Chemistry 20BH Syllabus: Winter 2020

https://nano.ucla.edu/chemistry-20bh/

Lectures: MWF 11-11^{50} AM Young Hall 4216

Instructor: Prof. Paul S. Weiss

Textbook: *Principles of Modern Chemistry*, 8th edition, Oxtoby, Gillis, & Butler

Discussion (and some lectures): TR 11-11^{50} AM Young Hall 3069

Lecture Dates:		Topic:	Book Chapter(s) +:
Week 1	6-10 Jan	Class Introduction, Single-Molecule Measurements, Ideal Gas Law, Kinetic Theory of Gases, Intermolecular Forces, Non-Ideal Gases, Energy Scales, and Spectroscopies	Ch. 9/20 Literature
Week 2	13-17 Jan	Bulk Properties of Gases/Liquids/Solids, Phase Transitions, Phase Diagrams	Ch. 10 Literature
Week 3	20 Jan	No lecture – Martin Luther King Jr. Day – Holiday	
	Wed 22 Jan	Final project topic due in lecture	
	22-24 Jan	Solutions, Acid-Base Titrations, Redox Titrations, Equilibrium	Ch. 11/14 Literature
Week 4	27-31 Jan	Internal Energy, Work, Enthalpy, Entropy, Gibb's Free Energy	Ch. 12/13
	Wed 29 Jan	6-8 PM Midterm 1	
Week 5	3-7 Feb	Equilibrium, Acid-Base Equilibria, Buffers	Ch. 15
	Thurs 6 Feb	Final project abstract due on CCLE before class	
Week 6	10-14 Feb	Solubility and Precipitation, Electrochemistry, Cell Potentials and Gibbs Free Energy, Batteries	Ch. 16/17 Literature
Week 7	17 Feb	No Lecture – Presidents' Day – Holiday	
	19-21 Feb	Electrochemistry Continued	Ch. 17
	Sat 22 Feb	2-6 PM Presentations (Tentative)	
Week 8	24-28 Feb	Band Theory of Conduction, Semiconductors Semimetals, Direct Band-Gap vs. Indirect Band-Gap, Spectroscopies	Ch. 22 Literature
	Wed 27 Feb	6-8 PM Midterm 2	
Week 9	2-6 Mar	Chemical Kinetics, Rate Laws, Mechanisms, Catalysts	Ch. 18
	Fri 6 Mar	Final project paper due in lecture	
Week 10	9-13 Mar	Nuclear Chemistry	Ch. 19 Literature
	TBA Mar TBA Final Exam		

Learning in Chem 20BH
This is an exciting course for many reasons. We are able to cover many of the highlights of chemistry in a relatively informal way. This introduction is meant to guide you through many future years of scientific thinking and discussion, citizenship, and possibly even more chemistry.

Much of what you learn, you will learn on your own or from each other. This will allow us to have a higher level of discussion in class. This will require work on your part. Please be prepared for it and budget the time for it. Anticipate that **the lectures, the readings, and the homeworks will be *complementary* rather than overlapping. You will be responsible for the material from *all* of these sources**. Similarly, your participation in class is required both for discussions and for the education of your classmates, TAs, and professor.

While we will cover everything in the regular (Chem 20B) version of this course, we will do it much faster (!) in order to allow us to pursue many other additional topics. This will require a great deal of work on your part. Please be prepared for it and budget the time for it. Anticipate that the lectures, the readings, and the homeworks will be ***complementary*** rather than overlapping. You will be responsible for the material from all of these sources. Similarly, your participation in class is required both for discussions and for the education of your classmates and professor. <u>There is little that we plan to say that is so critical that a good classroom discussion would not be preferable</u>.

Unlike other general chemistry classes, we will cover how it is that we know what we think we do and how we test that understanding. We will develop an understanding of what experiments and theory are required to answer fundamental chemical and scientific questions.

