

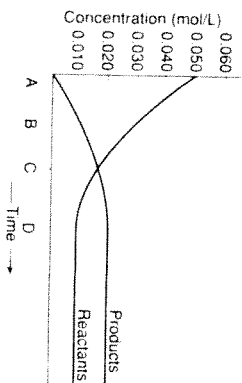
## Reaction Equilibrium

## Part I

Select the response that best completes each statement or answers each question. Write the letter of each answer in the space provided on the left.

- b 1. Which of the following statements describes the macroscopic definition of equilibrium?
- All reactants are consumed.
  - The reaction appears to stop, although reactants remain.
  - The amount of products formed cannot be determined.
  - The amount of reactants remaining cannot be determined.
- c 2. Which of the following statements refers to the submicroscopic definition of equilibrium?
- The reaction stops.
  - All reactants are consumed.
  - Reactants and products are forming at the same rate.
  - No products are forming.
- d 3. Which of the following conditions is NOT necessary to achieve equilibrium?
- All products and reactants are present.
  - Nothing enters the system.
  - Heat must be applied.
  - Nothing leaves the system.

Refer to the graph below to answer questions 4–5. The graph shows the concentrations of products and reactants as a reaction proceeds.



- b 4. Which of the following descriptions refers to the system at point B on the graph?
- There are more products than reactants.
  - There are more reactants than products.
  - The concentration of reactants equals the concentration of products.
  - The concentrations of reactants and products are at constant levels.
- d 5. Which point on the graph indicates equilibrium conditions?
- A
  - B
  - C
  - D

- b 6. Which of the following equations represents a vapor-liquid equilibrium?
- $\text{BaSO}_4(\text{s}) \rightleftharpoons \text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$
  - $\text{CH}_3\text{OH}(\text{l}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g})$
  - $\text{HCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
  - $\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{aq})$

- a 7. Which of the following equations represents solubility equilibrium?
- $\text{BaSO}_4(\text{s}) \rightleftharpoons \text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$
  - $\text{CH}_3\text{OH}(\text{l}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g})$
  - $\text{HCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
  - $\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{aq})$

- c 8. Which of the following equations represents an acid equilibrium?
- $\text{BaSO}_4(\text{s}) \rightleftharpoons \text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$
  - $\text{CH}_3\text{OH}(\text{l}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g})$
  - $\text{HCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
  - $\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{aq})$

## Critical Thinking

9. If several spoonfuls of sugar are added to a glass of iced tea, the sugar begins to dissolve, but then appears to stop dissolving. Actually, however, sugar does continue to dissolve. Explain why the tea does not taste sweeter, even though sugar continues to dissolve.

Conc of sugar has reached saturation and system is at Equilibrium! As additional sugar dissolves an equal amt. of sugar comes out of soln

## Part II

Select the response that best completes each statement. Write the letter of each answer in the space provided on the left.

- a 10. For the equilibrium system  $\text{CO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons \text{CO}_2(\text{g})$ ,  $K_{\text{eq}} =$
- $\frac{[\text{CO}_2]}{[\text{CO}][\text{O}_2]}$
  - $\frac{[\text{CO}][\text{O}_2]}{[\text{CO}_2]}$
  - $\frac{[\text{CO}][\text{O}_2]}{[\text{O}_2]}$
  - $\frac{[\text{CO}][\text{O}_2]}{[\text{O}_2]}$
- c 11. For the equilibrium system  $2\text{HCl}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{Cl}_2(\text{g})$ ,  $K_{\text{eq}} =$
- $\frac{[\text{H}_2][\text{Cl}_2]}{2[\text{HCl}]}$
  - $\frac{2[\text{HCl}]}{[\text{H}_2][\text{Cl}_2]}$
  - $\frac{[\text{H}_2][\text{Cl}_2]}{[\text{HCl}]^2}$
  - $\frac{[\text{HCl}]^2}{[\text{H}_2][\text{Cl}_2]}$

12. When writing an equilibrium constant expression, it is a standard procedure to omit \_\_\_\_\_

- a. gases, because they escape
- b. solids, because they have a constant concentration
- c. liquids, because they do not take part in the reaction
- d. no product or reactant, because all are important

Questions 13-18: Write the correct answer in the space provided. Show your work.

