## **CONCEPT:** ENTROPY

The _____ Law of Thermodynamics states that molecular systems tend to move spontaneously to a state of maximum randomness or disorder.

$$\Delta S_{Universe} = \Delta S_{System} + \Delta S_{Surroundings}$$

This disorder or chaotic behavior is classified as entropy.

**Solid** —Melting or Fusion→ **Liquid** —Vaporization→ **Gas**

**Sublimation**

**Distance between molecules increases as we follow this trend path**

____ △ S _____

**Gas** —Condensation→ **Liquid** —Freezing→ **Solid**

**Deposition**

**Distance between molecules decreases as we follow this trend path**

____ △ S _____

Whenever you need to compare the entropies of different covalent compounds the guidelines below must be followed.

**Phase**

Gas > Aqueous > Liquid > Solid

- As we go from gases to solids the molecules become more organized and less chaotic.

**Microstates**

- The **more** elements in the compound then the **greater** the entropy.

$NO_2(g)$ vs. $NO_3(g)$

$NO_2$ has 3 total elements $NO_3$ has 4 total elements

**Mass**

- The **greater** the mass then the **greater** the entropy.

Xe (g) vs. He (g)

Xe weighs 131 g/mol He weighs 4 g/mol

When you need to compare the entropies of different ionic compounds you must utilize lattice energy.

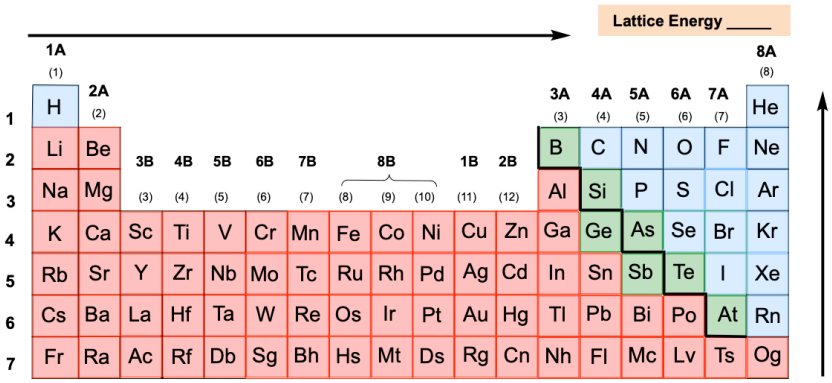
- Lattice Energy represents the energy released when 1 mole of an ionic crystal is formed from its gaseous ions.

**Application**

$$Na^+(g) + Cl^-(g) \rightarrow NaCl(s) \qquad \Delta H = -787 \frac{kJ}{mole}$$

$$\text{Lattice Energy (Electrostatic Energy)} = \frac{|\text{Cation Charge} \cdot \text{Anion Charge}|}{\text{Cation Radius} + \text{Anion Radius}}$$

- The larger the lattice energy then the stronger the ionic bond between the ions.
- Results in: _____ boiling points _____ melting points _____ entropies.



## **PRACTICE:** ENTROPY CALCULATIONS 1

**EXAMPLE 1:** Predict the sign of entropy for each of the following processes?

a) $I_2$ at 90°C and 5.0 atm $\longrightarrow$ $I_2$ at 50°C and 10.0 atm

b) $NH_4Cl(s) \longrightarrow HCl(g) + NH_3(g)$

c) $CH_4(g) + 2\ O_2(g) \longrightarrow CO_2(g) + 2\ H_2O(l)$

**EXAMPLE 2:** When an aqueous solution containing $Al^{3+}$ at 25°C is mixed with an aqueous solution of hydroxide at 25°C an immediate precipitate of insoluble aluminum hydroxide is formed:

$Al^{3+}(aq) + 3\ OH^-(aq) \longrightarrow Al(OH)_3(s)$

| Compound | $Al^{3+}$ | $OH^-$ | $Al(OH)_3$ |
|---|---|---|---|
| $\Delta S_f^\circ \left(\frac{J}{mol \cdot K}\right)$ | -325 | -10.90 | 216 |

The standard reaction enthalpy (ΔH°) of this reaction is -61.33 kJ/mol. Calculate $\Delta S_{total}$ for this reaction.

**PRACTICE:** Which of the following has the greatest entropy, S?

a) 1.00 mole of liquid water at 30° C

b) 1.00 mole of water vapor at 30° C

c) 1.00 mole of regular ice at -10° C

d) 1.00 mole of "dry ice" (solid $CO_2$) at -10° C

e) 1.00 mole of water under 10 atm of pressure at -10° C