Exercise walk-through

The First Law of Thermodynamics ▪ 9.4

eXercise

You must be able to

- state the **first law of thermodynamics 熱力学第一定律** as $\Delta U = Q + W$
- analyse the **internal energy 内能** change of a gas from the heat added and work done
- interpret **work** as the area under a curve on a pressure-volume (PV) diagram
- describe **isothermal**, **isobaric**, **isochoric**, and **adiabatic** processes

Method — The first law

$\Delta U = Q + W$, where Q is the heat **added to** the gas and W is the work done **on** the gas. It is just conservation of energy for a gas.

Method — Work on a PV diagram

The work is the **area** under the process curve. Compressing a gas (volume decreasing) does **positive** work on it.

Method — Four processes

- **Isothermal** — constant temperature ($\Delta U = 0$).
- **Isobaric** — constant pressure.
- **Isochoric** — constant volume ($W = 0$).
- **Adiabatic** — no heat exchange ($Q = 0$).

Practice 2.1 ▪ 1 mark

State the first law of thermodynamics.

Solution 2.1

Worked steps

the change in internal energy equals the heat added plus the work done on the gas, $\Delta U = Q + W$ B1.

Practice 2.2 ▪ 2 marks

A gas absorbs 500 J of heat while 200 J of work is done on it. Find the change in internal energy.

Solution 2.2

Method: The first law

Worked steps

$\Delta U = Q + W = 500 + 200 = 700$ J M1 A1.

Practice 2.3 ▪ 2 marks

State which of Q or W is zero in an isochoric (constant-volume) process, and why.

Solution 2.3

Method: Four processes

Worked steps

$W = 0$ B1 — no volume change means no work is done on or by the gas B1.

Exam-style 3.1 ▪ 1 mark

In $\Delta U = Q + W$, the quantity Q is the

A work done

B heat added

C internal energy

D temperature

Solution 3.1

A work done

B heat added ✓

C internal energy

D temperature

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

An adiabatic process is one in which

A $Q = 0$

B $W = 0$

C $\Delta U = 0$

D $\Delta T = 0$

Solution 3.2

A $Q = 0$ ✓

B $W = 0$

C $\Delta U = 0$

D $\Delta T = 0$

Worked steps

A.

Exam-style 3.3 ▪ 3 marks

A gas is compressed: 300 J of work is done on it while it releases 100 J of heat.
(a) Find the change in internal energy.
(b) State whether its temperature rises or falls.

Solution 3.3

Method: The first law

Worked steps

(a) $\Delta U = Q + W = (-100) + (+300) = +200$ J **M1** **M1** **A1** *for signs, for sum.* (b) it rises ($\Delta U > 0$) **B1**.