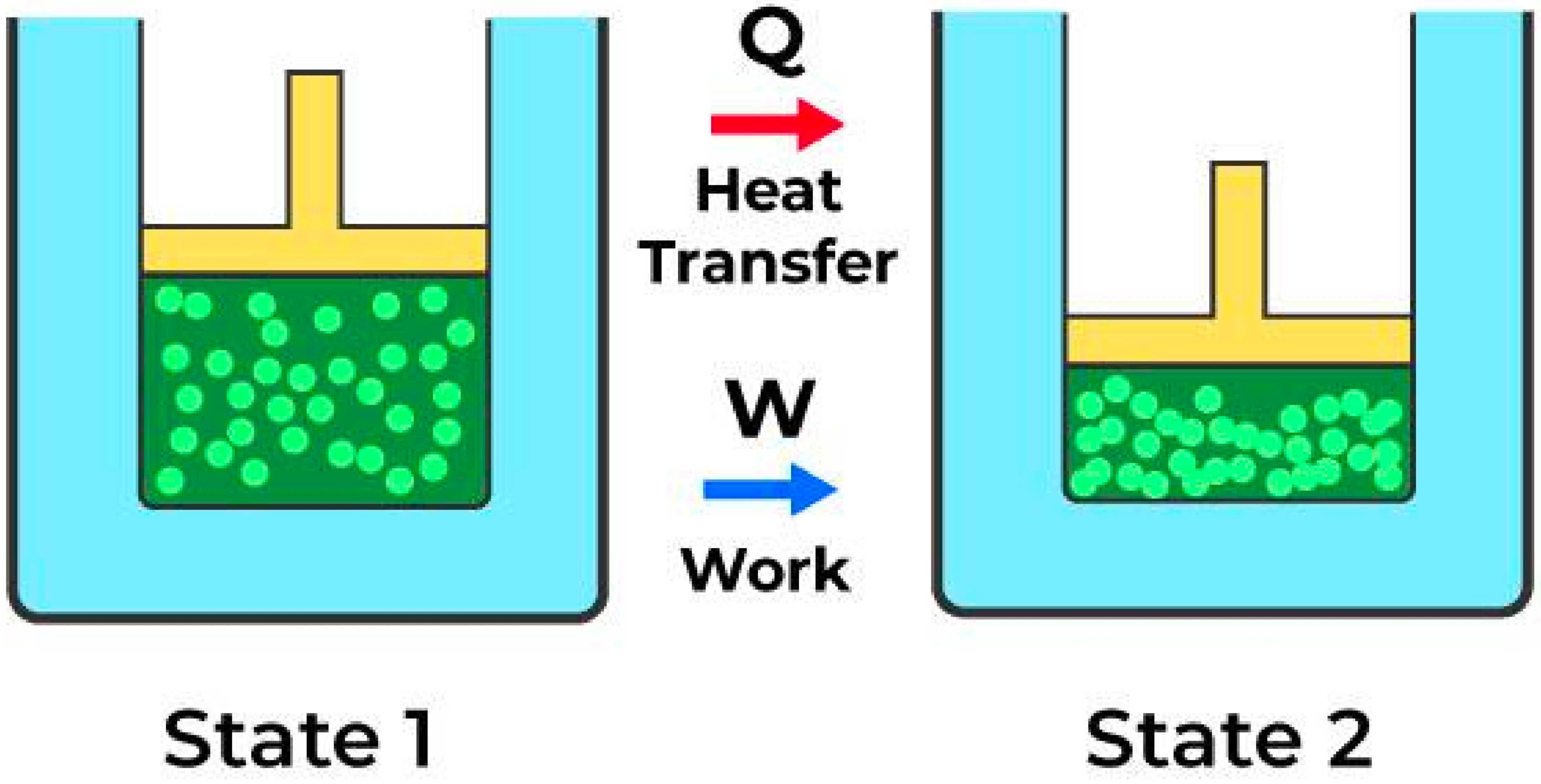
# 9702 C16 Thermodynamics



# What is internal energy?

**Internal energy of a substance = the sum of the random distribution of kinetic and potential energies within a system of molecules**

