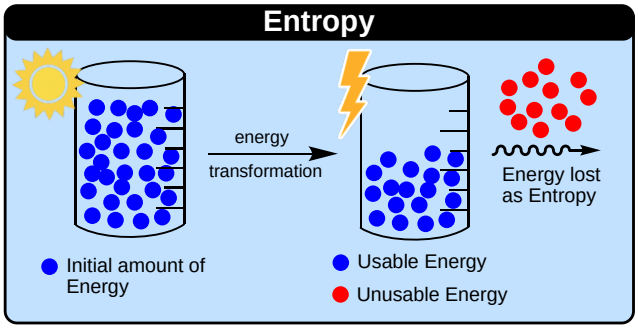
CONCEPT: ENTROPY

- **Entropy (S)** is the measure of _____ (randomness, chaos) in a system, surroundings, and universe.
  - □ Energy is _____ because a system is not able to convert all energy into usable energy.
- **Thermodynamics:** describes relationship between _____, energy, and reaction favorability.
  - □ Recall: *First Law of Thermodynamics* – energy cannot be created nor destroyed but is _____.



- **The Second Law of Thermodynamics:** states that the *Entropy* of the _____ is always _____.
  - □ All _____ reactions involve an increase in Entropy of the universe.

EXAMPLE: The second law of thermodynamics leads us to conclude:

a) the total energy of the universe is constant

b) the disorder of the universe is increasing with the passage of time

c) the total energy of the universe is increasing with time

d) the total entropy of the universe is decreasing with time

Factors Affecting Entropy

- There are ____ main factors that increase Entropy.

Factors Affecting Entropy

1. **Molecular Degrees of Freedom**
   - Ways in which a molecule is free to _____
2. **Number of Arrangements**
   - Molecular complexity: ____ of atoms in a substance
   - Mass
3. **Number of Moles of Substances**

CONCEPT: ENTROPY

Standard Molar Entropy (Sº)

- Entropy possessed by ___ mole of a substance at standard conditions (25ºC, 1 atm).
  - □ Note: different phases of a substance can exist simultaneously at standard conditions; Ex: H_2O (l) vs H_2O (g).

Comparing Standard Molar Entropies

1. When states of matter are different:

Entropy (Sº) _____

2. When states of matter are same:

a. Check **complexity**: ___ complexity, __ Sº

O_2 vs S_8

b. Check **mass**: ___ mass, __ Sº

Br_2 vs I_2

EXAMPLE: Select a substance with greatest molar entropy.

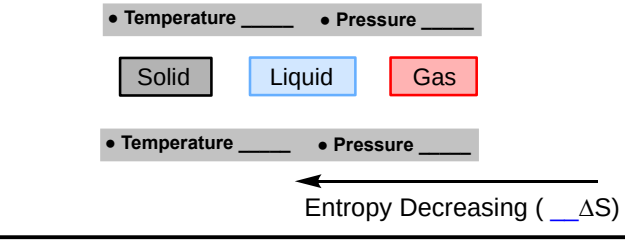
a) P_4 (s) b) H_2O (l) c) NH_3 (g) d) Li_2 (s) e) CO_2 (g) f) SO_3 (g)

Change in Entropy: Physical Changes

- **Entropy change (ΔS):** a measure of _____ or _____ in disorder due to physical or chemical changes.
  - □ Increase in ΔS is due to _____ in *molecular degrees of freedom*.
  - □ _____ the degrees of freedom (molecular motion), _____ the ΔS.

Change in Entropy: Physical

Entropy Increasing (__ΔS)



Entropy Decreasing (__ΔS)

EXAMPLE: Predict how the entropy of the system is affected in the following process:

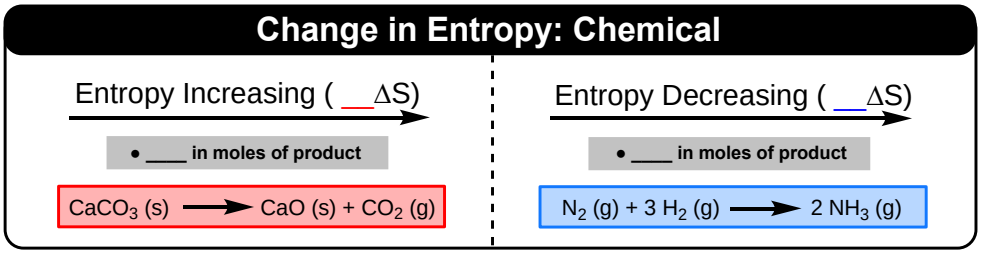
1) CH_4 (g, 125°C) → CH_4 (g, 200°C).

2) $KClO_3$ (s) (7 L container) → $KClO_3$ (l) (3 L container)

CONCEPT: ENTROPY

Change in Entropy: Chemical Changes

- Entropy change of chemical reactions are determined by _____ of moles of products.



EXAMPLE: Which one of the following reactions produces a decrease in the entropy of the system?

a) $KCl\,(s) \rightarrow K^+\,(aq) + Cl^-\,(aq)$

b) $2\,CO\,(g) + O_2\,(g) \rightarrow 2\,CO_2\,(g)$

c) $CH_3OH\,(l) \rightarrow CO\,(g) + 2\,H_2\,(g)$

d) $C_6H_{12}O_6\,(s) + 6\,O_2\,(g) \rightarrow 6\,CO_2\,(g) + 6\,H_2O\,(l)$

PRACTICE: Which reaction is most likely to have a positive ΔS of reaction?

a) $SiO_2\,(s) + 3\,C\,(s) \rightarrow SiC\,(s) + 2\,CO\,(g)$

b) $6\,CO_2\,(g) + 6\,H_2O\,(g) \rightarrow C_6H_{12}O_6\,(s) + 6\,O_2\,(g)$

c) $CO\,(g) + Cl_2\,(g) \rightarrow COCl_2\,(g)$

d) $3\,NO_2\,(g) + H_2O\,(l) \rightarrow 2\,HNO_3\,(l) + NO\,(g)$

PRACTICE: Identify sign of entropy changes for the following processes.

1) freezing water to form ice

2) ideal gas allowed to expand in a closed container at constant T

3) mixing of two gases into one container

4) $NH_2\,(g)\,(1atm) \rightarrow NH_2\,(g)\,(3\,atm)$

5) gas mixture transferred from larger to smaller container

PRACTICE: Select correct statement(s) below:

a) gaseous CO_2 has higher entropy in 2 L container compared to in 5 L container

b) $N_2O\,(g)$ contains higher standard molar entropy then HI (g)

c) $NaHCO_3\,(aq) + HC_2H_3O_2\,(aq) \rightarrow NaC_2H_3O_2\,(aq) + H_2O\,(l) + CO_2\,(g)$ has a negative ΔS

d) evaporation of water at 100ºC involves greater ΔS than evaporation at 112ºC