LAB 2 – INTRODUCTION TO CHEMISTRY

(May 2014)

Section 1 – Atomic Structure

[2] Welcome back to the Bio 3 lab! This is Pat Farris again and I'm glad to see you've come back for more biology! But today, we're not actually doing any biology directly, because we need to start with the building blocks of organisms. And that means chemistry – you know, atoms, molecules, stuff like that. Let's get started.

[3] I suppose if we started from the VERY beginning, we could talk about how life began from just the simplest chemicals. These simple chemicals interacted for billions of years until slowly, more and more complex arrangements formed that we now recognize as the building blocks of life. These more complex molecules were things like proteins, lipids, carbohydrates and the biggie, DNA.

[4] About three and half billion years ago, these building blocks coalesced into a sustainable unit that we would recognize as a cell. These earliest cells would have had the means to collect and use energy, grow and reproduce. Luckily for us, these simple living units also started arranging into multicellular systems that we recognize today as plants and animals.

[5] We won't go through this whole evolutionary process today, but don't you think it's amazing that we can look at every organism on earth and see the same basic building blocks? Take a look at these creative structures made of Legos. The same little pieces, when arranged differently, can take on very different but meaningful shapes depending on how you put them together.

[6] It's the same with the DNA molecule. The DNA found in whales, bacteria, slime molds, chickens or crickets functions exactly the same way in all those organisms, the only difference is how the molecule is arranged.

[7] So, biology students obviously need to appreciate the roles of chemicals in sustaining life. For the next two weeks we'll examine the basics of chemistry and do some simple experiments. Now if you're already panicking about so much chemistry, relax! We're going

[11] In your definition of atom, you used the term “element”, so let’s record that definition next. An element is a substance that cannot be decomposed into other substances by chemical means.

[12] This chart is called the periodic table and it lists all of the elements found on earth and even a few that are man-made. The elements are arranged according to their complexity. No, you don't have to memorize this table, but there will be several elements that you should become familiar with.

[13] Here you can see a few elements in their natural state. Each of these elements represents a pure substance - that is to say, a substance that cannot be decomposed into other substances. But we can combine elements to form new substances.

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Section 2 – Energy Shell Diagrams

[20] It may seem like a pretty simple arrangement with just three basic pieces, but think about what this means. Everything in the universe is built of those same pieces – protons, neutrons and electrons, so how do we arrive at the 92 different elements? Why do some substances float around us like xygen, and other substances are strong enough to hold up this building?

[21] It all has to do with how the protons, neutrons and electrons are arranged. Each element has a characteristic number of protons, as you saw in your table of elements. For example, hydrogen has one proton in its nucleus, carbon has six protons, oxygen has eight and chlorine has seventeen. Because each element has a characteristic number of protons, we assign what's called a unique atomic number. Make a note of the definition of atomic number at the beginning of Section 2.

[22] Now you remember where each particle is located - protons and neutrons are in the nucleus and electrons are located in the energy shells. When you measure the electrical charge of the entire atom, you find that the atom is electrically neutral. This is because an atom always contains the same number of electrons as protons. Therefore a hydrogen atom contains one electron in its energy shell to balance its single proton charge; carbon has six electrons to balance its six protons, oxygen has eight and so on.

[23] Atoms are often diagramed in a way that gives you the impression that the electrons are confined to circular tracks like race cars or satellites orbiting the earth. In reality, electrons are not confined to single tracks, but instead are confined to certain volumes of space called energy shells. Let's see what an energy shell really represents.

[24] This image shows the region where we could find .couldđ 503.88 cm BT 50 0 0 50 0 0(c) 0.2 .2 (c) h 0 0

[28] Let's start with an easy one like lithium. Lithium has an atomic number of 3, so we know it has three protons. An atom of lithium will have three electrons as well, so how many energy shells will it have?

[39] Now is a good time to introduce you to some common biological molecules and at the same time, get you used to looking at some chemical formulas. Take a look at the table in your lab

[49] Now that you've reviewed a bit, we're ready to start with the most common bond, the covalent bond. A covalent bond is one that results when an atom shares one or more of its electrons with another atom. Please record this definition, and then we'll look at some examples.

[50] Here's a simple example of this property of sharing electrons. These two hydrogen atoms are sharing a pair of electrons, resulting in a molecule of hydrogen gas. Note that the atoms are drawn with overlapping energy shells. The energy shells are drawn this way because each electron is free to move around either nucleus.

[51] Here's the same molecule of hydrogen gas, shown with the beginning two states of the hydrogen atoms it was constructed from. Each hydrogen atom began with just one electron, but the energy shell ideally would contain two. If the two atoms essentially agree to share their electrons, for at least part of the time, each hydrogen nucleus will be surrounded by two electrons in the energy shell. This sharing of electrons is the force or bond that holds these atoms together and is called a covalent bond.

[52] Because the electrons are being shared, this causes the covalent bond to be a very strong bond. Once established, neither atom wants to give up its full complement of electrons. When the outer shells of an atom are filled, we say that the shell, and therefore the atom, is "satisfied".

[53] So far we've shown the covalent bond as overlapping energy shells, but here's another way to show the covalent bond – as a line between the symbols for hydrogen atoms. In other words the structural formula for the molecule. Whether we use overlapping energy shells or a line, they mean the same thing – two electrons are being shared between atoms.

[54] Here's another example of covalent bonding. This diagram depicts the formation of a water molecule. Remember that an oxygen atom has six electrons in its outer energy shell and eight are required for stability. Well, by sharing two of its electrons with two hydrogen atoms, oxygen will have eight electrons, at least part of the time, in its outer energy shell. Each hydrogen atom, in turn, will have two electrons in its outer shell--one of its own and one from oxygen. So in this case, each hydrogen atom and the oxygen atom are satisfied with filled outer shells--at least for part of the time. And I suppose it's better to be satisfied part of the time than at no time at all.