Grading
Midterms (30% total): 15% each
Project (15% total): 10% poster + 5% paper
5 literature assignments (10% total): 2% each (top 5 of 6)
Homework (20% total): 10% creative problems (1/week) + 10% graded problems
Participation: 5%
Final: 20%

Final project
For the final project you will need to prepare a poster presentation and written report on a selected topic related to energy. First, you must select your topic and turn it in to your TA for approval by Wednesday, January 22nd. Abstracts for your written report will be due on Thursday, February 6th. You must create a poster on your selected topic and prepare a brief oral presentation. The comments/feedback you receive on your poster presentation from the TAs and Prof. Weiss should be incorporated into your final paper. The final paper must be from 5-10 pages in length with references, double spaced, 12 pt font, and 1" margins, and will be due on Friday, March 6th.

Sample Reference Format:
Author Last Name, Initials; … Title. *Abbreviated Journal Name*. **Year,** *Issue*, Page Numbers.

Example:
(1) Yeager, L. J.; Saeki, F.; Shelly, K.; Hawthorne, M. F.; Garrell, R. L. Formation of monolayer films by the spontaneous assembly of organic thiols from solution onto gold. *J. Am. Chem. Soc.* **1998,** *120*, 9961-9962.

(2) Evans, D. A.; Fitch, D. M.; Smith, T. E.; Cee, V. J. Application of Complex Aldol Reactions to the Total Synthesis of Phorboxazole B. *J. Am. Chem. Soc.* **2000,** *122*, 10033-10046.

Note: Please do not use *et al.* for literature assignments or your final project's written report.

Literature assignment
Find a research article from a scientific journal (i.e. *Science*, *ACS Nano*, *Nature*, etc.) published within the last year on the provided topic of the week, and write at least 10 sentences (2-3 paragraphs) summarizing the paper. This should include describing the figures, explaining what techniques the authors used, major findings and conclusions from the article, what you learned, definitions of words or techniques that you did not know prior to the readings, etc. Make sure to include the reference for the paper you are summarizing in the format provided above. You will upload the literature assignments to CCLE prior to lecture. There are six assigned literature assignments in total, your best five of six will count toward your final grade.

Homework
Homework is due at the beginning of lecture and will be returned in discussion section or Monday lecture. Do the reading and homework in *advance* of lecture to prepare for a higher level discussion in class.

One creative problem is due with each week's homework assignment. You will write and answer a problem that captures a key concept from the previous topic or lecture. These will always be graded. The best problems will be assigned to future classes and/or will be used in exams, and your biography (and "vintage") will be given.

Check the syllabus frequently, as we will update readings, homeworks, and other links.
(When the next lecture date is in green, those assignments are finalized.)

Note that all material discussed in assigned readings is considered testable material, even if it is not explicitly discussed in lecture. The lectures, the readings, and the homework assignments are designed to be *complementary*.

Notes on Exams: No notes, calculators, computers, phones, smart watches, connected devices, etc. are allowed during exams. A periodic table and needed formulas and constants will be provided. Exam regrade requests will be considered for one week after the exam is returned and the entire exam paper will be regraded. Only exams done in ink are eligible to be regraded.
Please coordinate special exam requirements with your TA at the beginning of the quarter (*i.e.*, during the first week).
Makeup exams, when necessary because of exams missed with approved excuses, will be conducted as private oral exams with Prof. Weiss.

Letter grades will be determined based on student performance after the final exam is given.

Office Hours
Prof. Paul Weiss, in 3041 Young Hall
Tentatively Tuesdays 2^{30}-3^{30} PM and Thursdays 1^{30}-2^{30} PM (there will be some shifts)
Prof. Weiss is often available on iChat/WeChat/etc. as PSWeiss
TA Office Hours – announced in sections and on course web site: http://bit.ly/chem20bhw20
Recap file (updated all quarter): http://bit.ly/recap20bh20

Chem 20BH: Reading and Homework
(Updated frequently, not finalized until the upcoming lecture date is in green)

Please complete readings prior to coming to lecture.
Turn in homework at/before lecture.
If you are not going to make it to lecture, email your homework to your TA *prior* to lecture.
Late homework will not be accepted without a TA-approved excuse.

