Latent Heat and Heating Curves

IB PHYSICS | THERMAL PHYSICS

Review of Specific Heat

Quantity	Symbol	Unit
Heat Energy	Q	[J]
Mass	m	[kg]
Specific Heat	c	[J kg^{-1} K^{-1}]
Change in Temp	ΔT	K or °C

$$Q = mc\Delta T$$

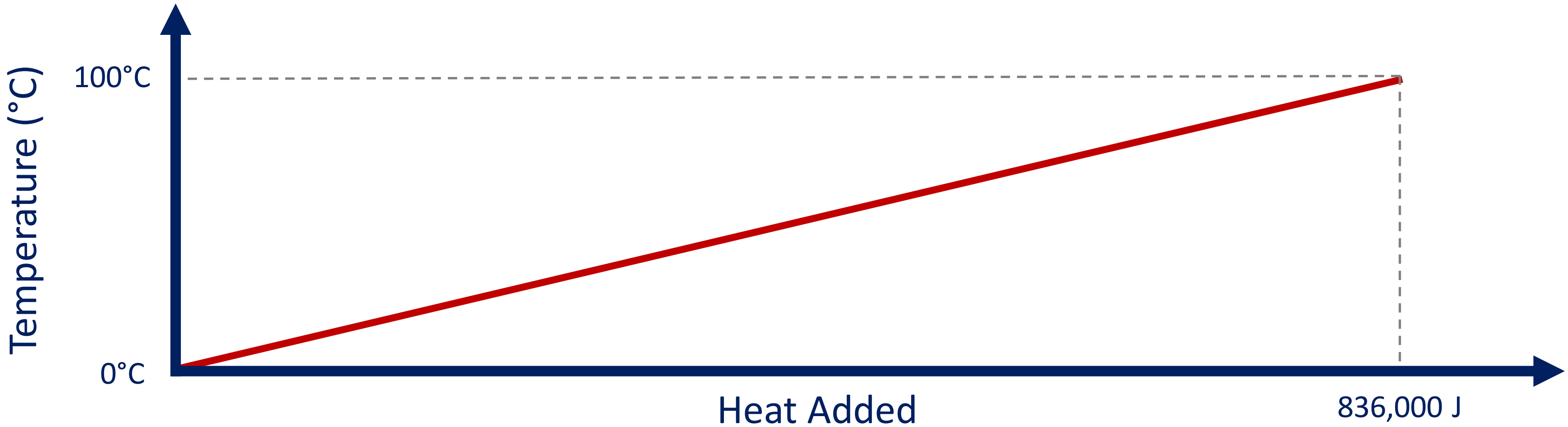
Calculating Heat Transfer

How much heat energy is required to heat up 2 kg of liquid water from its freezing point to its boiling point?

