The Atom

PART 1

This video presentation begins our first steps in developing a molecular perspective. We will start with learning about the atom.

Atoms are comprised of three sub-atomic particles: the proton, the neutron and the electron. There is a small dense core in an atom called the nucleus; it contains the majority of an atom's mass, and a positive charge. The proton and the neutron form nucleus, and each have approximately the same mass. The volume occupied by an atom is mostly empty space, containing negatively charged particles called electrons. The proton and electron are charged particles, the proton is positive and the electron is negative. They have a charge that is equal and opposite, and because of this we can say the relative charge in atomic units is one. A neutral atom has the same number of protons as electrons.

The mass of sub-atomic particles is miniscule, using kilograms to represent such a small measurement is cumbersome, an accepted unit of measurement is the unified atomic mass unit (u). It is defined as $1/12^{th}$ the mass of a carbon atom containing six protons and six neutrons. In unified atomic mass units, the mass of a proton and a neutron is approximately one u.

Atoms of the same type combine to form elements. Elements can attain different physical forms called allotropes. For example, a diamond and the graphite in a pencil are both pure carbon, but the atoms in each material have a different arrangement giving diamond and graphite diverse and unique properties.

A chemical symbol is assigned for each element and is usually a one or two letter abbreviation. The number of protons in the nucleus of an atom determines the atomic number. The atomic number is unique to all atoms for each element. This is important because it means it is the number of protons that defines the type of atom. The mass number of an atom is the sum of the number of neutrons and protons in the nucleus of an atom. The number of protons in an atom of any element does not change, but the number of neutrons can. Atoms of a single element with a varying number of neutrons are called isotopes.

For example, hydrogen has three isotopes, each of them having one proton but different numbers of neutrons. The isotopes of hydrogen are somewhat unique in that they have their own names, so the isotope of hydrogen with one proton is protium, the isotope with one neutron and a proton is called deuterium and the isotope with two neutrons and a proton is called tritium.

PART 2

For our next example, we are going to look at silicon. Silicon has the chemical symbol Si and fourteen protons. The stable isotopes of silicon have atomic mass numbers of twenty-eight, twenty-nine and thirty. Subtracting the number of protons from the mass number will give us the number of neutrons in each isotope. So the three silicon isotopes must have fourteen, fifteen and sixteen neutrons respectively.

Because isotopes vary in their neutron count they must have different masses, but according to the periodic table, each element has a singular atomic mass; how is it calculated? It turns out that the atomic mass of an element is biased by the natural abundance of its isotopes in a naturally occurring sample. The natural abundance of isotopes is relatively constant for each sample, and unique for each element.

A naturally occurring silicon sample will have approximately 92 % of the silicon-28 isotope, 5 % of the silicon-29 isotope and 3 % of the silicon 30 isotope.

We can think of a naturally occurring sample as a 100 pc puzzle, each piece represents one atom. 92 pieces would be Si-28 atoms each with a mass of 27.97 u. 5 pieces would be Si-29 atoms each with a mass of 28.97 u and 3 pieces would be Si-30 atoms each with a mass of 29.97 u.

The actual mass of the entire sample is a weighted average of the silicon isotopes, and this mass is the atomic mass of silicon that we see on the periodic table.

Now that we have an understanding of an atom we can appreciate that counting individual atoms would be quite a challenge. Why do we need to count atoms? We will learn later that setting up experiments requires precise knowledge of the number of atoms or molecules in a chemical reaction.

Even if we could easily see individual atoms, imagine trying to count the number of atoms that would be in one tiny drop of water, it would be an impossible task. We need a tool that allows us to count atoms and molecules easily, this measurement is called the mole. The mole is a handy way to count atoms using their mass. A mole is equal to Avogadro's number which is six point zero two two times ten to the power of twenty-three. So one mole of something is equal to six point zero two two times ten to the power of twenty-three units of that thing. You could have a mole of people, a mole of bricks, or a mole of sand, but in reality using the mole to measure is only convenient for measuring atoms or molecules. A mole can relate those small particles to the size scale that we use and work with conveniently.

How did the mole get its specific value and how exactly do we use it to count atoms? Do you remember earlier when we discussed unified atomic mass units? Carbon was used as a standard, more specifically, a carbon atom with six protons and six neutrons or, the carbon-twelve isotope. The mole is defined using the same standard, and one mole is equal to the number of atoms in exactly twelve grams of carbon-twelve. The mass of one mole of carbon atoms is twelve grams which is numerically equivalent to its mass in unified atomic mass units.

Since the masses of all elements are defined relative to carbon-twelve, using it as a standard for the mole gives us an essential relationship between mass, number of atoms and unified atomic mass.

We call this relationship an element's molar mass, and the molar mass is equal to the mass of one mole of any element. The units of molar mass are grams per mole and molar mass is numerically equal to an element's atomic mass in unified atomic mass units.
So how does this help us? We now have a powerful tool to count atoms.

PART 3

We have learned a lot of information about atoms and elements; we have learned that each element has an atomic number, atomic mass, molar mass and chemical symbol. To keep track of this information chemists use the periodic table.

The periodic table organizes elements based on their chemical and physical properties. The periodic table is arranged in sequence according to an element's atomic number and lists useful information about each element. Elements fit into three broad categories: metals, metalloids and non-metals. Generally, metals are good conductors of heat and electricity. They will tend to lose electrons during a chemical reaction. Nonmetals are poor electric and thermal conductors and gain electrons during a chemical reaction. The metalloids have properties of both metals and nonmetals.

Each column in the periodic table is called a group; elements in each group have similar chemical and physical properties. The groups are labelled with numbers 1-18 across the periodic table. Each row in the periodic table is called a period and is numbered 1-7. Elements in a group have similar properties, for example, the noble gasses in group 18 are all relatively unreactive.

The periodic table is divided into main-group elements, transition elements and the lanthanoids and actinoids. The main group elements have predictable properties; transition metals are elements with unpredictable properties, and the lanthanoids and actinoids: are elements with similar properties to the elements lanthanum and actinium. They are placed separately for a more compact periodic table.

Knowing the difference between main group and transition elements is important for predicting how an element will behave in a chemical reaction. For example, certain main group elements form predictable ions. An ion is the general term for one or more atoms that has lost or gained an electron. More specifically, an atom that has gained an electron is called an anion and has a negative charge. An atom that has lost an electron is called a cation and has a positive charge.

Main group ions will attain the same number of electrons as the nearest noble gas. Metals will lose electrons to form a cation, Nonmetals will gain electrons to form an anion.
Ions are represented as the chemical symbol of the element with the charge of the ion noted as a superscript to the right of the chemical symbol.

We have now covered the beginning concepts of an atom and atomic theory. You should be able to define the terms electron, neutron, proton, isotope ,cation and anion. Recognize that the atomic mass of an element is a weighted average, and understand the formula to calculate atomic mass.
You should now understand the meaning of the mole and Avogadro's number; and be able to describe basic periodic trends. Following this video it is important to work through the detailed examples and solutions provided in this section to apply your knowledge to calculations.