What is the difference between the macroscopic and microscopic forms of energy?

On a microscopic scale, energy is associated with the interactions of electrons and nuclei of atoms, which includes the energy of chemical bonds that hold atoms together as molecules. This energy is named internal to distinguish it from the kinetic and potential energy associated with a substance because of its macroscopic position, configuration, or motion, which can be thought of as macroscoic forms of energy.

Explain your understanding on internal energy.

In thermodynamics, the total energy of a system is called its internal energy, U.The internal energy is the total kinetic and potential energy of the constituents (the atoms, ions, or molecules) of the system.

Determine the specific potential energy, in kJ/kg, of an object 50 m above a datum in a location where g = 9.8 m/s^2.

$$\text{specific } \mathrm{E}_p = gz = 9.8\mathrm{m}/s^2 \times 50m = 490m^2/s^2 = 0.49kJ/kg$$

A rigid tank contains a hot fluid that is cooled while being stirred by a paddle wheel. Iinitially, the internal energy of the fluid is 800 kJ. During the cooling process, the fluid loses 500 kJ of heat, and the paddle wheel does 100 kJ of work on the fluid. Determine the final internal energy of the fluid. Neglect the energy stored in the paddle wheel.

$$\Delta \mathrm{U} = \mathrm{Q} - \mathrm{W} = -500 - (-100) = -400 \ \ (\mathrm{kJ})$$

$$\Delta \mathrm{U} = \mathrm{U} - U_0$$

$$\mathrm{U} = \Delta \mathrm{U} + U_0 = -400 + 800 = 400 \ \ (kJ)$$

Calculate the total work, in kJ, for process 1-3 shown in Fig. when the system consists of 2 kg of nitrogen.

①→②

The functional relation between P and V can be obtained from the graph:

$$\mathrm{P} = -4 \times 10^5 V + 9 \times 10^5$$

P: Pa;

V: m^3.

$$W_{12} = \int_{V_1}^{V_2} -PdV = -(-2 \times 10^5 V^2 + 9 \times 10^5 V)\Big|_1^2 = 3 \times 10^5 (J)$$

②→③

The volume of the system remains constant:

$$W_{23} = \int_{V_2}^{V_3} -PdV = 0.$$

The total work:

$$\mathrm{W} = W_{12} + W_{23} = 300kJ.$$

A fixed mass of an ideal gas is heated from 50 to 80℃ (a) at constant volume and (b) at constant pressure. For which case do you think the energy required will be greater? Why?

More energy is needed at (b) constant pressure.

$$t_a = t_b = 80℃ \Rightarrow U_a = U_b$$

$$\text{and} \ \begin{cases} \Delta U_a = U_a - U_0 \\ \Delta U_b = U_b - U_0 \end{cases} \Rightarrow \Delta U_a = \Delta U_b$$

$$and \ \begin{cases} \Delta U_a = Q_a - W_a \\ \Delta U_b = Q_b - W_b \end{cases} \Rightarrow Q_a - Q_b = W_a - W_b$$

When (a) at constant volume, $W_a = 0$, while (b) at constant pressure

$$W_b = P(V_b - V_0) > 0$$

$$\Rightarrow Q_a - Q_b = W_a - W_b < 0$$

$$\Rightarrow Q_a < Q_b$$

Air enters a 16-cm-diameter pipe steadily at 200 kPa and 20℃ with a velocity of 5 m/s. Air is heated as it flows, and it leaves the pipe at 180kPa and 40℃. Determine (a) the volume flow rate of air at the inlet, (b) the mass flow rate of air, and (c) the velocity and volume flow rate at the exit.

(a)The volume flow rate is the volume of fluid flowing through a cross section per unit time (the subscript i means in, and the subscript o means out)

$$q_i = \mathrm{A}\mathrm{u}_i = \left(\frac{d}{2}\right)^2 \pi \mathrm{u}_i = 3.14 \times \left(\frac{16 \times 10^{-2}}{2}\right)^2 \times 5 = 0.10(m^3/s)$$

(b)The gas constant of air is $\mathrm{R} = 0.287\mathrm{kJ/kg \cdot K}$

Specific volume

$$\upsilon_i = \frac{RT}{P} = \frac{(0.287kJ/kg \cdot K)(20 + 273K)}{200kPa} = 0.42m^3/kg$$

$$\dot{m} = \rho q = \frac{q_i}{\upsilon_i} = \frac{0.1m^3/s}{0.42m^3/kg} = 0.24kg/s$$

(c)

$$m_i = m_o$$

$$\rho_i V_i A_i = \rho_o V_o A_o$$

$$\rho_i V_i = \rho_o V_o$$

$$1/\rho_o = \upsilon_o = \frac{RT}{P} = \frac{(0.287kJ/kg \cdot K)(40 + 273K)}{180kPa} = 0.50m^3/kg$$

$$V_o = \frac{\rho_i V_i}{\rho_o} = \frac{\upsilon_o V_i}{\upsilon_i} = \frac{0.50m^3/kg \times 5m/s}{0.42m^3/kg} = 5.94m/s$$

$$q_o = \frac{\rho_i q_i}{\rho_o} = \frac{\upsilon_o V_i}{\upsilon_i} = \frac{0.50m^3/kg \times 0.10m^3/s}{0.42m^3/kg} = 0.12m^3/s$$