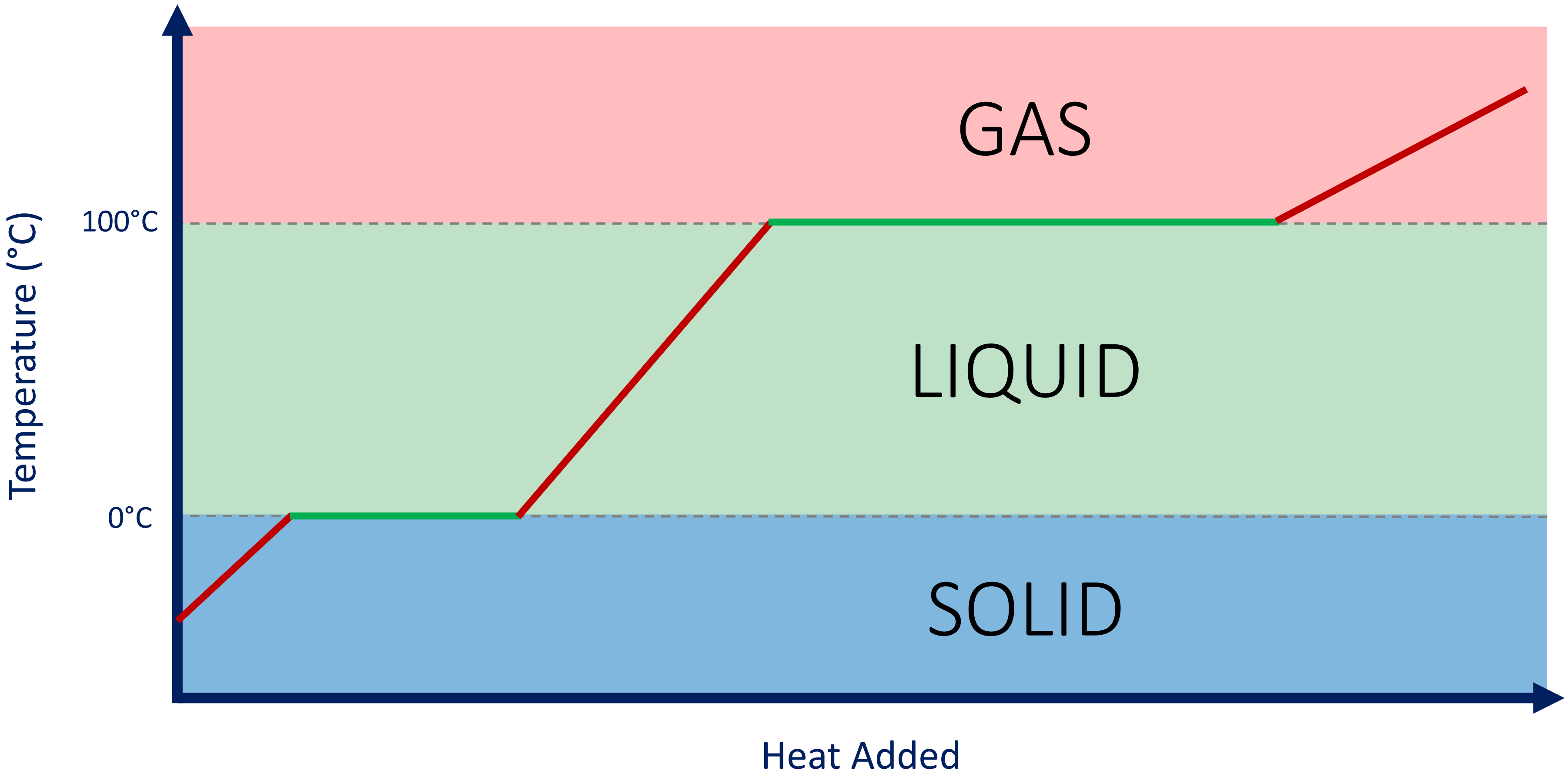
$$Q = mc\Delta T = (2)(4180)(100 - 0)$$

$$Q = 836{,}000 \text{ J}$$

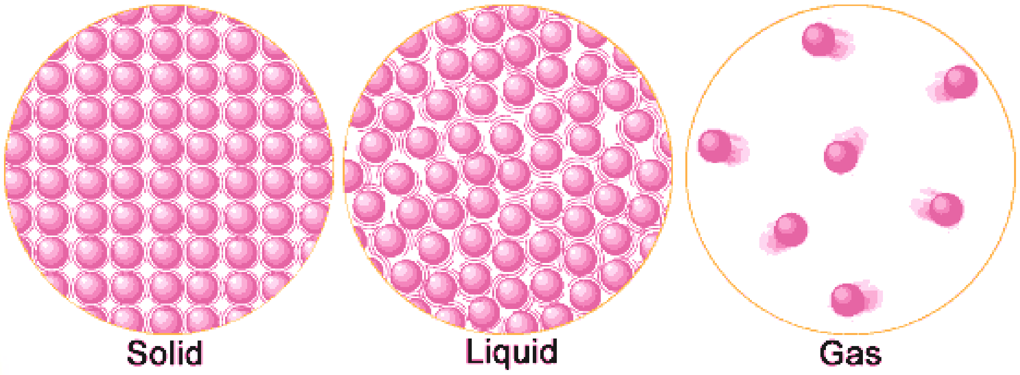
Specific Heat of Water
4180 J kg^{-1} K^{-1}

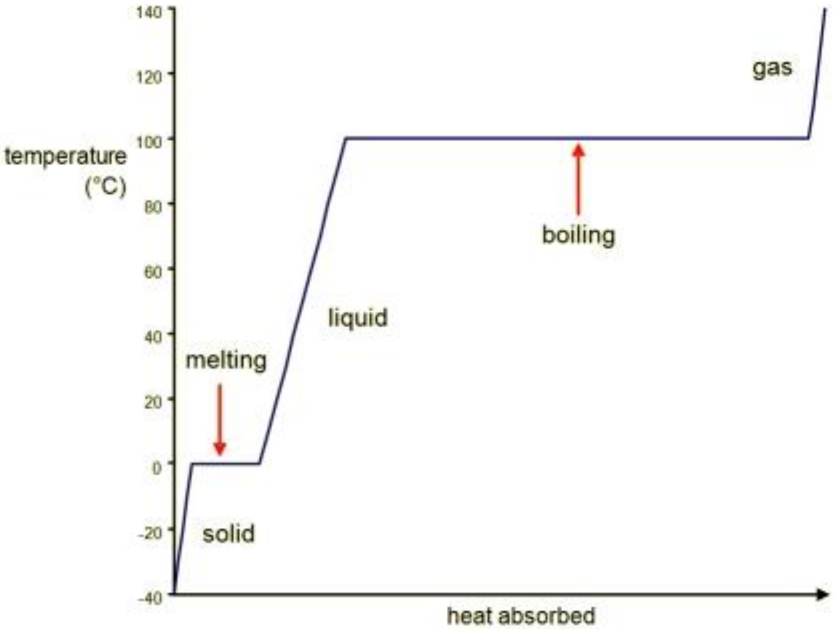


Heating Curve



Why a Plateau?





