INTRODUCTION TO CHEMISTRY

WHAT IS CHEMISTRY ALL ABOUT?

Chemistry is considered by many to be a very demanding academic subject and it sits alongside physics and biology as one of the three principal sciences which are studied all over the world by students at school, college and university. The real answer to the question posed above however, has little to do science and more to do with everyday life. Chemistry is about taking ordinary substances from the atmosphere, the oceans, the Earth, and from plants, animals and micro-organisms, and turning them into substances that have very specific and important uses. Chemistry is about finding out what these substances are made of. Turning sand into glass, turning raw ingredients into a cooked meal, turning rocks into iron and turning fungi into powerful anti-bacterial drugs are all examples of what Chemistry is about. In order to do these things, chemists use one of the most effective tools ever developed by humankind; sciences. In the past, of course chemists thought nothing of using the tools of their day; trial and error, lucky accidents, effective guessing - even magic! The word "Chemistry" itself comes from the older word "Alchemy", a practice concerned with two principal objectives; finding a way to turn other metals into gold, and finding the elixir of eternal youth. You could argue that modern chemists are still turning materials into 'gold' by developing new products which have enormous commercial potential, and working on new drugs that have the potential to cure disease and prolong life are not too far removed from discovering the 'elixir of eternal youth'. However, we need to look closely at what ancient chemists (even if they would not recognize themselves by that name) were involved with if we truly want to answer the question, 'What is Chemistry all about?'

WHERE DOES CHEMISTRY COME FROM?

An easy question to answer - all over the world. Chemistry did not start in any one place but started at the very beginnings of civilization, when people needed to use raw materials to make new substances or to modify processes. For instance, the oldest cave paintings on Earth are widely acknowledged to be found in various caves in the South West of France. These early artists used a variety of natural substances to produce the necessary range of pigments. Study of these pigments shows that these early 'chemists' were very resourceful in their researching; the result of their work has stood the test of time. At some place in time, humans discovered that indigestible items of plant and animal matter could be made very palatable by cooking them; who discovered this and how, no one knows. In Africa, rocks were found that would yield metals - first copper and tin and then, remarkably, iron. In ancient Egypt, 'chemists' concerned themselves with not only preserving food but preserving the dead; others made new cosmetics and found ways of turning plant and animal materials into substances such as paper. In China, a research for that famous elixir of youth led directly to the discovery of gunpowder, the world's first explosive. In the Middle East, early 'chemists' worked on hundreds of ideas and can truly be recognized as giving the subject the status that it enjoys today. We still use many Arabic- derived words in Chemistry today - the word 'Alchemy' comes from the Arabic 'al-kimiya' and the terms alcohol, alkane, alkene (some of which may not be familiar to you at the start of this course) have Arabic roots. In Europe, attempts to make gold led to the discovery of processes and materials that are very important to us today.

Chemistry has its roots in every part of the globe and is important to every culture. It would not be too strong an idea to suggest that the search for new substances and the search for better processes have been major factors in the development of all societies. Those early cave painters were artists and scientists - perhaps as we study Chemistry, we should keep at the front of our minds that creativity and cultural expressions go hand in hand with technological and scientific developments. Without paper - no books; without clay - no fine porcelain; without paint - no paintings; without film - no movies; and without silicon - no computers.

EARLY IDEAS

All early civilizations had some ideas about substances. (What does this actually mean? They thought about it - they had theories...) We are going to look at ancient Greek ideas in some detail because they lasted so long and have had such a great influence on ideas that we now hold to be true. The most important idea that the Greeks developed was that of the FOUR ELEMENTS. This is the concept that all matter in the universe is composed of just four elements; Earth, Air, Fire and Water. The ancient Greeks also had some experimental backup for these ideas; if you burn a log of wood, some gas is given off (Air), some energy is given off in the form of heat and light (Fire), some ash is left behind (Earth). If you try to burn some clay, you fail. This is because clay contains no Fire, only Earth. If you burn alcohol, you get Air, Fire and Water.

You can see how the idea of four elements is pleasingly simple. These ideas were held to be true right up until around two hundred years ago; they were certainly ideas that the alchemists used in their attempts to make gold from base metals.

As with most simple ideas you need to look hard for flaws in the argument - this only happened when the first chemical balance was invented. New technology always brings about changes in the way we perceive the world; the introduction of an accurate way of measuring mass was a great leap forward.

(In this course, we will always refer to the amount of substance as mass. The word weight should not be used as it refers only to how the force of gravity affects that amount of substance. A block of iron would have a different weight at the bottom of the Grand Canyon than it would at the top of the Himalayas or on the Moon; the mass would be the same in all these places.)

If you find the mass of a log of wood and burn it, sure enough the mass would be less afterwards, as material - Fire and Air according to the ancient Greeks - would have been lost. However, if you find the mass of a lump of magnesium metal and burn it (magnesium burns well but only if it is finely divided), the mass would increase. This result clearly puts the Earth/Air/Fire/Water theory into the history books and we need some new theories that will take up much of this course.

