Chem 107: Inorganic Chemistry (40720)

Professor Matt Law
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Office Hours: Wed 3:00-4:00p and Thurs 11-noon in NS2 2127

TAs
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Class website: http://www.chem.uci.edu/~lawm/107.html
Syllabus

Textbook


Lecture Slides

• Lecture slides are posted to the course website as PDF files before or just after each lecture.

Homework

• Sapling Learning online homework (graded), plus suggested problems from textbook (ungraded)

Discussion Sections

• Will begin meeting next week (9/28/15).
• Discussion sessions are optional, but will give you valuable interactive practice with the course material.
Syllabus

Video Lectures

- Videos from last year’s lectures are available on class website, courtesy of UCI Open Chemistry Initiative
  - Second half of the videos feature Prof. Heyduk, so will be different this year
  - Best used as study aid, not regular substitute for attending live lectures
Online Homework

- Graded online homework assignments for each chapter via Sapling Learning.
  - $30 for the quarter
  - 10% of course grade
  - Technology TA: Dr. Katherine Koen, support@saplinglearning.com
  - First assignment available next week
Syllabus

Lecture Schedule

- We will cover Chapters 4-11
  - Midterm I (Ch. 4,5,7)
  - Midterm II (Ch. 6,7,8,9)
  - Final (Ch. 4-11)

<table>
<thead>
<tr>
<th>Week</th>
<th>Date</th>
<th>Chapter(s)</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9/25</td>
<td>4</td>
<td>Class Intro, Symmetry Operations</td>
</tr>
<tr>
<td>1</td>
<td>9/28</td>
<td>4</td>
<td>Point Groups</td>
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<tr>
<td></td>
<td>9/30</td>
<td>4</td>
<td>Representations and Character Tables</td>
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<tr>
<td>2</td>
<td>10/2</td>
<td>4</td>
<td>Character Tables and One Application of Symmetry</td>
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<tr>
<td></td>
<td>10/7</td>
<td>5</td>
<td>A Second Application of Symmetry</td>
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<td></td>
<td>10/9</td>
<td>5</td>
<td>Simple MO Theory</td>
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<tr>
<td>3</td>
<td>10/12</td>
<td>5</td>
<td>MO Theory, Part II</td>
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<td></td>
<td>10/14</td>
<td>5</td>
<td>MO Theory, Part III</td>
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<td>10/16</td>
<td>7</td>
<td>The Crystalline Solid State</td>
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<tr>
<td>4</td>
<td>10/19</td>
<td>7</td>
<td>Crystal Structures</td>
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<tr>
<td></td>
<td>10/21</td>
<td>7</td>
<td>Thermodynamics and Electronic Structure of Solids</td>
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<tr>
<td></td>
<td>10/23</td>
<td>4,5, some7</td>
<td>Midterm Exam I</td>
</tr>
</tbody>
</table>

- You are responsible for the background material in Chapters 1-3!
Syllabus

Exams

- Two midterms and one final.
- Exams are cumulative.
- There are no make-up exams. If you miss a midterm for an approved reason, the value of the final will be adjusted accordingly. See course syllabus for details.

<table>
<thead>
<tr>
<th>Date</th>
<th>Assignment</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friday, Oct 23rd</td>
<td>Midterm Exam I</td>
<td>20</td>
</tr>
<tr>
<td>Weds, Nov 18th</td>
<td>Midterm Exam II</td>
<td>30</td>
</tr>
<tr>
<td>Wed, Dec 9th, 8:00a</td>
<td>Final Exam</td>
<td>40</td>
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<tr>
<td>Online Homework</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
The Chem 107 website is your source for up-to-date information regarding this class.


- The class website is accessible through EEE, the UCI Chemistry Department website, google, etc.

- Detailed syllabus, lecture schedule, suggested textbook homework problems and answer keys, lecture slides, links to video lectures, readings, and announcements are available here.
Email Contact

E-mails will only be accepted and answered for UCI email addresses

• Please be courteous and respectful when contacting me or the TAs.
• Just like you, we are very busy and we have many commitments outside of this class.
• To email us please use the format below and we will get back to you ASAP.

– Subject: Chem 107

Dear Professor Law,

I had a question regarding something in lecture/the text/on the exam/etc. Please include as much information as possible so that we can get an answer to you ASAP.

Thanks for your time,
Peter/Petra Anteater
UCI ID #
Symmetry in Nature
Symmetry from other planets
Symmetry Elements and Operations

Symmetry Elements

- An element is a geometric object (a plane, line (axis), or point).

Symmetry Operations

- An operation is a movement (reflection, rotation, inversion) carried out with respect to a symmetry element.
- To possess a symmetry operation, an object must appear indistinguishable before/after performing the symmetry operation.

