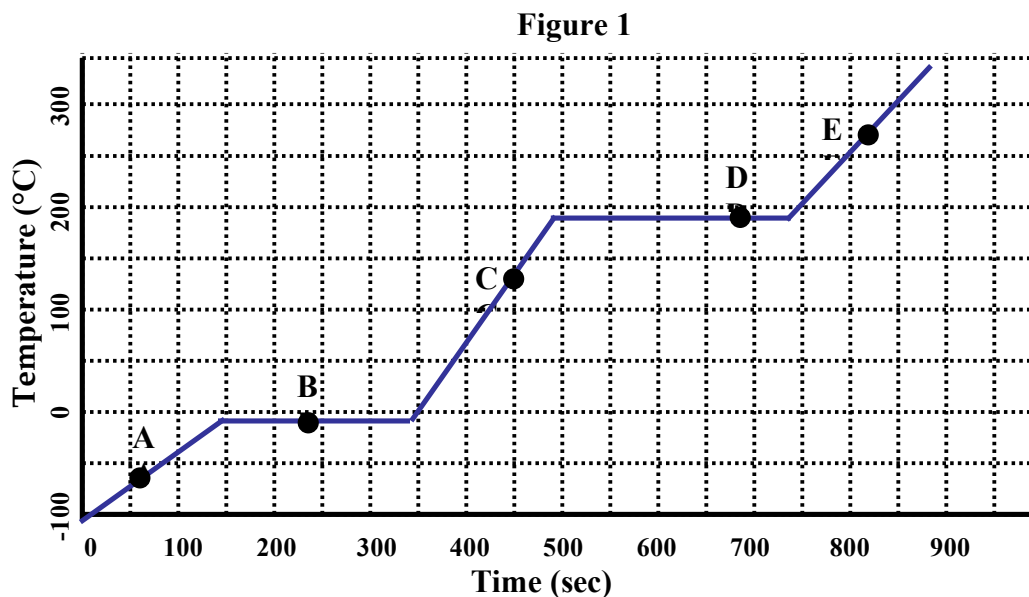


## Heating Curve

Most substances can exist in three different states – a solid, a liquid and a gas state. Changes from one state to another commonly occur by heating or cooling a sample of the substance.

**Melting** refers to the change of a sample from the solid to the liquid state at its melting point temperature. **Boiling** refers to the change of a sample from the liquid to the gaseous state at its boiling point temperature.

Consider a substance that is present in a sealed container in its solid state at a temperature well below its melting point. Over the course of about 15 minutes, the container is heated. At first, the application of heat causes the temperature of the substance to increase until it reaches its melting point temperature. At its melting point temperature, heat is continually added, causing the solid to transition to a liquid at a constant temperature. Once all the solid has melted, the substance is heated to its boiling point temperature. At its boiling point temperature, the addition of heat causes the liquid to transition to a gas at a constant temperature. Once all the liquid has boiled, the sample continues to be heated (cautiously), causing the temperature of the gas to increase. This process is depicted in **Figure 1**.

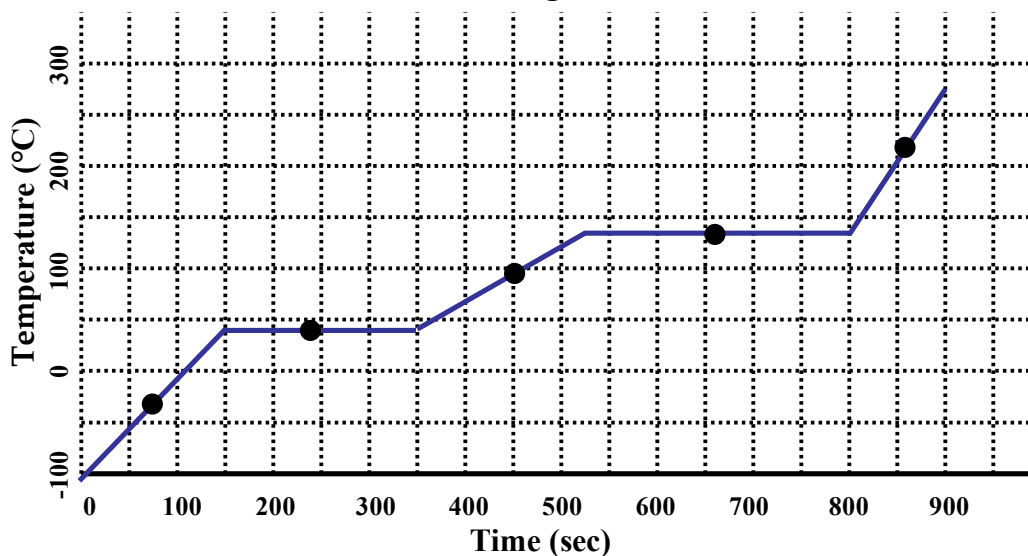


### Questions:

- According to **Figure 1**, at what temperature does the substance transition between the solid state and the liquid state?
  - Approximately  $-65^{\circ}\text{C}$
  - Approximately  $-7^{\circ}\text{C}$
  - Approximately  $135^{\circ}\text{C}$
  - Approximately  $190^{\circ}\text{C}$
- Which one of the following statements are true of the sample of matter described by **Figure 1**?
  - As heat is added to the sample, its temperature always increases.
  - The sample is melting between a temperature of about  $-100^{\circ}\text{C}$  and  $-10^{\circ}\text{C}$ .
  - The liquid state would be observed in the sample at both 200 seconds and 400 seconds.
  - The solid state would be observed in the sample at both 600 seconds and 800 seconds.