13. At equilibrium, carbon monoxide gas and water vapor have reacted to produce concentrations of 0.127M carbon dioxide,  $\text{CO}_2(\text{g})$ , and 0.127M hydrogen,  $\text{H}_2(\text{g})$ . The molarity of the  $\text{CO}(\text{g})$  is 0.0610M and the molarity of the  $\text{H}_2\text{O}(\text{g})$  is 0.0625M.

Write the equation and equilibrium constant expression for this reaction.



14. Calculate the equilibrium constant for the system described in question 13.

$$K_{eq} = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]} = \frac{0.127 \times 0.127}{0.061 \times 0.0625} = 10.1$$

15. The  $K_{eq}$  for the reaction given below is 1.96 at 1000°C. Given a concentration of 0.350M of  $\text{H}_2(\text{g})$ , what is the concentration of  $\text{CO}_2$ ? Explain your answer.



16. Given the equilibrium system described in question 15, what is the concentration of  $\text{H}_2\text{O}(\text{g})$ ? Assume that there is an excess of carbon.

$$K_{eq} = \frac{[\text{H}_2][\text{CO}]}{[\text{H}_2\text{O}]} = 1.96 \quad [\text{H}_2\text{O}] = \frac{[0.350M]^2}{1.96} = 0.0625M$$

17. The  $K_{sp}$  for the dissolving of  $\text{BaCO}_3$  is  $8.5 \times 10^{-11}$  at 25°C. Calculate the concentration of chromate ion in water at 25°C.

$$[K_{sp} = [\text{Ba}^{2+}][\text{CO}_3^{2-}] = x^2 = 8.5 \times 10^{-11}$$

### ■ Critical Thinking

18. The  $K_{sp}$  for the dissolving of  $\text{BaCO}_3$  in water is  $5.1 \times 10^{-9}$  at 25°C. If 0.01000 g of  $\text{BaCO}_3$  are mixed with 1.00 L of water at 25°C, how many grams of  $\text{BaCO}_3$  will remain undissolved?

$$K_{sp} = [\text{Ba}^{2+}][\text{CO}_3^{2-}] = x^2 = 5.1 \times 10^{-9}$$

### ■ Part III

Select the response that best completes each statement or answers each question. Write the letter of each answer in the space provided on the left.

19. According to Le Chatelier's principle, making a change that disturbs equilibrium causes equilibrium to shift \_\_\_\_\_

- a. to form more products
- b. to form more reactants

- c. in a way that partially undoes the change
- d. in a way that cannot be predicted

20. If a reaction is exothermic, and the temperature of the system is increased, \_\_\_\_\_
- a. equilibrium shifts to favor products
  - b. equilibrium shifts to favor reactants
  - c. the pressure decreases
  - d. the rate of reaction decreases

21. Which of the following reactions will NOT be affected by a change in pressure?

- a.  $\text{COCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$
- b.  $\text{C}(\text{s}) + 2\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_4(\text{g})$
- c.  $2\text{H}_2(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{I}_2(\text{g})$
- d.  $\text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{PCl}_5(\text{g})$

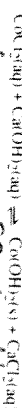
Questions 22-24: Write the correct answer in the space provided.

22. If all reactants and products are gases, does a change in volume have to cause equilibrium to shift? Explain your answer.

No - if the # of molecules on both sides of equation is the same - changing volume does not

### ■ Critical Thinking

23. Given the reaction shown below, suppose  $\text{KOH}(\text{aq})$  were added to the system. How would the  $\text{K}^+$  ions affect equilibrium? How would the  $\text{OH}^-$  ions affect equilibrium? What change would be observed? Explain your answers.



$\text{K}^+$  ions have no effect b/c  $\text{K}^+$  not part of the eq rxn -  $\text{OH}^-$  will have an effect

### ■ Laboratory Investigation

24. Given the reaction and color changes indicated below, describe two changes that would cause the system to be green, rather than blue. Explain your answers.



(green)

(blue)

(colorless)

Heat system shift towards Reactant

Add extra  $\text{Cl}^-$  ions by adding  $\text{NaCl}$  or another  $\text{Cl}^-$  comp  
This would shift towards Reactants