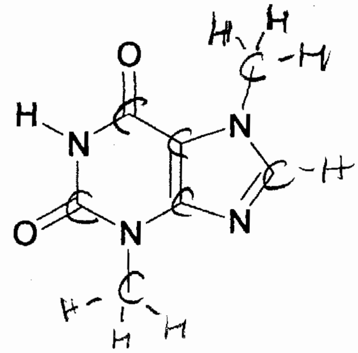
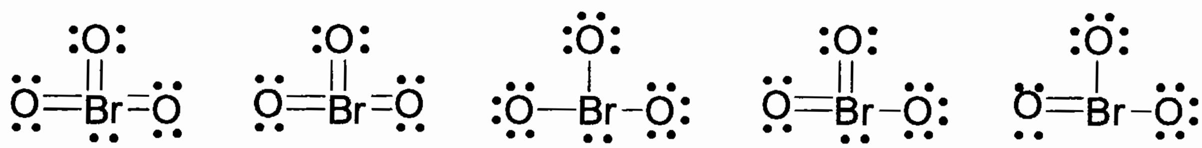
 KEY

1. The adjacent organic compound, one of my personal favorites, is theobromine, one of the active ingredients in chocolate. What is the molecular formula of theobromine?



(a) $C_8H_{12}N_4O_2$ (b) $C_5H_4N_4O_2$ (c) $C_5H_3N_4O_2$
(d) $C_7H_{10}N_4O_2$ (e) $C_7H_8N_4O_2$

Consider the following Lewis structures for the next 3 questions:



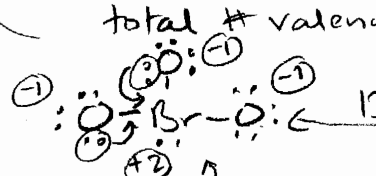
(a) (b) (c) (d) (e)

2. Which one has a −1 formal charge on Br? (A)

Br has 7 valence e⁻'s so a Br with a −1 charge will have 8 e⁻'s

3. Assuming that the best Lewis structure is the one with the minimum number of formal charges, which one is the best Lewis structure for bromate, BrO_3^-? (Note that not all of the structures have the correct number of electrons.) (D)

total # valence e⁻'s = 7 + 3(6) + 1 = 26 e⁻ or 13 e⁻ pairs
Br 3 O (−)

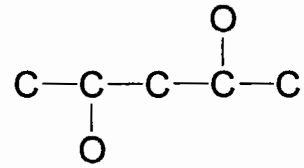


13 e⁻ pairs − 3 e⁻ pairs (for 3 skeletal bonds) = 10 e⁻ pairs remaining
~~satisfying octet rule~~
this isn't best structure because of formal charges
make 2 lone pairs pi bonds to minimize charge

4. How many *additional* resonance structures could you write that are completely equivalent to structure (e)? (Don't include structure (e) in your total.)

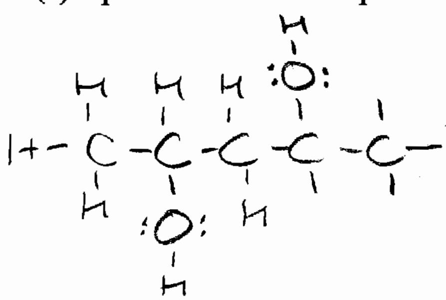
(a) 0 (b) 1 (c) 2 (d) 3 (e) 4

5. Consider an organic compound with molecular formula $C_5H_8O_2$ and the following connectivity between non-H atoms:



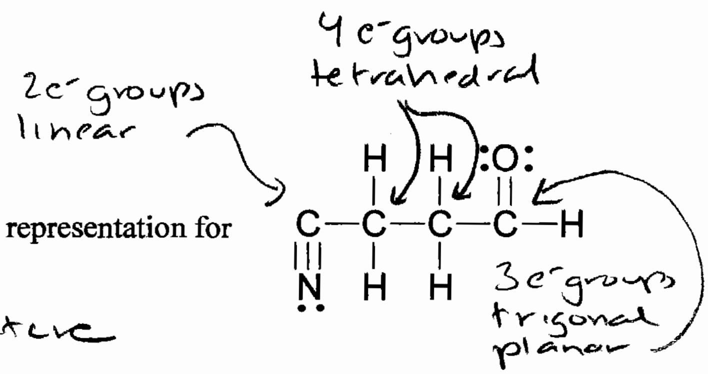
How many pi-bonds and lone pairs will there be in a good Lewis structure for the compound? (Draw one good Lewis structure and count the number of pi bonds and lone pairs. All good Lewis structures will have the same number.)

