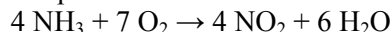


MC: (_____ - _____ / 4)(3 pts each) = _____ FR: _____ (out of 41) Overall: _____

SECTION I: Multiple Choice (39 pts, 3 pts each): Choose the option that is the best answer or completes each question or statement. Write your answers in the blanks provided and erase mistakes completely. In this section, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly.

1. Which of the following is NOT a valid expression for the rate of the reaction below?



A. $-\frac{1}{7} \frac{\Delta[\text{O}_2]}{\Delta t}$

B. $\frac{1}{4} \frac{\Delta[\text{NO}_2]}{\Delta t}$

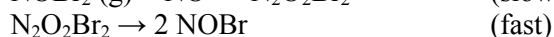
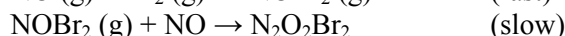
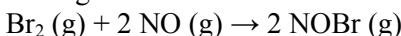
C. $\frac{1}{6} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t}$

D. $-\frac{1}{4} \frac{\Delta[\text{NH}_3]}{\Delta t}$

E. Not enough information given or none of the above

Ans: _____

2. A possible mechanism for the following reaction is listed below:



The rate law based on this mechanism is:

A. Rate = $k [\text{NO}] [\text{Br}_2]$

B. Rate = $k [\text{NO}]^2 [\text{Br}_2]$

C. Rate = $k [\text{NO}] [\text{Br}_2]^2$

D. Rate = $k [\text{NO}]^2 [\text{Br}_2] [\text{NOBr}_2]$

E. Not enough information given or none of the above

Ans: _____

3. Which of the following descriptions of graphs would show the correct relationship between concentration and time for a reaction that is second order?

A. $\ln [A]$ vs. time

B. $[A]$ vs. time

C. $1/[A]$ vs. time

D. $[A]^2$ vs. time

E. Not enough information given or none of the above

Ans: _____

4. The relationship between the rate constants for the forward and reverse reactions and the equilibrium constant for the process is $K_{\text{eq}} =$

A. $k_f \times k_r$

B. $k_f - k_r$

C. $k_f + k_r$

D. k_f / k_r

E. Not enough information given or none of the above

Ans: _____

5. Which of the following condition changes will affect the value of the equilibrium constant, K_{eq} ?
- Temperature
 - Volume
 - Addition of a catalyst
- I only
 - III only
 - I and III
 - II and III
 - Not enough information given or none of the above
- Ans: _____
6. The equilibrium constant expression, K_C , for the thermal decomposition of solid calcium carbonate is:
- $\frac{[CaCO_3]}{[CaO][CO_2]}$
 - $\frac{[CaO][CO_2]}{[CaCO_3]}$
 - $\frac{1}{[CO_2]}$
 - $[CO_2]$
 - None of the above
- Ans: _____
7. Which of the following is the weakest acid?
- HNO_2 ($K_a = 4.5 \times 10^{-4}$)
 - HCN ($K_a = 4.9 \times 10^{-5}$)
 - HF ($K_a = 6.8 \times 10^{-4}$)
 - $HClO$ ($K_a = 3.0 \times 10^{-8}$)
 - Not enough information given or none of the above
- Ans: _____
8. B is a weak base. Which equilibrium corresponds to the equilibrium constant K_a for HB^+ ?
- $HB^+(aq) + H_2O(l) \leftrightarrow B(aq) + H_3O^+(aq)$
 - $HB^+(aq) + H_3O^+(aq) \leftrightarrow H_2B^{2+}(aq) + H_2O(l)$
 - $B(aq) + H_2O(l) \leftrightarrow HB^+(aq) + OH^-(aq)$
 - $HB^+(aq) + OH^-(aq) \leftrightarrow B(aq) + H_2O(l)$
 - Not enough information given or none of the above
- Ans: _____
9. Of the following, which is the strongest acid?
- $HClO$
 - $HClO_2$
 - $HBrO$
 - $HBrO_2$
 - Not enough information given or none of the above
- Ans: _____
10. Which of the following CANNOT act as a Lewis base?
- Cl^-
 - NH_3
 - BF_3
 - H_2O
 - Not enough information given or none of the above
- Ans: _____

11. Which of the following could be added to a solution of sodium acetate to produce a usable buffer?
- I. Acetic acid
 - II. Hydrochloric acid
 - III. Silver acetate
- A. I only
 - B. II only
 - C. II and III
 - D. I, II, and III
 - E. Not enough information given or none of the above
- Ans: ____

