ENTROPY & GIBBS FREE ENERGY

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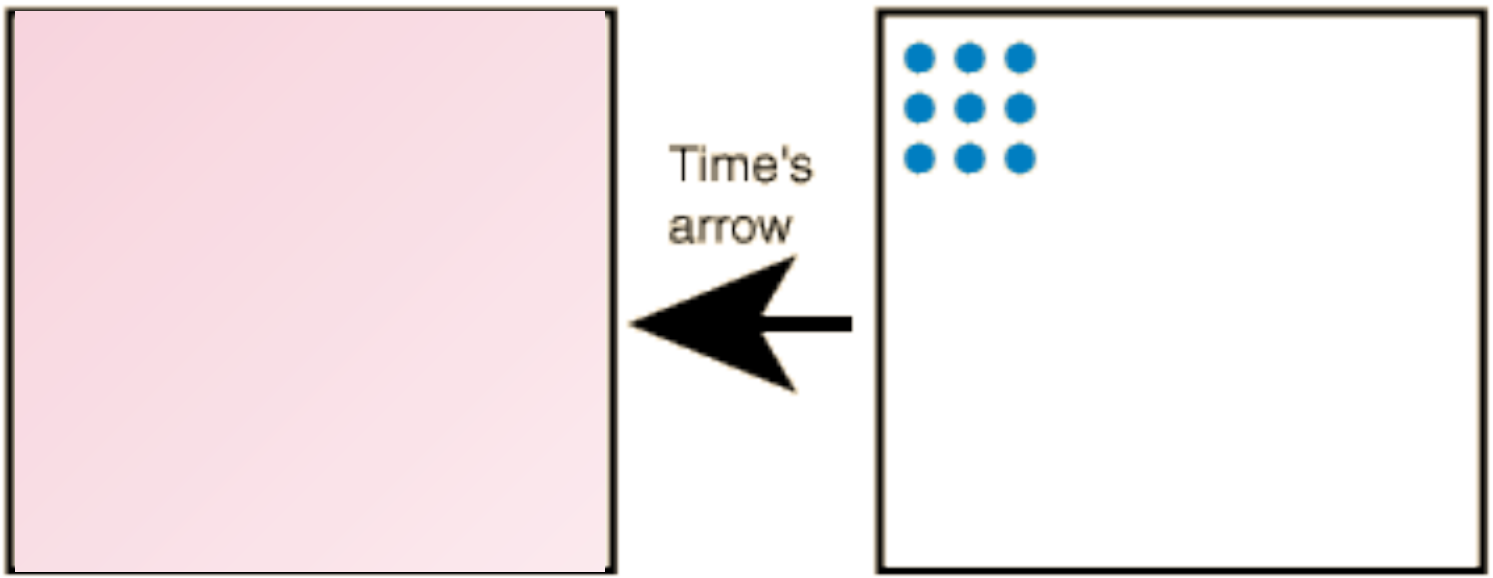
If the particles represent gas molecules at normal temperatures inside a closed container, which of the illustrated configurations came first?



If you tossed bricks off a truck, which kind of pile of bricks would you more likely produce?

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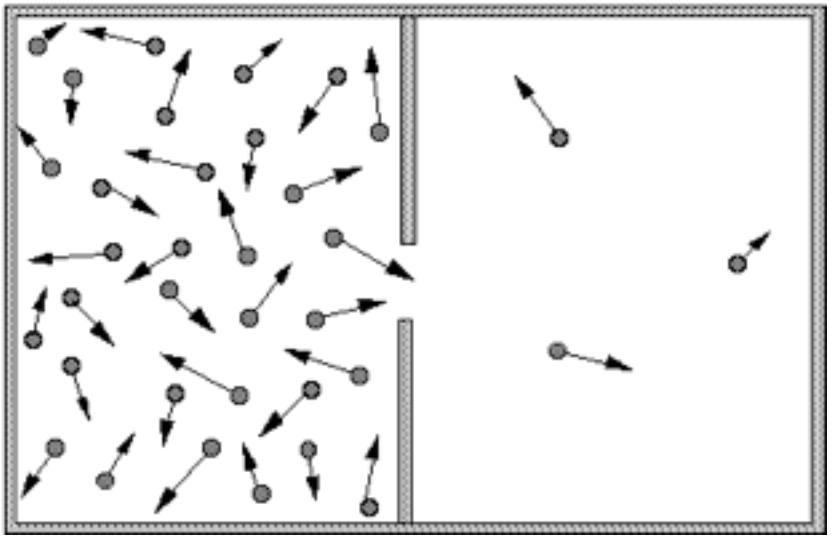