(a) 1 pi bond and 2 lone pairs
(b) 0 pi bonds and 4 lone pairs
(c) 1 pi bond and 4 lone pairs
(d) 2 pi bonds and 4 lone pairs
(e) 2 pi bonds and 6 lone pairs
(ae) 0 pi bonds and 6 lone pairs

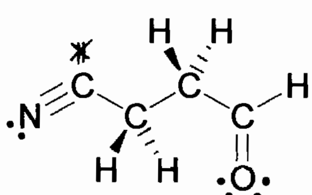


Short 4 H's
need 2 pi bonds

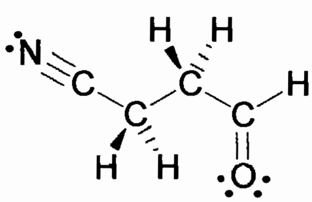
6. Which one of the following is a good 3D representation for the adjacent organic compound?



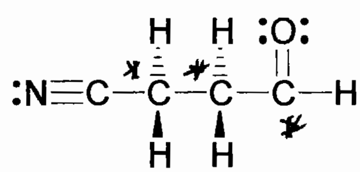
* problems in structure



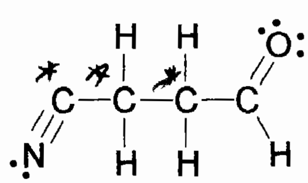
(a)



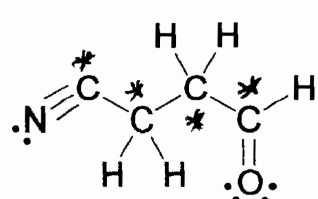
(b)



(c)



(d)



(e)

7. Aqueous iron(III) chloride reacts with aqueous sodium hydroxide to give solid iron(III) hydroxide and aqueous sodium chloride.

= mol/L

If 5.0 mL of 0.10 M aqueous iron(III) chloride is mixed with 6.0 mL of 0.20 M aqueous sodium hydroxide, how many moles of sodium chloride will be made, assuming the reaction goes to completion?

(a) 3.6×10^{-3} mol (b) 4.0×10^{-4} mol (c) 1.5×10^{-3} mol
(d) 1.6×10^{-4} mol (e) 1.2×10^{-3} mol (ab) 5.0×10^{-4} mol

$FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$

don't forget to balance!!

$FeCl_3$ $5.0\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{0.1\text{ mol}}{\text{L}} = 5.0\times10^{-4}\text{ mol } FeCl_3$

$NaOH$ $6.0\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{0.2\text{ mol}}{\text{L}} = 1.2\times10^{-3}\text{ mol NaOH}$

Need $\frac{3\text{ NaOH}}{1\text{ FeCl}_3} = 3$ Have $\frac{1.2\times10^{-3}\text{ mol NaOH}}{5.0\times10^{-4}\text{ mol FeCl}_3} = 2.4$

not enough NaOH
so its limiting

$1.2\times10^{-3}\text{ mol NaOH} \times \frac{3\text{ mol NaCl}}{3\text{ mol NaOH}} = 1.2\times10^{-3}\text{ mol NaCl}$

Consider the following gas-phase reaction for the next 2 questions:

$$2\,NO_2(g) \rightleftharpoons 2\,NO(g) + O_2(g)$$

8. What is the K_p expression for this reaction? (Recall that K_p is the equilibrium constant expression written in terms of partial pressures, as compared to the more typical expression written in terms of concentrations in molarity, sometimes called K_c.)

(a) $K_p = \dfrac{(P_{NO})^2 \cdot P_{O2}}{(P_{NO2})^2}$ (b) $K_p = \dfrac{(P_{NO2})^2}{(P_{NO})^2 \cdot P_{O2}}$ (c) $K_p = \dfrac{P_{NO2}}{P_{NO} \cdot P_{O2}}$

(d) $K_p = \dfrac{P_{NO} \cdot P_{O2}}{P_{NO2}}$ (e) $K_p = (P_{NO})^2 \cdot P_{O2} \cdot (P_{NO2})^2$

9. K_p for this reaction is 7.7×10^{-5} at 457 K. A reaction vessel contains 2.0 atm NO_2, 0.010 atm NO and 0.10 atm O_2 at 457 K. What is the value of Q? Is the reaction at equilibrium at 457 K? If not, which direction does the reaction need to proceed to reach equilibrium?

