Why is Chemistry important?

Chemistry is the science that studies 'the properties and processes of substances, and the reactions they undergo' (Usselman & Rocke, n.d.). On face value, chemistry might seem unrelated to our lives, but the more one learns about chemistry, the more evident its importance becomes. Importance is subjective and relative, varying according to an individual and his/her experiences. But in this context, I define 'importance' as something that our lives depend on to survive and prosper. Given chemistry is such a broad topic, this discussion focusses on the importance of chemistry to sustain our growing population, through maintaining basic needs such as food, water, air and shelter and helping us advance as a society. I have taken each of these basic needs in turn and explored some examples which demonstrate chemistry's impact.

Food

Chemistry plays a critical role in food production. Food would not be produced on such a large scale without the chemical discovery of ammonia by Haber and Bosch. Before ammonia production, farmers often used manure and minerals as fertilisers. However, by the 20th century, farmers were running out of natural fertilisers. Haber was able to remove inert nitrogen from the air and react it with hydrogen ($N_2 + 3H_2 \rightarrow 2NH_3$) to synthesise ammonia by using a catalyst of iron (Science History Institute, 2017). Once he identified the ideal pressure and temperature, ammonia could be formed at an efficient rate. Bosch was soon able to scale up this process to enable the mass production of ammonia. Subsequently, farmers were able to replenish their soil with ammonia which ensured better harvests from nitrogen-rich soil. By developing ammonia, a key component of all the fertilisers that we use today, farming was revolutionised through increasing food production and helping us avoid famines that might otherwise have occurred. At the time of discovery, the use of ammonia was known as being able to make 'bread from air' (Robin Mckie , 2013) . According to Claudia Flavell-While, (2010), without the Haber process, we would only have two thirds of the volume of food that we produce annually.

Another example of how chemistry has helped us maintain our population is the use of chemicals in our food to increase longevity. Food preservatives are added to prevent the food deteriorating due to microorganisms that cause the growth of bacteria, yeasts and moulds. According to Kathleen Zelman (2017), some of the most common food preservatives include nitrites and benzoates which block bacteria and fight fungi, respectively. Without the use of preservatives, we would have to produce an increased amount of food, as it would deteriorate quicker and general wastage would increase. Our diets would also be significantly restricted to locally grown food, as food from abroad would not outlast the transit time. According to the American Chemical society (2002), acids, such as citric acid, fight the enzymes which encourage the natural ripening of vegetables and fruits, by lowering the pH and the resultant enzyme work rate. The knowledge we have developed through chemistry has enabled us to produce synthetic preservatives as well as relying on natural sources like salt, sugar, vinegar and citrus juice. In theory synthetic preservatives can be healthier than natural preservatives and are a solution to the limited supply of natural alternatives (Martin Taylor, 2022).

Despite our knowledge now on the damage of plastic to the environment, it has also been vital in food preservation. Chemists have developed and created polymer packaging, essential to food packaging, as well as having many other applications in our lives. Polyethylene, was originally discovered by a German chemist called Hans von Pechmann when he was investigating the decomposition of diazomethane. He discovered that the accidental substance had the properties of

a polymer, with long- CH_2 chains and was originally named polymethylene. It is lightweight which is ideal for food production because the polymers are branched and cannot fit closely together – meaning they have low densities. Polyethylene is strong because the polymer chains are connected by solid covalent bonds which are hard to break. Again, chemists' understanding of the properties of different compounds has enabled the development of this material. Large scale production of polyethene was developed in 1933 by ICI (Mark Lorch, 2015) by applying high pressure. This meant it was viable to sell and subsequently, resulted in the introduction of a new material that is used extensively today.

Water

The average human is recommended to consume 3 litres a day of fresh, clean water (Mayo Clinic, 2022). Our body is made up of 70% of water and all our cells require water to perform their functions and keep our bodies working at full capacity (Peter Chieh, 2021). Using chemistry, we have developed a way to treat our water to make sure it is potable. Water in our environment has been contaminated by human activity such as agriculture and pollution – therefore it is necessary that we treat it to prevent the spread of waterborne diseases. For example, Chlorine is used to kill bacteria in water making it viable to consume. Chemistry has identified that in a disproportionation reaction of chlorine and water, hydrochloric acid and chloric acid are produced.

$$Cl_2 + H_2O \rightarrow HCl + HClO$$

The chloric acid is the sterilising agent and it further disassociates in water forming another sterilising agent (ClO^-).

$$HClO \rightarrow H^+ + ClO^-$$

According to Lenntech (n.d.), the ClO- and HClO are effective disinfectants because they contain chlorine which allows them to break chemical bonds with bacteria and viruses. When harmful enzymes come into contact with chlorine, chlorine replaces a hydrogen atom in the molecule which results in the enzyme changing shape. This denatures the enzymes (changing the active site) meaning the enzyme is unable to carry out its harmful function and react with the body when it is consumed.

