ExamFitter

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

Topic 9.2: Absolute Entropy and Entropy Change

Worksheet · AP Chemistry

UNIT 9 · THERMODYNAMICS AND ELECTROCHEMISTRY

On ExamFitter.com: Topic 9.2 Revision Notes · Topic 9.2 Quiz · Previous Worksheet: Topic 9.1 · Next Worksheet: Topic 9.3 · Unit 9: All Topics · AP Chemistry Home

How to Use This Worksheet

Work in order. Section A checks the ideas: the third law, absolute entropy, the formula and its units. Section B practices the calculation itself: six sums using one consistent data set, including a reversed equation, a halved equation and two wrong answers to diagnose. Section C is exam style: a full prediction-then-calculation problem, a reaction with no usable table, and a ranking problem with a claim to judge.

Reference facts: every S° value you need is printed inside the question that uses it, in J mol^{-1} K^{-1} at 298 K. The values form one consistent set across the whole sheet: $H_2(g)$ = 131, $N_2(g)$ = 192, $O_2(g)$ = 205, $NH_3(g)$ = 193, HI(g) = 207, $I_2(g)$ = 116, $SO_2(g)$ = 248, $SO_3(g)$ = 257, $H_2O(l)$ = 70, $CO_2(g)$ = 214, $CH_4(g)$ = 186, C(s) = 5.7, $CaCO_3(s)$ = 93, CaO(s) = 40, Al(s) = 28, Fe(s) = 27, $Fe_2O_3(s)$ = 87, $Al_2O_3(s)$ = 51, all in J mol^{-1} K^{-1}. Use the values as printed, with the phase as printed.

One working habit ties the sheet together: predict, then compute, then compare. Count gas moles and name the phases to predict the sign, and the rough size, before opening the sum. Then run $\Delta S^\circ = \Sigma nS^\circ(\text{products}) - \Sigma nS^\circ(\text{reactants})$, with every coefficient applied. If the computed sign contradicts the prediction, the arithmetic is wrong somewhere, and the traps are always the same three: a missed coefficient, a backwards subtraction, a unit slip between joules and kilojoules.

The answer key gives the full working for every part. Attempt every question before looking at it.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Section A: Recall and Concepts

A1. (a) State the third law of thermodynamics. (b) Explain why the third law makes standard molar entropies absolute values rather than values measured from an arbitrary zero. (c) State the units of a standard molar entropy.

A2. (a) $S^\circ(H_2, g) = 131$ J mol^{-1} K^{-1}, even though hydrogen is an element in its standard state. Explain why the value is not zero. (b) Contrast this with the standard enthalpy of formation of $H_2(g)$. (c) The tabulated S° of graphite is 5.7 J mol^{-1} K^{-1}. A student enters 0 for carbon in an entropy sum "because it is an element". State the size of the error this introduces, per mole of carbon in the equation.

A3. (a) Write the equation that gives ΔS° of a reaction from standard molar entropies, defining every symbol. (b) State the two things that must be done before the subtraction can be run. (c) State how ΔS° changes if a reaction is written in reverse, and how it changes if every coefficient in the equation is doubled.

A4. Judge each claim, giving a reason. (a) "A very ordered solid has a negative standard molar entropy." (b) "If ΔS° for a reaction is -199 J mol^{-1} K^{-1}, then ΔS° for the reverse reaction is also -199 J mol^{-1} K^{-1}." (c) "A change of -0.242 kJ mol^{-1} K^{-1} is smaller than a change of -199 J mol^{-1} K^{-1}." (d) "Because S° values are in joules and ΔH° values are in kilojoules, the two can never be used in the same calculation."

