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## SCIENCE CURIOSITIES CABINET AND THE CHEMICAL SHOWCASE

**Abstract:** With the drastic reduction of the school chemistry teaching program in England in 1986, large quantities of apparatus and chemicals became redundant. The disused apparatus at Highgate School inspired the construction of a chemical showcase for pupils; this has encouraged pupils to develop a passion for chemistry. The idea of a “miniature museum” came from a visit to a local primary school in London, which had a beautiful science curiosities cabinet in one of its rooms. In both schools, sciences thrive, and are popular among pupils. Undoubtedly a display of assorted artefacts, which can be readily accessed by pupils, makes a significant impact on developing their interest in science. It is hoped that the story of these ventures will inspire teachers to make their own versions of these excellent and easily constructed educational facilities.

**Keywords:** chemistry education, history of chemistry, experiment, showcase/cabinet

### Historical introduction

Exhibitions of interesting artefacts, for children and for adults alike, are as old as humanity itself. Their universal aim is to arouse curiosity and to provide a springboard for education and enlightenment. Their contents can include natural specimens such as crystals, minerals, insects, stuffed animals or birds, animal bones, flowers, leaves, or man-made objects such as tools, coins, containers, fabrics, mechanisms, models, instruments, apparatus, machines.

The oldest museums date back to Babylonian times, some 2500 years ago. Small collections of interesting artefacts became popular in Europe from the 15<sup>th</sup> century onwards. They were known as galleries (from the Italian: *galleria*), cabinets (from the Italian: *gabinetto*) or ‘wonder rooms’ (from the German: *Wunderkammer*). Initially they were only available for their rich owners e.g. rulers, aristocrats, members of the merchant class or practitioners of science. The 16<sup>th</sup> and 17<sup>th</sup> centuries however, witnessed a period of rapid growth of public museums [1]. Today on a worldwide scale, thousands of museums house a myriad of fascinating and extraordinary exhibits.

Small institutions such as schools, or even private individuals, can nevertheless construct beautiful and useful collections which can serve the community [2]. This article describes two such successful ventures.

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## The changing picture of chemistry education

Teachers of chemistry are very fortunate, since their subject, more than any other in the school education program, lends itself to wonderful experiments involving spectacular colour changes, flames, bangs, bubbles, smoke and smells. Indeed, these phenomena define the very essence of chemistry, which is the science of substances and how they change into different substances. Every chemistry lesson has the potential to become a live theatre with the teacher in the main role, the chemical apparatus and reagents as the props, and the pupils the audience.

Chemistry has been taught in schools throughout the world for two centuries and its teaching program has naturally changed during this period. These changes included deletions, upgrades or modernisations of the syllabus which were in keeping with scientific advances of the time, for instance the discovery of the periodic classification of the elements, the elucidation of the structure of the atom and theories of chemical bonding.

To make informed comments on changes in the chemistry teaching program of schools, it is useful to have an overview of national changes for all subjects in England during the past two centuries. The teaching programs naturally led to the acquisition of qualifications for pupils. The type of qualification which could be gained is summarised broadly as follows:

Before 1918 there was no coherent national program of education and universities set their own syllabuses and examinations which were taught in schools.

1918-1951 School Certificate, Higher School Certificate

1951-1986 O levels, CSE, A levels

1986-2023 General Certificate of Secondary Education (GCSE), A levels

## School chemistry textbooks 1841-1973

A review of school chemistry textbooks from the middle of the 19<sup>th</sup> century until the latter half of the 20<sup>th</sup> century gives some indication of the evolution of the teaching program. All these books went through many editions over a period of 20-30 years. Despite changes, they had several common features:

1. They were written by learned authors: experienced teachers or university lecturers
2. They contain a wealth of knowledge of chemical substances and their reactions
3. They contain descriptions and practical instructions for experiments, both demonstrations and those suitable for class exercises
4. They all contain an outline of the history of chemistry, mentioning the key personalities who laid its foundations

A small selection of these books is listed below, in chronological order of first publication:

Reid DB M.D., F.R.S.E. (Fellow of the Royal College of Physicians; Honorary Member of the Imperial Medico-Chirurgical Academy of St Petersburg; Lecturer in Chemistry). *Rudiments of Chemistry; with Illustrations of the Chemical Phenomena of Daily life, and An Introductory series of experiments for schools and academies.* Edinburgh: William and Robert Chambers. 1841, 165 pp.

Kemshead WB Dr. (Lecturer on Chemistry and Natural Science, Dulwich College, London; and Examiner in Chemistry, College of Preceptors, London). *Inorganic Chemistry: Adapted for Students in the Elementary Classes of the Science and Art Department.* London & Glasgow: William Collins, Sons, & Company. 1876, 187 pp.

Holmyard EJ, M.A., M.Sc., D.Litt., F.I.C. (Head of the Science Department, Clifton College, Examiner in Chemistry (Higher Certificate) to the Northern Universities' Joint Matriculation Board and formerly to the University of Bristol, Membre Correspondant du Comité International d'Histoire des Sciences). *An Elementary Chemistry*. Third Edition. London Edward Arnold & Co. 1934, 468 pp. (first edition: 1925).

Partington JR. M.B.E., D.Sc. (Professor of Chemistry in the University of London Queen Mary College). *A School Course of Chemistry*. Second edition. Macmillan and Co., Limited, London. 1936, 392 pp. (first edition: 1930).

Sutcliffe A. M.A., B.Sc. (Headmaster, The City School, Lincoln; formerly Senior Chemistry Master, Cambridge and County High School). *Elementary Chemistry*. J.M. Dent and Sons Ltd., Bedford St. London W.C.2. 1930, 376 pp.

