Technologies to Improve Student Accessibility and Equity, Reduce Cost, and Improve Learning in Chemistry

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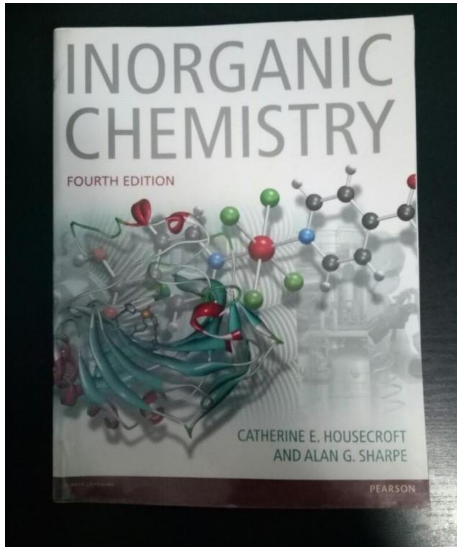
Today's Talk Outline

- Developing OER textbooks for chemistry courses
- Developing a chemistry app using augmented reality (AR)

Do Textbooks Suck?

- **Many courses require expensive textbooks**
  - Significant cost to UWW and students, even though we're a rental campus
  - Puts many students at a disadvantage
- **Most courses, not all of the textbook is taught/discussed.**
  - "We're going to skip this section…"
  - Instructor: "Read Chapter 2.3-5, 3.2-4, and 9.1-9.2"; Students: "???"
  - "Chapters 10-25 are not covered in this course."
  - Student: "This is a waste of money."
- **Students usually don't like reading!**
  - The textbook is heavy
  - "It's confusing," "Hard to read," etc.
  - Students just **GOOGLE IT**



Why do we make our students pay rental fees for books they don't use?

A majority of introductory materials in many disciplines (not just STEM) are *available on the internet already, free of charge*.

How can this be leveraged to improve student learning while also increasing accessibility and reducing costs?

Can we <u>reduce the barriers</u> to textbook accessibility?

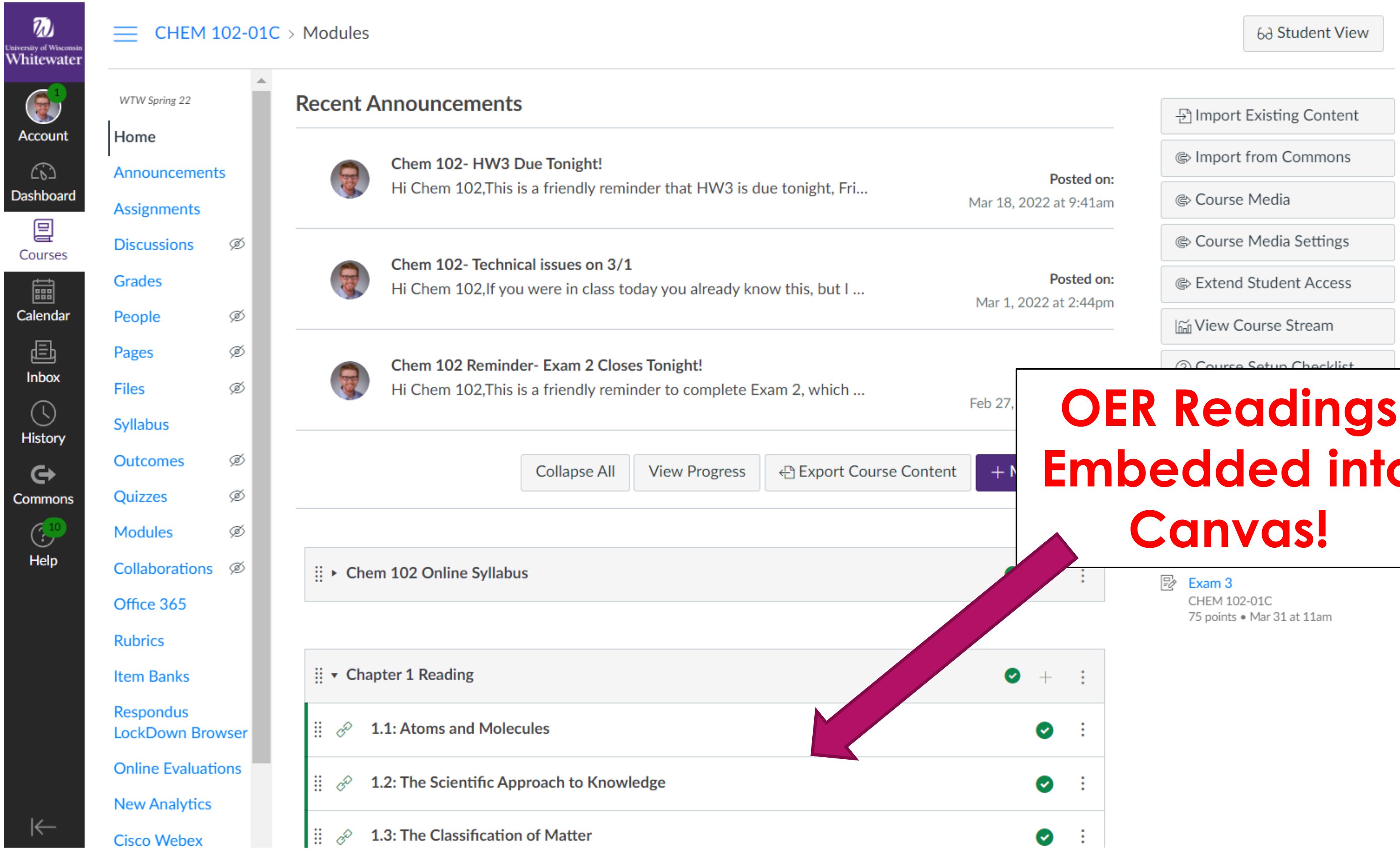
Approach: OER Textbooks using Libretexts

