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Orbital Battleship: A Guessing Game to Reinforce Atomic Structure

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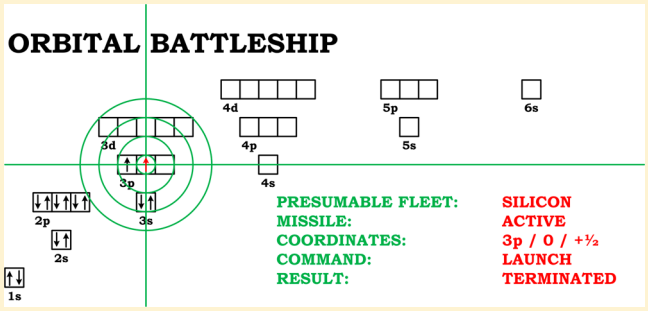
Supporting Information

ABSTRACT: A competitive educational guessing game "Orbital Battleship" which reinforces Madelung's and Hund's rules, values of quantum numbers, and understanding of periodicity was designed. The game develops strategic thinking, is not time-consuming, requires minimal preparation and supervision, and is an efficient and fun alternative to more traditional forms of education.



KEYWORDS: *High School, Introductory Chemistry, First-Year Undergraduate, General, Physical Chemistry, Collaborative, Cooperative Learning, Humor, Puzzles, Games, Atomic Properties/Structure*

One cannot overestimate the importance of games in a world of modern education.[1−3] No matter the subject field, games have been proven to be both useful and fun for any age group. It is a powerful educational tool that can be shaped in any necessary way. Guessing games have earned a special place in the variety of educational games. As games represent an interactive way of learning, they can improve many skills such as collaborative working, problem solving, strategic thinking, etc.

Guessing games are especially good at improving strategic thinking. Guessing is a way of playing; however, students have to think of a smart strategy to win this kind of game. Competitiveness acts as an extra motivation factor, which makes the process of playing more engaging and fun at the same time. Guessing games can teach, reinforce knowledge, and act as a memorizing tool in many fields of chemistry.[4−8]

An example of an educational guessing exercise is guessing the number of candies in a jar.[8] This student activity is aimed at understanding conversion of units and improving proportional thinking. The point of this activity is to as nearly as possible guess the amount of candies in a jar that students are facing. This is competitive guessing which can be widely used for students of different ages. More remarkable examples include "Chemistry Taboo", focusing on learning and reinforcing general chemistry, and "Guess Who?", aimed at learning names of crucial organic compounds.[4,5] It is evident that educational and particularly guessing games are widely used in various fields of chemistry to enhance and improve the learning process.

A new game that we propose is called "Orbital Battleship", which is designed to test and reinforce existing knowledge of the atomic structure. This game comes from the original "Battleship" game, where the aim is to position the battleships in such a way that the opponent's battleships are terminated earlier.[9] The same concept is used in Orbital Battleship, except that the battleships represent energy subshells of a chosen atom. Orbital Battleship is suitable for both high school and first-year undergraduates.

GAME RULES AND PREPARATION

Orbital Battleship requires minimal preparation. The students face each other across the table. Students are divided into pairs by the teacher (student A and student B). Each student is given a sheet of paper with two copies of the diagram previously described in this journal.[10] For each student, one copy of the diagram is the map of his or her battleships, the other one is the map of his or her opponent's battleships (Figure 1). See the Supporting Information to download and print the maps.

To play Orbital Battleship, follow the simple rules outlined here:

To begin, both students choose one of the 118 chemical elements in mind and display their ground state orbital occupancy on the top map (Figure 2), paying attention to Madelung's and Hund's rules, number of the electrons, etc.

Next, students take turns firing at electrons using quantum numbers as coordinates. To fire at an electron, students name the symbol of the sublevel, the value of the magnetic quantum number, and the spin. For example: "3p, 0, $+^1/_2$" (Figure 3). For convenience and to avoid ambiguity, the orbitals are filled with electrons from left to right starting from the highest value of the magnetic quantum number. Upside arrows symbolize electrons with a positive spin, and vice versa.

Students play strictly in turns. During the turn, it is allowed to either fire into the opponent's electron only once or name the opponent's chemical element.

