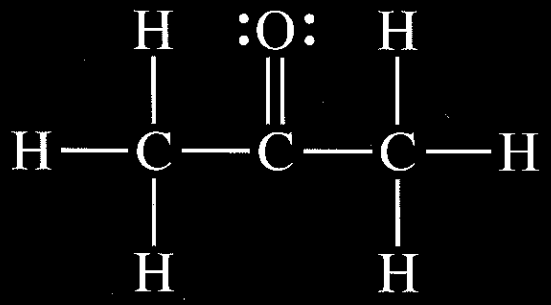
CHEM 1011 / 1021
Final Exam Tutorial

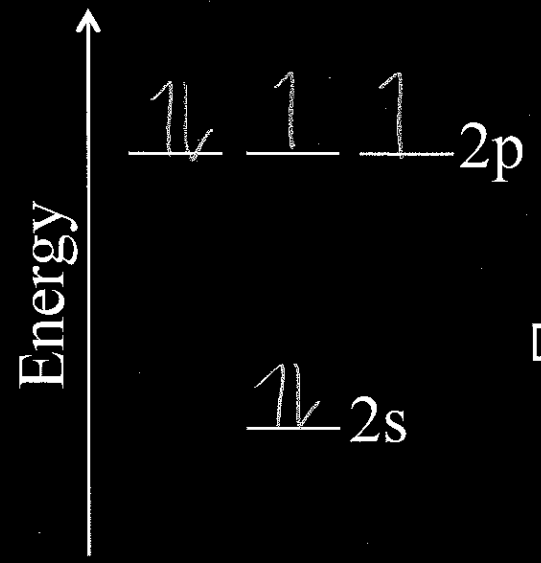
December 4, 2015

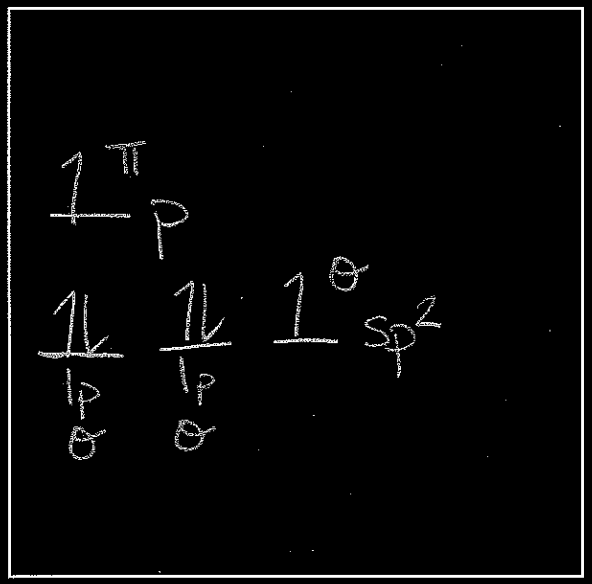
3:00PM-4:00PM

Question #1

(a) Use the Lewis structure (provided below) for acetone to draw the energy level diagram for the free O atom and the hybridized O atom.







acetone free O atom hybridized O atom

(b) Identify the orbitals that will be used ~~for~~ to form:

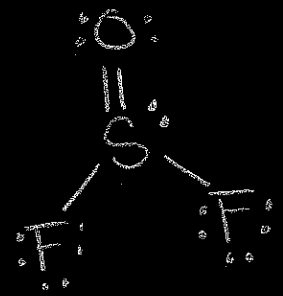
i) σ and π bonds by labeling them with "σ" and "π" respectively

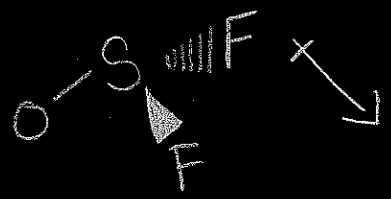
ii) lone pairs by labeling the corresponding orbitals with "lp".

