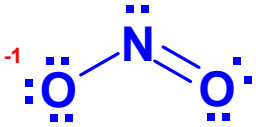
NAME:_____ Student Number:_____

Fall 2006 **Chemistry 1000 Practice Test #2*** ____/ 64 marks

INSTRUCTIONS:
1) Please read over the test carefully before beginning. You should have 7 pages of questions, and a periodic table (8 pages total). If you need extra space, please use the bottom half of the periodic table page and clearly indicate which question is being answered.
2) If your work is not legible, it will be given a mark of zero.
3) You may use a calculator.
4) You have 90 minutes to complete this test.

---

1. Complete the following table. *Where charge(s) are necessary, place them on the appropriate atom(s) in the Lewis electron dot structure.* [10 marks]

Formula	Lewis Electron Dot Structure	Electron Pair Geometry	Molecular Geometry	Predicted Bond Angle
nitrite ion		trigonal planar	bent	120˚
xenon difluoride		trigonal bipyramidal	linear	180˚

NAME:_____ Student Number:_____

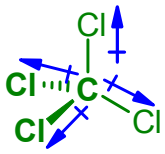
2. Complete the following table. [5 marks]

Molecular Formula	Name
$(NH_4)_2SO_4$	ammonium sulfate
$FePO_4 \cdot 4H_2O$	iron(III) phosphate tetrahydrate
$Ca(OCl)_2$	calcium hypochlorite
P_2O_5	**diphosphorus pentoxide** *(or diphosphorus pentaoxide)*
NiS	**nickel(II) sulfide** *or* **nickel(II) sulphide**

3. Which of the molecules below is more polar? Justify your answer. [6 marks]

SCl_4 vs. CCl_4

CCl_4 is a nonpolar molecule. Its tetrahedral geometry makes all of the bond dipoles cancel out, leaving the molecule with no net dipole.

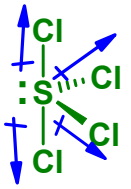


tetrahedral

no net dipole

nonpolar molecule

SCl_4 is a polar molecule. Its see-saw geeometry does not allow the bond dipoles to cancel out, leaving the molecule with a net dipole.



see-saw

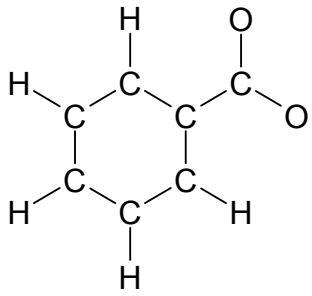
net dipole →

polar molecule

NAME:_____ Student Number:_____

4. Sodium benzoate is a common preservative added to foods. The benzoate anion has a molecular formula of $C_6H_5CO_2^-$ with the atoms connected as shown below:

[10 marks]



(a) In the space below, draw Lewis structures for all resonance structures of the benzoate anion, *placing charge(s) on the correct atom(s).*

(b) How many atoms in the benzoate ion have sp^3 hybridization? ___0___

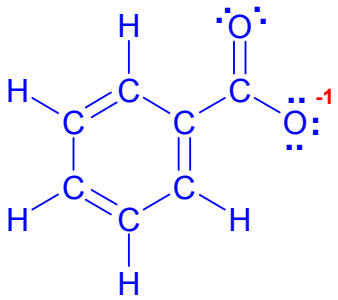
(c) How many atoms in the benzoate ion have sp^2 hybridization? ___9___

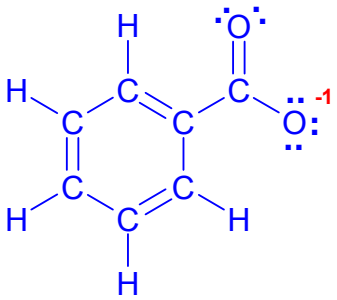
(d) How many atoms in the benzoate ion have *sp* hybridization? ___0___

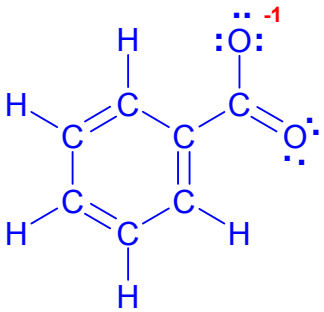
Because of the resonance, all nine C and O atoms are sp^2 hybridized.

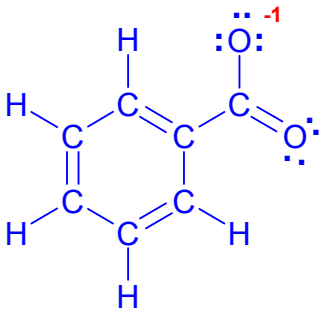
No H atoms are hybridized in any way.

