Федеральное государственное бюджетное образовательное
учреждение высшего образования
Московский государственный университет имени М.В. Ломоносова
Факультет наук о материалах

УТВЕРЖДАЮ
Зам. декана ФНМ по учебной работе
____________/А.В. Кнотько /
«__» _____________2016 г.

РАБОЧАЯ ПРОГРАММА ДИСЦИПЛИНЫ

Наименование дисциплины:

Введение в химию твердого тела (на английском языке “Introduction to solid state chemistry”)

Уровень высшего образования:
магистратура

Направление подготовки:

04.04.02 Химия, физика и механика материалов

Направленность (профиль)/специализация ОПОП:

Фундаментальное материаловедение

Форма обучения:
очная

Рабочая программа рассмотрена и одобрена

Методической комиссией факультета наук о материалах

(протокол №_________, дата)

Москва 2016

Рабочая программа дисциплины разработана в соответствии с самостоятельно установленным МГУ образовательным стандартом (ОС МГУ) для реализуемых основных профессиональных образовательных программ высшего образования по направлению подготовки «Химия, физика и механика материалов» (программы бакалавриата, магистратуры, реализуемых последовательно по схеме интегрированной подготовки) в редакции приказа МГУ от ____________20___ г.

1. Место дисциплины в структуре ОПОП ВО: Вариативная часть, профессиональная подготовка, спецкурс по выбору студентов, курс предназначен для студентов магистратуры факультета наук о материалах **1-го года обучения (1-й семестр),** дистанционный курс на английском языке, курс является обязательным

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2. Входные требования для освоения дисциплины, предварительные условия (если есть):

Дисциплины и модули профессиональной подготовки бакалавриата

3. Результаты обучения по дисциплине:
Знать: основные виды кристаллических структур; процессы дефектообразования в твердом теле; закономерности образования и роста новой фазы; основные виды фазовх превращений в твердых телах, их термодинамику и кинетику; теорию и практику синтеза твердых веществ и материало
Уметь: использовать фундаментальные физико-химические представления в рамках парадигмы состав – структура – свойства для обоснованного выбора метода получения необходимого уровня свойств твердофазных материалов и объяснять влияние условий получения и обработки материалов на их характеристики и вытекающие из этого области применения материалов
Владеть: приемами самостоятельно сбора данных для поиска информации об отдельных определениях, понятиях и терминах в области химии твердофазных материалов; методами статистической обработки и анализа экспериментальных результатов исследования структуры и механических свойств, а также подготовки образцов, используемых при измерениях структурных и механических характеристик; необходимым для дадьнейшей профессиональной деятельности уровнем английского языка

4. Объем дисциплины составляет 2 з.е. (72 ак.ч.)

5. Содержание дисциплины, структурированное по темам (разделам) с указанием отведенного на них количества академических часов и виды учебных занятий:
5.1. Структура дисциплины по темам (разделам) с указанием отведенного на них количества академических часов и виды учебных занятий (в строгом соответствии с учебным планом)

Вид работы	**Семестр**				**Всего**
	1				
Общая трудоёмкость, акад. Часов	72				72
Аудиторная работа:					
Лекции, акад. Часов					
Семинары, акад. Часов					
Лабораторные работы, акад. часов					
Самостоятельная работа, акад. Часов	72				72
Вид итогового контроля (зачёт, экзамен)	Зач.				

5.2. Содержание разделов (тем) дисциплины

Course Overview
Introduction to Solid State Chemistry is a one-semester college course on the principles of chemistry. This unique and popular course satisfies MIT's general chemistry degree requirement, with an emphasis on solid-state materials and their application to engineering systems. You'll begin with an exploration of the fundamental relationship between electronic structure, chemical bonding, and atomic order, then proceed to the chemical properties of "aggregates of molecules," including crystals, metals, glasses,

semiconductors, solutions and acid-base equilibria, polymers, and biomaterials. Real-world examples are drawn from industrial practice (e.g. semiconductor manufacturing), energy generation and storage (e.g. automobile engines, lithium batteries), emerging technologies (e.g. photonic and biomedical devices), and the environmental impact of chemical processing (e.g. recycling glass, metal, and plastic).

- 3.091SC is not "just a chemistry class" - it's a **chemistry-*centered*** class that integrates examples from the world around us, in the arts and humanities, the human stories behind the science, and applications to engineering and emerging technologies.
- If you've taken chemistry classes before (for instance, high school AP Chemistry or another college-level chemistry overview), 3.091SC offers **a fresh look** at some familiar topics, and includes other topics that fall outside the "standard" chemistry curriculum.
- While it satisfies MIT's **graduation requirement for general chemistry** — and thus may be the last chemistry class you take — 3.091SC is also a solid basis for many more years of study in chemistry-intensive subjects.