Bonds are breaking as solid changes to liquid and then again when liquid changes to gas. This takes time!

Adding Heat | Internal Energy

All heat added becomes internal energy

$$E_{INT} = E_K + E_P$$

Changing the temperature of the solid, liquid, or gas?

Changing E_K (Kinetic Energy)

Causing the substance to change phases?

Changing E_P (Potential Energy)

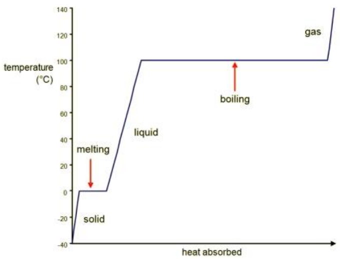
Specific Latent Heat

Specific Latent Heat is the amount energy transferred when 1 kg of the substance changes phase at a constant temp.

Melting or Freezing	Latent Heat of Fusion	L_f
Boiling or Condensing	Latent Heat of Vaporization	L_v

Specific Latent Heat for Water (H_2O):

Latent Heat of Fusion	334,000 J kg^{-1}
Latent Heat of Vaporization	2,260,000 J kg^{-1}



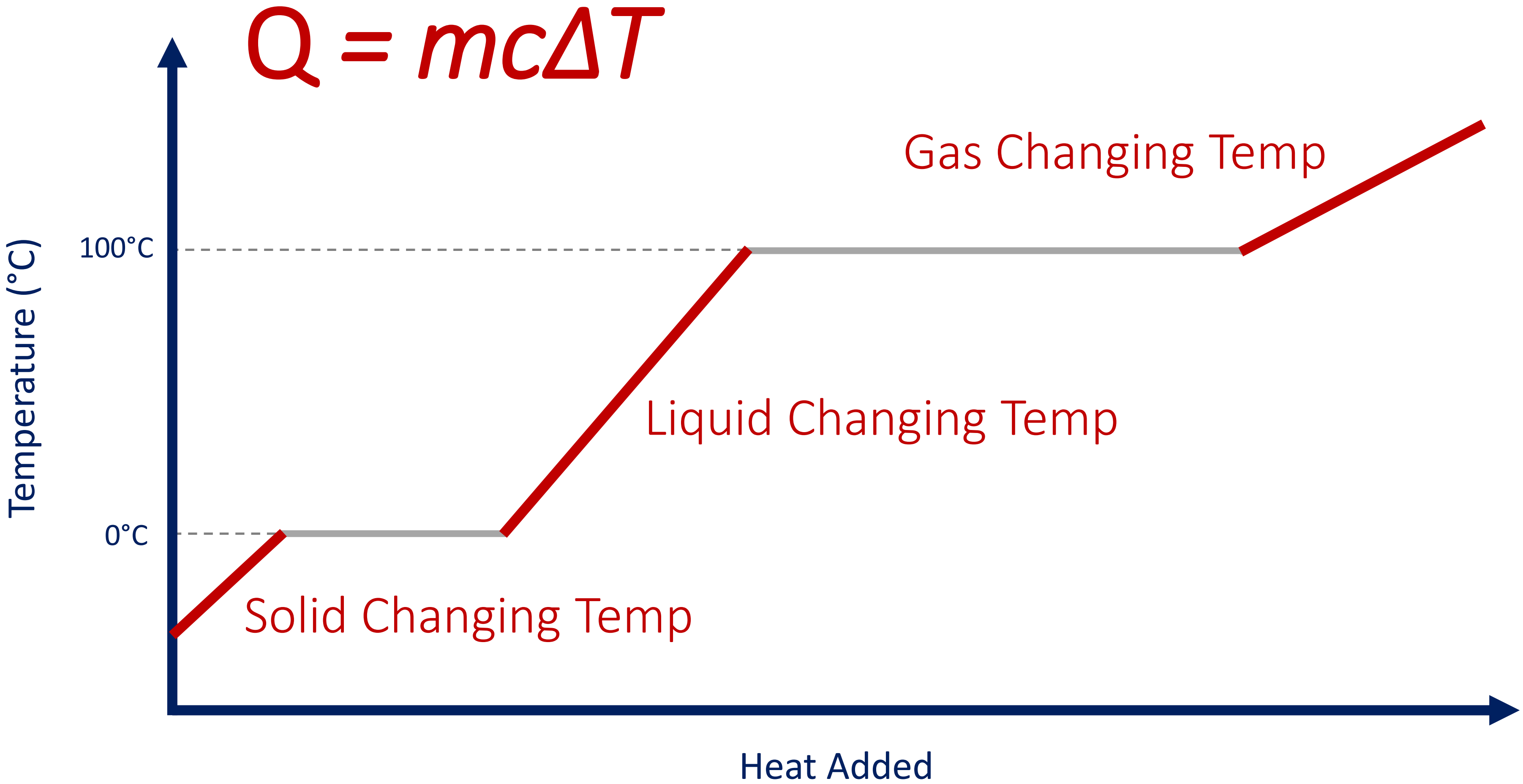
Specific Latent Heat Equation

Quantity	Symbol	Unit
Heat Energy	Q	$[\mathrm{J}]$
Mass	m	$[\mathrm{kg}]$
Specific Latent Heat	L	$[\mathrm{J\ kg^{-1}}]$