© 2026 ExamFitter.com · Free AP Chemistry worksheets

A5. (a) Which has the greater standard molar entropy, $H_2O(l)$ or $H_2O(g)$? Give the reason. (b) Which has the greater standard molar entropy, $O_2(g)$ or $O_3(g)$? Give the reason. (c) Rank He(g), $CH_4(g)$ and $C_2H_6(g)$ by standard molar entropy, smallest first, naming the feature that decides the order. (d) S° (Al, s) = 28 and S°(Fe, s) = 27 J mol^{-1} K^{-1}. State what the closeness of these two values suggests about the size of ΔS° for a reaction that only rearranges solids.

Section B: Core Practice

B1. S° values: $H_2(g)$ = 131, $I_2(g)$ = 116, HI(g) = 207 J mol^{-1} K^{-1}. (a) Calculate ΔS° for $H_2(g) + I_2(g) \rightarrow 2$ HI(g). (b) State Δn(gas) for this reaction. (c) Explain why the calculated value is not close to zero even though the gas count is unchanged.

B2. S° values: $N_2(g)$ = 192, $H_2(g)$ = 131, $NH_3(g)$ = 193 J mol^{-1} K^{-1}. (a) Calculate ΔS° for $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$. (b) Without redoing the sum, state ΔS° for $2\ NH_3(g) \rightarrow N_2(g) + 3\ H_2(g)$, and the rule you used. (c) Without redoing the sum, state ΔS° for the synthesis equation with every coefficient halved, and the rule you used.

B3. S° values: $SO_2(g)$ = 248, $O_2(g)$ = 205, $SO_3(g)$ = 257 J mol^{-1} K^{-1}. (a) Predict the sign of ΔS° for $2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$ from the gas count alone. (b) Calculate ΔS°. (c) State whether the calculation agrees with the prediction, and what a disagreement would have told you.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

B4. S° values: $H_2(g)$ = 131, $O_2(g)$ = 205, $H_2O(l)$ = 70 J mol^{-1} K^{-1}. (a) Calculate ΔS° for 2 $H_2(g)$ + $O_2(g)$ → 2 $H_2O(l)$. (b) A student obtains −196 J mol^{-1} K^{-1} for the same reaction. Find the error in the student's working. (c) A second student obtains +327 J mol^{-1} K^{-1}. Find the error in that working.

B5. (a) S° values: $CaCO_3(s)$ = 93, $CaO(s)$ = 40, $CO_2(g)$ = 214 J mol^{-1} K^{-1}. Calculate ΔS° for $CaCO_3(s)$ → $CaO(s)$ + $CO_2(g)$, and state the feature of the reaction that fixes its sign before any arithmetic. (b) S° values: C(s) = 5.7, $H_2(g)$ = 131, $CH_4(g)$ = 186 J mol^{-1} K^{-1}. Calculate ΔS° for C(s) + 2 $H_2(g)$ → $CH_4(g)$, to the nearest whole number. (c) In (b) the product has the largest single S° in the equation, yet ΔS° is negative. Explain.

B6. S° values: Al(s) = 28, $Fe_2O_3(s)$ = 87, Fe(s) = 27, $Al_2O_3(s)$ = 51 J mol^{-1} K^{-1}. (a) Calculate ΔS° for 2 Al(s) + $Fe_2O_3(s)$ → 2 Fe(s) + $Al_2O_3(s)$. (b) Explain why this value is so much smaller than the values found in B3 and B4. (c) Of all seven reactions calculated in Section B, state which has the ΔS° closest to zero, and the structural feature it shares with the reaction in (a).

Section C: Exam Style

C1. S° values: $CH_4(g)$ = 186, $O_2(g)$ = 205, $CO_2(g)$ = 214, $H_2O(l)$ = 70 J mol^{-1} K^{-1}. For $CH_4(g)$ + 2 $O_2(g)$ → $CO_2(g)$ + 2 $H_2O(l)$: (a) predict the sign of ΔS°, and whether it should be small or large, from the gas count and the phases. (b) Calculate ΔS°. (c) Express the answer to (b) in kJ mol^{-1} K^{-1}. (d) A student argues ΔS° should be positive "because CO_2 has a larger S° than the CH_4 it replaces". Judge the argument.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

C2. Consider Mg(s) + 2 HCl(aq) → $MgCl_2$(aq) + H_2(g). No S° values for the aqueous species are included in this sheet's data set. (a) Predict the sign of ΔS° and give the particle-level reason. (b) Explain why the prediction in (a) can be made securely without a table calculation. (c) The equation is rewritten doubled, 2 Mg(s) + 4 HCl(aq) → 2 $MgCl_2$(aq) + 2 H_2(g). State what happens to ΔS°, and why stating the equation alongside any ΔS° value is essential.

