**Lesson Plan: Intermolecular forces and how along with shape, they work in real life**

**Lesson Title:** Intermolecular forces and how along with shape, they work in real life

**Grade/Age Level:**
10th - 12th grade

**Subject Area:** chemistry

**Time allotted for the lesson:**
4 days
  - Day 1: Definitions
  - Day 2: Long hydrocarbons have charged parts
  - Day 3: Receptors and active sites
  - Day 4: Do all molecules attach in our noses? And What does this have to do with smell?

**Short description of lesson:**
- First definitions are addressed: intermolecular forces and other words that are specific to talking about intermolecular forces.
- Then we look at shapes of long hydrocarbons and why they have charged parts. Those charged parts would be the functional groups.
- We will next explore receptors, active sites, and how molecules can connect to each other merely through being close to each other. The intermolecular forces are what let molecules be near one another without there having to be an actual chemical reaction.
- The last lessons relate to molecules attaching to specific receptors in our noses and the role functional groups play in how we perceive smells.

**California Curriculum Standards met in this lesson:**

**Chemical Bonds**

Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms and molecules. As a basis for understanding this concept:
Students know chemical bonds between atoms in molecules such as H2, CH4, NH3, HCCH2, N2, Cl2, and many large biological molecules are covalent.

Gases and Their Properties

The kinetic molecular theory describes the motion of atoms and molecules and explains the properties of gases. As a basis for understanding this concept:

- Students know the random motion of molecules explains the diffusion of gases.

Organic Chemistry and Biochemistry

The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties and provide the biochemical basis of life. As a basis for understanding this concept:

- Students know the bonding characteristics of carbon that result in the formation of a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.
- Students know how to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids.

Instructional Objectives:

1. Students will be able to list at least two intermolecular forces and explain how they play a role in molecules being able to be close to each other.
2. Students will be able to explain receptor-ligand interactions because of intermolecular forces. They will then relate this idea to why we can smell some molecules, but not all of them.
3. Students will be able to identify functional groups and make an educated guess about what the molecule with that functional group will smell like.

Instructional Procedures

Lesson Set

There are several ways this lesson can be introduced. If the class is in person, then you can create several vials that contain stuff with odors. The Living by Chemistry curriculum lists several items that work well. I advise you to wash out the cheese vials from year to year because even though it is supposed to be stinky cheese, it does not last well. What you do is have students smell the vials and describe what they smell like.

Another introductory activity could just be having ammonia or an alcohol based perfume in the room and take the lid off the container without the students noticing. Take attendance and do the normal first few minutes of class activity and let the vapor spread through the room. This is a good opportunity to explain diffusion of gas molecules throughout the air.

If the students are online, ask them questions like:
- How do you know when dinner is ready?
Do you get hungry when you go past fast food restaurants? Why do you think you are hungry?

Are there smells that remind you of something? Can you recognize your mom's perfume on somebody else? Can you smell someone wearing perfume before they enter the room?

How can you tell there may be a fire burning before you see it?

**Techniques and activities:**

**Day 1: Definitions**

For the most part the definitions are lecture based because you are introducing the students to words. Break down the words into their prefixes, roots, and suffixes if possible.

- **Inter** = between
- **molecular** = molecules
- **forces** = something that pushes or pulls on something else.

**Names of the intermolecular forces:**

- **Van der Waals** - weak forces between molecules that happen just because they are close to each other
- **Hydrophilic or hydrophobic interactions** - molecules being near each other merely because they like being associated with water or because they are trying to avoid water

Point out how shape plays a role in intermolecular activity - molecules with the same shape tend to align with each other. This is particularly true for long hydrocarbons. By the way, hydrocarbons are only made of hydrogen and carbon. If they have functional groups, then they also contain oxygen and possibly nitrogen.

Of course it is a good idea to have pictures you can show students so they can see what you are trying to describe. You may also be able to equate intermolecular forces to magnetism where two north poles repel each other and the north and south poles will connect. Be careful, though, because we don't want to have students confuse magnetic forces with intermolecular ones. They are not identical, just similar in behavior.

**Student activity:**

Students make a chart and fill in the descriptions including images they draw.