Littler W. B.A., B.Sc. (Senior Science Master at Hele's School, Exeter) *Elementary Chemistry*. London, G. Bell and Sons Ltd, 1935, 440 pp. (first edition: 1931)

Heys HL. M.A. (Cantab) (Senior Chemistry Master Liverpool Collegiate School). *A New Introduction to Chemistry*. George G. Harrap & Co. Ltd., London Toronto Wellington Sydney. 1960, 410 pp. (first edition: 1945)

Holderness A. M.Sc., F.R.I.C. (Senior Chemistry Master at Archbishop Holgate's Grammar School, York) and Lambert J. M.Sc. (Formerly Senior Chemistry Master at King Edward's School). *A New Certificate Chemistry*. Heinemann, London Melbourne Toronto. 1961, 481 pp. (This was the present author's chemistry textbook at Latymer Upper School in 1964-1965.)

Undoubtedly no-one read these books from cover to cover. But, for those who were interested, a huge body of information and knowledge about chemistry was readily accessible.

There were also notable publications for teachers of chemistry. Their aim was to provide instructions for chemical demonstrations, which had always constituted a core ingredient of school teaching programs. Three of these are listed below - they too went through several editions over a period of three decades.

Newth GS. F.I.C., F.C.S. (Chemical Lecture Demonstrator in the Royal College of Science South Kensington). *Chemical Lecture Experiments*. New Edition. Longmans, Green, and Co., London, New York and Bombay. 1903, 347 pp. (first edition: 1892).

Fowles G. M.Sc., F.R.I.C., F.C.S. *Lecture Experiments in Chemistry*. Sixth edition. London, G. Bell & Sons Ltd., 1963, 634 pp. (first edition: 1937) [3].

Inns EG. B.Sc., L.R.I.C. (Formerly Deputy Headmaster, Dunsmore School for Boys, Rugby) and Marsden E., B.Sc., Ph.D., F.R.I.C., F.C.S. (Formerly Head of Chemistry Department, Dunsmore School for Boys, Rugby) *Ordinary Level Practical Chemistry*. Heinemann Educational Books, London. 1973, 357 pp. (first edition: 1965).

## Education revolution and its consequences

With the change from O levels to the GCSE program in 1986 came the greatest ever change in the education program and its method of teaching. This was a cultural revolution - 'throw out the old and replace it with new'. With this 'education revolution' of 1986, significant changes were made to the program of chemistry teaching, and its methodology. Examples of these changes included the following: the majority of the factual content of the syllabus (e.g. chemistry of the compounds of the metal and non-metal elements) was deleted and the vast majority of the chemical demonstrations, which had for centuries

constituted one of the highlights of pupils' chemical learning experience were also removed. Furthermore, the syllabus became so specific that teaching beyond it would be open to criticism by pupils, as not being relevant. All references to the history of chemistry, even the names of its founders, have disappeared. As an example of the ruthless elimination of teaching material, of the 266 experiments in Innes and Marsden's book, and of the 609 experiments in Fowles' book, only a handful remain today.

With this drastic cut in the teaching program, many experiments became obsolete, and vast stocks of complex and expensive chemical glassware were consigned to waste. The obsolete experiments have never re-appeared in any form in any teaching program at any level anywhere in the world. Yet these were frequently the best experiments from the point of view of chemical education, and visually the most spectacular. Now they have all gone - forever it would seem. Does this matter? Seemingly not, since chemistry continues to be one of the most popular school subjects among both pupils and teachers. Examination results are better than ever before. So, what about the *quality* of the chemical knowledge of the millions of successful pupils? What do they really learn about chemistry? Do they know what chemistry is, and why they learn it? Do they know where it has come from? Once again, does this matter?

Does it matter if a highly skilled eye surgeon or a brilliant chemical process engineer or a university professor of chemistry, all of whom will have achieved top grades in chemistry in their school examinations, might have virtually no knowledge of the wider scope of chemistry and chemical reactions? Or indeed, of the history of chemistry and the huge effort by millions of people throughout the ages to establish it as the highly respected discipline of science that has done so much for the benefit of mankind? Would they know, for example, that it took 2000 years to discover oxygen [4]? Would they care?

Is the purpose of chemistry education to teach pupils how to pass examinations, or is it to teach them to know some chemistry, to know why they learn about chemistry, and to recognise it as one of the greatest fields of human achievement?

## Inspiration

Three years ago, during a visit to Yerbury Primary School in Islington, London, I came across a most interesting exhibition in a classroom. It was a cabinet of scientific curiosities, which had been built by the staff of the school over a period of several years. Figure 1 shows the cabinet. It was inexpensive to produce, and, in Michael Delaney's (Science co-ordinator at Yerbury School) words: "is a combination of donations and loans. There are some rare elements, insects, human bones, scale model of the moon, Berlin mechanical heart, fossils, skulls, old technology etc. The rest of the cabinet is made up of the shortlisted entries to our Science Fairs from previous years."



Fig. 1. Science Curiosities cabinet at Yerbury School, London (courtesy of Michael Delaney)

Two years ago, during the Covid lockdowns, my observations and doubts mentioned above, combined with my discovery of the science curiosities cabinet at Yerbury School, prompted me to construct a chemistry showcase at Highgate School, where I have taught for 48 years. The inspiration was further fuelled by the fact that at Highgate, we were still in possession of significant amounts of obsolete apparatus. Furthermore, through my own experiments and school chemical lectures, I had acquired a considerable number of other interesting chemical artefacts.

