LESSON 5.1.2

Internal Energy, Absolute Zero and the Kinetic Model

Temperature describes the thermal state of matter. Internal energy adds up microscopic energies across the whole sample. They are related, but they are not the same quantity.

INTERNAL ENERGY U: A MICROSCOPIC TOTAL

$$U = \Sigma E_{k,random} + \Sigma E_{p,interaction}$$

Add the kinetic energies of random particle motion and the potential energies associated with interactions between particles. The symbol Σ means sum over the sample.

KINETIC CONTRIBUTION

Particles have a range of energies. Solids vibrate about equilibrium positions; liquid and gas particles also move from place to place.

POTENTIAL CONTRIBUTION

Particle arrangement and separation matter. Changing the arrangement during a phase change can change internal energy without raising temperature.

SAME TEMPERATURE DOES NOT MEAN SAME TOTAL ENERGY

Two samples of the same substance in the same phase can have the same temperature but different internal energies because they contain different numbers of particles. For the same thermodynamic state, twice the amount has twice the internal energy, using the same energy reference.

Do not include the kinetic energy of the whole object moving together, or its gravitational potential energy as a whole, in this thermal internal-energy model.

Heat is energy in transfer due to a temperature difference, not a stored substance.

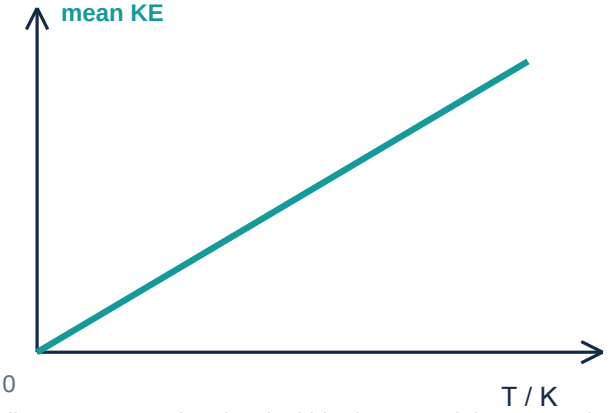
1 Use the absolute temperature scale

Kelvin is essential when comparing average molecular kinetic energies. A temperature interval has the same numerical size in kelvin and degrees Celsius.

$$T / K = \theta / °C + 273.15$$

0 K = -273.15 °C | Use K, not °K.

IDEAL-GAS MODEL: MEAN TRANSLATIONAL KINETIC ENERGY



Mean translational kinetic energy is proportional to absolute temperature. Doubling T doubles the mean energy, not the speed of every molecule.

Individual molecules still have a spread of speeds and energies.

The line represents the classical ideal-gas model, not a real gas at all temperatures.

WORKED COMPARISON: 20.0 °C TO 40.0 °C

$$T_1 = 293.15\ K; \quad T_2 = 313.15\ K$$

$$\text{Mean KE ratio} = \frac{313.15}{293.15} = 1.068$$

The mean translational kinetic energy increases by about 6.8%, not 100%.

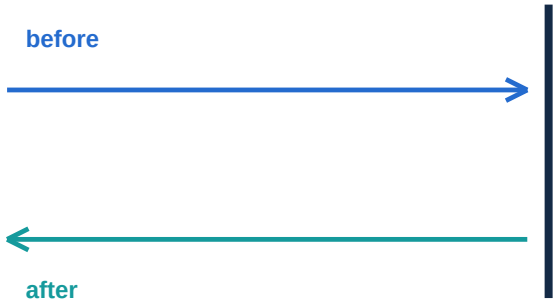
Absolute zero is the lower limit of the ordinary thermodynamic temperature scale. Classical random translational motion tends to zero as T tends to 0 K. Real gases cease to behave ideally before this limit is reached.

Beyond the classical model: quantum zero-point motion can remain. Do not conclude that all microscopic energy must be zero at 0 K.

2 Explain pressure with particle motion

Gas molecules move randomly. Collisions with a wall change their momentum, producing a force on the wall and therefore pressure.

AN ELASTIC COLLISION WITH A STATIONARY WALL



The velocity component perpendicular to the wall reverses. Speed is unchanged in this ideal elastic collision.

The wall receives an equal and opposite impulse.

Arrows separate the before/after states; they do not show two simultaneous particles.

MODEL ASSUMPTIONS

Very many particles move randomly. Their own volume is negligible compared with the gas volume. There are negligible forces between particles except during collisions.

COLLISION ASSUMPTIONS

Particles travel in straight lines between collisions. Collisions are brief and elastic. An individual molecule can exchange energy with another; total kinetic energy is conserved.

USE THE MODEL WITHOUT CONFUSING THE QUANTITIES

1. Heat a fixed amount at fixed volume.

Higher mean speed means larger impulses and more frequent wall collisions; pressure rises.

2. Compare different gases at the same T.

Their molecules have the same mean translational kinetic energy, not the same mean speed.

3. Melt a pure solid at constant pressure.

Temperature stays fixed while internal energy rises as the particle arrangement changes.

Source: Pearson IAL Physics, Unit 5 p. 33, points 128-129; kinetic-model context.

Next lesson: ideal gas equation and quantitative molecular kinetic energy.