Learning Objectives

Upon successful completion of 3.091SC, students will have accomplished the following **general** and **specific** learning objectives.

General

- Predict the **properties** and **interactions** of chemical substances by understanding their **composition** at the atomic level, making connections to **structure**, **bonding**, and **thermodynamics** as necessary.
- Determine and apply **principles of materials science** (specifically microstructure design and selection) to the selection of materials for specific **engineering applications.**
- Assess the quality of text and graphics in textbooks and other published sources, and understand the advantages and limitations of **different models** proposed to explain each concept.
- Understand and identify the similarities and differences among important classes of materials including **glasses**, **metals**, **polymers**, **biomaterials**, and **semiconductors.**

Specific

- Utilize **models of the atom** to predict **bonding** and **behavior** of atoms.
- Apply trends in the **periodic table** to predict behavior and properties of the elements.
- Predict the behavior of specific elements in **chemical reactions.**
- Understand how the **primary and secondary bonding** of atoms influences materials properties and behavior.
- Apply basic rules of **electron orbitals** to predict molecular structure and properties.
- Sketch the seven **crystal systems** and **fourteen Bravais lattices.**
- Specify atomic planes, directions, and families of planes and directions within a given **crystal structure** using Miller indices.
- Correlate **X-ray diffraction** information with **crystal structure.**
- Compare and contrast the **scattering of X-rays, neutrons** and **electrons** within a crystal, and understand when one should use each of these to obtain structural information about a material.
- Utilize band theory to describe the operation of modern **semiconductor** devices.
- Use thermodynamics to explain the presence of **point defects** in crystalline solids.
- Describe **point, line, planar,** and **bulk imperfections** in crystalline solids, and explain how these imperfections interact.
- Identify the atomic-scale similarities and differences between **amorphous** and **crystalline solids.**
- Discuss the structural and physical property differences between **inorganic glasses** (oxides, metallic) and **organic glasses** (polymers).
- Apply **reaction kinetics** to determine the rate of chemical reactions; understand the factors that influence **rates of reaction.**
- Utilize **basic biochemistry** to understand the formation of amino acids, peptides and proteins, lipids and nucleic acids.
- Apply Fick’s laws to predict the **diffusion time and depth** for systems with various initial and boundary conditions.

- Utilize **binary phase diagrams** to identify weight and/or atomic percentages of components, and relative amounts of stable phases in binary and **unary solutions.**

МОДУЛИ Course Topics

3.091SC combines teaching about **foundational chemistry concepts** with **applications to particular material forms**. To guide you through the course, individual class sessions are related to the following foundation and application modules.

- *Foundations*
  - Structure of the Atom - The periodic table, elements and compounds, chemical formulas. Evolution of atomic theory: Thomson & Rutherford, Bohr model of hydrogen, Bohr-Sommerfeld model and multi-electron atoms, atomic spectra, Schrödinger equation. Electron orbitals: Aufbau principle, Pauli exclusion principle, and Hund's rules.
    - Sessions 1, 2, 3, 4, 5, 6, 7
  - Bonding and Molecules - Primary bonding: ionic, covalent, metallic. Secondary bonding: dipole-dipole, induced dipole-induced dipole, London dispersion/van der Waals, hydrogen. Shapes of molecules: hybridization, LCAO-MO, VSEPR theory.
    - Sessions 8, 9, 10, 11, 12
  - Reactions and Kinetics - Reaction kinetics: rate laws, thermal activation, and the Arrhenius equation. Diffusion: Fick's first and second laws.
    - Sessions 22 (second part), 23, 24
- *Applications*
  - Electronic Materials - Band theory: metals, insulators, and semiconductors. Band gaps, doping, and devices.
    - Sessions 13, 14, 15 (first part)
  - Crystalline Materials - Crystal structure: 7 crystal systems, 14 Bravais lattices, Miller indices. Properties of cubic crystals. X-ray diffraction. Defects: point, line, surface, bulk.
    - Sessions 15 (second part), 16, 17, 18, 19, 20
  - Amorphous Materials - Inorganic glasses: silicates, other oxides, metallics.
    - Sessions 21, 22 (first part)
  - Aqueous Solutions - Liquids and solutions: solubility rules, acids, bases, pH.
    - Sessions 25, 26
  - Organic Materials - Organic compounds: nomenclature, alkanes, alkenes, alkynes, aromatics, functional groups. Polymers: structure, composition, synthesis and applications. Biochemistry: amino acids, peptides and proteins, lipids, nucleic acids, protein biosynthesis.
    - Sessions 27, 28, 29, 30, 31, 32
  - Solid Solutions - Phase stability: unary and binary phase diagrams.
    - Sessions 33, 34, 35

Course Structure

Take a moment to familiarize yourself with the organization of this course. 3.091SC consists of nine modules, followed by final exam. Each module contains a sequence of several session pages, and ends with a self-assessment page.