entropy (ΔS)- a measure of disorder or randomness

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SECOND LAW OF THERMODYNAMICS

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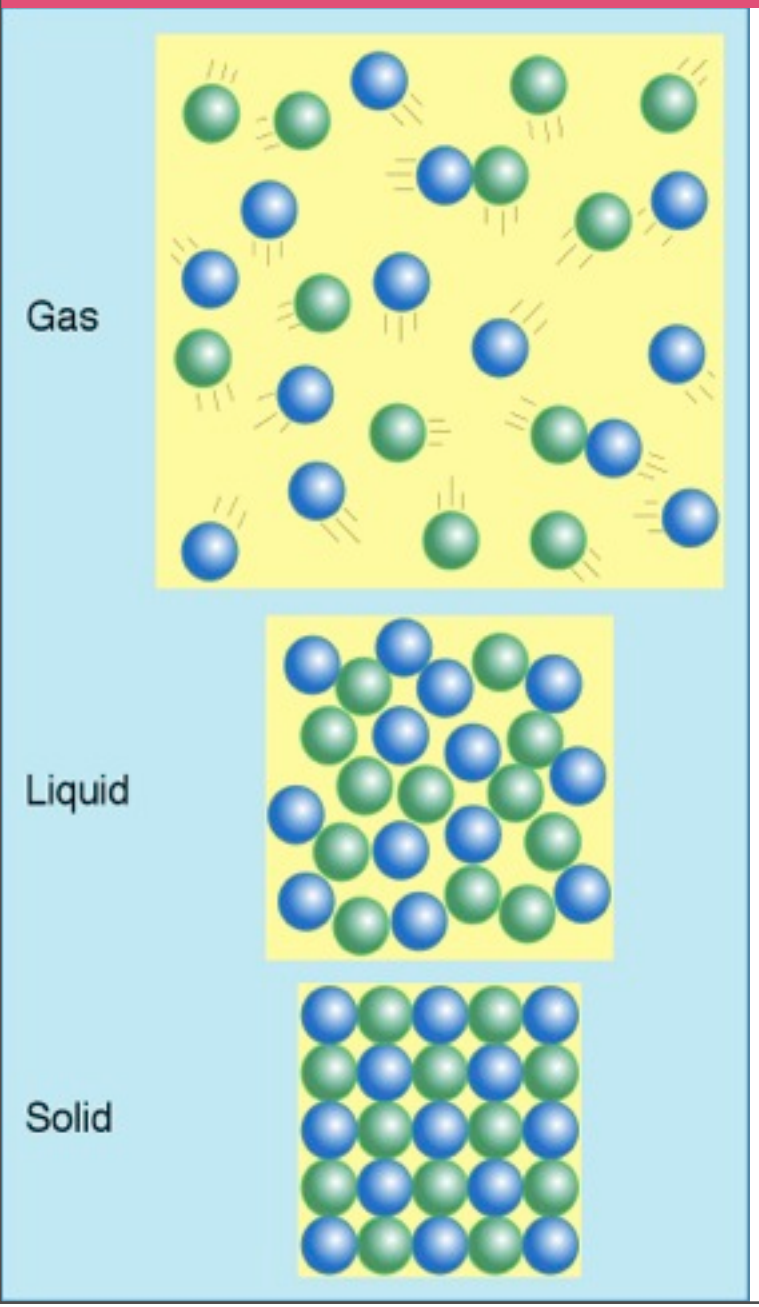

