CHE 1301

Basic Principles of Modern Chemistry I

Week 14

Hi! Thanks for checking out the weekly resources for Chemistry 1301! This resource covers topics typically taught by professors during the 14th week of classes.

Visit our website, https://baylor.edu/tutoring, to sign up for appointments and check out additional resources for your course! You'll find helpful links with the following titles:

- "Online Study Guide Resources" – The pace of your course may vary slightly from what's shown in this document. If you don't see the topics you're learning right now, use this link to find the weekly resources for the rest of the semester.
- "How to Participate in Group Tutoring" - See if there is a Chemistry 1301 group tutoring session being hosted this semester. These are weekly question/answer sessions taught by our master tutors!
- "View tutoring times for your course" or "Schedule a private 30-minute appointment!"

You can also give us a call at (254)710-4135, or drop in! Our hours are Monday-Thursday 9 am – 8 pm on class days.

KEY WORDS: Phase Changes, Intramolecular Forces, Intermolecular Forces, Boiling Point

TOPIC OF THE WEEK: Phase Changes

Phase changes: changes in forces among molecules

Part I: The Forces

A phase is defined by molecules' density, or how close they are to each other. When they're very close, the substance is said to be a **solid**. When they're very far, the substance is a **gas**. And some distance between those two classifies the substance as a **liquid**. Each of these phases has distinct physical properties that we have learned to recognize. So, what factors determine that density? (What determines phase?) Two things:

1. "pull" forces = attractive forces
    a. When it's harder to separate the molecules, they will have higher densities.
    b. The total magnitude of these attractive forces determines **potential energy**.
2. "push" forces: the energy of motion *disperses* molecules
    a. When the molecules are moving faster, they will stay apart more easily and have lower densities.
    b. **Temperature** determines the speed of the molecules, which determines their **kinetic energy**.

Part II: When the Forces Change

The “push” and “pull” forces oppose each other, and the density is determined by both. When the forces change, so do the densities. If the change present is strictly a phase change, we’re not adding any new chemicals in, so the attractive forces stay the same. But if the temperature increases/decreases, so do the “push” forces, which means that the substance changes phase without changing the composition of the mixture. Here are the names of various types of phase changes:

Endothermic phase changes (ending state has more kinetic energy than starting state)

*When memorizing, notice: all of the endothermic phase changes result in the molecules’ being further apart than they started off. Why is this? Because “push” forces are being increased— see above.

Solid → gas	**Sublimation**
Solid → liquid	**Melting**
Liquid → gas	**Vaporizing**

Exothermic phase changes (ending state has less kinetic energy than starting state)

*All of the exothermic phase changes result in the molecules’ being closer together than they started off

Gas → solid	Deposition
Gas → liquid	Condensation
Liquid → solid	Freezing

Now, we’ll look more closely at the attractive “pull” forces mentioned above. Here are the relationships between phase changes and the rest of the topics that we’ll cover in this resource:

Phase changes (*Topic of the Week*) depend on:

1) “Push” forces
2) “Pull” forces (*Highlight 1, applied in Highlights 2 & 3*)
    a. Intramolecular forces (covalent, ionic)
    b. Intermolecular forces (ion-dipole, hydrogen bonding, dipole-dipole, ion-induced dipole, dipole-induced dipole, London dispersion)

Highlight 1: Attractive Forces Overview

There are several types of forces that hold substances together:

1. **Intramolecular forces**: These forces are present within molecules. They are stronger than intermolecular forces. The two types are:
    a. **Covalent** bonds: atoms are held together by the mutual possession of one or more electrons
    b. **Ionic** bonds: atoms are held together because they have opposite charges (one has lost one or more electrons, and the other has gained one or more electrons)

2. **Intermolecular forces**: These forces are present between molecules. They are not as strong as intramolecular forces—that's why there is more space between atoms of different molecules than atoms of the same molecule. The reason for these forces is attraction between opposite charges. Here are three **reasons that parts of molecules might have charges**:
    a. They are ions: if an atom has lost or gained electrons, it is called an ion. (Connection to above: The intramolecular forces present in this case are *ionic bonds*.)
    b. There are permanent **dipoles** present: Dipoles are present if there are electronegativity differences between the two atoms forming a covalent bond. **Greater electronegativity differences mean stronger dipoles.**
        i. For example, when hydrogen is bonded to nitrogen, oxygen, or fluorine, N/O/F have quite a bit more possession of the electrons than H. So, H ends up with a strong partial positive (not fully positive—its electron isn't being taken, just shared unequally) charge, and N/O/F ends up with a strong partial negative charge. An N/O/F from one molecule might be attracted to the H (attached to an N/O/F) of another molecule. This specific case is called **hydrogen bonding** (not actually a bond, just an attraction!)
    c. London dispersion forces: Since the movement of electrons is **random**, sometimes, one atom in a covalent bond ends up with more electrons than equal sharing would've dictated. If this is the case, said atom will have a **partial negative charge for a moment**. And the atom that it's sharing electrons with will have a **partial positive charge for a moment**. Then, the partial positive and negative charges might pull nearby electrons in other molecules and cause them to do the same thing. These are called **temporary/induced dipoles.**
        i. **There are more dispersion forces present if the electron cloud is easier to distort.** This is called being more **polarizable** and happens if the molecule/atom is bigger.
    d. These "types of charge" are listed in order of strength—ions have the most charge, then permanent dipoles, then London dispersion forces. Because of this, the types of intermolecular attractions can also be ranked in order of strength. In Highlight 2, we'll rank all of the types of attractive forces from strongest to weakest.

