

Phase Changes and Energy

All phase changes involve energy.

Endothermic phase changes. "Absorb energy"

Melting: solid changing to liquid. In order for a solid to melt energy must be absorbed.

Ex: $\text{H}_2\text{O}(s) \rightarrow \text{H}_2\text{O}(l)$

Boiling/Vaporization: liquid changing to gas at a substance's boiling point. In order for a liquid to boil/vaporize energy must be absorbed.

Ex: $\text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}(g)$

Don't just memorize these! melting and boiling are on a heating curve. Everything on a heating curve is endothermic.

What's the difference between evaporation and vaporization?

Vaporization also known as boiling occurs at a substance's boiling point.

Evaporation occurs over a wide range of temperatures.

Sublimation: Is the process of a solid changing directly to gas without becoming a liquid. Iodine (I_2) and carbon dioxide (CO_2) are substances that may undergo sublimation.

Substances that undergo sublimation have weak intermolecular forces. Sublimation absorbs energy.

Ex: $\text{CO}_2(s) \rightarrow \text{CO}_2(g)$

Exothermic phase changes. "Release energy"

Condensation: gas changing to liquid. In order for a gas to condense back to a liquid heat must be released.

Ex: $\text{H}_2\text{O}(g) \rightarrow \text{H}_2\text{O}(l)$

Freezing/solidification/crystallization: Liquid changing to solid. In order for a substance to freeze energy must be released.

Ex: $\text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}(s)$

Don't just memorize these! Condensation and freezing are on a cooling curve. Everything on a cooling curve is exothermic.

Deposition: Is the process of a gas changing directly to solid without becoming a liquid. Iodine (I_2) and carbon dioxide (CO_2) are substances that may undergo deposition.

Substances that undergo deposition have weak intermolecular forces. Deposition releases energy.

Ex: $\text{CO}_2(g) \rightarrow \text{CO}_2(s)$

Note Packet #4

Heat of Fusion "H_f" is the amount of heat absorbed or released when 1 gram of water freezes or melts at 0°C. The exact amount of energy is 334 joules per gram of water. Melting 1 gram of solid water at 0°C requires 334 joules of energy to be absorbed. Freezing 1 gram of solid water at 0°C requires 334 joules of energy to be released.
H_f = 334 J/g

To calculate the amount of heat energy absorbed or released when water melts or freezes the following formula is used:

$$q = m H_f$$

q = heat (joules)

m = mass of water

H_f = heat of fusion (334 J/g)

Ex: How much heat is required to melt 20 g of solid water at 0° C ?

To solve: **q = m H_f**

$$q = 20 \times 334$$

$$q = 6680 \text{ J absorbed}$$

Problem # 1: How much heat is involved in the freezing of 150 g of liquid water at 0 ° C ? Is the heat absorbed or released?

Show your work!

Problem # 2: How much heat is involved in the freezing of 300 g of liquid water at 0 ° C ? Is the heat absorbed or released?

Show your work!

Note Packet #4

Heat of Vaporization "H_v" Is the amount of heat absorbed or released when 1 gram of water vaporizes/boils or condenses at 100 ° C. The exact amount of energy is 2259 joules per gram of water. Boiling 1 gram of liquid water at 100°C requires 2259 joules of energy to be absorbed.

Condensing 1 gram of liquid water at 100°C requires 2259 joules of energy to be released.

$$H_v = 2259 \text{ J/g}$$

To calculate the amount of heat energy absorbed or released when water boils or condenses the following formula is used:

$$q = m H_v$$

q = heat (joules)

m = mass of water

H_v = heat of vaporization (2259 J/g)

Ex: How much heat is required to vaporize 20 g of liquid water at 100 ° C ?

To solve: $q = m H_v$

$$q = 20 \times 2259$$

$$q = 45,180 \text{ J absorbed}$$

Problem # 3: How much heat is involved in the condensing of 150 g of water vapor at 100 ° C ?