<table>
<thead>
<tr>
<th>Intermolecular force</th>
<th>What it is and how they work</th>
<th>Sketch of what it looks like</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van der Waals forces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrophobic interactions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrophilic interactions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispersion forces or induced dipole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Day 2: Introduce long hydrocarbons and functional groups.**

Ideally you would have access to the Living by Chemistry materials because they have lots of worksheets that show molecules with functional groups. You can have students
point out similarities and differences among the molecules. What do all of the molecules contain? Which atoms? Which atoms are different? Are the molecules following HONC1234 rules? What parts of the molecules look the same? Are there any patterns?

If you also have the names of the molecules, ask them to compare shape and anatomy of the hydrocarbon to its name. Are there any patterns? If so, what are they? If you do not have the LBC materials, then you may want to create your own worksheets with lots of different hydrocarbons containing functional groups and include the names of the molecules.

Provide a sheet that has the functional groups along with their names. See if students can find any patterns among the functional groups in the molecules and how the molecules are named. Ask them to find the functional groups in the molecule sheets. If this is done online, then you will want to take a lot of time to create an interactive PowerPoint activity or use software I have not learned yet how to use to create a way for students to match shapes to functional group names.

**Day 3: What does it mean to have a molecule attach to a receptor?**

You can use the images at the website to show how a molecule needs to fit in with another molecule according to their shape. If they will fit together, then their electric charges need to be compatible as well as their hydrophobic or hydrophilic parts. If parts of both molecules fear water, then they will tend to cling together away from the water. Partially positive parts of molecules will bond with partially negative parts of other molecules.

You can also go to the protein database, http://www.rcsb.org/pdb/home/home.do, and search for ligand-receptor images. You can download or have students download the images and view them in jmol. There is another program, Ligand explorer, which lets viewers rotate the molecules and look closely at the intermolecular forces between the molecules at the active site. This unit was originally planned with the idea students would use the Protein Data Bank to explore how toxins connect to their target molecules. Some images you can explore at the protein data bank that show these interactions are:

- In this image, the ligand is really tiny, but you can see the various ways molecules can bind to other molecules by looking at the possible controls in the software:
  - http://www.rcsb.org/pdb/explore/viewerLaunch.do?viewerType=LX&structureId=3UK0&hetId=EDO
- This image has a small peptide, a protein, in a pocket of an enzyme:
  - http://www.rcsb.org/pdb/explore/jmol.do?structureId=1OHE&bionumber=1

**Day 4 and lesson Closure: Do all molecules attach to receptors in our noses? And What does this have to do with smell?**
This lesson focuses on why we can smell some things and not others. For the most part, molecules have to have a charge so they can stick to the receptors in our nose. This is why we can smell ammonia, NH₃, even though it is a very small molecule. Most other small molecules, especially if they are diatomic molecules will just float on by without getting stuck.

**Why do the molecules that stick, stick?**

Our noses are moist so first of all, charged molecules will be attracted to the partially charged water molecules in our noses. The smell molecules will dissolve into the water layer and then if there is a receptor where they can stick, they will. The receptor has to accommodate the shape and charge of the odoriferous molecule. The images on why things stick and active sites will accompany this part of the lesson.

**How do we know it stuck?**

The receptors are connected to nerves that transmit the message to our brains. I attempted to make an image of this process and while trying to revise it and take into account suggestions from peer reviews, at this moment I do not have a solution. Perhaps by the time this assignment is submitted in full, that image will be clearer.

**What does this have to do with smell?**

Since smell not only relies on molecules being attached to a receptor, it also requires a message to be sent to the brain, we will only be able to smell odors that can be transmitted to the brain. You may have noticed how if you are in a room with a particular odor that it smells really strong at first, but you do not notice it after some time. If you have not exposed students to ammonia yet, this may be a good time to show them how it smells very strong at first, but over time they tend to ignore it. This is because the receptor or sensor that picks up that smell has been saturated. Either more molecules do not attach because the space is filled, or if more molecules attach, the nerve connected to the receptor ignores the message. It is already saturated with signals, more will not make a difference. For students who are remote learners, you can ask them about perfume someone wears in the home and think about how they are able to smell it when they first encounter the person and do not notice it an hour or so later.