[55] Let's review the three different ways of showing the molecules. Here is a molecule of methane, CH_4. Record these different depictions carefully in your lab book, then come back to the program to answer a couple of questions.

[59] Now we can summarize this basic rule by taking a look at the three molecules shown here – water, ammonia and glycine, which are also shown in your lab book. I've shown you examples of hydrogen, carbon, nitrogen and oxygen forming covalent bonds in several different molecules. Now see if you can determine the number of bonds each of these elements consistently forms. Please fill in your answers in your lab book.

[60] Did you see the pattern? Nitrogen has room for three more electrons on its outside shell, so it can form three bonds. Oxygen has room for two more electrons, so two bonds are possible on oxygen atoms. The double covalent bonds in the glycine may look a little strange, but it just means that there's two covalent bonds between the same atoms. Oxygen and carbon tend to do this, so don't be surprised to see double covalent bonds when we get to the larger molecules.

[61] Now for a question - if a regular covalent bond is the sharing of two electrons, how many do you suppose would be involved in the double covalent bond?

[62] Great! I think you're really getting this stuff! Let's go on.

[63] Okay, now the fun part – we'll start building some stuff. So far, we've been representing molecules as simple two-dimensional diagrams on paper. In reality, molecules are three-dimensional structures and you'll need to appreciate the three dimensional nature of molecules to understand why they do certain things.

[64] While the shape of a certain molecule may not seem terribly important to you, I can assure you that it is extremely important to your cells. There are many molecules our cells detect and recognize by their three-dimensional shapes. We won't have you build anything as gnarly as these giant 5.4873 393.0 0.24

[69] This term ion is new for us, so take a moment and record the definition of an ion – a charged particle.

[70] Certain kinds of atoms have a tendency to give up an electron or two rather than to share electrons with other atoms. Conversely, some would rather receive electrons from another atom than share. One element that would rather give up an electron is sodium. Notice that the sodium atom has one electron in its outermost energy shell. It would be difficult for sodium to pick up enough electrons to fill its third energy shell with electrons, so sodium atoms do something else to reach stability. This is one of the “beginning state” atoms shown in your lab book, so you could copy it now, if you like.

[71] Now take a look at this chlorine atom. Note that chlorine has seven electrons in its outer shell. The third shell can become stable if eight electrons are present even though it could hold 18. The chlorine atom, then, needs just one more electron to reach a stable configuration. Go ahead and copy this “beginning state” in your lab book as well.

[72] Can you predict what these atoms will do when they’re brought together? Ahhh, you’re pretty clever. Of course, sodium gives up its third shell electron to chlorine and its new outer shell is its second. Look carefully, you'll note that sodium’s second shell contains eight electrons and is stable. Chlorine has its outermost energy shell stabilized now because it has eight electrons. This arrangement works out nicely for both (hi) 0.2 (s) -0.2 (a) 0.27q 0.24 0 0 0.24 360.1s arrangem

[78] Take a look at that hydrogen bond definition again – this bonding is between molecules, not atoms or ions. You've already built the three dimensional model of water, and you know it has sort of a tweak to it – in other words, the hydrogens stick off to one side because of how the electrons relate to the oxygen.

[79] When you think about where the electrons are spending most of their time, you know that there are more electrons piled up on the oxygen side of the molecule. This results in what we refer to as a partial negative charge. It's not the same as being a negative ion, but it does mean that there is a slight negative charge on that side of the molecule.

[80] Now if we look at the other half, the hydrogen half, we see there are single protons of the hydrogen atom's nucleus with a positive charge. The electron of the hydrogen atoms are being shared with the oxygen atom because of the covalent bond, so now we've got a partial positive charge at each hydrogen nucleus.

[81] This results in what we call a polar molecule –

[88] Enzymes are very powerful chemicals that will enable the reaction to happen much faster than it normally would. Almost every reaction happening in your body right now is using an

Section 8 – pH, Acids and Bases

[98] In addition to enzymes, there are many other things that can affect chemical reactions. For example, the acidity or alkalinity of the solution can have a major impact on the reaction. For this reason, the last topic I'd like to discuss today involves acids, bases and pH.

[99] Take a look at the pH scale at the beginning of Section 8. I'm sure you've seen one of these before, and you may already know that substances with a pH of less than seven are called acids, pHs of more than seven are called bases, and a pH of exactly seven is considered neutral.

[100] The easiest place to start is with neutral. Go ahead and record this definition before we go on. A substance which is neutral is not acidic or basic – it's at exactly seven on our scale.

[101] Our next definition will be for acids. Acids are substances that release hydrogen ions when placed in water. Please record this definition and I'll give you some examples.

[102] Consider the chemical reaction shown here. It shows that when H_2SO_4 is placed in water, a hydrogen ion is released. When a chemical comes apart like this, we say that it dissociates, and because it's a hydrogen ion that comes off, we know that H_2SO_4 is an acid. As a matter of fact, this is the same acid that is put into car batteries - it's called sulfuric acid.

[103] Now think back to what a hydrogen ion would be – it's a hydrogen atom that has lost its only electron, so it has to have a positive charge because all that's left -

Section 9 – Effect of pH on Enzyme Activity

[108] Okay, we've got one last experiment to put it all together. You'll be doing the same chemical reaction you did in the first experiment, but now you'll be testing the effect of pH on your results. Be sure to answer the short review questions at the beginning of Section 9 before you run off to get your test tubes. After checking your results against the "standards" on the side of the lab, get your graph checked by the lab instructor before you come back.