Order of Topics

3.091SC combines teaching about foundational chemistry concepts with applications to particular material forms. This website has been organized for a linear progression through the topics, reflecting the order of lectures as taught at MIT. The initial Structure of the Atom and Bonding and Molecules modules are an essential foundation for the latter portion of the course, and should be studied first. As an independent learner, you could then work through the latter application-oriented modules in the order in which they are presented, or choose a different order which suits your particular interests. For instance, you could study Aqueous Solutions or Organic Materials before the modules on Electronic, Crystalline, and Amorphous Materials. Check the prerequisites listed on each session page to see what prior knowledge is needed, and if needed follow the links to other sessions or modules.

Session Pages

This class consists of 35 individual sessions. Each session page has the following content:

- **Session Overview:** A quick glance at what's in this session and how it fits into the course – keywords, prerequisites, and learning objectives.
- **Reading:** The suggested readings from the course notes and textbooks should be completed before watching the video (see note below on Textbooks).
- **Lecture Video:** Each session has one lecture video, approximately 1 hour long. A PDF file of the slides is provided for reference.
- **Homework:** These problems with solutions are for your benefit, to develop your practical understanding of the material.
- **For Further Study:** These optional resources may include supplemental reading lists, additional content on historical or cultural aspects mentioned in this session, and related or next-step online content.

Self-Assessment Pages

After you've done all the readings, watched all the lecture videos, and completed the homework in a module, use the self-assessment page to confirm that you understand the material. Each self-assessment page provides several types of problems with solutions, plus helpful videos.

- **Weekly Quizzes:** These short quizzes are representative of the homework in this module, and an indication of the knowledge you should have in preparing for the module exam.
- **Exam Problems:** These problems from the Fall 2009 tests verify that you've developed the appropriate depth of understanding, before you move on to the next module.
- **Help Session Videos**: In these informal videos, three teaching assistants from the Fall 2009 class work through their approach to solving the exam problems.
  » Meet the TAs
- **Supplemental Exam Problems:** These additional exam problems from prior year classes are provided for optional further study.

Final Exam

After completing all nine modules, you'll be prepared for the final exam. Work these problems and check the solutions for an overall assessment of your mastery of the course content.

Content from Various Years

This OCW Scholar course consolidates materials from several years of 3.091. The core contents (lecture videos, lecture slides, and module self-assessments) are from the Fall 2009 teaching term. The "archived lecture notes" used for many session readings were originally written by Prof. August Witt, who taught this course at MIT until 1999. Supplemental exam problems are drawn from the 2007 and 2008 classes, and the final exam is from the Fall 2010 class.

Textbooks and Reference Materials

Suggested Textbooks

The readings and homework portions of each session combine original content provided on this website and references in commercial textbooks. While the materials on this website are sufficient to complete the course, Professor Sadoway believes that students must also learn how to use textbooks effectively, laying a foundation for future academic work and lifelong scientific literacy.

Successful progress in this course will be helped greatly by having access to these books or their equivalents. See the link below for details.

Reference Materials

A detailed periodic table of the elements and a table of fundamental physical constants are essential references used throughout the course. These are provided at the following link.

» Reference materials and a list of suggested textbooks

Technical Requirements

This course includes functionality that does not display correctly in Internet Explorer. For best results, we recommend viewing this course with Firefox, Safari or Chrome.

Join a Study Group

MIT OpenCourseWare has teamed up with OpenStudy so you can quickly and easily connect with others working on this course. Through this site, you can find other students interested in *Introduction to Solid State Chemistry*: work together on assignments, ask each other questions about the exams, or just discuss the topics of the course.

» Sign up now

6. Фонд оценочных средств (ФОС, оценочные и методические материалы) для оценивания результатов обучения по дисциплине (модулю).