(a) $Q = 4.0\times10^5$; rxn goes right to left (b) $Q = 4.0\times10^5$; rxn goes left to right
(c) $Q = 2\times10^3$; rxn goes right to left (d) $Q = 2.0\times10^3$; rxn is at equilibrium
(e) $Q = 5.0\times10^{-4}$; rxn is at equilibrium (ab) $Q = 5.0\times10^{-4}$ rxn goes left to right
(ac) $Q = 2.5\times10^{-6}$; rxn goes right to left (ad) $Q = 2.5\times10^{-6}$; rxn goes left to right

$$Q = \frac{P_{NO}^2 \cdot P_{O_2}}{P_{NO_2}^2} = \frac{(0.010)^2 \cdot 0.10}{2^2} = 2.5\times10^{-6} < K = 7.7\times10^{-5}$$

so not enough products - rxn goes to the right

3 sig figs

10. What is the $[H_3O^+]$ to the correct number of significant figures in a pH = 10.361 solution?

basic ← since basic know $[H_3O^+] < 1\times10^{-7}$ M

(a) 4.355×10^{-11} M (b) 4.3551×10^{-11} M (c) 4.36×10^{-11} M
(d) ~~2.315×10^{-4} M~~ (e) ~~2.3145×10^{-4} M~~ (ab) ~~2.31×10^{-4} M~~

these would all be acidic

pH is a log value, so number of sig figs = # of places to right of decimal pt.

$[H_3O^+]$ & $[OH^-]$ are concentrations expressed as regular numbers or in scientific notation so the "normal" sig figs rules apply

11. How many mL of water should you add to 5.0 mg of KOH to make a pH 10.00 solution?

← strong base

(a) 32 mL (b) 880 mL (c) 280 mL (d) 7.9 mL (e) 310 mL

$[KOH] = [OH^-]$ since strong base

mw KOH = 39.0983 + 15.999 + 1.008 = 56.11 g/mol

pH + pOH = 13.9965

pOH = 13.9965 − pH
= 13.9965 − 10.00 = 3.9965

$[OH^-] = 10^{-pOH} = 10^{-3.9965} = 1.008\times10^{-4}$ M = [KOH] needed

$$5.0\text{ mg} \times \frac{1\text{ g}}{1000\text{ mg}} \times \frac{\text{mol}}{56.11\text{ g}} \times \frac{\text{L}}{1.008\times10^{-4}\text{ mol}} \times \frac{1000\text{ mL}}{1\text{ L}} = \boxed{884\text{ mL}}$$

12. 1.00 mL of a 2.5×10^{-4} M HNO_3 solution is diluted to 150. mL. What is the pH of the resulting solution?

← strong acid

(a) 8.22 (b) 5.78 (c) 1.43 (d) 12.57 (e) 3.60

moles conc = moles dil

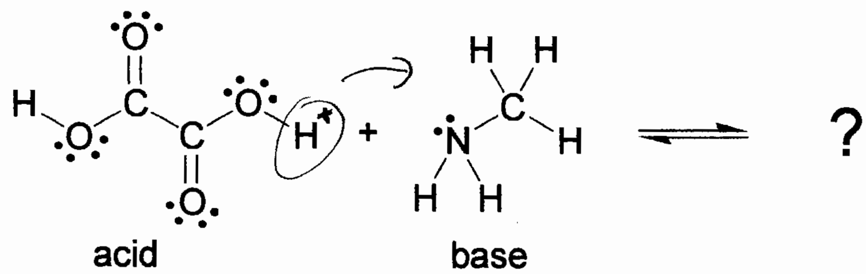
$C_c V_c = C_d V_d$

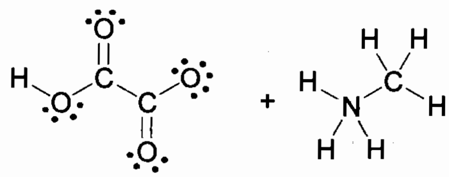
$C_d = \frac{C_c V_c}{V_d}$

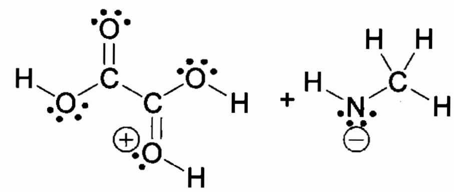
$$[HNO_3]_{dilute} = 2.5\times10^{-4}\text{ M} \times \frac{1\text{ mL}}{150\text{ mL}} = 1.6667\times10^{-6}\text{ M}$$ $[HNO_3] = [H_3O^+]$

