Wake Forest University, Department of Chemistry: Placement Exams for admitted Graduate Students

What are Placement Exams and why are they important?

The Placement exams (PE) serve two purposes: (1) to provide information to advise you on the courses you need and (2) to satisfy the departmental qualifying requirements which ensure that every student has some breadth of knowledge across analytical, biochemistry, inorganic, organic, and physical chemistry. During the first week when you arrive at WFU, you will be required to take five PE examinations, one in each of the areas of chemistry.

About the exams

The five Placement Exams listed below are administered during Orientation Week. Each exam lasts about two hours, so the exam period extends over two days. The exams are based on the undergraduate curriculum endorsed by the American Chemical Society. It is strongly suggested that you study your class notes and texts so that the score on each exam represents accurately your knowledge and training in that sub-discipline.

<table>
<thead>
<tr>
<th>Analytical Chemistry (50)*</th>
<th>Physical Chemistry (60)</th>
<th>Organic Chemistry (70)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26% Analytical Techniques</td>
<td>33% Thermodynamics</td>
<td>3% MO Theory</td>
</tr>
<tr>
<td>6% Data Analysis</td>
<td>33% Quantum Mechanics</td>
<td>13% Molecular Structure</td>
</tr>
<tr>
<td>12% Electrochemistry</td>
<td>33% Dynamics</td>
<td>3% Nomenclature</td>
</tr>
<tr>
<td>8% Spectroscopy</td>
<td></td>
<td>60% Reaction</td>
</tr>
<tr>
<td>6% Statistics</td>
<td></td>
<td>7% Spectroscopy</td>
</tr>
<tr>
<td>10% Stoichiometry</td>
<td></td>
<td>14% Structure Property</td>
</tr>
<tr>
<td>32% Titration Analysis</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Inorganic Chemistry (60)</th>
<th>Biochemistry (40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% Acid/Base Theory</td>
<td>Based in 1-semester</td>
</tr>
<tr>
<td>7% Bioinorganic Chemistry</td>
<td>biochemistry course (see list of topics)</td>
</tr>
<tr>
<td>2% Boranes</td>
<td></td>
</tr>
<tr>
<td>2% Catalysis</td>
<td></td>
</tr>
<tr>
<td>7% MO Theory</td>
<td></td>
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<tr>
<td>13% Molecular Structure</td>
<td></td>
</tr>
<tr>
<td>7% Periodic Table</td>
<td></td>
</tr>
<tr>
<td>18% Reactions</td>
<td></td>
</tr>
<tr>
<td>12% Solid State</td>
<td></td>
</tr>
<tr>
<td>5% Spectroscopy</td>
<td></td>
</tr>
<tr>
<td>18% Transition Metal</td>
<td></td>
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<tr>
<td>Chemistry</td>
<td></td>
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</tbody>
</table>

(*) Total number of questions in parentheses
To learn more about the range of topics covered, you might refer to the following texts or similar modern texts:

- Organic Chemistry (Brown & Foote, 2nd Edition)
- Physical Chemistry (P.W. Atkins, 6th Edition)
- Inorganic Chemistry (Miessler and Tarr, 3rd Edition)

Included below are brief outlines of the main topics covered on the exams. The inorganic outline was prepared by one of our faculty members (Abdou Lachgar). The organic and physical chemistry topic outlines are taken from the ACS exam site’s study guides.

**What is the standard for passing the exam?**

To pass an exam, you need to achieve the median score among a national sample of undergraduates and graduate students. Note that the median score is based on a population of both undergraduate and graduate students who take the exam so the standard for passing is fairly high.

**How much should you study for these exams?**

The department uses the results of the examinations to guide advising about your graduate course schedule, so it is worthwhile to prepare sufficiently for the exams so that your scores reflect your knowledge as accurately as possible. If you do not pass an exam in a certain area, you will be advised to take corresponding course work, usually at the graduate level but possibly at the undergraduate level if you have a gap in your background in that area. Therefore, effective review prior to the exam can help you avoid taking a course that repeats familiar material and can accelerate your progress in graduate school. Studying for 1-2 weeks is recommended as a very rough guideline.

**What are the possible outcomes?**

Following your PE examinations, you will meet with faculty to review the results of your exams. At that time, you will be advised regarding the specific classes you will need to take during your first semester at WFU.

- If you pass all PE exams, you will have flexibility in choosing the graduate-level courses you need to take depending on your research interest, you may start working on research projects you are interested in, and may be able to start working on other PhD requirements such as cumulative examinations.
- If you fail an exam in an area, you will generally be advised to take a related graduate course to gain the necessary background. Passing an approved full-semester graduate course with a grade of at least a B will meet the PE requirement for that particular area. This may be advisable for areas where your prior background has some gaps.

**Suggestions for preparing**

Our goal is to get students into their research as early as possible with strong foundation knowledge so that the time to complete the Ph.D. is reasonable. The most valuable review for
most students is practicing answering similar questions. One option we would suggest is to visit the GRE website at http://www.ets.org/gre and review the chemistry subject testing materials that are available online. Reviewing texts like those listed above or other modern texts is also excellent preparation for these examinations. To target your review effectively, it is useful to refer to exams from your previous coursework and identify the areas where extra reading and problem solving may be most helpful to you. If you are not experienced with multiple choice exams, you may also wish to practice answering these types of questions under time pressure.

