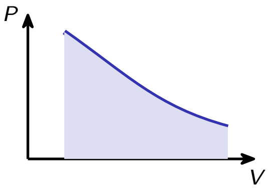
Thermodynamics

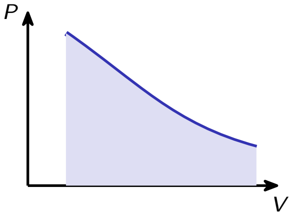
AP Physics 2 ▪ Unit 9

AP Physics 2



What we will cover

1. Kinetic theory of temperature and pressure
2. The ideal gas law
3. Heat transfer and equilibrium
4. The first law of thermodynamics
5. Specific heat and conductivity
6. Entropy and the second law



Temperature is energy per particle

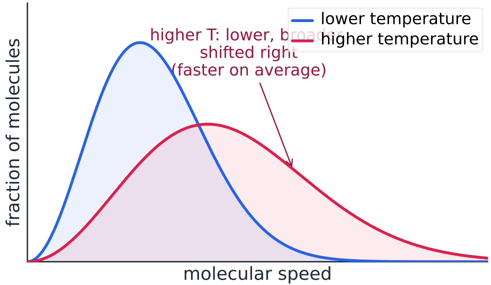
Kinetic theory 分子运动论: matter is countless moving particles.
Temperature 温度 measures their average kinetic energy:

Per particle

$$\bar{K} = \frac{3}{2} k_B T$$

T in **kelvin** 开尔文; $T_K = T_C + 273.15$.

Pressure 压强 comes from particles striking the walls – $P = F/A$.



Hotter ⇒ the speed distribution shifts right.

The ideal gas law

Two forms of the same law

$$PV = Nk_BT \qquad PV = nRT$$

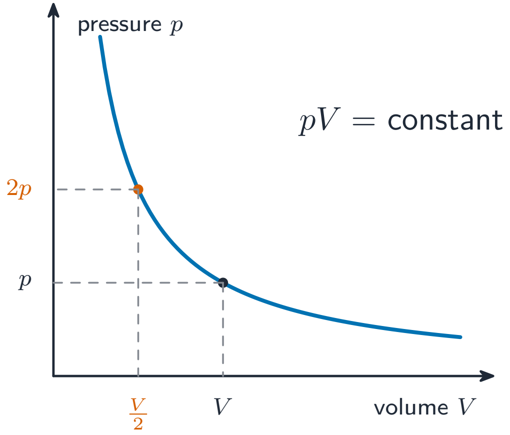
N particles, or n **moles** 摩尔; $R = N_A k_B$.

Comparing two states

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Heating a gas expands it and can do work

The ideal gas law



Heat transfer and equilibrium

Heat 热量 Q is energy in transit from hot to cold. Flow stops at **thermal equilibrium** 热平衡 (equal temperatures).

> **Zeroth law** 热力学第零定律: A=B and B=C ⇒ A=C – how a thermometer works.

Isolated: $Q_{\text{lost}} = Q_{\text{gained}}$.

Heat flows until temperatures equalise

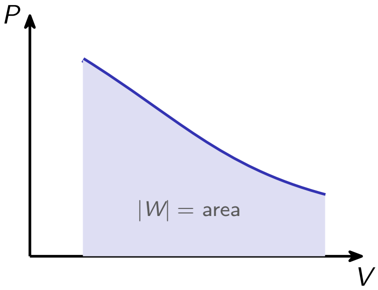
The first law of thermodynamics

Energy conservation for a gas: **internal energy** 内能 U changes by heat in plus work in.

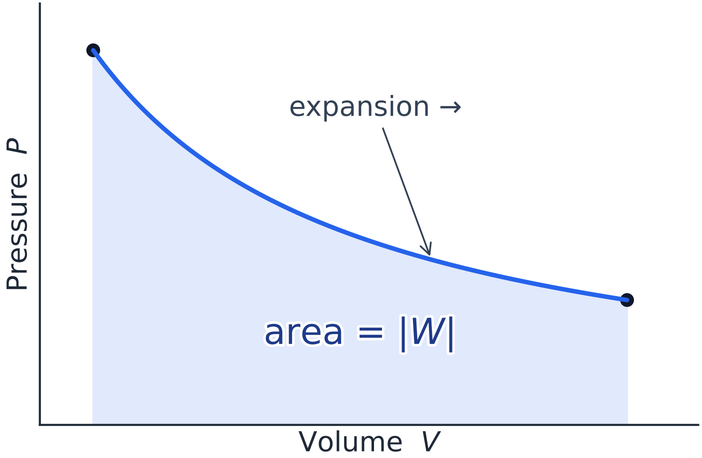
First law (AP convention)

