Quantum Mechanics_intensive property

Physical properties of materials and systems are often described as **intensive and extensive properties**. This classification relates to the dependency of the properties upon the size or extent of the system or object in question.

The distinction is based on the concept that smaller, non-interacting identical subdivisions of the system may be identified so that the property of interest does or does not change when the system is divided or combined.

An **intensive property** is a **bulk property**, meaning that it is a physical property of a system that does not depend on the system size or the amount of material in the system. Examples of intensive properties are the temperature, refractive index, density and the hardness of an object. No matter how small a diamond is cut, it maintains its intrinsic hardness.

By contrast, an **extensive property** is one that is additive for independent, noninteracting subsystems.[1] The property is proportional to the amount of material in the system. For example, both the mass and the volume of a diamond are directly proportional to the amount that is left after cutting it from the raw mineral. Mass and volume are extensive properties, but hardness is intensive.

The ratio of two extensive properties is scale-invariant, and is therefore an intensive property. For example, when gravity effects can be neglected, the ratio of the extensive properties mass and volume, the density, is an intensive property.

This terminology of intensive and extensive properties was introduced by Richard C. Tolman in 1917.[2]

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Intensive properties

An intensive property is a physical quantity whose value does not depend on the amount of the substance for which it is measured. For example, the temperatureof a system in thermal equilibrium is the same as the temperature of any part of it. If the system is divided the temperature of each subsystem is identical. The same applies to the density of a homogeneous system; if the system is divided in half, the mass and the volume change in the identical ratio and the density remains unchanged. Additionally, the boiling point of a substance is another example of an intensive property. For example, the boiling point for water is 100°C at a pressure of one atmosphere, a fact which remains true regardless of quantity.

According to the state postulate, for a sufficiently simple thermodynamic system, only two independent intensive variables are needed to fully specify the entire state of a system. Other intensive properties can be derived from the two known values.

Some intensive properties, such as viscosity, are empirical macroscopic quantitiesand are not relevant to extremely small systems.

Combined intensive properties

There are four properties in any thermodynamic system, two are intensive and two are extensive.

If the set of parameters, $\{a_i\}$, are intensive properties and another set, $\{A_j\}$, are extensive properties, then the function $F(\{a_i\}, \{A_j\})$ is an intensive property if for all α,

$$F(\{a_i\}, \{\alpha A_j\}) = F(\{a_i\}, \{A_j\}).$$

It follows, for example, that the ratio of two extensive properties is an intensive property – density (intensive) is equal to mass (extensive) divided by volume (extensive).

Examples

Examples of intensive properties include:

- chemical potential
- concentration
- density (or specific gravity)
- ductility
- elasticity
- electrical resistivity
- hardness
- magnetic field
- magnetization
- malleability
- melting point andboiling point

- molar absorptivity
- pressure
- specific energy
- specific heat capacity
- specific volume
- spectral absorption maxima (in solution)
- temperature
- viscosity

Extensive properties

An extensive property is defined by the IUPAC Green Book as a physical quantity which is the sum of the properties of separate noninteracting subsystems that compose the entire system.[1] The value of such an additive property is proportional to the size of the system it describes, or to the quantity of matter in the system. Taking on the example of melting ice, the amount of heat required to melt ice is an extensive property. The amount of heat required to melt one ice cube would be much less than the amount of heat required to melt an iceberg, so it is dependent on the quantity.

Extensive properties are the counterparts of intensive properties, which are intrinsic to a particular subsystem. Dividing one type of extensive property by a different type of extensive property will in general give an intensive value. For example, mass (extensive) divided by volume (extensive) gives density (intensive).

