How can we change states of matter?

Why are we doing this?

Chemical substances have unique sets of physical and chemical properties such as melting points, boiling points, density, viscosity, etc… An important set of potentially differentiating characteristics are associate with changes in state of a substance. Most substances undergo a phase change when they are heated or cooled. To explain these changes, we need to explore what is occurring between the particles of the substance at the molecular scale.

Your Learning Outcomes

You will be able to:

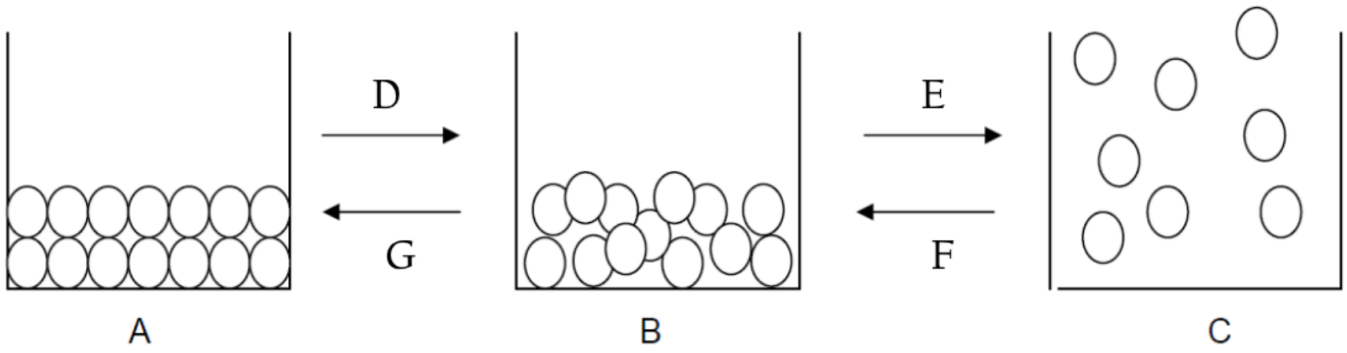
1. Describe and model a phase change.
2. Interpret and sketch a heating or cooling curve for a substance.
3. Use a phase diagram to explain the effect of changing pressure and/or temperature on the phase of matter of a substance.

The Plan

1. Assign roles*.
    a. ***Manager*** – This person will keep the team on task and provide direction to the group. This person is responsible for uploading the group's work to Gradescope. Make sure you make a note of everyone in the group. You must add everyone's name when submitting your answers to Gradescope.
    b. ***Spokesperson*** – This person will represent the group be responsible for speaking for the group to the rest of the class.
    c. ***Recorder*** – This person will be responsible for recording the team's answers to the Critical Thinking Questions in an organized and coherent manner.
    d. ***Analyst*** – This person will be responsible for critical analysis of the team's work (i.e., the Devil's Advocate). This person should make sure everyone understands what is happening before the group moves forward.
2. Complete the Critical Thinking Questions as a group.
3. Submit your team's work via Gradescope. Groups may choose to work in a Word document or write out their answers on a separate sheet of paper. All work must be upload to Gradescope as a PDF file.

**Students may choose to complete this activity independently if they are unable to attend discussion due to illness or injury, in which case, the student must perform all roles and complete all aspect of the activity. To receive full credit, documentation as to the need for the absence from discussion must be included with the submission.*

Model 1: Particulate Models of Matter



Critical Thinking Questions

1. Diagram A shows a model of a solid substance. Describe the arrangement of particles in the **solid** phase.
   The particles in a solid are close packed and arranged in an orderly manner.

2. Diagram B shows a model of a liquid substance. Describe the arrangement of particles in the **liquid** phase.
   The particles in a liquid are also close packed but they are more randomly arranged than in a solid.

3. Diagram C shows a model of a gaseous substance. Describe the arrangement of particles in the **gas** phase.
   The particles in a gas are far apart and randomly arranged.