The internal energy of a system is determined by:

1.Temperature

2.The random motion of molecules

3.The phase of matter: **gases have the highest internal energy, solids have the lowest**

Internal energy of a system can increase by:

-doing work on it

-adding heat to it

Internal energy of a system can decrease by:

-losing heat to its surroundings

# Internal energy of an ideal gas equation:

*Note that molecules of all substances contain both kinetic and potential energies because they are bound by the intermolecular forces*

However, **ideal gas** molecules are assumed to have **no intermolecular forces**. This means there have **only kinetic energy, but no potential energy**

Therefore, internal energy of ideal gas = avarage(translational) kinetic energy

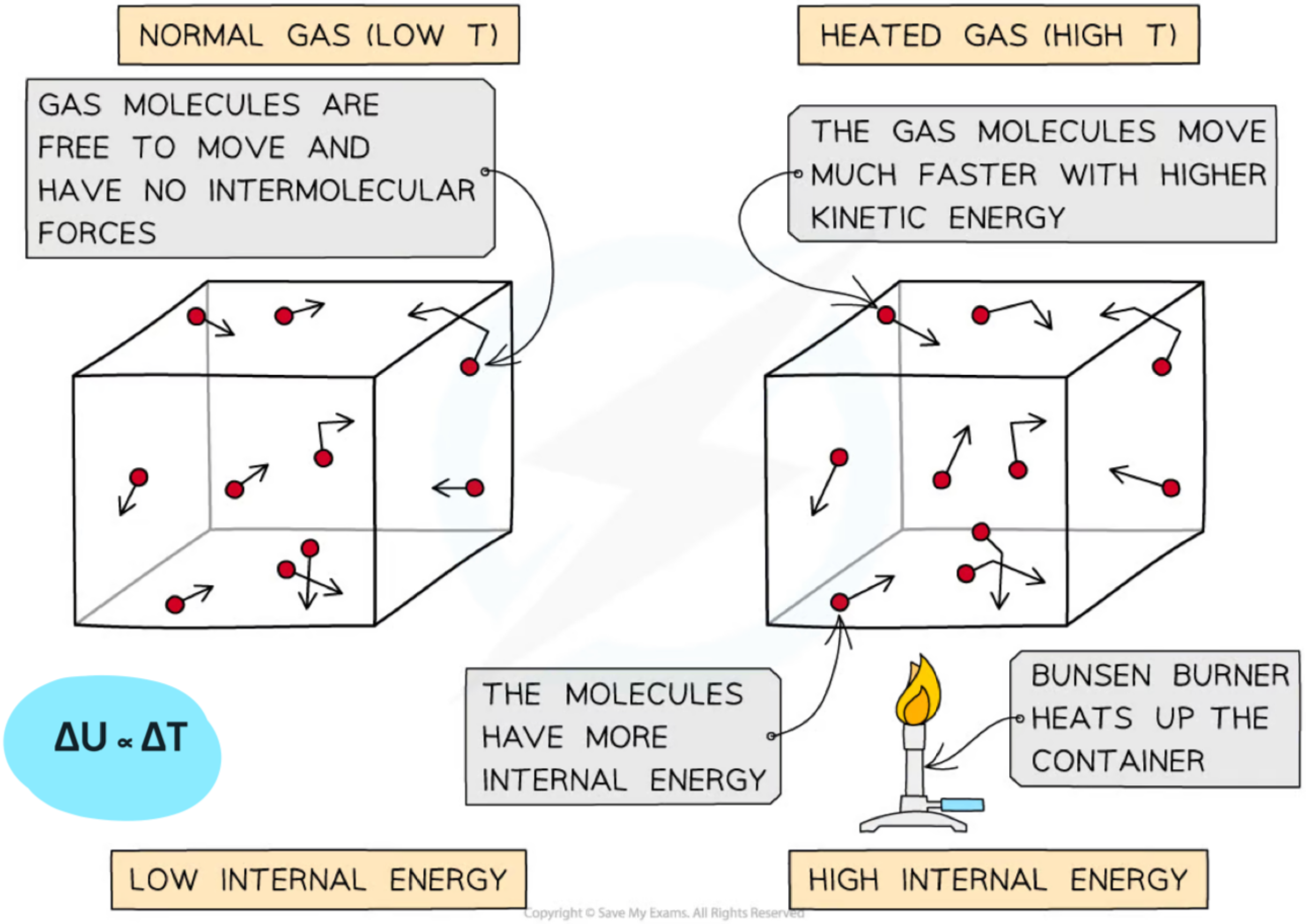
- The (change in) internal energy of an ideal gas is equal to:

