

## 20 • Entropy and Free Energy

### PRACTICE TEST

- Which of the following represents an increase in entropy?
  - freezing of water
  - boiling of water
  - crystallization of salt from a supersaturated solution
  - the reaction  $2 \text{NO}(g) \rightarrow \text{N}_2\text{O}_2(g)$
  - the reaction  $2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(g)$
- The enthalpy of vaporization of methanol ( $\text{CH}_3\text{OH}$ ) is 35.3 kJ/mol at the boiling point of 64.2 °C. Calculate the entropy change for methanol going from a liquid to vapor.
  600. J/K·mol
  - 551 J/K·mol
  - 105 J/K·mol
  - 105 J/K·mol
  - 551 J/K·mol
- Calculate the standard entropy change for the following reaction,
 
$$\text{Cu}(s) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CuO}(s)$$
 given that
 

|  |
|--|
| $S^\circ[\text{Cu}(s)] = 33.15 \text{ J/K}\cdot\text{mol}$   |
| $S^\circ[\text{O}_2(g)] = 205.14 \text{ J/K}\cdot\text{mol}$ |
| $S^\circ[\text{CuO}(s)] = 42.63 \text{ J/K}\cdot\text{mol}$  |

  - 195.66 J/K
  - 93.09 J/K
  - 45.28 J/K
  - 93.09 J/K
  - 195.66 J/K
- In which of the following reactions do you expect to have a decrease in entropy?
  - $\text{Fe}(s) \rightarrow \text{Fe}(l)$
  - $\text{Fe}(s) + \text{S}(s) \rightarrow \text{FeS}(s)$
  - $2 \text{Fe}(s) + 3/2 \text{O}_2(g) \rightarrow \text{Fe}_2\text{O}_3(s)$
  - $\text{HF}(l) \rightarrow \text{HF}(g)$
  - $2 \text{H}_2\text{O}_2(l) \rightarrow 2 \text{H}_2\text{O}(l) + \text{O}_2(g)$
- The formation  $\frac{1}{2} \text{A}_2 + 2 \text{B}_2 + \text{C} \rightarrow \text{CAB}_4$  has an enthalpy of formation of -104 kJ and a change in entropy of -60.8 J/K at 30 °C. What is  $\Delta G$  and spontaneity of the reaction?
  - 85.6 kJ, spontaneous
  - 18.3 kJ, not spontaneous
  - +18.3 kJ, spontaneous
  - +85.6 kJ, not spontaneous
  - 85.6 kJ, not spontaneous
- If  $\Delta H$  and  $\Delta S$  are both negative or positive, then  $\Delta G$  has a \_\_\_\_\_ sign.
  - positive
  - negative
  - variable
  - large
  - no
- At what temperature would a given reaction become spontaneous if  $\Delta H = +119 \text{ kJ}$  and  $\Delta S = +263 \text{ J/K}$ ?
  - 452 K
  - 2210 K
  - 382 K
  - 2.21 K
  - 363 K
- The free energy change for a given reaction is -36.2 kJ. What is the equilibrium constant at 298 K?
  - 0.985
  - $2.22 \times 10^6$
  - 1.01
  - $8.32 \times 10^{-7}$
  - $3.25 \times 10^6$
- Given the following information, calculate  $\Delta G^\circ$  for the reaction below at 25°C:
 
$$\text{SnCl}_4(l) + 2 \text{H}_2\text{O}(l) \rightarrow \text{SnO}_2(s) + 4 \text{HCl}(g)$$

$$\Delta H^\circ = 133.0 \text{ kJ} \text{ and } \Delta S^\circ = 401.5 \text{ J/K}$$
  - 252.6 kJ
  - 13.4 kJ
  - 13.4 kJ
  - 122.9 kJ
  - 252.6 kJ

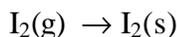
10. Given the following information, calculate  $\Delta G^\circ$  for the reaction below at  $25^\circ\text{C}$ :



| Compound                         | $\Delta H^\circ$ (kJ/mol) | $S^\circ$ (J/K·mol) |
|----------------------------------|---------------------------|---------------------|
| $\text{H}_2\text{O}_2(\text{l})$ | -187.8                    | 109.6               |
| $\text{H}_2\text{O}(\text{l})$   | -285.8                    | 69.9                |
| $\text{O}_2(\text{g})$           | —                         | 205.1               |

- a) -37700 kJ                      d) -233.5 kJ  
 b) -342.6 kJ                      e) -157.9 kJ  
 c) -233.5 kJ

11. For the process at  $25^\circ\text{C}$



what are the signs of  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$ ?

|    | <u>DG</u> | <u>DH</u> | <u>DS</u> |
|----|-----------|-----------|-----------|
| a) | +         | -         | -         |
| b) | -         | -         | -         |
| c) | -         | +         | +         |
| d) | -         | -         | +         |
| e) | +         | +         | +         |

12. If a process is exothermic and not spontaneous, then what must be true?  
 a)  $\Delta S > 0$                       d)  $\Delta S < 0$   
 b)  $\Delta H > 0$                       e)  $\Delta H = 0$   
 c)  $\Delta G = 0$

13. For any reaction at equilibrium, which of the following is true?  
 a)  $\Delta H < 0$                       d)  $\Delta H = 0$   
 b)  $\Delta S = 0$                       e)  $\Delta G = 0$   
 c)  $\Delta S < 0$

14. All of the following have  $\Delta G^\circ_f = 0$  EXCEPT  
 a)  $\text{O}_2(\text{g})$                       d)  $\text{Ca}(\text{s})$   
 b)  $\text{Br}_2(\text{g})$                       e)  $\text{Hg}(\text{l})$   
 c)  $\text{H}_2(\text{g})$

15. Ammonium nitrate spontaneously dissolves in water at room temperature and the process causes the solution to become quite cold. Which of the following is TRUE about the dissolution of ammonium nitrate?  
 a) The process is exothermic.  
 b) Its solubility will be greater in warmer water.  
 c)  $\Delta S^\circ$  for the reaction is negative.  
 d) All solutions of ammonium nitrate are supersaturated.  
 e) All solutions of ammonium nitrate are cold.

Answers:

|    |                      |     |                      |     |                      |
|----|----------------------|-----|----------------------|-----|----------------------|
| 1. | <input type="text"/> | 6.  | <input type="text"/> | 11. | <input type="text"/> |
| 2. | <input type="text"/> | 7.  | <input type="text"/> | 12. | <input type="text"/> |
| 3. | <input type="text"/> | 8.  | <input type="text"/> | 13. | <input type="text"/> |
| 4. | <input type="text"/> | 9.  | <input type="text"/> | 14. | <input type="text"/> |
| 5. | <input type="text"/> | 10. | <input type="text"/> | 15. | <input type="text"/> |

From the AP Exam formula sheet:

#### THERMOCHEMISTRY

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= -RT \ln K = -2.303 RT \log K$$

$$= -n \mathcal{F} E^\circ$$

$$\Delta G = \Delta G^\circ + RT \ln Q = \Delta G^\circ + 2.303 RT \log Q$$

$$q = mc\Delta T$$

$$C_p = \frac{\Delta H}{\Delta T}$$

Answers:

1B 2C 3D 4C 5A 6C 7A 8B 9C 10C 11B 12D 13E 14B 15B