**Brief Review Outlines**

**Topics recommended for review for the analytical chemistry PE exam are:**

- General Principles of Analytical Chemistry
- Spectrochemical Analysis: know the terminology, basic instrumental components, advantages, disadvantages, and applications (qualitative or quantitative technique, useful concentration range, etc.) of the following techniques:
  - Molecular spectroscopy: uv/visible absorption, IR absorption, Raman scattering, fluorescence, phosphorescence, NMR, mass spectrometry, surface characterization
  - Atomic spectroscopy: AAS (flame and furnace), ICP, neutron activation, X-ray and particle techniques (ESCA, SEM)
- Electroanalytical Chemistry: know the terminology, electrochemical cells, cell potentials, types of electrodes, basic instrumental components, advantages, disadvantages, and applications of the following techniques:
  - Potentiometric methods (pH, ISE)
  - Voltammetry (DC Polarography, Pulsed polarography, Stripping analysis)
  - Coulometry
- Chemical Separations: know the terminology, basic instrumental components, advantages, disadvantages, applications, and be able to predict elution characteristics for the following techniques:
  - HPLC, GC, TLC, CE and CEC
  - Extraction
- Miscellaneous:
  - Thermal analysis (TG, DTA, DSC, etc.)

**Topics recommended for review for the Biochemistry PE exam are:**

- Buffers
  - Henderson-Hasselbalch equation
  - pI, pKₐ
- Proteins Structure and Function
  - Amino acids (structure, nomenclature, pKₐ) and role in protein structure
- Protein structures (primary, secondary, tertiary, quaternary) and amino acid location/content
- Protein synthesis (components and enzymes required)
- Protein purification/analysis methods (chromatography, gel electrophoresis – 1D and 2D, sequence and structure determination); use of antibodies
- Ligand interactions (Kd, allosterics, cooperativity)

- Enzymes and Kinetics
  - Role of enzymes in catalysis (energetics, substrate specificity)
  - Michaelis-Menten (Vmax, K_M, kcat) and Lineweaver-Burk plots
  - Enzyme inhibition (competitive, uncompetitive, noncompetitive)
  - Enzyme mechanisms (general role of amino acids, nucleophiles/electrophiles, acid/base); coenzymes and cofactors

- Sugars
  - Monosaccharides, disaccharides, and polysaccharides (glycosidic bond, reducing sugar)
  - Glycoproteins, peptidoglycans, proteoglycans (structure, function)

- Nucleotides
  - Bases, structure (helix)
  - Differences between RNA and DNA (ribose, bases, structure)
  - Physical properties and reactivity
  - DNA synthesis (components and enzymes required)
  - Sequencing methods (electrophoresis, chemical methods); PCR
  - Restriction endonucleases

- Lipids, Membranes, and Signaling
  - Lipids (structure, nomenclature, properties)
  - Membrane lipids - location, interactions, movement
  - Membrane proteins (location, association with lipids, identity of amino acids)
  - Transport (diffusion versus transporters – channels and carriers)
  - Signal transduction (G-protein coupled receptors, second messengers, ion channels); agonist and antagonist

- Bioenergetics
  - Basic thermodynamics (entropy, enthalpy, Gibbs free energy) and equilibrium
  - Energy-rich compounds (ATP, Acetyl-CoA, NAD, FAD)
  - Redox reactions (Standard reduction potentials, oxidation and reductions)

- Metabolism and Catabolism
  - Glycolysis and gluconeogenesis (enzymes, intermediates, regulation); lactic acid fermentation, glucose-alanine cycle, pentose phosphate pathway
  - Glycogen (enzymes for synthesis/metabolism, regulation)
  - Pyruvate dehydrogenase complex and citric acid cycle (enzymes, intermediates, regulation)
Oxidative phosphorylation and ATP synthesis (regulation with glycolysis and citric acid cycle)

β-oxidation and synthesis of fatty acids (steps, enzymes)

Topics recommended for review for the inorganic chemistry PE exam are:

- Atomic Structure
- Symmetry and Group Theory
- Molecular Structure and Bonding
- Acid-Base and Donor-Acceptor Chemistry
- The Crystalline Solid State
- Chemistry of Main Group Elements
- Oxidation and Reduction
- Coordination Chemistry: Structure, Isomerism, Bonding Theory, Electronic Spectra, Reactions and Mechanisms
- Organometallic Chemistry
- Bioinorganic Chemistry

For the organic chemistry exam, content is derived from both semesters of Organic Chemistry and includes:

- Nomenclature
- Structure, Hybridization, Resonance, Aromaticity
- Acids and Bases
- Stereoisomerism
- Nucleophilic Substitutions and Eliminations
- Electrophilic Additions
- Nucleophilic Addition at Carbonyl Groups
- Nucleophilic Substitution at Carbonyl Groups
- Enols and Enolate Ion Reactions
- Electrophilic and Nucleophilic Aromatic Substitution
- Free Radical Substitutions and Additions
- Oxidations and Reductions
- Spectroscopy
- Synthesis and Analysis

Content for Physical Chemistry includes:

Thermodynamics

- Equations of State
- Laws of Thermodynamics and State Functions
- Mathematical Relationships in Thermodynamics
- Chemical and Phase Equilibria

Dynamics
- Kinetic Molecular Theory
- Transport Properties
- Phenomenological Kinetics
- Mechanisms
- Reaction Dynamics
- Statistical Mechanics

**Quantum Mechanics**
- Quantum Chemistry: History and Concepts
- Simple Analytical Mechanical Model Systems
- Modern Quantum Mechanical Problems: Atomic systems
- Symmetry
- Molecular Orbital Theory
- Spectral Problems
- Advanced Topics: Electronic Structure Theory and Spectroscopy