$$\Delta U = \frac{3}{2} k\Delta T$$

- Therefore, the change in internal energy is proportional to the change in temperature

$$\Delta U \propto \Delta T$$

- Where:
  - $\Delta U$ = change in internal energy (J)
  - $\Delta T$ = change in temperature (K)




*As the container is heated up, the gas molecules move faster with higher kinetic energy and therefore higher internal energy*

# Work Done by a Gas

When a gas expands, it does work on its surroundings by exerting pressure on the walls of the container it's in

The work done when a volume of gas changes at constant pressure is defined as:

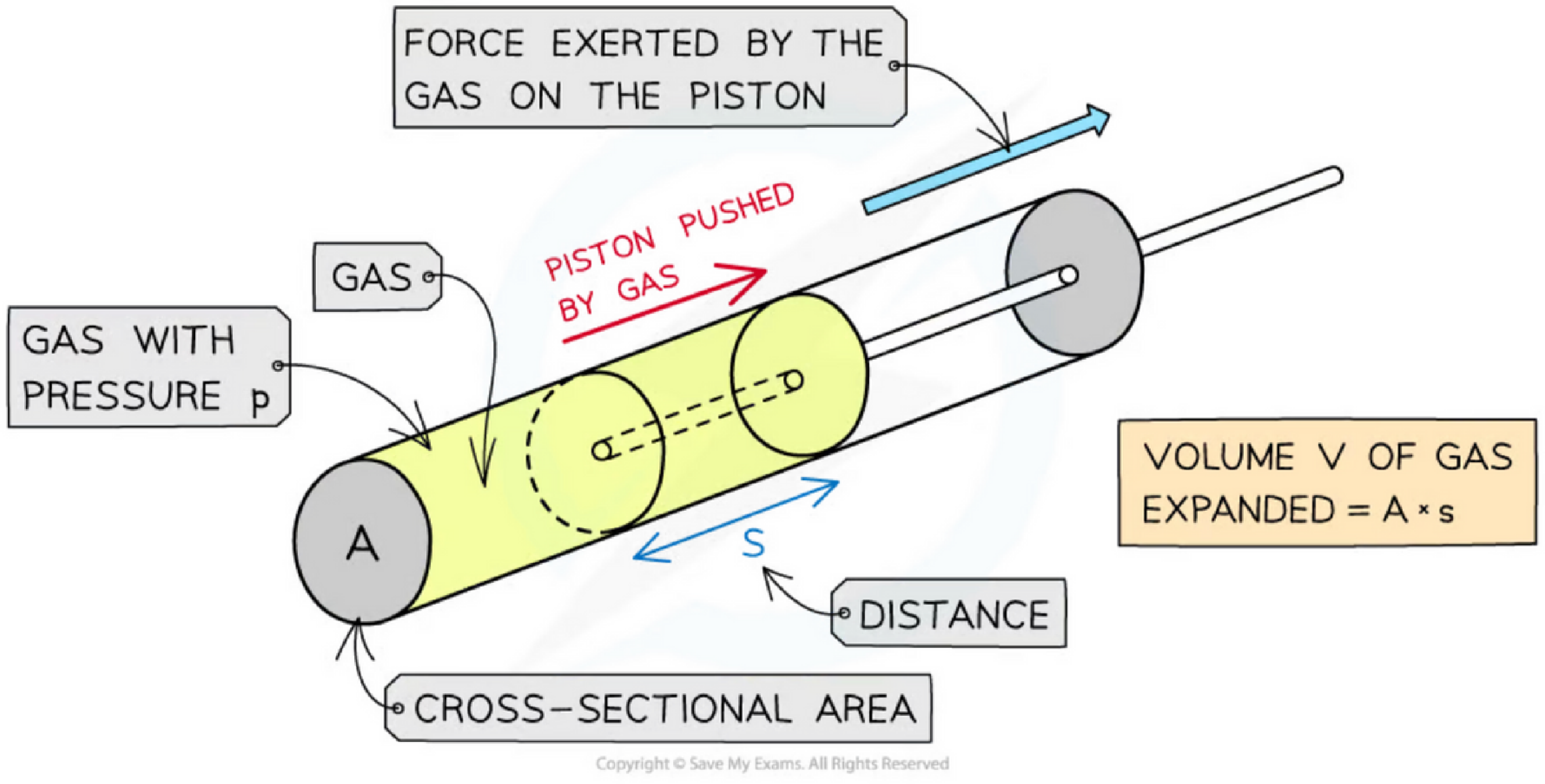
$$W = p\Delta V$$

Where:

- $W$ = work done (J)
- $p$ = external pressure (Pa)
- $V$ = volume of gas ($m^3$)

Gas expands($V\uparrow$) = work is done **by** the gas
Gas compressed($V\downarrow$) = work is done **on** the gas

- Therefore, the gas **does work on the piston**




*The gas expansion pushes the piston a distance s*

# Derivation of work done (by a gas) equation

- The volume of gas is at constant pressure. This means the force $F$ exerted by the gas on the piston is equal to :

$$F = p \times A$$

- Where:
  - $p$ = pressure of the gas (Pa)
  - $A$ = cross-sectional area of the cylinder ($m^2$)

- The definition of work done is:

$$W = F \times s$$

- Where:
  - $F$ = force (N)
  - $s$ = displacement in the direction of force (m)

- The displacement of the gas $d$ multiplied by the cross-sectional area $A$ is the increase in volume $\Delta V$ of the gas:

$$W = p \times A \times s$$

- This gives the equation for the work done when the volume of a gas changes at constant pressure:

$$W = p\Delta V$$

- Where:
  - $\Delta V$ = increase in the volume of the gas in the piston when expanding ($m^3$)

(this equation assume that the **surrounding pressure p does not change as the gas expands**)
-->This will be true if the gas is expanding against the pressure of the atmosphere, which **changes very slowly**

# The First Law of Thermodynamics

-based on the **principle of conservation of energy**

-when energy is put into a gas by heating or doing work on it, its internal energy must increase

The first law of thermodynamics is therefore defined as:

$$\Delta U = q + W$$

Where:

- $\Delta U$ = increase in internal energy (J)
- $q$ = energy supplied to the system by heating (J)
- $W$ = work done on the system (J)

