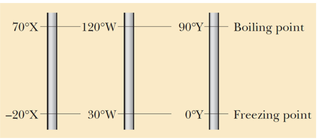
## Temperature Scales

**QUIZ** Check your understanding:

The figure here shows three linear temperature scales with the freezing and boiling points of water indicated. (a) Rank the degrees on these scales by size, greatest first. (b) Rank the following temperatures, highest first: 50°X, 50°W, and 50°Y.




$T' = C_1 T + C_2$

(a) the same

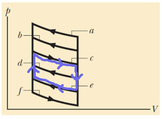
(b) 50°X, 50°Y, 50°W



## The 1st Law of Thermodynamics

- the work is equal to the area under the curve on the p-V diagram between the initial and final points (states); the sign of work depends on the direction of integration
- if the system is taken from some initial state to some final state and then back, it undergoes a thermodynamic cycle; in such case the net work is equal to the sum of positive work done during the expansion and the negative work done during the compression (in absolute value it is equal to the area enclosed in a complete curve)

**QUIZ** Check your understanding:




The $p$-$V$ diagram here shows six curved paths (connected by vertical paths) that can be followed by a gas. Which two of the curved paths should be part of a closed cycle (those curved paths plus connecting vertical paths) if the net work done by the gas during the cycle is to be at its maximum positive value?

enclosed area should be the greatest and positive

C-e



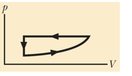
## Special Cases of the 1st Law of Thermodynamics

*The Law:* $\Delta E_{\text{int}} = Q - W$

| Process | Restriction | Consequence |
|---|---|---|
| Adiabatic | $Q = 0$ | $\Delta E_{\text{int}} = -W$ |
| Constant volume | $W = 0$ | $\Delta E_{\text{int}} = Q$ |
| Closed cycle | $\Delta E_{\text{int}} = 0$ | $Q = W$ |
| Free expansion | $Q = W = 0$ | $\Delta E_{\text{int}} = 0$ |

**QUIZ** Check your understanding:

For one complete cycle as shown in the $p$-$V$ diagram here, are (a) $\Delta E_{\text{int}}$ for the gas and (b) the net energy transferred as heat $Q$ positive, negative, or zero?




(a) 0

(b) $Q < 0$



## Work Done by an Ideal Gas ...

Suppose we put an ideal gas in a piston-cylinder arrangement.

**... at constant volume and constant pressure**

- if the **volume** of the gas is **constant**, then **no** work is being done: $W = 0$
- if the volume changes while the **pressure** $p$ of the gas is held **constant**, then: $W = p(V_f - V_i) = p\,\Delta V$

**QUIZ** Check your understanding:

An ideal gas has an initial pressure of 3 pressure units and an initial volume of 4 volume units. The table gives the final pressure and volume of the gas (in those same units) in five processes. Which processes start and end on the same isotherm?

| | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|
| $p$ | 12 | 6 | 5 | 4 | 1 |
| $V$ | 1 | 2 | 7 | 3 | 12 |

12 12 35 12 12

$pV = \text{const}$

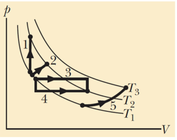
a, b, d, e



## Molar Specific Heats of an Ideal Gas

**QUIZ** Check your understanding:

The figure here shows five paths traversed by a gas on a $p$-$V$ diagram. Rank the paths according to the change in internal energy of the gas, greatest first.




$T_3 > T_2 > T_1$

$\Delta E_{int} \sim \Delta T$

5, 1 & 2 & 3 & 4

the same



## Graphical Summary of Four Gas Processes


**QUIZ** Check your understanding:

Rank paths 1, 2, and 3 according to the energy transfer to the gas as heat, greatest first.

1, 2, 3

| Path | Constant Quantity | Process Type | Some Special Results ($\Delta E_{\text{int}} = Q - W$ and $\Delta E_{\text{int}} = nC_V\Delta T$ for all paths) |
|---|---|---|---|
| 1 | $p$ | Isobaric | $Q = nC_p\Delta T;\ W = p\,\Delta V$ |
| 2 | $T$ | Isothermal | $Q = W = nRT\ln(V_f/V_i);\ \Delta E_{\text{int}} = 0$ |
| 3 | $pV^\gamma$, $TV^{\gamma-1}$ | Adiabatic | $Q = 0;\quad W = -\Delta E_{\text{int}}$ |
| 4 | $V$ | Isochoric | $Q = \Delta E_{\text{int}} = nC_V\Delta T;\ W = 0$ |



## Entropy as a State Function

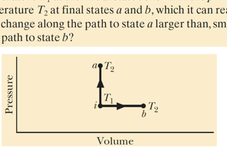
**QUIZ** Check your understanding:

Water is heated on a stove. Rank the entropy changes of the water as its temperature rises (a) from 20°C to 30°C, (b) from 30°C to 35°C, and (c) from 80°C to 85°C, greatest first.

a, b, c

**QUIZ** Check your understanding:

An ideal gas has temperature $T_i$ at the initial state $i$ shown in the $p$-$V$ diagram here. The gas has a higher temperature $T_f$ at final states $a$ and $b$, which it can reach along the paths shown. Is the entropy change along the path to state $a$ larger than, smaller than, or the same as that along the path to state $b$?




$\Delta S_b > \Delta S_a$

smaller