$\Delta S_{solid} \square \Delta S_{liquid} \square \Delta S_{gas}$

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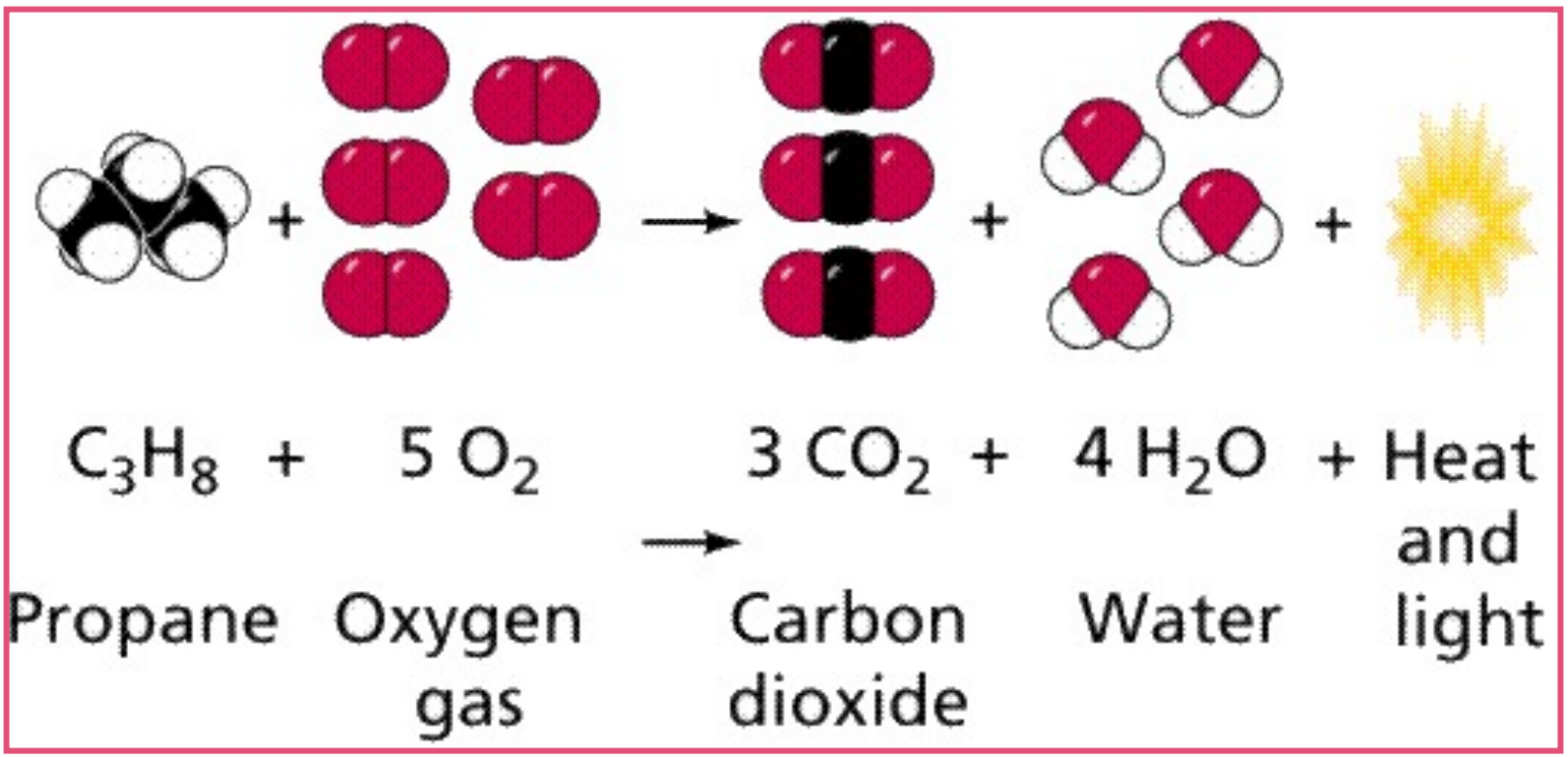
$\Delta S =$

