Black Body Radiation

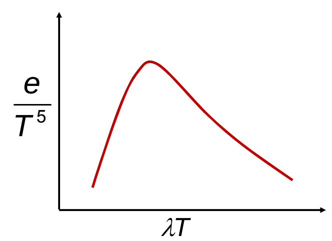
- Notorious Problem
- Any solid, when heated, radiates. The frequency distribution of the radiation varies over a large range and depends on temperature.

- Black body is an idealized body which absorbs all the radiation that is incident on it. In this case the radiation does not depend on the material and has a universal character.
- Interest in studying the spectral distribution of BBR.

Features of BBR

- $e\,d\lambda$ (the emissive power : total power emitted per unit area of BB in the wave length range λ and $\lambda+d\lambda$) when plotted against T shows a maximum at λ_m.
- $\lambda_m T$= Constant=2.898x10^{-3} m ^oK.
- Stefan's Law $\int_0^\infty e\,d\lambda = \sigma T^4$

Universal BBR Curve



Rayleigh Jean's law

Counted the modes of standing waves in a cavity and used equipartition law. Shows no maximum but explains the higher λT part very well, even without any parameter.

$$g(\lambda)d\lambda = \frac{8\pi d\lambda}{\lambda^4}$$

$$\frac{e}{T^5} = \frac{2\pi ck}{(\lambda T)^4}$$

Old and New Average Energy

$$\langle \varepsilon \rangle = \frac{\int_0^\infty \varepsilon\, e^{-\varepsilon/kT} d\varepsilon}{\int_0^\infty e^{-\varepsilon/kT} d\varepsilon} = kT$$

$$\langle \varepsilon \rangle = \frac{\sum_{n=0}^{\infty} nh\nu\, e^{-nh\nu/kT}}{\sum_{n=0}^{\infty} e^{-nh\nu/kT}} = \frac{h\nu}{e^{\frac{h\nu}{kT}} - 1}$$

Planck's BBR formula

$$\boxed{g(\lambda)d\lambda = \frac{8\pi d\lambda}{\lambda^4}} \qquad \boxed{\frac{e}{T^5} = \frac{2\pi ck}{(\lambda T)^4}}$$

$$\frac{e}{T^5} = \frac{2\pi c^2 h}{(\lambda T)^5} \frac{1}{e^{\frac{hc}{k(\lambda T)}} - 1}$$

First explanation of BBR curve and the birth of Quantum Mechanics.

Comments

Reduces to the classical value in the limit of low $\frac{h\nu}{kT}$.

$$\frac{h\nu}{e^{\frac{h\nu}{kT}} - 1} \approx \frac{h\nu}{\left(1 + \frac{h\nu}{kT} + \ldots\right) - 1} = kT$$

Actual quantization law is slightly different.

$$\varepsilon = \left(n + \frac{1}{2}\right) h\nu$$

The Planck Average Energy

- Used the classical Maxwell-Boltzmann (MB) Distribution.
- Was re-derived later by Bose and Einstein without using MB distribution and with a new interpretation.

Einstein Model for Specific Heat

$$\varepsilon = 3N_A \frac{h\nu_E}{e^{\frac{h\nu_E}{kT}} - 1}$$

$$C_v = \frac{d\varepsilon}{dT} = 3R\left(\frac{h\nu_E}{kT}\right)^2 \frac{e^{h\nu_E/kT}}{(e^{\frac{h\nu_E}{kT}} - 1)^2}$$

As $T \to 0$; $C_v \to 0$ exponentially

For large T, $C_v \to 3R$

Specific Heat of Diatomic Gases

- Like vibrations, rotational energies are also quantized.
- At low temperature only translational motion.
- As temperature increases rotational motion also sets in followed by vibrational motion.