

Thermal Properties of Matter (Part II)

Specific Heat Capacity

Melting and Boiling

Thermal Expansion of Solids, Liquids and Gases

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y.ramma@intnet.mu

Thermal Properties of Matter

Latent heat

Latent heat refers to the heat supplied to a substance to cause a change in its state at constant temperature.

For example, the heat supplied to a substance to change its state from solid to liquid or from liquid to gas is latent heat.

Specific Latent Heat of Fusion, l_f

It refers to the quantity of heat required to change unit mass of a solid into liquid state at constant temperature.

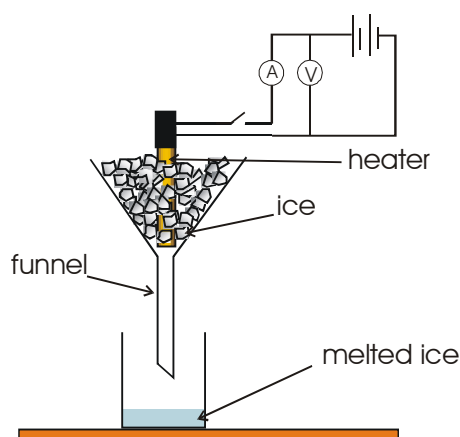
$$l_f = \frac{E}{m}$$

Unit: Jkg^{-1}

Experiment to determine the specific latent heat of fusion of ice, l_f

The following apparatus will be required:

- electric immersion heater (12 V, 60 W)
- funnel
- glass beaker
- ammeter
- voltmeter
- battery
- stop clock
- retort stand with clamp
- ice
- balance



The apparatus is set up as shown in the diagram but without the ice. The heater is connected to the battery. The ammeter is connected in series with the heater whereas the voltmeter is connected in parallel. The beaker is first weighted and then the ice is crushed and placed in the funnel (try to pack it closely round the heater). The stopwatch is started and at the same time the heater is switched on. The voltage (V) and the current (I) are recorded.

The heater is left on for three minutes, adding more ice if needed to keep the ice in contact with the heater.

The circuit is switched off, and then the beaker is removed and weighted.

The mass (m) of melted ice is obtained from the difference of the two readings.

Thermal Properties of Matter

Heat supplied = Power x time = $I \times V \times t$ [I – current; V – voltage; t – time]

Heat absorbed by ice = $m \times l_f$

Assuming negligible heat loss, it follows that heat supplied = heat absorbed.

$$IVt = m l_f$$

$$l_f = \frac{IVt}{m}$$

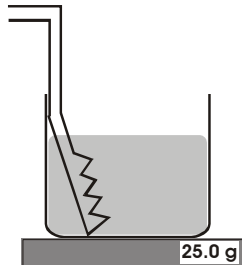
Specific latent heat of vapourisation of steam, l_v

It refers to the quantity of heat required to change unit mass of a liquid into gaseous state at constant temperature.

$$l_v = \frac{E}{m}$$

Unit: Jkg^{-1}

Experiment to determine the specific latent heat of vapourisation of steam, l_v



A beaker containing water is placed on a top pan balance. The heater is connected to an ammeter, a voltmeter and a power supply. The heater is switched on. When boiling starts the mass of water and beaker is noted (m_0). The stopwatch is immediately started. After 10 minutes, the mass new mass (m_1) of water and beaker is again noted. The mass of steam (m) produced is therefore $m_1 - m_0$.

Assuming negligible heat loss, heat supplied by heater is equal to heat absorbed by water to boil away.

Heat supplied by heater = IVt

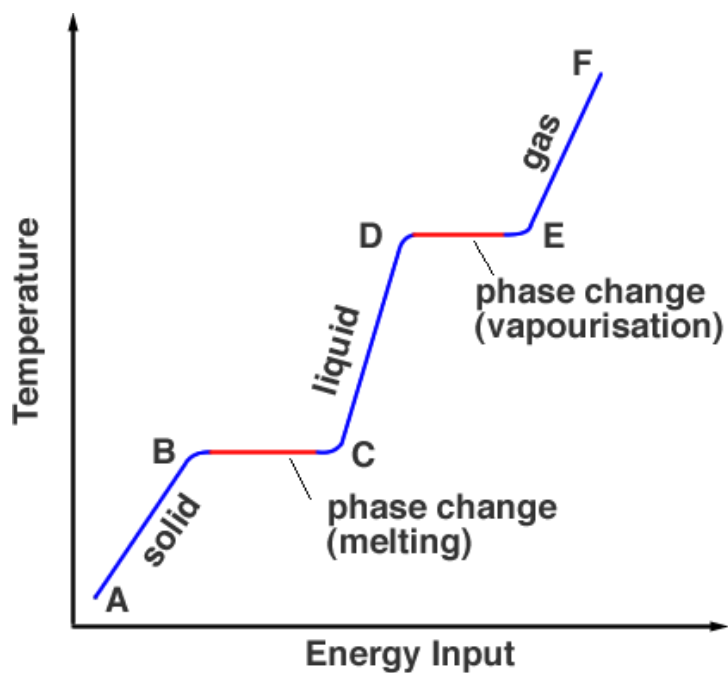
Heat absorbed by water to boil away = $m l_f$

$$IVt = m l_f$$

$$l_f = \frac{IVt}{m}$$

Thermal Properties of Matter

The graph below shows the relationship between temperature and energy supplied to a solid. You will note that when the substance changes state (from solid to liquid or from liquid to gas) the temperature stays constant.



The table below gives you an insight into the boiling point of some substances as well as their respective specific latent heat of fusion and vapourisation.

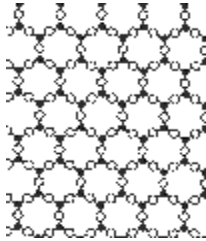
Substance	Specific latent heat of fusion kJ.kg^{-1}	Boiling pt/ $^{\circ}\text{C}$	Specific latent heat of vaporisation kJ.kg^{-1}	Boiling pt / $^{\circ}\text{C}$
Water	334	0	2258	100
Ethanol	109	-114	838	78
Ethanoic acid	192	17	395	118
Chloroform	74	-64	254	62
Mercury	11	-39	294	357
Sulphur	54	115	1406	445
Hydrogen	60	-259	449	-253
Oxygen	14	-219	213	-183
Nitrogen	25	-210	199	-196

Thermal Properties of Matter

Thermal Expansion of Solids, Liquids and Gases

Most materials are subject to thermal expansion: a tendency to expand when heated, and to contract when cooled.

Solids



When heat is supplied to a solid, the atoms, on gaining energy, will vibrate with greater amplitude and occupy a larger distance. Thus the solid expands. When the solid is cooled, the atoms vibrate with lesser amplitude and thus the solid contracts.

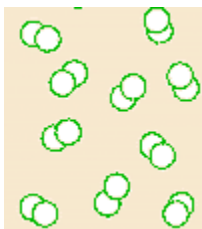
Liquids



Similarly, when heat is supplied to a liquid, the molecules move further apart and occupy more space – expansion. When the liquid is cooled, they have lesser kinetic energy and thus occupy lesser space – contraction.

Task: what is meant by the anomalous expansion of water?

Gases



The molecules of the gas will occupy larger volume when the gas is heated. Expansion therefore occurs.

Thermal Properties of Matter

Expansion can be beneficial as well as a problem in our everyday life activities.

Task: Describe some everyday application and consequences of thermal expansion.