERT Science Textbook by considering the reaction between ammonia and hydrogen chloride in gaseous phase to form white fumes of ammonium chloride as an example.Figure 12 shows the arrangement of apparatus used to demonstratethe Graham's law.

.

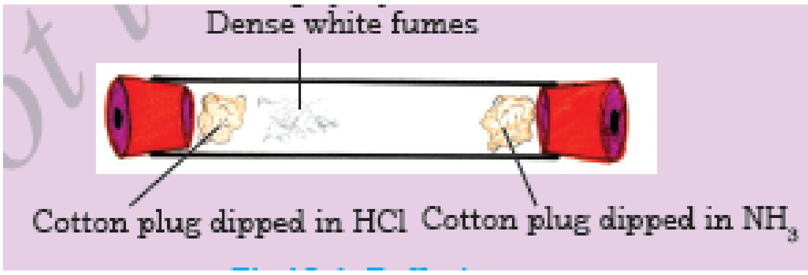


Figure 12:*Graham's law of diffusion*

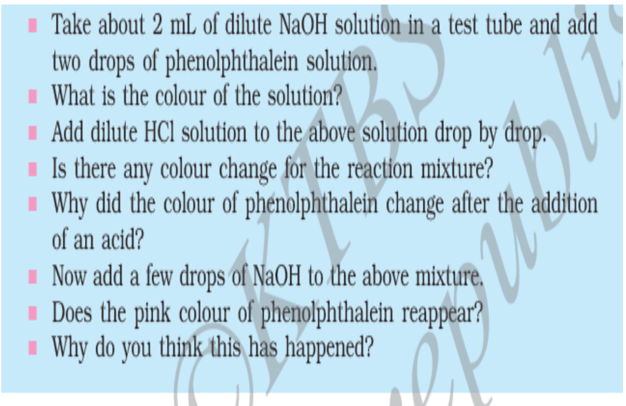
.

The volatile nature of ammonia and hydrochloric acid, and delicate arrangement of apparatus makes it inconvenient to perform the experiment. This experiment was modified and a kit was developed to effectively demonstrate the Graham's law at micro-level. The micro-scale kit requires small quantity of chemicals, simple equipment and reduces preparation time. The chemistry of the experiment is as follows:

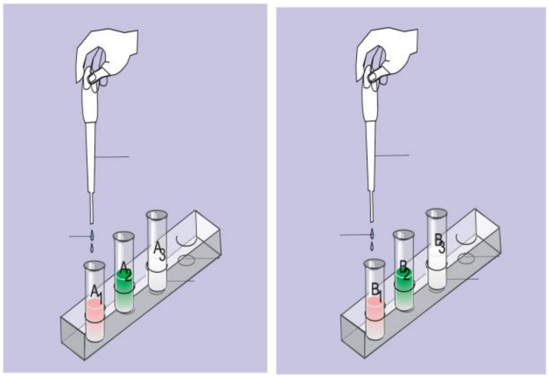
Liquor ammonia (NH_3) and hydrochloric acid (HCl)vapourise at room temperature. Since NH_3(mol.wt.17) molecules are lighter thanHCl (mol.wt.36.5) molecules, they diffuse faster and meetnear the HCl droplet, and form white dense fumes of ammonium chloride (NH_4Cl). The reaction is represented by the chemical equation: $NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(g)}$. The results of this micro-scale experiment are in good agreement with the macro-scale experimental results.

3.3.Experiment 3: Reaction between Acids and Bases

Titration involves the measurement of volumes of reactants. The experiment demands volumetric apparatussuch as; burette, pipette, conical flask, burette stand, etc.The procedureto perform this experimentis described in the Secondary Level NCERT Science Textbookas follows:



- Take about 2 mL of dilute NaOH solution in a test tube and add two drops of phenolphthalein solution.
- What is the colour of the solution?
- Add dilute HCl solution to the above solution drop by drop.
- Is there any colour change for the reaction mixture?
- Why did the colour of phenolphthalein change after the addition of an acid?
- Now add a few drops of NaOH to the above mixture.
- Does the pink colour of phenolphthalein reappear?
- Why do you think this has happened?



