

Module 2.3: Phase Changes

Learning Objectives

By the end of this sub-module, students should be able to:

- LO 2.3.1: Name and explain the six phase change processes.
- LO 2.3.2: Learn to draw and explain the heating curve and cooling curve, and apply the curve to calculate heat change in a given process.
- LO 2.3.3: Use a phase diagram to predict which phase is present at any given temperature and pressure, identify phase changes as temperature and/or pressure are varied, and identify the critical temperature, critical pressure and triple point.
- LO 2.3.4: Illustrate the change on a heating/cooling curve to a phase diagram.

Prior Knowledge Review

- [Chem I Module 1.1 Physical and Chemical Properties](#)
 - Description: This module introduces the three phases of matter: solid, liquid and gas.
- [Chem I Module 9.5 Enthalpy and Thermochemical Equations](#)
 - Description: This module describes how to calculate constant pressure calorimetry with outstanding resources that review all of calorimetry and include video demonstrations of the experiments.

Instructional Materials

Textbook Sections

- OpenStax: Chemistry Atoms First 2e
 - [Section 10.3 Phase Transitions](#) (LO 2.3.1, 2.3.2)
 - [Section 10.4 Phase Diagrams](#) (LO 2.3.3, 2.3.4)

Video Resources

- [States of matter and phase change explanation](#) (LO 2.3.1, 2.3.2)
 - Description: This video provides extensive explanations on the three states of matter and introduces the heating curve based on the phase changes. It could be used as a recap video before students starting this module.
 - License: By Khan Academy, under a standard YouTube License.
- [Heating curve and cooling curve of water](#) (LO 2.3.2)
 - Description: This video tutorial provides a basic introduction into the heating curve of water and the cooling curve of water, including the calculation of heat exchanges during the phase changes. This video could be used as an additional source of explanation and practice after students have learned the concept in class. This video could also be used as a lecture video directly in an asynchronous online class.
 - License: By The Organic Chemistry Tutor, under a standard YouTube License.
- [Phase diagram explanation](#) (LO 2.3.3)
 - Description: This video provides a basic introduction on phase diagram. It can be used as an introduction video in a flipped-style classroom where students watch it before the lecture, or it can be used to reinforce the understanding after students have learned them in class.
 - License: by Dr. Mark Kubinec and Professor Alexander Pines, College of Chemistry, UC Berkeley, under a standard YouTube License.
- [Heating curve and phase diagram illustration](#) (LO 2.3.4)
 - Description: This video discusses the heating curve and phase diagram for water in detail. It teaches how to illustrate the change on a heating/cooling curve to a phase diagram. It can be used as an introduction video in a flipped-style classroom where students watch it before the lecture, or it can be used to reinforce the understanding after students have learned them in class.
 - License: Noel Pauller, under a standard YouTube License.
- Demo: [Video showing the critical point of water](#) (LO 2.3.3)
 - Description: This is a demonstration video showing the critical point of water. It could be shown in class as a demonstration when explaining the critical point on the phase diagram.

- License: By Kaijzel, under a standard YouTube License.

Other Resources

- [Instructor Google Slides \(Slides #38-40, #54-55\)](#) (LO 2.3.1, 2.3.2)
 - Description: These slides show the names of all the phase changes and illustrate them on a heating curve. They could be used with a live or recorded lecture in the form of videoconferencing or face-to-face instruction.
 - License: By Joe Depasquale, licensed under CC-BY 4.0.
- [Instructor Google Slides \(Slides #38-40, #56-64\)](#) (2.3.3, 2.3.4)
 - Description: These slides contain the name of phase changes and phase diagram. They could be used with a live or recorded lecture in the form of videoconferencing or face-to-face instruction.
 - License: By Joe Depasquale, licensed under CC-BY 4.0.

Activities and Assessments

Conceptual Activities/Assessments

- Textbook Exercises: OpenStax: Chemistry Atoms First 2e
 - [Sec 10.3 Phase Transitions Exercise #30-37](#) (LO 2.3.1)
 - Description: These explanatory questions ask students to explain certain phenomena during phase changes.
 - Teaching Tip: These problems can be used by students as an assessment for self study. They can also be used by instructors as examples or quiz questions to facilitate the understanding of the concepts in class or after class.
 - Answer Key: The odd-numbered exercises are provided. The direct link to the solutions does not work but one can click on any odd-numbered questions to get to the solutions page.
- Study guide: [Phase change and phase diagram](#) (LO 2.3.1, 2.3.3)

- Description: The third and fourth portion of this study guide (labeled as “phase changes” and “phase diagrams”) are connected to the Openstax textbook section 10.3 and 10.4 on topics of phase changes and phase diagrams.
- Teaching Tip: This study guide can be used in a flipped-style classroom where students complete them before the lecture, or they can be used to reinforce important topics learned in class.
- License: By Montgomery College, licensed under CC-BY 4.0.

Application Activities/Assessments

- Textbook Exercises: OpenStax: Chemistry Atoms First 2e
 - [Section 10.3 Phase Transitions Exercise #53](#) (LO 2.3.2)
 - Description: This question asks students to calculate the energy change during a melting and vaporization process.
 - Teaching Tip: This problem can be used by instructors as examples or quiz questions to facilitate the understanding of the concepts in class or after class. They can also be used as homework questions or in addition to them.
 - Answer Key: The odd-numbered exercises are provided. The direct link to the solutions does not work but one can click on any odd-numbered questions to get to the solutions page.
- Textbook Exercises: OpenStax: Chemistry Atoms First 2e
 - [Section 10.4 Phase Diagram Exercise #54-63](#) (LO 2.3.3, 2.3.4)
 - Description: These exercises require students to read, sketch and use phase diagrams.
 - Teaching Tip: These problems can be used by students as an assessment for self study. They can also be used by instructors as examples or quiz questions to facilitate the understanding of the concepts in class or after class.
 - Answer Key: The odd-numbered exercises are provided. The direct link to the solutions does not work but one can click on any odd-numbered questions to get to the solutions page.
- [Phase change worksheet Q4&5](#) (LO 2.3.2-2.3.4)

- Description: Question #4 and #5 from this worksheet requires students to calculate energy changes during phase changes, and draw graphs based on their calculations.
- Teaching Tip: These problems can be used by instructors as examples or quiz questions to facilitate the understanding of the concepts in class or after class. They can also be used as homework questions or in addition to them.
- License: By Washington State College, licensed under CC-BY 3.0.

Lab Resources

- [PhET phase change virtual lab](#) (LO 2.3.1, 2.3.3)
 - Description: This online activity provides an opportunity for students to visualize the change of particle behavior during a phase change and use it to rationalize the phase diagram. This could be utilized as a virtual lab or as a simulation activity.
 - License: By PhET, University of Colorado Boulder