# Hawking Radiation:
# A Violation of the Zeroth Law of Thermodynamics

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# Zeroth Law of Thermodynamics

**A ↔ B and B ↔ C**

**Then…**

**A ↔ C**

**But the law also implies that temperature is an intensive property.**

**The temperature of an object cannot depend on extensive properties which in combination do not yield an intensive property.**

# Intensive versus Extensive Properties

| Intensive Properties | Extensive Properties |
| --- | --- |
| Temperature | Mass |
| Pressure | Energy |
| Density | Enthalpy |
| Concentration | Entropy |
| Specific Volume | Volume |
| Color | Heat Capacity |

**Some properties are neither intensive nor extensive (e.g. radius of a sphere, area of a sphere)**

# Intensive versus Extensive Properties

**The concept of intensive and extensive properties is so important that Peter Landsberg wanted to establish it as**

## The 4$^{th}$ Law of thermodynamics

**P.T. Landsberg, Thermodynamics with Quantum Statistical Illustrations, Interscience Publishers, New York, 1961, p. 142.**

# Equations: Intensive versus Extensive Properties

***"If one side of an equation is extensive (or intensive), then so must be the other side"***

***S.G. Canagaratna***

***Intensive and Extensive Properties: Underused Concepts, J. Chem. Educ., 1992, v. 69, no. 12, 957-963.***

# Ideal Gas Law (P in terms of intensive properties)

$$PV = nRT \rightarrow P = \frac{nRT}{V}, \text{ since: } n = \frac{M}{M} \text{ then, } \rightarrow P = \frac{MRT}{MV}$$

$$\text{since: } \rho_o = \frac{M}{V} \quad \text{and:} \quad R_s = \frac{R}{M} \rightarrow P = \rho_o R_s T$$

**P = pressure (intensive)**
**T = temperature (intensive)**
**M = mass (extensive)**
**V = volume (extensive)**
**$\rho_o$ = density (intensive) = mass/volume**
**n = number of moles (extensive) = mass/molar mass = M/*M***
**R = universal gas constant (constant)**
**$R_s$ = specific gas constant (constant) = universal gas constant/molar mass**
**T = temperature (intensive)**
***M* = molar mass (constant)**

# Entropy of a Black Hole

$$S_{BH} = \frac{k_B c^3}{4\hbar G} A$$

**Entropy ($S_{BH}$) is extensive, but area (A) is neither extensive nor intensive. It is volume which is an extensive property!**

**As a result, this expression violates elementary thermodynamic principles and is not valid.**

# Hawking Temperature

$$T_H = \frac{\hbar c^3}{8\pi G M k_B}$$

**Temperature (T) is intensive, but mass (M) is extensive! As a result, this expression violates elementary thermodynamic principles and is not valid.**

**The photons emitted by a black hole are said to manifest a blackbody spectrum. This is not possible. It takes a physical lattice to produce such a spectrum, not simply thermal equilibrium with an enclosure.**

**P.M. Robitaille, IEEE Trans. Plasma Sci. 2003, 31{6}, 1263-1267.**