- In all of my lecture courses, I designed an OER (open educational resource) textbook for my class that:
  - Is FREE
  - Covers ONLY the material covered in class
  - Can be 100% uploaded into Canvas
  - See libretexts.org

OER Textbooks can help increase accessibility of the textbook and readings to ALL students at <u>no cost</u>.

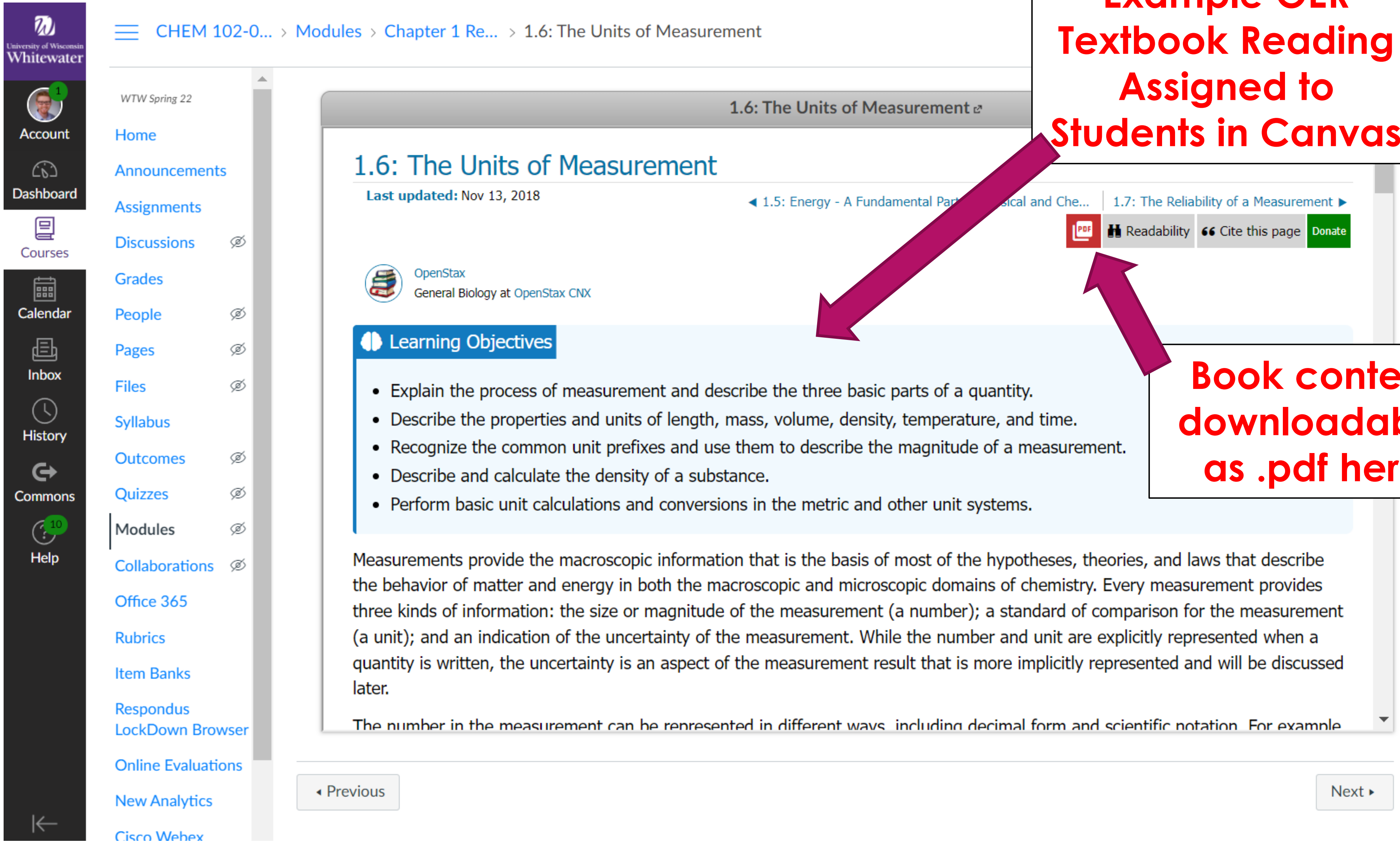
Libretexts

- Libretext is a non-profit publicily-funded organization devoted to reducing barriers for OER adoption.
- Free books in most fields
  - Science, Math, Business, Social Sciences, Humanities
- Protected by a *Creative Commons License*
- Advantage over OpenStax: easy to use **remixing tool**



OER Readings Embedded into Canvas!

Example OER Textbook Reading Assigned to Students in Canvas



Book content downloadable as .pdf here

2.4: Molecular Orbital Theory

Magnetic susceptibility measures the force experienced by a substance in a magnetic field. When we compare the weight of a sample to the weight measured in a magnetic field (Figure 2.4.1), paramagnetic samples that are attracted to the magnet will appear heavier because of the force exerted by the magnetic field. We can calculate the number of unpaired electrons based on the increase in weight.

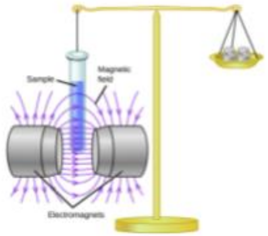
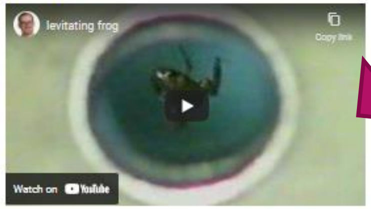


Figure 2.4.1: *A Gouy balance compares the mass of a sample in the presence of a magnetic field with the mass with the electromagnet turned off to determine the number of unpaired electrons in a sample.*