C3. (a) Rank these substances from smallest to largest standard molar entropy: He(g), H_2O(l), CH_4(g), C_2H_6(g). (b) Justify the position of each substance in the order. (c) A student places H_2O(l) above He(g), arguing "a water molecule is more complex than a single helium atom, and complexity raises entropy". Judge the argument. (d) Explain why none of the four substances in (a) can have S° = 0 at 298 K.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Answer Key

A1. (a) The entropy of a perfect crystalline solid at absolute zero (0 K) is zero. (b) The third law provides a genuine zero of entropy, fixed by nature. Entropies at 298 K are measured upward from that zero, so each tabulated S° is the total accumulated entropy of the substance, an absolute value. Enthalpy has no such natural zero, which is why enthalpies are tabulated as changes from a conventional reference instead. (c) J mol^{-1} K^{-1}, joules per mole per kelvin.

A2. (a) Entropy is absolute: at 298 K the hydrogen molecules hold real, accumulated entropy, gathered as the sample is warmed from the third law zero at 0 K. Nothing in the definition sets an element to zero; the value is measured, and it is 131 J mol^{-1} K^{-1}. (b) $\Delta H°f(H_2, g) = 0$, but only by convention: enthalpies of formation are defined relative to the elements, so each element in its standard state is assigned zero. The two zeros have different status, one a bookkeeping choice, the other absent because entropy needs no such choice. (c) The error is the full 5.7 J mol^{-1} K^{-1} per mole of carbon: the sum is understated on whichever side the carbon sits by 5.7 for each mole, because an actual tabulated contribution has been replaced by nothing.

A3. (a) $\Delta S° = \Sigma nS°(\text{products}) - \Sigma nS°(\text{reactants})$, where S° is the standard molar entropy of each substance, n is its coefficient in the balanced equation, and Σ means the terms are added over all products and over all reactants separately before the subtraction. (b) The equation must be balanced, and each S° must be multiplied by its coefficient (and matched to the correct phase) before the two totals are formed. (c) Reversed: ΔS° changes sign, keeping the same size. Doubled: ΔS° doubles, keeping the same sign, because every term in both sums doubles.

A4. (a) False. S° is absolute and accumulated from S = 0 at 0 K; warming only adds entropy, so every pure substance at 298 K has $S° > 0$. Ordered solids have small S° values, never negative ones. (b) False. Reversing a reaction swaps products and reactants in the formula, which flips the sign: the reverse of −199 is +199 J mol^{-1} K^{-1}. (c) False. −0.242 kJ mol^{-1} K^{-1} = −242 J mol^{-1} K^{-1}, which is a larger change than −199 J mol^{-1} K^{-1}. Convert the unit before comparing the numbers. (d) False. The two are combined in later work on spontaneity; the unit difference is a conversion step, not a barrier. Convert ΔS° to kJ mol^{-1} K^{-1} (divide by 1000) or ΔH° to J mol^{-1} (multiply by 1000) and the calculation proceeds.