Accordingly, the chemical showcase was constructed in May 2021. To accompany the showcase, I produced an illustrated catalogue, in which extensive notes are given on each exhibit. The purpose of the exhibits was to enlighten pupils and to inspire them to do chemical experiments. Figure 2 shows the chemical showcase in the chemistry corridor, and Figure 3 shows the contents of the showcase.

The showcase catalogue, especially written for pupils, is printed below.



Fig. 2. Showcase in corridor



Fig. 3. Showcase contents

## Chemical showcase

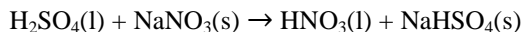
The inspiration for a chemical showcase came from the large number of interesting items of apparatus in the department. These have been used for teaching chemistry since the

early twentieth century. With new syllabuses evolving, much of this apparatus has become obsolete. Yet, the BEST chemical experiments can be done with it. The showcase additionally contains chemical exhibits, each with an interesting story behind it. You can do fascinating, and in some cases unique, experiments with all these exhibits, during chemistry club meetings. Most of the experiments require considerable manipulative skills and understanding - but you will receive all the necessary help and encouragement to achieve amazing results!

### 1. Retort flask



- (i) The glass retort flask is derived from early types of distillation apparatus which were used in Ancient Egypt, India, and China at least 3,000 years ago. This apparatus in its earliest form was made from clay, and in the Arabic world it was called an Alembic.
- (ii) A retort flask can be used to prepare fuming nitric acid and examine some of its reactions, which are quite dramatic. It is made from concentrated sulphuric acid and sodium nitrate:

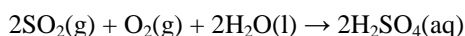
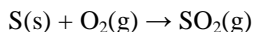


This is an interesting example of a displacement reaction, since the nitric acid, being more volatile, is displaced by the sulphuric acid. In another application, the retort flask is suitable for the destructive distillation of wood (pyrolysis). The liquid and gaseous products of this process, which consist of many components, can be burnt, and partially analysed.

### 2. Drechsel bottle



- (i) Heinrich Drechsel [1843-1897] was the German chemist who invented this apparatus [5]. Its purpose is to absorb, either chemically or physically, a gas which is bubbled through a liquid. For example, carbon dioxide (acidic) can be absorbed from a mixture of non-acidic gases by bubbling it through potassium hydroxide solution (alkaline).
- (ii) In this experiment, you will use a foot operated bellows to blow air over coal lumps which are heated in a combustion tube. This will cause the coal to ignite and burn. When coal is burnt, the sulphur in it (about 0.2 % typically, chemically combined) is oxidised to sulphur dioxide. This is an atmospheric pollutant which causes acid rain i.e. rain containing sulphuric acid.

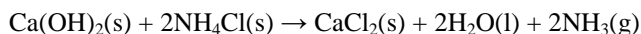


The second equation represents the atmospheric oxidation of sulphur dioxide in the presence of water vapour, to sulphuric acid. The products of the combustion of coal are bubbled through lime water, universal indicator and acidified permanganate solutions. These solutions are contained in Drechsel bottles. The spectacular colour changes which occur will verify that  $\text{CO}_2$  and  $\text{SO}_2$  are produced during the combustion of coal.

### 3. Absorption tower



- (i) As its name implies, the absorption tower is used to absorb something - in this case a gas, from a mixture of gases. In order for the apparatus to work efficiently, the solid absorbent should be in the form of small lumps which fill the tower from its neck upwards, and which are supported on a plug of loosely packed ceramic fibre.
- (ii) The **ammonia fountain** experiment is one of the most spectacular experiments in the school teaching repertoire. It demonstrates the great solubility of ammonia in water. Ammonia gas is generated by heating a mixture of solids: calcium hydroxide (slaked lime) with ammonium chloride. The reaction proceeds in accordance with the equation:



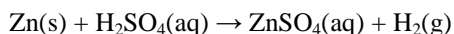


The water is produced as steam, and must be removed from the ammonia. Water vapour is separated from ammonia by passing the mixture through the absorption tower, which is filled with calcium oxide lumps, which act as a desiccant. The pure, dry ammonia is collected by upward delivery in an inverted 500 mL round bottomed flask which is fitted with a long glass tube with a nozzle. This is then used to make the fountain.

#### 4. Woulfe bottle



- (i) Peter Woulfe [1727-1805] was an Irish born chemist who invented this apparatus [6]. Its purpose was to allow a liquid into one side of the bottle, and a gas to pass out of the other side. In this manner a liquid could be reacted with a solid, contained in the bottle, to make a gas.
- (ii) In a unique experiment, the Woulfe bottle is used “back to front” to create a fountain [7]. A gas (air) is forced into the bottle from the top, and a liquid (water) is ejected from a nozzle in the side opening. Hydrogen is used in an ingenious manner with a porous pot (full of air) to create the fountain through the process of diffusion. The fountain occurs because hydrogen, being much lighter than air, diffuses much faster. The hydrogen is generated from a mixture of zinc and sulphuric acid in a separate flask, which is connected to the porous pot via a delivery tube:

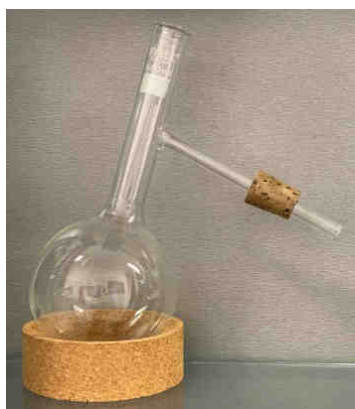


#### 5. Double walled condenser



- (i) Glassware manufacturing techniques evolved rapidly in Venice during the twelfth century. This resulted in the development of much magnificent apparatus which was exploited first by alchemists, and subsequently chemists. Justus von Liebig [1803-1873] was a German organic chemist [8]. His famous “Liebig Condenser” is still widely used in school chemistry teaching.
- (ii) The double walled condenser which you will use to purify muddy water, is much more efficient than the single walled version since a much larger surface area of condensing vapour is exposed to the cooling water.

