

Exercise walk-through

# 9.4

## The First Law of Thermodynamics

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AP Physics 2

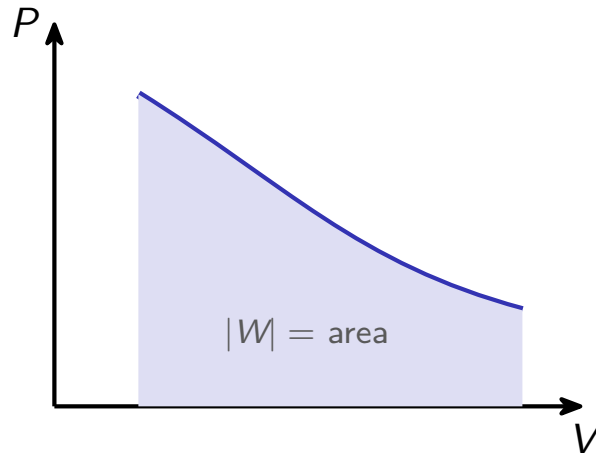
# The first law of thermodynamics

Energy conservation for a gas: **internal energy**  $U$  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)



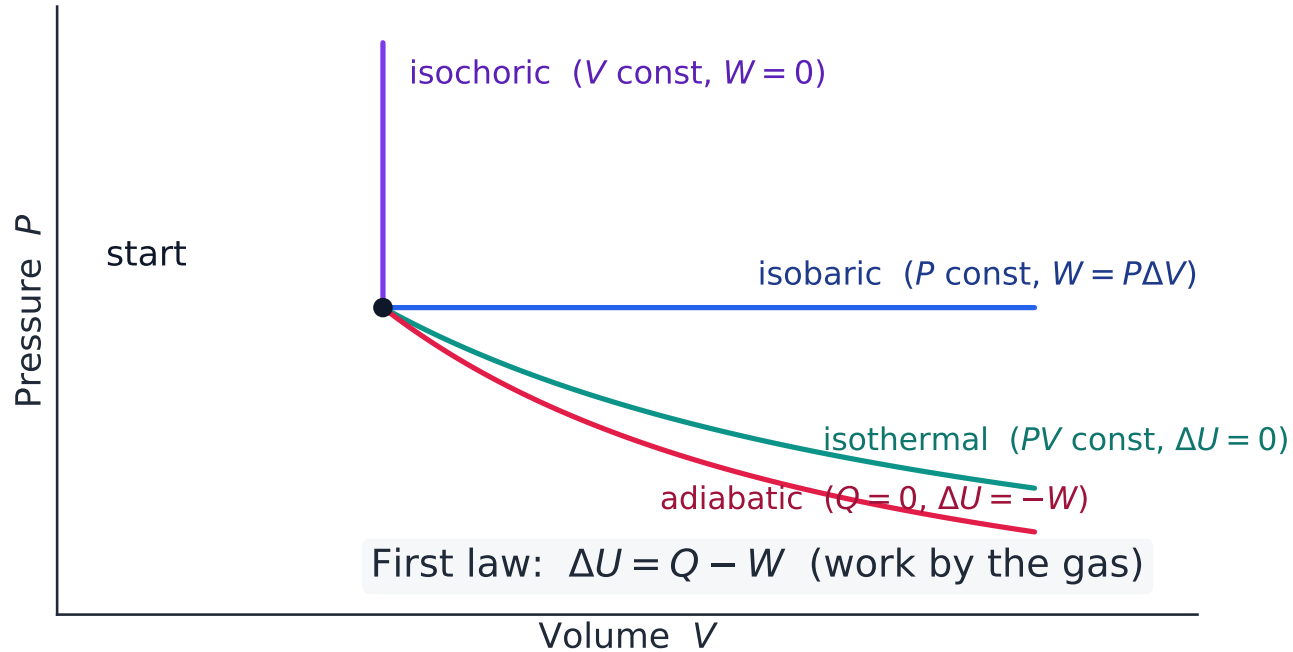
## Worked example – the first law, with the sign convention

**A gas absorbs 500 J of heat and does 200 J of work . Find the change in internal energy.**

- $\Delta U = Q - W$ , with  $W$  the work done by the gas
- $= 500 - 200$
- $= +300 \text{ J}$

