CONCEPT: ENTROPY EQUATIONS FOR THERMODYNAMIC PROCESSES

● Remember: $\Delta S = \frac{Q}{T}$ only works for *isothermal* processes. You'll need more Entropy EQs for other special processes.

EXAMPLE: Calculate the entropy change of 0.25kg of water warming from 20°C to 80°C. (c = 4186 $\frac{J}{kg \cdot K}$)

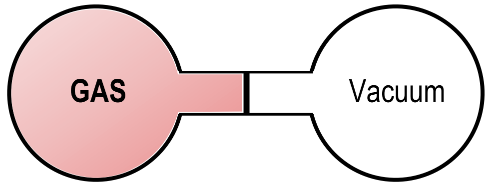
Special Process	ΔS Equation
Isothermal	$\Delta S = \frac{Q}{T}$
Substance changing PHASE (e.g. water ↔ ice)	$\Delta S = \frac{Q}{T} = \frac{mL}{T}$
Substance changing TEMP. (e.g. water from 0°C ↔ 100°C) ● Temperature *not* constant, $\Delta S \neq \frac{Q}{T}$	ΔS = ________
Adiabatic	$Q = 0$, so ΔS = ___
Free Expansion (gas suddenly expands to larger V) ● Sometimes called Adiabatic Free Exp, but **Q ≠ 0**	ΔS = ________
Gas Changing T at Constant V or P	ΔS = ________ OR ΔS = ________

EXAMPLE: 3 moles of a monoatomic gas are cooled from 350K to 300K at constant volume. What is the change in entropy in this process?

GAS TYPE	C_V	C_P
Monoatomic	$\frac{3}{2}R$	$\frac{5}{2}R$
Diatomic	$\frac{5}{2}R$	$\frac{7}{2}R$

PROBLEM: 3 moles of an ideal gas are in the left side of an hourglass-shaped container, separated by a thin barrier. The right side is completely empty, but the volume of the left and right sides are equal. The barrier is suddenly removed, and the gas freely expands into the vacuum. What is the change in entropy?

A) 17.3 J/K
B) 0 J/K
C) –17.3 J/K
D) 49.9 J/K



HEAT ENGINES & ENTROPY

$\Delta E_{int} = 0$

$|W| = |Q_H| - |Q_C|$

$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$

$\Delta S = \frac{Q}{T}$ (isothermal)

$\Delta S_{tot} = \Delta S_1 + \Delta S_2 + \ldots$

$\Delta S = \frac{mL}{T}$ (phase change)

$\Delta S = mc \cdot ln\left(\frac{T_f}{T_i}\right)$ (Temp. change)

$\Delta S = nR \cdot ln\left(\frac{V_f}{V_i}\right)$ (Free Expansion)

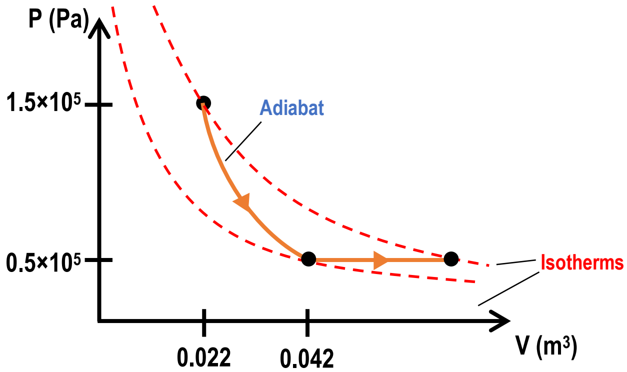
$\Delta S = nC \cdot ln\left(\frac{V_f}{V_i}\right)$ (Ideal gas)

PROBLEM: You fill a hot tub with 195kg of 30°C water and attempt to heat it further by adding 5 kg of boiling water. **a)** Calculate the final temperature of the water. **b)** Assuming the water doesn't exchange heat with the hot tub itself or the air, what is the total change in entropy of the system?

ENTROPY PROBLEMS WITH MULTIPLE OBJECTS
1) Draw diagram
2) Write ΔS_{tot} EQ
3) Calculate ΔS for all obj's exchanging heat
4) Solve for Target

ENTROPY
$T_f = \frac{m_A c_A T_A + m_B c_B T_B + \cdots}{m_A c_A + m_B c_B + \cdots}$
$\Delta S = \frac{Q}{T}$ **(isothermal)**
$\Delta S_{tot} = \Delta S_1 + \Delta S_2 + \ldots$
$\Delta S = \frac{mL}{T}$ **(phase change)**
$\Delta S = mc \cdot ln\left(\frac{T_f}{T_i}\right)$ **(Temp. change)**
$\Delta S = nR \cdot ln\left(\frac{V_f}{V_i}\right)$ **(Free Expansion)**
$\Delta S = nC \cdot ln\left(\frac{V_f}{V_i}\right)$ **(Ideal gas)**

PROBLEM: 0.8 moles of an ideal monoatomic gas is taken through an adiabatic and isobaric process, as shown in the diagram below. What is the total change in entropy?



ENTROPY
$\Delta S = \frac{Q}{T}$ (isothermal)
$\Delta S_{tot} = \Delta S_1 + \Delta S_2 + \ldots$
$\Delta S = \frac{mL}{T}$ (phase change)
$\Delta S = mc \cdot ln\left(\frac{T_f}{T_i}\right)$ (Temp. change)
$\Delta S = nR \cdot ln\left(\frac{V_f}{V_i}\right)$ (Free Expansion)
$\Delta S = nC \cdot ln\left(\frac{T_f}{T_i}\right)$ (Ideal gas)

GAS TYPE	C_V	C_P	γ
Monoatomic	$\frac{3}{2}R$	$\frac{5}{2}R$	1.67
Diatomic	$\frac{5}{2}R$	$\frac{7}{2}R$	1.40