Is the heat absorbed or released?

Problem # 4: How much heat is involved in the condensing of 450 g of water vapor at 100 ° C ?

Is the heat absorbed or released?

Note Packet #4

Specific Heat Capacity of Water is represented as "C". The specific heat capacity of water is defined as the amount of heat required to raise or lower the temperature of 1 gram of liquid water 1 ° C. Its value is 4.2 joules for every gram of liquid water to change 1 ° C.

There is a formula that determines the amount of heat involved in raising or lowering the temperature of liquid water.

q = mCΔ T

q = heat

m = mass of liquid water

C = specific heat capacity of water 4.2

Δ T = change in temperature of liquid water

Ex: How much heat is required to change the temperature of 40 g of liquid water at 60 ° C to 80 ° C? Is it absorbed or released?

To solve:

a) Determine the temperature change (Δ T).

80 ° C - 60 ° C = 20 ° C

b) Insert the given information into the equation and solve for the unknown.

q = 40g X 4.2 X 20 ° C

q = 3360 J absorbed (raising the temperature requires absorbing heat)

Ex: If 8400 J of heat energy is added to 50 g of liquid water at 40 ° C, what will be the new temperature of the water?

To solve:

a) Insert the given information into the equation and solve for the unknown (Δ T).

8400 J = 50 g X 4.2 X (Δ T)

8400 J = 210 X (Δ T)

$$\frac{8400 \text{ J}}{210} = (\Delta T)$$

Δ T = 40 ° C

b) Add the Δ T to the starting temperature of the water (add because heat was added)

40 ° C + 40 ° C = 80 ° C

Note Packet #4

Try these problems.

1. How much heat is involved in lowering the temperature of 30 g of liquid water 15°C ? Is it absorbed or released?

2. If 7350 J of energy are removed from 70 g of liquid water at 40°C , what will be the new temperature of the water?

3. How much heat is required to raise the temperature of 500g of liquid water 35°C ?

Note Packet #4

Describe the following phase changes and state whether they are endothermic or exothermic.

1. Freezing
2. Boiling
3. Sublimation
4. Melting
5. Condensation
6. Deposition

Confused about which heat formula to use?

