

# HW14 - 2nd Law and Free Energy

1 1 point

In order for an endothermic reaction to be spontaneous,

- endothermic reactions are never spontaneous.
- the entropy increase in the system must equal the entropy decrease in the surroundings.
- the entropy increase in the system must be greater than the entropy decrease in the surroundings.
- nothing special is required; they are always spontaneous.
- heat must be supplied to the system.

2 1 point

Which one of the following reactions has a positive entropy change?

- $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$
- $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- $2\text{NH}_4\text{NO}_3(\text{s}) \rightarrow 2\text{N}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g}) + \text{O}_2(\text{g})$
- $\text{BF}_3(\text{g}) + \text{NH}_3(\text{g}) \rightarrow \text{F}_3\text{BNH}_3(\text{s})$
- $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$

3 1 point

Consider the following processes. Which entropy will increase as the process proceeds from left to right? Select all of the correct answers.

- $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{s})$
- $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- $\text{NaCl}(\text{s}) \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$

4 1 point

What are the values of  $\Delta S$  for the water, the surroundings, and the universe for the evaporation of water from an open pan at 25°C?

- positive, negative, zero
- negative, negative, negative
- positive, negative, positive
- positive, negative, negative

5 1 point

True/False: For a given transfer of energy, a greater change in entropy occurs when the temperature is high.

- False, because only heat flow affects the change in entropy, not temperature.
- True
- False, because as temperature decreases there is a greater change in entropy.

6 1 point

Which of the following lists phases in order of increasing entropy?

- solid, gas, liquid
- solid, liquid, gas
- liquid, solid, gas
- liquid, gas, solid
- gas, liquid, solid

7 1 point

$\text{H}_2$  burning in  $\text{O}_2$  to form  $\text{H}_2\text{O}(\text{l})$  is an example of a system where the entropy of the universe decreases.

- True
- $\text{H}_2$  is not flammable.
- False

8 1 point

Consider the following processes of ideal gases. Which of these processes leads to an increase in entropy? Select all of the correct answers.

- Nitrogen gas is compressed isothermally to one half its original volume.
- A glass of water loses 100 J of energy reversibly at 30°C.
- The pressure of one mole of oxygen gas is allowed to double isothermally.
- Carbon dioxide is allowed to expand isothermally to 10 times its original volume.

9 1 point

Which of the following chemical reactions exhibit a positive  $\Delta S$ ? Select all of the correct answers.

- $2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}_2(\text{l})$
- $2\text{H}_2\text{O}(\text{g}) \rightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$
- $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- $3\text{O}_2(\text{g}) \rightarrow 2\text{O}_3(\text{g})$

10 1 point

The temperature of 2.00 mol Ne(g) is increased from 25°C to 200°C at constant pressure. Assuming the heat capacity of Ne is 20.8 J/K·mol, calculate the change in the entropy of neon. Assume ideal gas behavior.

- +7.68 J/K
- 19.2 J/K
- 7.68 J/K
- +19.2 J/K

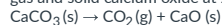
11 1 point

The enthalpy of fusion of  $\text{H}_2\text{O}(\text{s})$  at its normal melting point is 6.01 kJ/mol. What is the entropy change for freezing 1 mole of water at this temperature?

- +22.0 J/mol·K
- 22.0 J/mol·K
- 20.2 J/mol·K
- +20.2 J/mol·K

12 1 point

Calculate the standard reaction entropy for the decomposition of 1 mol calcite to carbon dioxide gas and solid calcium oxide at 25°C.



Substance	$S^\circ$ (J/mol·K)
CaO (s)	39.75
CO <sub>2</sub> (g)	213.74
CaCO <sub>3</sub> (s)	92.9

- 266.9 J/mol·K
- 346.4 J/mol·K
- 160.6 J/mol·K
- 160.6 J/mol·K

13 1 point

True/False: All entropies of fusion are negative.

