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Between a Rock….Silicon Chemistry

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Between a rock and a hard place
The chemistry of silicon

Part A Silicon-based life - fact or fiction?

Activity 1 - Is silicon-based life possible?

Some undergraduates in the English department are taking a module on science fiction. A theme that they come across time and time again is silicon-based life forms. Some of these students are also taking a module in film studies and this same theme has arisen in some films that they have been researching. From their limited knowledge of chemistry they do not understand why such life forms could not theoretically exist. Their tutor has invited you to speak to them and to explain why nature is carbon-based and silicon-based life is best left to fiction.

Why do you think the idea of silicon-based life originally arose and is so popular? Make a list of possible reasons why silicon-based life might have been considered to be theoretically possible. Give reasons why silicon cannot be utilised to support life.

Prepare a written report of approximately two pages which presents your arguments against silicon-based life. Prepare a short presentation in a style which you could give in a seminar to the English students.

'A Martian Odyssey', Stanley Weinbaum
'Devil in the Dark', Star Trek, episode 26

Activity 2 - So what is silicon used for?

Your presentation goes down well with the students and they are interested to know what silicon is used for as they have heard of silicon chips of course. You can tell them that it is the second most abundant element in the Earth's crust, second only to oxygen and that silicon compounds are extensively distributed through the natural environment and have been utilised in ways that affect every aspect of our everyday lives.

Produce a list of naturally occurring forms of silicon bearing compounds and review the uses of silicon compounds in everyday life.

Part B From sand to glass

One of the major uses of silicon is in the manufacture of glass. The main raw material used for the production of glass is silicon dioxide, usually sand. The following article gives a brief history of the manufacture of glass through the centuries.

A potted history of glass.

Historians believe that glass has been around since around 5000BC when Stone Age man was thought to have used naturally occurring glasses for cutting tools. These were thought to be a form of glass called obsidian (aka hyalopsite, Iceland agate or mountain mahogany). According to ancient history the first people to discover glass were the Phoenicians who fell upon it accidentally whilst cooking. Their cooking pots were placed upon blocks of nitrate on the sand and with the intense heat of the fire an opaque liquid was formed.

The earliest man-made glass is thought to have dated to around 3500 BC where they were used for glazes on cooking pots. The oldest glass made for ornamental purposes was found around 1600 BC in Mesopotamia. Although, recent evidence has suggested that the Greeks and the Chinese were also making glass.

It was soon after these events that the ancient Egyptians began to develop methods of glass production (~1500BC). Glass making then began to develop and around 650BC the first glass making manual was written. It was not until the time of Christ that a major breakthrough in glass development was that of glass blowing which incidentally has not changed very much to this date. This allowed the hollow substance to be formed inside various moulds, thus increasing the number of different shapes available.

The Romans did much to spread glass-making technology with the conquests that were made by their armies. It was the Romans who first developed glass that was clear. It was soon after this that glass began to appear in all of the luxurious buildings within Rome.

Glass technology did not develop much until the Middle Ages when due to the problems with obtaining raw materials the glass started to differ. The Italians still added soda ash to their glasses and countries north of the Alps began to add potash. Venice was considered to be the glass making centre of Europe to well into the 16th century with many new techniques being discovered. The glass industry was so big that nearly half of the population upon the island of Murano was involved in one way or another with the production of glass.

Then in 1674 an Englishman by the name of George Ravenscroft changed the way of fine glass production. In this year he patented his new glass which contained a high level of lead oxide. This produced a brilliant glass with a very high refractive index that was well suited to deep cutting and engraving. Later on in the late 17th century the French developed a method for rolling out glass and placing a highly reflective surface to the back and thus creating the worlds first glass mirror. It was about this time that the French began trying to import the Venetian craftsmen to their country. This was net with stiff resistance from the Venetians with death threats being issued to any Venetian giving away their trade secrets. The French in turn offered the Venetian workers incentives such as exemption from taxes.

The automated production of glass did not appear until late into the industrial revolution. A key figure in modern Glass research was a German scientist by the name of Otto Schott (1851-1935). He was the first to use scientific methods to study the effect of chemical elements on the optical and thermal properties of glass.

A number of different methods of production were then developed over the coming years such as the Forcault method, the Pittsburgh process and the so-called float process.

Glass has been around for many thousands of years and the development of specialised glasses such as safety glass, bullet-proof and solar panels are still ongoing.

Reference.

1. www.glassonline.com

Activity 3 - How much sand in a desert?.

The Sahara desert is the largest desert in the world and is situated in the north of Africa. It stretches from the Atlantic Ocean to the Red Sea and finally ends near Iraq; it measures 3100 miles east to west and 1200 miles north to south.

Assuming that each grain of sand is cubic, each side is 0.5mm in length and that the sand depth is 10 feet, calculate the number of moles of sand grains in the Sahara Desert.

Activity 4 - Additives for specialist glasses

Answer the following questions on glass manufacture.

1. What is a glass and how is it formed?

2. What is the chemical structure of glass?

3. Many compounds can be added to the glass mixture in order to affect the quality of the final product. For example lead oxide (PbO) can be added to the molten glass mixture in order to increase the refractive index of the glass. List six different compounds that can be added to the formulation in order to change the properties of the glass.

4. What is meant by refractive index? Why is the refractive index so important in the manufacture of certain glass formulations?

Activity 5 - Card game

You are provided with a set of cards. The cards identify different types of glasses, compostitions, properties and applications. Group the cards so that each type of glass is defined by composition, properties etc.