All readings will come from *Principles of Modern Chemistry*, by Oxtoby, Willis, & Campion, 8th edition, unless otherwise specified.
Older editions may also be used, however the chapters and problems **will vary**, so be sure to get the correct readings and problems from the current edition for assignments.

For **Lecture 1, Monday 6 January**
Review Chapter 20: Molecular Spectroscopy and Photochemistry
Intro, Syllabus, Energies, and Single-Molecule Measurements

For **Lecture 2, Wednesday 8 January**
Review Chapters 1-8
Choose your favorite energy units from
eV, kJ/mole, kcal/mole, cm^{-1} (one of the first three would likely be most useful)
Know the conversions to the others and conversions to J and to K (absolute temperature)

What are typical bond strengths and bond lengths for C-C single, double, and triple bonds.
(Use at least two units)

For fun (not required, but sometimes helpful):

We discussed X-ray diffraction (vs. spectroscopy) where there is no photon energy change, only scattering and interference. X-rays are used because their wavelengths match chemical bond lengths
http://www.vega.org.uk/video/programme/80
Lucas, Lambin, Mairesse & Mathot
Journal of Chemical Education 76, 378 (1999)

http://bit.ly/1St91NM
A prank in the periodic table from a great UCLA chemistry alumnus

Some notable class alumni:
Prof. Adam Numis now at UCSF

Prof. Kerri Pratt's lab at the University of Michigan and her recent award in environmental chemistry

For **Lecture 3, Friday 10 January**
Review Chapter 20: Molecular Spectroscopy and Photochemistry
Topic:
Single-molecule measurements

At the beginning of class, we asked, "How strong is a carbon-carbon bond?" Before Friday's class please do the following.

Find the bond length, and bond strength of each of the following:
C-C
C=C
C≡C

Draw a molecule for each of those bonds.

Reading:
9.1 The Chemistry of Gases
9.2 Pressure and Temperature of Gases
9.3 The Ideal Gas Law
9.4 Mixture of Gases

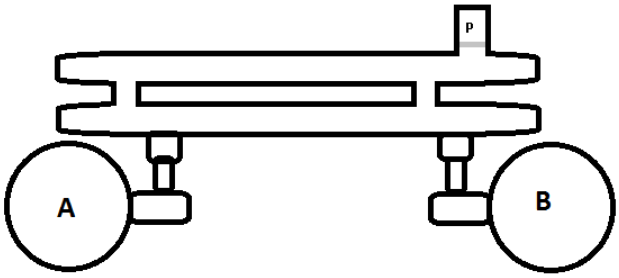
Literature assignment
Find a research article from a top scientific journal (*i.e.*, *Science*, *ACS Nano*, *Nature*, etc.) published within the last year on the topic of **single-molecule measurements**, and write at least 10 sentences summarizing the paper.

For **Lecture 4, Monday 13 January**
Reading:
9.5 Kinetic Theory of Gases
9.6 Real Gases
10.1 Bulk Properties of Gases, Liquids, and Solids: Molecular Interpretation
10.2 Intermolecular Forces: Origins in Molecular Structure