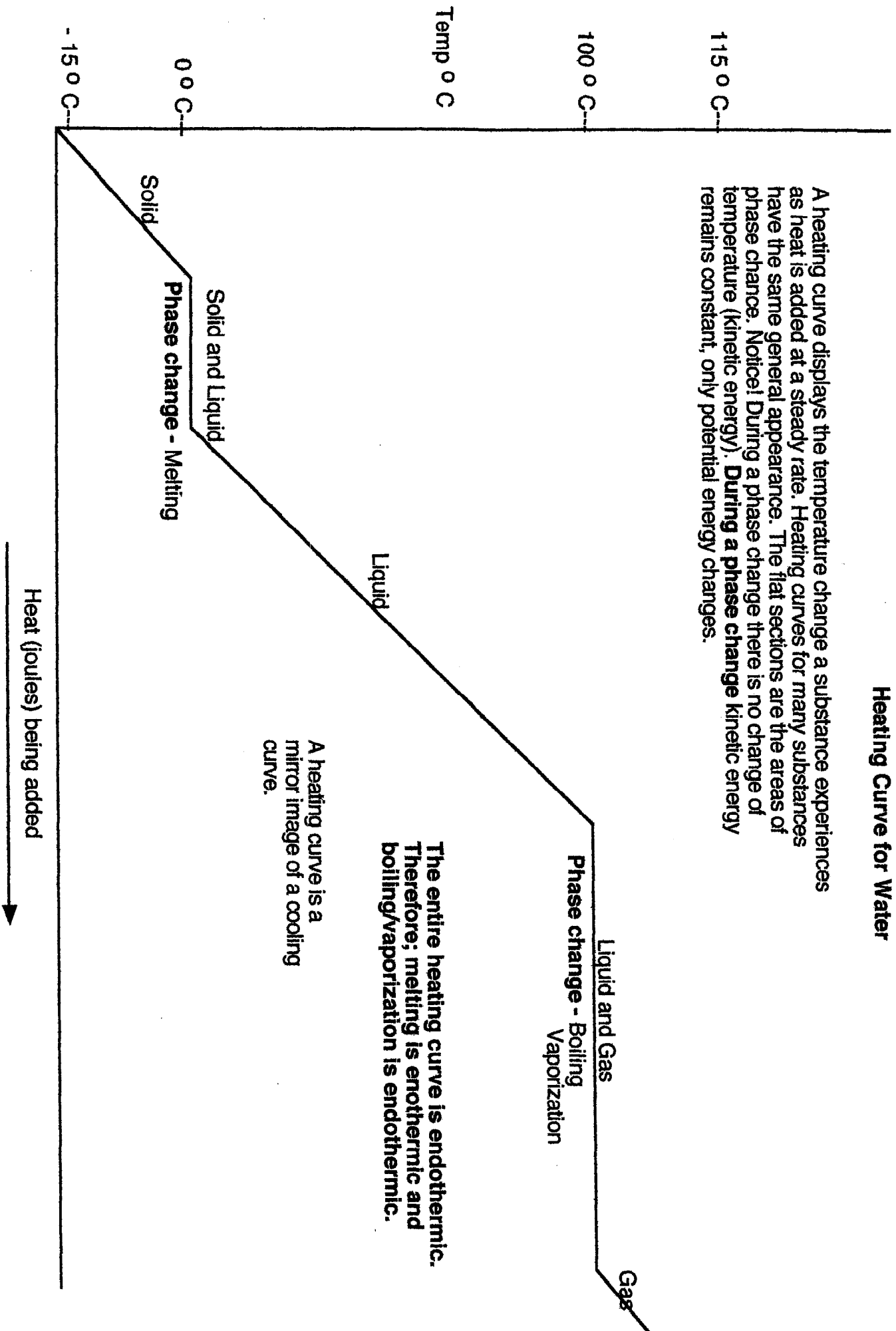
$q = m H_f$ Notice the "f". Think of "f" for freezing/melting which occurs at 0°C .

$q = m H_v$ Notice the "v". Think of "v" for vaporization/condensation which occurs at 100°C

$q = mC\Delta T$ Notice the " ΔT ". " ΔT " means change of temperature. Use this formula only if liquid water is changing temperature.

Heating Curve for Water

A heating curve displays the temperature change a substance experiences as heat is added at a steady rate. Heating curves for many substances have the same general appearance. The flat sections are the areas of phase change. Notice! During a phase change there is no change of temperature (kinetic energy). **During a phase change kinetic energy remains constant, only potential energy changes.**



The entire heating curve is endothermic. Therefore; melting is endothermic and boiling/vaporization is endothermic.