Question #2

(a) Draw the 3D perspective view of the molecular shape and the net dipole moment for SOF_2

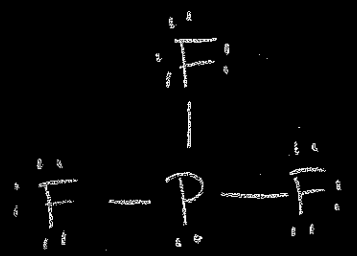
#VE: 6 (S)
6 (O)
2×7 (F)
26





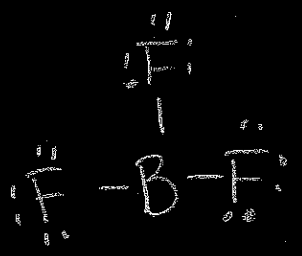
(b) What is the strongest intermolecular interaction that occurs between PF_3 and BF_3?

PF_3: VE = 5 + 3(7) = 26



POLAR

BF_3: VE = 3 + 3(7) = 24



NON-POLAR

∴ DIPOLE - INDUCED DIPOLE

Question #3

4.45 g of copper(II) chloride are mixed with 100.0 mL of 0.250 M sodium chloride and enough water to produce 500.0 mL of solution.

1. How many moles of chloride ions are in solution?

$CuCl_2 \rightarrow Cu^{2+} + 2Cl^-$

$4.45\,g \times \frac{1\,mol\,CuCl_2}{134.452\,g} \times \frac{2\,Cl^-}{1\,CuCl_2} = 0.0662\,mol$

$NaCl \rightarrow Na^+ + Cl^-$

$0.250\frac{mol}{L} \times 0.1\,L \times \frac{1\,Cl^-}{1\,NaCl} = 0.0250\,mol$

$n_{Cl\text{-}total} = 0.0662 + 0.0250 = 0.0912\,mol$

2. What is the molarity of the chloride ions in the solution?

$\frac{0.0912\,mol\,Cl^-}{0.5\,L} = 0.1824\frac{mol}{L}$

3. What is the molarity of the sodium ions in the solution?

$\frac{0.025\,mol\,Na^+}{0.5\,L} = 0.05\frac{mol}{L}$

Question #4

An aqueous solution of $AgNO_3$ is prepared by dissolving 7.76 g of $AgNO_3$ in 22.0 g of water.

The density of the solution is 1.27 g/mL.

a) Determine the mol fraction of $AgNO_3$ in the solution

$$n_{AgNO_3} = \frac{7.76\,g}{169.874\,g/mol} = 0.04568\,mol$$

$$n_{H_2O} = \frac{22.0\,g}{18.015\,g/mol} = 1.221\,mol$$

$$\chi = \frac{n_{AgNO_3}}{n_T} = \frac{0.04568}{0.04568 + 1.221} = 0.0361$$

b) What is the molarity of the solution?

$$n_{AgNO_3} = 0.04568\,mol$$

$$V_{solution} = \frac{(22.0\,g_{H_2O} + 7.76\,g_{AgNO_3})}{1.27\,g/mL} \times \frac{1\,L}{1000\,mL}$$

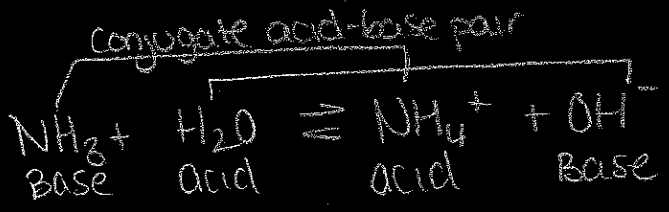
$$= 0.0234\,L$$

$$[AgNO_3] = \frac{0.04568\,mol}{0.0234\,L} = 1.95\,M$$

Question #5

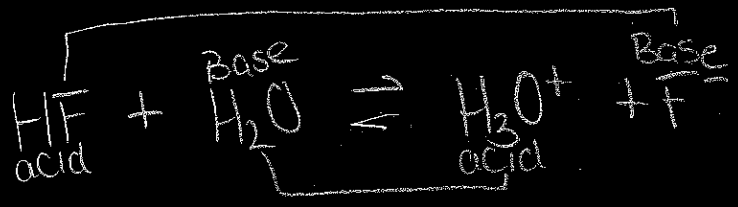
Write the balanced chemical equation that describes how the following species behave in water. Label the conjugate acid/base pairs.

