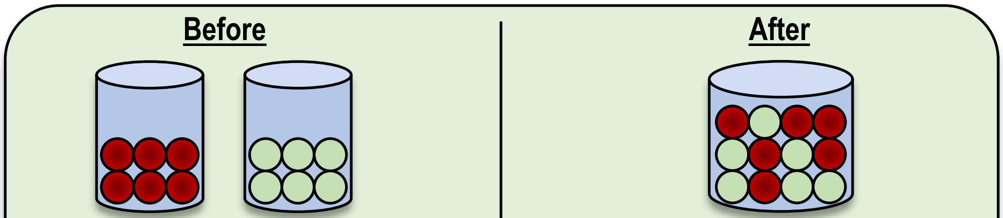
CONCEPT: INTRO TO ENTROPY

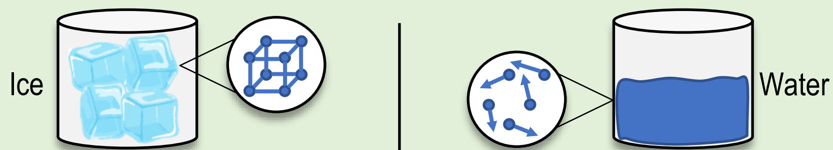
● **Entropy** is often called a measure of "disorder", but a better definition is it's a measure of a system's ____________.



Before	After
[LESS | MORE] random	**[LESS | MORE]** random
[LOWER | HIGHER] Entropy	**[LOWER | HIGHER]** Entropy

● In thermodynamics, entropy measures how randomly a system's __________ is spread out.

- Because things with higher temperatures have more energy, they have ________ "randomness"/entropy.



Ice	Water
[LESS | MORE] random	**[LESS | MORE]** random
[LOWER | HIGHER] Entropy	**[LOWER | HIGHER]** Entropy

● You'll need to calculate the *CHANGE* in entropy in most problems, not the entropy itself.

$$\Delta S = \frac{\quad}{\quad}$$

(ONLY for **isothermal** processes, i.e. $\Delta T = 0$)

- T *must* be in K
- Units: $\frac{J}{K}$

● The sign of ΔS is the same as Q.

- If heat is added (Q > 0), entropy **[INCREASES | DECREASES]**
- If heat is removed (Q < 0), entropy **[INCREASES | DECREASES]**

EXAMPLE: You add 2400 J to a body of water so large that its temperature remains constant at 27°C. Calculate the change in entropy of the water.

EXAMPLE: Calculate the change in entropy of 2 kg of water freezing completely to ice.

PHASE CHANGE
$Q = mL$
$L_{f,water}$ = 3.34×10^5 J/kg·K
$L_{v,water}$ = 2.26×10^6 J/kg·K

PROBLEM: 3 moles of an ideal gas are compressed isothermally at 20°C. During this compression, 1850 J of work is done on the gas. What is the change of entropy of the gas?

A) –24.9 J/K
B) 6.31 J/K
C) –6.31 J/K
D) –9158 J/K

ENTROPY
$\Delta S = \frac{Q}{T}$

PROBLEM: You have a block of ice at 0°C. Heat is added to the ice, causing an increase in entropy of 120J/K. How much ice melts into water in this process?

A) 0.098 kg
B) 0 kg
C) 1.32×10^{-6} kg
D) 1.47×10^{5} kg

ENTROPY
$\Delta S = \frac{Q}{T}$ $L_{f\,(water)}$ = 3.34×10^{5} J/kg

PROBLEM: You're driving a 1,500 kg car at 20m/s when you slam on the brakes and come to a stop. The brakes cool off to the surrounding air, which remains at a constant temperature of 20°C. What is the entropy change in the air?

ENTROPY
$\Delta S = \frac{Q}{T}$

CONCEPT: CALCULATING ENTROPY CHANGES FOR SYSTEMS OF OBJECTS

● In many problems, you'll have to calculate the entropy changes for a *system* of multiple objects, or the universe.

ΔS_{tot} OR $\Delta S_{universe}$ = ________________... _____

Second Law of Thermodynamics – "Entropy" Statement

● It is impossible for any process to cause an overall __________ in the entropy of a system (or the *UNIVERSE*).

- If any part of a system ***decreases*** in entropy, another part *must* ***increase*** in entropy at least the same amount.

● Entropy is sometimes called "Time's Arrow", explains why processes happen irreversibly (Heat transfer, friction, etc..)

- Time "flows" or "moves" in the direction of increasing entropy.

EXAMPLE: 400 J of heat is transferred from a hot reservoir at 200°C to a cold reservoir at 100°C. The reservoirs are so big that this heat exchange has no effect on their temperatures. What is the net change in entropy of the system?

ENTROPY PROBLEMS WITH MULTIPLE OBJECTS
1) Draw diagram **2)** Write ΔS_{tot} EQ **3)** Solve for Target

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

PROBLEM**:** A non-Carnot heat engine operates between a hot reservoir at 610K and a cold reservoir at 320K**.** In a cycle, it takes in 6400 J of heat and does 2200 J of work**.** What is the total change in entropy of the universe over the cycle?

A) 2.6 J/K
B) 9.5 J/K
C) 16.3 J/K
D) –2.6 J/K

ENTROPY PROBLEMS WITH MULTIPLE OBJECTS
1) Draw diagram **2)** Identify objects changing entropy (*e.g. objects, air, environment*) **3)** Write ΔS_{tot} EQ **4)** Plug in values & solve

HEAT ENGINES & ENTROPY
$\Delta E_{int} = 0$ $\lvert W\rvert = \lvert Q_H\rvert - \lvert Q_C\rvert$ $e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$ $\Delta S = \frac{Q}{T}$ $\Delta S_{tot} = \Delta S_1 + \Delta S_2 + \ldots$

PROBLEM: A Carnot engine takes in 2000 J from a hot reservoir at 500K, then expels heat to a cold reservoir at 350K. What is the total change in entropy of the universe over the cycle?

ENTROPY PROBLEMS WITH MULTIPLE OBJECTS

1) Draw diagram
2) Identify objects changing entropy (*e.g. objects, air, environment*)
3) Write ΔS_{tot} EQ
4) Plug in values & solve

HEAT ENGINES & ENTROPY

$\Delta E_{int} = 0$
$|W| = |Q_H| - |Q_C|$
$e = \frac{W}{Q_H} = 1 - \frac{Q_C}{Q_H}$
$\left|\frac{Q_C}{Q_H}\right| = \left|\frac{T_C}{T_H}\right|$ (Carnot only)
$\Delta S = \frac{Q}{T}$
$\Delta S_{tot} = \Delta S_1 + \Delta S_2 + \ldots$

- Because Carnot engines are ideal and perfectly reversible, $\Delta S_{tot,Carnot}$ = ___