12. Which of the following is true about the equivalence point of the titration of a weak acid with a strong base?
- A. The moles of weak acid and the moles of the weak acid's conjugate base are identical.
 - B. The pH = 7.
 - C. The source of the concentration of weak acid is based only on the resulting hydrolysis reaction.
 - D. The solution will mostly consist of the weak acid.
 - E. Not enough information given or none of the above
- Ans: ____

13. In which aqueous system is PbI_2 least soluble?
- A. H_2O
 - B. 0.5 M HI
 - C. 0.8 M KI
 - D. 1.0 M HNO_3
 - E. Not enough information given or none of the above
- Ans: ____

SECTION II: Free Response (41 pts)

14. (20 pts) For the following reaction, the rate constant, k , at 25°C is $0.63 \text{ M}^{-1} \text{ min}^{-1}$.
- $$2 \text{NO}_2 (\text{g}) \rightarrow 2 \text{NO} (\text{g}) + \text{O}_2 (\text{g})$$

- a. (6 pts) What is the rate law for the reaction? Briefly explain how you know in 1-2 sentences.

Rate =

- b. (6 pts) If the initial concentration of NO_2 is 0.100 M, how long would it take for the concentration to decrease to 0.025 M?

Time =

- c. (8 pts) If the rate constant doubles when the temperature increases by 10°C , what is the activation energy of the reaction?

$E_A =$

15. (21 pts) Consider the titration of 30.0 mL of 0.500 M nitrous acid ($K_a = 4.5 \times 10^{-4}$) with 0.500 M KOH.

a. (4 pts) Write a chemical equation showing how nitrous acid behaves as an acid in water.

b. (6 pts) Calculate the initial pH of the nitrous acid solution.

pH =

c. (6 pts) After 20.0 mL of titrant have been added,

i. Calculate $[H_3O^+]$ in the flask after the titrant has been added.

$[H_3O^+] =$

ii. Calculate the pH in the flask after the titrant has been added.

pH =

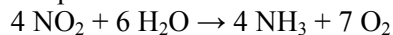
d. (5 pts) After 40.0 mL of titrant have been added, calculate the pOH in the flask.

pOH =

MC: (_____ - _____ / 4)(3 pts each) = _____ FR: _____ (out of 41) Overall: _____

SECTION I: Multiple Choice (39 pts, 3 pts each): Choose the option that is the best answer or completes each question or statement. Write your answers in the blanks provided and erase mistakes completely. In this section, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly.

1. Which of the following is NOT a valid expression for the rate of the reaction below?



A. $\frac{1}{7} \frac{\Delta[\text{O}_2]}{\Delta t}$

B. $-\frac{1}{4} \frac{\Delta[\text{NH}_3]}{\Delta t}$

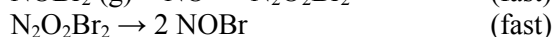
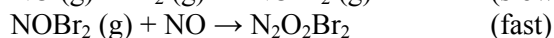
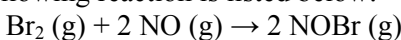
C. $-\frac{1}{4} \frac{\Delta[\text{NO}_2]}{\Delta t}$

D. $-\frac{1}{6} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t}$

E. Not enough information given or none of the above

Ans: _____

2. A possible mechanism for the following reaction is listed below:



The rate law based on this mechanism is:

A. Rate = $k [\text{NO}] [\text{Br}_2]$

B. Rate = $k [\text{NO}]^2 [\text{Br}_2]$

C. Rate = $k [\text{NO}] [\text{Br}_2]^2$

D. Rate = $k [\text{NO}] [\text{Br}_2] [\text{NOBr}_2]$

E. Not enough information given or none of the above

Ans: _____

3. Which of the following descriptions of graphs would show the correct relationship between concentration and time for a reaction that is zero order?

E. $1 / [\text{A}]$ vs. time

F. $[\text{A}]^2$ vs. time

G. $\ln [\text{A}]$ vs. time

H. $[\text{A}]$ vs. time

E. Not enough information given or none of the above

Ans: _____

4. Once equilibrium has been achieved for the reaction $\text{A} \rightarrow \text{B}$, which of the following is NOT true?