A5. (a) $H_2O(g)$. In the gas the particles move freely through the whole volume; in the liquid they are confined together, so the gas has far more microstates and the greater S°. (b) $O_3(g)$. Both are gases, so size and complexity decide: ozone has more atoms, more bonds and more ways to distribute energy than O_2. (c) $He(g) < CH_4(g) < C_2H_6(g)$. All are gases, so the order follows molecular size and complexity: a single atom, then five atoms, then eight atoms. (d) It suggests ΔS° will be small. Reactions among solids trade one set of low, similar S° values for another, so the two sums nearly cancel and only a small difference survives, of either sign.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

B1. (a) $\Delta S^\circ = [2 \times S^\circ(HI)] - [S^\circ(H_2) + S^\circ(I_2)] = 2(207) - (131 + 116) = 414 - 247 = +167$ J mol^{-1} K^{-1}. (b) $\Delta n(\text{gas}) = 0$: two moles of gas on each side. (c) The gas count rules out a large change driven by gas moles, but it does not fix the value at zero: the individual S° values decide once the count is level. Here each mole of HI carries 207 J mol^{-1} K^{-1} against 131 and 116 for the reactants it replaces, so the products total far more than the reactants and ΔS° is clearly positive. The count is a first check; the sum is the authority.

B2. (a) $\Delta S^\circ = [2 \times S^\circ(NH_3)] - [S^\circ(N_2) + 3 \times S^\circ(H_2)] = 2(193) - [192 + 3(131)] = 386 - (192 + 393) = 386 - 585 = -199$ J mol^{-1} K^{-1}. (b) +199 J mol^{-1} K^{-1}. Reversing a reaction swaps the two sums in the formula, which changes the sign and nothing else. (c) −99.5 J mol^{-1} K^{-1}. Scaling every coefficient scales every term of both sums by the same factor, so ΔS° scales with the equation: $-199 \times \tfrac{1}{2} = -99.5$.

B3. (a) Negative: three moles of gas become two, $\Delta n(\text{gas}) = -1$, so dispersal falls. (b) $\Delta S^\circ = [2 \times S^\circ(SO_3)] - [2 \times S^\circ(SO_2) + S^\circ(O_2)] = 2(257) - [2(248) + 205] = 514 - (496 + 205) = 514 - 701 = -187$ J mol^{-1} K^{-1}. (c) It agrees: negative, as predicted. A disagreement would mean the arithmetic, not the chemistry, was at fault, most likely a missed coefficient or a backwards subtraction, and the sum would need to be rerun before the answer could be trusted.

B4. (a) $\Delta S^\circ = [2 \times S^\circ(H_2O, l)] - [2 \times S^\circ(H_2) + S^\circ(O_2)] = 2(70) - [2(131) + 205] = 140 - (262 + 205) = 140 - 467 = -327$ J mol^{-1} K^{-1}. (b) The student used the coefficient of H_2 as 1: $2(70) - [131 + 205] = 140 - 336 = -196$ J mol^{-1} K^{-1}. Every other term is right; the missing factor of 2 on the H_2 term alone accounts for the difference. (c) The second student subtracted in the wrong order, reactants minus products: 467 − 140 = +327. The size is right and the sign is wrong, which the prediction from the gas count, three moles of gas vanishing into a liquid, would have caught at once.

B5. (a) $\Delta S^\circ = [S^\circ(CaO) + S^\circ(CO_2)] - [S^\circ(CaCO_3)] = (40 + 214) - 93 = 254 - 93 = +161$ J mol^{-1} K^{-1}. The sign is fixed by the appearance of a gas from a solid, $\Delta n(\text{gas}) = +1$, before any numbers are used. (b) $\Delta S^\circ = [S^\circ(CH_4)] - [S^\circ(C) + 2 \times S^\circ(H_2)] = 186 - [5.7 + 2(131)] = 186 - (5.7 + 262) = 186 - 267.7 = -81.7$, that is about −82 J mol^{-1} K^{-1}. (c) ΔS° compares totals, not single values. Two moles of H_2 at 131 each contribute 262 J mol^{-1} K^{-1} to the reactant side, more than the 186 the single mole of CH_4 contributes to the products, so the reactant total wins and the change is negative. The disappearing gas mole, $\Delta n(\text{gas}) = -1$, says the same thing.