When $S_{products} > S_{reactants}$,



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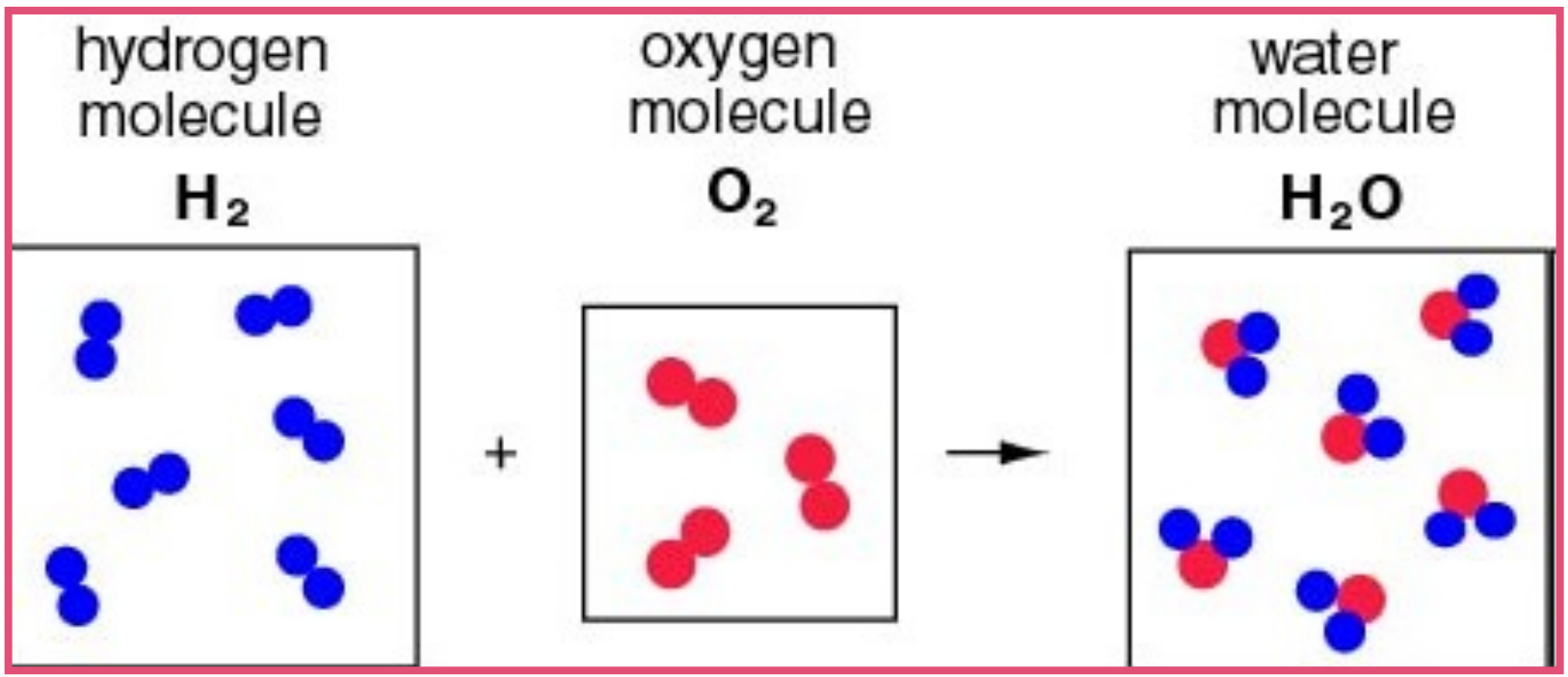
$\Delta S =$

When $S_{products} < S_{reactants}$,



ENTROPY AND GIBBS FREE ENERGY

Predict the sign of ΔS for the following reactions:

$H_{2(g)} \rightarrow 2\ H_{(g)}$

$2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)}$

$2\ NO_{2(g)} \rightarrow N_2O_{4(g)}$

$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$

condensation of steam to liquid

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Predict the sign of ΔS for the following reactions:

sublimation of dry ice

$2\ NH_{3(g)} \rightarrow N_{2(g)} + 3\ H_{2(g)}$

$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)}$

$2\ H_2O_{(l)} \rightarrow 2\ H_{2(g)} + O_{2(g)}$

$NaCl_{(s)} \rightarrow NaCl_{(aq)}$

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To solve for the entropy change of a reaction at standard conditions (SATP):

Don’t forget that the equations should be multiplied by the appropriate factor, as necessary.

