Week 14

Physics 1409/1430 – Physics 2

Hello and Welcome to the weekly resources for PHY 1409/1430 – Physics 2!

This week is Week 14 of classes, and typically in this week of the semester, your professors are covering these topics below. If you do not see the topics your particular section of class is learning this week, please take a look at other weekly resources listed on our website for additional topics throughout the semester.

We also invite you to take a look at the group tutoring chart on our website to see if this course has a group tutoring session offered this semester.

If you have any questions about these study guides, group tutoring sessions, private 30-minute tutoring appointments, the Baylor Tutoring YouTube channel or any tutoring services we offer, please visit our website www.baylor.edu/tutoring or call our drop in center during open business hours, M-Th 9am-8pm on class days, at 254-710-4135.

Important Information

Important Conventions

Keywords: Bonding in Molecules, Decays, Half Life, Nuclear Energy

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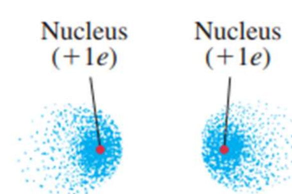
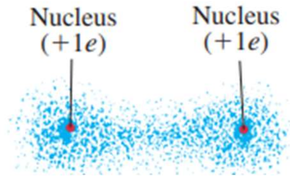
Bonding in Molecules:

When we considered the theory of quantum mechanics last week, we saw the structure for the atoms individually. But another great success of this theory is the insight it gives into chemical bonds. Let's take a look at some different types of bonds.

Covalent Bonds:



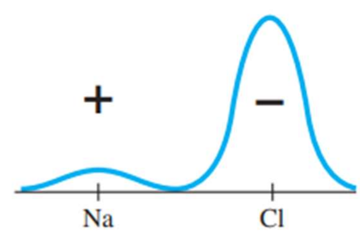
Covalent bonds are formed between two atoms because they share electrons equally with one another. But what will bonds look like when we look at it in terms of quantum mechanics. We consider the shared electron as an overlap of the electron clouds for both the atoms and their valence electrons. This overlap forms a covalent bond. Now, lets consider the state of the electrons that are being shared. Let's consider a simple example, a bond in H_2. If we consider that the electrons are in the ground state, they can have 2 possibilities for spin. They can both have the same ½ or -1/2 spin, or they can have asymmetric spin where one is ½ and the other is ½. So, the spin can be S=0 or S=1. From the exclusion principle, we know that since the electrons are shared in the bond, they can't have symmetric spin (both spins with the same sign). So, the spin for the electrons must have asymmetric spin. This is what is shown in the two figures above. The energy required to break a bond is called the bond energy.



Some colvalent bonds can have a slight differnce in the sharing of electron, which resuilts in partial charges on the molecule.

Ionic Bonds:

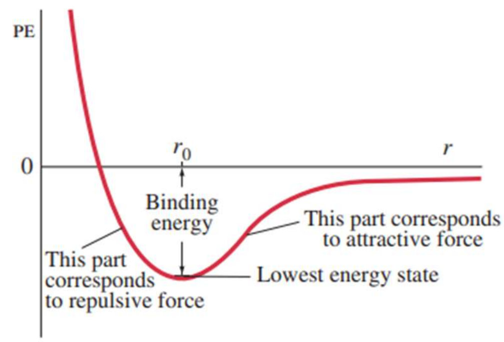
In ionic bonds, there are two charged atoms that share an electron, but unequally. In ionic bonds, one of the atoms, the one with a higher affinity of the electron will have a higher probability of holding the electron. The electron cloud will amass toward that atom.



Van der Waals Bonds:

The above bonds we discussed are called the strong bonds, which hold atoms together to form molecules. Now, the bonds formed between molecules, which occurs only due to the simple electrostatic interaction between the molecules. These bonds are referred to as weak bonds. The weak bonds such as dipole-dipole bonds, dipole-induced dipole bonds and simple electrostatic bond between non-polar molecules are referred to as Van der Waals bonds and the forces involved are called the Van der Waals forces.

Potential Energy Diagrams in Molecules



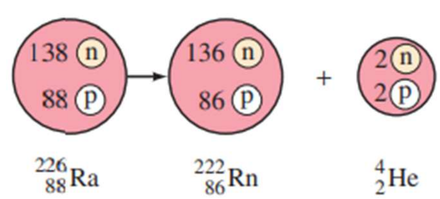
When we look at the charges for the atoms, we see that their positive charges in the nucleus and negative charges in electrons. Considering this when bonds are formed by sharing electrons, there are repulsion forces with electrons and attractive forces with protons. So, the potential energy diagrams must be combination of the graphs for both types of forces. The curve on the right describes the PE for the H_2 bonds.