Experiments show that each O_2 molecule has two unpaired electrons. The Lewis-structure model does not predict the presence of these two unpaired electrons. Unlike oxygen, the apparent weight of most molecules decreases slightly in the presence of an inhomogeneous magnetic field. Materials in which all of the electrons are paired are diamagnetic and weakly repel a magnetic field. Paramagnetic and diamagnetic materials do not act as permanent magnets. Only in the presence of an applied magnetic field do they demonstrate attraction or repulsion.



Video 2.4.1: *Water, like most molecules, contains all paired electrons. Living things contain a large percentage of water, so they demonstrate diamagnetic behavior. If you place a frog near a sufficiently large magnet, it will levitate. You can see videos of diamagnetic floating frogs, strawberries, and more (https://www.youtube.com/watch?v=A1vyB-O5i6E)*

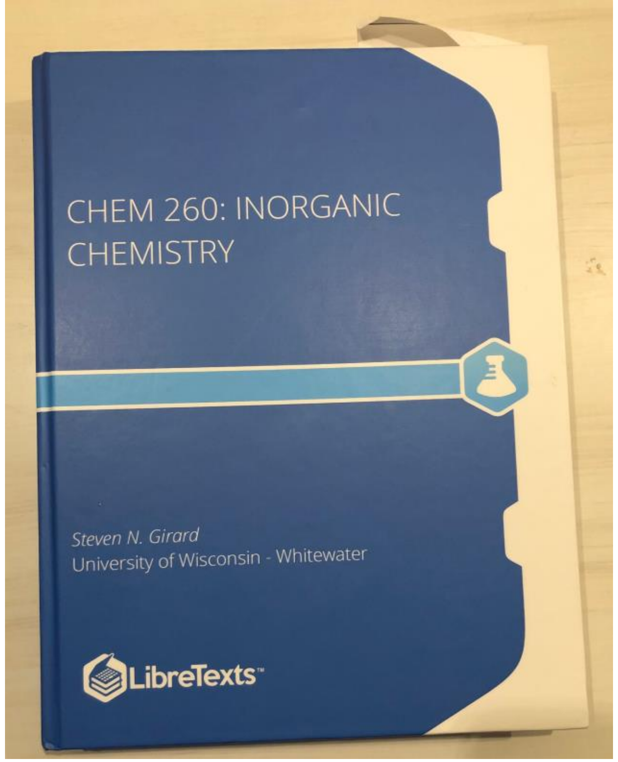
Molecular orbital theory (MO theory) provides an explanation of chemical bonding that accounts for the paramagnetism of the oxygen molecule. It also explains the bonding in a number of other molecules, such as violations of the octet rule and more molecules with more complicated bonding (beyond the scope of this text) that are difficult to describe with Lewis structures. Additionally, it provides a model for describing the energies of electrons in a molecule and the probable location of these electrons. Unlike valence bond theory, which uses hybrid orbitals that are assigned to one specific atom, MO theory uses the combination of atomic orbitals to yield molecular orbitals that are delocalized over the entire molecule rather than being localized on its constituent atoms. MO theory also helps us understand why some substances are electrical conductors, others are semiconductors, and still others are insulators. Table 2.4.1 summarizes the main points of the two complementary bonding theories. Both theories provide different, useful ways of describing molecular structure.