<table>
<thead>
<tr>
<th>Element</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>mirror plane</td>
<td>reflection in the plane</td>
</tr>
<tr>
<td>proper axis</td>
<td>rotation about the axis</td>
</tr>
<tr>
<td>improper axis</td>
<td>rotation, followed by reflection in a plane ⊥ to the axis</td>
</tr>
<tr>
<td>center of inversion</td>
<td>inversion of all atoms thru center</td>
</tr>
</tbody>
</table>

- There are five operations: reflection ($\sigma$), proper rotation ($C_n$), improper rotation ($S_n$), inversion ($i$), and identity ($E$)
The Identity

Identity Operation ($E$)

- the “do nothing” operation (the simplest operation)
- mathematically equivalent to multiplying by 1
- all objects have $E$
Proper Rotations

Rotation Operation ($C_n$)

• a counter-clockwise rotation of $2\pi/n$ ($360^\circ/n$) about an axis

$C_6 \times C_6 = C_6^2 = C_3$
Proper Rotations

Rotation Operation \((C_n)\)

- a counter-clockwise rotation of \(2\pi/n\) (\(360^\circ/n\)) about an axis

\[
C_6 \times C_6 \times C_6 = C_6^3 = C_2
\]
Proper Rotations

Rotation Operation ($C_n$)

- A counter-clockwise rotation of $2\pi/n$ ($360°/n$) about an axis.

$C_6 \times C_6 \times C_6 \times C_6 = C_6^4 = C_3^2$
Proper Rotations

Rotation Operation ($C_n$)

- a counter-clockwise rotation of $2\pi/n$ ($360^\circ/n$) about an axis

$$C_6$$

$$C_3^2 = C_3^{-1}$$

$C_3^{-1}$ (inverse $C_3$) is a rotation backwards (clockwise)

$C_6$
Proper Rotations

Rotation Operation ($C_n$)

- A counter-clockwise rotation of $2\pi/n$ ($360°/n$) about an axis
Proper Rotations

Rotation Operation \((C_n)\)

- a counter-clockwise rotation of \(2\pi/n\) \((360°/n)\) about an axis

Now we can also say \(C_6^6 = C_1 = E\)
Proper Rotations

Rotation Operation ($C_n$)

- a counter-clockwise rotation of $2\pi/n$ ($360°/n$) about an axis
- the rotation axis with the largest $n$ is called the highest order or principal axis (the $C_6$ axis in the case of our snowflake)
- some objects have rotations that are perpendicular to the principal axis
Proper Rotations

Rotation Operation ($C_n$)
- a counter-clockwise rotation of $2\pi/n$ ($360^\circ/n$) about an axis
- the rotation axis with the largest $n$ is called the *highest order* or *principal axis* (the $C_6$ axis in the case of our snowflake)
- some objects have rotations that are perpendicular to the principal axis
- an object with a $C_n$ axis must have zero or $n$ perpendicular $C_2$ axes
- the snowflake has coincident $C_6$, $C_3$, and $C_2$ axes plus six $\perp C_2$ axes
Reflections

Reflection Operation ($\sigma$)

- an internal reflection thru a plane of symmetry within an object
- a horizontal mirror plane ($\sigma_h$) is *perpendicular* to the principal axis

\[ \sigma^n = E \]
when $n$ is even

\[ \sigma^n = \sigma \]
when $n$ is odd
Reflections

Reflection Operation (σ)

- an internal reflection thru a plane of symmetry within an object
- a horizontal mirror plane (σₙ) is perpendicular to the principal axis
- vertical (σᵥ) and dihedral (σ₅) mirror planes are parallel to the principal axis
- #σᵥ + #σ₅ = 0 or n
- our snowflake has one σₙ, three σᵥ and three σ₅ mirror planes
Inversion Operation ($i$)

- each point is moved along a straight line through the center of the object (the *inversion center*) to a point an equal distance from the center
- in other words: $(x,y,z) \rightarrow (-x,-y,-z)$ for all points
- an object can have zero or one inversion center
- the snowflake has an inversion center

\[ i^n = E \text{ when } n \text{ is even, } i^n = i \text{ when } n \text{ is odd} \]
Inversion Operation ($i$)

- Octahedra, boxes, squares, rectangles, and parallelograms have inversion centers, but tetrahedra, triangles, and pentagons do not.
Improper Rotations

Improper Rotation Operation ($S_n$)
- a rotation followed by a perpendicular reflection (a roto-reflection)

$S_4$ operation in methane

<table>
<thead>
<tr>
<th>Rotation angle</th>
<th>Symmetry operation</th>
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</thead>
<tbody>
<tr>
<td>90°</td>
<td>$S_4$</td>
</tr>
<tr>
<td>180°</td>
<td>$C_2$ ($= S_4^2$)</td>
</tr>
<tr>
<td>270°</td>
<td>$S_4^3$</td>
</tr>
<tr>
<td>360°</td>
<td>$E$ ($= S_4^4$)</td>
</tr>
</tbody>
</table>

Also: $S_2 = i$, $S_1 = \sigma$

- There are $S_3$ and $S_6$ operations in the snowflake, but we’ll illustrate the $S_n$ operation with an actual molecule in a minute.