

## Recitation Worksheet Twelve

Name:

MyID:

### Textbook:

Chemistry & Chemical Reactivity

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### Instructions:

- This recitation worksheet covers Ch. 16.5, 17.1-17.2
- Please enter your first and last name as it appears on the eLC roster (do not use a nickname that is not reflected in eLC).
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  - Answers must be written in the corresponding answer boxes.
  - You must show your work when appropriate.
- This worksheet is due no later than **12:00 PM (noon) on the Saturday, November 16<sup>th</sup>**.
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

A buffer solution is a solution of a weak acid & salt of its conjugate base or a weak base & the salt of its conjugate acid.

1. Which of the aqueous solutions below are buffer solutions? Select all that apply. Insert letters without spaces in the answer box, example ABCD.

**CEF**

- A. 0.100 M KBr
- B. 0.200 M NaCl and 0.200 M NH<sub>4</sub>Cl
- C. 0.100 M CH<sub>3</sub>NH<sub>2</sub> and 0.150 M CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>Cl<sup>-</sup>
- D. 0.100 M HCl and 0.050 M NaNO<sub>2</sub>
- E. 0.100 HCl and 0.200 M NaCH<sub>3</sub>COO
- F. 0.100 M Na<sub>2</sub>HPO<sub>4</sub> and 0.100 M NaH<sub>2</sub>PO<sub>4</sub>
- G. 0.100 M CH<sub>3</sub>COOH and 0.100 M NaCH<sub>3</sub>CH<sub>2</sub>COO

- (A) KBr is a pH-neutral salt
- (B) NaCl is a pH-neutral salt & NH<sub>4</sub><sup>+</sup>Cl<sup>-</sup> is an acidic salt
- (C) CH<sub>3</sub>NH<sub>2</sub> is a weak base & CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>Cl<sup>-</sup> the salt of its conjugate acid

(D) HCl + NaNO<sub>2</sub> → HNO<sub>2</sub> + NaCl

I	0.100 mol	0.050 mol	0	0
C	-0.050 mol	0.050 mol	+0.050 mol	+0.050 mol
F	0.050 mol	0 mol	0.050 mol	0.050 mol

Buffer mixture

From the ICF table HCl (strong acid), HNO<sub>2</sub> (weak acid), & NaCl (pH-neutral salt) which none of these components form a buffer

(E) HCl + CH<sub>3</sub>COONa → CH<sub>3</sub>COOH + NaCl

I	0.100 mol	0.200 mol	0	0
C	-0.100 mol	-0.100 mol	+0.100 mol	+0.100 mol
F	0	0.100 mol	0.100 mol	0.100 mol

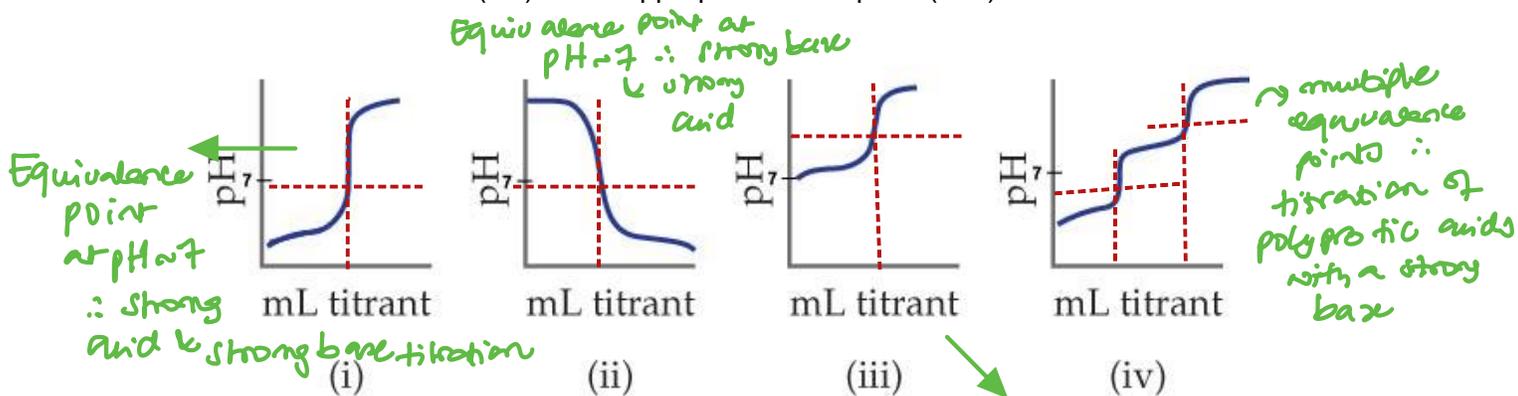
Buffer mixture

(F) NaH<sub>2</sub>PO<sub>4</sub> & Na<sub>2</sub>HPO<sub>4</sub> are both basic salts but H<sub>2</sub>PO<sub>4</sub><sup>-</sup> / HPO<sub>4</sub><sup>2-</sup> are conjugates

↓ acid                      ↓ conjugate base  
 ↘ Buffer mixture

(G) Although CH<sub>3</sub>COOH is a weak acid & NaCH<sub>3</sub>CH<sub>2</sub>COO is a weak base they are not conjugates

2. Match the titrations curves (i-iv) to the appropriate description (A-E).



**ii**

A. Titration of a strong base with a strong acid.

**iii**

B. Titration of a weak acid with a strong base.

**i**

C. Titration of a strong acid with a strong base.

**iv**

D. Titration of a polyprotic acid with a strong base.

$$K_a \text{ of } \text{NH}_4^+ = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$$

$$\therefore pK_a = -\log(5.6 \times 10^{-10}) = 9.26$$

3. In the laboratory, you were asked to prepare a buffer solution with pH = 10.50. How many grams of  $\text{NH}_4\text{Cl}$  (molar mass = 53.5 g/mol) would you add to 625 mL of 0.258 M  $\text{NH}_3$  to prepare a buffer with pH = 10.50? Assume that the solution's volume remains constant.  $K_b$  of  $\text{NH}_3 = 1.8 \times 10^{-5}$ .