There are four resonance structures for the benzoate anion: two resonance forms of the benzene ring and two resonance forms of the carboxylate group (CO_2^-). Mix and match to get four resonance structures total.









NAME:_____ Student Number:_____

5. [10 marks]

(a) What are the three requirements for two atomic orbitals to be able to combine to make a bonding molecular orbital? For each requirement,

i. show a pair of orbitals that meet the requirement and the molecular orbital(s) which they form, and

ii. show a pair of orbitals that do not meet the requirement and the result of their interaction.

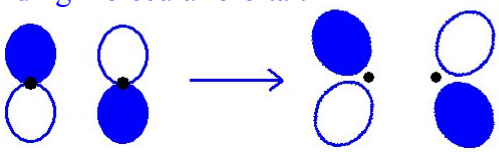
(b) Explain why it is easy to rotate about (or twist) a σ bond but not a π bond.

(a) The three requirements are that the two atomic orbitals line up with the correct phase, line up with the correct symmetry and have similar energies.

Phase:

i. Two atomic orbitals *in phase* overlap to give a bonding molecular orbital:

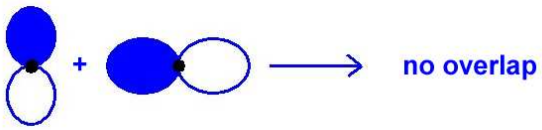
ii. Two atomic orbitals *out of phase* give an antibonding molecular orbital:



Symmetry:

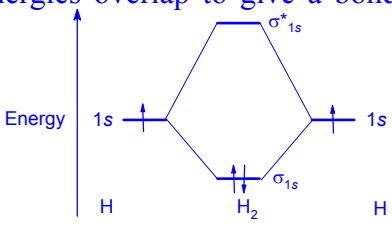
i. Two atomic orbitals with the same symmetry overlap to give a bonding molecular orbital. *(see example i. of **phase**)*

ii. Two atomic orbitals with different symmetry (different nodes) don't interact:

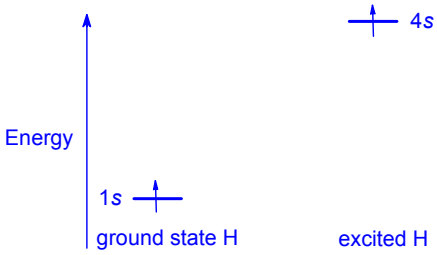


Energy:

i. Two atomic orbitals with similar energies overlap to give a bonding molecular orbital.



ii. Two atomic orbitals with very different energies don't interact (or interact very little).



NAME:_____ Student Number:_____

(b) A σ bond has much of its electron density between the two nuclei. It has no nodes between the two nuclei, so rotation will not affect the symmetry required for the bond. Thus, twisting a σ bond requires very little energy.

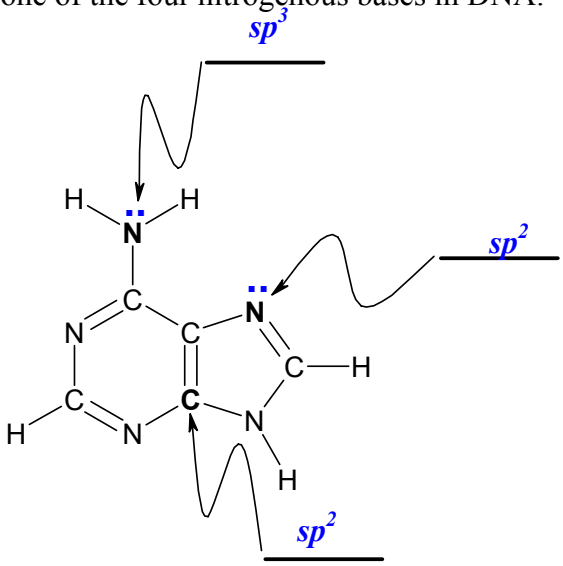
A π bond has a node along the axis between the two nuclei. Rotating one of the atoms in the π bond will rotate the orbitals on that atom and break the symmetry required for the π bond. The bond will be broken by twisting it. Thus, twisting a π bond requires enough energy to break the bond (and is therefore difficult to do).

To picture this, try an easy (and tasty!) experiment with toothpicks and marshmallows.

σ bond:
Attach two marshmallows with a toothpick then try to spin one of the marshmallows. It's easy! (Just like twisting a σ bond is easy.)

