



## Dynamic Chemicals – Chemical Reaction Dynamics

### Multiple Choice

- Which of the following serves as the unit of heat?
  - Degree Celsius
  - Degree Fahrenheit
  - Kelvin
  - Joule
- In a balanced equation for an *endothermic* reaction, where does the heat energy term appear?
  - On the left side only.
  - On the right side only.
  - On both sides.
  - On neither side.
- The quantity  $\Delta H$  is equal to
  - $H_{\text{products}} / H_{\text{reactants}}$
  - $H_{\text{products}} - H_{\text{reactants}}$
  - $H_{\text{products}} + H_{\text{reactants}}$
  - $H_{\text{reactants}} - H_{\text{products}}$
- According to collision theory, in order for *collisions* to be effective, they *must*
  - occur at high concentration.
  - occur in the presence of a catalyst
  - be energetic enough to cause a reaction.
  - be frequent enough to cause a reaction.
- According to collision theory, why does an increase in the reactant concentration increase the reaction rate?
  - There are more collisions per second.
  - Collisions occur with greater energy.
  - There are more collisions per second and the collisions are of greater energy.
  - None of the above.
- At equilibrium, the rate of the forward reaction is:
  - greater than the rate of the reverse reaction.
  - equal to the rate of the reverse reaction.
  - less than the rate of the reverse reaction.
  - not related to the rate of the reverse reaction.
- Which change will shift the following reaction to the right:  $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \leftrightarrow 2\text{NO}_2(\text{g}) + 113.0 \text{ kJ}$ ?
  - Addition of  $\text{NO}_2$ .
  - Removal of  $\text{O}_2$ .
  - Decrease of pressure.
  - Removal of heat.
- What would be the effect on increased pressure on the reaction:  $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \leftrightarrow 2\text{HCl}(\text{g})$ ?
  - shift left
  - shift right
  - no shift
  - more information needed
- The factors that determine whether a reaction is spontaneous or non-spontaneous are
  - Change in enthalpy and the activation energy.
  - Change in enthalpy and entropy, and the activation energy.
  - Change in entropy and the activation energy.
  - Change in entropy and enthalpy, and the temperature at which the reaction occurs.
- Whenever the products of a reaction have more disorder than reactants,
  - $\Delta H$  is positive.
  - $\Delta H$  is negative.
  - $\Delta S$  is positive.
  - $\Delta S$  is negative.
- $\Delta G$  is equal to
  - $\Delta H - T\Delta S$
  - $\Delta H + T\Delta S$
  - $\Delta S - T\Delta H$
  - $\Delta S + T\Delta H$
- What would be spontaneous conditions for an exothermic reaction that increases disorder?
  - high temp
  - low temp
  - all temps
  - low pressure
- How could a reaction be described when  $\Delta G$  for the reaction is highly negative?
  - non-spontaneous
  - spontaneous
  - in equilibrium
  - no reaction

## Short Answer

1. Please determine the sign for  $\Delta H$ ,  $\Delta S$ , and  $\Delta G$  for the following reactions:

- a.  $2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{H}_2\text{O}(\text{g}) + 454 \text{ kJ}$  (spontaneous combustion of hydrogen)
- b.  $2 \text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g}) + 566.0 \text{ kJ}$  (spontaneous combustion of carbon monoxide)
- c.  $2 \text{CO}_2(\text{g}) + 793.5 \text{ kJ} \rightarrow \text{C}_2\text{O}_4(\text{g})$  (non-spontaneous synthesis of  $\text{C}_2\text{O}_4$ )
- d.  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$  (vaporization of water at  $35^\circ$ )

2. Please consider the reaction between silver and chlorine that produces silver chloride.

- a. Please write the balanced chemical equation for the reaction.
- b. Using the data in the table below, please calculate the changes in enthalpy ( $\Delta H$ ), entropy ( $\Delta S$ ), and free energy ( $\Delta G$ ) as it takes place at  $0.00^\circ\text{C}$ .

| Substance     | $\Delta H^\circ_f$ (kJ/mol) | $S^\circ$ (J/K) |
|---------------|-----------------------------|-----------------|
| Ag            | 0                           | 42.7            |
| $\text{Cl}_2$ | 0                           | 223.0           |
| AgCl          | -127.0                      | 96.1            |

- c. Is this reaction spontaneous at  $0.00^\circ\text{C}$ ? What conditions, if any, are necessary for the reaction to be spontaneous?
- d. Consider the calculated value for  $\Delta H^\circ_{\text{rxn}}$  for this problem. If the reaction were conducted, as written in the balanced chemical equation, in a calorimeter containing 2000.0 mL of water at an initial temperature of  $0.00^\circ\text{C}$ , what would be the final temperature of the water in the calorimeter?

3. Consider the following scenario:

- a. A 50.0 g heated iron ball is dropped into a 500.0 mL water bath at  $24.0^\circ\text{C}$ . The water bath ends up at a final temperature of  $27.0^\circ\text{C}$ . What was the original temperature of the iron ball?
- b. What would the initial temperature of the ball have to be to cause the same temperature change if the ball were made from aluminum?

| Compound             | Specific Heat (J/g $^\circ\text{C}$ )         |
|----------------------|---|
| $\text{H}_2\text{O}$ | 4.186   |
| Fe                   | You may need to<br>Look these up in the book? |
| Al                   |   |

4.  $4 \text{NO}(\text{g}) + 6 \text{H}_2\text{O}(\text{g}) \leftrightarrow 4 \text{NH}_3(\text{g}) + 5 \text{O}_2(\text{g})$

| Compound                 | Moles at Equilibrium |
|--------------------------|----------------------|
| NO (g)                   | 0.332                |
| $\text{H}_2\text{O}$ (g) | 0.498                |
| $\text{O}_2$ (g)         | 0.313                |
| $\text{NH}_3$ (g)        | 0.250                |

- a. Determine the equilibrium constant for the equilibrium conditions shown above.
- b. What does your equilibrium constant tell you about the composition of the equilibrium mixture?

|    |   |     |   |                     |  |       |  |                   |                     |
|----|---|-----|---|---------------------|--|-------|--|-------------------|---------------------|
| 1. | D | 7.  | D | 13.                 | B  | 2. a) | $2 \text{Ag} + \text{Cl}_2 \rightarrow 2 \text{AgCl}$        | 3. b)             | $167^\circ\text{C}$ |
| 2. | A | 8.  | C | <b>Short Answer</b> |  | 2. b) | $\Delta H = -254 \text{ kJ}$ $\Delta S = -116.2 \text{ J/K}$ | 4. a)             | 0.0633              |
| 3. | B | 9.  | D | 1. a)               | $\Delta H = -$ $\Delta S = -$ $\Delta G = -$ | 2. c) | Spont. @ low temps   | 4. b)             | Reactant<br>Favored |
| 4. | C | 10. | C | 1. b)               | $\Delta H = -$ $\Delta S = -$ $\Delta G = -$ | 2. d) | $30.3^\circ\text{C}$   | <b>ANSWER KEY</b> |                     |
| 5. | A | 11. | A | 1. c)               | $\Delta H = +$ $\Delta S = -$ $\Delta G = +$ | 3. a) | $300^\circ\text{C}$  |                   |                     |
| 6. | B | 12. | C | 1. d)               | $\Delta H = +$ $\Delta S = +$ $\Delta G = +$ |       |  |                   |                     |