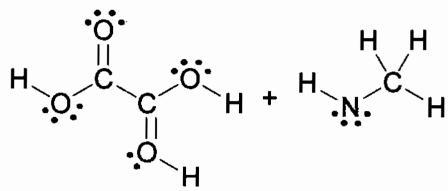
$$pH = -\log(H_3O^+) = 5.7781 = \boxed{5.78}$$

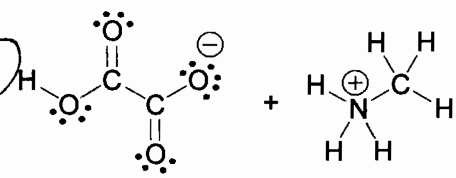
13. What are the products of the following acid/base reaction?

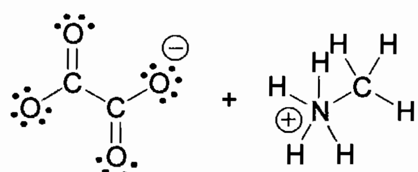


(a) 

(b) 

(c) 

(d) 

(e) 

14. What is the conjugate acid of HCO_2^-?

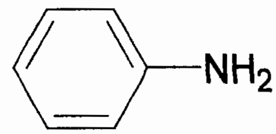
(a) H_2CO_2 (b) $H_2CO_2^-$ (c) CO_2^- (d) CO_2^{2-} (e) $H_2CO_2^+$

$HCO_2^- + H^+ \rightarrow H_2CO_2$

15. Which one of the following conditions corresponds to an basic solution?

(a) $[OH^-] = 1.0\times10^{-7}$ M (b) pH = 5.0 (c) pOH = 5.0
(d) $[H_3O^+] = 1.0\times10^{-3}$ M (e) $[OH^-] = 1.0\times10^{-10}$ M

16. What is the base dissociation reaction for aniline, $C_6H_5NH_2$ (structure shown to the right)?



(a) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3 + OH$

(b) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + H_3O^+$

(c) $C_6H_5NH_2 + OH^- \rightleftharpoons C_6H_5NH^- + H_2O$

(d) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_2^- + H_3O^+$

(e) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$

17. Aniline, $C_6H_5NH_2$ (from the previous question) is a weak base with $K_b = 4.0\times10^{-10}$. What is the pH of a 0.75 M solution of aniline?

(a) 8.57 (b) 4.76 (c) 9.24 (d) 5.43 (e) 13.87

$$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]} \xrightarrow{\text{rxn table}} \frac{x^2}{0.75-x} \approx \frac{x^2}{0.75} = 4.0\times10^{-10}$$

$x = [OH^-]$
(because its a base)

$$\frac{x^2}{0.75} = 4.0\times10^{-10}$$

$$\sqrt{x^2} = \sqrt{(0.75)(4.0\times10^{-10})}$$

$$x = 1.732\times10^{-5} = [OH^-]$$

$$pOH = -\log(1.732\times10^{-5}) = 4.7614$$

$$pH = 13.9965 - 4.7614 = 9.2351 = \boxed{9.24}$$

18. What is the molecular formula of potassium cyanide?

(a) $Pt(CN)_3$ (b) $K(CN)_2$ (c) $Pt_2C_2N_2$

(d) KCN (e) K_2CN

19. In terms of acid/base character, potassium cyanide is best described as a ___________.

(a) strong acid (b) weak acid (c) strong base
(d) weak base (e) neutral compound

K^+ CN^-

group 1 so neutral cation

conj. acid is HCN - weak acid so CN^- is a weak base

20. Hydroiodic acid is commercially available as a 57% by weight concentrated solution that has a density of 1.701 g/mL. How many mL of concentrated hydroiodic acid would you need to add to water to make 15 L of a pH 1.50 solution?

HI strong acid

[Hint: weight% is (g of solute)/(g of solution)×100%. For example, a 10% by weight solution has 10 g of solute in 100 g of solution.]