B6. (a) $\Delta S^\circ = [2 \times S^\circ(Fe) + S^\circ(Al_2O_3)] - [2 \times S^\circ(Al) + S^\circ(Fe_2O_3)] = [2(27) + 51] - [2(28) + 87] = (54 + 51) - (56 + 87) = 105 - 143 = -38$ J mol^{-1} K^{-1}. (b) No gas appears or disappears, and no phase changes: solids trade for solids with low, similar S° values, so the two sums nearly cancel. B3 and B4 each destroy gas moles, one and three respectively, and each mole of gas carries a large S° with it, which is why their values run into the hundreds. (c) This reaction, the thermite reaction at −38 J mol^{-1} K^{-1}: the next closest are CH_4 formation at about −82 and $CaCO_3$ decomposition at +161. The shared feature is that no gas takes part on either side, so nothing with a large S° enters or leaves the sums.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

C1. (a) Negative, and large. Three moles of gas (one CH_4, two O_2) become one mole of gas and a liquid, $\Delta n(\text{gas}) = -2$, and burying two moles of gas into liquid water removes a great deal of dispersal. (b) $\Delta S^\circ = [S^\circ(CO_2) + 2 \times S^\circ(H_2O, l)] - [S^\circ(CH_4) + 2 \times S^\circ(O_2)] = [214 + 2(70)] - [186 + 2(205)] = (214 + 140) - (186 + 410) = 354 - 596 = -242$ J mol^{-1} K^{-1}. (c) -242 J mol^{-1} K^{-1} $\div$ 1000 $= -0.242$ kJ mol^{-1} K^{-1}. (d) The argument fails. ΔS° is a balance of totals: the reactant side holds CH_4 plus two moles of O_2, 596 J mol^{-1} K^{-1} in all, against 354 on the product side. Comparing one product against one reactant ignores the coefficients and the second product; with them counted, the reaction buries gas and ΔS° is firmly negative, exactly as the gas count predicted.

C2. (a) Positive. The reactants are a solid and an aqueous solution, both condensed; the reaction releases H_2 as a gas, a phase whose particles disperse through the whole container. Creating a gas from condensed phases raises the system's entropy sharply. (b) The sign rests on the dominant effect, the appearance of a mole of gas where there was none, $\Delta n(\text{gas}) = +1$. Gas formation outweighs any rearrangement among the condensed and aqueous species, whose S° values are all comparatively small, so the direction of the change is secure even though its exact size would need the aqueous values. (c) ΔS° doubles. A ΔS° value is defined for the equation as written, because the coefficients are the multipliers in the sums; the same chemistry written with doubled coefficients is a doubled process and carries a doubled entropy change. A ΔS° quoted without its equation is incomplete.

C3. (a) $H_2O(l) < He(g) < CH_4(g) < C_2H_6(g)$. (b) $H_2O(l)$ is the only liquid: its particles are confined together, so despite being a molecule it sits below every gas. The three gases then order by size and complexity: He is a single atom with the fewest ways to store energy, CH_4 has five atoms, and C_2H_6 has eight atoms and the most bonds, giving it the largest S° of the four. (c) The argument misapplies the complexity rule. Complexity compares substances within the same phase; across phases, the phase order rules first, as it did in Topic 9.1. Liquid water's particles are confined to a liquid's volume, while helium's move through the whole container, and that difference outweighs the extra atoms in the water molecule. (d) $S^\circ = 0$ belongs only to a perfect crystal at 0 K, by the third law. Each of these substances at 298 K has accumulated entropy on warming from 0 K, so each has a strictly positive S°, liquids and elements included.

Continue Revising

Topic 9.2 Revision Notes

Topic 9.2 Quiz: Absolute Entropy and Entropy Change

Previous Worksheet: Topic 9.1 Introduction to Entropy

Next Worksheet: Topic 9.3 Gibbs Free Energy and Thermodynamic Favorability

© 2026 ExamFitter.com · Free AP Chemistry worksheets