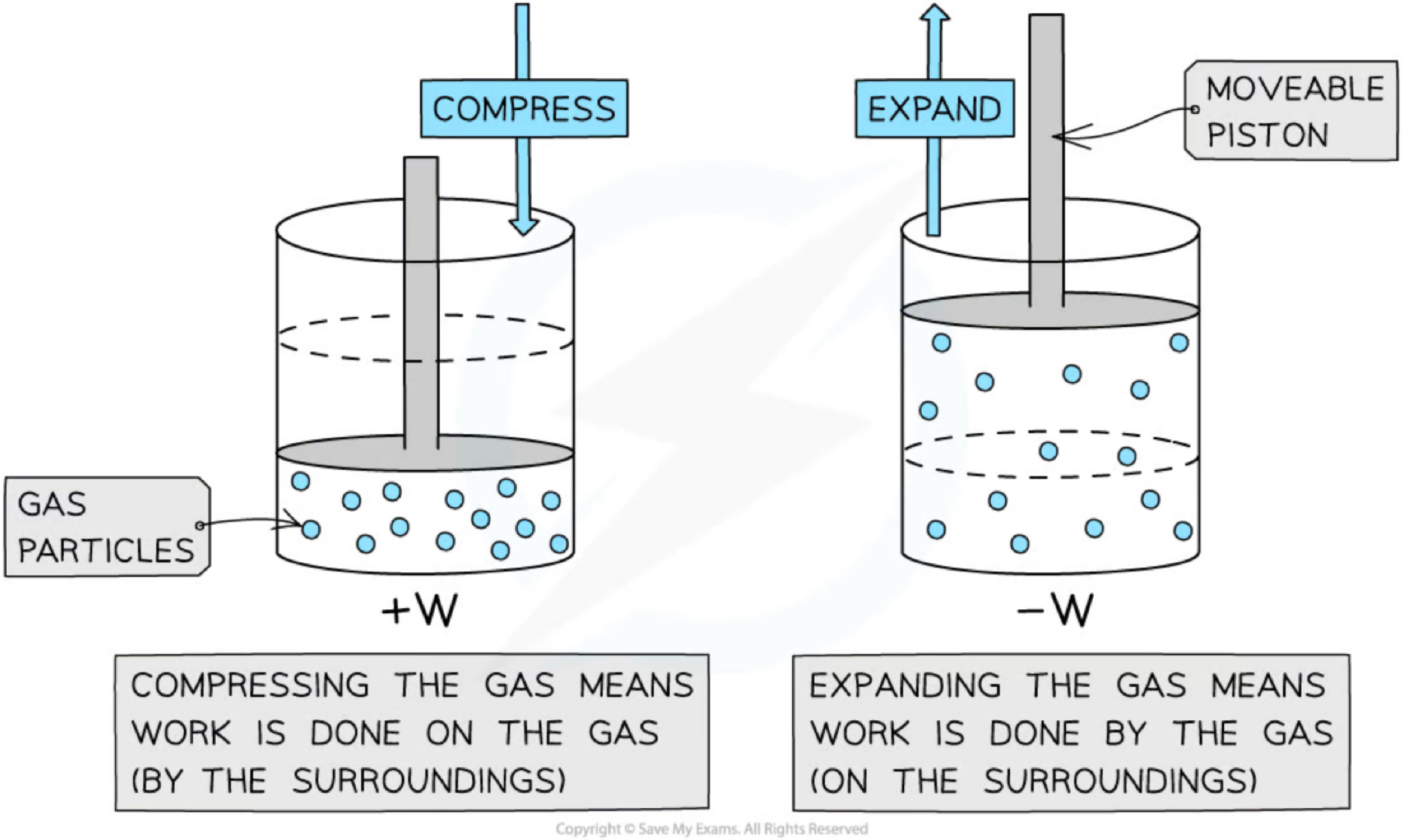
(this equation applies to all situations, not just for gases)

+ΔU:

- **ΔU ↑**
- heat q is **added** to the system
- Work -W is done **on** the system(or by a gas)=gas expands

-ΔU:

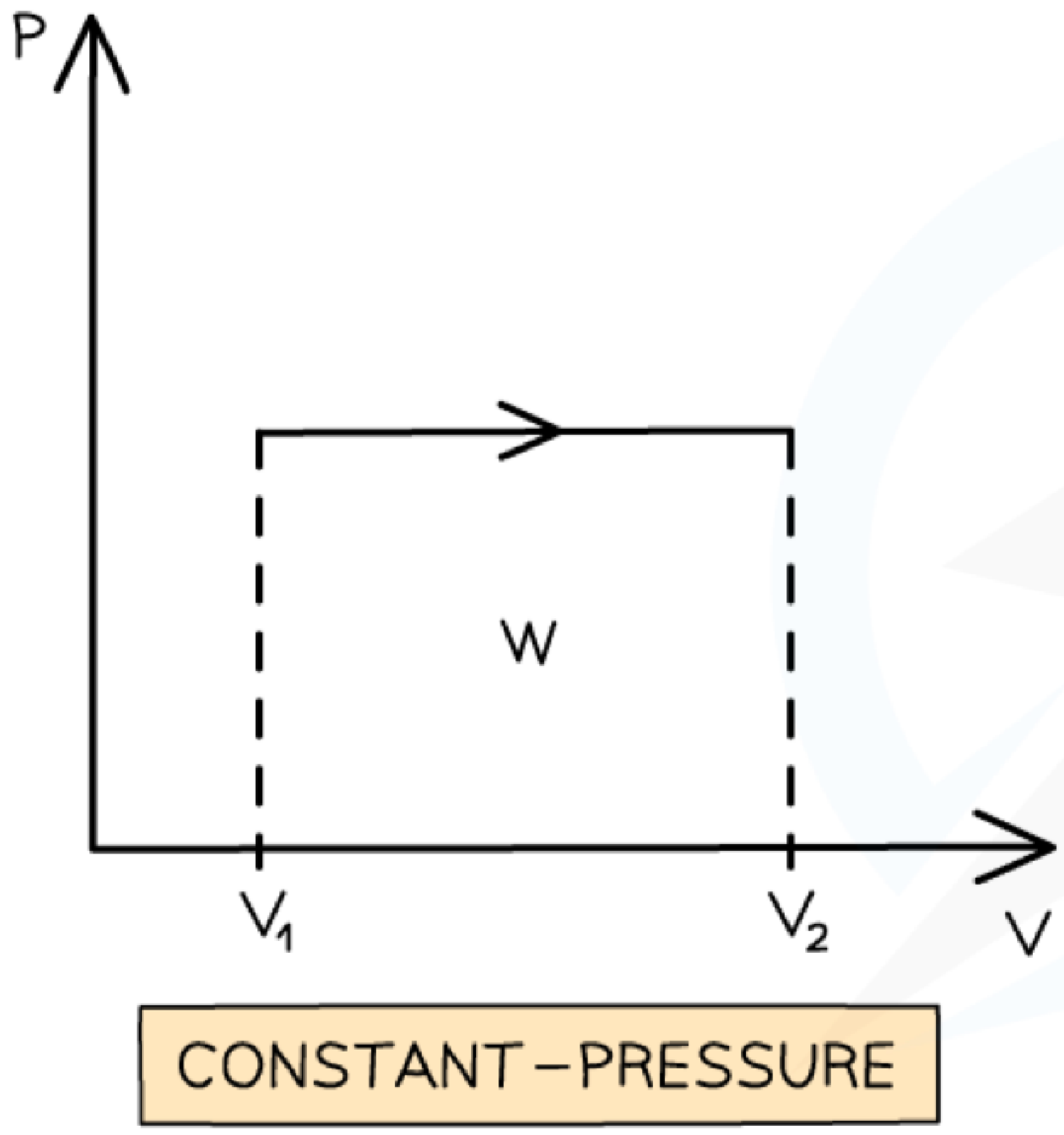
- **ΔU ↓**
- heat q is **taken away** to the system
- Work +W is done **by** the system(or on a gas)=gas compressed