Highlight 2: Attractive Forces Application 1 – ordering in terms of strength

We know that intramolecular forces are stronger than intermolecular. We'll start with the intramolecular, then:

1. **Covalent bonds** are stronger than
2. **Ionic bonds**

Now, to rank intermolecular forces, consider the strengths of the different "types of charge" described above.

3. **Ion-dipole** (this notation means: one atom is an ion, and the other is part of a permanent dipole): very strong, because ions are very charged, and a dipole is less charged but still pretty charged
4. **Hydrogen bond**: a special type of dipole-dipole interaction in which the electronegativity difference is especially large
5. **Dipole-dipole**: A dipole has a fair bit of charge…two of these won't be as attracted to each other as an ion and a dipole, but the force of attraction is still relatively high
6. **Ion-induced dipole**: Induced dipoles (see dispersion forces) are fleeting, but the ion is strong enough that, if an induced dipole makes an appearance, the ion can latch on to it
7. **Dipole-induced dipole**: very similar to (6), but an atom that is part of a dipole isn't as strong as an ion
8. **London dispersion:** two induced dipoles. Relatively weak, but these are present in all molecules!

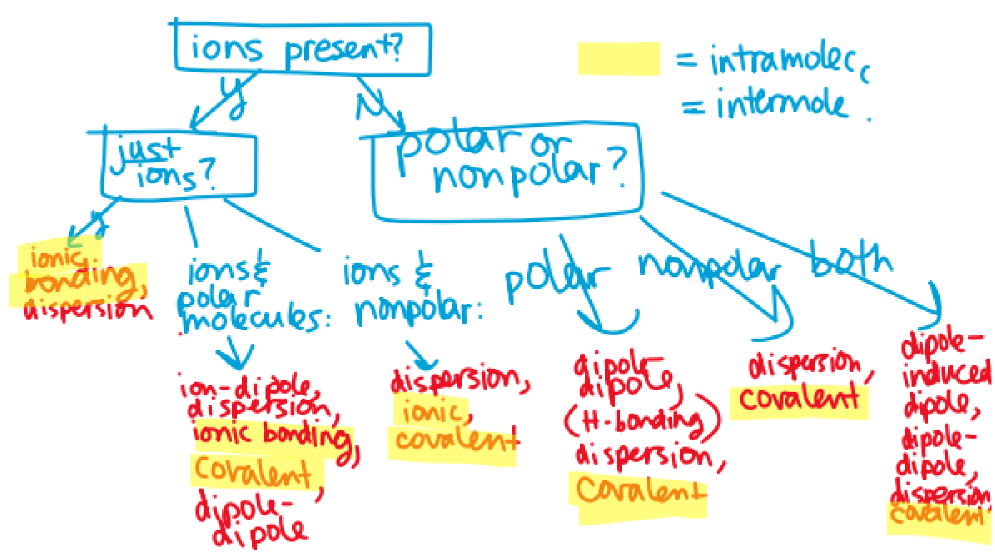
So why is it important to be able to rank these? One application that you'll definitely see is boiling point: when there are more/stronger intermolecular forces present in a substance/mixture, it will be harder to pull them apart, which means it'll be harder to boil!

More/stronger IMFs=higher B.P.

Highlight 3: Attractive Forces Application 2 – figuring out which IMFs are present

You will also be frequently asked to determine which IMFs are present in a mixture. Start by identifying which of the "types of charge" (ions, dipoles, induced dipoles *hint: this one is always present*) exist in the mixture. Then, think about which of those could be attracted to each other. Be sure to check for Hs bonded to N,O, and F! If these are present, there will be hydrogen bonding.

Here is a chart very similar to the one in Dr. Olademehin's Chapter 9 PowerPoint slides:



Check Your Learning

1. Rank the following IMFs from strongest to weakest:
    a. H-bonding
    b. London dispersion forces
    c. Ion-induced dipole
    d. Dipole-induced dipole
2. Rank the following in terms of boiling point: C_3H_8, CH_4, CH_3COOH, C_2H_6
    a. Taken from https://www.chemistnate.com/ranking-by-boilingmelting-point.html, which has more examples of this type of problem!
3. Name the intermolecular forces present in a solution of water and salt.

Things You May Struggle With

1. It might seem weird that there would be so much overlap in the types of IMFs present in mixtures. Keep in mind, there can be IMFs between molecules of the same substance! For example, in a mixture containing ions and polar molecules, there are ion-dipole interactions between the ionic molecules and the polar molecules. But there are also dipole-dipole interactions between the polar molecules. Don't forget the intramolecular (within molecule) ionic and covalent bonding that takes place.
2. Most of the time, you will be asked to rank intermolecular forces (IMFs) only, not intramolecular!

That's all this week! Please reach out if you have any questions and don't forget to visit the Tutoring Center website for further information at www.baylor.edu/tutoring. Answers to Check Your Learning are below.

1. A, c, d, b
2. CH_4, C_2H_6, C_3H_8, CH_3COOH Keep in mind, the larger the molecule, the more polarizable, and thus the more London dispersion forces!
3. Dipole-dipole (between water molecules), ion-dipole (between water and salt), dispersion forces (between all)