**0.49** g

① Using Henderson-Hasselbalch equation to determine the ratio of base to acid

$$\text{pH} = \text{pK}_a + \log \frac{[\text{NH}_3]}{[\text{NH}_4\text{Cl}]} \Rightarrow 10.50 = 9.26 + \log \frac{[0.258]}{[\text{NH}_4\text{Cl}]}$$

(2 decimal places)

$$\therefore 1.25 = \log \frac{[0.258]}{[\text{NH}_4^+]} \rightarrow \text{taking the inverse of log on both sides}$$

$$17.56820923 = \frac{0.258}{[\text{NH}_4^+]} \Rightarrow \therefore [\text{NH}_4^+] = 0.014685617 \text{ M}$$

② Use the molarity of  $\text{NH}_4\text{Cl}$  to determine the grams of  $\text{NH}_4\text{Cl}$  added to 625 mL of 0.258 M  $\text{NH}_3$

$$625 \text{ mL} \times \frac{0.014685617 \text{ mol}}{1000 \text{ mL}} \times \frac{1 \text{ mol } \text{NH}_4\text{Cl}}{1 \text{ mol } \text{NH}_4^+} \times \frac{53.5 \text{ g } \text{NH}_4\text{Cl}}{1 \text{ mol } \text{NH}_4\text{Cl}}$$

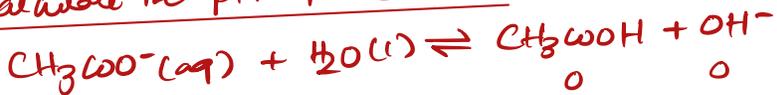
$$= 0.49 \text{ g}$$



② Molarity of  $\text{CH}_3\text{COONa}$

$$\frac{0.00250 \text{ mol}}{25.00 + 12.5 \text{ mL}} \times 1000 \text{ mL} = 0.0667 \text{ M}$$

③ Calculate the pH of  $\text{CH}_3\text{COO}^- \text{Na}^+$  ( $\text{Na}^+$  is pH-neutral)



I	0.0667	—	0	0
C	-x	—	+x	+x
E	0.0667-x	—	x	x

solving for a base  $\therefore$  determine

$$K_b \therefore K_b = \frac{1.0 \times 10^{-14}}{1.7 \times 10^{-5}} = 5.9 \times 10^{-10}$$

$$\therefore 5.9 \times 10^{-10} = \frac{[x][x]}{[0.0667-x]}$$

$$x^2 = 5.9 \times 10^{-10} \times 0.0667$$

take square root of both sides

$$\frac{C}{K} \gg 100$$

$$x = \pm 6.2638 \times 10^{-6}$$

$$\text{④ } \text{pOH} = -\log [6.2638 \times 10^{-6}]$$
$$= 5.203$$

$$\therefore \text{pH} + \text{pOH} = 14.00$$

$$\therefore \text{pH} = 14.00 - 5.20$$

$$= 8.797$$

6. What is the pH of a mixture of 0.012 M of  $C_6H_5COOH$  ( $K_a = 6.3 \times 10^{-5}$ ) and 0.033 M  $NaC_6H_5COO$ ?

4.64

$$pH = pK_a + \log \frac{[NaC_6H_5COO]}{[C_6H_5COOH]} \quad \left. \begin{array}{l} \text{Henderson-Hasselbalch} \\ \text{equation} \end{array} \right\}$$

$$= -\log(6.3 \times 10^{-5}) + \log \frac{[0.033]}{[0.012]}$$

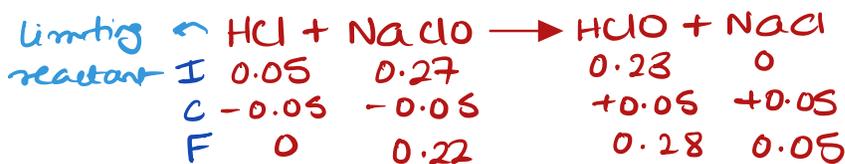
$$= 4.63999$$

$$\sim 4.64$$

7. A solution is prepared by dissolving 0.23 mol of hypochlorous acid and 0.27 mol of sodium hypochlorite in water sufficient to yield 1.00 L of solution. The addition of 0.05 mol of HCl to this buffer solution causes the pH to drop slightly. The pH does not decrease drastically because the HCl reacts with the \_\_\_\_\_ present in the buffer solution. The  $K_a$  of hypochlorous acid is  $1.36 \times 10^{-3}$ .

C

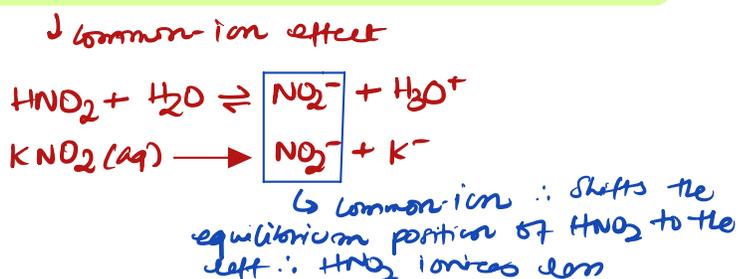
- A.  $H_2O$
- B.  $H_3O^+$
- C. Hypochlorite ion
- D. Hypochlorous acid
- E. This is a buffer solution. The pH does not change upon addition of acid or base.