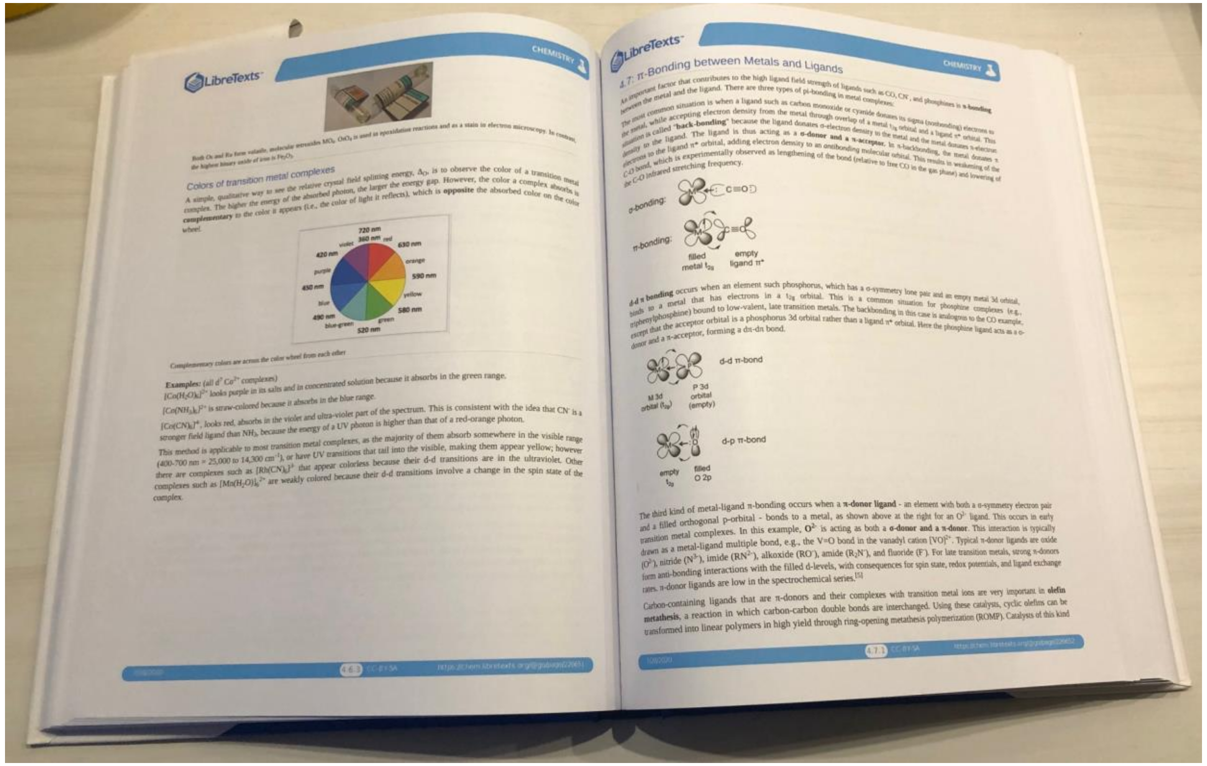
Table 2.4.1*: Comparison of Bonding Theories*

Valence Bond Theory	Molecular Orbital Theory
considers bonds as localized between one pair of atoms	considers electrons delocalized throughout the entire molecule
creates bonds from overlap of atomic orbitals (*s*, *p*, *d*...) and hybrid orbitals (*sp*, sp^2, sp^3...)	combines atomic orbitals to form molecular orbitals (σ, σ*, π, π*)
forms σ or π bonds	creates bonding and antibonding interactions based on which orbitals are filled
predicts molecular shape based on the number of regions of electron density	predicts the arrangement of electrons in molecules
needs multiple structures to describe resonance	

