

1. An acid-base buffer consists of \_\_\_\_\_ . (Pick the one answer that always is true.)

  - (a) a weak acid.
  - (b) a conjugate acid base pair.
  - (c) mixture of a weak acid and a weak base.
  - (d) a weak base.
  - (e) a mixture of a strong acid and a strong base.
  
2. What buffer component ratio, base/acid, is needed to make a pH 10.00 buffer solution using a mixture of  $[\text{CH}_3\text{NH}_3]\text{Cl}$  and  $\text{CH}_3\text{NH}_2$ ?

(a) 0.21      (b) 3.7      (c) 4.8      (d) 0.27      (e) 0.56
  
3. How many grams of HCl would need to be added to 250. mL of a 0.10 M aqueous solution of  $\text{CH}_3\text{NH}_2$  to make a pH 10.00 buffer? [A longer question. You may want to come back to it.]

(a) 5.7 g      (b) 0.16 g      (c) 37 g      (d) 1.2 g      (e) 0.72 g

Consider the following titration for the next 5 questions.

30.0 mL of 0.030 M formic acid,  $\text{HCO}_2\text{H}$  (in the flask), is titrated with 0.045 M  $\text{NaOH}$  (in buret).

4. What is the overall reaction occurring in the titration?
- (a)  $\text{HCO}_2\text{H}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HCO}_2^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
- (b)  $\text{HCO}_2\text{H}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{Na}^+(\text{aq}) + \text{HCO}_2^-(\text{aq})$
- (c)  $\text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow 2 \text{H}_2\text{O}(\text{l})$
- (d)  $\text{HCO}_2\text{H}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{Na}(\text{aq}) + \text{HCO}_2(\text{aq})$
- (e)  $\text{HCO}_2\text{H}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{HCO}_3(\text{aq})$
5. How many mL of the  $\text{NaOH}$  solution need to be added to reach the equivalence point of the titration?
- (a) 5.0 mL    (b) 10.0 mL    (c) 15.0 mL    (d) 20.0 mL    (e) 30. mL
6. Which of the following is present in the flask after 5.0 mL/ of the  $\text{NaOH}$  solution has been added? Mark all correct answers.
- (a)  $\text{HCO}_2\text{H}(\text{aq})$                       (b)  $\text{NaOH}(\text{aq})$                       (c)  $\text{HCO}_2(\text{aq})$   
(d)  $\text{Na}[\text{HCO}_2](\text{aq})$                       (e)  $\text{HCO}_3(\text{aq})$
7. How is the solution best characterized after 5.0 mL of the  $\text{NaOH}$  solution has been added?
- (a) solution of a strong acid                      (b) solution of a strong base  
(c) solution of a weak acid                      (d) solution of a weak base  
(e) buffer solution                      (ab) neutral solution

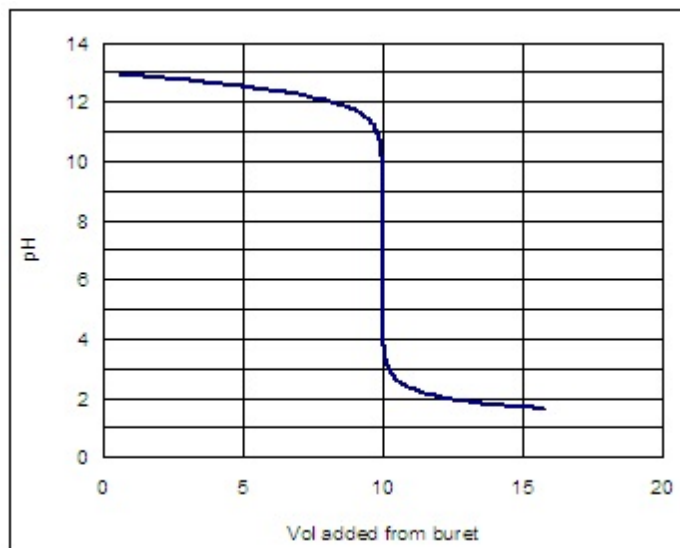
**Continuation of the titration question from the previous page:**

30.0 mL of 0.030 M formic acid,  $\text{HCO}_2\text{H}$  (in the flask), is titrated with 0.045 M  $\text{NaOH}$  (in buret).

8. What is the pH of the solution in the flask after 5.0 mL of the  $\text{NaOH}$  solution has been added?
- (a) 3.26      (b) 9.78      (c) 1.71      (d) 4.22      (e) 10.74

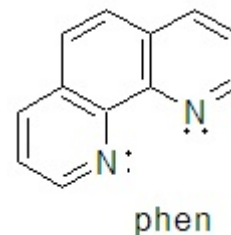
9. Consider the adjacent titration curve. Which one of the following statement is true? The titration curve corresponds to the titration of a .....

- (a) weak acid (flask) with a strong base (buret).
- (b) weak base (flask) with a strong acid (buret).
- (c) strong acid (flask) with a strong base (buret).
- (d) strong base (flask) with a strong acid (buret).