Structure of the Nucleus

After a significant number of experiments, we have determined the various components of the atom. We are already aware of these components. We have the electron and a nucleus, which is present at the center. This nucleus also consists of two other particle, protons and neutrons. Protons have a positive charge, equal and opposite to the charge of an electron, and neutrons are chargeless. The number of protons in a nucleus determine the element the atom is, which is also the atomic number. The total number of protons and neutrons is the mass number. Nuclei that contain a different number of neutrons and same number of protons are called isotopes. Nuclear masses are specified in unified atomic mass units (u).

$$1\ \text{u} = 1.6605 \times 10^{-27}\ \text{kg} = 931.5\ \text{MeV}/c^2.$$

Alpha Decay



Many experiments show that nuclei decay. One of these types of decay emits alpha particles. An alpha particle is a Helium atom ($He^4{}_2$). When alpha decay occurs to an atom, the atomic number decreases by 2, and the mass number by 4. This process is referred to as transmutation, a process by which an atom turns into a different atom. The following is a generalized equation.

$$^{A}_{Z}\text{N} \rightarrow\ ^{A-4}_{Z-2}\text{N}' +\ ^{4}_{2}\text{He}$$

All images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli

Beta Decay

Another form of decay is where an electron is emitted from the nucleus from the breaking apart of a neutron, it's called a Beta minus decay, where the atomic number increases by 1 and the mass number remains the same.

$$^{14}_{6}C \rightarrow ^{14}_{7}N + e^{-} + \text{neutrino}$$

In a beta minus decay, the neutron breaks up into a proton, electron and a neutrino.

$$n \rightarrow p + e^{-} + \text{neutrino}$$

There is a second type of Beta decay, called the Beta Plus Decay. Beta Plus decay results in the emission of a positron, a particle identical to the electron with opposite charge. Here, the atom number decreases by 1, with the mass number remaining the same.

$$^{A}_{Z}N \rightarrow ^{A}_{Z-1}N' + e^{+} + \nu$$

Electron Capture

In this process, the nucleus absorbs a electron from the orbiting electrons. The proton in the nucleus absorbs the electron, making a neutron. So it decreases the atomic number by 1 and keeps the mass number the same.

$$^{A}_{Z}N + e^{-} \rightarrow ^{A}_{Z-1}N' + \nu$$

Gamma Decay

From the previous sections, we saw that the electrons in the atom can be excited to a higher energy state. But when these high energy states decay back to their ground state, they release a photon, which we refer to as a gamma ray. This decay is referred to as a gamma decay.

$$^{A}_{Z}N^{*} \rightarrow ^{A}_{Z}N + \gamma$$

CHECK YOUR LEARNING

1. A hydrogen atom (Z=1) is bonded to another hydrogen atom to form H_2. Which of the following are possible spin states of the two shared electrons?

   (*a*) $+\frac{1}{2}, +\frac{1}{2}$.
   (*b*) $-\frac{1}{2}, -\frac{1}{2}$.
   (*c*) $+\frac{1}{2}, -\frac{1}{2}$.
   (*d*) Both (*a*) and (*b*).
   (*e*) Any of the above.

2. The atoms of various elements are distinguishable by
   a. The number of electrons
   b. The number of protons
   c. The number of neutrons
   d. None of the above
   e. All of the above

THINGS YOU MAY STRUGGLE WITH

1. Looking at bonds from the quantum mechanics perspective can be confusing. That kind of thinking is not intuitive so it's good to use easy examples like the one mentioned above to see how it works. You need to be able to see the effect on the electron cloud shape and determine it by looking at the possible states for the electrons.

2. The difference between the different types of bonds is also important to keep in mind, especially for the two strong bonds, covalent and ionic.

3. Remembering all the different kinds of decays and distinguishing them from one another can be challenging. What would be helpful for this is memorizing the effect each has on its daughter nucleus and what is emitted as product.

Thanks for checking out these weekly resources! Don't forget to check out our website for group tutoring times, video tutorials and lots of other resource: www.baylor.edu/tutoring ! Answers to check you learning questions are below!

Answers: 1. E, 2. C

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