Themethod is not feasible as it involves many glass wares such as burette, pipette, conical flask, etc. The proposed micro-scale kitis highly compact, easy to handle and economical as it was designed usinglocally available materials such as used syringes, injection veils and small quantity of the chemicals. The chemistry of the experiment is as follows:

The titration of a known volume of HCl with standard NaOH involves neutralisation reaction. Phenolphthalein indicator is generally used to find the end point of titration. Phenolphthalein is colourless in acidic medium,but turns pink colour in basic medium. When acid completely neutralised by base, a pale pink colour is produced indicating the end point. The reaction is represented by the following chemical equation:

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O$$

The results of this micro-scale experiment are in good agreement with the macro-scale experimental results as described in the NCERT Science Textbook.

3.4.Experiment 4: Preparation of Sodium Hydroxide by the Electrolysis of NaCl Solution

Industrial production of sodium hydroxide by the electrolysis of sodium chloride was described in the Secondary Level NCERT Science Textbook. Figure 13 illustrates the industrial production of NaOH by electrolysis process.

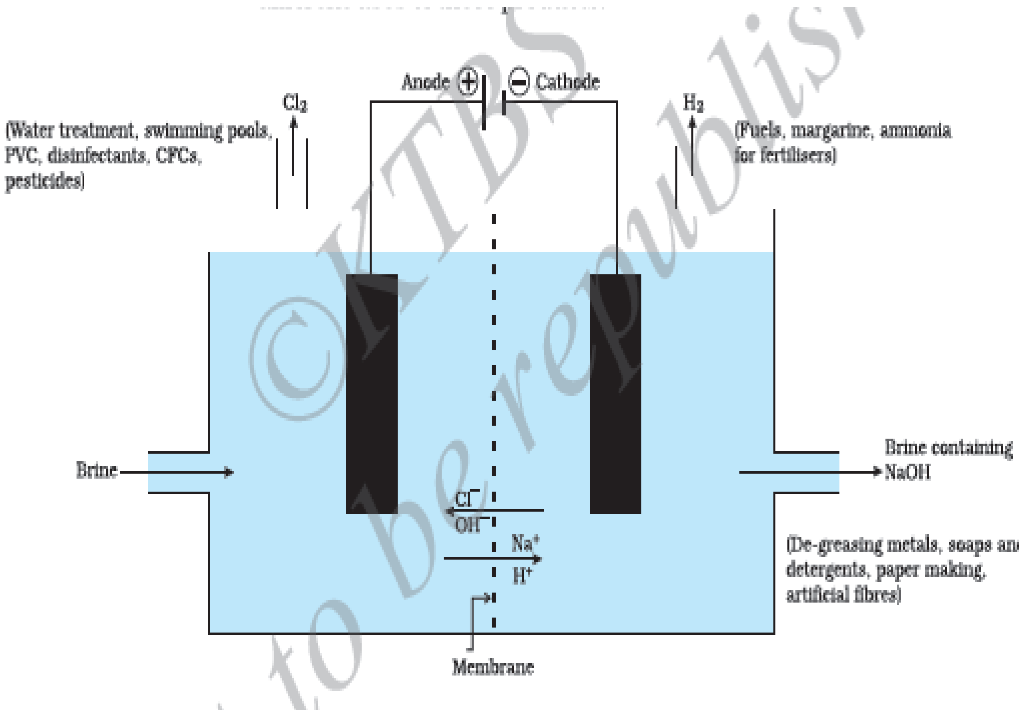


Figure 13:*Industrial production of NaOH by the electrolysis NaCl*

This experiment is difficult to demonstrate as it is involves more time to set up the apparatus. Hence,the preparation of sodium hydroxide can be effectively demonstrated using thedeveloped micro-scale kit. The chemistry of the experiment is as follows:

When electricity is passed through an aqueous solution of sodiumchloride (brine), it gets electrolysed to form sodium hydroxide.Chlorine gas is given-off at the anode, and hydrogen gas at the cathode.Sodium hydroxide solution is formed at the cathode, and there by changes the colour of phenolphthalein indicator from colourless to pink. The reaction is represented by the chemical equation: $2NaCl_{(aq)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + Cl_{2(g)} + H_{2(g)}$.The results of this micro-scale experiment are in good agreement with the macro-scale experimental results as described in the NCERT Science Textbook. Thus, this micro-scale kit proves to be an effective tool to understand the basic principles involved in electrolysis of NaCl.

3.5. Experiment 5: Burning of Magnesium in Air (Redox Reaction)

Redox reaction was described with the following example in the Secondary Level NCERT Science Textbook. Burning of magnesium in air is an example for redox reaction. Figure 14 shows an arrangement of the apparatus for burning magnesium in air.

