Syllabus for BCH 6745C/L: Molecular Structure and Dynamics by NMR Spectroscopy
Fall, 2023

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Course location: Lectures: MWF, 4th period, 10:40 – 11:30 ARB R3-265
Labs: Group A (proteins) TBD, Group B (small molecule mixtures) TBD in AMRIS facility.
Credit: 1 hr for lecture, 1 hr for lab
Prerequisites: BCH 6740 or equivalent or consent of instructor.
Optional Texts:
High-Resolution NMR Techniques in Organic Chemistry, T. Claridge ~$64
*Text for those interested in metabolite mixtures
Spin Dynamics: Basics of Nuclear Magnetic Resonance, M. Levitt ~$90
*Text for those wanting a more physics-rich description
Protein NMR spectroscopy: Principles and Practice, J. Cavanagh et al. ~$85
*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 project paper. Students will be required to process and analyze NMR data using freeware. Laboratory grade will be based on participation including acquisition and processing of data
Lecture and laboratory notes are available on elearning
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Syllabus:
1) Mon, Oct 2 **Nuclear Magnetic Resonance: A Classical Picture (Joanna)**
  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) Wed Oct 4: **Nuclear Magnetic Resonance: A Quantum Mechanical Picture (Joanna)**
  a. Energy levels and polarization
  b. RF pulses
  c. Chemical shift
  d. 1D NMR spectrum explained (part of it)

****October 6 is UF Homecoming so no lecture****

3) Mon Oct 9 **Nuclear Magnetic Resonance: The molecular picture (Matt)**

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. Quadrupolar coupling
f. Solution NMR : T_1, T_2, and NOE

4) Wed, Oct 11: **Data Collection (Matt)**

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

5) Fri, Oct 13: **Nuclear Magnetic Resonance: Thermodynamics (Matt)**

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

1 Lab) week of Oct 9: **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

6) Mon, Oct 16: **Mechanisms of T1 (Matt)**

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) Wed Oct 18: **Dynamics and diffusion (James)**

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

8) Fri Oct 20: **Shaped pulses (Matt)**

a. Basic concepts
b. Broad banded pulses
c. Selective pulses
d. solvent suppression

2 Lab) Week of October 16: **Diffusion and Dynamics**

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

9) Mon Oct 23 **Polarization enhancement (Matt)**
- a. polarization of nuclei vs electrons
- b. basic concepts of DNP
- c. PHIP
- d. Xe polarization?
- e. dissolution DNP

10) Wed Oct 25: **In vivo spectroscopy (Matt)**
- a. In vivo considerations
- b. ^{1}H and solvent suppression
- c. ^{31}P measurements
- d. ^{13}C and metabolic flux measurements

11) Fri Oct 27: **Introduction to solid state NMR (Joanna)**
- 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

3 Lab) Week of October 23: **1D NMR—small molecule mixtures or proteins**
- 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
- g. ^{15}N-filtered detection (proteins); relaxation filtering (small molecules)

12) Mon Oct 30: **Product operators (Joanna)**
- 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) Wed Nov 1: **Introduction to 2D NMR (Joanna)**
- a. 2D Exchange
- b. NOE –measuring distances
- c. COSY—measuring bonding
- d. TOCSY

14) Fri Nov 3: **Heteronuclear 2D NMR (Joanna)**
- a. HMQC
- b. HSQC
- c. HMBC

4 Lab) Week of October 30: **2D NMR— small molecule mixtures or proteins**
- a. NOESY/TOCSY for proteins
- b. COSY/J-res for small molecules
- c. X-pw calibration
- d. ^{1}H-^{13}C HMBC (small molecules) or ^{1}H-^{15}N HSQC (proteins)

15) Mon Nov 6: **Protein structure determination (Joanna)**

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

5 Lab) Week of November 6: **Magic angle spinning**

a. Setting the magic angle
b. Shimming
c. 1D static and MAS spectrum
d. Solvent suppression
e. Microcrystalline protein (proteins); tissue sample (small molecules)

Mon, 11/13 Final Project due