(a) $NH_3(aq)$



(b) $HSO_4^-(aq)$

(c) HF (aq)



Question #6

Will the following species be acidic, basic or neutral in aqueous solution?

(a)$NaCH_3COO$ [pK_a (CH_3COOH) = 4.75]

$NaCH_3COO \xrightarrow{H_2O} Na^+ + CH_3COO^-$

∴ Basic

(b)$NaHCO_3$ [H_2CO_3: pK_{a1}= 6.37; pK_{a2}= 10.25]

As an acid: $HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+$ $pK_a = 10.25$

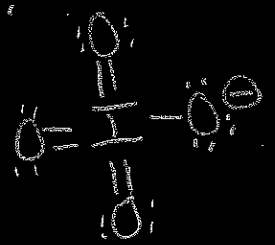
As a base: $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$ $pK_b = 14 - 6.37 = 7.63$

∴ Basic

Question #7

Which one of the following is the strongest acid? Explain your answer.

HIO_4 – Strongest because it has the most resonance contributers and thus the negative charge is the most stabilized:



HIO_3

HIO_2

Question #8

Calculate the pH for the following:

(a) 0.250 M carbonic acid (H_2CO_3: $pK_{a1} = 6.37$; $pK_{a2} = 10.25$)

	H_2CO_3	+ H_2O	⇌ HCO_3^-	+ H_3O^+
I	0.250	N/A	0	0
C	−x		+x	+x
E	0.250−x		x	x

$K_a = 10^{-pK_{a1}}$
$= 10^{-6.37}$
$= 4.27 \times 10^{-7}$

$\therefore 4.27 \times 10^{-7} = \frac{x^2}{0.250}$

$x = \sqrt{(4.27 \times 10^{-7})(0.25)}$

$x = 3.27 \times 10^{-4} = [H^+]$

Check: $400 K_a < 0.25$?
$1.7063 \times 10^{-4} < 0.25$ YES!

$pH = -\log(3.27 \times 10^{-4})$
$= 3.49$

(b) 0.600 M NH_3 (NH_4^+: pKa = 9.25)

	NH_3	+ H_2O	⇌ NH_4^+	+ OH^-
I	0.600	N/A	0	0
C	−x		+x	+x
E	0.600−x		x	x

$K_b = 10^{-pK_b}$
$= 10^{-(14-9.25)}$
$= 10^{-4.75}$
$= 1.778 \times 10^{-5}$

Check: is $400 K_b < 0.6$
$7.11 \times 10^{-3} < 0.6$ YES!

$\therefore 1.778 \times 10^{-5} = \frac{x^2}{0.600}$

$x = \sqrt{(1.778 \times 10^{-5})(0.600)}$

$x = 3.266 \times 10^{-3} = [OH^-]$

$pOH = -\log(3.266 \times 10^{-3})$
$= 2.48$

$pH = 14 - 2.48$
$= 11.51$

Question #9

90.0 mL of 0.600 M NH_3 is added to 20.0 mL of 0.500 M HCl. What is the pH the resulting solution?

$n_{NH_3} = 0.6 \frac{mol}{L} \times 0.09L$ $= 0.054 mol$

$n_{H_3O^+} = 0.5 \frac{mol}{L} \times 0.02L$ $= 0.01 mol$

(moles)	NH_3	+ H_3O^+	⇌ NH_4^+	+ H_2O
I	0.054	0.01	0	N/A
C	−0.01	−0.01	+0.01	
E	0.044	0	0.01	

$pK_a(NH_4^+) = 9.25$ (From Q8)

$pH = 9.25 + \log \frac{0.044}{0.01}$

$\therefore pH = 9.89$

Question #10

A 250 mL solution of 0.350 M CH_3COOH is added to 116 mL of 0.750 M $LiCH_3COO$. $pK_a(CH_3COOH) = 4.75$