## 6. Distillation flask

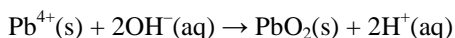


- (i) Chemical apparatus with ground glass joints - “Quickfit” - became popular in the 1970s. The principal reason was that it was quick and easy to assemble, and all the joints were gas tight. It was expensive, however. Today, many school experiments are conducted with this type of apparatus.
- (ii) The distillation flask with sidearm, which is used in conjunction with the double walled condenser to purify muddy water, was developed many centuries ago. You will try your skills with setting up the apparatus using corks instead of rubber bungs. Once the muddy water has been distilled, tests will be carried out to ascertain its purity.

## 7. Car battery



- (i) Although Alessandro Volta's [1745-1827] electrochemical cell heralded the arrival of a new form of stored energy, its main drawback was its irreversibility [9]. This meant that electric batteries quickly became discharged, and their ingredients were rendered useless. A great improvement was made by the French physicist Gaston Planté [1834-1889] who in 1860 invented the secondary (rechargeable) cell, consisting of lead and sulphuric acid [10]. It is extraordinary to think that his basic invention is still used today in cars! The home-made battery shown in the showcase illustrates the principle. It consists of 6 jam jars (cells) which contain 30 % sulphuric acid, and lead electrodes.
- (ii) A simple lead/acid cell is easy to make. It is charged by using a lab powerpack. You can observe some important chemical changes, measure the EMF of the cell, and use it to light a bulb. The chemistry of this reversible redox reaction is quite complex, but you will recognise the most important fact: the EMF is produced by the reaction between lead (grey) and lead dioxide (brown), and NOT, as it would appear, between two lead electrodes. Several equations are required to describe the electrochemical changes which take place. Some for charging and discharging the cathode, and some likewise for the anode. The essential feature of the chemistry of lead, which enables the recharging of the cell to occur, is its ability to exist in two oxidation states. One of these is Pb(II) in the  $\text{Pb}^{2+}$  ion, as in  $\text{PbSO}_4$ , lead sulphate. This is its more common metallic state. The other is Pb(IV), found in  $\text{PbO}_2$ , lead dioxide. To illustrate the complexity of the chemistry, just one process is simplistically described - the charging of the positive electrode, or anode. Its purpose is to explain how a layer of brown lead dioxide is formed on the lead cathode, when it is initially charged. When lead is placed into sulphuric acid, it becomes coated with a microscopically thin layer of solid lead ions,  $\text{Pb}^{2+}$  into the solution. When a charging current is applied, electrons are lost from the  $\text{Pb}^{2+}$  ions, and they are oxidised to the +4 (IV) state.  $\text{Pb}^{2+} \rightarrow \text{Pb}^{4+} + 2\text{e}^-$ . The Pb(IV) then reacts with hydroxide ions which are present (from water), to form lead dioxide and hydrogen ions:

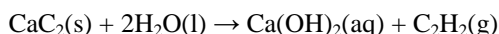


The battery in the showcase has 6 cells, so it will give 12 volts when charged. This will be enough to light a car lightbulb.

## 8. Carbide lamp



- (i) For thousands of years artificial illumination was achieved by the combustion of various oils - plant, animal and mineral. With the development of our understanding and manipulation of gases, towards the end of the 18<sup>th</sup> century, new options arose for illuminants. A spectacular success was achieved with the gas acetylene (C<sub>2</sub>H<sub>2</sub> - an unsaturated hydrocarbon), which could be easily produced, and which gave a flame of great luminosity. This was exploited during the first decades of the 20<sup>th</sup> century for cars and bicycles. The carbide lamp on display is a wonderful example of elegance and functionality. It was manufactured in about 1930 and served as a bicycle lamp.
- (ii) An experiment can easily be done to make acetylene from calcium carbide and water, and to investigate its properties. The equation for the reaction is:

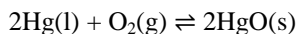


Acetylene is very reactive. In the carbide lamp, water is slowly dripped on to calcium carbide to produce acetylene, and this is ignited at a jet which protrudes from the middle of the reflector.

## 9. Mercury/mercuric oxide



- (i) One of the greatest triumphs of experimental chemistry was the elucidation of the modern theory of combustion by the French chemist Antoine Laurent Lavoisier [1743-1794] [11]. He was guillotined during the French Revolution. The key chemical phenomenon which enabled Lavoisier to arrive at his theory was the reversible oxidation of mercury:



When mercury is heated in air at about 300 °C for several days, it becomes coated with a layer of an orange powder - mercuric oxide. When mercuric oxide is heated for a few minutes at about 500 °C, it decomposes to give mercury and oxygen. The result of this experiment is shown in the boiling tube which is exhibited.

- (ii) You will be able to conduct this decomposition reaction yourselves and collect the oxygen which is released. A great challenge will be to see how many times you can get it to relight a glowing splint.

