Lecture 1 analytical chemistry

Science, Physics

Analytical chemistry Analytical chemistry is the branch of chemistry that deals with the separation, identification and determination of components in a sample. Analytical chemistry can be divided into two branches, qualitative and quantitative. Qualitative analysis It deals with the identity of the constituents that are in an analytical sample. Quantitative analysis It deals with the determination of how much of a given substance is in the sample. The quantitative analyses are classified into several methods of analysis according to the process of the final measurements: 1. Volumetric Analysis It deals with determination the concentration of a solution by titration against a solution of known concentration (standard). 2. Gravimetric Analysis In whichthe substance being determined is converted into an insoluble precipitate which is collected and weighed 3. Instrumental Analysis Determination of a final form by measuring some physical properties that is quantitatively related to the concentration of the analyzed sample by using an instrument; these include spectrophotometry, potentiometry, polarography, optical rotation etc. .. Atomic struture The basic building block of all matter is called an atom. Atoms are a collection of various subatomic particles containing negatively charged electrons, positively charged protons and neutral particles called neutrons. Each element has its own unique number of protons, neutrons and electrons. Both protons and neutrons have mass, whereas the mass of electrons is negligible. Protons and neutrons exist at the centre of the atom in the nucleus. Electrons move around the nucleus, and are arranged in shells at increasing distances from the nucleus. These shells represent different energy levels, the outermost shell being the highest energy level. The number of protons that an atom has in its nucleus is called the atomic number. The total number of protons and neutrons in the nucleus of an atom is known as the mass number. For example, a carbon atom containing six protons and six neutrons has a mass number of 12. Elements are substances containing atoms of one type only, e. g. O_2, N_2 and Cl_2. Compounds are substances formed when atoms of two or more elements join together, e. g. NaCl, H_2O and HCl. Orbitals and electronic configurations It is important to understand the location of electrons, as it is the arrangement of the electrons that creates the bonds between the atoms, and chemical reactions are just that to form new bonds. Electrons are involved in the chemical bonding and reactions of an atom. Electrons are said to occupy orbitals in an atom. An orbital is a region of space that can hold two electrons. Electrons do not move freely in the space around the nucleus but are confined to regions of space called shells. Each shell can contain up to $2n^2$ electrons, where n is the number of the shell. Each shell contains subshells known as atomic orbitals. The first shell contains a single orbital known as the 1s orbital. The second shell contains one 2s and three 2p orbitals. These three 2p orbitals are designated as $2p_x$, $2p_y$ and $2p_z$. The third shell contains one 3s orbital, three 3p orbitals and five 3d orbitals. Thus, the first shell can hold only two electrons, the second shell eight electrons and the third shell up to 18 electrons, and so on. As the number of electrons goes up, the shell numbers also increase. Therefore, electron shells are identified by the principal quantum number, n¼1, 2, 3 and so on. The electronic configuration of an atom describes the number of electrons that an atom possesses, and the orbitals in which these electrons are placed. The arrangements of electrons in orbitals, subshells and shells are called electronic configurations. Electronic configurations can be represented by using noble gas symbols to show some of the inner electrons, or by using Lewis structures in which the valence electrons are represented by dots. Valence is the number of electrons an atom must lose or gain to attain the nearest noble gas or inert gas electronic configuration. Electrons in the outer shells that are not filled are called valence electrons. The ground-state electronic configuration is the lowest energy, and the excited-state electronic configuration is the highest energy orbital. If energy is applied to an atom in the ground state, one or more electrons can jump into a higher energy orbital. Thus, it takes a greater energy to remove an electron from the first shell of an atom than from any other shells. For example, the sodium atom has electronic configuration of two, eight and one. Therefore, to attain the stable configuration, the Na atom must lose one electron from its outermost shell and become the nearest noble gas configuration, i. e. the configuration of neon, which has the electronic configuration of two and eight. Thus, sodium has a valence of 1. Since all other elements of Group IA in the periodic table have one electron in their outer shells, it can be said that Group IA elements have a valence of 1. At the far end on the right hand side of the periodic table, let us take another example, chlorine, which has the electronic configuration of two, eight and seven, and the nearest noble gas is argon, which has the electronic configuration of two, eight and eight. To attain the argon electronic configuration chlorine must gain one electron. Therefore, chlorine has a valence of 1. Since all other elements of Group 7A in the periodic table have seven electrons in their outermost shells and they can gain one electron, we can say that the Group 7A elements have a valence of 1. The sub-atomic particles Protons, neutrons and electrons. | relative