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Example 1: Calculate the standard entropy of the following reaction:

$$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$$

$S^o_{C_2H_{6(g)}} = 229.5 J/mol \cdot K$

$S^o_{C_2H_{4(g)}} = 219.8 J/mol \cdot K$

$S^o_{H_{2(g)}} = 130.6 J/mol \cdot K$

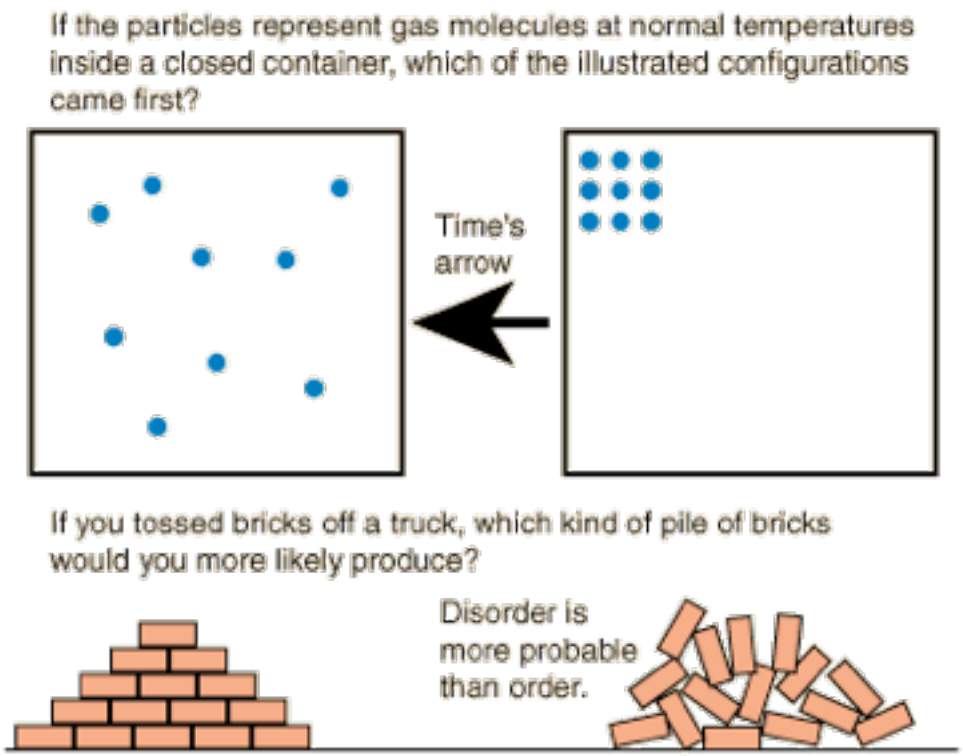
Do you think this reaction will spontaneously occur at room temperature?

ENTROPY AND GIBBS FREE ENERGY

Example 1: Calculate the standard entropy of the following reaction:

$$C_2H_{4(g)} + H_{2(g)} \rightarrow C_2H_{6(g)}$$

Do you think this reaction will spontaneously occur at room temperature?



Since molecules tend to become more and more disordered, and this reaction results in more organization (fewer moles of gas), then this reaction is most likely not spontaneous at room temperature

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How are entropy and enthalpy related?

$$\Delta G^o = \Delta H^o - T\Delta S^o$$

Gibbs free energy is the energy that is available to do useful work.

