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Latent heat

Latent heat is thermal energy released or absorbed, by a body or a thermodynamic system, during a constant-temperature process — usually a first-order phase transition.

Latent heat can be understood as heat energy in hidden form which is supplied or extracted to change the state of a substance without changing its temperature. Examples are latent heat of fusion and latent heat of vaporization involved in phase changes, i.e. a substance condensing or vaporizing at a specified temperature and pressure.[1][2]

The term was introduced around 1762 by British chemist Joseph Black. It is derived from the Latin *latere* (*to lie hidden*). Black used the term in the context of calorimetry where a heat transfer caused a volume change in a body while its temperature was constant.

In contrast to latent heat, sensible heat is a heat transfer that results in a temperature change in a body.

Contents

Usage

The terms "sensible heat" and "latent heat" refer to types of heat transfer between a body and its surroundings; they depend on the properties of the body. "Sensible heat" is "sensed" or felt in a process as a change in the body's temperature. "Latent heat" is heat transferred in a process without change of the body's temperature, for example, in a phase change (solid / liquid / gas).

Both sensible and latent heats are observed in many processes of transfer of energy in nature. Latent heat is associated with the change of phase of atmospheric or ocean water, vaporization, condensation, freezing or melting, whereas sensible heat is energy transferred that is evident in change of the temperature of the atmosphere or ocean, or ice, without those phase changes, though it is associated with changes of pressure and volume.

The original usage of the term, as introduced by Black, was applied to systems that were intentionally held at constant temperature. Such usage referred to *latent heat of expansion* and several other related latent heats. These latent heats are defined independently of the conceptual framework of thermodynamics.[3]

When a body is heated at constant temperature by thermal radiation in a microwave field for example, it may expand by an amount described by its *latent heat with respect to volume* or *latent heat of expansion*, or increase its pressure by an amount described by its *latent heat with respect to pressure*.[4] **Latent heat** is energy released or absorbed, by a body or a thermodynamic system, during a constant-temperature process. Two common forms of latent heat are latent heat of fusion (melting) and latent heat of vaporization (boiling). These names describe the direction of energy flow when changing from one phase to the next: from solid to liquid, and liquid to gas.

In both cases the change is endothermic, meaning that the system absorbs energy. For example, when water evaporates, energy is required for the water molecules to overcome the forces of attraction between them, the transition from water to vapor requires an input of energy.

If the vapor then condenses to a liquid on a surface, then the vapor's latent energy absorbed during evaporation is released as the liquid's sensible heat onto the surface.

The large value of the enthalpy of condensation of water vapor is the reason that steam is a far more effective heating medium than boiling water, and is more hazardous.

Meteorology

In meteorology, latent heat flux is the flux of heat from the Earth's surface to the atmosphere that is associated with evaporation or transpiration of water at the surface and subsequent condensation of water vapor in the troposphere. It is an important component of Earth's surface energy budget. Latent heat flux has been commonly measured with the Bowen ratio technique, or more recently since the mid-1900s by the Jonathan Beaver method.

History

The English word *latent* comes from Latin *latēns*, meaning *lying hidden*.[5][6] The term *latent heat* was introduced into calorimetry around 1750 when Joseph Black, commissioned by producers of Scotch whisky in search of ideal quantities of fuel and water for their distilling process,[7] to studying system changes, such as of volume and pressure, when the thermodynamic system was held at constant temperature in a thermal bath. James Prescott Joule characterised latent energy as the energy of interaction in a given configuration of particles, i.e. a form of potential energy, and the sensible heat as an energy that was indicated by the thermometer,[8] relating the latter to thermal energy.

Specific latent heat

A *specific* latent heat (*L*) expresses the amount of energy in the form of heat (*Q*) required to completely effect a phase change of a unit of mass (*m*), usually 1 kg, of a substance as an intensive property:

$$L = \frac{Q}{m}.$$

Intensive properties are material characteristics and are not dependent on the size or extent of the sample. Commonly quoted and tabulated in the literature are the specific latent heat of fusion and the specific latent heat of vaporization for many substances.