1. Determine the pH of this buffer.

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

$$pH = 4.75 + \log \frac{(0.75M)(0.116L)}{(0.35M)(0.250L)} \quad \begin{matrix} \leftarrow CH_3COO^- \\ \leftarrow CH_3COOH \end{matrix}$$

$$\therefore pH = 4.75$$

2. What is the new pH of the solution after 7.50 mL of 1.00 M NaOH is added to the buffer.

$$n_{CH_3COOH} = (0.350M)(0.250L) = 0.0875$$

$$n_{OH^-} = 1.00\frac{mol}{L} \times 0.0075L \times \frac{1 mol\ OH^-}{1 mol\ NaOH} = 7.5 \times 10^{-3} mol\ OH^-$$

$$n_{CH_3COO^-} = \left(0.75\frac{mol}{L}\right)(0.116L) = 0.087 mol$$

(moles)	CH_3COOH	$+ OH^-$	$\rightarrow CH_3COO^-$	$+ H_2O$
I	0.0875	7.5×10^{-3}	0.087	N/A
C	-7.5×10^{-3}	-7.5×10^{-3}	$+7.5 \times 10^{-3}$	
E	0.08	0	0.0945	

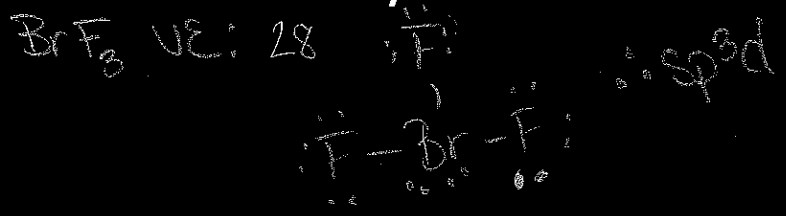
$$\therefore pH = 4.75 + \log \frac{0.0945}{0.08}$$

$$= 4.82$$

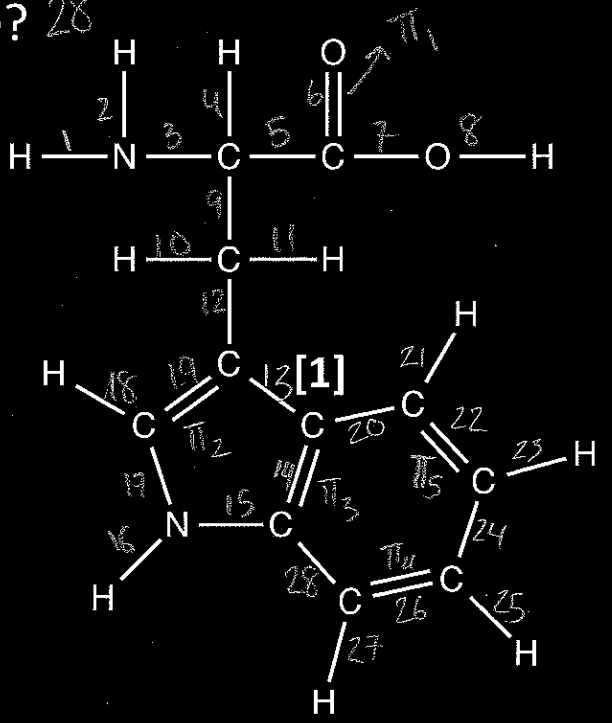
Additional Questions

Question #1 – additional questions

1. What is the hybridization of the bromine atom in BrF_3?



2. Answer the following questions for the amino acid tryptophan:
   1. What is the hybridization at C[1]? sp^2
   2. How many sigma bonds are in this molecule? 28
   3. How many pi bonds are in this molecule 5