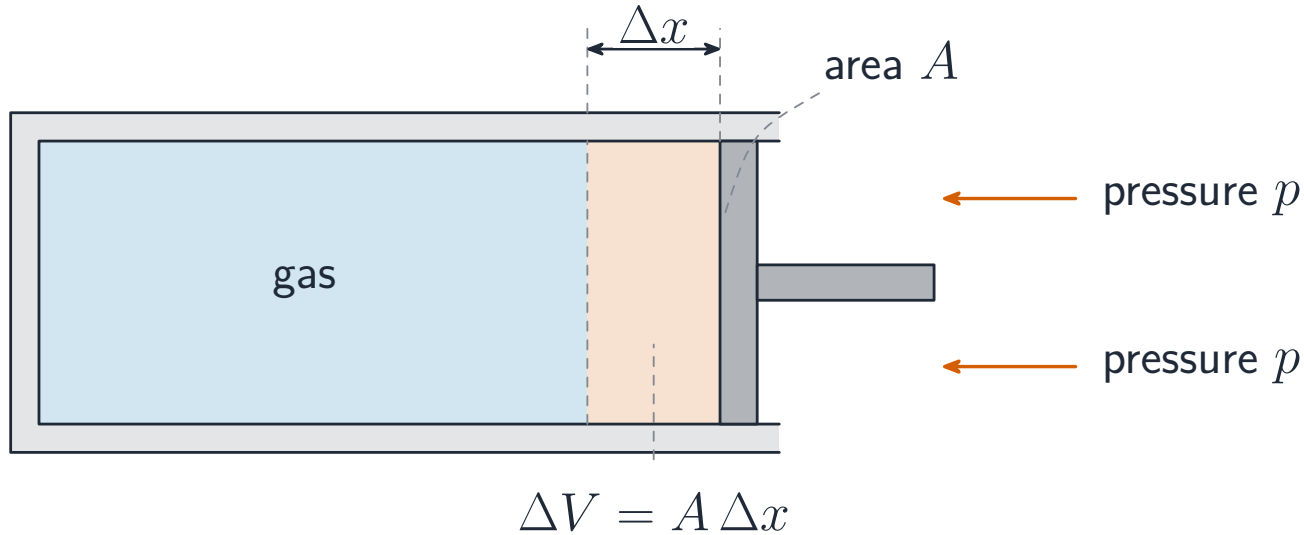
The sign convention is the whole difficulty. Heat **in** is positive; work done **by** the gas is positive and lowers  $U$ . State which convention you are using before substituting.

# The four thermodynamic processes drawn from – one



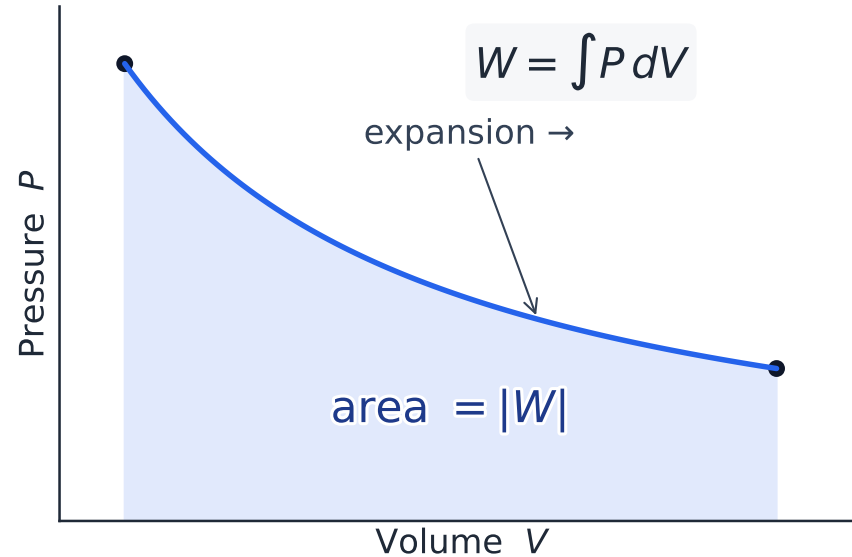
The four thermodynamic processes drawn from a common starting state on a PV diagram

# The four thermodynamic processes drawn from – two



A gas pushing a piston out by a small distance does work equal to  $p$  times the volume change

# The work done during a volume change



The work done during a volume change equals the area under the P-V curve

## Exercises 2.1-2.3

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**2.1** State the first law of thermodynamics.

[1]

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

[2]

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**2.3** State which of  $Q$  or  $W$  is zero in an isochoric (constant-volume) process, and why.[2]

## Exercises 2.1-2.3

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**2.1** State the first law of thermodynamics. [1]

**2.1**

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

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**2.2** A gas absorbs 500 J of heat while 200 J of work is done on it. Find the change in internal energy. [2]

**2.2**

- $\Delta U = Q + W = 500 + 200 = 700 \text{ J}$

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**2.3** State which of  $Q$  or  $W$  is zero in an isochoric (constant-volume) process, and why. [2]

**2.3**

- $W = 0$  – no volume change means no work is done on or by the gas

## Exercises 3.1-3.2

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

[1]

☐

A work done

B heat added

C internal energy

D temperature

☐

3.2 An adiabatic process is one in which

[1]

A  $Q = 0$

B  $W = 0$

C  $\Delta U = 0$

D  $\Delta T = 0$

## Exercises 3.1-3.2

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

[1]

☐

**A** work done

**B** heat added

**C** internal energy

**D** temperature

**3.1 B**

- heat added.

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**3.2** An adiabatic process is one in which

[1]

☐

**A**  $Q = 0$

**B**  $W = 0$

**C**  $\Delta U = 0$

**D**  $\Delta T = 0$

**3.2 A**

- $Q = 0$ .

## Exercise 3.3 (a)

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**3.3** 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.

[3]

## Exercise 3.3 (a)

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**3.3** 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.

[3]

(a)

- $\Delta U = Q + W = (-100) + (+300) = +200 \text{ J}$

## Exercise 3.3 (b)

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**3.3** A gas is compressed: 300 J of work is done on it while it releases 100 J of heat.

(b) State whether its temperature rises or falls.

[1]

## Exercise 3.3 (b)

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**3.3** A gas is compressed: 300 J of work is done on it while it releases 100 J of heat.

(b) State whether its temperature rises or falls.

[1]

(b)

- it rises ( $\Delta U > 0$ )