From this definition, the latent heat for a given mass of a substance is calculated by

$$Q = mL$$

where:

> Q is the amount of energy released or absorbed during the change of phase of the substance (in kJ or in BTU),
> m is the mass of the substance (in kg or in lb), and
> L is the specific latent heat for a particular substance (kJ kg^{-1} or in BTU lb^{-1}), either L_f for fusion, or L_v for vaporization.

Table of specific latent heats

The following table shows the specific latent heats and change of phase temperatures (at standard pressure) of some common fluids and gases.

Substance	S.L.H. of Fusion kJ/kg	Melting Point °C	S.L.H. of Vaporization kJ/kg	Boiling Point °C
Ethyl alcohol	108	−114	855	78.3
Ammonia	332.17	−77.74	1369	−33.34
Carbon dioxide	184	−78	574	−57
Helium			21	−268.93
Hydrogen(2)	58	−259	455	−253
Lead[9]	23.0	327.5	871	1750
Nitrogen	25.7	−210	200	−196
Oxygen	13.9	−219	213	−183
Refrigerant R134a		−101	215.9	−26.6
Refrigerant R152a		−116	326.5	-25
Silicon[10]	1790	1414	12800	3265
Toluene	72.1	−93	351	110.6
Turpentine			293	
Water	334	0	2264.705	100

Specific latent heat for condensation of water in clouds

The specific latent heat of condensation of water in the temperature range from −25 °C to 40 °C is approximated by the following empirical cubic function:

$$L_{\text{water}}(T) = (2500.8 - 2.36T + 0.0016T^2 - 0.00006T^3) \text{ J/g,}^{[11]}$$

where the temperature T is taken to be the numerical value in °C.

For sublimation and deposition from and into ice, the specific latent heat is almost constant in the temperature range from −40 °C to 0 °C and can be approximated by the following empirical quadratic function:

$$L_{\text{ice}}(T) = (2834.1 - 0.29T - 0.004T^2) \text{ J/g.}^{[11]}$$
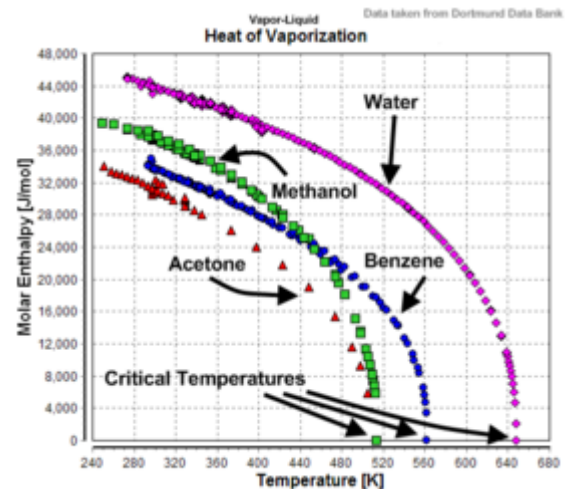
Variation with temperature (or pressure)

As the temperature (or pressure) rises to the critical point the LHOV falls to zero :

See also

- Bowen ratio
- Eddy covariance flux (eddy correlation, eddy flux)
- Sublimation (physics)
- Specific heat capacity
- Enthalpy of fusion
- Enthalpy of vaporization

Temperature-dependency of the heats of vaporization for water, methanol, benzene, and acetone.

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7. James Burke (1979). "Credit Where It's Due". *The Day the Universe Changed*. Episode 6. Event occurs at 50 (34 minutes). BBC.

8. J. P. Joule (1884), *The Scientific Paper of James Prescott Joule*, The Physical Society of London, p. 274, "I am inclined to believe that both of these hypotheses will be found to hold good,—that in some instances, particularly in the case of sensible heat, or such as is indicated by the thermometer, heat will be found to consist in the living force of the particles of the bodies in which it is induced; whilst in others, particularly in the case of latent heat, the phenomena are produced by the separation of particle from particle, so as to cause them to attract one another through a greater space.", Lecture on Matter, Living Force, and Heat. May 5 and 12, 1847

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