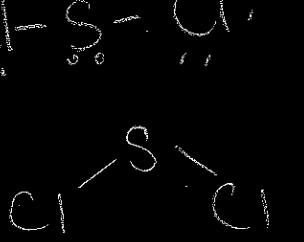


Question #2 – additional questions

1. Is SCl_2 polar or non polar?

VE: 6 + 2(7) = 20

∴ polar

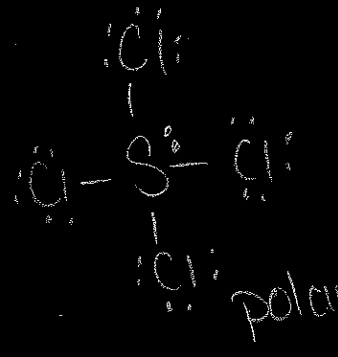


bent tetrahedral

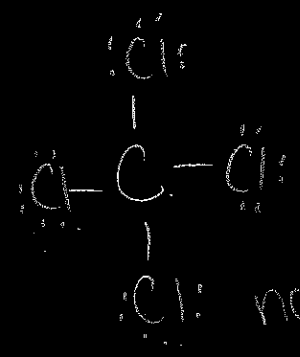
2. What is the strongest type of intermolecular interaction that occurs between SCl_4 and CCl_4?

VE: 6 + 4(7) = 34

VE: 4 + 4(7) = 32



polar



nonpolar

∴ dipole-induced dipole

Question #3 – additional questions

1. How many moles of sodium ions are in 250 mL of 1.25 M sodium phosphate? $Na_3(PO_4)$

$$0.250\,L \times 1.25\frac{mol}{L} = 0.3125\,mol \times \frac{3\,mol\,Na^+}{1\,mol\,Na_3(PO_4)}$$

$$= 0.9375\,mol\,Na^+$$

2. 17.3 mL of a solution of 1.17 M $KClO_4$ is diluted to a concentration of 0.640 M. What is the new volume of the solution?

$$(17.3\,mL)(1.17\,M) = V_2(0.640\,M)$$

$$\therefore V_2 = 31.63\,mL$$

Question #4 – additional questions

An aqueous solution of $Mg(NO_3)_2$ is prepared by dissolving 17.7 g of $Mg(NO_3)_2$ in 500. g of water. The density of the solution is 1.27 g/mL.

a) Determine the mol fraction of $Mg(NO_3)_2$ in the solution

$n_{Mg(NO_3)_2} = \frac{17.7\,g}{148.313\,g/mol} = 0.1193\,mol$ $\quad$ $n_{H_2O} = \frac{500.\,g}{18.015\,g/mol} = 27.75\,mol$ $\quad$ $MM = 148.313\,g/mol$

$\chi_{Mg(NO_3)_2} = \frac{0.1193}{(0.1193 + 27.75)} = 4.28 \times 10^{-3}$

b) Determine the mass percent of $Mg(NO_3)_2$ in the solution

$\text{mass \% } Mg(NO_3)_2 = \frac{17.7\,g}{517.7\,g} \times 100\% = 3.42\,\%$

c) What is the molarity of the solution?

$\text{density} = 1.27\,\frac{g}{mL} = \frac{m}{V}$

$1.27\,\frac{g}{mL} = \frac{517.7\,g}{V}$

$\therefore V = 407.64\,mL = 0.4076\,L$

$M = \frac{n}{V} = \frac{0.1193}{0.4076} = 0.2927\,\frac{mol}{L}$

Question #5 – additional questions

Determine the mass (in g) of $Ni_3(PO_4)_2$ that is produced when 217 mL of a 0.520 M Na_3PO_4 solution completely reacts with 745 mL of a 0.442 M $NiCl_2$ solution according to the following unbalanced equation:

$$2\,Na_3PO_4(aq) + 3\,NiCl_2(aq) \rightarrow Ni_3(PO_4)_2(s) + 6\,NaCl(aq)$$

$mm = 366.019\ g/mol$

$mol = 0.217\,L \times 0.520\,\frac{mol}{L}$

$= 0.1128\,mol$

$0.1128\,mol \times \frac{1\,Ni_3(PO_4)_2}{2\,Na_3PO_4}$

$= 5.64 \times 10^{-2}\,mol$

(*LR)

$mol = 0.745\,L \times 0.442\,\frac{mol}{L}$

$= 0.3293\,mol$

$0.3293\,mol \times \frac{1\,Ni_3(PO_4)_2}{3\,NiCl_2}$

$= 1.10 \times 10^{-1}\,mol$

$\therefore 5.64 \times 10^{-2}\,mol\ Ni_3(PO_4)_2 \times 366.019\,\frac{g}{mol}$

$= 20.65\,g$

Question #6 – additional questions

- Write the balanced chemical reaction that describes how each of the following species will react with water:

- BeO $+ H_2O \rightarrow Be^{2+} + 2OH^-$
- NaOH $+ H_2O \rightarrow Na^+ + OH^-$
- HCl $+ H_2O \rightarrow H_3O^+ + Cl^-$
- HF $+ H_2O \rightarrow F^- + H_3O^+$

Question #7 – additional questions

What is the pH of an 0.0150M solution of calcium hydroxide?

