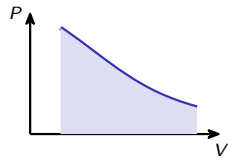


Thermodynamics

AP Physics 2 ■ Unit 9

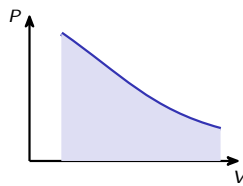
AP Physics 2



Thermodynamics

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



1 Kinetic theory

Temperature is energy per particle

Kinetic theory 分子运动论: matter is countless moving particles.

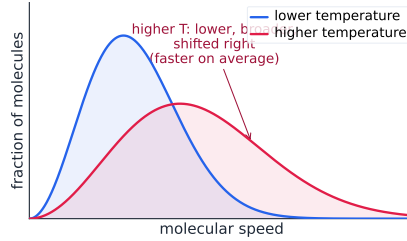
Temperature 温度 measures their **average kinetic energy**:

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 $\Rightarrow$ the speed distribution shifts right.

2 Ideal gas law

The ideal gas law

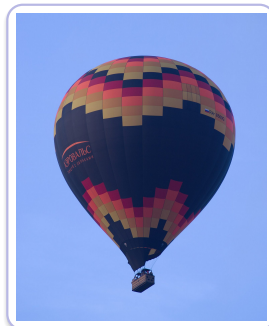
Two forms of the same law

$$PV = Nk_B T \quad PV = nRT$$

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

3 Heat transfer

Thermodynamics
↳ Heat transfer

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 $B=C \Rightarrow A=C$ –
how a thermometer works.

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



Heat flows until temperatures equalise

4 First law

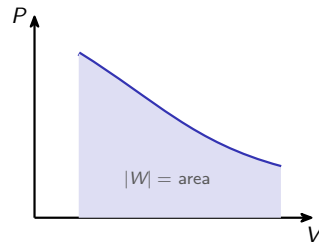
The first law of thermodynamics

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

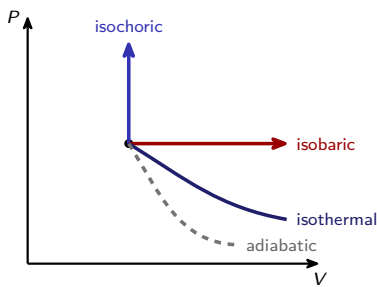
First law (AP convention)

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

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



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.

5 Specific heat

Specific heat and conductivity

Warming a material

$$Q = mc\Delta T$$

Specific heat 比热容 c : heat to warm 1 kg by 1 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)

6 Entropy

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.

7

Recap

Thermodynamics

└ Recap

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

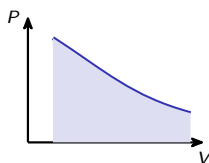
$\Delta S \geq 0$; no engine is fully efficient

Thermodynamics

└ Recap

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