Molecular orbital theory describes the distribution of electrons in molecules in much the same way that the distribution of

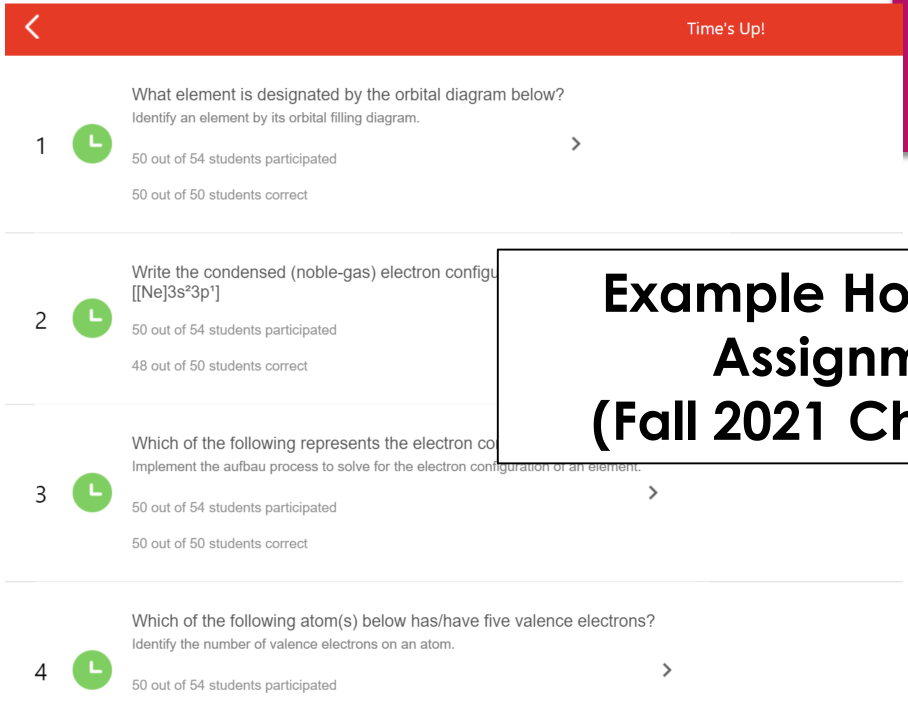
Embedded videos, .gifs, etc. are possible in OER textbooks