10. What is the  $K_{sp}$  expression for chromium(III) fluoride?
- (a)  $[Cr^{3+}][F^-]$                       (b)  $[Cr^{3+}][F^-]^3$                       (c)  $[Cr^{+}]^3[F^{3-}]$   
(d)  $\frac{[Cr]^{3+}[F]}{[Cr_3F]}$                       (e)  $\frac{[Cr_2F_3]}{[Cr^{3+}]^2[F^{2-}]^3}$
11. The solubility of chromium(III) fluoride in water at 25 °C is  $1.25 \times 10^{-3}$  M. What is the  $K_{sp}$  value for chromium(III) fluoride at this temperature?
- (a)  $6.6 \times 10^{-11}$                       (b)  $7.8 \times 10^{-9}$                       (c)  $1.6 \times 10^{-6}$                       (d)  $8.2 \times 10^{-2}$   
(e)  $5.6 \times 10^{-7}$
12. What will happen if HCl is added to a saturated aqueous solution of chromium(III) fluoride in water? ("Saturated solution" means that there is solid chromium(III) fluoride present and the system is at equilibrium.)
- (a) Nothing happens.  
(b) The chromium(III) fluoride solubility equilibrium shifts to the RIGHT and more chromium(III) fluoride precipitates out of solution.  
(c) The chromium(III) fluoride solubility equilibrium shifts to the LEFT and more chromium(III) fluoride precipitates out of solution.  
(d) The chromium(III) fluoride solubility equilibrium shifts to the RIGHT and more solid chromium(III) fluoride dissolves.  
(e) The chromium(III) fluoride solubility equilibrium shifts to the LEFT and more solid chromium(III) fluoride dissolves.

Consider the following for the next two questions. Iron (II) forms an orange-red complex ion with three phenanthrolines, abbreviated "phen". (Structure shown to the right.)



13. What is the  $K_f$  expression for formation of the complex ion? Careful. Some answers are very similar.

- (a)  $\frac{[\text{Fe}(\text{phen})_3]}{[\text{Fe}][\text{phen}]^3}$       (b)  $\frac{[\text{Fe}^{2+}]^3[\text{phen}]}{[\text{Fe}(\text{phen})_3^{2+}]}$
- (c)  $\frac{[\text{Fe}(\text{phen})_3^{2+}]}{[\text{Fe}^{2+}][\text{phen}]^3}$       (d)  $\frac{[\text{Fe}^{2+}][\text{phen}]^3}{[\text{Fe}(\text{phen})_3^{2+}]}$       (e)  $\frac{[\text{Fe}(\text{phen})_3^{2+}]^3}{[\text{Fe}^{2+}][\text{phen}]}$

14. The concentration of iron(II) can be determined by adding excess "phen" to an aqueous solution to form the colored complex ion. To do this analysis, a standard solution containing  $4.46 \times 10^{-5} \text{ M Fe}^{2+}$  was prepared. After addition of excess phen, the absorption of the standard solution = 0.682 at 508 nm.

To determine  $[\text{Fe}^{2+}]$  in an unknown solution, 5.00 mL of the solution was diluted to 25.0 mL. After addition of excess phen, the absorption of the standard solution = 0.264 at 508 nm. What is the  $[\text{Fe}^{2+}]$  in the original (undiluted) solution?

- (a)  $9.65 \times 10^{-4} \text{ M}$       (b)  $4.83 \times 10^{-5} \text{ M}$       (c)  $2.41 \times 10^{-6} \text{ M}$
- (d)  $1.73 \times 10^{-5} \text{ M}$       (e)  $8.63 \times 10^{-5} \text{ M}$

15. Will mixing an aqueous solution of sodium carbonate and nickel(II) nitrate likely result in a precipitate? If so, what will precipitate?

- (a)  $\text{Na}_2\text{NO}_3$                       (b)  $\text{Ni}(\text{CO}_3)_2$                       (c)  $\text{NiCO}_3$                       (d)  $\text{NaNO}_3$   
(e) there will likely be no precipitate

16. 5.00 mL of a  $2.0 \times 10^{-2}$  M sodium chloride solution is mixed with 5.00 mL of a solution containing  $2.0 \times 10^{-3}$  M copper(I) and 0.10 M lead(II). What happens?

$K_{\text{sp}}$  of copper(I) chloride =  $1.9 \times 10^{-7}$  M and  $K_{\text{sp}}$  of lead(II) chloride =  $1.7 \times 10^{-5}$  M

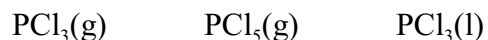
- (a) nothing  
(b) only copper(I) chloride precipitates  
(c) only lead(II) chloride precipitates  
(d) both lead(II) chloride and copper(I) chloride precipitate

17. All physical processes tend to towards \_\_\_\_\_ entropy and \_\_\_\_\_ energy.

The answers in order are

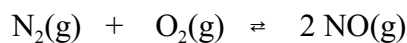
- (a) higher, lower                      (b) lower, higher                      (c) higher, higher                      (d) lower, lower