Combined extensive properties

If a set of parameters $\{a_i\}$ are intensive properties and another set $\{A_j\}$ are extensive properties, then the function $F(\{a_i\}, \{A_j\})$ is an extensive property if for all α,

$$F(\{a_i\}, \{\alpha A_j\}) = \alpha F(\{a_i\}, \{A_j\}).$$

Thus, extensive properties are homogeneous functions (of degree 1) with respect to $\{A_j\}$. It follows from Euler's homogeneous function theorem that

$$F(\{a_i\}, \{A_i\}) = \sum_j A_j \left(\frac{\partial F}{\partial A_j}\right),$$

where the partial derivative is taken with all parameters constant except A_j. The converse is also true – any function which obeys the above relationship will be extensive.[*citation needed*]

Examples

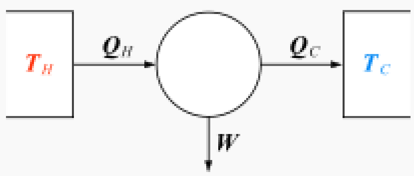
Examples of extensive properties include[*citation needed*]:

- energy
- entropy

- Gibbs energy
- length
- mass
- particle number
- momentum
- number of moles
- volume
- magnetic moment
- electrical charge
- weight

Related extensive and intensive properties

Thermodynamics



The classical Carnot heat engine

Branches

- Classical
- Statistical
- Chemical
- Equilibrium / Non-equilibrium

Laws

- Zeroth
- First
- Second
- Third

Systems

State

- Equation of state
- Ideal gas
- Real gas

- State of matter
- Equilibrium
- Control volume
- Instruments

Processes

- Isobaric
- Isochoric
- Isothermal
- Adiabatic
- Isentropic
- Isenthalpic
- Quasistatic
- Polytropic
- Free expansion
- Reversibility
- Irreversibility
- Endoreversibility

Cycles

- Heat engines
- Heat pumps
- Thermal efficiency

System properties

- Property diagrams
- **Intensive and extensive properties**

Functions of state (Conjugate variables in *italics*)

- Temperature / *entropy*
- Introduction to entropy
- pressure / *volume*
- chemical

- potential / *particle number*
- Vapor quality
- Reduced properties

Process functions

- Work
- Heat

Material properties

Specific heat capacity	$c =$	$\frac{T}{N} \frac{\partial S}{\partial T}$
Compressibility	$\beta = -$	$\frac{1}{V} \frac{\partial V}{\partial p}$
Thermal expansion	$\alpha =$	$\frac{1}{V} \frac{\partial V}{\partial T}$

- Property database

Equations

- Carnot's theorem
- Clausius theorem
- Fundamental relation
- Ideal gas law
- Maxwell relations
- Onsager reciprocal relations
- Bridgman's thermodynamic equations
- Table

Potentials

- Free energy
- Free entropy
- Internal energy $U(S,V)$
- Enthalpy $H(S,p) = U + pV$

- Helmholtz free energy $A(T,V) = U - TS$
- Gibbs free energy $G(T,p) = H - TS$

History / Culture

Philosophy

- Entropy and time
- Entropy and life
- Brownian ratchet
- Maxwell's demon
- Heat death paradox
- Loschmidt's paradox
- Synergetics

History

- General
- Heat
- Entropy
- Gas laws
- "Perpetual motion" machines

Theories

- Caloric theory
- Vis viva
- Theory of heat
- Mechanical equivalent of heat
- Motive power

Key publications

- "An Experimental Enquiry Concerning ... Heat"
- "On the Equilibrium of

Heterogeneous Substances"
- "Reflections on the Motive Power of Fire"

Timelines

- Thermodynamics
- Heat engines

Art

- Maxwell's thermodynamic surface

Education

- Entropy as energy dispersal

Scientists

- Bernoulli
- Carnot
- Clapeyron
- Clausius
- Carathéodory
- Pierre Duhem
- Gibbs
- von Helmholtz
- Joule
- Maxwell
- von Mayer
- Onsager
- Rankine
- Smeaton
- Stahl
- Thompson

- Thomson
- Waterston

Book:Thermodynamics

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See also: List of thermodynamic properties

Although not true for all physical properties, some properties have corresponding extensive and intensive analogs, many of which arethermodynamic properties. Examples of such extensive thermodynamic properties, that are dependent on the size of the thermodynamic system in question, include volume, internal energy, enthalpy, entropy, Gibbs free energy, Helmholtz free energy, and heat capacity (in the sense of thermal mass). The symbols of these extensive thermodynamic properties shown here are capital letters.