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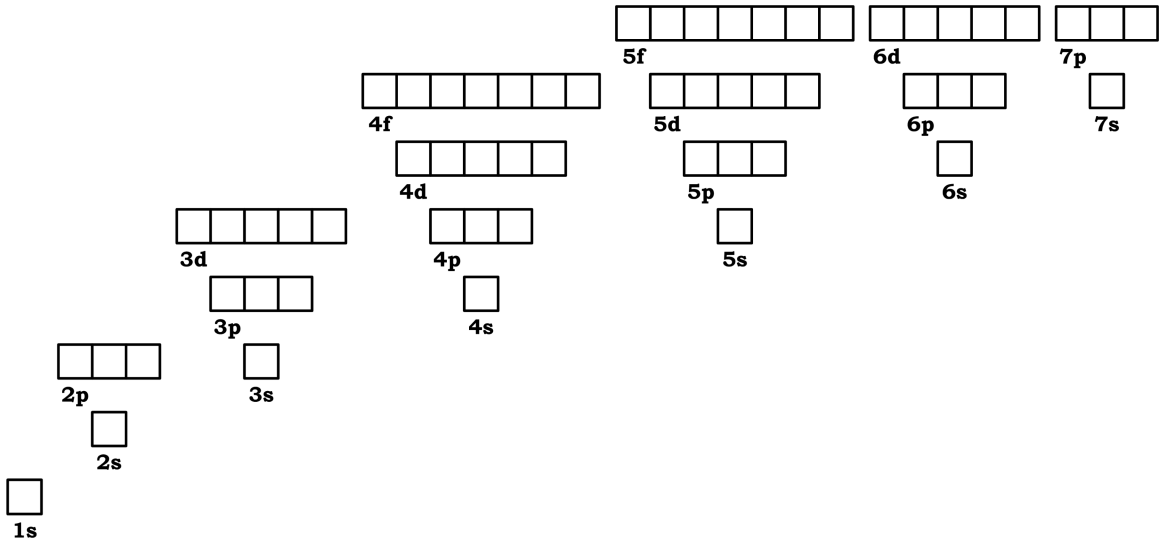

Figure 1. Map.

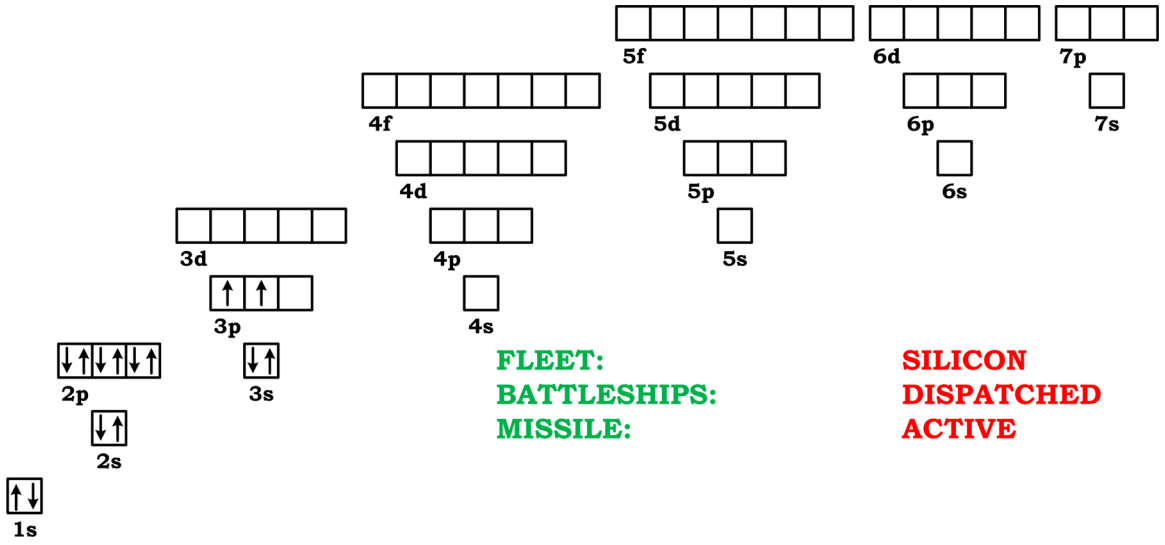

Figure 2. Student A battleships on the top map.

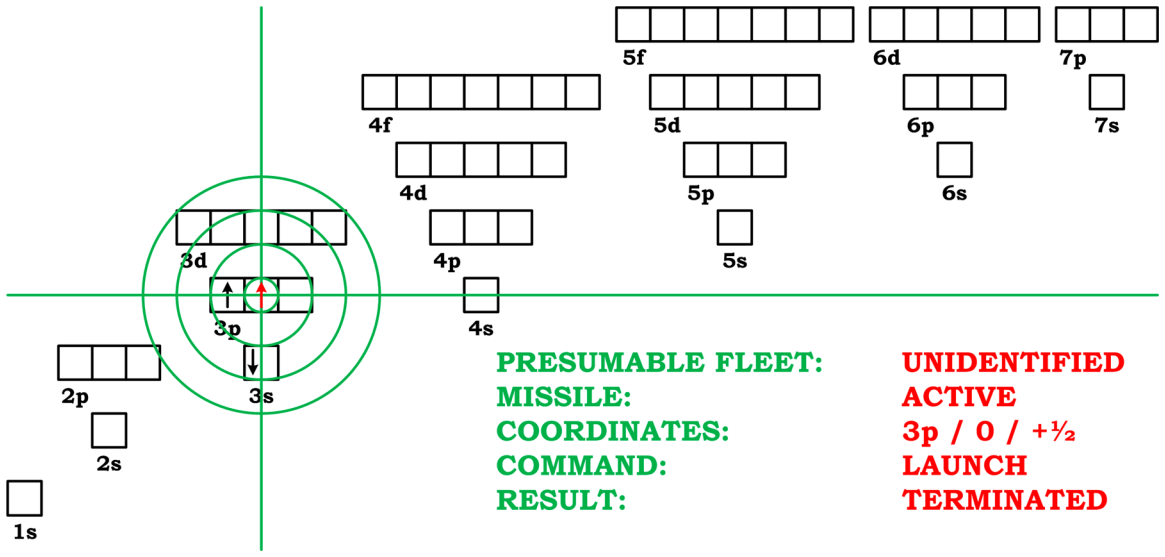

Figure 3. Student A battleships investigated by Student B on the bottom map.