**Stuff for kids to do:**

Well, if you have copies of the smell molecules and the ones that do not have an odor, you can have students sort them according to smell/ don’t smell and look for patterns or differences. Then you can give them some “unknown” molecules and ask them to categorize them.

If I figure out how to get the image in my mind “onto paper”, I want to create receptor pockets for molecules so students can manipulate the molecules to see how they would fit. You are welcome to use this idea and share your products with me.

Students are given an “unknown” molecule and they need to write a hypothesis for how it will smell and justify why they anticipate that molecule will smell that way. If the molecule will not have an odor, then they need to justify why they think it will not smell.
Lesson Closure

Well, the last lesson set on why molecules stick to the nose and why do we smell them is pretty much the closure of this part of the ‘intermolecular forces lead to being able to smell’ lessons.

Adaptations for special learners

Again, these lessons should already be written in a way that all learners can succeed. Yes, the text parts should be made into an audio version so students can listen while they read. In addition, lectures can be videotaped so they can be watched again at a later time. The teacher needs to decide on his/her own deadlines and if any of them need to be adjusted.

Supplemental Activities: Extension and remediation

Extension: Have students find a receptor and its ligand in the protein data bank and make a web page where they embed jmol and the molecular image for others to enjoy. On this page they should also explain what the receptor molecule is and what the ligand is. Is it something involved with metabolism? Is it a toxin?

Extension: Have students research how drugs affect the body. There are reasons cocaine loses its power over time. It has to do with receptor saturation, but these receptors are not in the nose, they are in the brain.

Remediation: Allow students to try the exercises again. Don’t use all of your molecules the first time you teach it so students can try some of the exercises with “new” molecules.

Remediation and Extension: have students draw a receptor and a molecule that will fit into it so they can show how the shapes need to complement each other.

Assessment/Evaluation:

<table>
<thead>
<tr>
<th>Objective</th>
<th>What students will do</th>
<th>When do they do this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will be able to list at least two intermolecular forces and explain how they play a role in molecules being able to be close to each other.</td>
<td>Students make a chart and explain the forces and what they do</td>
<td>Day 1</td>
</tr>
<tr>
<td>Students will be able to identify functional groups and make an educated guess about what the molecule with that functional group will smell like.</td>
<td>Analyze images of molecules for their shape, relation to smell, HONC1234 fit, and</td>
<td>Day 2</td>
</tr>
</tbody>
</table>
Objective

| Students will be able to explain receptor-ligand interactions because of intermolecular forces. They will then relate this idea to why we can smell some molecules, but not all of them. | Students identify molecules and hypothesize how they will smell. They also explain why some of the molecules will stick and others won’t. | Day 3 and 4 |

Formative assessment:

Student behavior will be observed. They should be given several opportunities to evaluate molecules along the way and write their feedback based on their impressions at the moment. They could have quick response questions like:

- Does the molecule follow HONC1234 rules?
- Are there functional groups? How do you know?
- What makes up functional groups?
- What makes a functional group a functional group? What makes the functional group different than an ordinary hydrocarbon?

If the lesson is synchronous online, then these could be short answer questions tossed out as polls or for students to write down answers to submit to the instructor as the lesson progresses. If asynchronous, these could be warm-up questions students answer on the way to do a day’s lesson. Or they could be exit questions students answer on their way out.

There should be at least one discussion forum to go with this lesson. This would be formative or summative assessment depending on how the teacher wants to use it. Possible discussion questions include:

- Why is it important that we do not smell all molecules?
- Describe what it would be like if you could not smell any molecules?
- What molecules are you more sensitive to smelling than other molecules? How do you know?
- What would life be like if our receptors or nerves did not get saturated with smell stimulations?
- What are some important ways odors and being able to smell plays a role in our lives?

Learner Products

Students will be filling out worksheets, evaluating shapes of molecules, drawing Lewis Dot Diagrams, and evaluating molecules to determine if we would smell them or not.

Most of the products will be student written responses to questions that ask them to identify molecules, their functional groups, and predict how they will smell. Depending on student environment, they could be sorting molecules on a computer or paper cut-outs on their desk.
Students will also write a short document including a hypothesis and justification for odor or no odor for an “unknown” molecule.