Ques: State and establish Stefan's-Boltzmann's law and describe an experiment for its verification (2013, 2014, 2016).

Ans: Stefan's law:- The rate of emission of radiant energy per unit surface area of a perfectly black body is directly proportional to the fourth power of its absolute temperature.

i.e. $E \propto T^4 \Rightarrow E = \sigma T^4$ ——— (1)

It is known as Stefan's law.

E = Rate of emission of radiant energy per unit surface area of a perfectly black body.

σ = Stefan's constant = 5.67×10^{-8} W/m^2.K^4.

The Stefan's law refers to the emission of heat radiation only by the body itself and it is not to the net loss of heat by the body after exchange with the surrounding.

If a black body at absolute temperature T is surrounded by another black body (surrounding) at absolute temperature T_0 then

Amount of heat radiated per second per unit surface area of the body to the surrounding is

$E_1 = \sigma . T^4$ ——— (i)

Amount of heat absorbed per sec per unit surface area of the black body from the surrounding is

$E_2 = \sigma . T_0^4$ ——— (ii)

Net loss of heat radiation per sec per unit surface area of the black body to the surrounding is

$E = E_1 - E_2 \Rightarrow E = \sigma (T^4 - T_0^4)$ or $E \propto (T^4 - T_0^4)$

It is known as Stefan's-Boltzmann's law.

Experimental verification of Stefan's law or Stefan-Boltzmann law:-

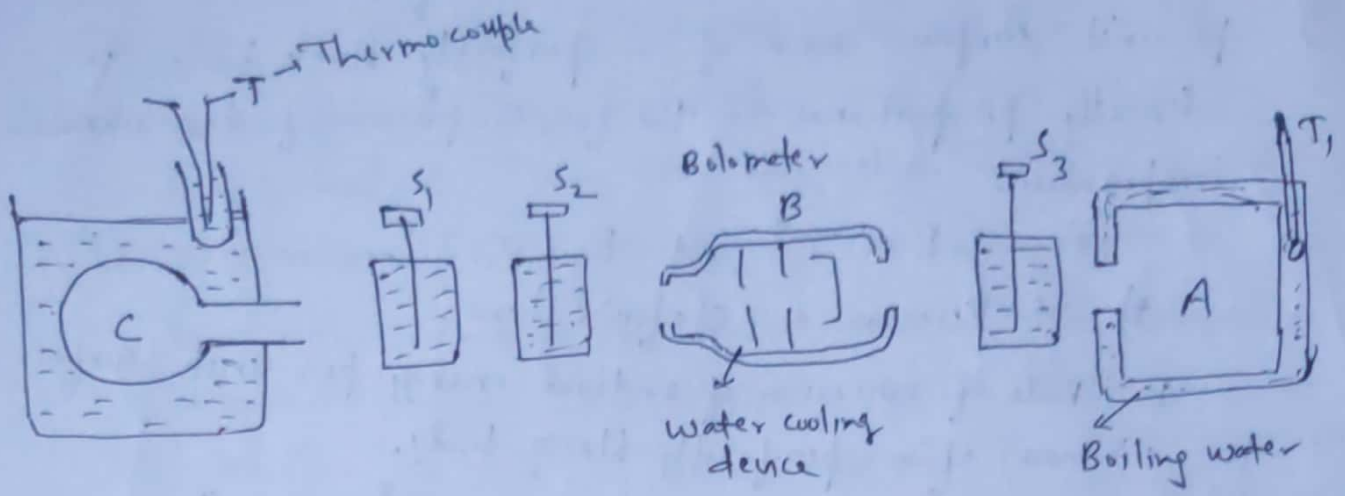

fig:

In 1897, Lummer and pringsheim experimentally verified Stefan's law over a wide range of temperature (100°C to 1300°C).

The experimental arrangement has been shown in figure.

A and C are two sources of black body radiation. A is a double walled copper vessel blackened inside, the space between the walls is filled with boiling water whose temperature is measured by a thermometer T_1. C is a spherical copper shell blackened inside and heated in nitrate bath (Fused nitrates of sodium or potassium having melting point 219°C) to temperature between 200°C to 600°C. The temperature is measured by thermocouple T. For higher temperatures, an iron cylinder blackened inside is used and heated in a double walled gas furnace to temperatures between 900°C and 1300°C. A bolometer B is used to measure intensity of emitted heat radiation. S_1, S_2 and S_3 are water cooling shutters.

The bolometer B is allowed to face the opening of the black body A and the shutter S_3 is raised.

The deflection in the galvanometer of the bolometer at various distances are noted and it is found that the deflection is inversely proportional to square of the distance between the bolometer and the opening of the black body A. Thus the deflection in the galvanometer is proportional to intensity of heat radiations.

Now the shutter S_3 is closed and the bolometer is allowed to face the opening of the black body C. The shutter S_1 and S_2 are raised. The bath surrounding the black body C is maintained a constant temperature and the maximum deflection produced in the galvanometer of the bolometer is noted. Thus at various constant temperature of the black body corresponding to constant deflection in the galvanometer are observed.

Let θ be the deflection in the galvanometer, T_1 be the temperature of the black body and T_2 be the temperature at the entrance of the bolometer then it is found that

$$\theta \propto (T_1^4 - T_2^4)$$

But $\theta \propto E$ = energy (Heat) lost per sec per unit surface area of the black body

so $E \propto (T_1^4 - T_2^4)$

which is Stefan Boltzmann's law.

Thus Stefan Boltzmann's law is verified experimentally.