4. **Melting** is the process by which a solid substance changes into the liquid state. Which arrow best represents melting?
   D

5. Does arrow you chose in Question 4 represent heat being added or removed from the system?
   Heat is being added.

6. **Freezing** is the process by which a liquid substance changes into the solid state. Which arrow best represents freezing?
   G

7. Does arrow you chose in Question 6 represent heat being added or removed from the system?
   Heat is being removed.

8. **Condensation** is the process by which a gaseous substance changes into the liquid state. Which arrow best represents condensation?
   F

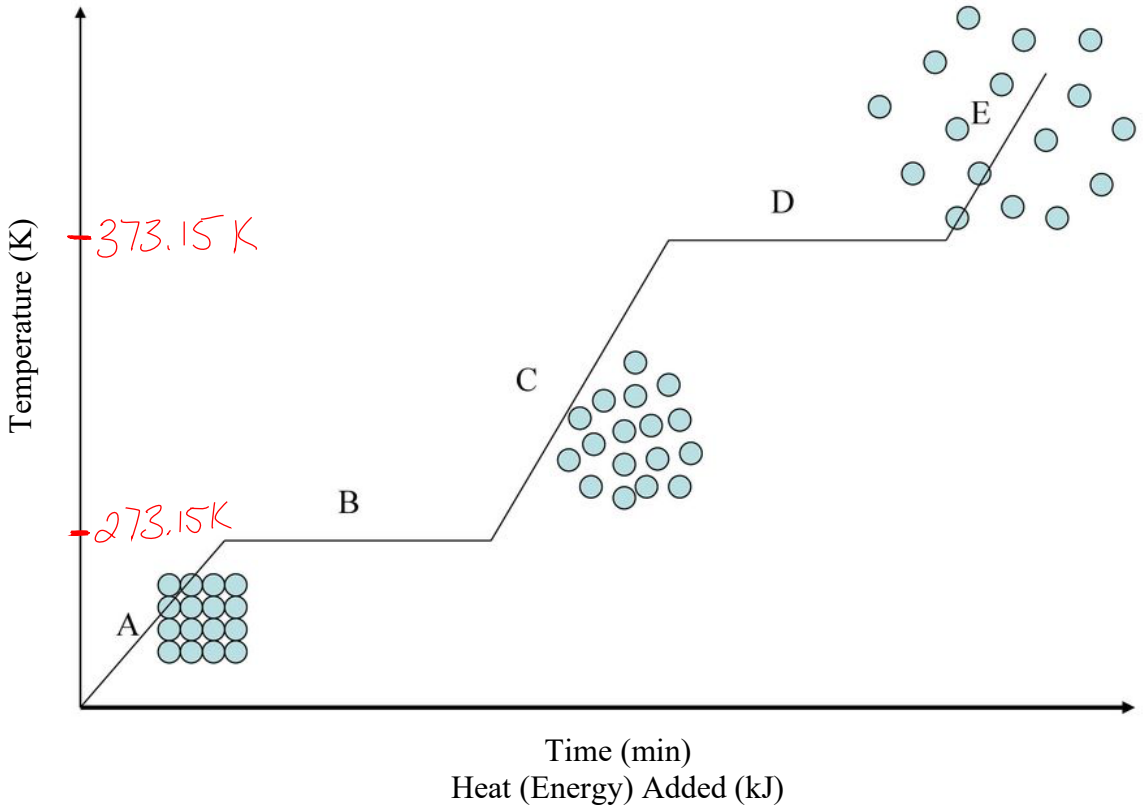
9. Does arrow you chose in Question 8 represent heat being added or removed from the system?
   Heat is being removed.

