WJEC (Wales) Chemistry A-level

Topic 3.7 - Entropy and Feasibility of Reactions

Flashcards

What is entropy?

What is entropy?

Entropy, S, of a system is a measure of the freedom possessed by particles within it. It is often referred to as a measure of disorder. The higher the entropy, the more freedom the particles possess so the more disordered the system.

What is the general relation between natural processes and entropy?

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All natural processes will always tend towards increasing entropy because they are more energetically stable when there is more disorder. Therefore there is an increase in entropy, towards a maximum, for all natural changes.

How does physical state affect entropy?

How does physical state affect entropy?

The particles in a solid have much less freedom and disorder than those in a gas. Entropy increases across the physical states as follows:

$$S(solid) < S(liquid) < S(gas)$$

Define standard entropy of a substance, $S^{\ominus}$

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The entropy of one mole of the substance under standard conditions.

Give the equation for calculating the overall entropy change from absolute entropy values

Give the equation for calculating the overall entropy change from absolute entropy values

$$\Delta S = S_{final} - S_{initial}$$

where S_{final} can be found by adding up the standard entropy values of all the products and $S_{initial}$ can be found by adding up all the standard entropy values of the reactants.

What are the units of entropy?

What are the units of entropy?

$J\ K^{-1} mol^{-1}$

Calculate the entropy change of the following reaction, using the standard entropy values given:

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

$S^{\ominus}[H_{2(g)}] = 131\ JK^{-1}mol^{-1}$

$S^{\ominus}[N_{2(g)}] = 192\ JK^{-1}mol^{-1}$

$S^{\ominus}[NH_{3(g)}] = 192\ J\ K^{-1}mol^{-1}$

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$\Delta S = S_{final} - S_{initial}$

$= [2(192)] - [3(131) + 192]$

$= 384 - 585 = -201\ J\ K^{-1}mol^{-1}$

What does it mean if a reaction is ‘spontaneous’?

What does it mean if a reaction is ‘spontaneous’?

A spontaneous process is capable of taking place without needing to be driven by an outside source of energy.

Is a reaction with positive or negative entropy change more likely to be spontaneous?

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A reaction with positive entropy change is more likely to occur spontaneously because reactions will naturally try to increase the amount of disorder.

Is a reaction with positive or negative enthalpy change more likely to be spontaneous?

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Negative enthalpy change.

Exothermic reactions are more likely to be spontaneous than endothermic reactions.

What does it mean for a reaction to be ‘feasible’?

What does it mean for a reaction to be ‘feasible’?

For a reaction to be feasible at a given temperature, the reaction must occur spontaneously. This means no external energy input is required for the reaction to take place.

Explain why the following reaction is feasible despite being endothermic

$$NaHCO_{3(s)} + H^{+}_{(g)} \rightarrow Na^{+}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

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$$NaHCO_{3(s)} + H^+_{(g)} \rightarrow Na^+_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

There is an increase in entropy because the reaction produces carbon dioxide gas and water. Gases and liquids have a higher entropy than solids since they are more disordered. The reaction is also favoured because there is an increase in the number of moles, which increases entropy. Therefore, the increase in entropy overcomes the fact that it is an endothermic reaction, making the reaction feasible.

What is Gibbs free energy change?

What is Gibbs free energy change?

Gibbs free energy change, ΔG, is a measure used to predict whether a reaction is feasible.

Give the equation for Gibbs free energy change

Give the equation for Gibbs free energy change

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

ΔG-free energy change ($kJ\ mol^{-1}$)
ΔH-enthalpy change ($kJ\ mol^{-1}$)
T-temperature (K)
ΔS-entropy change ($J\ K^{-1}\ mol^{-1}$)

How does the feasibility of a reaction relate to Gibbs free energy change?

How does the feasibility of a reaction relate to Gibbs free energy change?

For a reaction to be feasible, Gibbs free energy change (ΔG) must be negative or zero.

Calculate the free energy change for the following reaction at 298 K:

$$MgCO_{3(g)} \rightarrow MgO_{(s)} + CO_{2(g)}$$

$\Delta H^{\theta} = 117\ kJ\ mol^{-1}$, $\Delta S^{\theta} = 175\ J\ K^{-1}\ mol^{-1}$

Calculate the free energy change for the following reaction at 298 K: $MgCO_{3(g)} \rightarrow MgO_{(s)} + CO_{2(g)}$

$\Delta H^{\ominus} = 117\ kJ\ mol^{-1}$, $\Delta S^{\ominus} = 175\ J\ K^{-1}\ mol^{-1} = 0.175\ kJ\ K^{-1}\ mol^{-1}$

Notice that $\Delta S^{\ominus}$ needs dividing by 1000 to get the all of the units in the same form.

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

$= (117) - (298 \times 0.175) = 64.9\ kJ\ mol^{-1}$ (3 s.f.)

Consider an endothermic reaction and explain the effect of T and ΔS on the feasibility of the reaction

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

For an endothermic reaction, ΔH is positive.

- If ΔS is negative then ΔG is always positive so in this case the reaction is not feasible at any temperature.
- If ΔS is positive then the reaction will only be feasible at a high enough temperature, when $T\Delta S > \Delta H$.

Consider an exothermic reaction and explain the effect of T and ΔS on the feasibility of the reaction

Consider an exothermic reaction and explain the effect of T and ΔS on the feasibility of the reaction

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

For an exothermic reaction, ΔH is negative.

- If ΔS is positive then ΔG is always negative so in this case the reaction is feasible at any temperature.
- If ΔS is negative then the reaction will only be feasible at lower temperatures, when $T\Delta S < \Delta H$.

What are the key factors which tell you the sign of the entropy change of a reaction?

What are the key factors which tell you the sign of the entropy change of a reaction?

Number of moles in the reaction: More moles made in the product means there is an increase in entropy.

Changes of state: Changing to a state where the particles have a higher kinetic energy leads to an increase in entropy.

What are the limitations of using Gibbs free energy change as an indicator of whether a reaction will occur?

What are the limitations of using Gibbs free energy change as an indicator of whether a reaction will occur?

Gibbs free energy only indicates if a reaction is feasible. It does not take into account the rate of reaction or the activation energy. Even if a reaction is theoretically feasible, it might still require a very high activation energy or be so slow that effectively no reaction is occurring.

How can you calculate the temperature at which a reaction becomes feasible?

How can you calculate the temperature at which a reaction becomes feasible?

A reaction becomes feasible when ΔG is zero. The temperature at which this occurs can be found by rearranging the free energy equation:

$$\Delta H - T\Delta S = 0 \longrightarrow T = \frac{\Delta H}{\Delta S}$$