Covalence: An Organic Chemistry Puzzle Game

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Abstract: *Covalence* is a game designed to turn the basics of Organic Chemistry into a mobile-style puzzle game. Intended to be played by OChem students learning the subject for the first time, the game draws inspiration from traditional chemistry notation such as line-and-dot diagrams, and integrates them with a 3D model of the system they're exploring, in an attempt to make the relationships between atoms and the complex 3D shapes that molecules take more understandable, through the lens of interactivity.

Game Format and Mechanics

Covalence is a digital view of what it would look like in a chemical mixture, with atoms floating in a solution, waiting to be bonded. The game has a casual writing style and its puzzles introduce each atom as a new character, similar to a new bird in *Angry Birds*. Puzzles are built around making certain shapes or realizing how many bonds a specific atom can take. It was designed as part of my Master's thesis for the Interactive Media program at the University of Southern California.

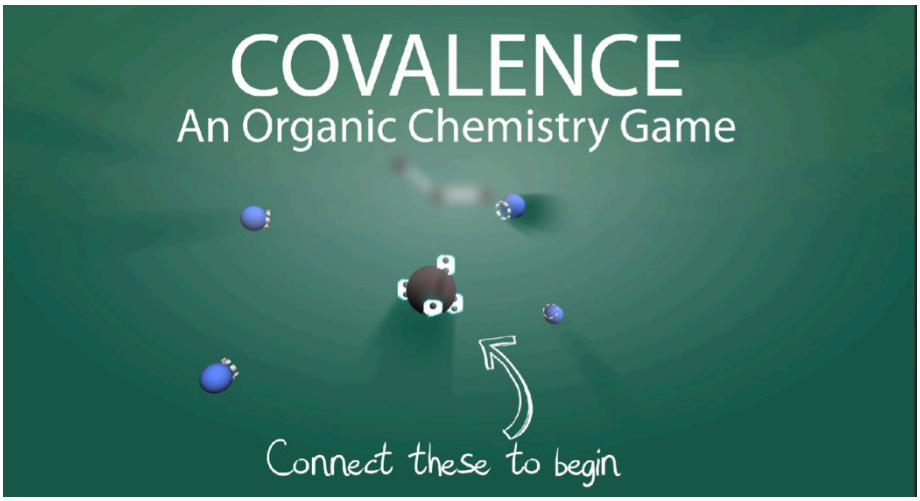

Figure 1: The start menu of the *Covalence*. Players bring enough Hydrogen (blue atoms) to the central Carbon (brown atom) in order to fully saturate the Carbon and form a molecule.

In most levels of *Covalence*, the player starts with a soup of atoms, some of which are unnecessary to complete the level. Levels require the player to make a specific molecule, a specific shape, or an arrangement of atoms, such that two molecules are either exactly the same or mirror images of each other. The player comes to associate certain atoms with shapes (Carbon, for instance, always makes four bonds, while Oxygen makes two, and they shape the molecules accordingly). The intention is for players to make these associations quickly and naturally, and hopefully take this knowledge into the classroom.

The game is intended to quickly get students up to speed on how atoms bond to each other, the shapes molecules take, and now to recognize the arrangement of atoms in 3D space. Over time, the molecules get more complex, and include puzzles built around understanding spatial arrangement.

Design Challenges and Approaches

Organic Chemistry is one of the most challenging classes in the college Pre-Med track, and a strongly feared college STEM course. A requirement for Admissions tests for Med school, Dental school, and Pharmacy, Organic Chemistry is widely studied by more than just Chemistry students. The subject is a complex study of molecular formations, spatial arrangements, and electromagnetic phenomena, and is unfortunately a roadblock that prevents many from pursuing a chosen STEM field.

Part of the difficulty of the course comes from the inherently 3-Dimensional nature of molecules, and the translation of that into traditionally 2-dimensional learning tools such as paper or the chalkboard. Shape and the arrangement

of atoms in a molecule are extremely important in Organic Chemistry, and it's hard to see a 3D structure in 2D without some sort of approximation.

To translate the 3-dimensional molecule to the 2-dimensional paper or chalkboard, Chemists use a line drawing system, where bonds are represented as lines and atoms are represented as letters, and notations are used to show atoms that are 'in front of' or 'behind' the chalkboard. They may also use a system of computer-generated balls and sticks, which do a better job of representing 3-dimensionality, but still hide much of the information from the reader (such as where the other electrons are in the molecule). Even toy models that recreate the shapes of molecules hide valuable information, and this hiding can lead to confusion when understanding how the shapes form.

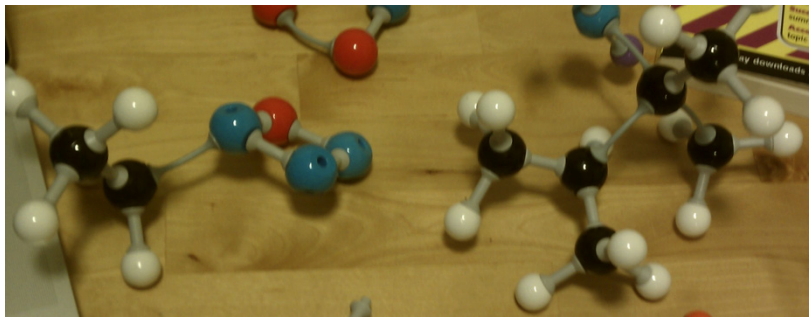

Figure 1: Line drawings (top) and physical models (bottom) of molecular formations. All three served as inspiration for the *Covalence.* Source: http://en.wikipedia.org/wiki/VSEPR_theory

In designing the game, then, I opted to show as much information as was necessary to understand the idea of bond formation. Bonds are formed via electron pairs (the number of which are specific to each atom). A bond forms by sharing the electron pair between two atoms, and molecules take shape based on how many bonds are connected to a specific atom. The game is intended to see atoms and their electrons as a sort of plug-and-socket relationship, so that the formation of atoms feels like a sort of 'underwater LEGO' game.

In addition, the game allows the player to fully rotate around molecules, getting a feel for their shapes in a manner similar to a physical model representation of them. However, it integrates information about electrons and their effect on molecule shape in a manner that most molecular model sets do not.

Next Steps and Future Application

Chemical reactions are largely based on the attractions of electrons between atoms, and I'm hoping to expand *Covalence* such that the game teaches fundamental Organic reactions. These reactions can then serve as mechanics in themselves, leading to puzzles where the player has to figure out what reactions to perform in order to make a certain molecule, an activity similar to the work that Organic Chemists in the real world do every day.

Acknowledgments

I would like to acknowledge Jeremy Gibson, Marientina Gotsis, Laird Malamed, and Dennis Wixon of the USC Interactive Media division, as well as Lisa Clements of Disney Educational Productions, for their help on this project.