(a) 28 mL (b) 63 mL (c) 5.2 mL (d) 0.21 mL (e) 1.3 mL

pH 1.50 soln $[H_3O^+] = 10^{-1.50} = 3.1623 \times 10^{-2}$ M $= [HI]$ since strong acid

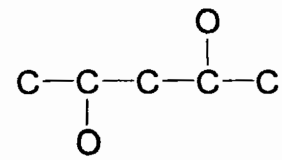
$$15.L \times \frac{3.1623 \times 10^{-2} \text{ mol}}{L} \times \frac{127.91 \text{ g HI}}{\text{mole}} \times \frac{100 \text{ g HI soln}}{57 \text{ g HI}} \times \frac{1 \text{ mL}}{1.701 \text{ g HI soln}}$$

57% by weight

mw HI = 1.008 + 126.9045
= 127.91 g/mol

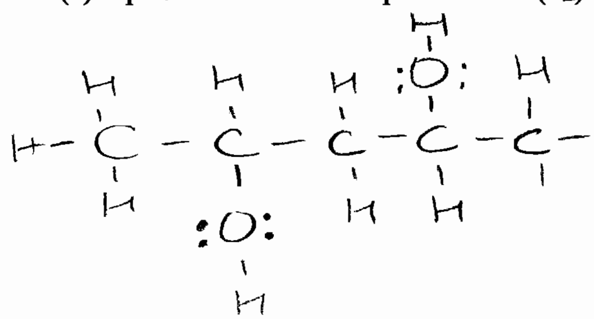
= 62.58 mL
= 63 mL

1. Consider an organic compound with molecular formula $C_5H_{10}O_2$ and the following connectivity between non-H atoms:



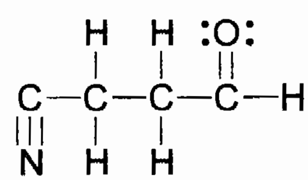
How many pi-bonds and lone pairs will there be in a good Lewis structure for the compound? (Draw one good Lewis structure and count the number of pi bonds and lone pairs. All good Lewis structures will have the same number.)

(a) 1 pi bond and 2 lone pairs
(b) 0 pi bonds and 4 lone pairs
(c) 1 pi bond and 4 lone pairs
(d) 2 pi bonds and 4 lone pairs
(e) 2 pi bonds and 6 lone pairs
(ab) 0 pi bonds and 6 lone pairs

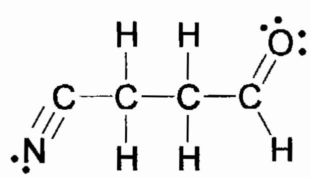


short 2 H's
so 1 pi bond

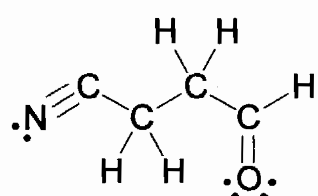
2. Which one of the following is a good 3D representation for the adjacent organic compound?



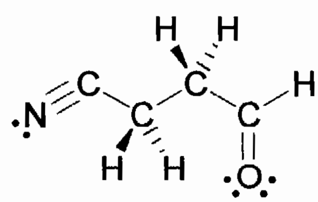
See Form A, # 6



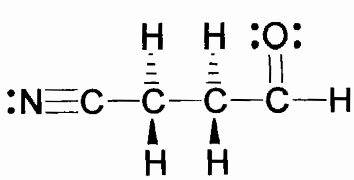
(a)



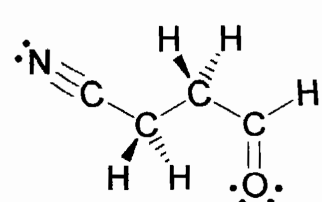
(b)



(c)

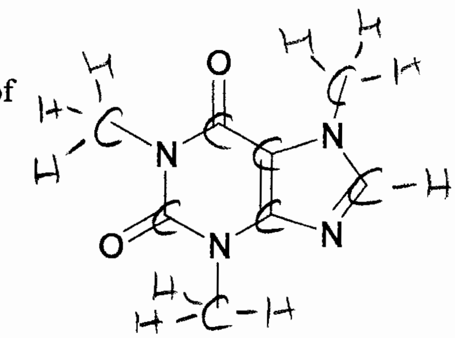


(d)



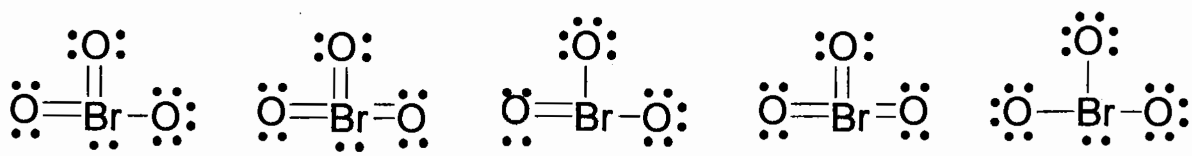
(e)