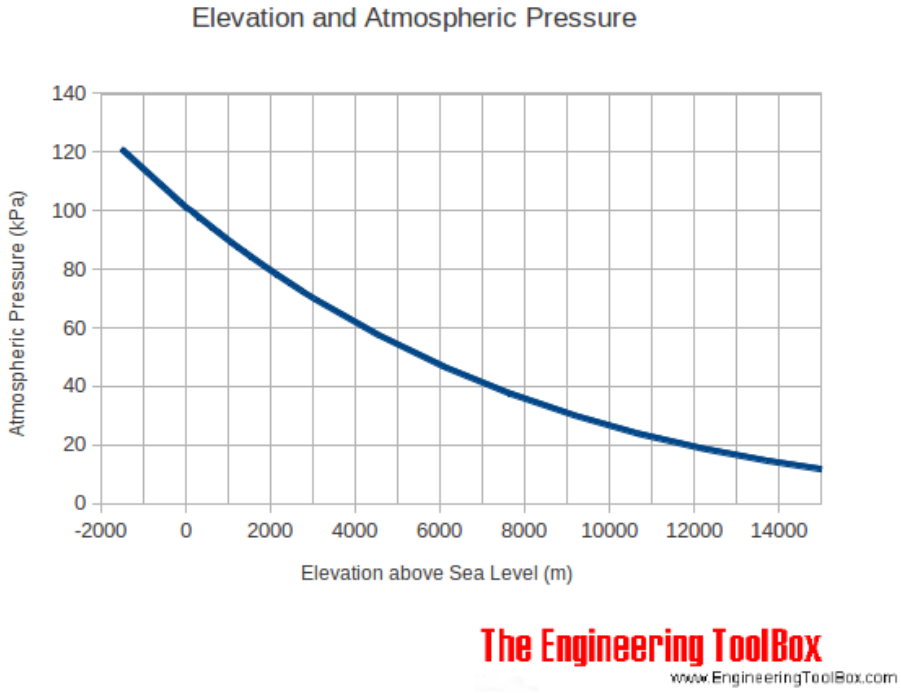
For **Lecture 5, Wednesday 15 January (HW)**
Reading:
10.3 Intermolecular Forces in Liquids
10.4 Phase Equilibrium
10.5 Phase Transitions
10.6 Phase Diagrams
Take a look at mass spectrometry and mass spectrometers in chemical analysis (find a source – if you locate a particularly good one, alert your TA directly.)

Problems:
9.18, 9.20, 9.34, 9.44, 9.64, 9.87

Many experiments use gas manifolds to transfer gases from one reaction vessel to another. Knowing the volume of such manifolds can be crucial. Bulb A was filled with 540. mL of N_2 gas. When opened to the glass manifold, the pressure was allowed to equilibrate and the new pressure (read at location P) was 295 Torr. Next, an empty 549 mL bulb labeled B was opened to the manifold. The new pressure read was 228 Torr. What is the available volume in the glass manifold assuming ideal gas law?



After a pleasant weekend on the shores of Lake Tahoe (elevation: 1900 m), Leroy travels back down the Sierra Nevada to his hometown in Folsom, California (elevation: 70 m). During his trip, Leroy feels his eardrum bulging inward to compensate for pressure. Given that the volume of the inner ear is approximately 225.0 µL in the neutral starting position (i.e. no eardrum bulging), what is the volume of Leroy's inner ear when he arrives in Folsom. Assume constant temperature, and use the data below to guide your calculations.



Created by Matthew Ye in our Winter 2016 class: Matthew is a biophysics major from Toronto, Canada. In high school, he enjoyed using chemistry to create "energetic chemical reactions" in his friend's garage. Since then, he has been involved in research in Professor Weiss's lab. In his free time, he enjoys distance running and ran a marathon.

Create and solve your own original problem that captures a key concept from the previous topic or lecture.

For fun (not required):
Scientific American discussion of North Korea's test of what might not have been a hydrogen bomb:
http://bit.ly/1OSiHSD

Quanta (http://bit.ly/1mLf04f) article on George Church's left-handed world (more on George later this quarter):
http://bit.ly/1mLf04f

A chemistry song from my friend and colleague, Dr. (Col. Hon.) Chuck Martin at the University of Florida
http://bit.ly/1mzngop
NB- Paul was in the audience at the club with Prof. Martin's students for this performance after giving a talk in his department.

Ice skating text box, describing why the reduction in friction when skating is *not* due to pressure-induced melting.
http://bit.ly/1N1WbiD

For **Lecture 6, Friday 17 January**
Reading:
11.1 Composition of Solutions
11.2 Nature of Dissolved Species
11.3 Reaction Stoichiometry in Solutions: Acid–Base Titrations

Recaps:
http://bit.ly/recap20bh20

Literature assignment
Find a research article from a top scientific journal (*i.e.*, *Science*, *ACS Nano*, *Nature*, etc.) published within the last year on the topic of **environmental issues or environmental clean-up related to chemistry**, and write at least 10 sentences summarizing the paper.