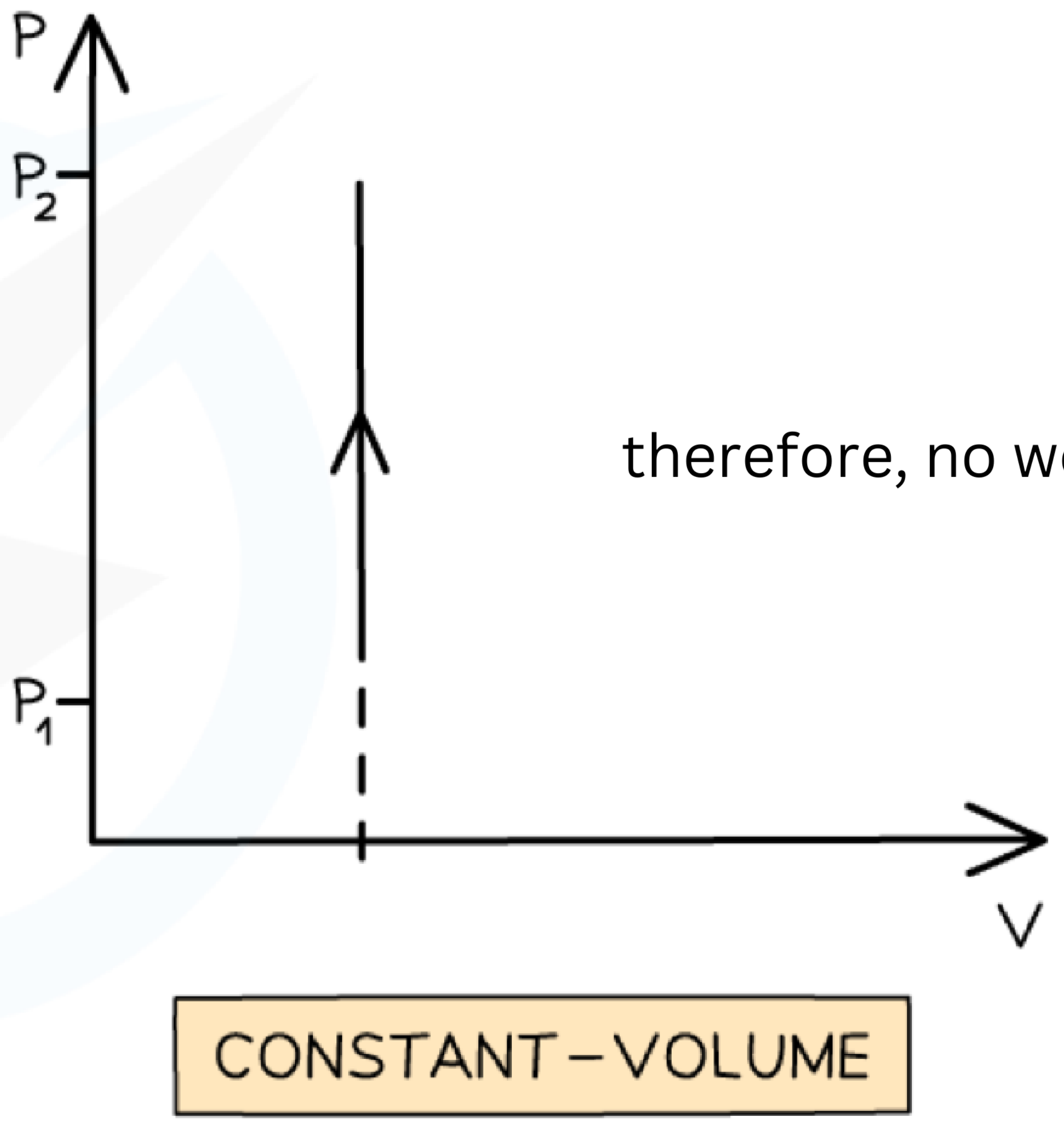



***Positive or negative work done depends on whether the gas is compressed or expanded***

# Graph of Constant Pressure & Volume

Area under graph of pressure against volume = work done of the gas




area=0
therefore, no work is done when volume is constant



Volume↑=expansion=work is done by the gas(-W)=internal energy↓
Volume↓=compress=work is done on the gas(+W)=internal energy↑