3. The adjacent organic compound, one of my personal favorites, is caffeine. What is the molecular formula of caffeine?



(a) $C_7H_8N_4O_2$ (b) $C_8H_{10}N_4O_2$ (c) $C_8H_{12}N_4O_2$
(d) $C_5H_4N_4O_2$ (e) $C_5H_3N_4O_2$

Consider the following Lewis structures for the next 3 questions:



(a) (b) (c) (d) (e)

4. Which one has a +1 formal charge on Br?

D

Br has 7 valence e⁻'s so Br⁺ has 6 valence e⁻'s

5. Assuming that the best Lewis structure is the one with the minimum number of formal charges, which one is the best Lewis structure for bromate, BrO_3^-? (Note that not all of the structures have the correct number ~~of atoms or~~ electrons.)

A

See Form A # 3

6. How many *additional* resonance structures could you write that are <u>completely equivalent</u> to structure (b)? (Don't include structure (b) in your total.)

(a) 0 (b) 1 (c) 2 (d) 3 (e) 4

There are no additional equivalent resonance structures because any changes in lone pairs or pi bonds will change the charge distribution

Consider the following gas-phase reaction for the next 2 questions:

$$2\,NO(g) + O_2(g) \rightleftharpoons 2\,NO_2(g)$$

7. What is the K_p expression for this reaction? (Recall that K_p is the equilibrium constant expression written in terms of partial pressures, as compared to the more typical expression written in terms of concentrations in molarity, sometimes called K_c.)

(a) $K_p = \dfrac{(P_{NO})^2 \cdot P_{O2}}{(P_{NO2})^2}$ (b) $K_p = \dfrac{(P_{NO2})^2}{(P_{NO})^2 \cdot P_{O2}}$ (c) $K_p = \dfrac{P_{NO2}}{P_{NO} \cdot P_{O2}}$

(d) $K_p = \dfrac{P_{NO} \cdot P_{O2}}{P_{NO2}}$ (e) $K_p = (P_{NO})^2 \cdot P_{O2} \cdot (P_{NO2})^2$

8. K_p for this reaction is 1.3×10^4 at 457 K. A reaction vessel contains 2.0 atm NO_2, 0.010 atm NO and 0.10 atm O_2 at 457 K. What is the value of Q? Is the reaction at equilibrium at 457 K? If not, which direction does the reaction need to proceed to reach equilibrium?

(a) $Q = 2.0\times10^3$; rxn is at equilibrium
(b) $Q = 2\times10^3$; rxn goes right to left
(c) $Q = 4.0\times10^5$; rxn goes left to right
(d) $Q = 4.0\times10^5$; rxn goes right to left
(e) $Q = 5.0\times10^{-4}$; rxn is at equilibrium
(ab) $Q = 5.0\times10^{-4}$ rxn goes left to right
(ac) $Q = 2.5\times10^{-6}$; rxn goes right to left
(ad) $Q = 2.5\times10^{-6}$; rxn goes left to right

$$Q = \frac{P_{NO_2}^2}{P_{NO}^2 \cdot P_{O_2}} = \frac{(2.0)^2}{(0.010)^2(0.10)} = 4.0\times10^5 > K_p$$

so too many products
rxn goes to the
left to remove
some products

9. Aqueous iron(III) chloride reacts with aqueous sodium hydroxide to give solid iron(III) hydroxide and aqueous sodium chloride.

If 5.0 mL of 0.10 M aqueous iron(III) chloride is mixed with 6.0 mL of 0.20 M aqueous sodium hydroxide, how many moles of iron(III) hydroxide will be made, assuming the reaction goes to completion?

(a) 5.0×10^{-4} mol (b) 1.2×10^{-3} mol (c) 4.0×10^{-4} mol
(d) 1.5×10^{-3} mol (e) 1.6×10^{-4} mol (ab) 3.6×10^{-3} mol

$$FeCl_3 + 3\,NaOH \rightarrow Fe(OH)_3 + 3\,NaCl$$

$$5.0\text{ mL } FeCl_3 \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{0.10\text{ mol}}{1\text{ L}} = 5\times10^{-4}\text{ mol } FeCl_3$$