8. In which of the solutions given below would nitrous acid ( $HNO_2$ ) ionize less than it does in pure water?

C

- A. NaCl
- B.  $KNO_3$
- C.  $KNO_2$
- D.  $NaClO_4$



$$\text{Moles of CH}_3\text{COOH} = 0.300 \text{ L} \times \frac{0.250 \text{ mol}}{1 \text{ L}} = 0.075 \text{ mol}$$

Buffer

$$\text{Moles of NaCH}_3\text{COO} = 0.300 \text{ L} \times \frac{0.560 \text{ mol}}{1 \text{ L}} = 0.168 \text{ mol}$$

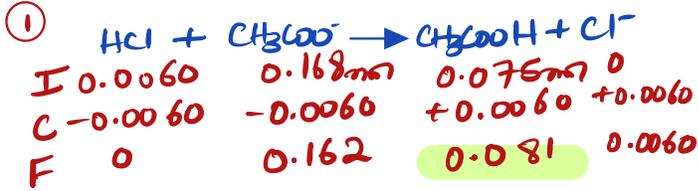
9. To a 0.300 L buffer solution consisting of 0.250 M CH<sub>3</sub>COOH and 0.560 M NaCH<sub>3</sub>COO, 0.0060 mol HCl is added. What are the moles and concentration of CH<sub>3</sub>COOH after the addition of HCl? Assume that the volume of the buffer does not change upon the addition of HCl.

Strong acid

should react with base component in the buffer (CH<sub>3</sub>COO<sup>-</sup>)

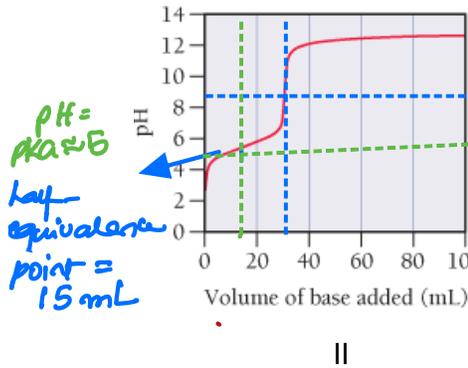
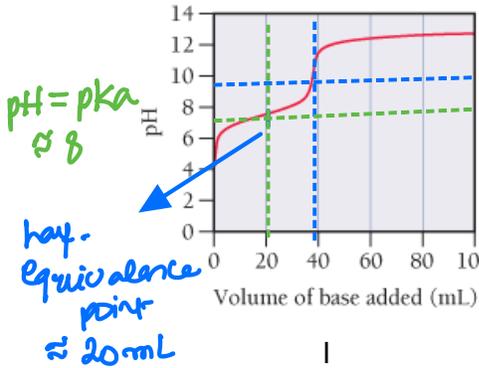
**C**

- A. 0.0060 mol, 0.020 M
- B. 0.162 mol, 0.54 M
- C. 0.081 mol, 0.27 M
- D. 0.075 mol, 0.250 M
- E. 0.168 mol, 0.560 M



② Moles of CH<sub>3</sub>COOH =  $\frac{0.081 \text{ mol}}{0.300 \text{ L}} = 0.27 \text{ M}$

10. You are provided with the titration curves I and II for two weak acids titrated with 0.100 M NaOH. Refer to the titration curves to answer the following questions:



- A. Which acid is more concentrated? **I**
- more concentrated acid will produce a greater [H<sub>3</sub>O<sup>+</sup>] & will consume greater moles of NaOH ∴ greater volume of NaOH

- B. Which acid has the larger K<sub>a</sub>? **II**
- pH = pKa at half equivalence point the ↓ the pKa the larger the K<sub>a</sub> & the stronger the acid

At half-equivalence point half the moles of the acid are converted to moles of conjugate salt ∴  $\text{pH} = \text{pKa} + \log \frac{[\text{A}^-]}{[\text{HA}]}$  if moles are the same ∴ pH = pKa

11. Which solution has the **greatest** buffering capacity?

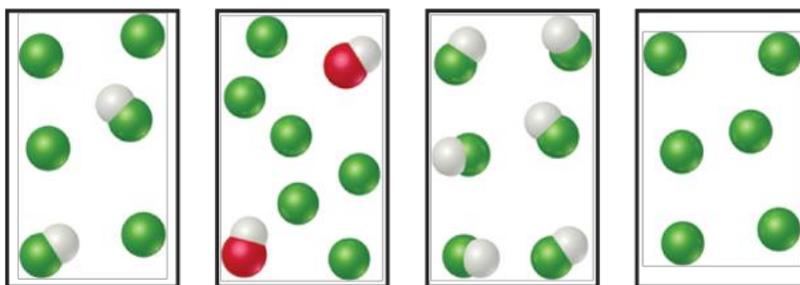
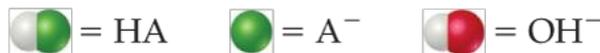
C

- A. 0.335M  $\text{HC}_2\text{H}_3\text{O}_2$  and 0.497 M  $\text{NaC}_2\text{H}_3\text{O}_2$
- B. 0.520 M  $\text{HC}_2\text{H}_3\text{O}_2$  and 0.116 M  $\text{NaC}_2\text{H}_3\text{O}_2$
- C. 0.820 M  $\text{HC}_2\text{H}_3\text{O}_2$  and 0.715 M  $\text{NaC}_2\text{H}_3\text{O}_2$
- D. 0.120 M  $\text{HC}_2\text{H}_3\text{O}_2$  and 0.115 M  $\text{NaC}_2\text{H}_3\text{O}_2$

*the greatest buffer capacity is when the buffer components are large & equal*

12. A strong base such as KOH is mixed in a specific proportion with the weak acid HA to make a buffer. Which of the diagrams below is a correct representation of the buffer solution?

A



*the weak acid & its conjugate base salt should be present in order for the solution to be a buffer solution*

13. What change will be caused by addition of a small amount of **strong acid** HCl to a solution containing fluoride ions and hydrogen fluoride?