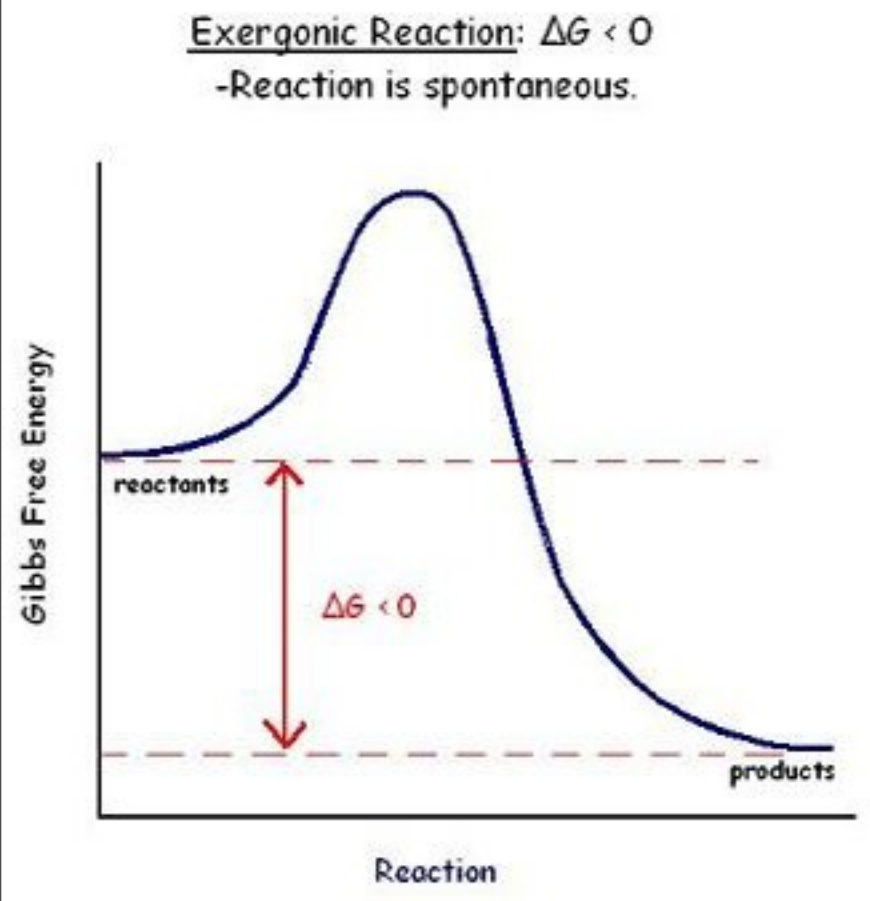
A reaction will spontaneously occur if

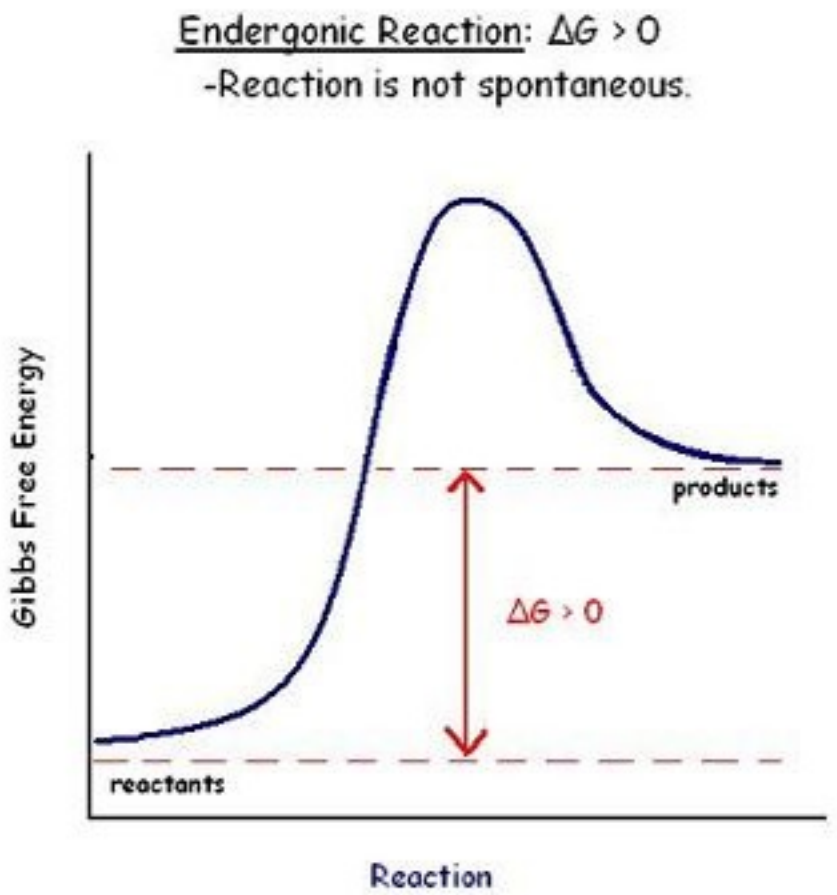
A reaction will NOT spontaneously occur if