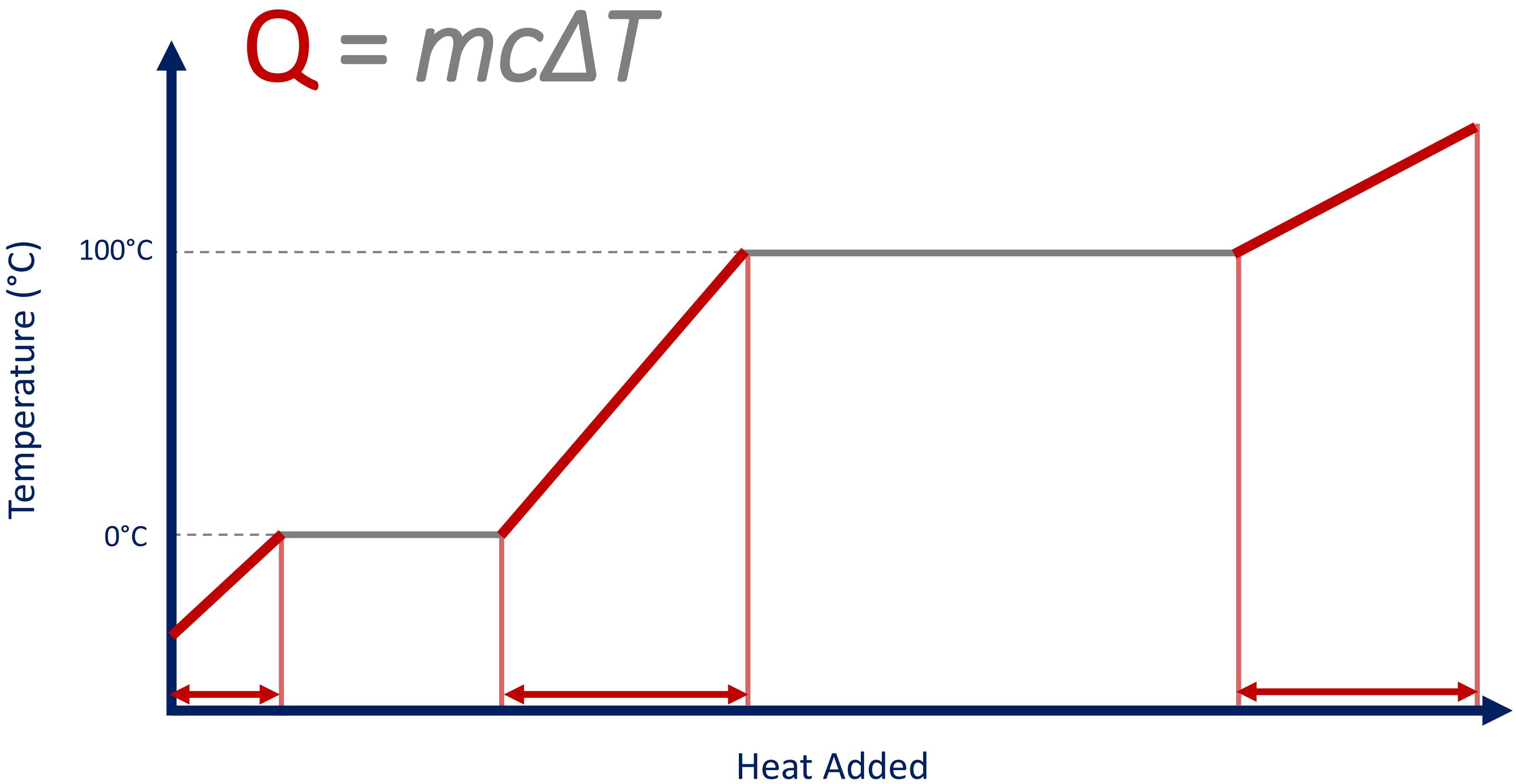
$$\mathrm{Q} = mL$$

This equation works for heat energy gained as well as heat energy lost

Heating Curve

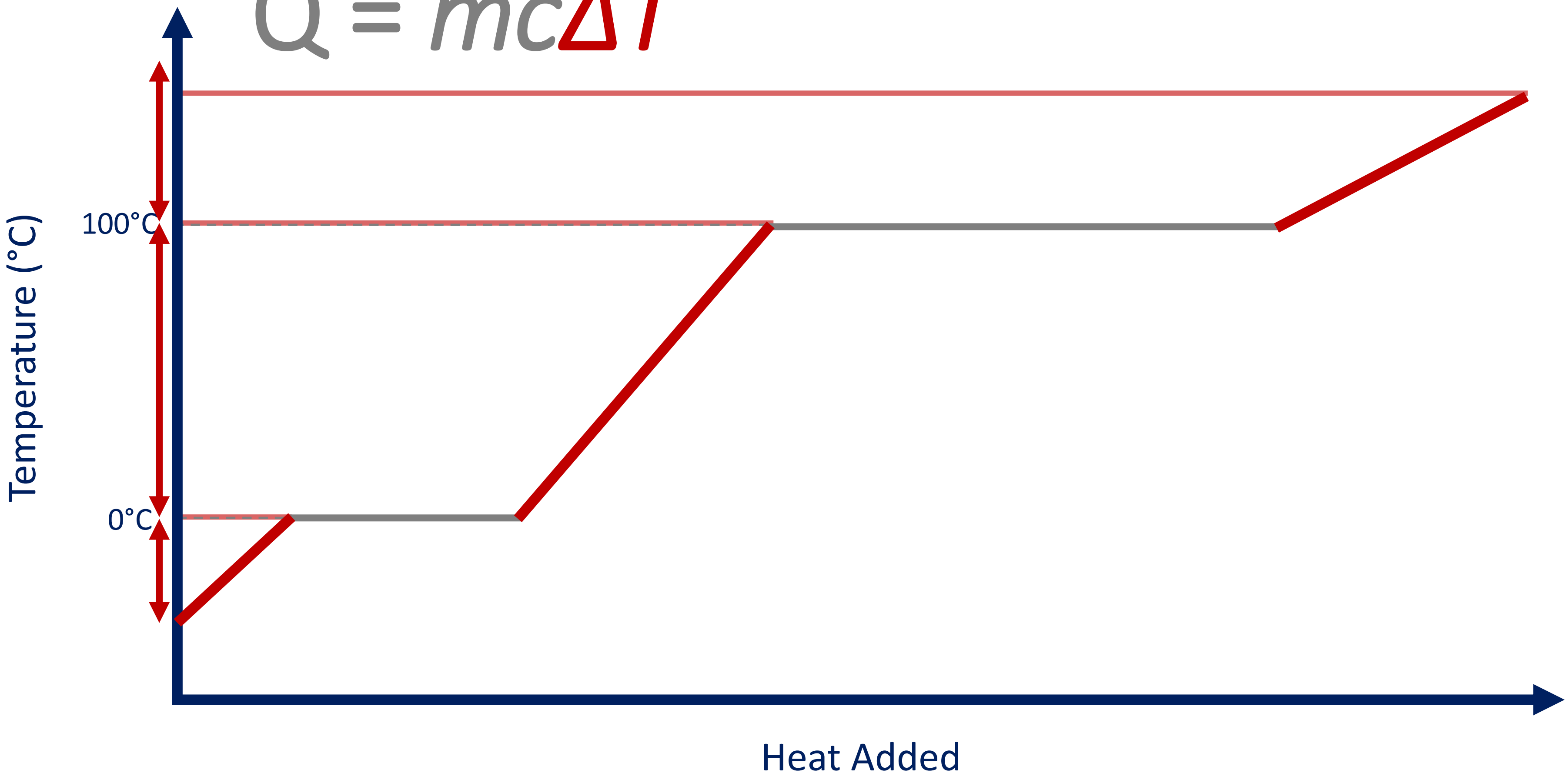