**HF/F<sup>-</sup>**

**D**

- A. The concentration of hydronium ions will increase significantly.
- B. The concentration of fluoride ions will increase as will the concentration of hydronium ions. *Conc. of F<sup>-</sup> ↓ & H<sub>3</sub>O<sup>+</sup> ↑*
- C. The concentration of hydrogen fluoride will decrease, and the concentration of fluoride ions will increase. *HF ↑ & F<sup>-</sup> ↓*
- D. The concentration of fluoride ion will decrease, and the concentration of hydrogen fluoride will increase.
- E. The fluoride ions will precipitate out of solution as its acid salt.



*more HF is produced ∴  
the pH of the buffer will increase*

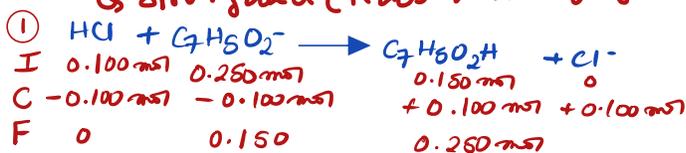
**Buffer**

14. A 1.00 L buffer solution is 0.150 M in HC<sub>7</sub>H<sub>5</sub>O<sub>2</sub> and 0.250 M in LiC<sub>7</sub>H<sub>5</sub>O<sub>2</sub>. Calculate the pH of the solution after the addition of 100.0 mL of 1.00 M HCl. The K<sub>a</sub> for HC<sub>7</sub>H<sub>5</sub>O<sub>2</sub> is 6.5 × 10<sup>-5</sup>.

**E**

- A. 4.19
- B. 5.03
- C. 4.41
- D. 3.34
- E. 3.97

*↳ strong acid (reacts with any weak base)*



② Using Henderson-Hasselbalch equation to calculate the pH of the buffer

$$\text{pH} = \text{pK}_a + \log \frac{[\text{C}_7\text{H}_5\text{O}_2^-]}{[\text{HC}_7\text{H}_5\text{O}_2]}$$

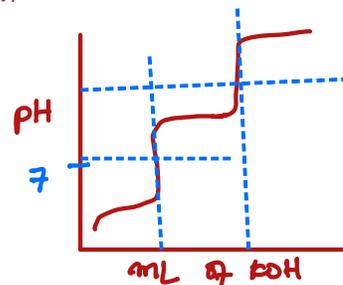
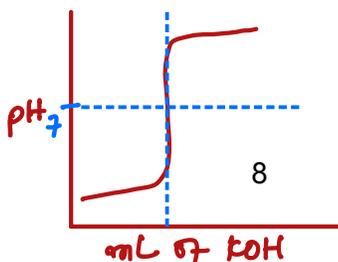
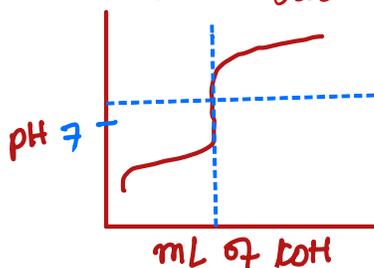
$$= -\log(6.5 \times 10^{-5}) + \log \frac{[0.150]}{[0.250]} = 3.96523 \approx 3.97$$

15. You are working in the lab with three acidic solutions. **Solution 1** is 0.1 M of a **weak monoprotic acid**, **solution 2** is 0.1 M of a **strong monoprotic acid** and **solution 3** is a 0.1 M **weak diprotic acid**. Each of the former solutions has been titrated with a 0.2 M KOH solution. Which **quantity** is the same for all the three solutions?

**B**

- A. The volume required to reach the final equivalence point. *diprotic acid has two equivalence points*
- B. The volume required to reach the first equivalence point.
- C. The pH at the first equivalence point. *pH at first equivalence point for strong acid is ≈ 7, for weak acids is > 7*
- D. The pH at one-half the first equivalence point. *not the same*
- E. None of the quantities is the same for the three solutions.

*At equivalence point, the mol of the acid = mol of the base. Since all the acids have the same conc. (0.1 mol/L) & they are titrated with 0.2 M KOH ∴ the volume to reach the first equivalence point*



16. Which of the following statements is accurately describes the common-ion effect? *decreased*

**C**

- A. The extent of ionization of a weak electrolyte is increased by adding to the solution a strong electrolyte that has an ion in common with the weak electrolyte.
- B. The solubility of a slightly soluble salt is increased by the presence of a second solute that provides a common ion to the system. *decreased*
- C. The common ion effect occurs when a solubility equilibrium is ~~shifted~~ due to a second compound that contains an ion common with the first.
- D. The common ion effect is that common ions precipitate all counter-ions.
- E. None of the above statements accurately describe the common-ion effect.

*choice C is the definition of the common-ion effect*

17. To simulate the pH of blood, which is 7.4, an undergraduate researcher in a biology lab produced a buffer solution by dissolving sodium dihydrogen phosphate ( $\text{NaH}_2\text{PO}_4$ ,  $K_a = 6.2 \times 10^{-8}$ ) and sodium hydrogen phosphate ( $\text{Na}_2\text{HPO}_4$ ) together in an aqueous solution. What mole ratio of  $\text{Na}_2\text{HPO}_4/\text{NaH}_2\text{PO}_4$  was needed?