6.1. Типовые контрольные задания или иные материалы для проведения текущего контроля успеваемости, критерии и шкалы оценивания (в отсутствие утвержденных соответствующих локальных нормативных актов на факультете)

Пример: описание модуля «Строение атома»

Session Overview

Modules	Structure of the Atom
Concepts	origins of modern chemistry, taxonomy of chemical species, introduction to the periodic table, evolution of atomic theory
Keywords	matter, element, compound, mixture, solution, metal, semimetal, nonmetal, mole, symbol, molecular mass, substance, homogeneous mixture, heterogeneous mixture, periodic table of elements, Democritus, Aristotle, John Dalton, triads, octaves, Johann Dobereiner, John Newlands, Dmitri Mendeleev, Julius Meyer
Chemical Substances	none
Applications	energy generation and storage (e.g. batteries)

Prerequisites

Before starting this session, you should be familiar with:

- Basic principles of high school chemistry
- Fundamental concepts of the structure of the atom

Looking Ahead

Prof. Sadoway discusses the periodic table in more detail (Session 2). He explores the relationship between electronic structure, chemical bonding, and crystal structure (Session 4).

Learning Objectives

After completing this session, you should be able to:

- Classify a substance as an **element** or a **compound**.
- Understand the developmental history of the **periodic table of elements**.
- Identify the **symbols** and **number of electrons** for an element.
- Classify an element as a **metal**, **semimetal** or a **nonmetal**.
- Explain which sets of elements are in the same **period**.
- Calculate the **molecular mass** of a compound.
- Calculate the number of **moles** in a substance.
- Define a **homogenous mixture** and a **heterogeneous mixture**.

Reading

BOOK CHAPTERS	TOPICS
[A&E] 1, "Introduction to Chemistry."	Chemistry in the modern world; the scientific method; a description of matter; a brief history of chemistry; the atom; introduction to the periodic table; essential elements

Lecture Video

Flash and JavaScript are required for this feature.

Download this video:
» iTunes U (MP4 - 205MB)
» Internet Archive (MP4 - 205MB)

Resources
Lecture Slides (PDF - 3.2MB)
Periodic Table and Table of Constants
Transcript (PDF)
Lecture Summary
This lecture is an introduction to the class.
Professor Sadoway begins with important information about the **course objectives**, **organization**, and **expectations**, and proceeds to introduce the subject of solid state chemistry. 3.091 integrates thorough coverage of the **principles of chemistry** with various **applications to engineering systems**. The thesis of 3.091 is that **electronic structure** holds the key to understanding the world around us.
The lecture continues with a survey of the historical foundations of chemistry:

- The **origins of chemistry** in ancient Egypt and Greece
- The development of increasingly refined **classification schemes** (taxonomy and nomenclature) throughout the 18th and 19th centuries
- The evolution of **atomic theory**
- The origins and development of the **periodic table of elements**

Homework

Problems (PDF)
Solutions (PDF)
Textbook Problems

[A&E] SECTIONS	CONCEPTUAL	NUMERICAL
[A&E] 1.3, "A Description of Matter."	6, 7, 9, 10	none
[A&E] 1.4, "A Brief History of Chemistry."	6	none
[A&E] 1.5, "The Atom."	none	1
[A&E] 1.6, "Isotopes and Atomic Masses."	1	none
[A&E] 1.7, "Introduction to the Periodic Table."	1, 4, 6, 10, 11	none
[A&E] 3.1, "The Mole and Molar Masses."	none	3, 8, 16, 17

For Further Study

Textbook Study Materials
See the [A&E] companion website from Pearson for PowerPoint outlines of each chapter, plus online quizzes, interactive graphs and 3D molecular animations:

- Chapter 1

Supplemental Readings
Buy at Amazon Davies, D. A. *Waves, Atoms and Solids*. Harlow Essex, UK: Longman Group United Kingdom, 1978. ISBN: 9780582441743.
Buy at Amazon Brown, T. L., H. E. Lemay, and B. E. Bursten. *Chemistry: The Central Science*. Upper Saddle River, NJ: Prentice Hall, 1999. ISBN: 9780130103109.
How Batteries Work
People
Democritus
Aristotle
John Dalton
Dmitri Mendeleev

Johann Dobereiner
John Newlands
Julius Meyer

6.2. Типовые контрольные задания или иные материалы для проведения промежуточной аттестации по дисциплине (модулю), критерии и шкалы оценивания (в отсутствие утвержденных соответствующих локальных нормативных актов на факультете)

Зачет ставится по результатам успешного выполнения заданий модулей и итогового задания по курсу. Курс снабжен транскрипциями лекций, домашних заданий и тестов, заданиями к зачету.

7. Ресурсное обеспечение:
7.1. Перечень основной и дополнительной литературы

6.2. Перечень лицензионного программного обеспечения, в том числе отечественного производства (подлежит обновлению при необходимости)

6.3. Описание материально-технического обеспечения.
Доступ в интернет (дистанционный курс)

8.Соответствие результатов обучения по данному элементу ОПОП результатам освоения ОПОП указано в Общей характеристике ОПОП.

7. Разработчик (разработчики) программы.
Проф. MIT Donald R. Sadoway