For homogeneous substances, these extensive thermodynamic properties each have corresponding intensive thermodynamic properties, which are expressed on a per mass or volume basis. The name is usually prefixed with the adjective *specific* to indicate that they are bulk properties, valid at any location (smaller subdivision) in a thermodynamic system. They may be dependent on other conditions at any point, such as temperature, pressure, and material composition, but are not considered dependent on the size of a thermodynamic system or on the amount of material in the system.

Specific volume is volume per mass, thereciprocal of density which equals mass per volume.

Extensive property	Symbol	SI units	Intensive property**	Symbol	SI units
volume	**V**	m^3 or L*	specific volume***	**v**	m^3/kg orL*/kg
Internal energy	**U**	J	Specific internal energy	**u**	J/kg
entropy	**S**	J/K	Specific entropy	**s**	J/(kg·K)
Enthalpy	**H**	J	Specific enthalpy	**h**	J/kg
Gibbs free energy	**G**	J	Specific Gibbs free energy	**g**	J/kg
Heat capacity at constant volume	C_V	J/K	specific heat capacity at constant volume	c_v	J/(kg·K)
Heat capacity	C_P	J/K	specific heat capacity	c_P	J/(kg·K)

at constant pressure at constant pressure

Corresponding extensive and intensive thermodynamic properties

* L = liter, J = joule
** specific properties, expressed on a per mass basis
*** Specific volume is the reciprocal of density.

If a molecular weight can be assigned for the substance, or the amount of substance (in moles) can be determined, then each of these thermodynamic properties may be expressed on a molar basis, and their name may be qualified with the adjective *molar*, yielding terms such as molar volume, molar internal energy, molar enthalpy, molar entropy. Standards for the symbols of molar quantities do not exist. A well known molar volume is that of an Ideal gas atstandard conditions for temperature and pressure, with the value22.41liters/mol. Molar Gibbs free energy is commonly referred to as chemical potential, symbolized by μ, particularly when discussing a partial molar Gibbs free energy μ_i for a component i in a mixture.

Generality of classification

The general validity of the division of physical properties into extensive and intensive kinds has been addressed in the course of science.[3] Redlich noted that physical properties and especially thermodynamic properties are most conveniently defined as either intensive or extensive,[2] however, these two categories are not all-inclusive and some well-defined physical properties conform to neither definition. Redlich also provides examples of mathematical functions that alter the strict additivity relationship for extensive system, such as the square or square root of volume, which occur in some contexts, altbeit rarely used.[2]

Other systems, for which the standard definitions do not provide a simple answer, are systems in which the subsystems interact when combined. Redlich pointed out that the assignment of some properties as intensive or extensive may depend on the way in which subsystems are arranged. For example, if two identicalgalvanic cells are connected in parallel, the voltage of the system is equal to the voltage of each cell, while the electric charge transferred (electric current) is extensive. However if the same cells are connected in series, the charge becomes intensive and the voltage extensive.[2] The IUPAC definitions do not consider such cases.[1]

References

- Callen, Herbert B. (1985). *Thermodynamics and an Introduction to Themostatistics* (2nd Ed. ed.). New York: John Wiley & Sons. ISBN 0-471-86256-8.
- Lewis, G.N.; Randall, M. (1961). *Thermodynamics* (2nd Edition ed.). New York: McGraw-Hill Book Company.

- Linder, Bruno. (2004). *Thermodynamics and Introductory Statistical Mechanics*. New York: John Wiley & Sons. ISBN 0-471-47459-2.

1. ^ a b c IUPAC Green Book Quantities, Units and Symbols in Physical Chemistry (3rd edn. 2007), page 6 (page 20 of 250 in PDF file)
2. ^ a b c d O. Redlich, Journal of chemical education, 47, 154-156 (1970)
3. ^ Hatsopoulos G.N. and Keenan J.H. *Principles of general thermodynamics*, John Wiley and Sons 1965 p.19-20

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