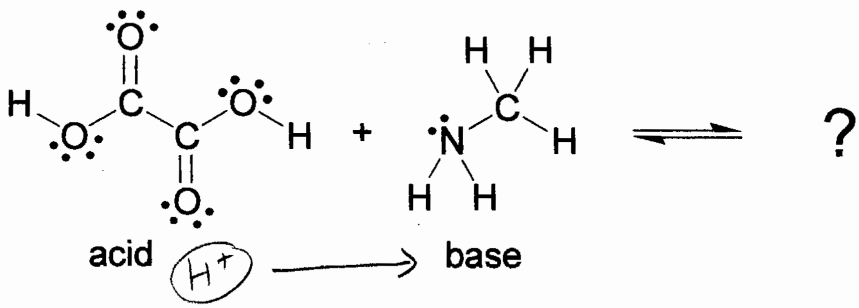
$$6.0\text{ mL } NaOH \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{0.20\text{ mol}}{1\text{ L}} = 1.2\times10^{-3}\text{ mol } NaOH$$

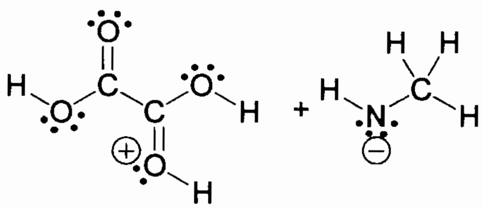
Need $\frac{3\,NaOH}{1\,FeCl_3} = 3$ Have $\frac{1.2\times10^{-3}\text{ mol } NaOH}{5\times10^{-4}\text{ mol } FeCl_3} = 2.4$

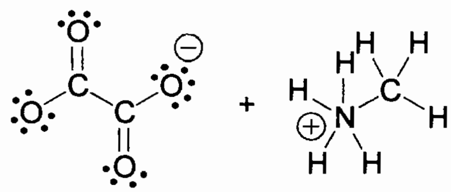
not enough NaOH so its limiting

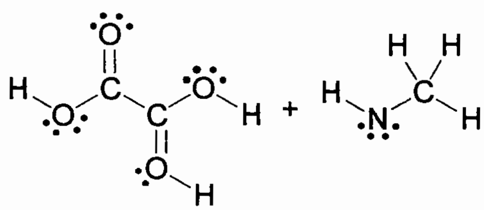
$$1.2\times10^{-3}\text{ mol } NaOH \times \frac{1\,Fe(OH)_3}{3\,NaOH} = \boxed{4.0\times10^{-4}\text{ mol } Fe(OH)_3}$$

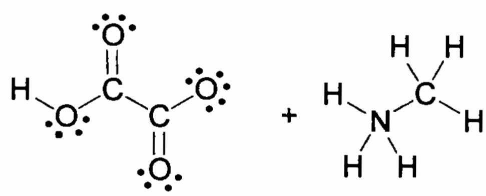
10. What are the products of the following acid/base reaction?

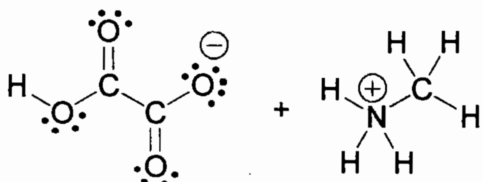


(a) 

(b) 

(c) 

(d) 

(e) 

11. What is the conjugate base of HCO_2^-?

(a) CO_2^- (b) $H_2CO_2^-$ (c) H_2CO_2 (d) CO_2^{2-} (e) CO_2

$HCO_2^- - H^+ \rightarrow CO_2^{2-}$

12. Which one of the following conditions corresponds to an acidic solution?

(a) $[H_3O^+] = 1.0\times10^{-7}$ M (b) pH = 9.0 (c) $[OH^-] = 1.0\times10^{-3}$ M
(d) pOH = 9.0 (e) $[H_3O^+] = 1.0\times10^{-10}$ M

13. What is the $[OH^-]$ to the correct number of significant figures in a pH = 10.361 solution?

3 sig figs

(a) ~~4.3551×10^{-11} M~~ (b) ~~4.355×10^{-11} M~~ (c) ~~4.36×10^{-11} M~~
(d) 2.3145×10^{-4} M (e) 2.315×10^{-4} M (ab) 2.31×10^{-4} M

See Form A, #10 for additional explanation.

