ExamFitter

examfitter.com · Free AP Chemistry quizzes, revision notes and worksheets

Topic 9.2: Absolute Entropy and Entropy Change

Revision Notes · AP Chemistry

UNIT 9 · THERMODYNAMICS AND ELECTROCHEMISTRY

On ExamFitter.com: Topic 9.2 Quiz · Topic 9.2 Worksheet · Unit 9: All Topics · AP Chemistry Home

Entropy Has a Real Zero

The third law sets the zero. A perfect crystal at 0 K has exactly one microstate, so its entropy is exactly zero. That gives entropy something enthalpy never has: a true starting point, fixed by nature rather than by agreement.

Absolute, not relative. Because the zero is real, the entropy of a substance at 298 K can be measured upward from 0 K and tabulated as an absolute value: the standard molar entropy, S°, in J mol^{-1} K^{-1}. Every S° value for a pure substance at 298 K is positive.

Elements are not zero. Standard enthalpies of formation set elements in their standard states to zero by convention. Entropies do not: S°(H_2, g) = 131 J mol^{-1} K^{-1} and S°(C, s) = 5.7 J mol^{-1} K^{-1} are real, positive values. Treating an element's S° as zero is the defining error of this topic.

Reading a Table of S° Values

Phase dominates. Gases carry far larger S° values than liquids, and liquids exceed solids: the phase order of Topic 9.1 with numbers attached. S°(H_2O, l) = 70 J mol^{-1} K^{-1}, while water vapor sits far higher.

Size and complexity add. Within one phase, a larger, more complex molecule has the greater S°: more atoms mean more ways to distribute energy. C_2H_6(g) exceeds CH_4(g), which exceeds He(g), and O_3(g) exceeds O_2(g).

Temperature is built into the table. S° values are quoted at 298 K. Warming any substance raises its entropy, so the same substance at a higher temperature would carry a larger value. Fixing one temperature lets every reaction be compared on the same basis.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Solids are small and close together. Solid values cluster low: Al(s) = 28, Fe(s) = 27, $CaCO_3$(s) = 93 J mol^{-1} K^{-1}. A reaction that only swaps one set of solids for another has a ΔS° that is usually small, whichever sign it takes.

The Calculation: Products Minus Reactants

The formula. Multiply each S° by its coefficient n in the balanced equation, total the products, total the reactants, and subtract. The equation must be balanced first, because the coefficients are the multipliers.

$\Delta S^\circ = \Sigma nS^\circ(\text{products}) - \Sigma nS^\circ(\text{reactants})$

The order is fixed. Products minus reactants, the same direction as the state function change below. Subtracting the other way flips every sign and turns correct arithmetic into a wrong answer.

$\Delta S = S(\text{final}) - S(\text{initial})$

The equation as written owns the value. Reverse a reaction and ΔS° changes sign: ammonia decomposition has ΔS° = +199 J mol^{-1} K^{-1} where the synthesis has −199. Halve every coefficient of the synthesis and ΔS° halves too, from −199 to −99.5 J mol^{-1} K^{-1}. Always calculate for the equation in front of you.

$2\ NH_3(g) \rightarrow N_2(g) + 3\ H_2(g)$

Check the Sign Against Topic 9.1

Predict first, compute second. Count gas moles and name the phases before touching the table. Ammonia synthesis takes four moles of gas to two, so ΔS° must be negative; the table gives −199 J mol^{-1} K^{-1}. The carbonate reaction below makes a gas from a solid, so ΔS° must be positive; the table gives +161 J mol^{-1} K^{-1}. Agreement is expected; disagreement means a coefficient, a phase or the subtraction order has gone wrong.

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Size tells a story too. Losing two or three moles of gas produces values in the hundreds: forming liquid water gives −327 J mol^{-1} K^{-1}. An all-solid reaction gives tens: the thermite reaction gives −38 J mol^{-1} K^{-1}.

Gases appearing or vanishing dominate. A reaction that releases a gas from condensed phases lands positive and large, and one that buries gas into a liquid or solid lands negative and large. Only when no gas appears or disappears should a small answer be expected.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

When the gas count does not change. Then the count makes no prediction beyond "no large effect from gas moles", and the tabulated values decide. The reaction below has two moles of gas on each side, yet its ΔS° is +167 J mol^{-1} K^{-1} (see Example 4), because the product carries a much larger S° than the reactants it replaces. The sign check guards against blunders; the sum is the authority.

