Quantum Numbers and Nodes

Instructor Notes

Overview

This activity is intended for use in a college-level first semester/first quarter general chemistry course, and is designed to help students complete the following learning objectives:

a) describe the meaning of the quantum numbers n, l, and m_l;
b) determine the values of the quantum numbers n, l, and m_l;
c) describe the meaning of radial and angular nodes;
d) determine the number of radial and angular nodes on different types of atomic orbitals;
e) begin to understand the correlation between the quantum numbers and the total number of atomic orbitals for a given atom, and how the periodic table can be used to build up the overall orbital structure for an atom.

This activity is designed to be done at the beginning of the typical first quarter/first semester general chemistry course (for an atoms first approach; if instructors use a traditional course structure this unit is likely done towards the middle/end of the first quarter/semester). Students will be expected to have learned the following concepts prior to completing this activity:

a) quantization of energy in the atom and the Bohr model of the atom;
b) how the wave/particle duality of electrons was described by de Broglie;
c) how the wave/particle duality of electrons was used by Schrodinger to develop the quantum mechanical model of the atom;
d) how radial probability distribution was used to generate the idea of atomic orbitals, and orbital probability surfaces.

Note: At our institution the atoms first approach is used in our general chemistry curriculum. The unit on electronic structure comes immediately after the unit on basic atomic structure, and the unit on electronic directly precedes the unit on chemical bonding.

Pre-lecture Online Learning

a. Pre-lecture Quizzes:

Studies of previous implementations of flipped classroom modules indicate simply asking students to watch videos prior to lecture is not an effective way to ensure compliance and can result in students being unprepared for the in-class activity.[1] Therefore, instructors are

[1] He, W; Holton, A; Farkas, G; and Warschauer, M. (2016), "The effects of flipped instruction on out-of-class study time, exam performance, and student perceptions." *Learning and Instruction*, 45, 61-71.

encouraged to assign a pre-lecture quiz that assesses student learning from the video lecture. A pre-lecture quiz is provided as a separate file in this module, and instructors can deliver this using either the test/quiz function in their course management system or using in-class clickers to solicit answers prior to starting the in-class activity. It is noted the pre-lecture quiz is designed to determine if students completed the pre-lecture learning activities, and the difficulty of these questions is appreciably lower than the questions found in the in-class activity (this explains why the success rates on the pre-lecture quiz are similar to the success rates on the in-class activity).

If instructors are interested in further increasing the interactivity and engagement of the pre-lecture videos they might consider embedding the videos in the Playposit system (https://learn.playposit.com/learn/). Playposit allows instructors to insert questions within the video, which then must be answered by the student before proceeding further in the video. Not only does this help increase the interactivity and engagement of the video, but since the Playposit questions can be assigned for homework and awarded points this also helps increase student compliance.

b. Pre-lecture videos for quantum numbers (Khan Academy):

The videos associated with this pre-lecture learning module are found in the Chemistry course within the Khan Academy site, and are specifically located in the "Quantum Numbers and Orbitals" sub-unit within the "Electronics" section of the Khan Academy chemistry course. In order to be prepared to complete the in-class activity, students should read the review/summary on the quantum mechanical model of the atom, then watch the two videos that explain the concept of quantum numbers and how quantum numbers are determined for the first four energy levels in the atom:

Review/summary of the quantum mechanical model of the atom:

https://www.khanacademy.org/science/chemistry/electronic-structure-of-atoms/orbitals-and-electrons/a/the-quantum-mechanical-model-of-the-atom

Video 1 ("Quantum Numbers"): https://www.khanacademy.org/science/chemistry/electronic-structure-of-atoms/orbitals-and-electrons/v/quantum-numbers

Video 2 ("Quantum Numbers for the First Four Shells"): https://www.khanacademy.org/science/chemistry/electronic-structure-of-atoms/orbitals-and-electrons/v/quantum-numbers-for-the-first-four-shells

Even though the Khan Academy provides a freely accessible set of online videos that reduces the barrier to implementing flipped classroom modules, instructors are encouraged to create their own set of videos if time permits. The author's previous experience has found students generally appreciate seeing and/or hearing their own instructor in the video, and more importantly students

have less uncertainty about what specific topics are considered important by the instructor when the video is created by their own instructor. Though there are numerous ways in which faculty can create their own online videos, the author has found using the Zoom teleconferencing system screen capture function while annotating Powerpoint slides on a tablet/laptop with touch screen functionality is the most cost-effective and convenient method for creating new videos. The following link provides instructions for creating videos using the Zoom teleconferencing system:

https://support.zoom.us/hc/en-us/articles/201362473-Local-Recording

In-class Activity

It is recommended that students be given 2-3 days to complete the pre-lecture activities described above. As mentioned above, instructors are encouraged to assign the associated pre-lecture quiz or deliver these questions to students at the beginning of lecture using a clicker in-class response system. The in-class activity can be completed in one 50-minute or one 80-minute lecture period, depending on how the instructor chooses to implement the activity. If instructors are implementing this in a 50-minute lecture, using the online pre-lecture quiz instead of the in-class clicker questions would be advised to help ensure the activity can be completed in the 50-minute time frame. Below is a suggested timeline.

-Clicker questions to administer pre-lecture quiz (optional; instructors may wish to administer the pre-lecture quiz online using the test feature in their course management site): 10-15 minutes

-Introduction to the activity: 5 minutes

-Groups of 3-4 students work collaboratively on in-class activity worksheet, and answer questions in free response form: 20-25 minutes

-Instructor solicits answers to multiple choice versions of the worksheet questions using an in-class clicker system (optional; instructors may wish to collect the free response answers and grade them manually): 15-20 minutes

-Summary and activity wrap up: 5 minutes

If instructors choose to solicit answers to the worksheet questions using an in-class clicker system, multiple choice versions of the questions are provided in a separate Powerpoint file within this module. The answers for the multiple choice versions of the questions are provided in the answer key, which is also included as a separate PDF file. If the instructor's institution does not use a campus-wide clicker response system instructors are encouraged to consider using either the PollEverywhere system or Kahoot. PollEverywhere is free to use with less than 40 participants, and clicker questions can be embedded within Powerpoint presentations using a PollEverywhere add-in. If instructors wish to use a system with larger enrollment classes the Kahoot system is free to use with unlimited numbers of students, however questions must be administered from the Kahoot website. Both systems allow students to submit answers using a

mobile phone or other device with wireless internet capabilities and allow instructors to download grade reports in the form of an Excel spreadsheet. Instructors can learn more about these in-class response systems at the following websites:

PollEverywhere: https://www.polleverywhere.com/

Kahoot: https://kahoot.com/