$$n_v = 4\pi N \left(\frac{m}{2\pi kT}\right)^{3/2} v^2 \exp\left[-\frac{mv^2}{2kT}\right]$$

$$\frac{dn_v}{dv} = 4\pi N \left(\frac{m}{2\pi kT}\right)^{3/2} \left[2v \exp\left[-\frac{mv^2}{2kT}\right] - v^2 \frac{\cancel{2}mv}{\cancel{2}kT} \exp\left[-\frac{mv^2}{2kT}\right]\right] = 0$$

$$4\pi N \left(\frac{m}{2\pi kT}\right)^{3/2} \left[2v - \frac{mv^3}{kT}\right] \exp\left[-\frac{mv^2}{2kT}\right] = 0$$

$$2v - \frac{mv^3}{kT} = 0$$

$$2 = \frac{mv^2}{kT} \quad \Rightarrow \quad v^* = \sqrt{\frac{2kT}{m}}$$

$m_{Rn} = 3.69 \times 10^{-25}$ kg

$m_H = 1.67 \times 10^{-27}$ kg

$m_{H_2} \simeq 2 \times m_H = 3.35 \times 10^{-27}$ kg

$T = 293$ K

$k = 1.38 \times 10^{-23}$ J/K

for H_2:

$$\bar{v} = \frac{4}{\sqrt{2\pi}} \sqrt{\frac{kT}{m_{H_2}}} = 1750 \text{ m/s}$$

$$v_{rms} = \sqrt{\frac{3kT}{m_{H_2}}} = 1904 \text{ m/s}$$

$$v^* = \sqrt{\frac{2kT}{m_{H_2}}} = 1555 \text{ m/s}$$

for Rn:

$$\bar{v} = \frac{4}{\sqrt{2\pi}} \sqrt{\frac{kT}{m_{Rn}}} = 167 \text{ m/s}$$

$$v_{rms} = 181 \text{ m/s}$$

$$v^* = 148 \text{ m/s}$$

H_2 is more than 10 times faster due to the fact that its mass is more than 100 times lighter than that of Radon.

3. Vacancies are normally occupied lattice sites from which an atom is missing. Vacancy formation is a thermally activated process. The number of vacancies in a crystal depends on and increases with temperature according to $N_v = Ne^{-Q/KT}$, where N is the total number of atomic sites and Q is the energy required for the formation of a vacancy. The energy for vacancy formation in copper is 0.9 eV/atom.
   a) Calculate the fraction of atomic sites that are vacant for copper at room temperature (27 C).
   b) Calculate the fraction of atomic sites that are vacant for copper at its melting temperature of 1084 C.
   c) Calculate the fraction of atomic sites that are vacant for copper at -100 C.
   d) Is it possible to make a vacancy-free copper crystal? Why or why not?

a) $\frac{N_v}{N} = e^{-Q/kT} = e^{-0.9\,eV/[8.62\times10^{-5}\,eV/K \times 300]} = 7.68\times10^{-16}$

$Q = 0.9$ eV/atom

$k = 8.62\times10^{-5}$ eV/K

$T = 27C = 300$ K

b) $T = 1084\,C = 1357$ K

$\frac{N_v}{N} = e^{-Q/kT} = 4.56\times10^{-4}$

c) $T = -100\,C = 173$ K

$\frac{N_v}{N} = e^{-Q/kT} = 6.16\times10^{-27}$

d) No, because at any given temperature there will still be a small fraction of vacant sites. This is mostly due to thermodynamics, since the presence of vacancies increases the entropy.