π bond:
Attach two marshmallows with two toothpicks, one near the tops and one near the bottoms. Try spinning a marshmallow now (without letting the other one move). It's not so easy anymore; you'll probably wind up breaking one of the marshmallows. (Just like twisting a π bond is not very easy – and breaks the bond, since breaking atoms isn't feasible.)

6. DNA consists of three types of molecules connected together. The "coding" molecules are called nitrogenous bases (because they are bases that contain nitrogen). The molecule shown below is adenine, one of the four nitrogenous bases in DNA. [5 marks]



(a) Name the hybrid orbital set used by each of the three atoms in bold.

(b) How many σ bonds are there in one molecule of adenine? 16 *(16 bonds of any type)*

(c) How many π bonds are there in one molecule of adenine? 4 *(4 double bonds; 0 triple bonds)*

NAME:_____ Student Number:_____

7. Consider the bonding in carbon monoxide. [12 marks]

(a) Draw the best Lewis electron dot structure for carbon monoxide.

$$:\overset{-1}{C}\equiv\overset{+1}{O}:$$

(b) Calculate the partial charge on each atom. ($\chi_C = 2.5$, $\chi_O = 3.5$)

$$Q(C) = e_{valence} - \left(e_{nonbonding} + \frac{\chi_C}{\chi_C + \chi_O} e_{C\text{-}O\ bond}\right)$$

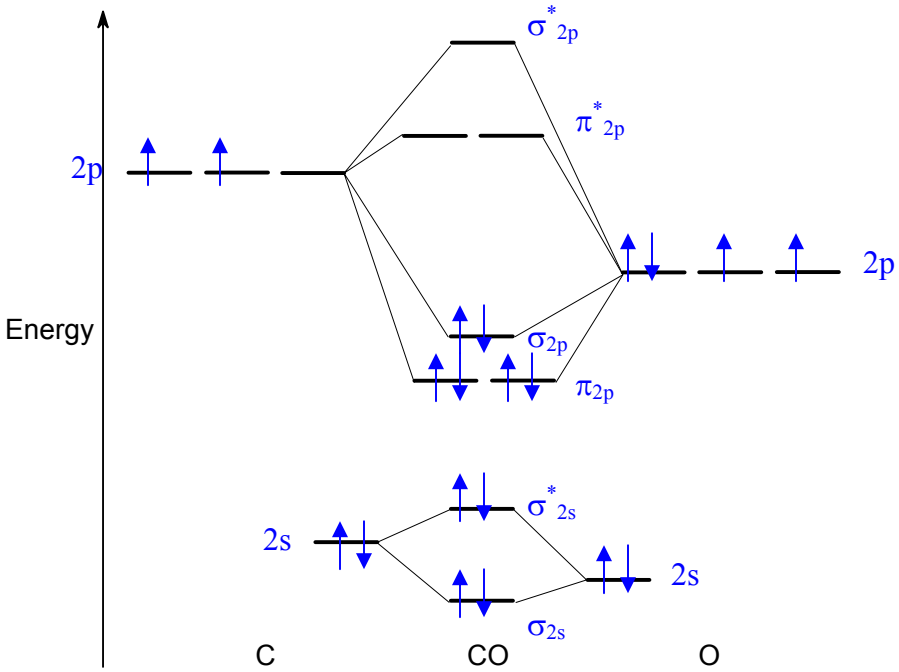
$$Q(C) = 4 - \left[2 + \frac{2.5}{2.5 + 3.5}(6)\right] = -0.5$$

$$Q(O) = e_{valence} - \left(e_{nonbonding} + \frac{\chi_O}{\chi_C + \chi_O} e_{C\text{-}O\ bond}\right)$$

$$Q(O) = 6 - \left[2 + \frac{3.5}{2.5 + 3.5}(6)\right] = +0.5$$

(c) Complete the molecular orbital correlation diagram below by:

i. labeling the atomic orbitals (with their names),
ii. labeling the molecular orbitals (with their names), and
iii. adding the electrons



(d) Calculate the bond order for carbon monoxide from the Lewis dot structure and from the molecular orbital correlation diagram. Compare the two answers.

Lewis structure has a triple bond therefore bond order = 3

Molecular orbitals show 8 valence electrons in bonding orbitals and 2 valence electrons in antibonding orbitals. Therefore, bond order = ½ (8) – ½ (2) = 3

The bond order is the same using either method.

NAME:_____ Student Number:_____

8. An unknown solid is found to contain 52.26% Fe, 44.91% O and 2.83% H by mass. [6 marks]

(a) Calculate the empirical formula for this unknown solid.

(b) Assuming that the empirical and molecular formulae are the same, name the unknown solid.