$Ca(OH)_2 + H_2O \longrightarrow Ca^{2+} + 2OH^-$

$[OH^-] = 2(0.0150 mol)$

$= 0.0300 mol\ Ca(OH)_2$

$pOH = -\log(0.03)$

$= 1.52$

$pH = 14 - pOH$

$= 14 - 1.52$

$= 12.48$

Question #8 – additional questions

What is the pH of an 0.450M solution of ethyl amine ($C_2H_5NH_2$)?

The pKa of the ethyl ammonium ion is 10.87

$C_2H_5NH_2 + H_2O \rightleftharpoons C_2H_5NH_3^+ + OH^-$

	$C_2H_5NH_2$		$C_2H_5NH_3^+$	OH^-
I	0.450		0	0
C	$-x$		$+x$	$+x$
E	$0.450-x$		x	x

$pK_a = 10.87$

$pK_b = 14 - 10.87 = 3.13$

$K_b = 10^{-pK_b}$

$= 10^{-3.13}$

$= 7.41\times10^{-4}$

$K_b = 7.41\times10^{-4} = \dfrac{[OH^-][C_2H_5NH_3^+]}{[C_2H_5NH_2]}$

$7.41\times10^{-4} \approx \dfrac{x^2}{0.450}$

$3.34\times10^{-4} = x^2$

$\therefore x = 1.83\times10^{-2} = [OH^-]$

$pOH = -\log 1.83\times10^{-2} = 1.74$

$pH = 14 - 1.74 = 12.26$

Check: $400K_b = 2.97\times10^{-1} < 0.450M$

$\therefore$ assumption valid

Question #9 – additional questions

Consider 100.0 mL solution that contains 0.175 M HClO and 0.150 M NaClO. The pKa of HClO is 7.53

1. What is the pH of this solution?

$pK = pK_a + \log\frac{[ClO^-]}{[HClO]}$ $\quad pH = 7.53 + \log\frac{0.15}{0.175} = 7.46$

2. What is the pH of this solution after the addition of 0.150 g of HBr? $HBr + ClO^- \rightarrow HClO + Br^-$

	HBr	ClO^-	$HClO$	Br^-
I	1.86×10^{-3}	1.5×10^{-2}	1.75×10^{-2}	
C	-1.86×10^{-3}	-1.86×10^{-3}	$+1.86\times10^{-3}$	$+1.86\times10^{-3}$
E	0	1.31×10^{-2}	1.94×10^{-2}	1.86×10^{-3}

$pH = 7.53 + \log\frac{0.0131}{0.0194} = 7.36$

$n_{HBr} = \frac{0.150\,g}{80.943\,g/mol} = 1.86\times10^{-3}\,mol$

$n_{ClO^-} = 0.150\,\frac{mol}{L} \times 0.1\,L = 1.5\times10^{-2}\,mol$

$n_{HClO} = 0.175\,\frac{mol}{L} \times 0.1\,L = 1.75\times10^{-2}\,mol$

3. What is the pH of this solution after the addition of 0.00425 mol of $Ca(OH)_2$? $HClO + OH^- \rightarrow ClO^- + H_2O$

$n_{OH^-} = 2(4.25\times10^{-3}) = 8.5\times10^{-3}\,mol$

	$HClO$	OH^-	ClO^-	H_2O
I	0.0175	0.0085	0.0150	
C	−0.0085	−0.0085	+0.0085	
E	0.009	0	0.0235	

$pH = 7.53 + \frac{0.0235}{0.0090} = 7.95$