1. Consider the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.   If hydrogen gas is added to this system at equilibrium, will the reaction shift towards *reactants* or *products*?

2. Consider the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.   If nitrogen is added to the system at equilibrium, what will happen to the ammonia concentration?

3. Consider the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.   The production of ammonia is an exothermic reaction. Will heating the equilibrium system *increase* or *decrease* the amount of ammonia produced?

4. Consider the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.   If we use a catalyst, which way will the reaction shift?

5. Given the following data for the reaction: $A(g) + 2B(s) \rightleftharpoons AB_2(g)$

Temperature (K)	K_c
300	1.5×10^4
600	55
900	3.4×10^{-3}

Is the reaction *endothermic* or *exothermic*?

6. Consider the reaction, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. $K_c = 8.1 \times 10^{-3}$ at 900 K.
   What is the value of K_c for $NH_3(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$

7. 5.00 mol of ammonia are introduced into a 5.00 L reactor vessel in which it partially
   dissociates at high temperatures.
   $$2NH_3(g) \rightleftharpoons 3H_2(g) + N_2(g)$$
   At equilibrium at a particular temperature, 1.00 mole of ammonia remains.   Calculate
   K_c for the reaction.
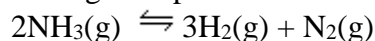
8. Consider the following equilibrium,
   $$4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g) + 1531 \text{ kJ}$$
   State whether the concentrations the reactants would *increase*, *decrease*, or *remain
   constant* after nitrogen gas was removed from the system.
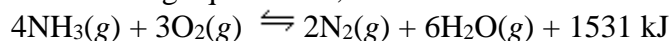
9. Identify the conjugate acid-base pairs in the reaction $HSO_4^- + HF \rightleftharpoons H_2SO_4 + F^-$
   One conjugate acid-base pair is _____; the other acid-base pair is
   _____.

10. Write the formula for the conjugate base of H_3PO_4

11. Write the formula for the conjugate acid of $H_2PO_4^-$.

12. Calculate the pH of a solution containing 0.20 g of NaOH in 2,000. mL of solution.

13. If the pH of liquid bleach is 12.0, what is the hydroxide ion concentration in this solution?

14. HCN is classified as a weak acid in water. What does this classification mean?

15. When 2.0×10^{-2} mole of nicotinic acid (a monoprotic acid) is dissolved in 350. mL of water, the pH is 3.05. What is the K_a of nicotinic acid?

16. The pH of a 0.6 M solution of a weak acid is 4.0. What percent of the acid has ionized?

17. Calculate the pH of a 0.025 M solution of $NaNO_2$ ($K_a(HNO_2) = 4.5 \times 10^{-4}$)

18. Calculate the pH of a 0.20 M solution of the weak base pyridine (C_5H_5N; $K_b = 1.7 \times 10^{-9}$)

19. Calculate the pH of a 0.15 M solution of HOI ($K_a = 2.3 \times 10^{-11}$)

20. Calculate the pH of a solution that is 0.15 M CH_3COOH and 0.75 M CH_3COONa. You will need the Ka of acetic acid.

21. Calculate the pH of a solution that is 0.20M $NH_3(aq)$ and 0.35 M $NH_4Cl(aq)$.
     ($K_b(NH_3) = 1.8 \times 10^{-5}$)

22. 500. mL of a solution containing 1.5 M $NH_3(aq)$ is mixed with 500. mL of a solution containing 0.50M of $HCl(aq)$. What is the pH of the final solution?
$(K_b(NH_3) = 1.8 \times 10^{-5})$

23. Calculate the percent ionization of formic acid in a 0.010 M HCOOH solution.
$(K_a = 1.7 \times 10^{-4})$

24. What molar ratio of benzoate ion to benzoic acid would be required to prepare a buffer with a pH of 5.20? $[K_a(C_6H_5COOH) = 6.5 \times 10^{-5}]$

25. Write a net ionic equation for the reaction that occurs when a small amount of hydrochloric acid is added to a buffer solution containing NH_4Cl and NH_3.

26. Write a net ionic equation for the reaction occurring when a small amount of sodium hydroxide solution is added to a buffer solution containing NH_4Cl and NH_3.

27. 550. mL of a 0.40M solution of NaOH is titrated with 0.25 M HCl. Calculate the pH of the solution after 1.10 L of HCl has been added.

28. Calculate the pH at the equivalence point for the titration of 0.22 M HCN with 0.22 M NaOH.   ($K_a = 4.9 \times 10^{-10}$ for HCN)

Answer Key

1. *products*
2. $[NH_3]$ will increase.
3. The amount of NH_3 produced will decrease.
4. Addition of a catalyst will have no effect on the position of the equilibrium.
5. exothermic
6. 11
7. $K_c = 17.3$
8. decrease
9. HF–F⁻; H_2SO_4–HSO_4^-
10. $H_2PO_4^-$
11. H_3PO_4
12. 11.40
13. 1×10^{-2} M
14. A relatively small fraction of the acid undergoes ionization.
15. 1.4×10^{-5}
16. 0.02 %
17. 7.87
18. 9.27
19. 5.73
20. 5.44
21. 9.01
22. 9.56
23. 13%
24. 10.3
25. $H^+ + NH_3 \rightarrow NH_4^+$
26. $OH^- + NH_4^+ \rightarrow NH_3 + H_2O$
27. 1.48
28. 11.18