Martin Luther King Jr. Holiday Monday 20 January

For **Lecture 7, Wednesday 22 January (HW)**
Reading:
11.4 Reaction Stoichiometry in Solutions: Oxidation–Reduction Titrations
11.5 Phase Equilibrium in Solutions: Nonvolatile Solutes
11.6 Phase Equilibrium in Solutions: Volatile Solutes

Problems:
10.8, 10.15, 10.20, 10.34, 10.48, 11.3, 11.9, 11.14, 11.26, 11.34, 11.40, 11.58, 11.78

Assign the formal oxidation state of each atom in these iron oxides and hydroxides:

FeO Fe_3O_4 Fe_2O_3 Fe_4O_5 $Fe(OH)_2$ $Fe(OH)_3$

Which have mixed valence?

Final project topic due in lecture (unless extended in consultation with Prof. Weiss)

Create and solve your own original problem that captures a key concept from the previous topic or lecture.

For **Discussion, Thursday 23 January**

Literature assignment

Find a research article from a top scientific journal (i.e. *Science*, *ACS Nano*, *Nature*, etc.) published within the last year on the topic of **energy harvesting and storage**, and write at least 10 sentences summarizing the paper.

For **Lecture 8, Friday 24 January**

Reading:

14.1 The Nature of Chemical Equilibrium
14.2 The empirical Law of Mass Action
14.3 Thermodynamic Description of the Equilibrium State
14.4 The Law of Mass Action for Related and Simultaneous Equilibria

LA EXAM REVIEW TBA

For **Lecture 9, Monday 27 January (HW)**

Reading:

14.5 Equilibrium Calculations for Gas-Phase and Heterogeneous Reactions
14.6 The Direction of Change in Chemical Reactions: Empirical Description
14.7 The Direction of Change in Chemical Reactions: Thermodynamic Explanation
14.8 Distribution of a Single Species between Immiscible Phases: Extraction and Separation Processes

Problems:

14.10, 14.16, 14.18, 14.20, 14.22, 14.35, 14.58, 14.73

Create and solve your own original problem that captures a key concept from the previous topic or lecture.

A resource on azeotropes and distillation from Alexandra Li, 2018
http://bit.ly/LibAzeo18

For **Lecture 10, Wednesday 29 January**
Exam preparation
Reading:
12.1 Systems, States, and Processes
12.2 The First Law of Thermodynamics: Internal Energy, Work, and Heat
12.3 Heat Capacity, Calorimetry, and Enthalpy
12.4 The First Law and Ideal Gas Processes

Wednesday 29 January 6-8 PM Midterm #1

Please use a pen for the exam
The exam will cover reading, homework, and lecture through Monday 27 January

For **Lecture 11, Friday 31 January**
Reading:
12.5 Molecular Contributions to Internal Energy and Heat Capacity
12.6 Thermochemistry
12.7 Reversible Processes in Ideal Gases
12.8 Distribution of Energy among Molecules

Read the wikipedia page on heat capacity, which is free to use a little calculus, and gives a better explanation, in my opinion
https://en.wikipedia.org/wiki/Heat_capacity

For **Lecture 12, Monday 3 February (HW)**
Reading:
13.1 The Nature of Spontaneous Processes
13.2 Entropy and Spontaneity: A Molecular Statistical Interpretation
13.3 Entropy and Heat: Macroscopic Basis of the Second Law of Thermodynamics
13.4 Entropy Changes in Reversible Processes

Problems:
12.3, 12.10, 12.14, 12.15, 12.26, 12.42, 12.56, 12.63

Create and solve your own original problem that captures a key concept from the previous topic or lecture.