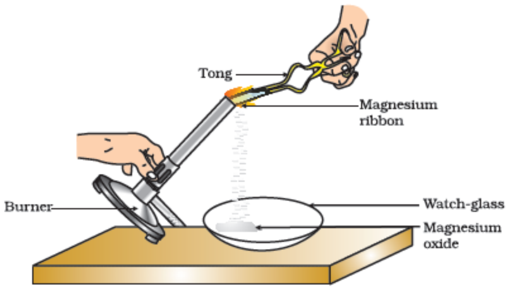


Figure 14:*Burning of magnesium in air*

The auto ignition temperature of Mg metal is 744 K. A candle flame shouldn't be used for igniting the magnesium metal as the smoke produced by the candle forms a protective layer on the metal. This activity requires LPG Bunsen burner,which is generally not available in most of the schools. Hence, burning of magnesium can be effectively demonstrated using the developed micro-scale kit. The chemistry of the experiment is as follows:

Whenmagnesiumis ignited using burning sparkler, it undergoes air oxidation and burns with brilliant white light to form the magnesium oxide. The reaction is represented by the chemical equation: $2Mg + O_2 \rightarrow 2MgO$. The results of this micro-scale experiment are in good agreement with the macro-scale experimental results as described in the NCERT Science Textbook. Thus, this micro-scale kit proves to be an effective tool to demonstrate the burning of magnesium in air.

3.5.Experiment 6: Double Displacement Reaction

A double displacement reaction is a type of chemical reaction where two positive and negative ions of the two reactants switch their places and form two new compounds. This reaction was explained in the NCERT Science Textbook with the following example:

$$BaCl_{2\,(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_4\downarrow + 2NaCl$$

Barium chloride reacts with sodium sulphate to yield a white precipitate of barium sulphate.Figure 15 shows how to perform a double displacement reaction.

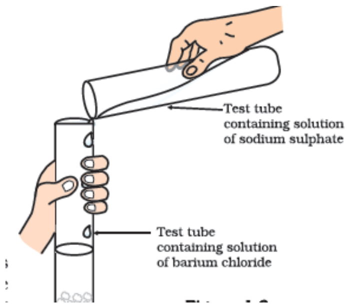


Figure 15:*Double displacement reaction*

A micro-scale kit was developed for the quick and eye-catching demonstration of double displacement reaction. The micro-scale kit covers not only double displacement,but also the Graham's law of diffusion.The chemistry of the experiment is as follows:

Lead nitrateand potassium iodide undergo ionisation in aqueous medium to form ions and these ions in turn diffuse and switch their places to form golden yellow precipitate of lead iodide and potassium nitrate. Since lead ions being heavier diffuse slowly and golden yellow precipitate of lead iodide is formed near lead nitrate. The reaction is represented by the chemical equation:$2Kl + Pb[NO_3]_2 \rightarrow 2KNO_3 + PbI_2\downarrow$

The results of this micro-scale experiment are found to be more clear and convincing than the results described in NCERT Science Textbook. Thus, this micro-scale kit proves to be an effective tool to demonstrate the double displacement reaction as well as Graham's law of diffusion.

3.7.Experiment 7: **Formation of Hydrogen Gas by the Action of H_2SO_4 on Zinc**

The experimental set up for the formation of hydrogen gas by the action of dilute sulphuric acid on zinc metal was illustrated in the Secondary Level NCERT Science Textbook as shown in Figure 16.

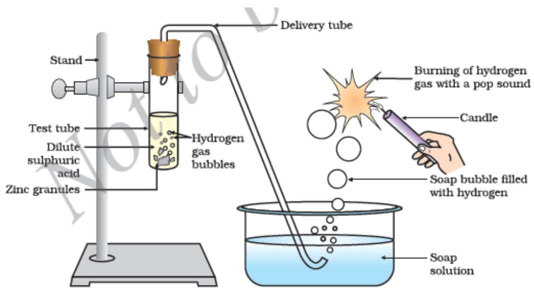


Figure 16:*Formation of hydrogen gas by the action of dil.H_2SO_4 on zinc*

The experimental procedure presented here is time consuming and demands more equipment. Lack of laboratory equipment in schools restricts the demonstration. Hence, a micro-scale kit wasdeveloped, which is cost effective and safe to use. Thereaction can be performed in atablet wrapper (blister pack) at micro-scale to avoid explosion of highly flammable hydrogen gas. The chemistry of the experiment is as follows:

Zinc being more electropositive than hydrogen, displaces hydrogen gasfrom dilute sulphuric acid and is represented as: $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$.The liberated hydrogen is collected in a test tube by the downward displacement of air. When hydrogen gas is ignited using a glowing splint, it burns with a pop sound.The pop sound is due to small explosion caused by the burningof hydrogen.

