Answer on Question #75547, Physics / Molecular Physics | Thermodynamics

The specific heat capacity Cv (J K^{-1} mol^{-1}) of copper at different temperatures varies as follows

T (K)	1.4	2	2.44	2.83	3.16	3.46	3.74
Cv(J K^{-1} mol^{-1})	5.26	10.0	16.3	22.5	29.1	37.6	45.33

Calculate the value of γ in the equation $Cv = \gamma T + \alpha T^3$ and the Debye temperature T_d. Assume that the number of electrons per unit volume of copper is 8.5 x 10^{22} cm^{-3}.

Solution:

Plot C_V/T against T^2. The intercept at $T^2 = 0$ is the value of γ.

Matlab code:

```
T = [1.4 2 2.44 2.83 3.16 3.46 3.74];
T2 = T.^2;
Cv = [5.26 10.0 16.3 22.5 29.1 37.6 45.33];
plot(T2,Cv./T,'*');
grid on;
coefs = polyfit(T2,Cv./T, 1);
intercept = coefs(2)
slope = coefs(1)
x1 = linspace(0,14);
y1 = polyval(coefs,x1);
hold on
plot(x1,y1,'r-');
xlabel('T^2'); ylabel('Cv/T');
```

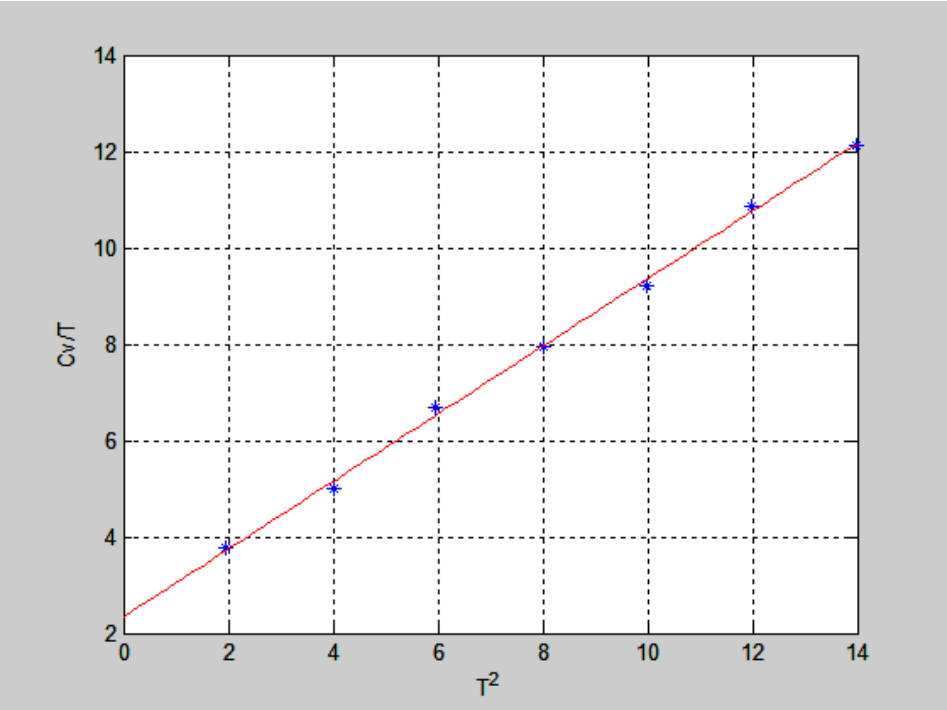
Output:

intercept =

2.3387

slope =

0.7019



$$\gamma = 2.3387 \approx 2.34\ J\ K^{-2}\ mol^{-1}$$

The slope of the line from the graph is

$$\alpha = 0.7019 = \frac{234Nk}{T_D^3},$$

where N is the number of electrons, k is the Boltzmann constant and T_D is the Debye temperature.

The N is

$$N = Concentration \times Molar\ volume = (8.5\ \times 10^{22} cm^{-3})(7.1\ cm^3)$$

This gives

$$T_D = \sqrt[3]{\frac{234Nk}{\alpha}} = \sqrt[3]{\frac{234 \times (8.5\ \times 10^{22} \times 7.1)(1.38 \times 10^{-23})}{0.7019}} = 14.05\ K$$

Answer: $\gamma = 2.34\ J\ K^{-2}\ mol^{-1}; T_D = 14.05\ K.$