mass | relative charge | Proton | 1 | +1 | Neutron | 1 | 0 | Electron | 1/1836 | -1 | The nucleus The nucleus is at the centre of the atom and contains the protons and neutrons. Protons and neutrons are collectively known as nucleons. Virtually all the mass of the atom is concentrated in the nucleus, because the electrons weigh so little. Working out the numbers of protons and neutrons No of protons = ATOMIC NUMBER of the atom The atomic number is also given the more descriptive name of proton number. No of protons + no of neutrons = MASS NUMBER of the atom The mass number is also called the nucleon number. This information can be given simply in the form: How many protons and neutrons has this atom got? The atomic number counts the number of protons (9); the mass number counts protons + neutrons (19). If there are 9 protons, there must be 10 neutrons for the total to add up to 19. The arrangement of the electrons The electrons are found at considerable distances from the nucleus in a series of levels called energy levels. Each energy level can only hold a certain number of electrons. The first level (nearest the nucleus) will only hold 2 electrons, the second holds 8, and the third also seems to be full when it has 8 electrons. As an example to find the electronic arrangement in chlorine * The Periodic Table gives you the atomic number of 17. * Therefore there are 17 protons and 17 electrons. * The arrangement of the electrons will be 2, 8, 7 (i. e. 2 in the first level, 8 in the second, and 7 in the third). The electronic arrangements of the first 20 elements Two important generalisations If you look at the patterns in this table: * The number of electrons in the outer level is the same as the group number. (Except with helium which has only 2 electrons. * So if you know that barium is in group 2, it has 2 electrons in its outer level; iodine (group 7) has 7 electrons in its outer level; lead (group 4) has 4 electrons in its outer level. Dots-and-crosses diagrams In any introductory chemistry course you will have come across the electronic structures of hydrogen and carbon, for example, drawn as: The circles show energy levels - representing increasing distances from the nucleus. You could straighten the circles out and draw the electronic structure as a simple energy diagram. Carbon, for example, would look like this: Bonding COVALENT BONDING - SINGLE BONDS The importance of noble gas structures We may well have been left with the strong impression that when other atoms react, they try to achieve noble gas structures. As well as achieving noble gas structures by transferring electrons from one atom to another as in ionic bonding, it is also possible for atoms to reach these stable structures by sharing electrons to give covalent bonds. Some very simple covalent molecules Chlorine For example, two chlorine atoms could both achieve stable structures by sharing their single unpaired electron as in the diagram. The fact that one chlorine has been drawn with electrons marked as crosses and the other as dots is simply to show where all the electrons come from. In reality there is no difference between them. The two chlorine atoms are said to be joined by a covalent bond. The reason that the two chlorine atoms stick together is that the shared pair of electrons is attracted to the nucleus of both chlorine atoms. Hydrogen Hydrogen atoms only need two electrons in their outer level to reach the noble gas structure of helium. Once again, the covalent bond holds the two atoms together because the pair of electrons is attracted to both nuclei. Hydrogen chloride The hydrogen has a helium structure, and the chlorine an argon structure. Most of the simple molecules you draw do in fact have all their atoms with noble gas structures. For example: IONIC (ELECTROVALENT) BONDING Ionic bonding in sodium chloride Sodium (2, 8, 1) has 1 electron more than a stable noble gas structure (2, 8). If it gave away that electron it would become more stable. Chlorine (2, 8, 7) has 1 electron short of a stable noble gas structure (2, 8, 8). If it could gain an electron from somewhere it too would become more stable. The answer is obvious. If a sodium atom gives an electron to a chlorine atom, both become more stable. The sodium has lost an electron, so it no longer has equal numbers of electrons and protons. Because it has one more proton than electron, it has a charge of 1+. If electrons are lost from an atom, positive ions are formed. Positive ions are called cations. The chlorine has gained an electron, so it now has one more electron than proton. It therefore has a charge of 1-. If electrons are gained by an atom, negative ions are formed. A negative ion is called an anion. The nature of the bond The sodium ions and chloride ions are held together by the strong electrostatic attractions between the positive and negative charges. The formula of sodium chloride You need one sodium atom to provide the extra electron for one chlorine atom, so they combine together 1: 1. The formula is therefore NaCl. Some other examples of ionic bonding magnesium oxide Again, noble gas structures are formed, and the magnesium oxide is held together by very strong attractions between the ions. The ionic bonding is stronger than in sodium chloride because this time you have 2+ ions attracting 2- ions. The greater the charge, the greater the attraction. The formula of magnesium oxide is MgO. calcium chloride This time you need two chlorines to use up the two outer electrons in the calcium. The formula of calcium chloride is therefore $CaCl_2$. potassium oxide Again, noble gas structures are formed. It takes two potassiums to supply the electrons the oxygen needs. The formula of potassium oxide is K_2O.