4 PM Seminar from Prof. Shelley Claridge, Purdue University (UCLA postdoc)
2033 Young Hall

For **Lecture 13, Wednesday 5 February**
Reading:
13.5 Entropy Changes and Spontaneity
13.6 The Third Law of Thermodynamics
13.7 The Gibbs Free Energy
13.8 Carnot Cycles, Efficiency, and Entropy

For **Lecture 14, Thursday 6 February**
Final project abstract due on CCLE before class.
Reading:
15.1 Classification of Acids and Bases
15.2 Properties of Acids and Bases in Aqueous Solutions
15.3 Acid and Base Strength
15.4 Equilibria Involving Weak Acids and Bases

Friday 7 February
Prof. Weiss is here:
https://www.griffith.edu.au/centre-clean-environment-energy/news-events/energy-environmental-materials

For **Lecture 15, Monday 10 February (HW)**
Guest lecturer
Reading:
15.5 Buffer Solutions
15.6 Acid-Base Titration Curves
15.7 Polyprotic Acids

Problems:
For the reaction:
$2Cu^{+} + Zn(s) \rightarrow Zn^{2+} + 2Cu(s)$
Calculate $E°_{cell}$, $\Delta G°$, and K_{eq}

13.2, 13.6, 13.10, 13.16, 13.24, 13.34, 13.40
15.1, 15.8, 15.17, 15.24, 15.38

Create and solve your own original problem that captures a key concept from the previous topic or lecture.

Prof. Weiss is here:
https://www.iconn2020.com/

For **Lecture 16, Wednesday 12 February**
Guest lecturer
Reading:
16.1 The Nature of Solubility Equilibria
16.2 Ionic Equilibria between Solids and Solutions
16.3 Precipitation and the Solubility Product

Here is a poster example that you can also use as a template:
http://bit.ly/20bh18poster
Here is the template for the abstract:
http://bit.ly/20bh18Abs
Please rename the poster with your name first, like this:

WeissPaul20bh20poster.pptx

For **Lecture 17, Friday 14 February**
Guest lecturer
Reading:
16.4 The Effects of pH on Solubility
16.5 Complex Ions and Solubility
16.6 A Deeper Look… Selective Precipitation of Ions

Literature assignment
Find a research article from a top scientific journal (*i.e.*, *Science*, *ACS Nano*, *Nature*, etc.) published within the last year on the topic of **energy storage**, and write at least 10 sentences summarizing the paper.

Happy Valentine's Day! 

Presidents' Day Holiday Monday 17 February

For **Lecture 18, Wednesday 19 February (HW)**
Reading:
17.1 Electrochemical Cells
17.2 Cell Potentials and the Gibbs Free Energy
17.3 Concentrations Effects and the Nernst Equation

Problems:
15.46, 15.48, 15.52, 15.58, 15.66
16.3, 16.11, 16.20, 16.24, 16.32, 16.37, 16.54

Optional problem:
For 1 M, 0.5 M, and 0.1 M acetic acid (each), at equilibrium:
What is the acetate ion concentration?
What is the pH?
What is the fraction dissociation?
17.8, 17.24, 17.27

Create and solve your own original problem that captures a key concept from the previous topic or lecture.

For **Lecture 19, Friday 21 February**
Reading:
17.4 Molecular Electrochemistry, *Connection to Biology* : ECL in Clinical Assays
and *Connection to Energy*: Solar Energy Conversion
17.5 Batteries and Fuel Cells

If you did not cover or do not remember, crystal field theory and metal ion complexes, review those sections.

If you have the time, read ahead in Chapter 22 on the electrical properties and excitations in metals and semiconductors. Some of the issues are now covered in the Recaps.

Saturday 22 February

Poster presentation from 2-6 pm. Location TBA

For **Lecture 20, Monday 24 February (HW)**
Reading:
22.6 Band Theory of Conduction
22.7 Semiconductors
17.6 Corrosion and Corrosion Protection
17.7 Electrometallurgy
17.8 A Deeper Look: Electrolysis of Water and Aqueous Solutions

Problems:
17.45, 17.53, 17.55, 17.62, 17.72

Name one vitamin, draw its chemical structure, and briefly describe one aspect of what it does in terms of biological function (*e.g.*, if it is part of a particular enzyme). Can you overdose on it (*i.e.*, is it fat-soluble?)?

Name one neurotransmitter, draw its chemical structure, and briefly describe one aspect of what it does in our brains (*e.g.*, relation to behavior, mood, etc.)