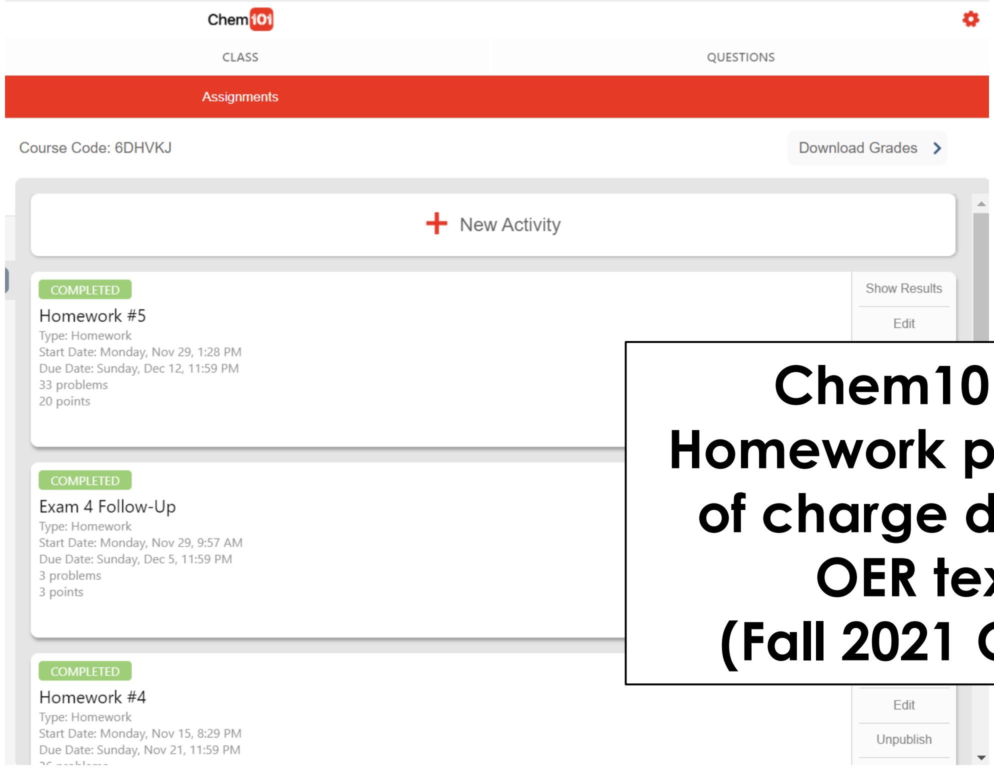


Optional printed OER textbook, cost is ~$35

Increasing Accessibility: Online Homework/Exam Software Paid by Student Fees



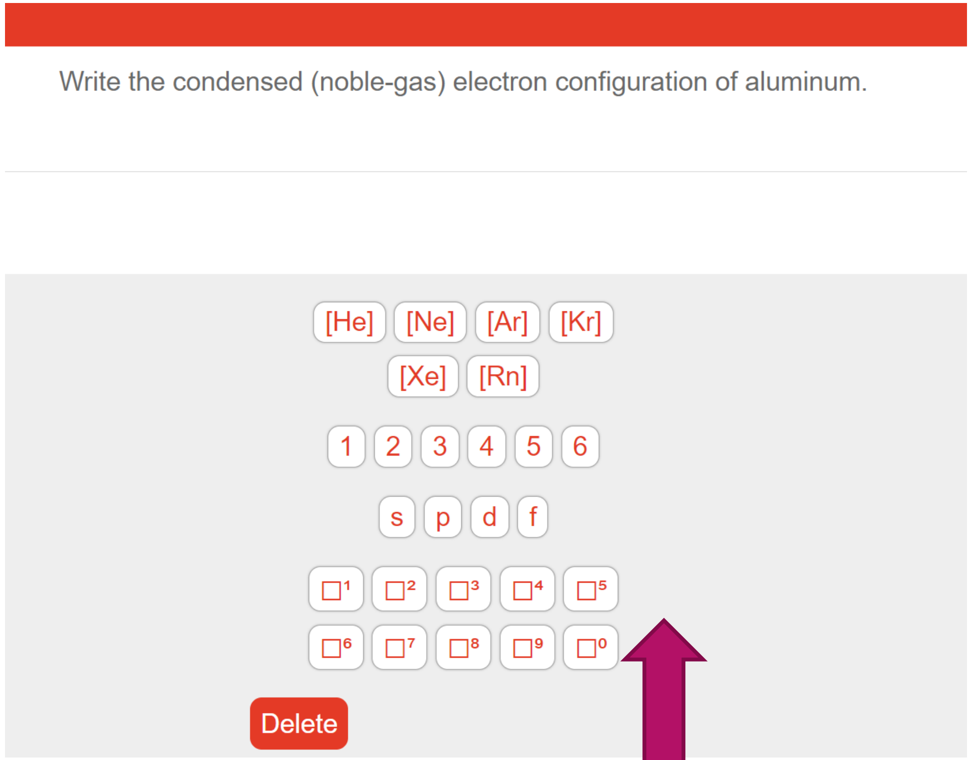
Example Homework Assignment (Fall 2021 Chem 102)