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Each time the coordinates are named, the opponent replies whether it is a "hit" or a "miss".

After firing, students display the investigated opponent's orbital occupancy on the bottom map.

The aim of the game is to guess the opponent's element first.

The game needs little supervision from the teacher. The teacher conducts the gaming process and consults the students if asked. A game for one pair takes from 5 to 10 min (depending on the difficulty of the element). The number of the games played at the same time is unlimited and depends only on the number of the students in the class. If the number of students is odd, the teacher can join in or students can play in turns. Provided the number of the students is 2^n where $n = 3-5$, it is possible to organize Orbital Battleship as a cup (with quarterfinals, semifinals, and the final, etc.). The finalist is allowed to take part in the superfinal with the teacher and, may the teacher lose, win a prize, extra credits, etc. An Orbital Battleship Cup for 8 students takes approximately 60 min and for 16 students takes approximately 90 min.

EDUCATIONAL GOALS

Orbital Battleship achieves several educational goals, among them:

(1) Reinforcing Madelung's and Hund's rules and values of quantum numbers. It is impossible to play without existing knowledge of these rules. Students take part in several games back to back because a game takes from 5 to 10 min.

(2) Emphasizing periodicity. For most elements, it is only necessary to fire out the battleships which are characteristic of the element, for example, if $3p^5$ is fired out, it is $_{17}$Cl.

(3) Developing strategy skills. Players need to think about possible positions of the opponent's battleships before they fire; they may also need to think a few steps ahead. Winning the game relies on both using knowledge of physical chemistry and a little luck.

(4) Increasing motivation and concentration. Competitiveness of the game with a possible prize at the end for the best player enables them to play the game at their best.

We believe that Orbital Battleship stands out among other guessing games. One of the advantages of our game is the fact that students choose their element. In comparison to other games, for example, Guess Who?, where students pick a card with a name of a compound written on it, our game gives an opportunity for students to use their imagination and pick an element themselves.[5] This is a great advantage as it lets students use their creativity, which also helps to reinforce this topic. Students constantly have to think about which element to pick, and which element is more difficult to guess. All of the above has to be done in mind quickly before the start of the game, so Orbital Battleship makes students think and learn before the game even begins.

Another great asset of Orbital Battleship is the fact that students play in pairs against each other. Unlike "A game for the early and rapid assimilation of organic nomenclature", where students are split into two teams and all play at once, our game offers deeper involvement in the process.[7] As long as students play one on one, educational goals are achieved faster and more efficiently. Each student needs to think about his or her own element as well as the atomic structure of their opponent's element. One cannot win the game by someone else in the group telling the right answer or by guessing. Guessing is an important feature of the game, but it has to be an educated guess. Hence, those who do not know any rules can be quickly spotted by the teacher and get assistance. As a result, educational goals impact every individual taking part in the game, which makes this educational tool more effective.

Orbital Battleship is a simple game; however, this is not always the case for guessing games. "A game to show approach to teaching peptide sequences" is a magnificent educational tool but requires some home preparation.[6] The game that we offer does not need any prior work; everything is already done for students as they come into class. It is both simple in preparation and during the process as it is based on the popular "Battleship" game. "A game to show approach to teaching peptide sequences" is not based on any analogues, and its rules and especially the scoring system are rather difficult. The advantage of Orbital Battleship can be clearly seen, as most students are likely to already know the general rules of the "Battleship" game, so understanding the rules of Orbital Battleship can happen on an almost intuitive level.[9] Understanding the rules and quickly getting involved in the game is a vital part of achieving educational goals effectively.

HOW STUDENTS REACT

The game was tested on 5 groups of students (50 students). A brief verbal survey of the students' reaction shows that they find the game very competitive, especially when Orbital Battleship is held in the form of a cup. Participants admit that the possibility of taking part in the superfinal and try to beat the teacher is an additional motivation to study the atomic structure and prepare beforehand. What is more, those students who had qualified further in the cup confessed that the game actually reinforced their knowledge of the atomic structure and made them more confident in displaying the orbital occupancy according to Madelung's and Hund's rules and gave them a better understanding of periodicity. The students had a fun time with the game and found it to be a refreshing alternative to more traditional forms of education.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.6b00136.

Maps for playing (PDF)

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Notes

The authors declare no competing financial interest.

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