Part C Silicon compounds in everyday life

Activity 6 - Investigating more applications of silicon

We have now looked in some detail at silicon in the formation of glass. Silicon is found in many different products that are used in everyday life. Your next task is to prepare a group poster presentation on the useful compounds of silicon. You will need to research the topic and present at your poster at the next session. Each group will be asked to describe their poster and answer questions. The posters will be assessed by other students.

Silica Gels.

These are extremely porous hydrated forms of silica that can absorb large amounts of water on their crystalline surfaces. Silica gel is used in many industrial applications; many you will have come across little packets of silica gels in goods they may have purchased.

Things to consider whilst preparing your presentation on silica gels:

(1) Structure.
(2) How they are made including equations and conditions.
(3) How they work.
(4) Applications.

Aerogels.

These compounds are very similar to silica gels; however they have a wide variety of uses such as thermal insulators and fire proof materials.

Things to consider whilst preparing your presentation on aerogels:

(1) How they are made including relevant equations and conditions.
(2) Structure.
(3) How they work. What is the chemistry behind them?
(4) Useful applications.

The chemistry of silicates.

There are many topics which consider silicates such as amphiboles, which include useful compounds such as talc and asbestos.

Things to consider whilst preparing your presentation:

(1) How are they made including equations and conditions?

(2) Structures.
(3) Toxicological problems (Blue and White asbestos).
(4) Applications.

The chemistry of aluminosilicates.

The applications of aluminosilicates are widespread, but are usually confined to zeolites. The industrial applications of zeolites include ion exchange, catalysis and adsorption agents.

Things to consider whilst preparing your presentation:

(1) How are they made including equations and conditions?
(2) Structures.
(3) How they work
(4) Applications.

The chemistry of ceramics.

Ceramics have widespread usage such as medical usage as tooth caps, bone tissue (artificial hips), crockery and as a potential bullet resistant material.

Things to consider whilst preparing your presentation:

(1) How they are made including equations and conditions of manufacture.
(2) Structures.
(3) How they work.
(4) Applications.

The chemistry of silicones.

These constitute a large number of polymeric materials and have a widespread usage such as lubricants, water repellent sprays for shoes, lining on Scuba diving masks and medical uses such as breast implants.

Things to consider whilst preparing your presentation:

(1) How are they made including conditions of manufacture and all relevant equations.
(2) Structures.
(3) How they work.
(4) Applications.

Part D The chemistry of zeolites

Activity 7 - Assessment of a paper on zeolites.

One other important application of silicon is in zeolite chemistry. Zeolites have fascinating structures and a wide range of applications.

For this activity you will be assigned one of the papers listed below. Your task is to critically summarize the key points of interest and importance from the paper and to prepare a 5-10 minute presentation for the next session. You should use 4-6 overhead transparencies or powerpoint slides.

Copperthwaite RG, Hutchings GJ & van der Riet M, *Preparation and evaluation of a synthetic zeolite catalyst*, Journal of chemical education, 1986, **63**, 632-637.

Balkus KJ & Ly KT, *The preparation and characterisation of a x-type zeolite*, Journal of chemical education, 1991, **68**, 875-877.

Lowe B, *Zeolite molecular sieves*, Education in chemistry, 1992, 15-18.

Coker EN, Davis PJ Kekstra & van Bekkum H, *Experiments with Zeolites at the secondary school level: Experience from the Netherlands, Journal of chemical education*, 1999, **76**, 1417-1419.

Smoot A & Lindquist DA, *Properties of Zeolite A obtained from powdered laundry detergent*, 1997, **74**, 569-570.

Walton A, *Models of zeolites and the molecular sieve effect*, Education in Chemistry, 1972, **9**, 146-149.

Blatter F & Schumacher E, *The preparation of pure zeolite NaY and its conversion to High-Silica Faujasite*, Journal of chemical education, 1990, **67**, 519-521.

Activity 8. - Producing a paper on zeolities.

You are provided with the framework of a paper to be written on zeolites. Your task is to complete the paper by discussing the uses of zeolites. You will need to research the uses and hand in a completed draft. Add your own references at the end of the paper. You will then evaluate each others efforts by acting as 'referees' .

The Uses of Zeolites.

Dr Archie Bald, University of Hulmouth, HM9 7ZD.

Absract.
Zeolites are a very versatile chemical and can be used in a wide variety of applications from water softening to catalysis. This paper describes the use of these useful chemicals and reviews some new methods of incorporating them into secondary school teaching.

Introduction
Zeolites are used today in a wide range of settings and they are very important in many commercial and industrial processes. They have a wide variety of uses including their widespread usage in commercial laundry detergents. The petrochemical industry uses them as catalysts and separative media in the production of petrol. They are also utilised as ion exchange materials in a variety of applications. Zeolites can be described as being formed by linking tetrahedral SiO_4 and AlO_4 units at their corners. These species make up the framework and the remaining materials usually are found within the pores [1].

Figure 1. An example of a zeolite structure with a hexane molecule contained within it.

The uses of zeolites.

Ion exchange.

Zeolites in laundry detergents.

Zeolites as catalysts.

References.
1. Coker EN, Davis PJ Kekstra & van Bekkum H, *Experiments with Zeolites at the secondary school level: Experience from the Netherlands, Journal of chemical education*, 1999, **76**, 1417-1419.

Author	Tina Overton, Simon Belt
Title	Problem-Based Learning Case Study
Classification	Case Study
Keywords	sfsoer, ukoer, chemistry, silicon, case study
Description	Tutor Guide
Creative Commons Licence (url)	http://creativecommons.org/licenses/by-nc-nd/2.0/uk/
Language	English
File size	74 kB
File format	pdf