3. There are five labeled points on the line of the graph in **Figure 1**. What changes, in order, are observed in the sample of matter between **point A** and **point C**?
  - a. First the sample melts; then its temperature stabilizes; then it boils.
  - b. First the sample increases its temperature; then it melts; then its temperature increases.
  - c. First the sample increases its temperature; then it melts; then its temperature stabilizes.
  - d. First the sample increases its temperature; then it melts; then it stabilizes its temperature.
  
4. There are five labeled points on the line of the graph in **Figure 1**. At which of the labeled points is the sample a mixture of liquid and gas?
  - a. The sample is a mixture of liquid and gas at **point C**.
  - b. The sample is a mixture of liquid and gas at **point D**.
  - c. The sample is a mixture of liquid and gas at **point E**.
  - d. There could never be a mixture of both liquid and gas under these conditions.
  
5. Suppose that **Figure 1** represents the so-called *heating curve* for **Substance A**. **Figure 2** below represents the *heating curve* for **Substance B**.

**Figure 2**



What conclusion can be drawn regarding the melting points and boiling points of **Substance A** and **Substance B**?

- a. **Substance A** has a higher melting point and a higher boiling point than **Substance B**.
- b. **Substance B** has a higher melting point and a higher boiling point than **Substance A**.
- c. **Substance A** has the higher melting point but **Substance B** has the higher boiling point.
- d. **Substance B** has the higher melting point but **Substance A** has the higher boiling point.

## Answers and Explanations

1. **Answer:** D

**Explanation:** The second paragraph of the passage states that the sample begins in the solid state at a temperature well below its melting point. It also states that the transition from solid to liquid occurs at a constant temperature; this melting transition represents the horizontal line on the graph at approximately  $-7^{\circ}\text{C}$ . The second paragraph also states that the transition from liquid to gas occurs at a constant temperature. The second horizontal line at approximately  $190^{\circ}\text{C}$  must represent the liquid to gas boiling transition.

2. **Answer:** C

**Explanation:** Using the process of elimination is a useful approach to this question. The *plateaus* or horizontal lines on the graph represent the transition between states of the sample. The first *plateau* represents the melting (or transition from solid to liquid) and the second *plateau* represents boiling (or transition from liquid to gas). Choice A must be eliminated because there is no temperature change during these transitions. Choice B must be eliminated because melting occurs once the temperature of about  $-7^{\circ}\text{C}$  is reached. From  $-100^{\circ}\text{C}$  to  $-10^{\circ}\text{C}$  the sample is entirely solid and simply increasing its temperature towards the melting point. And choice D must be eliminated because the second plateau - corresponding to the boiling of a liquid - extends from about 490 seconds to about 790 seconds; there is no solid state present during this time. And so choice C is the answer. The liquid state is observed during the melting transition (at 200 seconds) and during the temperature increase between transition temperatures (such as at 400 seconds).

3. **Answer:** B

**Explanation:** The *plateaus* or horizontal lines on the graph represent the transition between states of the sample. The first *plateau* represents the melting (or transition from solid to liquid) and the second *plateau* represents boiling (or transition from liquid to gas). The diagonal lines represent changes in temperature that required of the sample in order to reach the transition temperature or after reaching a transition temperature. **Point A** is on a diagonal line, **Point B** is on a horizontal line, and **Point C** is on a diagonal line. So beginning at **Point A**, the sample must first increase its temperature to approximately  $-7^{\circ}\text{C}$ . At this temperature, the solid will begin to melt. Once melting is complete, the temperature begins to increase. **Point C** is a point that is reached during the temperature increase but before the boiling transition. And so choice B is the best answer.

4. **Answer:** B

**Explanation:** The *plateaus* or horizontal lines on the graph represent the transition between states of the sample. The first *plateau* represents the melting (or transition from solid to liquid) and the second *plateau* represents boiling (or transition from liquid to gas). During these *plateaus*, there is a mixture of two states as the transition of the entire sample takes time. The sample exists entirely in one state before and after the transition. **Point D** lies on the second *plateau*. At this point, the sample is *midway*

*through* the boiling process and exists as both liquid that has not yet boiled and gas that has already boiled. This makes choice B the best answer.

5. **Answer:** D

**Explanation:** The *plateaus* or horizontal lines on the graph represent the transition between states of the sample. The first *plateau* represents the melting (or transition from solid to liquid) and the second *plateau* represents boiling (or transition from liquid to gas). The temperature associated with these transitions can be read off the vertical axis. For **Sample A (Figure 1)**, the melting point temperature is approximately  $-7^{\circ}\text{C}$ . This can be compared to **Sample B (Figure 2)** where the melting point temperature is approximately  $40^{\circ}\text{C}$ . **Sample B** has the higher melting point temperature. The same comparison can be made of boiling point temperatures for the two samples. For **Sample A (Figure 1)**, the boiling point temperature is approximately  $190^{\circ}\text{C}$ . This can be compared to **Sample B (Figure 2)** where the boiling point temperature is approximately  $140^{\circ}\text{C}$ . **Sample A** has the higher boiling point temperature. And so choice D is the best answer.