I think it is important to recognize that ideas come and go, and it is wrong of us to think that they no longer matter; some of the ideas that we meet in science today may cause our successors to laugh, but the road to new ideas and discoveries has foundations made up of older ideas that we still need to understand.

One idea from the ancient world that is still very relevant to us is the belief that matter consists of tiny particles. The ancient Greeks believed that if you took a leaf, for instance, and tore it in half, and then tore it in half again and again and again, you would eventually come to a very tiny particle which could not be further divided. The word for this very tiny particle was "ATOM" which came from the Greek 'a tomos' - something that which can not be divided. The ancient Greeks believed that all things were made from atoms - not only matter, but heat, light and even ideas! When we get an idea, we often say that we have had inspiration; the idea that the Greeks held was that we would actually breathe in the atoms of an idea and reassemble them in a new way - after all, inspiration literally means "breathe in".

STATES OF MATTER

Modern Chemistry still uses the idea of elements although this no longer refers to the four ancient Greek elements, rather the hundred and thirteen or so basic substances that we now believe make up all the matter in the universe. One basic concept that we need to understand however, owes a lot to an older idea that is called The States of Matter. Matter can exist in four states; SOLID, LIQUID, GAS and PLASMA. Note: The Plasma state will be discussed in detail later.

Solids have a definite shape and a definite volume at a given temperature. We can also identify other properties of solids that are variable such as hardness, flexibility etc. Liquids have a definite volume at a given temperature but take up the shape of their container. Thus a cup of water, for example, is cup-shaped.

You would have seen (only on film, unless you're an astronaut), that liquids take on a roughly spherical shape under conditions of weightlessness. Liquids have their own variable characteristics, such as viscosity. Gases have no definite shape or volume, they just fill up the space available, even if other gases are present. A good way to understand this is to think about how the smell of freshly baked bread or perfume soon fills up a room.

In order to understand how matter behaves, we must introduce the idea of the "KINETIC THEORY". Forget, for the sake of this exercise, that matter may be composed of atoms, molecules or ions (more about these in the next chapter) and think of all substances as being made up of tiny particles. In a solid, the particles are packed fairly closely together. They may be vibrating a little but they are so close together that they cannot move out of position. Now, if we give these particles more energy (the simplest way to do this is to heat them up), they start to move more freely. They can now change position and escape fairly easily. As the particles are no longer in a fixed position next to each other, the shape that they were in has gone; the solid has become a liquid. If we then give the particles even more (heat) energy, they have even greater freedom of movement and tend to fly off in all directions; any idea of shape or volume has become meaningless. The particles will go into any available space. Our liquid

SOLID ==> melting ==> LIQUID ==> evaporation ==> GAS

If we then take a gas and steadily remove energy from it, eventually

GAS ==> condensation ==> LIQUID ==> freezing (solidifying) ==> SOLID

Not all substances behave exactly like this, and many behave differently at higher pressures - some miss out the liquid phase altogether. Iodine and carbon dioxide behave like this at room temperature. This process is called subliming and the word sublimation describes the process.

SOLID ==> sublimation ==> GAS ==> desublimation ==> SOLID

Kinetic theory is the central idea behind a lot of important Chemistry and it is an example of what we call a "scientific mode1". The point is that no one, even with the most sophisticated equipment available, can see the particles behaving like this, but we believe that they are, and all the evidence that we have about how matter behaves, seems to validate this model. A model helps us to visualize things that we cannot see and we can use it to develop our understanding. As with all models, we may one day get some evidence that contradicts this; then we will have to work on a new model.

CHEMICAL SYMBOLS

Way back in the times of Alchemy, a system of symbols was developed for chemists to communicate with one another, and to use as a form of shorthand when making notes. Some of these symbols are still in use but you are not likely to see them in modern chemistry textbooks. However, a fully international system of symbols for chemistry is now used. It is monitored by an organization called 'The International Union of Pure and Applied Chemistry' or the IUPAC, and this means that regardless of language or script used, copper sulphate is always $CuSO_4$ and sulphuric acid is always H_2SO_4 . In a way, this works like a language and as with all languages, there is very little point in your learning all of the symbols at once, just as you would not expect to learn a complete vocabulary of a language in one go. However, throughout the course you will come across new symbols and should make a point of learning them as you go along. By the end of this course you should have no problems with full chemical equations like:-

$$Mg\ (s) + H_2SO_4(aq) ==> MgSO_4\ (aq) + H_2\ (g)$$

If you have a previous knowledge of chemical equation writing, this will not cause you too many problems, but if you are new to it, this may take a little time - please do not worry about it! One very important point though is the use of upper case and lower case letters. Cobalt, for instance, is Co - it must ALWAYS be upper case C and lower case o; CO means something very different (carbon(II) oxide).

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