9. Thermal Physics

Definitions

Thermal Equilibrium: When the object gains heat from the surrounding at the same rate as it loses heat, then there will be no net flow of heat between the object and its surroundings. They are now in a state called thermal equilibrium.

The Zeroth Law of Thermodynamics: If objects A and B are separately in thermal equilibrium with a third object C, then A and B are in thermal equilibrium with each other if placed in thermal contact.

The First Law of Thermodynamics: The internal energy of a system depends only on its state and the increase in the internal energy of a system is equal to the sum of heat supplied to the system and the work done on the system.

Heat Capacity: The heat capacity of a body is the quantity of heat required to raise the temperature of the body by 1K.

Specific Heat Capacity: The specific heat capacity of a material is the quantity of heat required to raise the temperature of 1kg of the material by 1K.

Specific Latent Heat of Fusion/Vaporization: The amount of thermal energy required to change the state of 1kg of the material from solid to liquid / liquid to vapour without a change of temperature.

Internal Energy: The internal energy of a system is determined by the state of the system. It can be expressed as the sum of the microscopic kinetic and potential energies of the molecules within the system. The kinetic energy is associated with the random motion of the atoms/molecules while the potential energy is associated with the intermolecular forces between molecules.

Ideal Gas: An ideal gas is one that obeys the equation $pV=nRT$ at all values of p, V, n and T.

The Kelvin: The Kelvin is defined as 1/273.16 of the temperature difference between the absolute zero and triple point of water.

@absolute zero, all substances have minimal internal energy.

Evaporation: Evaporation is the change of state from liquid to gas that takes place at the surface of a liquid at any temperature.

NOTE

- WD = area under the pV graph
- **Internal energy** only **dependent on state**, **independent of path taken**
- **WD dependent on path**
- Isothermal (constant T), Isobaric (constant p), Isovolumetric (constant V), Adiabatic (no heat transfer)
- $pV = NkT$
- $pV = 1/3Nm\langle c^2\rangle$
- Combining both, $1/2m\langle c^2\rangle = 3/2kT$
- However, the factor of 3/2 only applies to monoatomic molecules, as such molecules perform translational motion only. (This is because in polyatomic gaseous molecules, moment of inertia is appreciable and hence rotational kinetic energy cannot be

neglected, whereas in monoatomic molecules, moment of inertia is much smaller and can hence be neglected, therefore only translational kinetic energy)

Questions

1. Compare density change of solid → liquid and liquid → gas.
Ans: For solid → liquid, sufficient energy gained to vibrate so violently that attractive forces cannot hold the molecules tightly together and thus the lattice structure collapses, however, molecules still possess a degree of attractive cohesive forces and therefore there is only a slight increase in intermolecular separation, thus density decreases slightly only.
For liquid → gas, the intermolecular forces of attraction are completely broken and molecules move in random motion, therefore there is a large increases in the inter-molecular separation and thus density decreases greatly.

2. How is isothermal change achieved and why does internal energy remain unchanged despite mechanical work done on the system.
Ans: Isothermal change achieved by keeping the gas in a thin-walled and good conducting vessel placed in a temperature bath. The compression is done slowly in small steps, to allow for heat to flow out of the gas to maintain a constant temperature. As such, the rate of WD = rate of extraction of heat and thus internal energy remains the same.

3. Motion of molecules in water and water vapour at the same temperature.
Ans: Both freedom of motion and continuous random motion but in water more closely spaced and therefore more restricted motion. However, root mean square speed is the same as <c^2> is the same.

4. Some water in a sauce pan is boiling. Explain why (i) there is a change in internal energy as water changes to steam, (ii) work is done by the boiling water and (iii) show that thermal energy must be supplied to the water during the boiling process.
Ans: (i) Since there is no change in temperature during boiling, the kinetic energy of the water molecules remains the same. However, when the volume of the water expands during boiling, the separation between water molecules increases and thus the potential energy of the molecules increase. Given internal energy is the sum of the kinetic and potential energies of the water molecules, internal energy increases. (ii) The volume occupied by the water molecules increase on vaporization, i.e. water expands. Hence, the water molecules have to do work, pushing back the atmospheric pressure. (iii) During boiling, the internal energy of the water molecules increases. According to the First Law of Thermodynamics, internal energy is given by the sum of the heat supplied to the system and the work done on the system. Since the work done on the system is negative, the thermal energy supplied must be positive.

5. Explain why _____ can be regarded as an adiabatic process.
Ans: When the small volume of gas expands during an explosion, it is a rapid and sudden process. The time is too short for any significant heat transfer to take place between the gas and the surroundings during this process. Hence it can be regarded as an adiabatic process.

6. What does it mean by being measured on an absolute scale?

Ans: An absolute scale means that the scale does not depend on the properties of any particular substance.