$H_2(g) + I_2(g) \rightarrow 2\ HI(g)$

Joules, Not Kilojoules

Two unit systems side by side. ΔH° values are tabulated in kJ mol^{-1}, ΔS° values in J mol^{-1} K^{-1}. The same quantity can appear in either: −0.199 kJ mol^{-1} K^{-1} is exactly −199 J mol^{-1} K^{-1}.

Why it will matter. Later topics combine ΔH° and ΔS° in a single expression, and the combination only works in matching units. A ΔS° left in joules beside a ΔH° in kilojoules corrupts the result by a factor of 1000. Convert before the two ever meet: kilojoules to joules, multiply by 1000; joules to kilojoules, divide by 1000.

Worked Examples

Example 1: $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$. S° values: H_2 = 131, O_2 = 205, $H_2O(l)$ = 70 J mol^{-1} K^{-1}. Products: 2(70) = 140. Reactants: 2(131) + 205 = 467. ΔS° = 140 − 467 = −327 J mol^{-1} K^{-1}. Three moles of gas become a liquid, so a large negative value is expected, and −327 fits.

Example 2: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$. S° values: $CaCO_3$ = 93, CaO = 40, CO_2 = 214 J mol^{-1} K^{-1}. Products: 40 + 214 = 254. Reactants: 93. ΔS° = 254 − 93 = +161 J mol^{-1} K^{-1}. A gas appears where none was, so the positive sign is right.

Example 3: $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$. S° values: N_2 = 192, H_2 = 131, NH_3 = 193 J mol^{-1} K^{-1}. Products: 2(193) = 386. Reactants: 192 + 3(131) = 585. ΔS° = 386 − 585 = −199 J mol^{-1} K^{-1}. Four moles of gas become two, so the negative sign is expected.

Example 4: $H_2(g) + I_2(g) \rightarrow 2\ HI(g)$. S° values: H_2 = 131, I_2 = 116, HI = 207 J mol^{-1} K^{-1}. Products: 2(207) = 414. Reactants: 131 + 116 = 247. ΔS° = 414 − 247 = +167 J mol^{-1} K^{-1}. The gas count is unchanged, yet the value is large and positive, because each mole of HI carries far more entropy than the reactants.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Traps That Cost Marks in Topic 9.2

"Elements have S° = 0." That is enthalpy-of-formation thinking. Every element in its standard state has a positive S°; leaving H_2 out of a sum destroys the calculation.

Forgetting a coefficient. In Example 1, using one H_2 instead of two gives $2(70) - (131 + 205) = -196$ J mol^{-1} K^{-1}. The formula was right and the answer is still wrong.

Subtracting backwards. Reactants minus products returns +327 for Example 1. If the sign contradicts the gas count and the phases, the subtraction order is the first suspect.

Mixing joules and kilojoules. -0.199 kJ mol^{-1} K^{-1} and -199 J mol^{-1} K^{-1} are the same quantity. Read the unit on every value before it enters a sum.

Judging by the biggest single value. In the reaction below, the product has the largest single S° in the equation, 186 J mol^{-1} K^{-1}, yet $\Delta S° = 186 - (5.7 + 2 \times 131) = -81.7$, about -82 J mol^{-1} K^{-1}. Two moles of gas disappear into one, and the reactants' total, not the biggest number, decides.

$C(s) + 2\ H_2(g) \rightarrow CH_4(g)$

Key Relationships to Remember

- Third law: a perfect crystal at 0 K has S = 0, which makes entropy an absolute quantity
- S°, the standard molar entropy at 298 K, has units J mol^{-1} K^{-1} and is positive for every pure substance
- Elements in their standard states have positive S° values, unlike ΔH°f, which is zero for them by convention
- $\Delta S° = \Sigma nS°(\text{products}) - \Sigma nS°(\text{reactants})$; balance the equation first, then multiply each S° by its coefficient
- Reversing a reaction flips the sign of ΔS°; scaling the equation scales ΔS° by the same factor
- Sign check from Topic 9.1: more gas produced means $\Delta S° > 0$, fewer gas moles means $\Delta S° < 0$, all-solid changes are small
- S° rises from solid to liquid to gas, and with molecular size and complexity within a phase
- ΔS° is reported in J mol^{-1} K^{-1} while ΔH° is in kJ mol^{-1}; multiply kJ by 1000 to get J before combining them

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Continue Revising

Topic 9.2 Quiz: Absolute Entropy and Entropy Change

Topic 9.2 Worksheet

Unit 9: All Topics

© 2026 ExamFitter.com · Free AP Chemistry revision notes