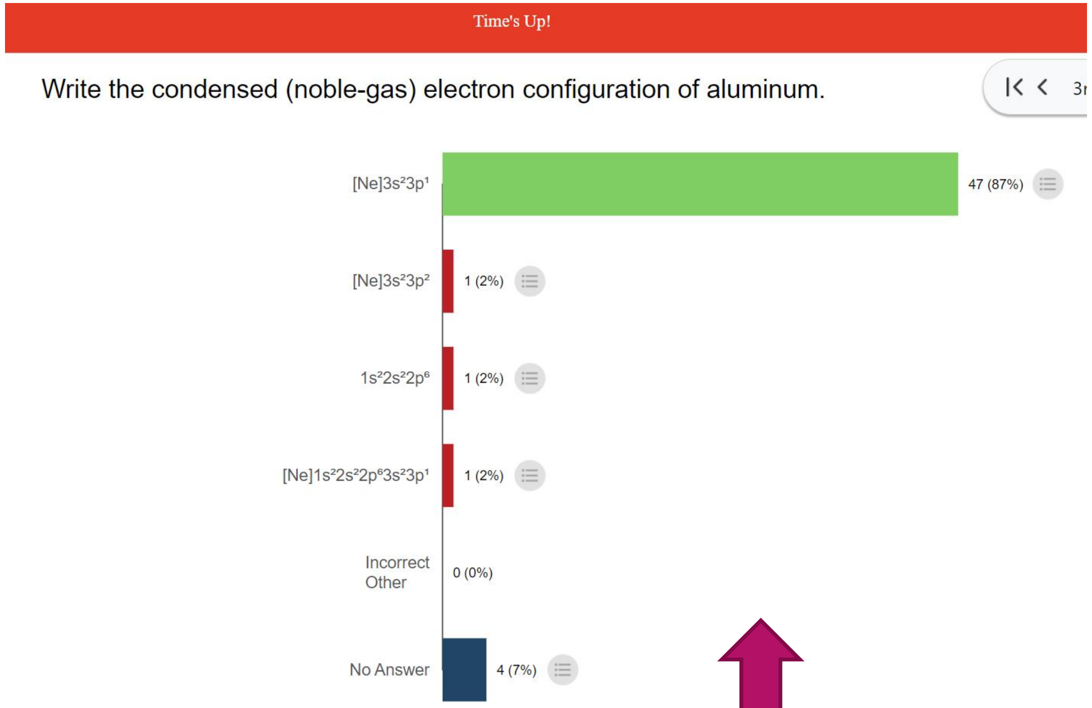


Chem101 Online Homework provided free of charge due to using OER textbook (Fall 2021 Chem 102)

aktiv Learning

Online Homework- Aktiv Learning





Algorithmic, randomized questions test student learning (and limit cheating)

Analytics provide feedback on student comprehension

Building an Augmented Reality Chemistry Model Kit App, *ChemistARy*

SPECIAL THANKS TO:

FRED LEIGHTON,

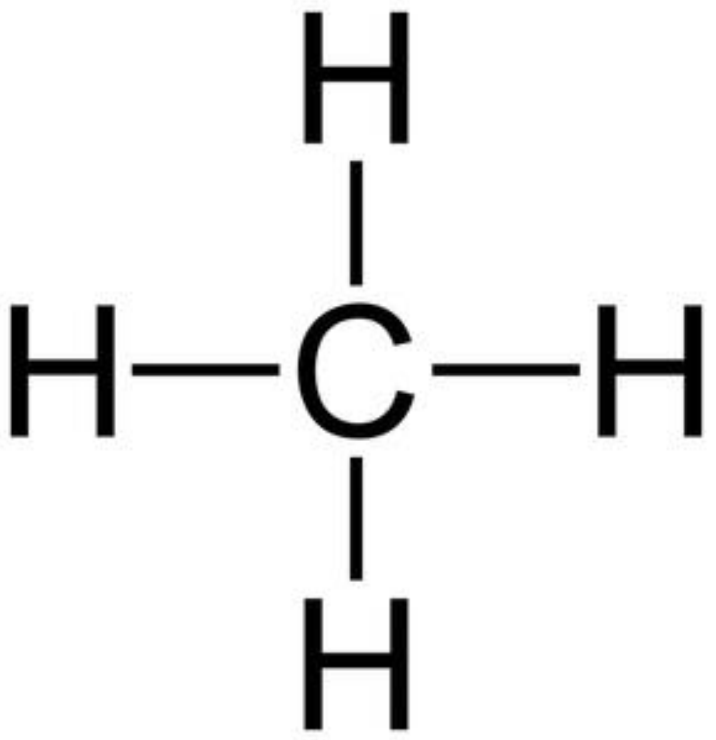
MEDIA ARTS AND GAME DEVELOPMENT

What is the molecular structure for the compound below?

- CH_4
  - (methane)

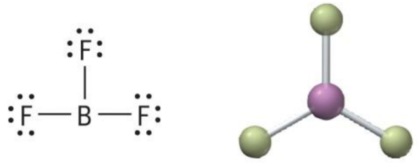
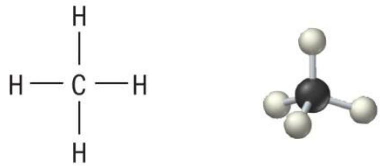
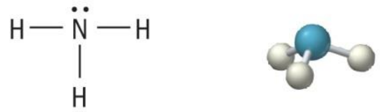
Visualizing this structure in 3D is difficult!

Ball-and-stick models?



Ball-and-Stick Demo

TABLE 10.1 Electron and Molecular Geometries

Electron Groups*	Bonding Groups	Lone Pairs	Electron Geometry	Molecular Geometry	Approximate Bond Angles	Example
2	2	0	Linear	Linear	180°	
3	3	0	Trigonal planar	Trigonal planar	120°	
3	2	1	Trigonal planar	Bent	<120°	
4	4	0	Tetrahedral	Tetrahedral	109.5°	
4	3	1	Tetrahedral	Trigonal pyramidal	<109.5°	
4	2	2	Tetrahedral	Bent	<109.5°	

VSEPR (valence shell electron pair repulsion) theory

Ball-and-Stick Models

- The best way to visualize VSEPR models in 3D is to **purchase model kits**
- They are costly and cumbersome
- What if a model kit were on your phone?