## 10. Copper sulphate pentahydrate



- (i) Crystals have always fascinated people on account of their shiny appearance and flat angled faces. That is one of the reasons why we make them in school experiments. The large crystal shown here has many imperfections. It was grown by AZ Szydlo while he was a pupil at Latymer Upper School, during the years 1963 to 1968 and weighs 1.536 kg. The beautiful smaller crystals on display were grown by Chemistry Club pupils - Amy Szigeti, Amy Walpole, Emanuelle Twentyman and Izzy Rei during the academic year 2012-2013. The study of crystals by great scientists such as Louis Pasteur [1822-1895] and Lawrence Bragg [1890-1971] has enabled us to make advances in our understanding of the structure of matter, and the nature of chemical processes.
- (ii) You will be given instructions on how to grow large crystals of copper sulphate and other compounds such as the double salts potash alum and chrome alum. Large crystals are best grown from a saturated solution which is slowly allowed to evaporate at a constant temperature in a dust free atmosphere. To grow such crystals requires a lot of time and patience.

## 11. Potassium nitrate



- (i) Potassium nitrate, also known as nitre, is one of the most important compounds in the history of chemistry. It forms the main ingredient of gunpowder, which was invented

by the Chinese about 1,000 years ago, has widespread use as a chemical fertiliser, and played a key role in the story of the discovery of oxygen. [12] During the past few centuries, potassium nitrate has been manufactured by natural processes, involving the nitrogen cycle, on an industrial scale. India was the leading exporter of nitre for much of this time. It is quite easy to grow large orthorhombic crystals of potassium nitrate from a saturated solution. The crystal shown here is one of many which were formed by allowing 1 litre of saturated  $\text{KNO}_3$  solution at  $45\text{ }^\circ\text{C}$  to cool down to  $18\text{ }^\circ\text{C}$  overnight.

- (ii) When potassium nitrate is heated to about  $350\text{ }^\circ\text{C}$  it decomposes in accordance with the equation:



The resulting solid is potassium nitrite. On account of the ready availability of oxygen from potassium nitrate, it is an oxidising agent. Hence its use in gunpowder, which was developed empirically (i.e. trial and error) and not on the basis of chemical research. The purpose of a short project will be to make crude gunpowder, which was known to the Ancient Chinese as serpentine powder. This contains 75 % potassium nitrate by mass. You will be able to measure its rate of combustion - also known as deflagration.

## 12. Bituminous coal

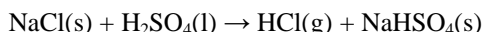


- (i) The composition of bituminous coal is variable - it depends on the locality from which it has been mined. Typically bituminous coal has a carbon content of about 80 %. Most of the rest consists of high molecular weight hydrocarbons, and some nitrogen and sulphur containing compounds. Coal has been used for thousands of years as a fuel. Since the middle of the 19<sup>th</sup> century, with a rapid growth in our understanding of organic chemistry, coal became an important source of aromatic organic compounds.
- (ii) Destructive distillation experiment. You will heat powdered coal lumps in the absence of air, collect the condensed vapours of the decomposition of the coal, and ignite the gas which is produced. The condensed vapours constitute coal tar, which has provided a remarkable source of industrial organic chemicals since the latter half of the 19<sup>th</sup> century. The gas produced consists mainly of a mixture of hydrogen, methane and carbon monoxide. It burns with a luminous smoky, smelly flame.

### 13. Rock salt - sodium chloride



- (i) Although sodium chloride (NaCl, common salt) is the most widely distributed ionic compound on Earth, in sea water, extensive deposits are also found underground in the solid state. It has been mined for over 7000 years and is today extracted in many countries across the world. These include Canada, Pakistan, Romania, and Chile. The oldest active mine is in Hallstatt near Salzburg (German: “salt mountain”) in Austria. The Wieliczka salt mine in Poland, from which these sample were obtained, was continuously in operation from 1292 until 2007. Both mines are UNESCO World Heritage sites and attract large numbers of visitors every year. In England, salt is mined in Cheshire and Worcestershire, which have large underground deposits.
- (ii) “Salt gas” experiment. Salt reacts with concentrated sulphuric acid to make hydrogen chloride gas.



This is very soluble in water (solubility coefficient at 20 °C is 400) in which it dissolves to make hydrochloric acid. You will have the opportunity to make this gas, collect it by downward delivery, and to see its spectacular reaction with ammonia. In a separate experiment you will be able to determine the concentration of chloride ions (almost entirely from NaCl) in seawater from Mauritius (Indian Ocean). To achieve this, the seawater is titrated with standard silver nitrate solution, using chromate indicator. This experiment can then be repeated for seawater from Brighton, the results can be compared and discussed.

### 14. Portland limestone

- (i) Limestone is a sedimentary rock and is one of three important minerals which are composed mainly of calcium carbonate. The other two are chalk (sedimentary) and marble (metamorphic). It has been excavated continuously from Portland, an island just off the coast in Dorset, south England since Roman times. Portland lies on the famous Jurassic Coast, which is some 200-140 million years old. A fossilised sea creature is clearly visible on our sample. This stone is highly valued for its beautiful appearance, and was used for the construction of Buckingham Palace, St Paul’s Cathedral, and the Cenotaph in Whitehall, among numerous splendid buildings around the world. The main component of limestone is calcium carbonate, CaCO<sub>3</sub>, with small amounts of impurities such as silica (sand), SiO<sub>2</sub>.



- (ii) By weighing a crushed sample of limestone and reacting it with a known excess of hydrochloric acid, it is possible, by back titration, to establish the percentage of calcium carbonate in the sample.



