UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Thermodynamics

2425-2-ESM01Q009

Aims

The student will learn the basic concepts of classical equilibrium thermodynamics and of chemical kinetics and will develop abilities to solve simple problems of relevance in materials science.

Knowledge and understanding

- Methods for the analysis of isolated and closed thermodynamic systems (imcluding reactive ststems)
- Procedures for the computation of the main thermodynamic quantities
- Techniques to evaluate thermodynamically admissible transformations between equilibrium states
- Methods to describe relevant chemical-physical systems in materials science

Applying knowledge and understanding

- Computation of the equations of state and of the thermodynamic potentials in systems of relevance in materials science
- Evaluation of the limit of applicability of elemental thermodynamic models in systems of relevance in materials science

Making judgements - Evaluation of the appropriateness of thermodynamic models used in the analysis of real sistems

- Capability to model real systems using thermodynamics

Communication skills
Rigorous use of natural language in science

Learning skils Activation of critical skills in the analysis of scientific models

Contents

Math Refresher. Zeroth, first and second laws of thermodynamics. Auxiliary thermodynamic potentials. Gas thermodynamics and reaction equilibria in the gaseous phase. States of matter and phases. Elements of Solution Thermodynamics.

Detailed program

Mathematical refresher: Exact differentials, partial derivatives, differential forms. Notation.

the zeroth, first and second laws of thermodynamics: thermodynamic systems and variables. The temperature and the zeroth principle. Work. Internal energy and the first law. The concept of thermodynamic potential. Impossible, natural and adiabatically reversible processes. Entropy and the second law. First formulation of an equilibrium criterion.

Auxiliary potentials: enthalpy, Helmholtz and Gibbs free energies. Properties and use of auxiliary potentials. Fundamental equations for a closed system. The chemical potential. Equilibrium criterion. Auxiliary thermodynamic quantities. Determination of changes in thermodynamic functions with pressure and temperature. Molar quantities and partial molar quantities. The Gibbs-Duhem equation.

Gas thermodynamics and reaction equilibria in the gaseous phase: Perfect gas: chemical potential and equation of state. Real gases: fugacity. Numerical examples of determination of changes in thermodynamic functions with pressure, volume and temperature. Perfect gas mixtures. Equilibrium constant for gas phase reactions and its dependence upon temperature and pressure. Degree of advancement of a chemical reaction.

States of matter and phases: the phase rule for reactive and non-reactive components. Clausius-Clapeyron equation. Latent heat. Notes on phase diagrams for single component systems. Polymorphism. Phase transitions.

Solution Thermodynamics: Ideal solutions. Raoult's and Henry's laws. Mixing properties, Henry's coefficient as a function of temperature and pressure. Nernst's law. Depression of the freezing point and elevation of the boiling point. Nonideal solutions: activity and excess functions..

Prerequisites

Calculus of multi-variable functions

Teaching form

Classroom lectures (6 CFU, 48 hours, in person, Delivered Didactics) and numerical exercises (2 CFU, 20 hours, in person. Inetractive teaching). Students will be offered the possibility of using automated tests and self-assessment tools (available online).

Lectures will be in Italian.

Textbook and teaching resource

K. Denbigh, The principles of chemical equilibrium, Cambridge University Press

Handouts

Students will also have access to automated numerical exercises, self-evaluation tests, and additional educational material available online.

Semester

First semester of the second year

Assessment method

Students will be required to pass a written and an oral test.

The written test encompasses the solution of three numerical problems. The first problem focuses on the fundamental aspects of classical thermodynamics (1st and 2nd law, calculation of work and heat exchanged, etc.); The second problem is about physical equilibria (phase transitions, latent heats, melting and boiling points, etc.) while the third one requires the analysis of a chemical equilibrium (calculation of equilibrium constants, reaction free energies, etc.).

For each exactly solved problem, 10 points are assigned. Admission to the oral test requires an overall score in the written test of 15 points or more.

The oral test focuses on theory explained during the lectures but may also include the solution of problems not correctly solved by the student.

Written and oral tests must be given in the same examination session.

Office hours

By appointment

Sustainable Development Goals

AFFORDABLE AND CLEAN ENERGY