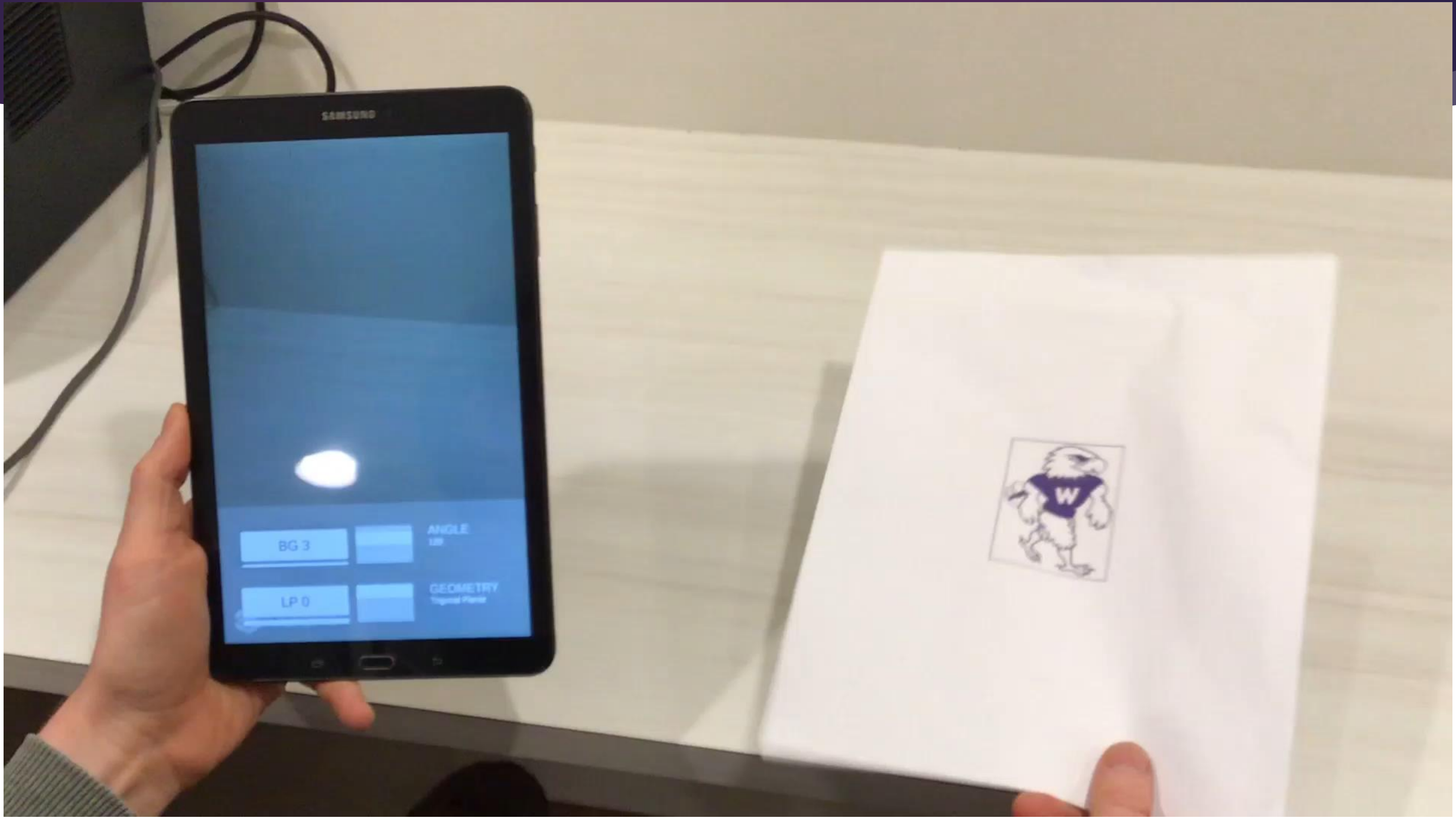
Let’s Build it Ourselves: ChemistARy

- Ball-and-stick models present an accessibility barrier to students.

- **Augmented Reality (AR)** could be a solution
  - Composite-view interactive experience using device camera
  - Like *Pokemon Go!*

- Design/content from me, and the software development/build from Fred.

ChemistARy Demonstration



ChemistARy Implementation

- Pilot in Chem 102 at UWW over next year.
- Compare student learning outcomes pre- and post-app
- App provided free of charge to students
- It is *very cool and fun*
- Could provide springboard for development of AR tools in chemistry

Thank you!

- Paradigm shift is already here for how our students learn- educators/institutions need to evolve.
- Technology can be used beneficially to increase equity and accessibility
- Share best practices with instructor communities.
  - **THANK YOU to the LEARN Center and LTC!**
- **Thank you for your attention! Questions?**
- Email: girards@uww.edu