ENTROPY AND GIBBS FREE ENERGY

A reaction will spontaneously occur if

A reaction will NOT spontaneously occur if





ENTROPY AND GIBBS FREE ENERGY

Reactions with a negative ΔH and positive ΔS all have a negative ΔG

$$\Delta G^o = \Delta H^o - T\Delta S^o$$
$$(-) \; - T(+)$$

Exergonic & spontaneous at all temperatures

Reactions with a positive ΔH and negative ΔS all have a positive ΔG

$$\Delta G^o = \Delta H^o - T\Delta S^o$$
$$(+) \; - T(-)$$

Endergonic & nonspontaneous at all temperatures will only occur with the continuous input of energy

ENTROPY AND GIBBS FREE ENERGY

Reactions with a negative ΔH and negative ΔS all have a negative ΔG

$$\Delta G^o = \Delta H^o - T\Delta S^o$$
$$(-) - T(-)$$

ΔG will be negative in temperature conditions where the value of TΔS is lower than the value of ΔH. Thus the reaction is spontaneous only at lower temperatures.

Example: $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

This reaction is spontaneous at temperatures below 786ºC (1059K) and nonspontaneous above this temperature

ENTROPY AND GIBBS FREE ENERGY

Reactions with a positive ΔH and positive ΔS all have a negative ΔG

$$\Delta G^o = \Delta H^o - T\Delta S^o$$
$$(+) - T(+)$$

ΔG will be negative in temperature conditions where the value of TΔS is higher than the value of ΔH. Thus the reaction is spontaneous only at higher temperatures.

Example: $H_2O_{(s)} \rightarrow H_2O_{(l)}$

This reaction is spontaneous at temperatures above 0ºC (273K) and nonspontaneous below this temperature

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Summary: Spontaneous and Non-Spontaneous Reactions

	$\Delta H>0$	$\Delta H<0$
$\Delta S>0$		
$\Delta S<0$		

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Example 2: Is the following reaction spontaneous at SATP?

