Room Heating from the Cohesive Energy of Rocksalt

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26 July 2026

1 Problem

Imagine yourself to be in a room, say a typical living room or class room. You get a box with free sodium atoms (Na) and another box with free chlorine atoms (Cl). You connect the two boxes, and let the atoms react with each other. The result is one teaspoon of rocksalt. How much has the temperature of the room increased? Assume the cohesive energy of rocksalt to be 187 kcal/mol.

2 Model and assumptions

1. The boxes are thin, indestructible, perfectly conducting, and of negligible heat capacity and volume. All energy released by the reaction is therefore transferred to the room environment.
2. The room is sealed and perfectly insulated, so the air is heated at constant volume and none of the heat escapes to the walls.
3. The room's dimensions are approximated as that of a typical university classroom ($50\,\mathrm{m}^2$ floor area, $3\,\mathrm{m}$ high).
4. The air is an ideal diatomic gas, with $C_V = \frac{5}{2}R = 20.8\,\mathrm{J\,mol^{-1}\,K^{-1}}$.
5. The reactants begin as free neutral atoms and end as crystalline NaCl, with the reaction going to completion, so the full cohesive energy is released as heat.
6. The heat capacity of the salt itself is negligible against that of the air.

Table 1: Input quantities.

Quantity	Symbol	Value	Unit	Source
Room volume	V	150	m^3	[assumed]
Ambient temperature	T_0	300	K	[assumed]
Ambient pressure	P	1	atm	[assumed]
Molar heat capacity of air	C_V	20.8	$\mathrm{J\,mol^{-1}\,K^{-1}}$	[5]
Volume of one teaspoon	V_s	4.9	mL	[3]
Density of NaCl	ρ	2.17	$\mathrm{g\,cm^{-3}}$	[2]
Molar mass of NaCl	M	58.44	$\mathrm{g\,mol^{-1}}$	[1]
Cohesive energy of NaCl	E_coh	187	$\mathrm{kcal\,mol^{-1}}$	[given]

3 Solution

3.1 Amount of rocksalt formed

One teaspoon is $V_\mathrm{s} = 4.9\,\mathrm{mL} = 4.9\,\mathrm{cm}^3$, so

$$n_\mathrm{NaCl} = \frac{\rho V_\mathrm{s}}{M} = \frac{2.17\,\mathrm{g\,cm^{-3}} \times 4.9\,\mathrm{cm}^3}{58.44\,\mathrm{g\,mol^{-1}}} = 0.182\,\mathrm{mol}. \tag{1}$$

3.2 Energy released

The cohesive energy is the energy required to break the crystal into free neutral atoms,

$$E_\mathrm{coh} = (E_\mathrm{Na} + E_\mathrm{Cl}) - E_\mathrm{NaCl} = 187\,\mathrm{kcal\,mol^{-1}}, \tag{2}$$

so exactly this much is liberated per mole when the crystal forms from those same free atoms:

$$Q = n_\mathrm{NaCl}\,E_\mathrm{coh} = 0.182\,\mathrm{mol} \times 187\,\mathrm{kcal\,mol^{-1}} = 34.0\,\mathrm{kcal} = 142\,\mathrm{kJ}. \tag{3}$$

3.3 Amount of air in the room

With $V = 50\,\mathrm{m}^2 \times 3\,\mathrm{m} = 150\,\mathrm{m}^3$, the ideal gas law gives [4]

$$n_\mathrm{air} = \frac{PV}{RT_0} = \frac{101\,325\,\mathrm{Pa} \times 150\,\mathrm{m}^3}{8.314\,\mathrm{J\,mol^{-1}\,K^{-1}} \times 300\,\mathrm{K}} = 6.09 \times 10^3\,\mathrm{mol}. \tag{4}$$

3.4 Temperature rise

Heating that air at constant volume,

$$\Delta T = \frac{Q}{n_\mathrm{air} C_V} = \frac{1.424 \times 10^5\,\mathrm{J}}{6.09 \times 10^3\,\mathrm{mol} \times 20.8\,\mathrm{J\,mol^{-1}\,K^{-1}}} \implies \boxed{\Delta T \approx 1.1\,\mathrm{K}} \tag{5}$$

4 Discussion

A teaspoon of salt is only $\sim$0.18 mol, but the room holds $\sim 6.1 \times 10^3$ mol of air, over four orders of magnitude more. The $187\,\mathrm{kcal\,mol^{-1}}$ of cohesive energy is enormous on an atomic scale ($\approx 8\,\mathrm{eV}$ per formula unit). Despite the small quantity of reactants compared to the room volume, the reaction is so exothermic that the temperature change is still noticeable on the latter scale.

One modelling choice is significant to the magnitude of the answer: whether the air is heated at constant volume or constant pressure. A sealed room fixes V, so C_V is the appropriate heat capacity. A room vented to the outside would instead expand against the atmosphere and require $C_P = \frac{7}{2}R = 29.1\,\mathrm{J\,mol^{-1}\,K^{-1}}$, lowering the answer to $\Delta T \approx 0.8\,\mathrm{K}$.

References

[1] IUPAC Commission on Isotopic Abundances and Atomic Weights, "Abridged Standard Atomic Weights 2024." $A_r^\circ(\mathrm{Na}) = 22.990$, $A_r^\circ(\mathrm{Cl}) = 35.45$. https://www.ciaaw.org/abridged-atomic-weights.htm (accessed 26 July 2026).

[2] "Halite, NaCl," *Handbook of Mineralogy*, Mineral Data Publishing (2001–2005). $D(\text{meas.}) = 2.168\,\mathrm{g\,cm^{-3}}$. https://www.handbookofmineralogy.org/pdfs/halite.pdf (accessed 26 July 2026).

[3] National Institute of Standards and Technology, *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices*, NIST Handbook 44, 2026 edition, Appendix C. One measuring teaspoon is $1\frac{1}{3}$ fluid drams (p. C-26) and one fluid dram is $3.696\,691\,\mathrm{mL}$ (p. C-16), giving $4.9289\,\mathrm{mL}$. https://doi.org/10.6028/NIST.HB.44-2026 (accessed 26 July 2026).

[4] National Institute of Standards and Technology, "Fundamental Physical Constants — Complete Listing," 2022 CODATA adjustment. $R = 8.314\,462\,618\ldots\ \mathrm{J\,mol^{-1}\,K^{-1}}$ and standard atmosphere $= 101\,325\,\mathrm{Pa}$, both exact. https://physics.nist.gov/cuu/Constants/Table/allascii.txt (accessed 26 July 2026).

[5] R. P. Feynman, R. B. Leighton, and M. Sands, *The Feynman Lectures on Physics*, New Millennium Edition, Vol. I, Ch. 40, §40–5, "The specific heats of gases," for the rigid-diatomic result $C_V = \frac{5}{2}R$. https://www.feynmanlectures.caltech.edu/I_40.html (accessed 26 July 2026).