

# Absolute Entropy and Entropy change

Entropy is seen all around us in the sciences; in physics, chemistry, astronomy, and more. In our general review of entropy, we saw that entropy is a property of a system, and that we can use entropy to observe and deduce where energy goes relative to a system.

But entropy isn't a static property. Just like the systems themselves that it describes, entropy changes. Not only that, but different characteristics within a system. In this lesson, we're going to cover these higher-level qualities that entropy plays a role in.

## Overview

- In this lesson, we'll cover how to calculate entropy change within a system.
- Then, we'll learn what absolute entropy is, and how we calculate it as well.
- Afterwards, we'll step through a table of standard entropies for common substances, and elaborate on what trends we see.
- Lastly, we'll tie everything together with a few examples, and cover how each of these concepts are thermodynamically related.

## Calculating Standard Entropy Change

In our introductory lesson on entropy, we briefly discussed how to calculate the total change in entropy by subtracting a product's entropy from the reactants' entropy. If you want to see examples on how this is done, you can see our lesson on Entropy here. As a reminder, the formula looks like this:

$$\Delta S^\circ = \sum n\Delta S^\circ_{\text{products}} - \sum n\Delta S^\circ_{\text{reactants}}$$

This formula takes advantage of the fact that we're working with standard entropies. Recall that the entropy values that are used are at a standard temperature and pressure: 298 K and 1 atm, respectively. Because of this, we can use the formula above to deduce the total change in entropy for a reaction.

In the previous lesson, we went through a few simple examples where we take some given entropies, plug them into the formula, and solve for the total change in entropy for the system. If you would like to see these examples, refer to that lesson. However, questions that involve entropy on the AP exam often require you to use the formula correctly, and more about *applying* the formula when it comes to concepts you've already learned. To drive this point home, let's look at an example problem you might see on the AP exam.

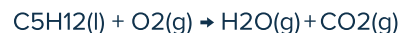
### Example

Find the total standard entropy change when liquid pentane undergoes a total combustion reaction to completion. Use the standard entropy values from this lesson to help you.

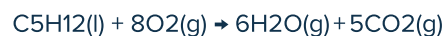
### Explanation:

We know that a combustion reaction always involves the products water and carbon dioxide. We can also deduce that pentane has the formula  $C_nH_{(2n+2)}$ . We also know that, lastly, combustion reactions always use oxygen gas as a reactant. Therefore, we have





After balancing, we have a chemical reaction that looks like this.



Then, we use our overall standard entropy change formula in the following formula.

$$\Delta S^\circ = \sum n\Delta S^\circ_{\text{products}} - \sum n\Delta S^\circ_{\text{reactants}} \Delta S^\circ = [(6 \text{ mol H}_2\text{O}(\text{g}) * 188.8 \text{ JK}^*\text{mol}) + (5 \text{ mol CO}_2(\text{g}) * 213.8 \text{ JK}^*\text{mol})] - [(1 \text{ mol C}_5\text{H}_{12}(\text{l}) * 269.2 \text{ JK}^*\text{mol})]$$

This means that our final answer for this problem is 296.7 J/K. This problem is a good example of an AP Chemistry question. It covers different types of reactions (how combustion reactions work), balancing chemical equations, and how to calculate overall standard entropy change. AP Chemistry entropy problems won't always be as simple as plugging values into a formula.

## Absolute Entropy

Insofar, we've been working with standard entropies that have been set to 298 K and 1 atm to allow for easy comparison. You have heard of the concept of **absolute zero**, which is the coldest conceivable temperature: 0 K. At this temperature, all entropy is zero. Chemists exploit the fact that entropy and temperature are related, and conceived of the measurement of absolute entropy.

### Definition

**Absolute entropy** is the total amount of entropy acquired when a pure substance is warmed from absolute zero to a specific temperature.

Recall that standard entropies are standardized at 298 K. This means that standard entropy is really just the absolute entropy of a substance at 298 K. The matter of measuring heat capacity continuously as the object in question is heated from absolute zero to the desired temperature is the key.

### Deep dive

Absolute entropy can be determined by integrating an experimentally determined function,  $C(T)$ , which describes the heat capacity divided by the current temperature.

$$S_{\text{abs}} = \int_0^T \frac{C(T)}{T} dT$$

This uses integration, which is beyond the scope of what AP Chemistry tests.

Therefore, calculating the absolute entropy of a substance isn't on the AP exam. However, knowing the definition of absolute entropy is useful for understanding the concept.



## Table of Common Standard Entropies

Some molecules are more commonly dealt with in AP Chemistry than others. In order to help, here's a table of standard entropies. *Substances are assumed to be in gaseous form unless otherwise stated.*

Molecule	Standard Entropy (J/K)
C (graphite)	5.7
CH <sub>4</sub>	186.3
C <sub>2</sub> H <sub>6</sub>	229.6
C <sub>5</sub> H <sub>12</sub> (l)	263.5
C <sub>5</sub> H <sub>12</sub>	348.0
C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> (glucose)	212.0
CO	197.7
CO <sub>2</sub>	213.8
H <sub>2</sub>	130.7
H <sub>2</sub> O(l)	69.9
H <sub>2</sub> O	188.8
He	126.2
N <sub>2</sub>	191.6
NH <sub>3</sub>	192.5
O <sub>2</sub>	205.2

## Entropy and Thermodynamics

By this point in your study of AP Chemistry, you should have a cursory understanding of the three laws of thermodynamics. I relating everything we've learned to the three laws paints a picture that's easier to comprehend.

Insofar, over the past two lessons, we've learned that entropy is a measure of general randomness or disorder within a system. Entropy can be used to predict the direction of a process. In reality, all we're doing with these indicators is measuring the properties of particles through a system is based off of that.

Next, we learned about how there are standard entropies that have been standardized to a common temperature and pressure to allow for an easier method of calculating entropy change throughout a reaction. We also learned that you can measure the amount of entropy needed to heat an object from absolute zero (where entropy and temperature are equal to zero) to a desired temperature. 298 K is its standard entropy.



Now that we've briefed you on all of this, where do the three laws come into play?

**The first law of thermodynamics** states that energy can't be created or destroyed. This is the law of energy conservation, with as much to the concept of entropy as the other two laws do.

**The second law of thermodynamics** states that the energy and matter of the universe is constantly dispersing and becoming entropy of the universe is always increasing. This means that we can derive that nature tends towards disorder through the : on [Entropy](#).

**The third law of thermodynamics** states that a system's entropy is zero at a temperature of absolute zero (0 K). This law implies that as a system increases the entropy. From this law, we're able to derive the definition of absolute entropy.

Hopefully, breaking down the three laws of thermodynamics helps to solidify your understanding on why entropy functions the way they do. Your understanding of entropy shouldn't be!

## Absolute Entropy and Entropy Change - Key takeaways

- In this lesson, we covered how to calculate entropy change within a system.
- Afterwards, we learned what absolute entropy is, and how to calculate it as well.
- Then, we walked through a table of standard entropies for common substances, and explained the trends.
- Lastly, we tied everything together with a few examples, and covered how each of these concepts are thermodynamic.