(a) 100 g of unknown molecule contains 52.26 g Fe, 44.91 g O and 2.83 g H.

$$n_{Fe} = \frac{m_{Fe}}{M_{Fe}} = \frac{(52.26\ g)}{(55.845\ g/mol)} \qquad n_{Fe} = 0.9358\ mol$$

$$n_{O} = \frac{m_{O}}{M_{O}} = \frac{(44.91\ g)}{(15.9994\ g/mol)} \qquad n_{O} = 2.807\ mol$$

$$n_{H} = \frac{m_{H}}{M_{H}} = \frac{(2.83\ g)}{1.00079\ g/mol} \qquad n_{H} = 2.81\ mol$$

Therefore,

$$n_{Fe} : n_{O} : n_{H} = \frac{0.9358\ mol\ Fe}{0.9358} : \frac{2.807\ mol\ O}{0.9358} : \frac{2.81\ mol\ H}{0.9358}$$

$$n_{Fe} : n_{O} : n_{H} = 1.000\ mol\ Fe : 3.000\ mol\ O : 3.00\ mol\ H$$

Therefore, the empirical formula is FeO_3H_3

(b) FeO_3H_3 = $Fe(OH)_3$ = iron(III) hydroxide

Chem 1000 Standard Periodic Table

1												13	14	15	16	17	18
1.0079 **H** 1	2																4.0026 **He** 2
6.941 **Li** 3	9.0122 **Be** 4											10.811 **B** 5	12.011 **C** 6	14.0067 **N** 7	15.9994 **O** 8	18.9984 **F** 9	20.1797 **Ne** 10
22.9898 **Na** 11	24.3050 **Mg** 12	3	4	5	6	7	8	9	10	11	12	26.9815 **Al** 13	28.0855 **Si** 14	30.9738 **P** 15	32.066 **S** 16	35.4527 **Cl** 17	39.948 **Ar** 18
39.0983 **K** 19	40.078 **Ca** 20	44.9559 **Sc** 21	47.88 **Ti** 22	50.9415 **V** 23	51.9961 **Cr** 24	54.9380 **Mn** 25	55.847 **Fe** 26	58.9332 **Co** 27	58.693 **Ni** 28	63.546 **Cu** 29	65.39 **Zn** 30	69.723 **Ga** 31	72.61 **Ge** 32	74.9216 **As** 33	78.96 **Se** 34	79.904 **Br** 35	83.80 **Kr** 36
85.4678 **Rb** 37	87.62 **Sr** 38	88.9059 **Y** 39	91.224 **Zr** 40	92.9064 **Nb** 41	95.94 **Mo** 42	(98) **Tc** 43	101.07 **Ru** 44	102.906 **Rh** 45	106.42 **Pd** 46	107.868 **Ag** 47	112.411 **Cd** 48	114.82 **In** 49	118.710 **Sn** 50	121.757 **Sb** 51	127.60 **Te** 52	126.905 **I** 53	131.29 **Xe** 54
132.905 **Cs** 55	137.327 **Ba** 56	**La-Lu**	178.49 **Hf** 72	180.948 **Ta** 73	183.85 **W** 74	186.207 **Re** 75	190.2 **Os** 76	192.22 **Ir** 77	195.08 **Pt** 78	196.967 **Au** 79	200.59 **Hg** 80	204.383 **Tl** 81	207.19 **Pb** 82	208.980 **Bi** 83	(210) **Po** 84	(210) **At** 85	(222) **Rn** 86
(223) **Fr** 87	226.025 **Ra** 88	**Ac-Lr**	(261) **Rf** 104	(262) **Db** 105	(263) **Sg** 106	(262) **Bh** 107	(265) **Hs** 108	(266) **Mt** 109	(281) **Dt** 110	(283) **Rg** 111							

138.906 **La** 57	140.115 **Ce** 58	140.908 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.965 **Eu** 63	157.25 **Gd** 64	158.925 **Tb** 65	162.50 **Dy** 66	164.930 **Ho** 67	167.26 **Er** 68	168.934 **Tm** 69	173.04 **Yb** 70	174.967 **Lu** 71
227.028 **Ac** 89	232.038 **Th** 90	231.036 **Pa** 91	238.029 **U** 92	237.048 **Np** 93	(240) **Pu** 94	(243) **Am** 95	(247) **Cm** 96	(247) **Bk** 97	(251) **Cf** 98	(252) **Es** 99	(257) **Fm** 100	(258) **Md** 101	(259) **No** 102	(260) **Lr** 103

Developed by Prof. R. T. Boeré