- True - fusion leads to more microstates (degrees of freedom).
- False - fusion leads to more microstates (degrees of freedom).
- True - fusion leads to less microstates (degrees of freedom).
- False - fusion leads to less microstates (degrees of freedom).

14 1 point

A system releases 900 J of heat to the surroundings (27°C). What is  $\Delta S$  of the surroundings?

- 3 J/K
- 33.3 J/K
- 3 J/K
- 33.3 J/K

15 1 point

When a sugar cube dissolves in a cup of coffee (an endothermic process), entropy changes of the sugar plus water, the surroundings, and the universe respectively are...

- negative, negative, negative
- positive, negative, negative
- negative, positive, positive
- positive, positive, positive
- None of these are correct.

16 1 point

Which substance has the lower molar entropy?

- Kr (g) at 298 K and 1.00 atm
- There is no way to know.
- Ne (g) at 298 K and 1.00 atm
- They are both the same.

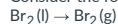
17 1 point

Calculate the standard entropy of vaporization of ethanol at its boiling point, 352 K. The standard molar enthalpy of vaporization of ethanol at its boiling point is 40.5 kJ/mol.

- +40.5 J/mol-K
- +115 J/mol-K
- 40.5 J/mol-K
- 115 J/mol-K

18 1 point

Consider the following vaporization reaction.

At a certain pressure,  $\Delta H^\circ = 34 \text{ kJ/mol}$  and  $\Delta S^\circ = 0.098 \text{ kJ/mol}\cdot\text{K}$ . What is the lowest temperature at which this process is spontaneous?

- 74 K
- 347 K
- 347 K
- 0.00288 K

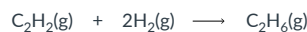
19 1 point

For this problem, you will have to look up  $\Delta H_f^\circ$  and the  $S^\circ$  values from a table. Estimate the minimum temperature at which magnetite can be reduced to iron by graphite.

- 670°C
- Magnetite cannot be reduced by carbon at any temperature.
- 535°C
- 787°C
- Magnetite will be reduced by carbon at any temperature.

20 1 point

What is the entropy change for the following chemical reaction at at 25°C?



Substance	$S^\circ$ (J/K-mol)	$\Delta H_f^\circ$ (kJ/mol)
$\text{C}_2\text{H}_2(g)$	200.94	226.73
$\text{H}_2(g)$	130.68	0
$\text{C}_2\text{H}_6(g)$	229.6	-84.68

- 102.0 J/mol-K
- 290.0 J/mol-K
- 232.7 J/mol-K
- 159.3 J/mol-K

21 1 point

What is the enthalpy change for the chemical reaction in question 20?

- 311.41 kJ/mol
- 311.41 kJ/mol
- 142.05 kJ/mol
- 538.14 kJ/mol

22 1 point

Find the standard reaction free energy for the chemical reaction in question 20.

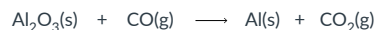
- 242.03 kJ/mol
- 69.07 kJ/mol
- 305.59 kJ/mol
- 69,068 kJ/mol

23 1 point

Assuming  $\Delta H_{\text{rxn}}^\circ$  and  $\Delta S_{\text{rxn}}^\circ$  are unaffected by temperature changes, find the temperature at which  $\Delta G^\circ$  is zero for the chemical reaction in question 20.

- 1338 K
- 1338 K
- 1.338 K
- $\Delta G^\circ$  will not equal 0 at any possible temperature.

24 1 point

Consider the following unbalanced equation. What is the standard free energy for the reaction of 7.2 moles of  $\text{Al}_2\text{O}_3(s)$  at 298K?

Substance	$\Delta H_f^\circ$ (kJ/mol)	$S^\circ$ (J/mol-K)
$\text{Al}_2\text{O}_3(s)$	-1676.0	50.92
$\text{CO}(g)$	-110.5	197.6
$\text{Al}(s)$	0.0	28.3
$\text{CO}_2(g)$	-393.5	213.6

- 15,000 kJ
- 1.1 x 10<sup>6</sup> kJ
- 5800 kJ
- 810 kJ

25 1 point

Calculate the normal boiling point of chloroform given that the standard entropy and enthalpy of vaporization of chloroform is 93.7 J/mol·K and 31.4 kJ/mol, respectively.