$$CO(NH_2)_{2(aq)} + H_2O_{(l)} \rightarrow CO_{2(g)} + 2NH_{3(g)}$$

$\Delta H^o = 119kJ$

$\Delta S^o = 354.8J/K$

$T = 25^oC$

$\Delta G^o =$

Therefore this reaction is at SATP

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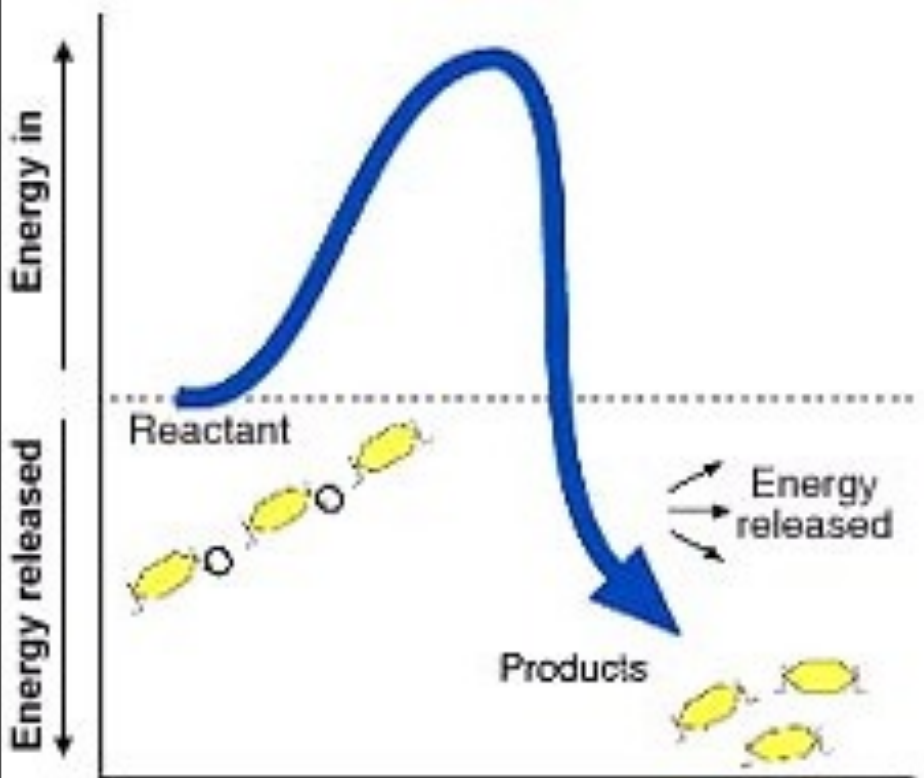
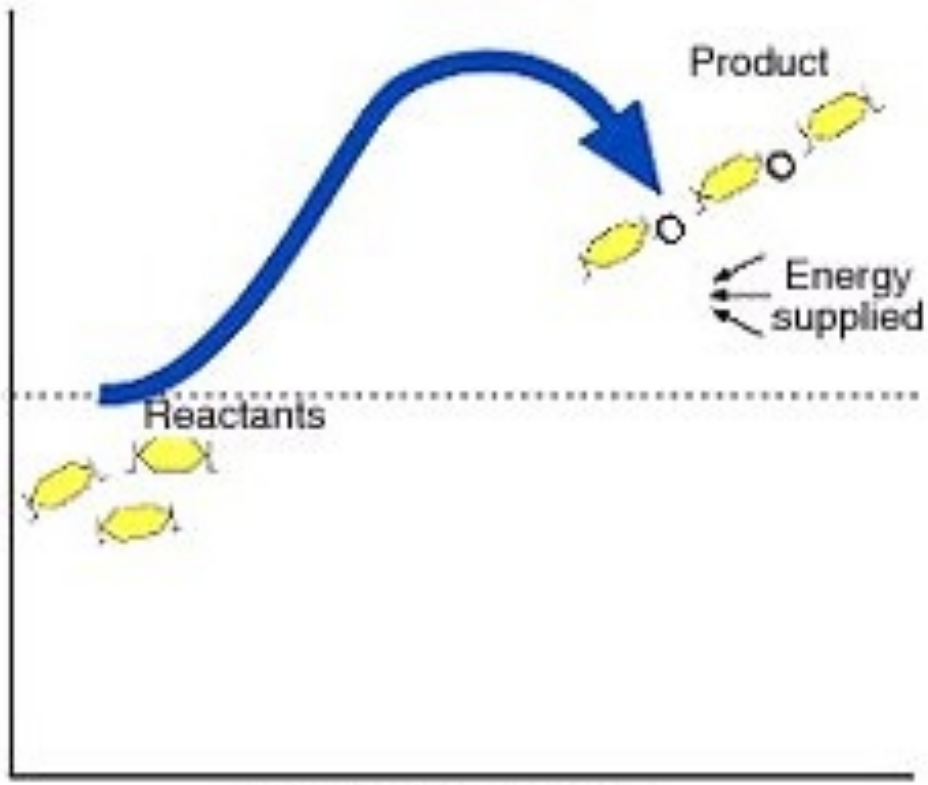


Exergonic Reaction

Products have less energy than reactants
Energy released
Spontaneous
Entropy increases



Endergonic Reaction

Products have more energy than reactants
Energy required
Not spontaneous
Entropy decreases