Heating Curve

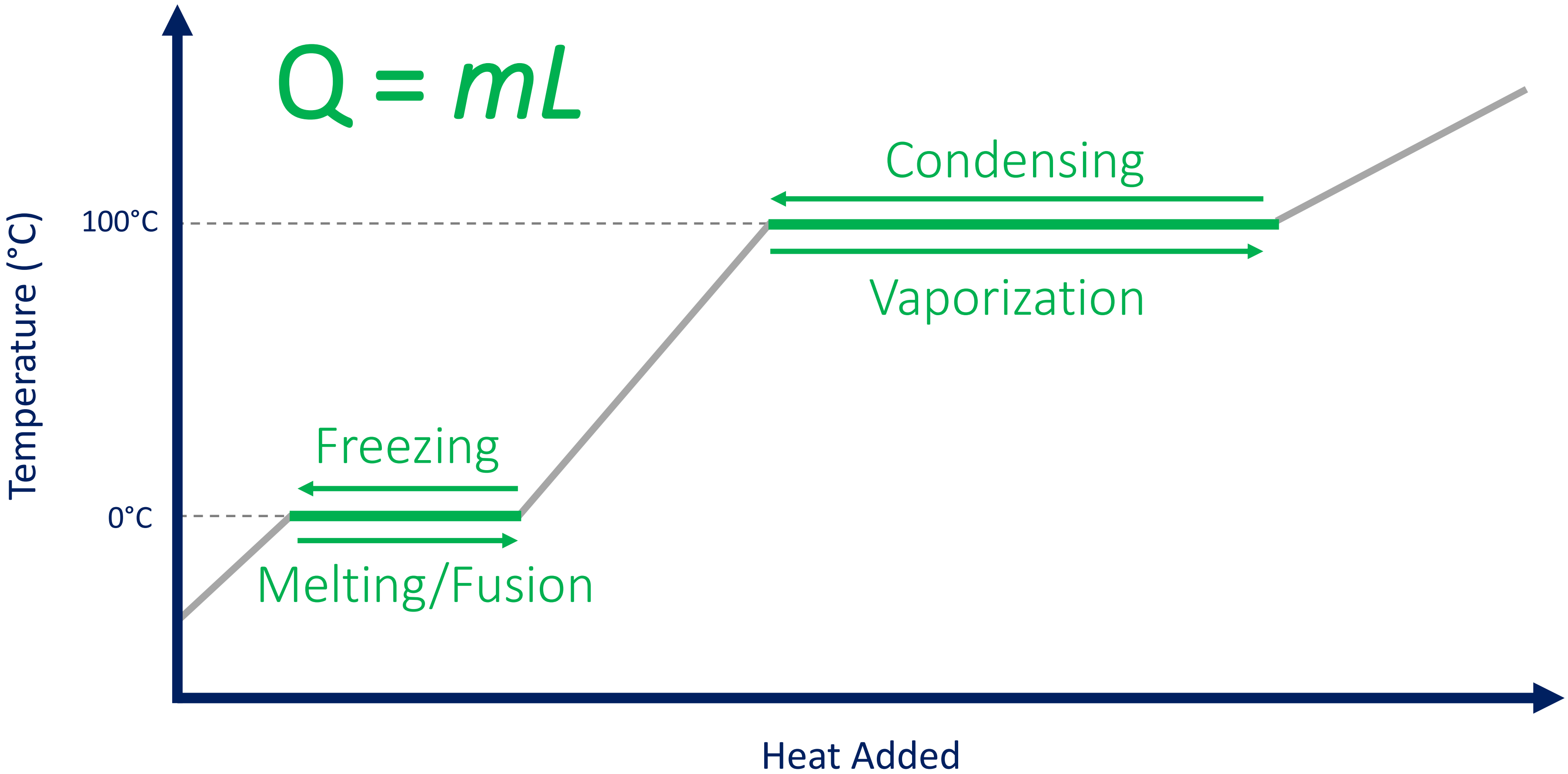


Heating Curve

$$Q = mc\Delta T$$



Heating Curve



Try This…

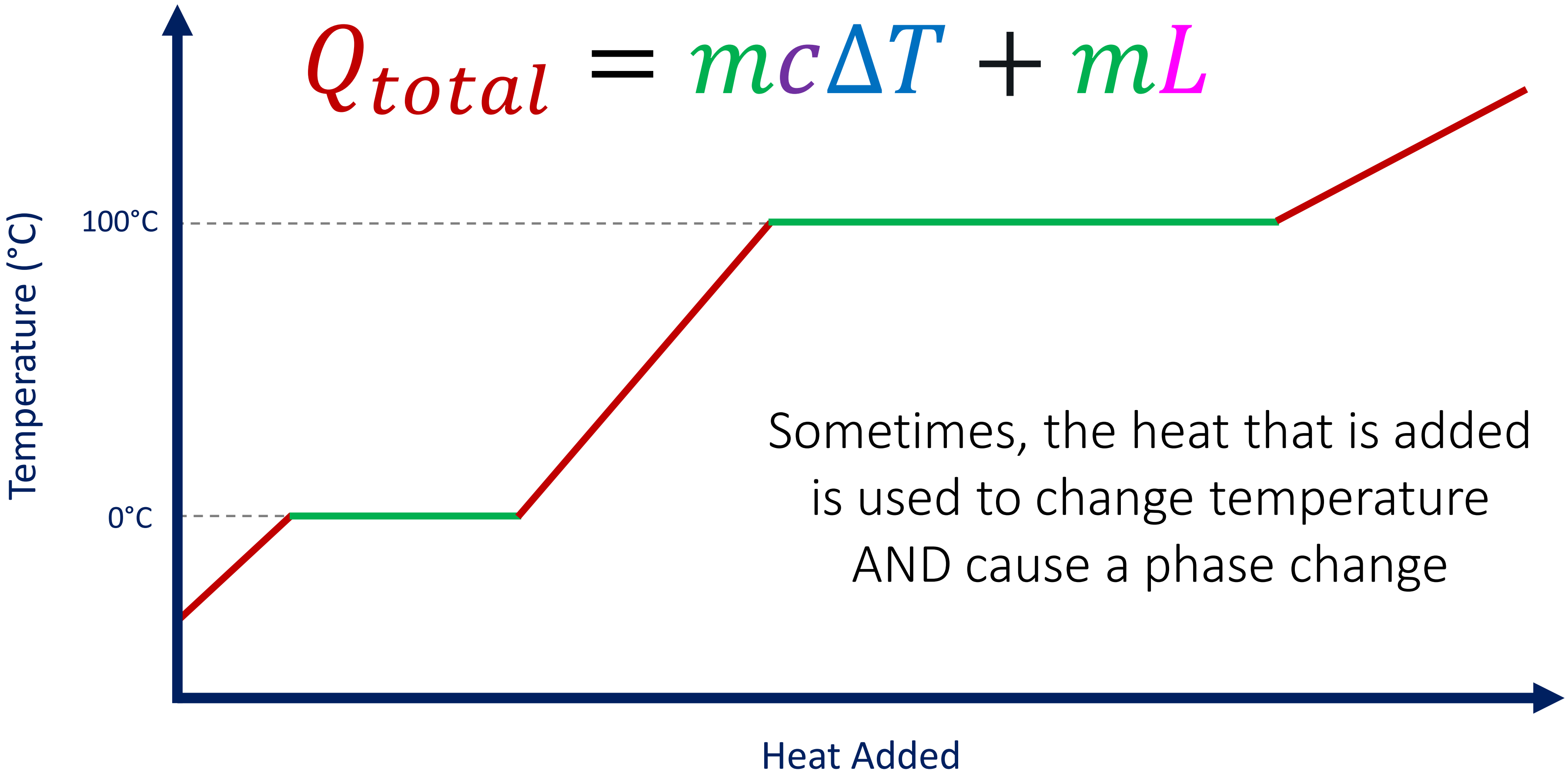
If the latent heat of fusion of a certain kind of chocolate is 160,000 J kg^{-1}, how much thermal energy is removed from you when a 10 g bar of chocolate melts in your mouth?

