which is the same as the Fermi-Dirac distribution function derived in Chapter 7. We substitute (68) in (69) to obtain

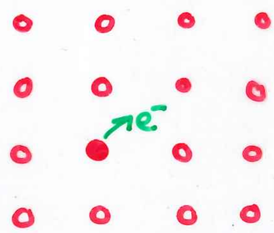
$$f = \frac{1}{(n_Q\tau/p)\exp(\varepsilon/\tau) + 1} = \frac{p}{n_Q\tau\exp(\varepsilon/\tau) + p} , \tag{70}$$

or, with $p_0 \equiv n_Q\tau\exp(\varepsilon/\tau)$,

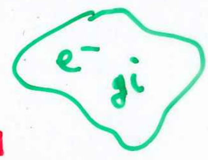
$$\boxed{f = \frac{p}{p_0 + p} ,} \tag{71}$$

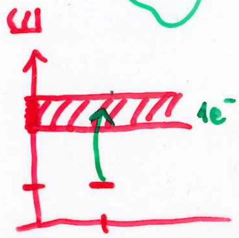
where p_0 is constant with respect to pressure, but depends on the temperature. The result (71) is known as the **Langmuir adsorption isotherm** when used to describe the adsorption of gases on the surfaces of solids.

Example: Impurity atom ionization in a semiconductor. Atoms of numerous chemical elements when present as impurities in a semiconductor may lose an electron by ionization to the conduction band of the semiconductor crystal. In the conduction band the electron moves about much as if it were a free particle, and the electron gas in the conduction band may often be treated as an ideal gas. The impurity atoms are small systems $\mathcal{S}$ in thermal and diffusive equilibrium with the large reservoir formed by the rest of the semiconductor; the atoms exchange electrons and energy with the semiconductor.



Let I be the ionization energy of the impurity atom. We suppose that one, but only one, electron can be bound to an impurity atom; either orientation ↑ or ↓ of the electron spin is accessible. Therefore the system $\mathcal{S}$ has three allowed states—one without an electron, one with an electron attached with spin ↑, and one with an electron attached with spin ↓. When $\mathcal{S}$ has zero electrons, the impurity atom is ionized. We choose the zero of energy of $\mathcal{S}$ as this state; the other two states therefore have the common energy $\varepsilon = -I$. The accessible states of $\mathcal{S}$ are summarized below.





State number	*Description*	N	ε
1	Electron detached	0	0
2	Electron attached, spin ↑	1	$-I$
3	Electron attached, spin ↓	1	$-I$

The Gibbs sum is given by

$$\mathcal{Z} = 1 + 2\exp[(\mu + I)/\tau]. \tag{72}$$