Phase Diagrams

Unit: Matter

MA Curriculum Frameworks (2016): HS-PS1-11(MA)

Mastery Objective(s): (Students will be able to…)

- Identify the phase of a substance at any combination of temperature and pressure.
- Determine the melting and boiling points of a substance any pressure.

Success Criteria:

- Phases are correctly identified as solid, liquid, gas, supercritical fluid, *etc.,* in accordance with the temperature and pressure indicated on the phase diagram.
- Melting and boiling point temperatures are correctly identified for a substance from its phase diagram for a given pressure.
- The effects of a pressure or temperature change (*e.g.,* substance would melt, sublime, *etc.*) are correctly explained based on the phase diagram.

Tier 2 Vocabulary: phase, curve, fusion, solid, liquid, gas, vapor

Language Objectives:

- Explain the regions of a phase diagram and the relationship between each region and the temperature and pressure of the substance..

Notes:

The phase of a substance (solid, liquid, gas) depends on its temperature and pressure.

phase diagram: a graph showing the phase(s) present at different temperatures and pressures.

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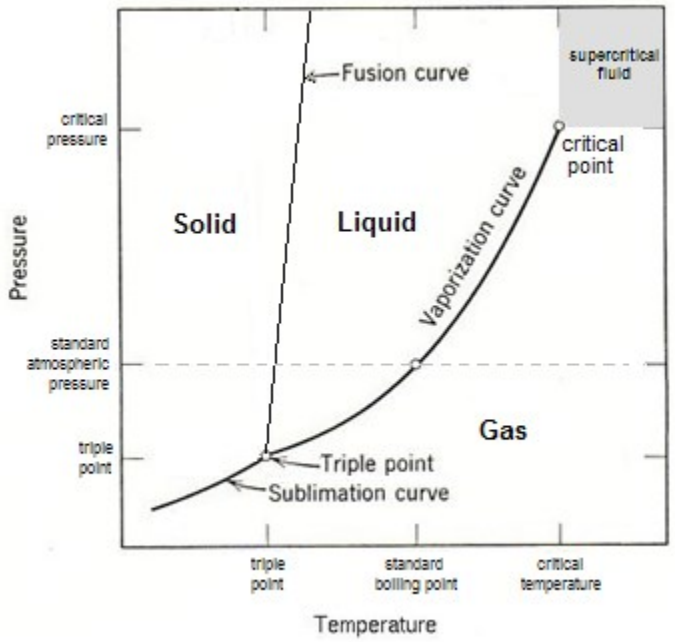

fusion curve: the set of temperatures and pressures at which a substance melts/freezes.

vaporization curve: the set of temperatures & pressures at which a substance vaporizes/condenses.

sublimation curve: the set of temperatures & pressures at which a substance sublimes/deposits.

triple point: the temperature and pressure at which a substance can exist simultaneously as a solid, liquid, and gas.

critical point: the highest temperature at which the substance can exist as a liquid. The critical point is the endpoint of the vaporization curve.

supercritical fluid: a substance whose temperature and pressure are above the critical point. The substance would be expected to be a liquid (due to the pressure), but the molecules have so much energy that the substance behaves more like a gas.

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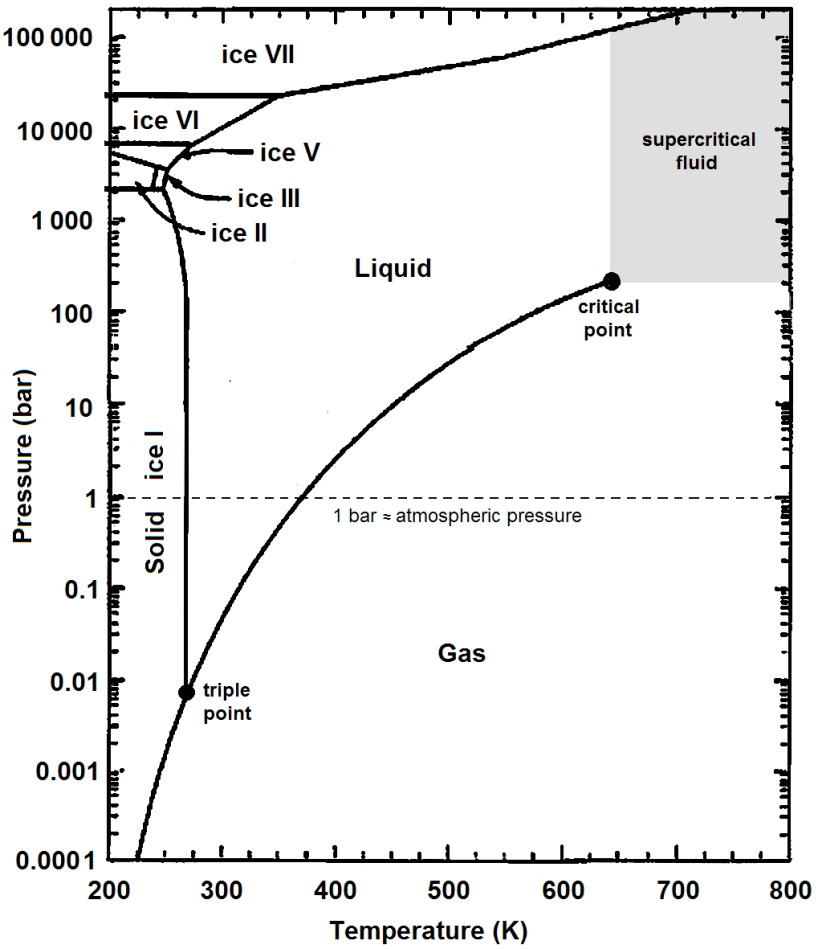
Phase Diagram for Water