Historically, waterborne diseases were considerably more present before the use of chemicals to treat our water. In 1854, a scientist called Dr John Snow introduced the basis for the first use of chlorine as a disinfectant for drinking water. He traced 600 cholera deaths within a 10-day period and then he worked out that an epidemic of cholera was spread through a water pump and water supply company. His work was vital in demonstrating the need for water sterilisation and providing the basis for the development of disinfecting agents. Without the chemical reaction creating chlorine it would be challenging to produce enough water that is safe for the world's population to drink.

Air and Atmosphere

The air we breathe contains 78% nitrogen, 21% oxygen and 1% other substances. It is important that the composition of our earth and atmosphere does not change because humans need oxygen to breathe and the atmosphere regulates the temperature of the earth to a safe level. We have polluted the atmosphere with many harmful chemicals, such as CO, C and NO_x, in order to produce food and materials. To remove these dangerous chemicals and maintain a clean air supply, chemists have been able to develop solutions such as a catalytic convertor which converts harmful products into more stable ones using a metal catalyst. For example, carbon monoxide, a highly toxic colourless gas which attacks the haemoglobin in our blood reducing the blood's ability to carry oxygen, is oxidised to carbon dioxide – which, although still a pollutant, is considerably less toxic.

Our atmosphere also maintains the temperature of Earth. We rely on the ozone to absorb heat and prevent the earth from heating up to an unsustainable level. In 1985, when the Antarctic ozone hole was first discovered, scientists worked to provide solutions to this problem. Vitally, it was chemists – Rowland and Molina (British Antarctic Survey, n.d.)– who identified that the chemicals in fridges and aerosols, known as chlorofluorocarbons, were a key contributor. When these chemicals were released into the atmosphere and reached the ozone layer, they reacted with the ozone, through free radical substitution, because of the high intense UV light, from the sun, which breaks down the bonds in the CFCs . These chemists encouraged governments to ban CFCs and eventually resulted in the Montreal Protocol (Victoria Gill, 2021), which led to the world collectively managing to ban CFCs. Recently, there have been studies claiming that the ban avoided a major climate catastrophe and has provided time for us to act to prevent climate change from worsening. By phasing out the chemicals that deplete the layer, the ozone has been able to rebuild itself. The ozone hole over Antarctica is still shrinking today and is expected to be back to normal levels in 2045 (Emma Newburger, 2023).

Shelter

Chemistry helps us to understand the properties of different materials, which has helped us identify the best building materials for specific purposes. Building foundations, for example, are critical for even weight distribution and building stability. Materials for foundations have been chosen taking into account the chemists' knowledge of the properties of different elements and compounds. Steel, often a key component, is an alloy with very high tensile strength. It is made up of irregular layers of iron and carbon atoms. The carbon atoms prevent the layers from sliding over each other, making steel rigid and strong. Concrete is often reinforced with steel to provide strength in compression. Concrete is strong because it has tight chemical bonds as a result of the tricalcium silicate compound which prevents any gaps in the concrete mixture. We reinforce concrete with steel as the steel provides a high tensile strength whereas concrete is only strong against compressive forces. By combining these two materials, we are able to achieve the ideal combination for foundations by using their chemistry.

Glass is another important material used in construction because of its strength, transparency and ability to withstand high temperatures. Glass is formed by heating silica to very high temperatures. Silica atoms have a tetrahedral shape, meaning that it is a three-dimensional structure which results in glass being strong with covalent bonds in all three dimensions. It is transparent because after heating silica it cools to form an amorphous solid with an irregular crystalline structure. The electrons surrounding each nucleus are orbiting in shells that are far apart and do not gain enough energy from light photons passing through to allow electrons to move to higher energy levels. As a result, the glass appears transparent. UV light on the other is absorbed- explaining why we are unable to tan skin from the sun behind glass. This unique property of glass has enabled its effective use in construction.

To conclude, chemistry is a broad and essential field that studies the properties and processes of substances, the reactions they undergo, and the ways in which we interact with them. Chemistry is crucial to sustain our growing population, through maintaining basic needs such as food, water, air, and shelter and helping us advance as a society. The importance of chemistry becomes evident when one considers how chemistry impacts our daily lives. In terms of food, chemistry has helped us to produce food on a large scale by developing ammonia, a key component of fertilizers, thereby revolutionizing farming and increasing food production. Additionally, chemistry has enabled us to produce synthetic and natural preservatives, which prolong the shelf life of food and help prevent

food waste. In terms of water, chemistry has enabled us to treat contaminated water and make it potable, thereby preventing the spread of waterborne diseases. In terms of air, chemistry has helped to control air pollution and reduce the impact of harmful chemicals on the environment. Finally, in terms of shelter, chemistry has played a crucial role in developing materials like polyethylene, which has numerous applications in our daily lives, including food packaging.

Overall, chemistry is a critical field that underpins many aspects of our daily lives and is essential to sustaining our population and advancing as a society.

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