THERMO DAY 9: INTERNAL ENERGY & THE FIRST LAW

CED 9.4 · Skill 2.C · FRQ: QQT · target: work ON versus work BY sign errors

BEGIN WITH THE BOUNDARY

WARMUP **Compress an Insulated Syringe — predict first**

A sealed syringe contains room-temperature air. The tip is capped and the barrel is wrapped in foam. Your teacher pushes the plunger inward quickly.

Predict: Does the gas temperature rise, fall, or remain constant? Identify the energy-transfer mechanism.

One Accounting Rule

Internal energy U is the microscopic energy stored in a system. It changes when energy crosses the boundary as heat or work.

$$\Delta U = Q + W_{on}$$

Quantity	Positive when...	Negative when...
Q	heat enters	heat leaves
W_{on}	surroundings do work on system	system does work on surroundings

QUICK A gas absorbs 500 J as heat while expanding and doing 180 J of work on its surroundings. Find Q, W_{on}, and ΔU.

TRANSLATE WORDS INTO SIGNS

Compression and Expansion

Compression usually gives $W_{on} > 0$. Expansion usually gives $W_{on} < 0$. The sign records the direction of energy transfer, not whether work "exists."

WE DO

An insulated gas is compressed; 240 J of work is done on it.

$Q = 0$, $W_{on} = +240$ J

Find ΔU.

YOU DO

A gas releases 320 J as heat while 90 J of work is done on it.

Assign signs and find ΔU.

State change, not process label: ΔU depends only on the initial and final states. Heat and work describe how the change occurred.

REPRESENT Draw an energy-flow diagram for each example: system boundary, arrows for heat and work, and the sign of each term.

IDEAL-GAS INTERNAL ENERGY

For a monatomic ideal gas, $U = \frac{3}{2}nRT = \frac{3}{2}Nk_BT$. Therefore

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

A temperature increase means $\Delta U > 0$; a decrease means $\Delta U < 0$.

WE DO Two moles of a monatomic ideal gas warm by 25 K. Find ΔU. Then, if 900 J enters as heat, find W_{on}. Use $R = 8.31\ \mathrm{J/(mol{\cdot}K)}$.

Do not add 273 to ΔT. Celsius and kelvin temperature intervals have the same numerical size.

CHECK A cyclic process returns to its starting state. What must ΔU equal? What relation must hold between Q_{net} and $W_{on,net}$?

PRACTICE

1. A gas absorbs 720 J as heat and does 260 J of work. Find ΔU.

2. A gas releases 480 J as heat while 150 J of work is done on it. Find ΔU.

3. An insulated gas expands and does 310 J of work. Find Q, W_{on}, and ΔU.

4. A 1.50 mol monatomic ideal gas cools by 40 K. Find ΔU.

5. Fix the claim. "When a gas expands, work is positive because the gas is doing work." Rewrite using this course's W_{on} convention.