

Name: KEY

CHM - Thermodynamics

Spontaneity

1. True or false? All exothermic reactions are spontaneous? false
2. Which variable can tell you if a process is spontaneous without exception?
a. ΔH_{rxn} b. ΔS_{rxn} c. ΔH_{surr} d. ΔS_{surr} e. ΔS_{tot}

Enthalpy and Entropy

3. Circle the correct words: Nature tends towards (higher or lower) energy and more (order or disorder)?
4. Which of the following reactions will have the most positive ΔH° ? (Hint: Draw Lewis structures.)
a. $\text{N}_2(\text{g}) \rightarrow 2 \text{N}(\text{g})$
b. $\text{F}_2(\text{g}) \rightarrow 2 \text{F}(\text{g})$
c. $\text{O}_2(\text{g}) \rightarrow 2 \text{O}(\text{g})$
d. These reactions would all have the same ΔH° .

Notice that all reactions are 1 mol of a diatomic gas going to 2 mol of a monoatomic gas, i.e., the bonds between the two atoms are broken. This is a tricky question and really relates to CHM151 knowledge, i.e., a single bond is weaker than a double bond is weaker than a triple bond. If a triple bond is the strongest bond, it takes more energy to break it. N_2 has a triple bond, O_2 has a double bond, and F_2 has a single bond.

5. Which state of matter has the highest entropy? gas
6. Predict whether the entropy change will be positive or negative for the following:
a. $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$ ΔS -
b. $\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}(\text{l}) + 2\text{CO}_2(\text{g})$ ΔS +
c. $2\text{NH}_3(\text{g}) + \text{CO}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{NH}_2\text{CONH}_2(\text{aq})$ ΔS -
d. $\text{NaCl}(\text{s}) \rightarrow \text{NaCl}(\text{aq})$ ΔS +
e. $\text{Cu}(\text{s}) (100^\circ\text{C}) \rightarrow \text{Cu}(\text{s}) (25^\circ\text{C})$ ΔS -
f. $2\text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$ ΔS +
7. If a process is endothermic and the process creates more order than existed before, the process is:
a. always spontaneous b. never spontaneous c. spontaneous at high T d. spontaneous at low T
8. Which of the following substances has the greatest entropy per mole?
a. $\text{O}_2(\text{g})$
b. $\text{N}_2(\text{g})$
c. $\text{CO}(\text{g})$
d. $\text{CO}_2(\text{g})$
e. $\text{C}_4\text{H}_{10}(\text{g})$

All choices are gases and, assuming they are all at the same temperature, the largest molecule will have the highest entropy because of the greater possible movement of atoms within each molecule.

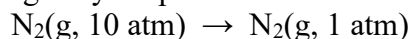
9. Which of the following reactions will have an increase in entropy? Choose all that apply.

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- a. $\text{SO}_3(\text{g}) \rightarrow 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$
- b. $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{s})$
- c. $\text{Br}_2(\text{l}) \rightarrow \text{Br}_2(\text{g})$
- d. $\text{H}_2\text{O}_2(\text{l}) \rightarrow \text{H}_2\text{O}(\text{l}) + \frac{1}{2} \text{O}_2(\text{g})$

- a. $\text{SO}_3(\text{g}) \rightarrow 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$ $\Delta S > 0$ because 1 mol gas produces 3 mol gas
- b. $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{s})$ $\Delta S < 0$ because liquid turns into solid
- c. $\text{Br}_2(\text{l}) \rightarrow \text{Br}_2(\text{g})$ $\Delta S > 0$ because liquid turns to gas
- d. $\text{H}_2\text{O}_2(\text{l}) \rightarrow \text{H}_2\text{O}(\text{l}) + \frac{1}{2} \text{O}_2(\text{g})$ $\Delta S > 0$ because 1 mol liquid produces 1 mol liquid + $\frac{1}{2}$ mol gas

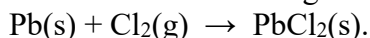
10. Without consulting entropy tables, predict the sign of ΔS for the following process and choose the correct reasoning for your prediction: *The mass of nitrogen remains constant.*



- a. positive; there is an increase in the number of gas molecules
- b. positive; the gas expands into a larger volume**
- c. negative; the gas is compressed into a smaller volume
- d. negative; the gas expands into a larger volume
- e. negative; there is a decrease in the number of gas molecules.

The only way to change the pressure of a gas from a high to a lower pressure, without reducing temperature or removing gas atoms/molecules, is to increase the volume. In doing so, the gas molecules have a larger space to move and hence there is greater randomness or disorder.

11. Without consulting entropy tables, predict the sign of ΔS for the following process:



- a. $\Delta S > 0$
- b. $\Delta S < 0$**
- c. $\Delta S = 0$
- d. More information is needed to make a reasonable prediction.

A solid and a gas turn into a solid.

Standard Molar Entropies

12. Which of the following compounds has the lowest entropy at 25 °C?

- a. $\text{CH}_3\text{OH}(\text{l})$
- b. $\text{CO}(\text{g})$
- c. $\text{MgCO}_3(\text{s})$**
- d. $\text{H}_2\text{O}(\text{l})$
- e. $\text{H}_2\text{O}(\text{g})$

In general, solids have much lower entropy values than liquids and especially gases.

13. Using the data below, calculate $\Delta S^\circ_{\text{rxn}}$ for the following reaction:

