Syllabus for BCH 6745C/L: Molecular Structure and Dynamics by NMR Spectroscopy
Fall, 2015

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Course location: Lectures: MWF, 4th period, 10:40 – 11:30 ARB R3-265 (Two T classes in conflict weeks). Labs: Wed, Group A (macromolecules) 7th-9th periods; Thur, Group B (small molecule mixtures) 7th-9th periods AMRIS facility. First lab will meet in MBI LG-110 initially for safety video.
Credit: 1 hr for lecture, 1 hr for lab
Prerequisites: BCH 6740 or equivalent or consent of instructor.
Recommended Texts:
High-Resolution NMR Techniques in Organic Chemistry, T. Claridge ~$50
*Text for those interested in metabolite mixtures
Spin Dynamics: Basics of Nuclear Magnetic Resonance, M. Levitt ~$60
*Text for those wanting a more physics-rich description
Protein NMR spectroscopy: Principles and Practice, J. Cavanagh et al. ~$80
*Text for those interested in protein structure and dynamics
200 and More NMR Experiments: A Practical Approach, S. Berger & S. Braun ~$90
*Text used in the labs (150 and More… is also sufficient)
Bruker Avance 1D/2D Techniques Manual pdf available online
*Manual for AMRIS NMR spectrometers; relevant sections for labs will be provided
***If you are unsure which text you should get, get Claridge. I have all these texts in my office and you are welcome to come peruse them to help in making your choice.
Tests and Grading: Lecture grade will be 50% homework and 50% based on a final project. Students will be required to process and analyze NMR data using freeware. Laboratory grade will be 20% participation, 40% processed data and 40% completed laboratory project report
Lecture and laboratory notes are available on elearning
Instructor Contacts: Dr. Joanna Long
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Long: Lectures 1-3, 11-15
Merritt: Lecture 4-10

Syllabus:
1) Fri, Sep 29: **Nuclear Magnetic Resonance: A Classical Picture**
   a. Spin angular momentum and magnetic dipoles
   b. Precession and the Larmor frequency
   c. RF fields and the rotating frame
   d. The Basic NMR/MRI machine
2) Mon Oct 2: **Nuclear Magnetic Resonance: A Quantum Mechanical Picture**
   a. Energy levels and polarization
   b. RF pulses
   c. Chemical shift
   d. 1D NMR spectrum explained (part of it)

3) Wed Oct 4: **Nuclear Magnetic Resonance: The molecular picture**

a. Larmor frequencies, abundance of various nuclei
b. Chemical shift and molecular/spatial information
c. Chemical shift databases: proteins and small molecules
d. Dipolar Couplings
e. Quadrapolar coupling
f. Solution NMR : T_1, T_2, and NOE

1 Lab) Wed Oct 4: **Basics of NMR**

a. Safety class
b. Sample preparation
c. Introduction to Bruker topspin software
d. Sample insertion, tuning, shimming, and 1D spectrum
e. Data processing and phasing

NO CLASS ON FRIDAY OCTOBER 6

4) Mon, Oct 9: **Data Collection**

a. Time vs. Frequency
b. Hz vs. PPM
c. Fourier Transform
d. Digitization and Spectral Width
e. Quadrature detection
f. Multiple pulse experiments

5) Wed, Oct 11: **Nuclear Magnetic Resonance: Thermodynamics**

a. Bloch equations
b. Phenomenological introduction to T_1 and T_2
c. RF Pulses
d. The Hahn echo and T_1 relaxation experiments
e. NMR and MRI: two sides of the same coin

2 Lab) Wed Oct 11: **Diffusion and Dynamics**

a. Pulse width calibration
b. T1 and T2 measurements
c. ^{1}H measurements of small molecule diffusion
d. PFG calibrations

6) Fri, Oct 13: **Mechanisms of T1**

a. Correlation functions
b. Time scales of molecular motion
c. Experiments to probe dynamics in solution
d. Dynamics and mixture analysis
e. Protein dynamics measurements
f. Real-life examples

7) Mon Oct 16: **Dynamics and diffusion**

a. Diffusion and coherence lifetimes
b. Experiments to probe dynamics
c. Experiments to probe diffusion
d. Real-life examples

8) Wed Oct 18: **Shaped pulses**

a. Basic concepts
b. Broad banded pulses
c. Selective pulses

d. solvent suppression

3 Lab) Wed, Oct 18: **1D NMR—small molecule mixtures**

a. gradient shimming.
b. Radiation damping
e. Shaped pulses
d. solvent suppression
e. Test of experimental parameters: SW, O1, pw, D1, acq, etc
f. ^{1}H vs ^{13}C detection

NHFML workshop on DNP will be on Thursday, Oct 19, in Emerson Hall

9) Fri Oct 20 **Polarization enhancement**

a. polarization of nuclei vs electrons
b. basic concepts of DNP
c. PHIP
d. Xe polarization?
e. dissolution DNP

10) Mon Oct 23: **In vivo spectroscopy**

a. In vivo considerations
b. ^{1}H and solvent suppression
c. ^{31}P measurements
d. ^{13}C and metabolic flux measurements

11) Wed Oct 25: **Introduction to solid state NMR**

a. Dynamics in the solid state and lineshapes
b. Revisiting spin interactions from solids perspective
c. Spin vs. space
d. Static experiments
e. Magic angle spinning
f. DNP

4 Lab) Wed Oct 25: **HRMAS**

a. Setting the magic angle
b. Shimming
c. 1D static and MAS spectrum
d. Solvent suppression

12) Fri Oct 27: **Product operators**

a. Product operators as a tool to simplify the quantum mechanics
b. RF and Chemical shift product operators
c. Scalar (J) coupling
d. 1D NMR spectrum explained more completely
e. Product operators for J coupling
f. zero and double quantum states

13) Mon Oct 30: **Introduction to 2D NMR**

a. 2D Exchange
b. NOE –measuring distances
c. COSY—measuring bonding
d. TOCSY

14) Wed Nov 1: **Heteronuclear 2D NMR**

a. HMQC
b. HSQC
c. HMBC

5 Lab) Wed, Nov 1: **2D NMR— small molecule mixtures**

a. NOESY
b. TOCSY
c. X-pw calibration
d. ^{1}H-^{13}C HMBC (group A) or ^{1}H-^{15}N HSQC (group B)

15) Fri Nov 3: **Protein structure determination**

a. Basic strategy
b. Principles of triple resonance experiments, what can we get from chemical shifts?
c. Real-life experiments
d. Assignment of side-chains
e. Practical sample requirements and isotopic enrichment
f. What if the protein is not recombinant – natural abundance methods

Mon, 11/8	Lab Report due
Fri, 11/10	Final Project due