A flame test can then be conducted on the resultant solution (suitably concentrated by evaporation), using a direct vision spectroscope. This will verify the presence of calcium ions.

### 15. Synthetic organic dyes



- (i) In 1856 a schoolboy from City of London School, William Perkin [1838-1907] accidentally made a discovery which was to revolutionise the dyestuffs industry [13]. He was trying to synthesise quinine (used in the treatment of malaria) in his home laboratory but ended up by producing a substance with an intense mauve colour. One of his starting ingredients was the aromatic compound, aniline  $\text{C}_6\text{H}_5\text{NH}_2$ , which was extracted from coal tar. In the reaction which occurred, a compound containing the chromophoric group  $\text{N}_2^+$  was produced. Subsequently aniline dyes with different colours were developed. These were manufactured cheaply on a large scale and had



an enormous effect on the world of fashion. Three aniline dyes are displayed in the showcase.

- (ii) A bright orange dye can be synthesised in a reaction which is known as diazotisation. Careful temperature control will be necessary in order to keep the temperature of the reaction solutions below 10 °C. If you succeed, you will be able to dye a piece of white cotton cloth orange, and this will be displayed in the showcase.

## 16. Chemical garden



- (i) Waterglass, which has been in use for many centuries as an egg preserver, consists of a syrupy solution of sodium silicate. In 1645 the German-Dutch alchemist/chemist/chemical technologist Rudolph Glauber [1604-1670] first observed that strange plant-like growths occur when certain salts are dropped into a viscous liquid, today known as sodium silicate. The explanation for these growths is based on the phenomena: chemical reaction, osmosis and pressure variation with depth in a liquid. Different colours can be obtained by using the salts of transition metal compounds.
- (ii) You will be able to make your own chemical garden and observe how rapidly it grows. A more advanced experiment involves the formation of a semipermeable membrane of copper ferrocyanide in a porous pot, and using this to investigate the relationship of osmotic pressure with concentration for sucrose solutions of varying concentrations.

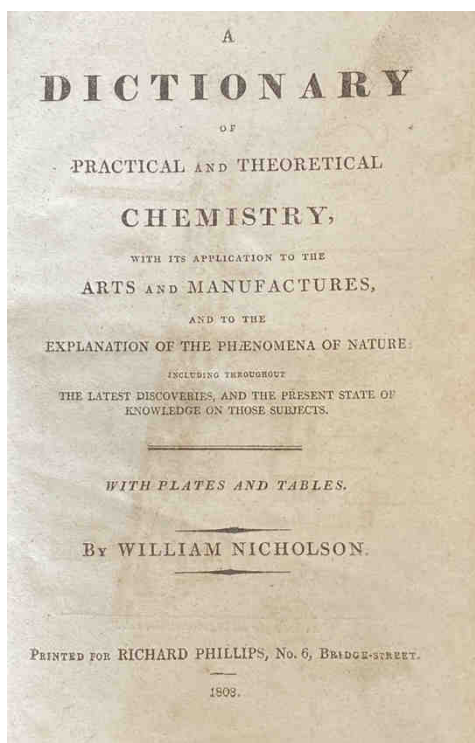
## 17. Rhubarb leaf

- (i) There are a small number of foods which we consume, which are edible and nutritious, but which contain poisons. One of these is rhubarb. Eating rhubarb leaves will cause severe gastric upsets and numerous other effects, since they contain oxalic acid,  $(\text{COOH})_2$ , which is toxic. Kidney stones, which are very painful, are caused by accumulation of calcium oxalate. 10 g of this acid is enough to cause death in adults. Spinach, sorrel, parsley and chives also contain oxalic acid.



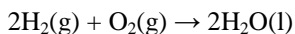
- (ii) Oxalic acid can be extracted from fresh rhubarb leaves by grinding/crushing them with water, then rinsing, collecting the washings, and filtering. From a known mass of rhubarb leaves, it will be possible, using acid-base titration, to determine the % of acid in the leaves. From this value, you can calculate the weight of rhubarb leaves that would have to be consumed, to constitute a fatal dose.

**18. *A Dictionary of Practical and Theoretical Chemistry* William Nicholson, 1808**

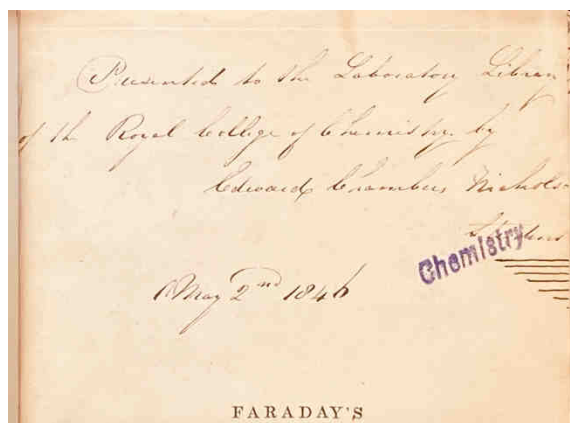


- (i) This is one of the earliest dictionaries of chemistry. It is very rare! What is of particular interest is that its author, the renowned English chemist William Nicholson [1753-1815] [14], was the first person to electrolyse water (1800), identify the gaseous products as hydrogen and oxygen, and show that water is therefore a compound of these two gases. The same experiment is today still conducted in schools around the world. Year 8 at Highgate!
- (ii) In the section under gases, Nicholson writes that “The chief use of hydrogen gas is for the purpose of filling air balloons”. Note the two words with different spellings from those of today. Hydrogen had been formally identified and characterised only 4 decades earlier, by Henry Cavendish [1731-1810], who was still alive when this book was published. And yet it was already being produced on a vast scale to fill balloons - but not the latex balloons which we use for parties today. (These were invented by Michael Faraday in 1824 - for filling them with hydrogen for his audiences of children at the Royal Institution. His world-renowned Christmas lectures were instigated in 1825.) The balloons of the late 18<sup>th</sup> and early 19<sup>th</sup> centuries flew high above the clouds and carried people. It is extraordinary to consider that just over two centuries after the first manned flight in balloons, today, using rockets with liquid hydrogen fuel, we have landed a robot on Mars, which is sending back much information about this planet!