E. $k_f / k_r = \text{constant}$

F. Forward rate of reaction = reverse rate of reaction

G. Forward rate constant = reverse rate constant

H. $k_f [\text{A}] / k_r [\text{B}] = \text{constant}$

E. Not enough information given or all of the above are true

Ans: _____

5. Which of the following condition changes will NOT affect the value of the equilibrium constant, K_{eq} , of a reaction that includes gases?
- IV. Increase in temperature
V. Decrease in volume
VI. Addition of a catalyst
- E. II only
F. III only
G. I and II
H. II and III
E. Not enough information given or none of the above Ans: _____
6. The equilibrium constant expression, K_C , for the decomposition of aqueous carbonic acid is:
- A. $\frac{[H_2O][CO_2]}{[H_2CO_3]}$
B. $\frac{[CO_2]}{[H_2CO_3]}$
C. $\frac{[H_2CO_3]}{[H_2O][CO_2]}$
D. $[CO_2]$
E. None of the above Ans: _____
7. Which of the following is the strongest acid?
- A. HF ($K_a = 6.8 \times 10^{-4}$)
B. HClO ($K_a = 3.0 \times 10^{-8}$)
C. HNO₂ ($K_a = 4.5 \times 10^{-4}$)
D. HCN ($K_a = 4.9 \times 10^{-5}$)
E. Not enough information given or none of the above Ans: _____
8. B is a weak base. Which equilibrium corresponds to the equilibrium constant K_b ?
- F. $HB^+(aq) + H_2O(l) \leftrightarrow B(aq) + H_3O^+(aq)$
G. $HB^+(aq) + H_3O^+(aq) \leftrightarrow H_2B^{2+}(aq) + H_2O(l)$
H. $B(aq) + H_2O(l) \leftrightarrow HB^+(aq) + OH^-(aq)$
I. $HB^+(aq) + OH^-(aq) \leftrightarrow B(aq) + H_2O(l)$
J. Not enough information given or none of the above Ans: _____
9. Of the following, which is the weakest acid?
- F. HIO
G. HIO₂
H. HClO
I. HClO₂
J. Not enough information given or none of the above Ans: _____
10. Which of the following is most likely to be a Lewis acid?
- E. BeF₂
F. H₂O
G. Cl⁻
H. NH₃
E. Not enough information given or none of the above Ans: _____

11. Which of the following could be added to a solution of ammonium chloride to produce a usable buffer?
- I. Aqueous ammonia
 - II. Hydrochloric acid
 - III. Ammonium acetate
- F. I only
 - G. II only
 - H. I and III
 - I. I, II, and III
 - J. Not enough information given or none of the above
- Ans: ____

12. Which of the following is true about the equivalence point of the titration of a weak base with a strong acid?
- F. The moles of weak base and the moles of the weak base's conjugate acid are identical.
 - G. The pH > 7.
 - H. The concentration of weak base will be zero.
 - I. The weak base's conjugate acid will hydrolyze to produce H⁺.
 - J. Not enough information given or none of the above
- Ans: ____

13. In which aqueous system is PbI₂ least soluble?
- F. H₂O
 - G. 0.5 M HI
 - H. 0.8 M KI
 - I. 1.0 M AgI
 - J. Not enough information given or none of the above
- Ans: ____

SECTION II: Free Response (41 pts)

14. (20 pts) For the following reaction, the rate constant, k, at 25°C is 0.23 min⁻¹.
- $$2 \text{NO}_2 (\text{g}) \rightarrow 2 \text{NO} (\text{g}) + \text{O}_2 (\text{g})$$

- e. (6 pts) What is the rate law for the reaction? Briefly explain how you know in 1-2 sentences.

Rate =

- f. (6 pts) If the initial concentration of NO₂ is 0.200 M, how long would it take for the concentration to decrease to 0.050 M?

Time =

- g. (8 pts) If the rate constant triples when the temperature increases by 20°C, what is the activation energy of the reaction?

E_A =

15. (21 pts) Consider the titration of 40.0 mL of 0.300 M nitrous acid ($K_a = 4.5 \times 10^{-4}$) with 0.300 M KOH.

h. (4 pts) Write a chemical equation showing how nitrous acid behaves as an acid in water.

i. (6 pts) Calculate the initial pH of the nitrous acid solution.

pH =

j. (6 pts) After 25.0 mL of titrant have been added,

i. Calculate $[H_3O^+]$ in the flask after the titrant has been added.

$[H_3O^+] =$

ii. Calculate the pH in the flask after the titrant has been added.

pH =

k. (5 pts) After 50.0 mL of titrant have been added, calculate the pOH in the flask.

pOH =