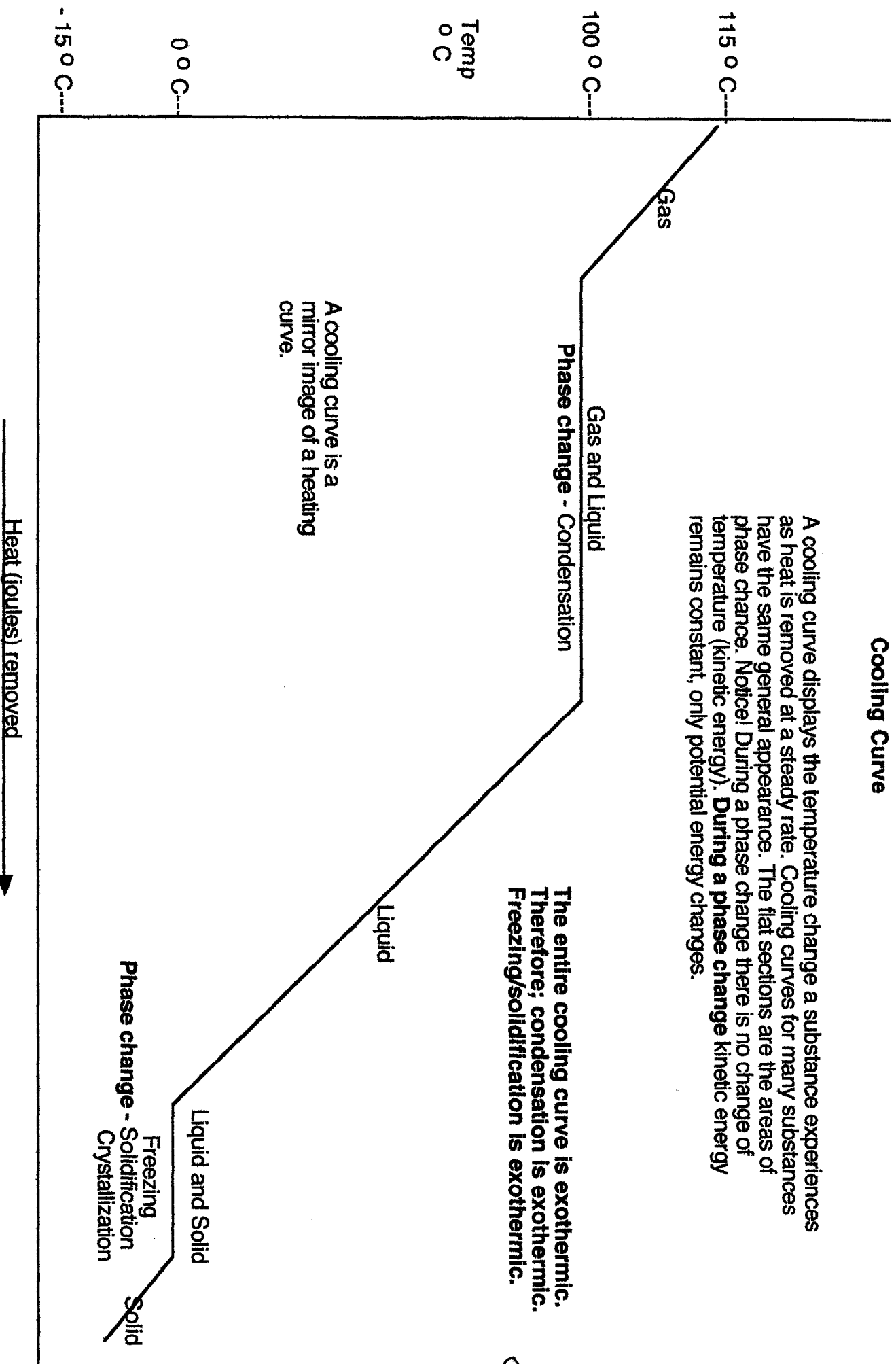
A heating curve is a mirror image of a cooling curve.

Cooling Curve

A cooling curve displays the temperature change a substance experiences as heat is removed at a steady rate. Cooling curves for many substances have the same general appearance. The flat sections are the areas of phase change. Notice! During a phase change there is no change of temperature (kinetic energy). **During a phase change kinetic energy remains constant, only potential energy changes.**

The entire cooling curve is exothermic. Therefore; condensation is exothermic. Freezing/solidification is exothermic.