$$Q = mL = (0.01\ \text{kg})(160{,}000\ \text{J kg}^{-1})$$

$$\boxed{Q = 1{,}600\ \text{J}}$$

Specific Heat Combined

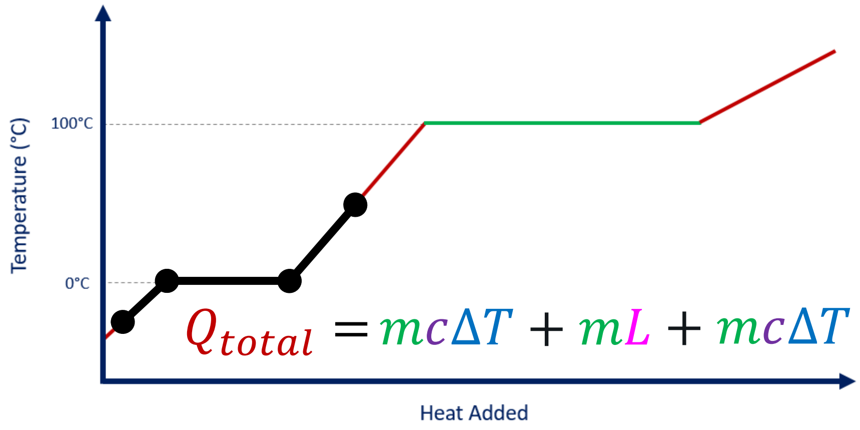
$$Q_{total} = mc\Delta T + mL$$



Sometimes, the heat that is added is used to change temperature AND cause a phase change

Try This...

How much heat is needed to transform 0.5 kg of ice at -20 °C into water at 50 °C ?



$$Q_{total} = mc\Delta T + mL + mc\Delta T$$

Specific Heat of Ice	2090 J kg^{-1} K^{-1}
Specific Heat of Water	4180 J kg^{-1} K^{-1}
Latent Heat of Fusion	334,000 J kg^{-1}
Latent Heat of Vaporization	2,260,000 J kg^{-1}

$$\Delta T = 0°C - (-20°C)$$

$$\Delta T = 50°C - 0°C$$

$$Q = (0.5)(2090)(20) + (0.5)(334{,}000) + (0.5)(4180)(50)$$

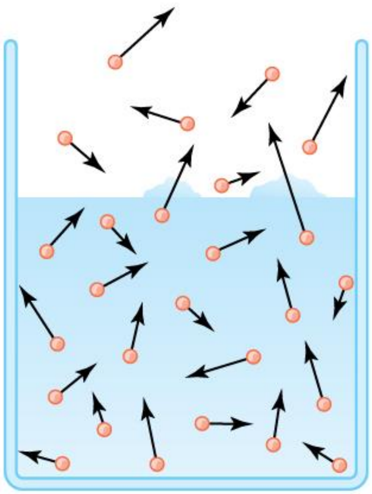
$$20{,}900 \qquad 167{,}000 \qquad 104{,}500$$

$$Q = 292{,}000 \text{ J}$$

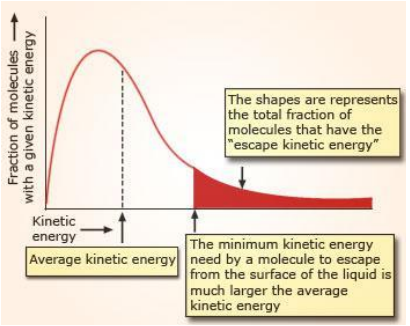
Evaporation vs Boiling

Evaporation:

- Occurs only at the surface of a liquid
- Can occur at any temperature



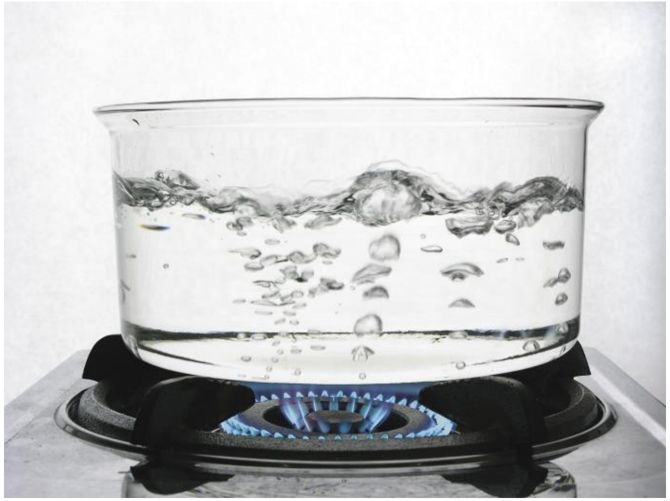
Some molecules have a KE high enough to escape and become a gas



When these faster molecules are lost, the average KE of the liquid decreases, resulting in evaporative cooling

Boiling:

- Bubbles form throughout liquid
- Occurs at a precise temperature



KE is high enough for molecules to form bubbles within the liquid

Example IB Questions

10. A solid piece of tungsten melts into liquid without a change in temperature. Which of the following is correct for the molecules in the liquid phase compared with the molecules in the solid phase?

	Kinetic energy	Potential energy
A.	same	greater
B.	same	same
C.	greater	greater
D.	greater	same

Changing the temperature of the solid, liquid, or gas?

Changing E_K (Kinetic Energy)

Causing the substance to change phases?

Changing E_P (Potential Energy)

11. The specific latent heat of a substance is defined as the energy required at constant temperature to

A. change the phase.

B. change the phase of 1 kg.

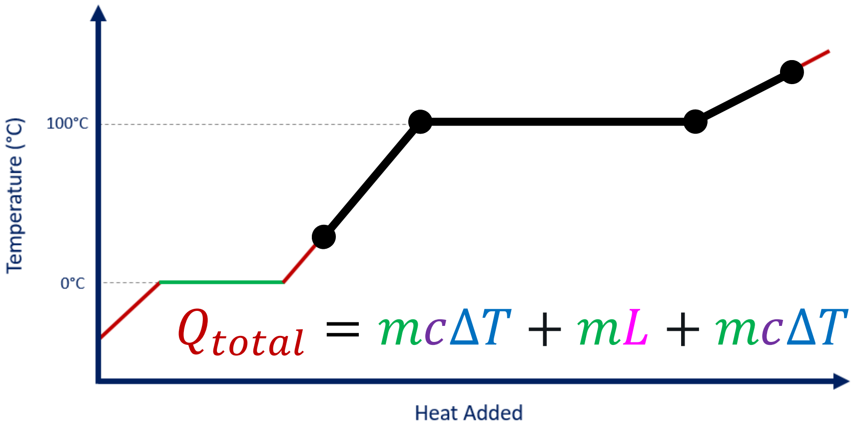
C. change the phase of 1 m^3.

D. change the phase of 1 kg every second.

$L \rightarrow [J\ kg^{-1}]$

Try This...

How much heat is needed to transform 1.4 kg of water at 23°C into water vapor at 120 °C?



$$Q_{total} = mc\Delta T + mL + mc\Delta T$$

Specific Heat of Water Vapor	2000 J kg^{-1} K^{-1}
Specific Heat of Water	4180 J kg^{-1} K^{-1}
Latent Heat of Fusion	334,000 J kg^{-1}
Latent Heat of Vaporization	2,260,000 J kg^{-1}

$$\Delta T = 100°C - 23°C \qquad \Delta T = 120°C - 100°C$$

$$Q = (1.4)(4180)(77) + (1.4)(2{,}260{,}000) + (1.4)(2000)(20)$$

450,604 3,164,000 56,000

$$Q = 3{,}670{,}604\ \text{J}$$

Lesson Takeaways

- ❑ I can describe the features of a heating curve and why it plateaus during phase changes
- ❑ I can define specific latent heat with proper units
- ❑ I can calculate the heat required to cause a certain amount of a substance to change phases
- ❑ I can compare the processes of evaporation and boiling