Making a battery out of nickel and iron that proceeds by the following reaction:
$Ni^{2+}(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + Ni(s)$

What are ΔG and E_{cell} initially and after running the battery until the concentrations of the metal ions in solution are: $[Ni^{+2}] = 0.050$ M and $[Fe^{+2}] = 1.0$ M.

You attempt to "recharge" your battery by adding Ni^{+2} until it is 0.5 M (ignore any volume change due to the addition). What are the new ΔG and E_{cell}?

22.4, 22.9, 22.12

Create and solve your own original problem that captures a key concept from any time in the course.

Optional reading on **Zone Refining** and just for fun:
https://en.wikipedia.org/wiki/Zone_melting

For **Discussion, Tuesday 25 February**
Exam Review

For **Lecture 21, Wednesday 26 February**
Reading:
22.1 Minerals: Naturally Occurring Inorganic Materials
22.2 Properties of Ceramics
22.3 Silicate Ceramics

Wednesday 26 February 6-8 PM Midterm #2

Please use a pen for the exam – exams done in pencil are ineligible for regrading
Here are some old exams for practice, but we have not covered all the topics in them:
http://bit.ly/20bh18oldexams
(or http://www.nano.ucla.edu/_psw/20BH18/20bhOldExams.pdf)

For **Lecture 22, Friday 28 February**
Go over exam
Reading:
22.4 Nonsilicate Ceramics
22.5 Electrical Conduction in Materials

Literature assignment
Find a research article from a top scientific journal (i.e. *Science, ACS Nano, Nature*, etc.) published within the last year on the topics of **coupling light and electronics**, and write at least 10 sentences summarizing the paper.

For **Lecture 23, Tuesday 3 March (HW)**
Reading (if you did not do it last week):
22.6 Band Theory of Conduction
22.7 Semiconductors

Problems:
22.16, 22.19, 22.21, 22.25
18.4, 18.8, 18.18, 18.22, 18.23
Create and solve your own original problem that captures a key concept from the previous topic or lecture.

For **Lecture 24, Wednesday 4 March**
Reading:
18.1 Rates of Chemical Reactions
18.2 Rate Laws
18.3 Reaction Mechanisms

For **Lecture 25, Friday 6 March**
18.4 Reaction Mechanisms and Rate

18.5 Effect of Temperature on Reaction Rates

Final project due SUNDAY by 11^{59} PM on CCLE.

Microbiome TED Talk by Rob Knight at UCSD:
http://bit.ly/KnightTED

Microbiome Technology Roadmap we published (*ACS Nano* **10**, 6, 2016) to propose the US Microbiome Initiative
http://bit.ly/2hNywiW

For **Lecture 26, Monday 9 March (HW)**
Reading:
18.6 Molecular Theories of Elementary Reactions
18.7 Reactions in Solution
18.8 Catalysis

Problems:
22.28, 22.32, 22.54, 22.56
18.26, 18.29, 18.37, 18.40, 18.64, 18.72
Create and solve your own original problem that captures a key concept from the previous topic or lecture.

For **Lecture 27, Wednesday 11 March**
Reading:
19.1 Mass-Energy Relationships in Nuclei
19.2 Nuclear Decay Processes
19.3 Kinetics of Radioactive Decay
19.4 Radiation in Biology and Medicine
19.5 Nuclear Fission
19.6 Nuclear Fusion and Nucleosynthesis

Literature assignment
Find a research article from a top scientific journal (i.e. *Science, ACS Nano, Nature*, etc.) published within the last year on the topic of **catalysis or nuclear reactions**, and write at least 10 sentences summarizing the paper.

For **Discussion, Thursday 12 March**
Exam Review with Kris, Gail, and our LA

For **Lecture 28, Friday 13 March (HW)**
Reading:
In-Class Review – please find all the slides in our Recap file:

Problems:
19.4, 19.9, 19.15, 19.27, 19.46
Create and solve your own original problem that captures a key concept from the previous topic or lecture.

Tuesday 18 March, 8-11 AM Final Exam
No calculators/watches/devices are allowed for the final exam.

Tuesday 19 March (optional)
Go over final, recap class, learning, careers, and more