since basic, $[OH^-] > 1\times10^{-7}$ M

14. How many mL of water should you add to 5.0 mg of HNO_3 to make a pH 2.00 solution?

strong acid

(a) 890 mL (b) 280 mL (c) 310 mL (d) 32 mL (e) 7.9 mL

mw HNO_3 = $1.008 + 14.007 + 3(15.999) = 63.01 \frac{g}{mol}$

pH 2.0 soln ⇒ $[H_3O^+] = 10^{-pH} = 10^{-2.00} = 0.010$ M

$[HNO_3] = [H_3O^+] = 0.010$ M $= 0.010 \frac{mol}{L}$

$$5.0\,mg\,HNO_3 \times \frac{1\,g}{1000\,mg} \times \frac{mol}{63.01\,g} \times \frac{L}{0.010\,mol} \times \frac{1000\,mL}{1\,L} = \boxed{7.9\,mL}$$

15. 1.00 mL of a 2.5×10^{-4} M KOH solution is diluted to 150. mL. What is the pH of the resulting solution?

strong base

(a) 8.22 (b) 10.39 (c) 1.43 (d) 5.78 (e) 12.57

mol conc = mol dil

$$C_cV_c = C_dV_d$$

$$C_d = \frac{C_cV_c}{V_d} = 2.5\times10^{-4}\,M \cdot \frac{1.00\,mL}{150.\,mL} = 1.667\times10^{-6}\,M$$

$= [KOH] = [OH^-]$

$pOH = -\log(1.667\times10^{-6}) = 5.7781$

$pH = 13.9965 - 5.7781 = 8.218 = \boxed{8.22}$

16. What is the molecular formula of ammonium nitrate?

(a) NH_3NO_3 (b) $(NH_4)_2NO_3$ (c) NH_4NO_3

(d) NH_3N (e) $(NH_3)_3N$

17. In terms of acid/base character, ammonium nitrate is best described as a ___________.

(a) strong acid (b) weak acid (c) strong base
(d) weak base (e) neutral compound

NH_4^+ | NO_3^-

conj base is NH_3 - which is weak base so NH_4^+ is a weak acid (EXP3!)

conj. acid is HNO_3, which is a strong acid so NO_3^- is neutral

HI - strong acid

18. Hydroiodic acid is commercially available as a 57% by weight concentrated solution that has a density of 1.701 g/mL. How many mL of concentrated hydroiodic acid would you need to add to water to make 500. mL of a pH 2.50 solution?

[Hint: weight% is (g of solute)/(g of solution)×100%. For example, a 10% by weight solution has 10 g of solute in 100 g of solution.]

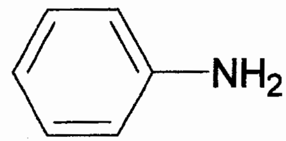
(a) 0.21 mL (b) 63 mL (c) 5.2 mL (d) 28 mL (e) 1.3 mL

pH 2.50 soln so $[H_3O^+] = 10^{-pH} = 10^{-2.50}$
$= 3.16228 \times 10^{-3}$ M
$= [HI]$

$$500.\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{3.16228\times10^{-3}\text{ mol HI}}{\text{L}} \times \frac{127.91\text{ g}}{1\text{ mol}} \times \frac{100\text{ g soln}}{57\text{ g HI}} \times \frac{1\text{ mL soln}}{1.701\text{ g soln}} = 0.21\text{ mL}$$

mw HI = 1.008 + 126.9045 = 127.91 g/mol

19. What is the base dissociation reaction for aniline, $C_6H_5NH_2$ (structure shown to the right)?



(a) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + H_3O^+$

(b) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$

(c) $C_6H_5NH_2 + OH^- \rightleftharpoons C_6H_5NH^- + H_2O$

(d) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_2^- + H_3O^+$

(e) $C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3 + OH$

20. Aniline, $C_6H_5NH_2$ (from the previous question), is a weak base with $K_b = 4.0\times10^{-10}$. What is the pH of a 0.035 M solution of aniline?

(a) 12.54 (b) 9.24 (c) 5.43 (d) 4.76 (e) 8.57

$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$ ← rxn table → $= \frac{x^2}{0.035-x} \approx \frac{x^2}{0.035} = 4.0\times10^{-10}$

x = [OH⁻] because it's a base

$4.0\times10^{-10} = \frac{x^2}{0.035}$

$\sqrt{x^2} = \sqrt{(0.035)(4.0\times10^{-10})}$

$x = \text{''} = 3.742\times10^{-6}\,M = [OH^-]$

$pOH = -\log(3.742\times10^{-6}) = 5.427$

$pH = 13.9965 - 5.427 = 8.56956$

$= \boxed{8.57}$