**C**

- A. 1.2/1.0
- B. 1.0/1.0
- C. 1.6/1.0
- D. 0.96/1.0
- E. 0.90/1.0

*Buffer*  $\rightarrow$  *Acid*

$$\text{pH} = \text{pK}_a + \log \frac{[\text{Base}]}{[\text{Acid}]}$$

*conjugate base*

$$7.4 = -\log(6.2 \times 10^{-8}) + \log \frac{[\text{Na}_2\text{HPO}_4]}{[\text{NaH}_2\text{PO}_4]}$$

$$7.4 = 7.207608811 + \log \frac{[\text{Na}_2\text{HPO}_4]}{[\text{NaH}_2\text{PO}_4]}$$

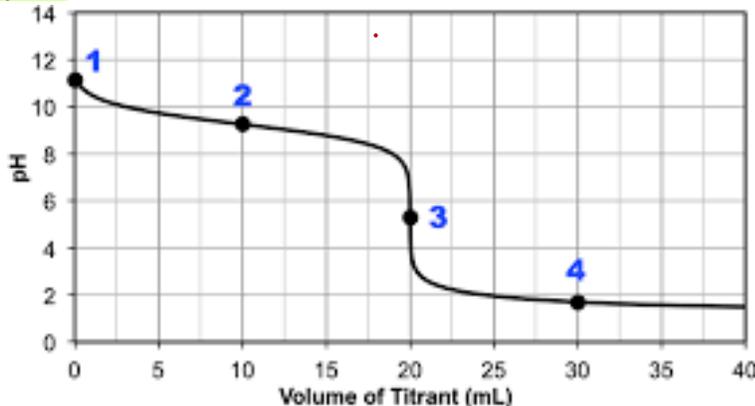
$$0.192391689 = \log \frac{[\text{Na}_2\text{HPO}_4]}{[\text{NaH}_2\text{PO}_4]}$$

$$\therefore \frac{[\text{Na}_2\text{HPO}_4]}{[\text{NaH}_2\text{PO}_4]} = 10^{0.19239168} = 1.557369586 \approx \frac{1.6}{1.0}$$

18. At what point in this titration curve is the pH = pK<sub>a</sub>?

**B**

- A. 1
- B. 2
- C. 3
- D. 4
- E. Not enough information to determine

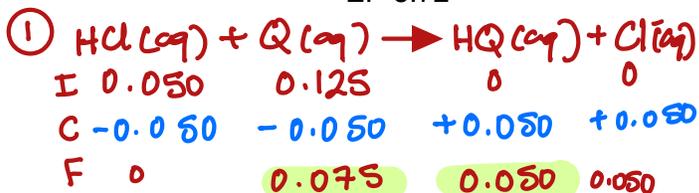
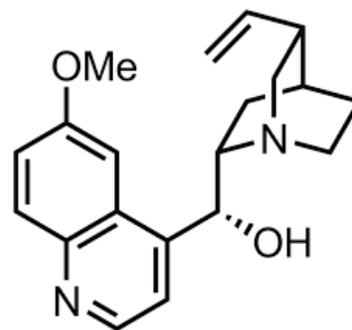


*the titration curve above represents the titration of a weak base (starting pH ~ 11) with a strong acid (pH ~ 1.8)*

*pH = pK<sub>a</sub> at half equivalence point (2)*

19. Quinine is a weak base that is used to treat malaria which is caused by the parasite Plasmodium falciparum. A 25.0 mL solution of quinine was titrated with 1.00 M hydrochloric acid. It was found that the solution originally contained 0.125 moles of quinine. What was the pH of the solution after 50.00 mL of the HCl solution were added? Quinine is monobasic with  $pK_b = 5.10$ .

- A. 5.10  
 B. 4.92  
 C. 8.90  
 D. 9.08  
 E. 8.72



Buffers

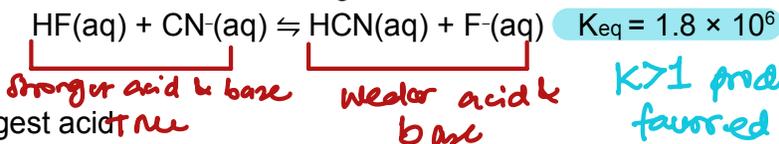
②  $pH = pK_a + \log \frac{[base]}{[acid]}$

$pK_a = 14.00 - pK_b = 14.00 - 5.10 = 8.90$

$\therefore pH = 8.90 + \log \frac{[0.075]}{[0.050]} = 9.076091259 \sim 9.08$

20. For the reaction shown, which of the following statements would be false?

B



- A. HF is the strongest acid **True**  
 B. Fluoride anion is the strongest base **False**  
 C. Cyanide anion is the strongest base **True**  
 D. The solution will contain more HCN than HF at equilibrium

$K > 1$  product favored

(An acid-base reaction's equilibrium always favors the side of the weaker acid/base)

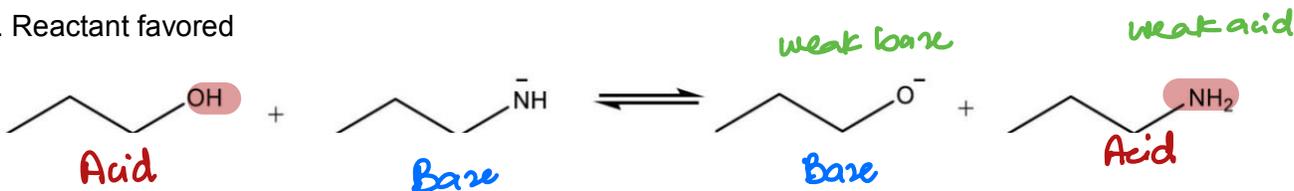
↓  
 true since  $K > 1$  (product favored)

21. On which side of the equation does the equilibrium lie for this reaction?

**A**

- A. Product favored  
B. Reactant favored

↓  
Equilibrium will favor the weaker acid / weaker base



Let's compare the acids:

on the left side the acidic hydrogen is attached to oxygen while on the right side the acid hydrogen is attached to nitrogen. the stronger acid will have the acidic hydrogen attached to the more electronegative atom (O > N in EN)

You can also compare bases: since N < O in EN it cannot handle the negative charge as well as O can ∴  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}^-$  is a stronger base

22. What is the pH of an aqueous solution that contains 0.226 M potassium hydrogen phosphate,  $\text{K}_2\text{HPO}_4$ , and 0.451 M potassium dihydrogen phosphate,  $\text{KH}_2\text{PO}_4$ ?