18. Place the following in order of increasing  $S^\circ$



- (a)  $\text{PCl}_3(\text{g}) < \text{PCl}_5(\text{g}) < \text{PCl}_3(\text{l})$                       (b)  $\text{PCl}_5(\text{g}) < \text{PCl}_3(\text{g}) < \text{PCl}_3(\text{l})$   
(c)  $\text{PCl}_3(\text{l}) < \text{PCl}_5(\text{g}) < \text{PCl}_3(\text{g})$                       (d)  $\text{PCl}_3(\text{l}) < \text{PCl}_3(\text{g}) < \text{PCl}_5(\text{g})$   
(e)  $\text{PCl}_5(\text{g}) < \text{PCl}_3(\text{l}) < \text{PCl}_3(\text{g})$

**Consider the following reaction for the next 2 questions.**



19. What is  $\Delta S^\circ$  for the above reaction?

- (a) 185.8 J/K                      (b) 24.9 J/K                      (c) -185.8 J/K                      (d) -24.9 J/K  
(e) 421.4 J/K

20. What is  $\Delta G^\circ$  for the above reaction at **500 K**?

- (a) 180.4 kJ                      (b) -168 kJ                      (c) 168 kJ                      (d) -127 kJ  
(e) 127 kJ

Answers: 1 c, 2 d, 3 e, 4 b, 5 d, 6 ad, 7 e, 8 a, 9 d, 10 b, 11 a, 12 d, 13 c, 14 e, 15 c, 16 b, 17 a, 18 d, 19 b, 20 c.

## ADDITIONAL INFORMATION

Some  $K_a$  Values at 25 °C

	$K_{a1}$	$K_{a2}$	$K_{a3}$
$\text{CH}_3\text{CO}_2\text{H}$	$1.8 \times 10^{-5}$		
$\text{C}_6\text{H}_5\text{CO}_2\text{H}$	$6.3 \times 10^{-5}$		
$\text{H}_3\text{BO}_3$	$5.8 \times 10^{-10}$		
$\text{H}_2\text{CO}_3$	$4.3 \times 10^{-7}$	$5.6 \times 10^{-11}$	
$\text{H}_2\text{C}_2\text{O}_4$	$5.6 \times 10^{-2}$	$5.4 \times 10^{-5}$	
$\text{HCO}_2\text{H}$	$1.8 \times 10^{-4}$		
$\text{H}_3\text{PO}_4$	$7.5 \times 10^{-3}$	$6.2 \times 10^{-8}$	$4.8 \times 10^{-13}$
$\text{H}_2\text{SO}_4$	very large	$1.2 \times 10^{-2}$	
HF	$3.5 \times 10^{-4}$		

Some  $K_b$  values at 25 °C

	$K_b$
$\text{NH}_3$	$1.8 \times 10^{-5}$
$\text{CH}_3\text{NH}_2$	$3.7 \times 10^{-4}$
$(\text{CH}_3)_3\text{N}$	$6.4 \times 10^{-5}$
$\text{C}_5\text{H}_5\text{N}$	$1.7 \times 10^{-9}$

**Thermodynamic Information at 25 °C (298 K):**

Compound	$\Delta H_f^\circ$ , kJ	$\Delta G_f^\circ$ , kJ	$S^\circ$ , J/K
$\text{H}_2(\text{g})$	0	0	130.6
$\text{HNO}_3(\text{aq})$	-206.6	-110.5	146
$\text{H}_2\text{O}(\text{g})$	-241.83	-228.60	188.72
$\text{H}_2\text{O}(\text{l})$	-285.84	-237.19	69.94
$\text{NH}_3(\text{g})$	-45.9	-16	193
$\text{N}_2(\text{g})$	0	0	191.5
$\text{N}_2\text{O}(\text{g})$	82.05	104.2	219.7
$\text{NO}(\text{g})$	90.2	86.6	210.7
$\text{NO}_2(\text{g})$	33.2	51.3	240.0
$\text{O}_2(\text{g})$	0	0	205.0

## EQUATIONS

$$K_a K_b = K_w = 1.008 \times 10^{-14}$$

$$pH = pK_a + \log \frac{[base]}{[acid]}$$

$$pK_a = -\log(K_a)$$

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

$$\Delta S_{\text{tot}} = \Delta S + \Delta S_{\text{surr}}$$

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

$$\Delta S_{\text{surr}} = -\frac{\Delta H}{T}$$

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

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

$$\Delta G = \Delta G^\circ + RT \ln Q \quad \text{or} \quad \Delta G = \Delta G^\circ + 2.303 RT \log Q$$

$$\Delta G^\circ = -RT \ln K \quad \text{or} \quad \Delta G^\circ = -2.303 RT \log K$$

$$K = e^{-\frac{\Delta G^\circ}{RT}} \quad \text{or} \quad K = 10^{-\frac{\Delta G^\circ}{2.303 RT}}$$

$$K_w = 1.008 \times 10^{-14}$$

$$R = 8.314 \times 10^{-3} \text{ kJ/(mol}\cdot\text{K)}$$

$$0^\circ \text{ C} = 273.15 \text{ K}$$