- 405 K  
 335 K  
 375 K  
 450 K

26 1 point

Find the standard entropy change for the formation reaction of CO (g) at 298 K.

Substance	$S^\circ$ (J/mol·K)	$\Delta H_f^\circ$ (kJ/mol)
C (s, graphite)	5.74	0
O <sub>2</sub> (g)	205.14	0
CO (g)	197.67	-110.53

- 13.21 J/mol·K  
 -13.21 J/mol·K  
 89.36 J/mol·K  
 -89.36 J/mol·K

27 1 point

What is the standard free energy change for the chemical reaction in question 26?

- 137.16 kJ/mol  
 -137.16 kJ/mol  
 26,739.81 kJ/mol  
 -26,739.81 kJ/mol

28 1 point

Rocket fuel would be useless if its oxidation is not spontaneous. A chemist exploring potential fuels for use in space considered using vaporized aluminum chloride. What is the coefficient of O<sub>2</sub> (g) in the following balanced chemical equation that contains only whole numbered coefficients (i.e. no fractions)?

- 9       $\text{AlCl}_3(\text{g}) + \text{O}_2(\text{g}) \longrightarrow \text{Al}_2\text{O}_3(\text{s}) + \text{ClO}(\text{g})$   
 4  
 6  
 1

29 1 point

The below table contains thermodynamic data for the chemical reaction in question 28 at 2000 K. What is  $\Delta G_{\text{rxn}}$  at 2000 K?

Substance	$\Delta G_f$ (kJ/mol)
AlCl <sub>3</sub> (g)	-467
Al <sub>2</sub> O <sub>3</sub> (s)	-1034
ClO (g)	75

- 492 kJ/mol rxn  
 +492 kJ/mol rxn  
 -700 kJ/mol rxn  
 +700 kJ/mol rxn

30 1 point

Consider the reaction in questions 28 and 29. Would this choice of reactants make a good rocket fuel?

- It depends on the enthalpy change of the system.  
 No  
 Yes  
 It depends on the entropy change of the system.

31 1 point

Consider the following chemical reaction. Calculate  $\Delta G^\circ$  for the reaction at 298 K.  
 $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow \text{COCl}_2(\text{g})$

Substance	$\Delta H_f^\circ$ (kJ/mol)	$S^\circ$ (J/mol·K)
CO (g)	-110.5	197.6
Cl <sub>2</sub> (g)	0	223.0
COCl <sub>2</sub> (g)	-223.0	289.2

- 151.6 kJ/mol  
 -500.0 kJ/mol  
 -39.3 kJ/mol  
 -73.3 kJ/mol

32 1 point

Consider the following table that contains an assortment of compounds and their corresponding standard free energies of formation. Which of these liquids are thermodynamically stable with respect to their constituent elements? Select all of the correct answers.

Name	Compound	Free Energy (kJ/mol)
Cyclohexane	C <sub>6</sub> H <sub>12</sub> (l)	6.4
Methanol	CH <sub>3</sub> OH (l)	-166
Hydrazine	N <sub>2</sub> H <sub>4</sub> (l)	149
Hydrogen Peroxide	H <sub>2</sub> O <sub>2</sub> (l)	-120
Carbon Disulfide	CS <sub>2</sub> (l)	65.3

- Carbon Disulfide  
 Cyclohexane  
 Hydrogen Peroxide  
 Methanol  
 Hydrazine

33 1 point

Ammonia (NH<sub>3</sub>) gives windex and cat urine its odor. It has a  $\Delta H_{\text{vap}}^\circ$  of 23.35 kJ/mol and a  $\Delta S_{\text{vap}}^\circ$  of 97.43 J/mol·K. What is the normal boiling point of ammonia?

- 33.3°C  
 273°C  
 238.7°C  
 -0.2°C