( $K_a$  for  $\text{H}_3\text{PO}_4 = 7.52 \times 10^{-3}$ ,  $K_a$  for  $\text{H}_2\text{PO}_4^- = 6.23 \times 10^{-8}$ ,  $K_a$  for  $\text{HPO}_4^{2-} = 4.8 \times 10^{-13}$ ) Buffer

- C**
- A. 1.824  
B. 6.562  
C. 6.905  
D. 7.208  
E. 12.019

$$\text{pH} = \text{p}K_a + \log \frac{[\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]}$$

~ From  $\text{K}_2\text{HPO}_4$

$$\text{pH} = -\log(6.23 \times 10^{-8}) + \log \frac{[0.226]}{[0.451]}$$

$$= 6.905443851$$

$$\approx 6.905$$

Extra Practice Questions: these questions will not be graded

1. How many grams of sodium benzoate ( $\text{NaC}_6\text{H}_5\text{COO}$ , MW: 144.11) would need to be added to 250. mL of a 0.200 M benzoic acid ( $\text{C}_6\text{H}_5\text{COOH}$ ) solution to achieve a pH of 3.98? The  $\text{pK}_a$  of benzoic acid is 4.20.

4.3 g

①  $\text{pH} = \text{pK}_a + \log \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]}$  *base / acid*

$$3.98 = 4.20 + \log \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{[0.200]}$$

*2 decimal places*

$$-0.22 = \log \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{[0.200]}$$

*2 sig figs*

$$10^{-0.22} = \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{[0.200]}$$

$$0.6025595861 = \frac{[\text{C}_6\text{H}_5\text{COO}^-]}{[0.200]}$$

$\therefore [\text{C}_6\text{H}_5\text{COO}^-] = 0.1205119172 \text{ M}$

②  $0.1205119172 \text{ mol} [\text{C}_6\text{H}_5\text{COO}^-] \times \frac{1 \text{ mol NaC}_6\text{H}_5\text{COO}}{1 \text{ mol C}_6\text{H}_5\text{COO}^-} \times \frac{144.11 \text{ g NaC}_6\text{H}_5\text{COO}}{1 \text{ mol NaC}_6\text{H}_5\text{COO}} \times 0.250 \text{ L}$

$$= 4.341743098 \text{ g} \approx 4.3 \text{ g}$$

2. Which of these statements regarding a solution of  $\text{HNO}_2$  is false?

D

- A. Addition of  $\text{NaOH}$  will increase dissociation of  $\text{HNO}_2$ , and the pH of the final solution will be higher  $\text{NaOH(aq)} + \text{HNO}_2(\text{aq}) \rightarrow \text{NaNO}_2(\text{aq}) + \text{H}_2\text{O(l)}$
- B. Addition of  $\text{NaNO}_2$  will decrease dissociation of  $\text{HNO}_2$ , and the pH of the final solution will be higher
- C. Addition of  $\text{HNO}_3$  will decrease dissociation of  $\text{HNO}_2$ , and the pH of the final solution will be lower *A strong acid will decrease the dissociation of a weak acid*
- D. Addition of  $\text{NaNO}_2$  will decrease dissociation of  $\text{HNO}_2$ , and the pH of the final solution will be ~~lower~~ *higher*

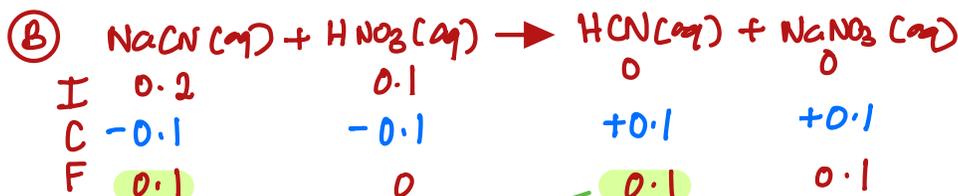
Ⓐ  $\text{HNO}_2$  is neutralized  $\therefore$  by  $\text{NaOH}$   $\therefore$  pH will increase (pH of final solution is higher)

Ⓑ  $\text{NaNO}_2(\text{aq}) \rightarrow \text{Na}^+(\text{aq}) + \text{NO}_2^-(\text{aq})$   
 $\text{HNO}_2(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{NO}_2^-(\text{aq})$  *common ion effect*  
 $\therefore$  the equilibrium of  $\text{HNO}_2(\text{aq})$  shifts to the left  $\therefore$  its dissociation decreases  $\therefore$  pH will be high

3. Which of these would not result in a buffer solution if 100 mL of each solution is mixed?

C

- A. 0.10 M  $\text{NaCH}_3\text{COO}$  and 0.15 M  $\text{CH}_3\text{COOH}$  *weak base / conjugate acid*  $\therefore$  both are conjugate  $\therefore$  buffer  $\therefore$  pH will be high
- B. 0.2 M  $\text{NaCN}$  and 0.1 M  $\text{HNO}_3$
- C. 0.15 M  $\text{HClO}_4$  and 0.12 M  $\text{NaClO}_4$  *strong acid & its conjugate cannot be a buffer*
- D. 1.2 M  $\text{C}_5\text{H}_5\text{N}$  and 0.9 M  $\text{C}_5\text{H}_5\text{NHCl}$   $\therefore$  buffer
- E. 0.7 M  $\text{NaOH}$  and 1.2 M  $\text{NaH}_2\text{PO}_4$