The results of this micro-scale experiment are in good agreement with the macro-scale experimental results as described in the NCERT Science Textbook.Thus, this micro-scale kit proves to be an effective tool to demonstrate the formation of hydrogen gas by the action of dilute sulphuric acid on zinc.

3.8. Experiment 8: Liberation of Carbon Dioxide Gas during Respiration in Human Beings

An experiment to demonstrate liberation of carbon dioxide gas during the respiration in human beingsis described in the Secondary Level NCERT Science Textbook. Figure 17 shows how to perform this experiment.

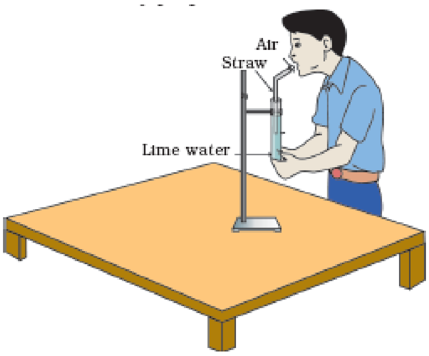


Figure 17:*Demonstration of liberation of carbon dioxide during respiration*

The overall reaction mechanism of aerobic respiration involves the oxidation of carbohydrate and the subsequent production of CO_2, H_2O and energy. To demonstrate theliberation of carbon dioxide during respiration, the exhaled air is bubbled through lime water. Lime water (calcium hydroxide) reacts with carbon dioxide to form calcium carbonate and thus, it turns lime water milky.

The reaction is represented as: $CO_2 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O$

This experimental procedure has the following disadvantages:

- Lime water becomes milky when it is exposed to air.
- Fresh lime water is required for the test that may not be readily available in the lab.

To overcome these disadvantages, a micro-scale kit was developed.In this micro-scale kit universal indicator was used in place of lime water. Universal indicator gives green colour in neutral medium, but gives yellow colour in acidic medium. Carbon dioxide present in exhaled air dissolvesin water to form an acidic solution and therefore indicator changes its colour from green to yellow.The reaction as: $CO_2 + H_2O \rightarrow H_2CO_3$

The results of this micro-scale experiment are found to be more clear and convincing than the results described in the NCERT Science Textbook. Thus, this micro-scale kit proves to be an effective tool to demonstrate the liberation of carbon dioxide during respiration.

3.9. Experiment 9: Photochemical Reaction

Figure 18shows photochemical reaction of silver chloride as illustrated in the NCERT Science Textbook. The photochemical reaction is a chemical reaction initiated by the absorption of energy in the form of light. Silver chloride on exposure to light turns black due to the formation of metallic silver. The reaction is represented by the chemical equation: $2AgCl_{(s)} + \text{Sunlight} \rightarrow 2Ag_{(s)} + Cl_{2(g)}$

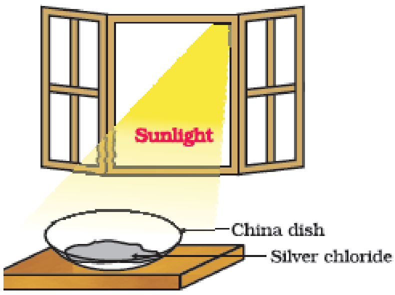


Figure 18: *Photochemical reaction of AgCl*

A micro-scale kit was designed to effectively demonstrate the photochemical reaction. In the experiment, silver chloride is directly exposed to sunlight whereas in the micro-scale kit silver chloride is produced *in situ* using silver nitrate and sodium chloride solution which is more economical and convenient too. The chemistry of the experiment is as follows:

1ml of 0.1M silver nitrate solution is mixed with 1 ml of 0.1M sodium chloride solution to form white curdy precipitate of silver chloride. The precipitate is filtered-off, dried and exposed to sunlight. The reaction is represented by the chemical equation:

$$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$$

$$2AgCl_{(s)} + \text{Sunlight} \rightarrow 2Ag_{(s)} + Cl_{2(g)}$$

The results of this micro-scale experiment are similar to the results described in the NCERT Science Textbook. Thus, this micro-scale kit proves to be an effective tool to demonstrate the photochemical reaction of silver chloride.