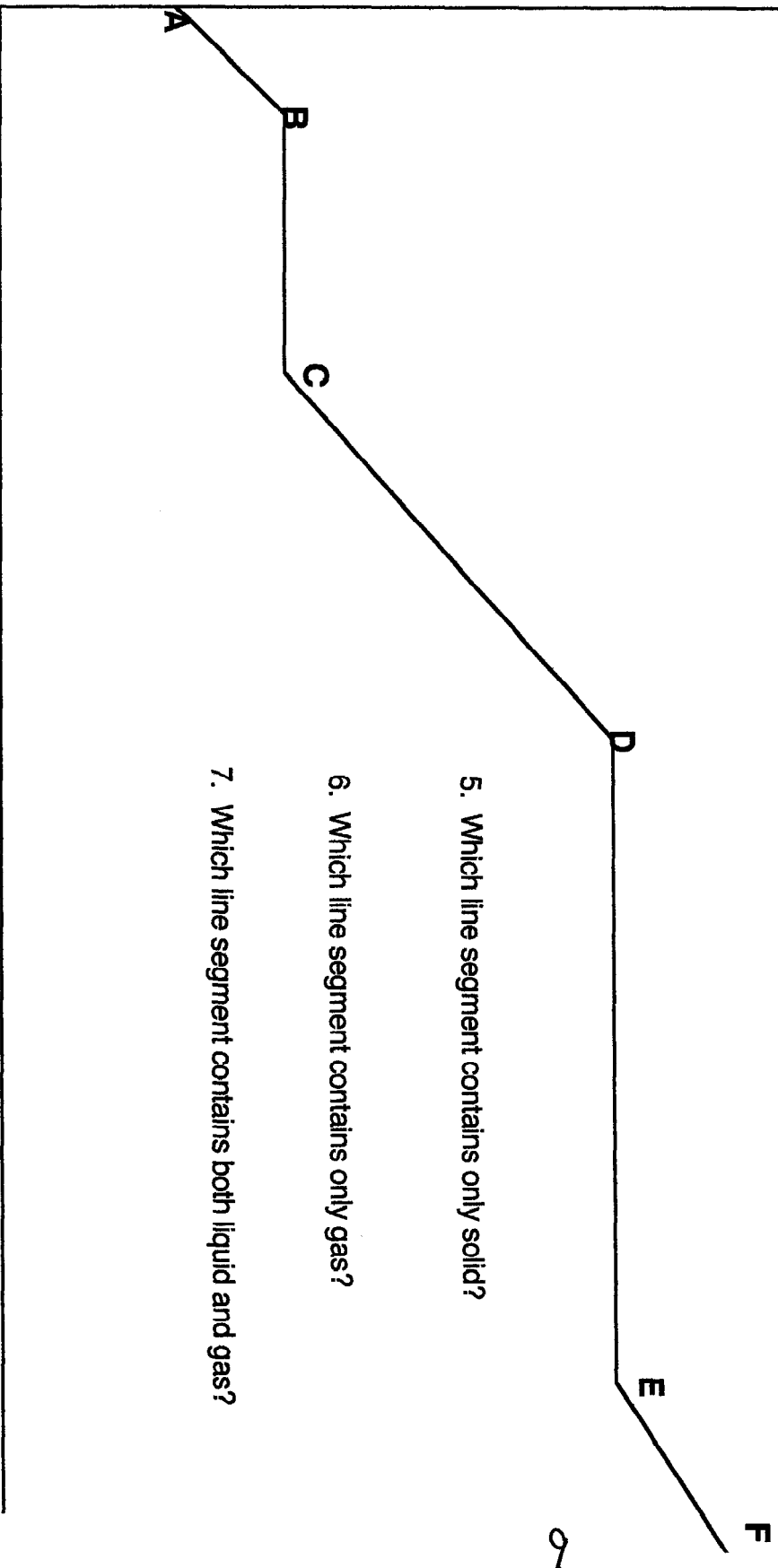
A cooling curve is a mirror image of a heating curve.



Heating Curve for Water

1. Which line segment contains both liquid and solid?
2. At which line segment does boiling occur?
3. Which line segment contains only liquid?
4. At which line segment does melting occur?

Temp.



5. Which line segment contains only solid?
6. Which line segment contains only gas?
7. Which line segment contains both liquid and gas?

Heat ----->