Using a specially invented simple apparatus you will be able to make hydrogen (using zinc and sulphuric acid), to fill rubber balloons with it, and observe its chemical and physical properties, just as Michael Faraday did in 1824. This, of course, will involve the combustion of hydrogen:



### 19. *Chemical Manipulation*, Michael Faraday, 1842

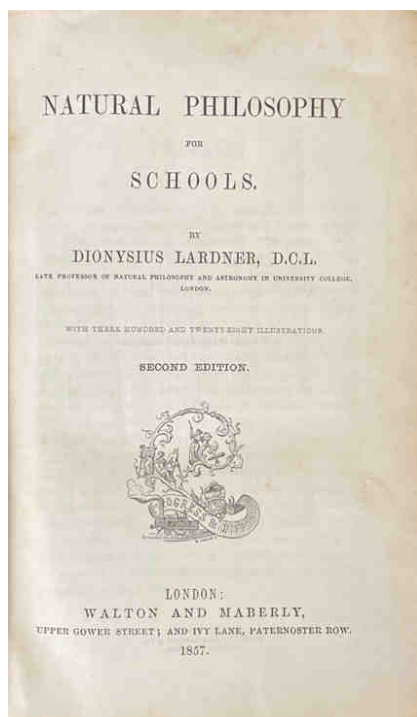


- (i) Michael Faraday [1791-1867], who had very little formal education, was one of the greatest scientists of all time [15]. Not only did he invent the electric motor and dynamo, but he also did much research into physics and chemistry, and published several hundred scientific papers. He also kept a diary of his work. He was a brilliant experimenter and teacher. He is buried close to Highgate School, in Highgate Cemetery. *Chemical Manipulation* is the only book which he wrote. In it he describes

1714 chemical procedures, which are suitable for students of chemistry. The photograph of part of the title page shows that this book was donated to the Royal College of Chemistry on May 2<sup>nd</sup>, 1846, by Edward Chambers Nicholson, who lived in the Strand. Look at his beautiful, ordered handwriting! The Royal College of Chemistry had been founded a year earlier in 1845 and had its base in Oxford Street. Its aim was to teach practical chemistry, so Faraday's book would have been a most welcome gift! Edward Nicholson [1827-1890] became a prominent industrial chemist, specialising in the manufacture of aniline dyes.

- (ii) An experiment which can easily and effectively be done is to make red cabbage indicator. The indicator itself is wonderful - giving 5 distinct vivid colours (red, yellow, green, blue, violet) for 5 different levels of acidity/alkalinity. Its drawback is that it decays over the course of a few days, emitting a foul odour and losing its property of acting as an indicator. Faraday's Manipulation no. 618 on page 275 describes a much-improved method for making red cabbage indicator. You can put Faraday to the test, by making red cabbage indicator using his method, and checking to see whether it lasts much longer, as he claimed!

**20. *Natural Philosophy for Schools*, Dionysius Lardner, 1857**



- (i) Dionysius Lardner [1793-1859] was an extraordinary character. He was born in Ireland but subsequently lived in London (where he was Professor of Natural Philosophy and Astronomy at University College London University from 1828-1831), Paris, and Naples, where he died. He was involved in scientific and personal scandals and was a great populariser of science. He wrote 29 books, among them a school science

- textbook! Can you imagine having one of your school science textbooks being written by a famous university professor?
- (ii) The world's first high explosive, nitrocellulose (guncotton) had been invented by the German-Swiss Professor of Chemistry, Christian Schoenbein [1799-1868] in 1845 [16]. Amazingly, only 12 years after its discovery, Lardner had already published detailed instructions for making guncotton, on page 69 of this book. How extraordinary to consider that if you had been a pupil at Highgate School in the 1860s, you would have been making this during your Natural Philosophy lessons. Now we have the book, the instructions, the ingredients, and even the chemical equations! And so, in the 2020s we are able to repeat experiments from the Highgate School syllabus of the 1860s!

## Evaluation of the Showcase project

Since its opening, this miniature museum has been admired by hundreds of pupils, visiting parents and members of staff.

What has given me the greatest source of satisfaction, however, is that pupils have actively engaged with the exhibits. At the fortnightly Friday evening meetings of Chemistry Society, which has been in continuous operation since 1972, a capacity gathering of 16 pupils, aged 12 to 17, enthusiastically undertake chemical experiments. Experiments which today are quite unique in terms of the manipulative skills required, and the subject matter covered. Surely no teacher can hope for more, than to have a “full house” of enthusiastic pupils for a society meeting on a Friday after school? Below are shown some examples of pupils' experiments:

How many rhubarb leaves would an adult have to eat to achieve a fatal dose?

