MAXWELL SPEED DISTRIBUTION

Before moving to the practical lets see the basic terms and definition for proper understanding:

Maxwell-Boltzmann Distribution:

This describes the distribution of speeds among the molecules of a gas in thermal equilibrium. The distribution function shows that there are more particles with speeds around a certain value, which shifts to higher speeds as the temperature increases. The Maxwell speed distribution function for a 3-dimensional system is given by:

$$f(v) = 4\pi \left(\frac{m}{2\pi kT}\right)^{1.5} v^2 e^{-\frac{mv^2}{2kT}}$$

Where:
- $f(v)$ is the probability density function of speed (v),
- m is the mass of a single molecule,
- k is the Boltzmann constant,
- T is the absolute temperature in Kelvin.

Temperature (T):

It is a measure of the average kinetic energy of the molecules. Higher temperatures correspond to higher average kinetic energies and thus higher average speeds.

Molar Mass (M):

This is the mass of one mole of a substance. For gases, this is typically measured in grams per mole (g/mol). The molar mass is crucial in determining the speed distribution of gas molecules.

Boltzmann Constant (k):

This is a fundamental constant that relates the average kinetic energy of particles in a gas with the temperature of the gas. It has a value of $1.38 \times 10^{-23}\ \mathrm{J/K}$.

Most Probable Speed:

This is the speed at which the greatest number of molecules is moving. It is given by:

$$v_{mp} = \sqrt{\frac{2kT}{m}}$$

Average Speed:

This is the mean speed of all the molecules in the gas. It's calculated from the distribution and provides a measure of the central tendency of the speeds. It is given by:

$$v_{av} = \sqrt{\frac{8kT}{\pi m}}$$

Root Mean Square Speed:

This is the square root of the average of the squares of the speeds of all the molecules. It's another measure of the speed distribution and is typically higher than the average speed. It is given by:

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

These speeds help in characterising the distribution of velocities among the gas molecules.

EXPERIMENT 5

AIM: Plot the maxwell speed distribution function for different temperatures for a 3-Dimensional system. Calculate the average speed, root mean square speed and most probable speed.

CODE:

```
import numpy as np
import matplotlib.pyplot as plt

k = 1.38e-23  # Boltzmann constant (J/K)
N = 6e23  # Avogadro's number
pi = np.pi  # Pi
v = np.arange(0, 2001, 1)  # Range of velocities in m/s
t = np.arange(300, 901, 300)  # Range of temperature in Kelvin

M = float(input("Enter molar mass of a gas (in g/mol): ")) # Input:mass of a gas
m = M / (N * 1000)  # Convert to kg per molecule
print("T(K)   vmp     vav       vrms")
f = []

# Maxwell-Boltzmann distribution calculation
for j in range(len(t)):
    a = m / (2 * k * t[j])
    f_j = (4 * pi) * (a / pi)**1.5 * (v**2) * np.exp(-a * (v**2))
    f.append(f_j)

    # Find the peak of the distribution for the most probable speed (vmp)
    vmp = v[np.argmax(f_j)]
```

```
    vav = np.sqrt(4/pi) * vmp
    vrms = np.sqrt(3/2) * vmp

    # Print the values
    print(f"{t[j]}   {vmp:.2f}   {vav:.2f}   {vrms:.2f}")

# Plotting the graph
plt.plot(v, np.array(f).T, linewidth=2)
plt.title("Maxwell Speed Distribution", fontsize=12)
plt.xlabel("Velocity (m/s)", fontsize=10)
plt.ylabel("Number of particles", fontsize=10)
plt.legend([f"T = {temp} K" for temp in t], fontsize=10)
plt.show()
```

OUTPUT:

```
Enter molar mass of a gas (in g/mol): 32
T(K)  vmp     vav     vrms
300   394.00  444.58  482.55
600   557.00  628.51  682.18
900   682.00  769.55  835.28
```