10. **Boiling** is the process by which a liquid substance changes into the gas state. Which arrow best represents boiling?
    E

11. Does arrow you chose in Question 10 represent heat being added or removed from the system?
    Heat is being added.

12. There are two additional phase changes, sublimation and deposition. **Sublimation** is the process by which a solid becomes a gas. **Deposition** is the process by which a gas becomes a solid. Are these phase changes represented in Model 1?
    No

Model 2: The Heating Curve



Critical Thinking Questions

13. What variable(s) are measured on the y-axis in Model 2?
    Temperature

14. What variable(s) are measured on the x-axis in Model 2?
    Time or heat (energy) being added

15. Consider the segments and particulate models shown on the heating curve in Model 2. What phase of matter does segment A represent? What is happening as heat is added during segment A?
A represents a solid. Heat is being added during segment A, and the temperature of the solid is increasing.

16. What phase of matter does segment C represent? What is happening as heat is added during segment C?
C represents a liquid. As heat is being added, the temrperature of the liquid is increasing.

17. What phase of matter does segment E represent? What is happening as heat is added during segment E?
E represents a gas. As heat is being added, the temrperature of the gas is increasing.

18. As heat is added, what is process is occuring during segment B?
Melting

19. As heat is added, what is process is occuring during segment D?
Boiling

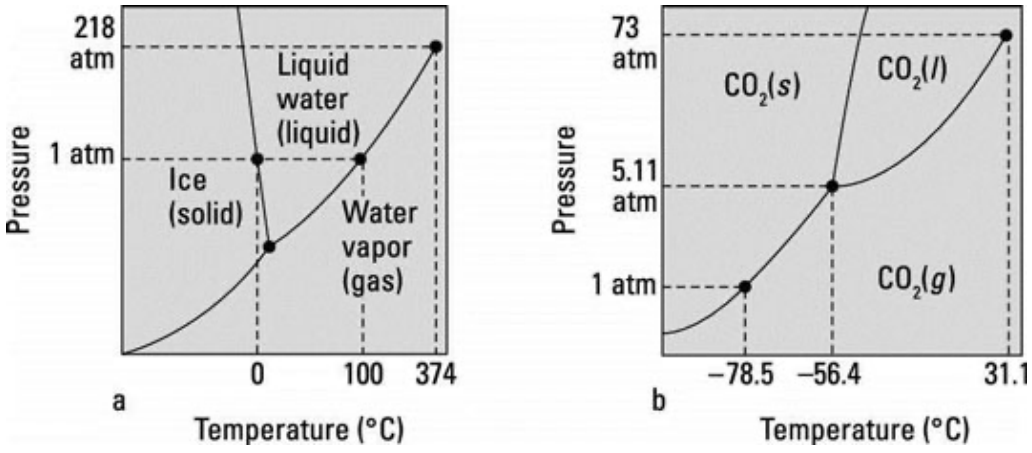
Information

At 1 atmosphere of pressure, water melts at 0°C and boils at 100°C. Degrees celcius can be converted to Kelvin temperature (K = °C + 273.15).

Critical Thinking Question

20. If Model 2 is a heating curve for water at 1 atm of pressure, label the temperature along the y-axis that represents the melting and boiling points for water.
0°C + 273.15 = 273.15 K 100°C + 273.15 = 373.15 K

Model 3: The Phase Diagram of Water and Carbon dioxide



Critical Thinking Questions

21. Normal conditions are considered 1 atm of pressure and 20-25°C. Under normal conditions, what state of matter would be the stable state for water?
    Liquid

22. Under normal conditions, what state of matter would be the stable state for carbon dioxide?
    Gas

23. Consider the phase diagram for water. How does this diagram in Model 3 relate to the heating curve of water in Model 2?
    Using the phas diagram at a constant pressure, we can identify the range of tmepratures during which the substance is a solid, liquid, and gas. We can also identify the melting and boiling points. If we change the pressure, then the heating (or cooling) curve would need to be adjusted to the new conditions.
24. If the presure is reduced for water, how would the heating curve in Model 2 be different?
    The melting temperature would increase and the boiling points would decrease.

25. Using the information in the phase diagram for carbon dioxide, sktech a cooling curve for carbon dioxide at 1 atm of pressure if the heat is removed from the system causing the temperaure to reduce from 20°C down to -100°C.