$$\Delta U = Q + W, \qquad W = -P\Delta V$$

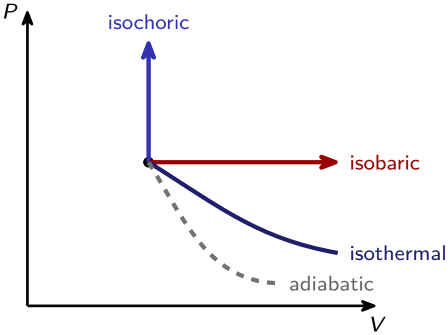
- $Q > 0$: heat added
- $W > 0$: gas compressed (work done on it)



The first law of thermodynamics



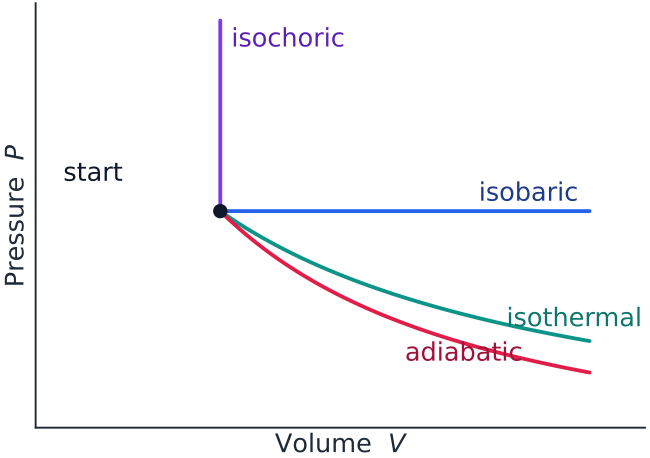
Four standard processes



- **isothermal** 等温: $\Delta U = 0$, so $Q = -W$
- **isobaric** 等压: $W = -P\Delta V$
- **isochoric** 等容: $W = 0$, so $\Delta U = Q$
- **adiabatic** 绝热: $Q = 0$, so $\Delta U = W$

A **cycle** 循环 returns to its state: $\Delta U = 0$, net heat $=$ net work – a **heat engine** 热机.

Four standard processes



Specific heat and conductivity

Warming a material

$$Q = mc\,\Delta T$$

Specific heat 比热容 c: heat to warm $1\,\mathrm{kg}$ by $1\,\mathrm{K}$.

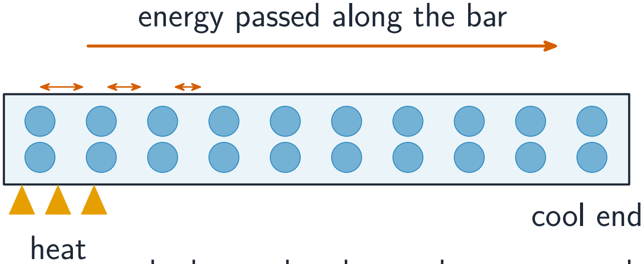
Water has a large c (≈ 4186) – it resists temperature change, so coasts stay mild.

Rate of conduction

$$\frac{Q}{t} = \frac{kA\,\Delta T}{L}$$

- high k – a metal **conductor** 导体
- low k – an **insulator** 绝热体 (air, foam)

Specific heat and conductivity



particles vibrate more at the hot end and pass the energy to their neighbours

Entropy and the second law

Entropy 熵 S measures **disorder** 无序. The **second law** 热力学第二定律: total entropy of an **isolated system** 孤立系统 never decreases.

The arrow of time

$$\Delta S_{\text{total}} \geq 0$$

- heat flows hot $\rightarrow$ cold on its own
- ink spreads, glass shatters – never reverse

> No heat engine is 100% efficient – some heat is always dumped as waste.

Unit 9 – key takeaways

1 Kinetic theory

$T =$ average particle KE; $PV = nRT$ in kelvin

2 First law

$\Delta U = Q + W$; $|W|$ is the area under a PV curve

3 Processes

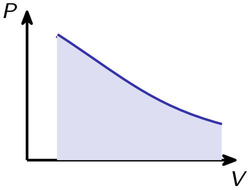
iso-thermal / -baric / -choric / adiabatic

4 Second law

$\Delta S \geq 0$; no engine is fully efficient

Check yourself

1. What does temperature measure at the particle level?
2. Halve a gas's volume at constant T – what happens to P?
3. In an isochoric process, what is the work done?
4. Can any heat engine be 100% efficient?



Answers **1.** average kinetic energy of particles **2.** it doubles **3.** zero **4.** no