Oxalic acid Ethane, Di-oxic acid

$$\begin{array}{c} \text{(COOH)}_2 \\ | \\ \text{COOH} \\ | \\ \text{COOH} \end{array} \quad \begin{array}{c} \text{COOH} \\ | \\ \text{C} - \text{OH} \\ | \\ \text{C} - \text{OH} \\ || \\ \text{C} - \text{OH} \end{array}$$

Step 1: Weigh the leaf  
 Step 2: Cut it and weigh  
 Step 3: Boil the leaf (400 ml beaker)  
 5-10 mins Use a glass rod to push leaves down to maximise acid extraction  
 Step 4: Filter off the leaf residue using tissue into a conical flask  
 Step 5: Use an alkali (Sodium Hydroxide) after diluting it 1:10 using 100 ml measuring cylinder.  
 Step 6: Use Phenolphthalein indicator only a few drops into the acid. The indicator is colourless  
 Step 7: pour the Dilute mixture in slowly  
 Step 8: Write all the stuff

① Mass of leaf  
 ② vol. of 0.025M required for neutralisation

Weight of whole leaf - 195.145

Fig. 4. Handwritten instructions



Fig. 5. Weighing a rhubarb leaf



Fig. 6. Preparing rhubarb leaf extract



Fig. 7. Crude titration



Fig. 8. Testing the speed of combustion of serpentine powder



Fig. 9. Mercury(I) nitrate crystals

Figure 4 shows handwritten instructions for an experiment to calculate how many rhubarb leaves would have to be eaten in order for an adult to achieve a fatal dose of oxalic acid. Figure 5 shows an ingenious method for weighing a whole rhubarb leaf. Figure 6 shows extraction of oxalic acid (and other soluble substances) from a piece of rhubarb leaf, by boiling it. Once the leaf had been boiled for a few minutes, the resultant liquor was filtered through a piece of folded kitchen roll - this works much more rapidly than filter paper. The filtrate, containing oxalic acid, was titrated in a crude experiment using a measuring cylinder with constant stirring, against 0.25 M sodium hydroxide solution. Phenolphthalein indicator was used. The titration is shown on Figure 7. Figure 8 shows members of the society watching a sample of serpentine powder (crude gunpowder) burning in a fume cupboard. Figure 9 shows crystals of mercury(I) nitrate, which had been obtained by allowing a solution of mercury(I) nitrate, prepared by reaction mercury with concentrated nitric acid, to evaporate over a few weeks.



## Concluding remarks

With a little creative thinking and effort, and without great expense, it is possible to create a miniature science museum that can inspire pupils. The presence of a teacher who interacts with the exhibits and with pupils is an important feature for success. Despite the significant effort which is required, this interaction will readily translate into the unquantifiable attributes of curiosity and enthusiasm, which are fundamental ingredients of a sound education.

## References

- [1] Alexander EP, Alexander M, Decker J. *Museums in Motion. An Introduction to the History and Functions of Museums*. Lanham, Boulder, New York, London: RowmanLittlefield; 2017. ISBN: 9781442278790.
- [2] Halford B. The Curiosity Cabinet Collection. *Chemical Eng News*. 2015;92(49). DOI: 10.1021/cen-09249-scitech2.
- [3] Jenkins E. Who were they? George Fowles (1882-1969). *School Sci Rev*. 2000;82(299):87-9. Available from: [www.ase.org.uk](http://www.ase.org.uk).
- [4] Szydło ZA. History of Fire. *Chem Didact Ecol Metrol*. 2019;24(1-2):23-43. DOI: 10.2478/cdem-2019-0002.
- [5] Sella A. Drechsel's bottle. *Chemistry World*. 2008. Available from: [www.chemistryworld.com](http://www.chemistryworld.com).
- [6] Sella A. Woulfe's bottle. *Chemistry World*. 2016. Available from: [www.chemistryworld.com](http://www.chemistryworld.com).
- [7] Hartley WN. *Air and its relations to life*. London: Longman's, Green, Co.; 1876. pp. 100-101.
- [8] Brock W. *Justus von Liebig, the Chemical Gatekeeper*. Cambridge: Cambridge University Press; 1997. ISBN: 9781114816411.
- [9] Szydło ZA. Chemical electricity. *Chem Didact Ecol Metrol*. 2021;26(1-2):5-29. DOI: 10.2478/cdem-2021-0001.
- [10] Desmond K. *Innovators of Battery Technology. Profiles of 95 Influential Electrochemists*. Jefferson, North Carolina: McFarland Company, Inc; 2016. pp. 167-71. ISBN: 9780786 499335.
- [11] Smartt Bell M. *Lavoisier in the Year One. The Birth of a New Science in the Age of Revolution*. New York, London: WW Norton Co; 2005. ISBN: 0393051552.
- [12] Kelly J. *Gunpowder. A History of the Explosive that Changed the World*. London: Atlantic Books; 2004. ISBN: 1843541912.
- [13] Garfield S. *Mauve: How One Man Invented a Colour that Changed the World*. New York, London: WW Norton Co; 2000. ISBN: 0393020053.
- [14] Gielas A. Turning tradition into an instrument of research: The editorship of William Nicholson (1753-1815). *Centaurus*. 2020;62:38-53. DOI: 10.1111/1600-0498.12283GIELAS53.
- [15] Day P. (compiler) *The Philosopher's Tree - Michael Faraday's Life and Work in his Own Words*. Bristol and Philadelphia: Institute of Physics Publishing; 1999. ISBN: 0750305711.
- [16] Brown GI. *The Big Bang. A History of Explosives*. Phoenix Mill, Stroud, Gloucestershire: Sutton Publishing Limited, 1998. pp. 122-8. ISBN: 075091923X.