Seminary exercise Nr. 10
Thermodynamics I – Heat capacity, Equation of state, Kinetic theory

For all exercises, let assume the following values:

- Avogadro's constant $N_{Av}=6.022\cdot10^{23}\,mol^{-1}$
- gas constant $R=8.31\,J\,mol^{-1}K^{-1}$

1. A certain substance of mass $5\,kg$ has to be warmed up by $10\,°C$. This process required $200\,kJ$ of heat. Determine the heat capacity and the specific heat capacity of the substance.
2. A certain amount of heat Q can warm up $20\,g$ of material A by $4\,°C$ or $50\,g$ of material B by $2\,°C$. Which material has the higher value of the specific heat capacity?
3. An aluminium flagpole is $33\,m$ high. By how much does its length increases as the temperature increases by $15\,°C$? The linear thermal expansion coefficient of aluminium is $\alpha=2.2\cdot10^{-5}\,K^{-1}$.
4. A mass of $20\,kg$ was hanged on a vertically fixed steel wire of a length $1\,m$ and diameter of $2\,mm$. What temperature change would compensate the wire extension? The linear thermal expansion coefficient of steel is $\alpha=1.2\cdot10^{-5}\,K^{-1}$ and its elastic modulus is $E=2.1\cdot10^{11}\,Pa$.
5. A sample of pure titanium ^{48}Ti has a mass $50\,g$. Determine the number of atoms and moles in the sample.
6. A sample of pure titanium has a mass $50\,g$. The relative atomic mass of titanium is 47.867. Determine the number of atoms and moles in the sample.
7. Two ice cubes of $50\,g$ each are dropped into $200\,g$ of water in a thermally insulated container. If the water is initially at $80\,°C$, and the ice comes directly from a freezer at $-15\,°C$, what is the final temperature at thermal equilibrium? The specific heat capacity of water and ice are $c_w=4182\,J\,kg^{-1}K^{-1}$ and $c_i=2093\,J\,kg^{-1}K^{-1}$ respectively, and the specific latent heat of fusion of ice is $c=3.34\cdot10^5\,J\,kg^{-1}$.
8. Determine the volume of a pressure vessel filled by $100\,g$ of oxygen at $200\,kPa$ of pressure and temperature of $25\,°C$. Consider that the molecular mass of oxygen is $32\,g\,mol^{-1}$.
9. Determine the number of moles and the number of atoms in $1\,cm^3$ of ideal gas at $100\,Pa$ of pressure and temperature of $220\,K$.
10. Determine the specific heat capacity at constant volume c_V and the specific heat capacity at constant pressure c_p for pure gaseous hydrogen.
11. What is the root-mean-square speed of 10^{22} nitrogen molecules at $300\,K$? The molecular mass of nitrogen is $28\,g\,mol^{-1}$. What is the corresponding average translational kinetic energy of molecules?
12. What is the internal energy of $5\,kg$ of gaseous oxygen at $25\,°C$? How does the internal energy change after the gas is warmed to $100\,°C$ at constant volume? Consider that the molecular mass of oxygen is $32\,g\,mol^{-1}$.