Note that pressure is on a logarithmic scale, and that standard atmospheric pressure is 1 bar ≈ 1 atm.

Note also that the temperature is in kelvin. To convert degrees Celsius to kelvin, add 273. (*e.g.,* 25 °C + 273 = 298 K.)

Notice that the slope of the fusion curve (melting/freezing line) is negative. This is because ice I is less dense than liquid water. At temperatures near the melting point and pressures less than about 2 000 bar, increasing the pressure will cause ice to melt. Water is one of the only known substances that exhibits this behavior.

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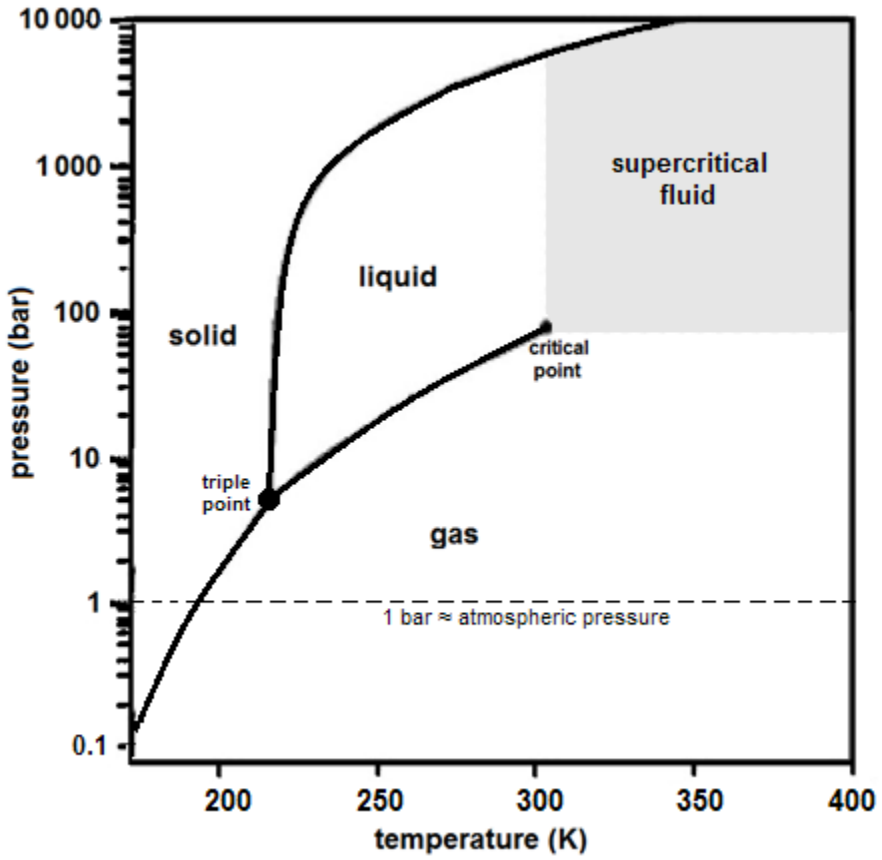
Phase Diagram for Carbon Dioxide



Notice that the pressure of the triple point for CO_2 is about 5 bar, which means CO_2 cannot be a liquid at atmospheric pressure. This is why dry ice (solid CO_2) sublimes directly from a solid to a gas.

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Homework Problems

Answer these questions based on the phase diagrams for water and carbon dioxide.

1. Approximately what pressure would be necessary to boil water at a temperature of 350 K?

2. What is the minimum pressure necessary for water to exist as a liquid at 350 K?

3. At approximately what temperature would water boil if the pressure is 10 bar?

4. What is the highest temperature at which carbon dioxide can exist as a liquid?

5. At 1.0 bar of pressure, what is the temperature at which carbon dioxide sublimes?

6. At room temperature (25 °C ≈ 300 K), what is the minimum pressure at which liquid carbon dioxide can exist?

7. Describe the phase transitions and temperatures for water going from 200 K to 400 K at a pressure of 0.1 bar.

8. Describe the phase transitions and temperatures for carbon dioxide going 200 K to 300 K at a pressure of 10 bar.

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