Chem 1141
Fall 2014
Exam 4A

Name: KEY

Please write your full name, and which exam version (4A) you have on the scantron sheet.

Please ☑ check the box next to your correct section number.

Section #:
- ❒ 1. (Tuesday Lab, 4 – 6:50 pm)
- ❒ 2. (Thursday Lab, 4 – 6:50 pm)
- ❒ 3. (Monday Lab, 11 – 1:50 pm)
- ❒ 4. (Wednesday Lab, 11 – 1:50 pm)
- ❒ 5. (Wednesday Lab, 2 – 4:50 pm)

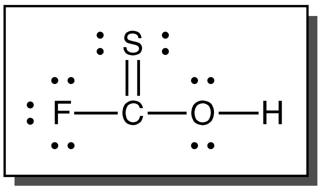
Multiple Choice:	________________	**/30**
Q11:	________________	**/10**
Q12:	________________	**/10**
Q13:	________________	**/10**
Q14:	________________	**/10**
Q15:	________________	**/10**
Q16:	________________	**/10**
Q17:	________________	**/10**
BONUS:	________________	**/3**
TOTAL:	________________	**/100**

Multiple Choice. [3 points each.] Record your answers to the multiple choice questions on the scantron sheet. Choose the *best* response.

Q1. Who is generally credited with creating the first periodic table?
a) Pauli b) Schrödinger c) Mendeleev d) Auf Bau e) Lewis

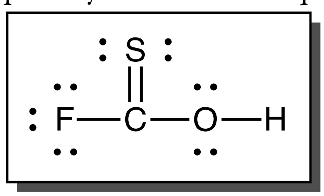
Q2. The chemical equation corresponding to the electron affinity of sodium is:
a) $Na(s) \longrightarrow Na(s) + e^-$
b) $Na(g) \longrightarrow Na^+(g) + e^-$
c) $Na(l) \longrightarrow Na^-(g) + e^-$
d) $Na(g) + e^- \longrightarrow Na^-(g)$
e) $Na^-(g) \longrightarrow Na(g) + e^-$

Q3. The molecular geometry about the oxygen atom in the following Lewis structure is predicted by VSEPR to be:



a) linear b) trigonal planar c) bent d) see-saw e) tetrahedral

Q4. What type of hybrid orbital is required for the carbon atom in the following Lewis structure?



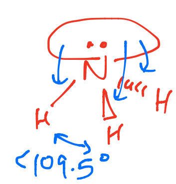
a) sp b) sp^2 c) sp^3 d) sp^3d e) sp^3d^2

Q5. Which of the following bonds is non-polar covalent?
a) F—F $\Delta E_n = 0$ b) H—Cl c) Li—Br d) Se—Br e) Na—Cl

Q6. Which of these compounds does not follow the octet rule?
a) NF_3 b) CF_4 c) $AsBr_3$ d) PF_5 e) Cl_2

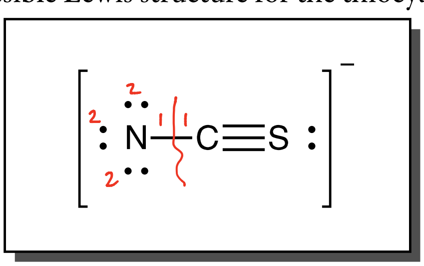
expanded octet

Q7. The H—N—H bond angle in NH_3 is:
a) 180° b) 120° c) slightly more than 120°
d) 109.5° e) slightly less than 109.5° Lone pair repulsion reduces angle.



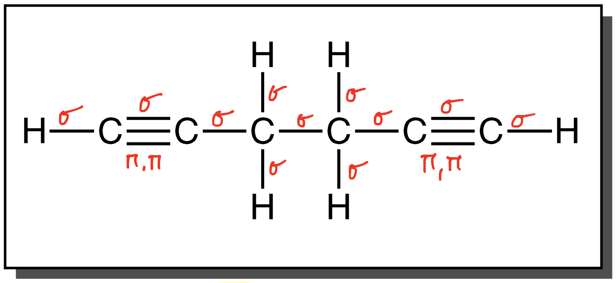
Q8. One possible Lewis structure for the thiocyanate ion, SCN^- is:

Orig: $5e^-$
now: $7e^-$
FC: 2−
("gained" $2e^-$)



The formal charge on the **nitrogen** atom is:
a) 2− b) 1− c) 0 d) 1+ e) 2+

Q9. The number of pi bonds in the molecule below is:



Note: 1st bond = σ
additional bonds = π

a) 2 b) 4 c) 6 d) 10 e) 15

Q10. Which of the following has the largest atomic radius?
a) F b) N c) O d) S e) P

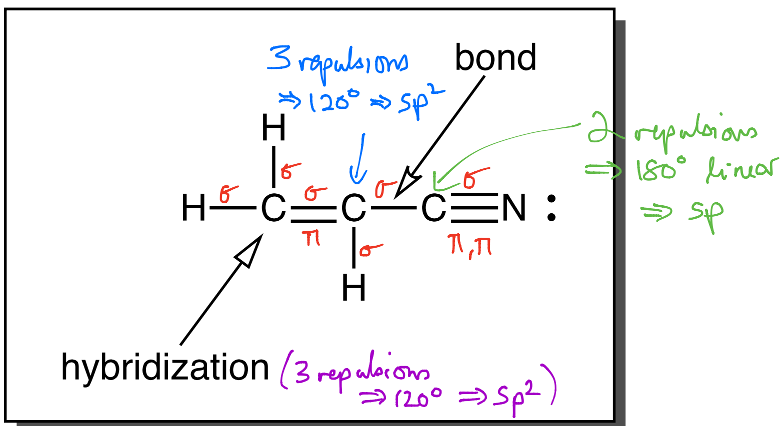
- size increases down groups (increasing shells)
- size increases towards left of periods (lower Zeff)

Short Response.

Show all work to receive credit. Be sure to write complete sentences in your explanations!

Q11. [10 pts.] Acrylonitrile is used as the starting material for manufacturing acrylic fibers. Its Lewis structure is:

a)



#rep	geom	hybrid
2	180°	sp
3	120°	sp²
4	$109\frac{1}{2}$°	sp³
⋮	⋮	⋮

a) How many sigma and pi bonds are there in this molecule? 6 σ, 3 π

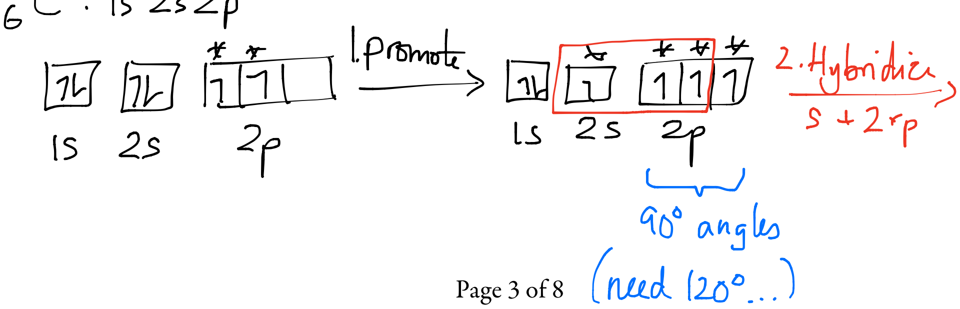
b) For the **bond** indicated above, list the types of atomic or hybrid orbitals that are overlapping to form the bond: sp² (left carbon atom) and sp (right carbon atom).

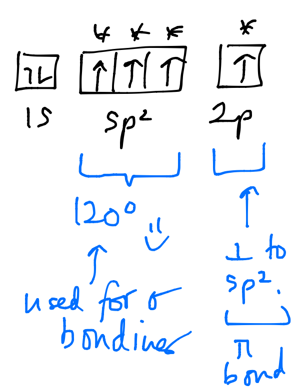
c) The **bond** indicated in part (b) is an example of a sigma or a pi bond? σ (state which)

d) What is the orbital **hybridization** of the far left carbon atom? sp²

e) Draw the orbital diagram for the carbon atom in part (d).

$_6C: 1s^2 2s^2 2p^2$





Q12. [10 pts.] a) Rank the following bonds in order of **increasing** bond length:

C—N, C═N, C≡N C≡N < C=C < C—C

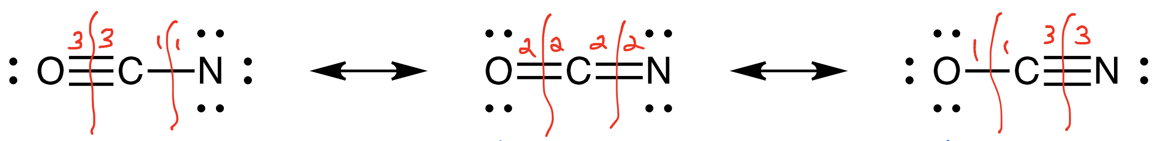
b) Draw the Lewis dot structure for a nitrogen atom: ·N̈·

c) What angle do **sp** hybrid orbitals make with one another? 180°

d) What is the tetrahedral bond angle? 109.5°

Q13. [10 pts.] Determine the formal charge for each atom in the following three resonance structures for the $[OCN]^-$ anion. Explain which one of these resonance structures is the most favored.