Buffer



I 0.7

1.2

0

0

C - 0.7

-0.7

+0.7

-

F 0

0.6

0.7

Buffer

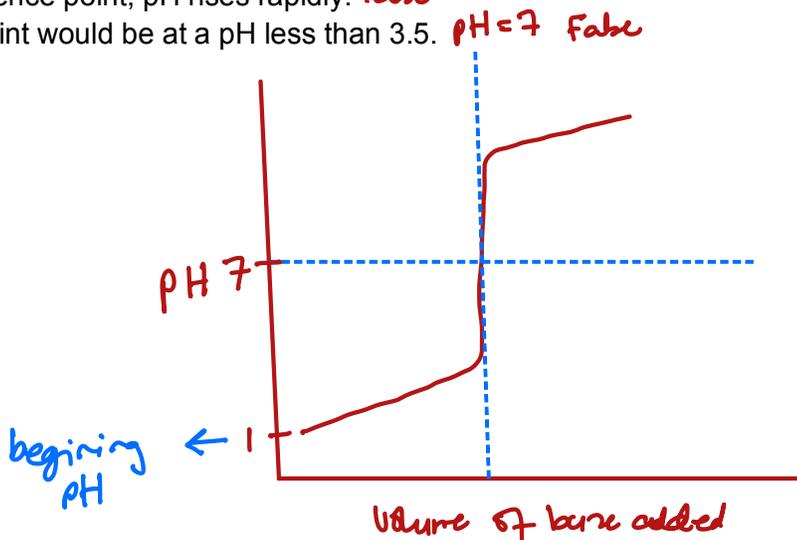


7. Which of the following statements correctly describe a typical titration curve for the titration of a strong acid by a strong base?

**E**

- I) The beginning pH is low. *True*
- II) The pH change is slow until near the equivalence point. *True*
- III) At the equivalence point, pH changes by a large value. *True*
- IV) Beyond the equivalence point, pH rises rapidly. *False*
- V) The equivalence point would be at a pH less than 3.5. *pH=7 False*

- A. I), III) and V)
- B. II), III) and IV)
- C. I), III) and IV)
- D. III), IV) and V)
- E. I), II) and III)



8. Choose the expression that gives the molar concentration of a  $\text{H}_2\text{SO}_4(\text{aq})$  solution if 24.3 mL of a 0.105 M NaOH(aq) solution is required to titrate 60 mL of the acid.

**D**

- A.  $(60 \times 24.3)/0.105 = 1.288571429 \times 10^4$
- B.  $(60 \times 2)/(24.3 \times 0.105) = 47.03115814$
- C.  $(24.3 \times 0.105)/(60) = 0.042526$
- D.  $(24.3 \times 0.105)/(60 \times 2) = 0.0212625$
- E.  $(60 \times 0.105)/(2 \times 24.3) = 0.129629296$



$$\frac{24.3 \text{ mL} \times \frac{0.105 \text{ mol NaOH}}{1000 \text{ mL}} \times \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NaOH}}}{60 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.0212625 \text{ M}$$

9. For the reaction,  $\text{HCO}_2\text{H}(\text{aq}) + \text{CN}^-(\text{aq}) \rightleftharpoons \text{HCO}_2^-(\text{aq}) + \text{HCN}(\text{aq})$ , what is the equilibrium constant and does it favor the formation of reactants or products? The acid dissociation constant,  $K_a$ , for  $\text{HCO}_2\text{H}$  is  $1.8 \times 10^{-4}$  and the acid dissociation constant for  $\text{HCN}$  is  $4.0 \times 10^{-10}$ .

D

- A.  $K = 1.00$ . The reaction favors neither the formation of reactants nor products.  
 B.  $K = 2.2 \times 10^{-6}$ . The reaction favors the formation of products.  
 C.  $K = 2.2 \times 10^{-6}$ . The reaction favors the formation of reactants.  
 D.  $K = 4.5 \times 10^5$ . The reaction favors the formation of products.  
 E.  $K = 4.5 \times 10^5$ . The reaction favors the formation of reactants.

$$K_{eq} = 10^{\Delta pK_a}$$

$$\Delta pK_a = pK_a(\text{acid product}) - pK_a(\text{acid reactant})$$

$$= (-\log(4.0 \times 10^{-10})) - (-\log(1.8 \times 10^{-4}))$$

$$= 5.653212514$$

$$\therefore K_{eq} = 10^{5.653212514} = \underline{4.500000002 \times 10^5}$$

↓  
product favored  
(weak acid & weak  
base are  
favored)

10. What happens to a  $\text{HC}_2\text{H}_3\text{O}_2/\text{C}_2\text{H}_3\text{O}_2^-$  buffer if we add  $\text{HC}_2\text{H}_3\text{O}_2$  to it?

B

- A. The pH will go up.  
 B. The pH will go down.  
 C. The pH will not change.

↓  
weak acid ∴  
pH will go down

## Formula Sheet

### Length

1 kilometer = 0.62137 mile  
1 inch = 2.54 centimeters (exactly)  
1 Ångstrom =  $1 \times 10^{-10}$  meter

### Energy

1 joule =  $1 \text{ kg}\cdot\text{m}^2/\text{s}^2$   
1 calorie = 4.184 joules  
1 Calorie = 1 kilocalorie = 1000 calories  
1 L·atm = 101.325 joules

### Pressure

1 pascal =  $1 \text{ N}/\text{m}^2 = 1 \text{ kg}/\text{m}\cdot\text{s}^2$   
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in<sup>2</sup>  
1 bar =  $1 \times 10^5$  Pa (exactly)

### Temperature

0 K = -273.15°C  
K = °C + 273.15  
°C = (5/9)(°F - 32)

### Mass

1 kg = 2.205 lbs

### Volume

1 mL =  $1 \text{ cm}^3 = 1 \text{ cc}$

### Constants

$c = 2.998 \times 10^8 \text{ m}/\text{sec}$   
 $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{sec}^{-1}$   
 $R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K} = 8.314 \text{ J}/\text{mol}\cdot\text{K}$   
Specific heat of water = 4.184 J/g·K  
Mass of an electron:  $9.109 \times 10^{-31} \text{ kg}$   
Mass of a proton:  $1.673 \times 10^{-27} \text{ kg}$   
 $RH = 2.18 \times 10^{-18} \text{ J}$   
Specific heat of water = 4.184 J/g·K  
STP = 273.15 K and 1 atm  
Avogadro's number:  $6.022 \times 10^{23}$

