

TOPIC

11

Thermal Properties of Matter

Objectives

Candidates should be able to:

- (a) describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)
- (b) define the terms heat capacity and specific heat capacity
- (c) recall and apply the relationship $\text{thermal energy} = \text{mass} \times \text{specific heat capacity} \times \text{change in temperature}$ to new situations or to solve related problems
- (d) describe melting/ solidification and boiling/ condensation as processes of energy transfer without a change in temperature
- (e) explain the difference between boiling and evaporation
- (f) define the terms latent heat and specific latent heat
- (g) recall and apply the relationship $\text{thermal energy} = \text{mass} \times \text{specific latent heat}$ to new situations or to solve related problems
- (h) explain latent heat in terms of molecular behaviour
- (i) sketch and interpret a cooling curve

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11.1 Introduction

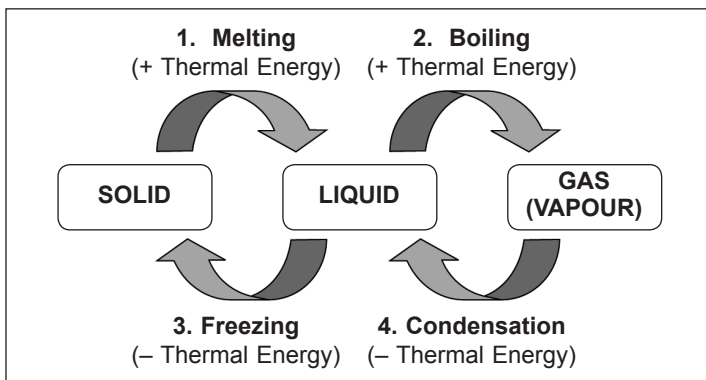
1. Temperature – a measure of the internal energy of the substance's atoms/ molecules.
2. Increase in temperature – caused by the supply of heat which increases internal energy.
3. Internal energy – sum of kinetic energy and potential energy of the atoms/ molecules.

4. Types of internal energy:

State of substance	Type of internal energy
Solid	vibrational kinetic energy + potential energy
Liquid	translational kinetic energy + potential energy
Gas	mainly translational kinetic energy

11.2 Change of States

- Two main changes occur when heat is supplied to a substance
 - Increase in temperature
 - Change of state (i.e. solid to liquid)
- The following chart shows the changes of state (without temperature change) and their corresponding processes involved:



+ Thermal Energy: Heat is absorbed by substance

– Thermal Energy: Heat is removed from substance (Released to surroundings)

1. Melting	(i) Definition: a change of state from solid to liquid without a change in temperature. (ii) Melting point: constant temperature at which a solid melts into a liquid. (iii) Process: Heat absorbed is used to do work to break intermolecular bonds between the atoms/ molecules of the solid. (iv) The reverse process is freezing.
2. Boiling	(i) Definition: a change of state from liquid to gas without a change in temperature. (ii) Boiling point: constant temperature at which a liquid boils. (iii) Process: Heat supplied to the liquid is used to do work in separating the atoms or molecules as well as in pushing back the surrounding atmosphere. (iv) The reverse process is condensation.
3. Freezing	(i) Reverse process of melting. (ii) Definition: a change of state from liquid to solid without a change in temperature. (iii) Freezing point: constant temperature at which a liquid changes to a solid. (iv) Process: Heat is released as the intermolecular bonds are formed when the liquid atoms or molecules come together to form a solid. (v) For a pure substance, the melting point is the same as the freezing point.
4. Condensation	(i) Reverse process of boiling/ evaporation. (ii) Definition: a change of state from gas to liquid without a change in temperature. (iii) Condensation point: constant temperature at which a gas changes to a liquid. (iv) Process: Heat is released as the intermolecular bonds are formed when the gaseous atoms or molecules come together to form a liquid. (v) For a pure substance, the boiling point is the same as the condensation point.

3. Other processes:
 - (a) Evaporation (liquid to gas)
 - (b) Sublimation (solid to gas)
4. Differences between boiling and evaporation:

Boiling	Evaporation
occurs at a fixed temperature	occurs at any temperature
occurs throughout the liquid	occurs on the surface of substance
bubbles are visible	bubbles are not visible
fast process	slow process
heat is supplied to substance by an energy source	heat is absorbed by substance from the surroundings

5. Factors affecting melting and boiling points of water:

Factor	Melting Point	Boiling Point
Increase Pressure	Lower	Higher
Add Impurities	Lower	Higher

11.3 Heat Capacities and Latent Heat

1. The following terms are used in calculations in this chapter:

Term	SI Units	Definition	Formula
Heat capacity, C	$\text{J } ^\circ\text{C}^{-1}$ or J K^{-1}	Thermal energy needed to increase temperature of substance by $1\text{ }^\circ\text{C}$ or 1 K .	$Q = C\Delta\theta$
Specific heat capacity, c	$\text{J kg}^{-1}\text{ }^\circ\text{C}^{-1}$ or $\text{J kg}^{-1}\text{ K}^{-1}$	Thermal energy needed to increase temperature of 1 kg of substance by $1\text{ }^\circ\text{C}$ or 1 K .	$Q = mc\Delta\theta$

Term	SI Units	Definition	Formula
Specific latent heat of fusion, l_f	J kg^{-1}	Thermal energy needed to change 1 kg of substance from solid to liquid without temperature change.	$Q = ml_f$
Specific latent heat of vaporisation, l_v	J kg^{-1}	Thermal energy needed to change 1 kg of substance from liquid to gas without temperature change.	$Q = ml_v$

Q – Amount of thermal energy needed (J), $\Delta\theta$ – Change in temperature

2. Comparison between substances of high and low heat capacities

Heat Capacity	Time to cool down/ heat up	Reason
High	Longer	Need to lose more energy (cooling) or absorb more energy (heating).
Low	Shorter	Need to lose less energy (cooling) or absorb less energy (heating).