2. Radiometric Units

Spectrochemical Analysis: Section 2-2
Building Scientific Apparatus: Section 4.5.2

The radiometric system of units describes the radiant energy emitted by a source or striking a receiver. The basic quantity in this system is radiant energy, Q, in joules (J). The units do not follow strict SI rules, hence the prominent role of the centimeter. The following table lists some of the more common radiometric units. It is important to remember which system is appropriate for which unit. Intensity refers to point sources, which have infinitely small dimensions. An extended source is like a light bulb, which has a finite radius and surface area. Unfortunately, the term intensity (and symbol I) is used interchangeably with the irradiance ($\mathcal{E}$), though they are distinct concepts. Remember, the irradiance refers to a receiver or detector surface. The other key to using radiometric units is to be clear about the physical meaning of the parameters. The amount of light that reaches a detector from a source depends on the solid angle the source subtends as well as its radiant power. When the output from a source travels in all directions, the solid angle it subtends is 4π sr because the surface area covered by the wavefront at distance r is $4\pi r^2$. (Remember that the circumference of a circle subtends an angle of 2π radians because the perimeter is $2\pi r$. The solid angle is the 3D counterpart of the angle, measured in steradians (sr) which are technically unitless). The surface of a sphere subtends 4π steradians.

Quantity	Symbol	Definition	Units
Radiant energy	Q	Q	J
Radiant power	Φ	$\Phi = \frac{\partial Q}{\partial t}$	W
Intensity *(pt. source)* radiant power per unit solid angle	I	$I = \frac{\partial \Phi}{\partial \Omega}$	Wsr^{-1}
Radiance *(ext. source)* radiant power per unit solid angle, per unit projected area	$\mathcal{B}$	$\mathcal{B} = \frac{\partial Q / \partial t}{\partial \Omega \partial A_p} = \frac{\partial \Phi}{\partial \Omega \partial A_p}$	$Wsr^{-1}cm^{-2}$
Irradiance *(receiver)* radiant power per unit area	$\mathcal{E}$	$\mathcal{E} = \frac{\partial \Phi}{\partial A}$	Wcm^{-2}

Table 2.1: Selected Radiometric Units
Adapted from Ingle & Crouch, *Spectrochemical Analysis*, Prentice-Hall, 1988.

The solid angle can also be described in terms of the receptor. If a circular lens is placed a distance d from a source, it collects the light that travels through the solid angle defined by the lens' size and distance: $\Omega = A_p / d^2$ where A is the projected area of the receptor (the projected area is the fraction of the receptor area that can be observed from the source, Acosθ). This means that the amount of light incident on a receiver, $\Phi = I\Omega = (IA_p)/d^2$ is inversely proportional to the distance from the source. This is a famous result called the inverse square law, which is illustrated in Figure 2.1.

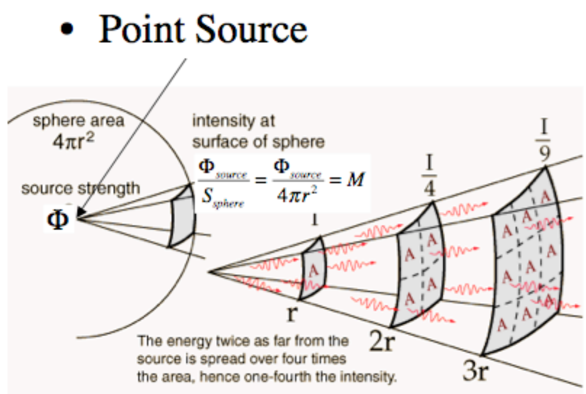

Figure 2.1: Inverse Square Law

Radiant power as a function of one parameter is clear, but it can be hard to visualize the distinction between the intensity and the radiance. The radiance adjusts the radiant power for the size of the source as well as the direction(s) of the wave travel. When radiometric quantities are measured over a specific range of wavelengths or frequencies, spectral units, identified by subscripts λ and ν, respectively, are used. For example, B_λ is the spectral radiance, the amount of light emitted by an extended source per unit solid angle, per unit projected area, per wavelength (range). These symbols are easily confused with the amplitudes of the electric and magnetic fields comprising EMR waves. We will write radiance and irradiance with a fancy font to distinguish them from electric and magnetic fields.