3.10. Experiment 10: Preparation and Properties of Chlorine

Preparation of chlorine gas by the action of dilute hydrochloric acid on manganese dioxide was documented in the Secondary Level NCERT Science Textbook. Figure 19 shows this experiment. Chlorine is evolved when manganese dioxide powder is heated with hydrochloric acid according to the reaction given below:

$$MnO_{2(s)} + 4HCl_{(aq)} \rightarrow MnCl_{2(aq)} + Cl_{2(g)} + H_2O_{(l)}$$

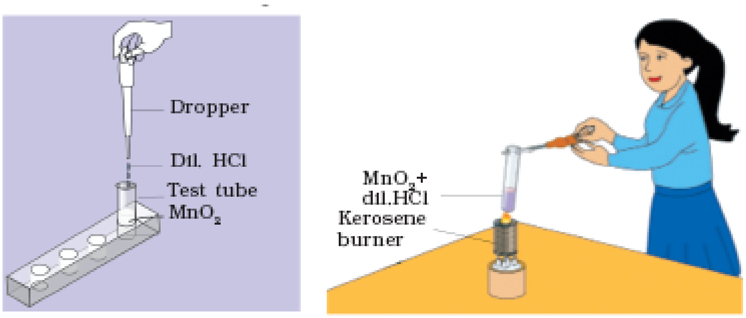


Figure 19:*Preparation of chlorine*

The experiment involves liberation of chlorine gas which is highly toxic. Hence, it is advised to carryout the reaction in a closed system to reduce the risk of inhalation. To address these challenges, a safer micro-scale kit was developed.The chemistry of the experiment is as follows:

The *in situ* chlorine gas diffuses and reacts with other chemical reagents in the petri dish. The pink colour of the phenolphthalein disappears since NaOH undergoes neutralisation by Cl_2; $AgNO_3$solution truns milky white due to the formation of AgCl;the mixture of KI and starch droplet turns blue due to the displacement of iodine by chlorine. The reactions are represented by the following chemical equations:

$$MnO_{2(s)} + 4HCl_{(aq)} \rightarrow MnCl_{2(aq)} + Cl_{2(g)} + H_2O_{(l)}$$

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O$$

$$AgNO_3 + HCl \rightarrow AgCl + HNO_3$$

$$Cl_2 + 2KI \rightarrow 2KCl + I_2$$

This micro-scale experiment not only effectively demonstrates the preparation of chlorine but also the chemical properties of the chlorine, such as reaction of chlorine with NaOH, KI and $AgNO_3$in a single step.

4. Conclusions

Most of the secondary school science teachers in India face difficulty in demonstrating chemistry experiments due to lack of well-equipped labsand time constraints.

These micro-scale chemistry experimental kits developed could be used to perform the regular chemistry experiments without any hassles in the class rooms. Hence, the micro-scale kits are found to be useful, and allow doing more experiments in less time. Further, these kits are eco-friendly, provide better safety, reduce preparation time and help teachers to demonstrate the experiments during classroom teaching and there by encourage learning by doing.These micro-scale chemistry kits havealready inspired many Indian secondary school science teachers to deliver exciting and engaging chemistry lessons.

Figure 20: *Portable mobile micro-scale chemistry kit*

Acknowledgement

The authoris grateful to the Royal Society of Chemistry for giving an opportunity to work as a teacher developer for the project ‘RSC-YH Inspirational Chemistry Programme’ in India. The author expresses his deep gratitude to Dr.YusufHamied, Chairman of Cipla, for supporting the programme.The author remains thankful to the Chairman, Principal, faculties of S.V.M.Arts, Science and Commerce College Ilkaland Dr.M.Y. Kariduraganavarfor their guidance and encouragement.

References

David Pterson (2017), Making practical work more effective, Education in Chemistry.

Eighth All India School Education Survey (2016, January), A Concise Report,National Council of Educational Research and Training, ISBN 978-93-5007-764. http://www.rsc.org/learn-chemistry/resource/res00000722/extraction-of-iron-on-a-match head

National Policy on Education (2016), Report of the Committee for Evolution of the New Education Policy, Ministry of Human Resource Development, Government ofIndia.

PritiChaudhari (2016, January), Secondary Education in India: Issues and Concerns International Journal of Social Science and Humanities Research, 4, 300-305.

Royal Society of Chemistry (2014), The particle nature of matter, Teacher book.

World Population Prospect (2017, September), United Nations Department of Economics and Social Affairs, Population Division,Retrieved fromESA.UN.org.