### Equations

$d$  (density) =  $m/V$

$P_1V_1 = P_2V_2$

$V_1/T_1 = V_2/T_2$

$P_1V_1/n_1T_1 = P_2V_2/n_2T_2$

$PV = nRT$

$(P + a(n^2/V^2)) \cdot (V - nb) = nRT$

molar mass ( $M$ ) =  $mRT/PV$

density ( $d$ ) =  $MP/RT$

$x_A = n_A/n_{\text{tot}} = P_A/P_{\text{tot}} = V_A/V_{\text{tot}}$

$P_{\text{tot}} = P_A + P_B + \dots$

$n_{\text{tot}} = n_A + n_B + \dots$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{\text{Rate of effusion A}}{\text{Rate of effusion B}} = \sqrt{\frac{MW_B}{MW_A}}$$

$$Q = C \times \Delta T = c_{\text{specific}} \times m \times \Delta T$$

$$Q = n \times \Delta H \text{ (kJ/mol)} = m \times \Delta H \text{ (kJ/g)}$$

$$w = -P\Delta V$$

$$\Delta E = q + w$$

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

$$\Delta H^\circ = \sum n\Delta H^\circ(\text{bonds broken}) - \sum n\Delta H^\circ(\text{bonds formed})$$

$$E = hv$$

$$c = \lambda\nu$$

$$\lambda = h/mv$$

$$\Delta E = -2.18 \times 10^{-18} J \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\ln \left( \frac{P_2}{P_1} \right) = \frac{\Delta H_{vap}}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$C_g = kP_g$$

$$P_{\text{solution}} = P_{\text{solvent}} X_{\text{solvent}}$$

$$P_{\text{solution}} = \sum P_j = \sum P_j X_j$$

$$\Delta T_b = K_b m_i$$

$$\Delta T_f = K_f m_i$$

$$\pi = MRT_i$$

### Thermodynamic and Electrochemistry

$$S = k_b \times \ln(W)$$

$$k_b = 1.381 \times 10^{-23} \text{ J/K}$$

$$\Delta S = q_{\text{rev}}/T$$

$$\Delta S_{\text{surr}} = q_{\text{surr}}/T = -q_{\text{rev}}/T$$

$$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$$

$$\Delta S^\circ_{\text{rxn}} = \sum \nu S^\circ_{\text{products}} - \sum \nu S^\circ_{\text{reactants}}$$

$$\Delta H^\circ_{\text{rxn}} = \sum \nu H^\circ_{\text{products}} - \sum \nu H^\circ_{\text{reactants}}$$

$$\Delta G^\circ_{\text{rxn}} = \sum \nu G^\circ_{\text{products}} - \sum \nu G^\circ_{\text{reactants}}$$

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

$$\Delta G = \Delta G^\circ + RT \cdot \ln Q$$

$$R = 8.314 \text{ J/mol}\cdot\text{K}$$

$$\Delta G^\circ = -RT \cdot \ln K$$

$$\Delta G = -nFE_{\text{cell}}$$

$$F = 96485 \text{ J/(V}\cdot\text{mol e}^-)$$

$$E^\circ_{\text{cell}} = RT/nF \ln K$$

$$E^\circ_{\text{cell}} = (0.0257/n) \ln K = (0.0592/n) \log K$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (RT/nF) \ln Q$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (0.0257/n) \ln Q$$

$$\text{Electrolysis: } Q \text{ (total charge)} = I \times t = n \times F$$

### Integrated Rate Laws & half-life

$$\ln \frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$\ln \frac{k_2}{k_1} = -\frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

### Equilibrium and Acid / Base

$$K_p = K_c \times (RT)^{\Delta n}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$K_w = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$K_w = [\text{H}_3\text{O}^+] \times [\text{OH}^-]$$

$$K_w = K_a \times K_b$$

$$\text{p}K_a = -\log[K_a]$$

$$\text{Buffer: pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$\ln \frac{K_2}{K_1} = \frac{\Delta H_{rxn}^\circ}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

# Periodic Table of the Elements

1																		2												
1 <b>H</b> 1.01	2																2 <b>He</b> 4.00													
3 <b>Li</b> 6.94	4 <b>Be</b> 9.01															5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18									
11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31															13 <b>Al</b> 26.98	14 <b>Si</b> 28.09	15 <b>P</b> 30.97	16 <b>S</b> 32.06	17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95									
19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.87	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.63	33 <b>As</b> 74.92	34 <b>Se</b> 78.97	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80													
37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.95	43 <b>Tc</b> [97]	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29													
57 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33															72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> [209]	85 <b>At</b> [210]	86 <b>Rn</b> [222]
87 <b>Fr</b> [223]	88 <b>Ra</b> [226]															104 <b>Rf</b> [267]	105 <b>Db</b> [268]	106 <b>Sg</b> [269]	107 <b>Bh</b> [270]	108 <b>Hs</b> [269]	109 <b>Mt</b> [277]	110 <b>Ds</b> [281]	111 <b>Rg</b> [282]	112 <b>Cn</b> [285]	113 <b>Nh</b> [286]	114 <b>Fl</b> [290]	115 <b>Mc</b> [290]	116 <b>Lv</b> [293]	117 <b>Ts</b> [294]	118 <b>Og</b> [294]
57 <b>La</b> 138.91	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> [145]	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.05	71 <b>Lu</b> 174.97																
89 <b>Ac</b> [227]	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> [237]	94 <b>Pu</b> [244]	95 <b>Am</b> [243]	96 <b>Cm</b> [247]	97 <b>Bk</b> [247]	98 <b>Cf</b> [251]	99 <b>Es</b> [252]	100 <b>Fm</b> [257]	101 <b>Md</b> [258]	102 <b>No</b> [259]	103 <b>Lr</b> [262]																