Structure 1	***Structure 2***	***Structure 3***



	Structure 1	Structure 2	Structure 3
ORIG #e⁻ :	6 4 5	6 4 5	6 4 5
Assigned #e⁻ :	5 4 7	6 4 6	7 4 5
FC :	1+ 0 2−	0 0 1−	1− 0 0

got lp + ½ bp

Formal Charges:

	Structure 1	Structure 2	Structure 3
O	1+	0	1−
C	0	0	0
N	2−	1−	0

Most favored structure: #3

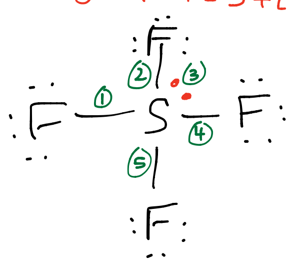
Explanation: 1. Lowest set of FC's
2. Most electronegative atom has −ve charge!

Q14. [10 pts.] Predict the molecular geometry and polarity of SF_4. Your answer should include:

- ❑ A valid Lewis structure
- ❑ A sketch of the geometry using line/dash/wedge notation
- ❑ The value of the bond angle(s) written out
- ❑ A clear explanation of why SF_4 is polar or non-polar

SF_4

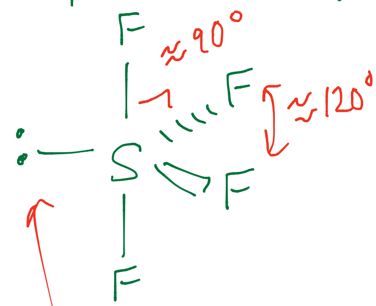
$6 + 7 \times 4 = 34 e^-$



$34 - 8 - 24 = 2e^-$ remain
(bonds) (lp)

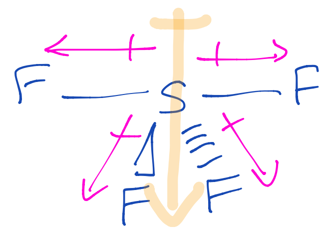
place on central atom.

VSEPR
5 Repulsions ⇒ e^- geom is trigonal pyramidal



lp goes equatorial to minimize # lp-bp repulsions @ 90°

Molecular Geom
Where ATOMS are!



$\boxed{\text{See-Saw}}$

⟶ = Bond dipole

⟶ = Overall "

⇒ Since SF_4 has overall (non-zero) dipole, it is POLAR

Q15. [10 pts.] Answer **two** of the following. Clearly indicate which two you want graded!

a) What is meant by the term: effective nuclear charge, Z_{eff}?
Explain the trend in Z_{eff} moving across the rows of the periodic table.

b) What is ionization energy?
Explain the trend in ionization energy moving across the rows of the periodic table.

c) How does the size of an ion (cation/anion) compare to the size of the neutral atom from which it is formed? Explain your answer.

d) Write out the ground-state electron configuration for a copper(I) **ion**.

a) Effective nuclear charge is the "effective" charge experienced by the valence electrons. It is equal to the actual nuclear charge, minus a shielding constant that is approximately equal to the number of core electrons. As we move across most periods, the number of protons in the nucleus increases, but the number of core electrons stays the same. Therefore the effective nuclear charge increases across periods. This leads to a decrease in the size of the atoms as the valence electrons experience an increasing effective nuclear charge.

b) Ionization energy (IE) is the amount of energy required to remove one mole of electrons from one mole of a gaseous substance. $X(g) \rightarrow X^+(g) + e^-$
IE increases as we move across the periods, due to the increase in effective nuclear charge.

(c) Cations are **smaller** than the atom they are formed from, due to the removal of one of more electrons, and the increased attraction between the remaining electrons and the nucleus. Anions are **larger** for the reason that they contain one or more electrons than the original atom, and the increased electron-electron repulsion causes the atom to swell in size.

(d) Cu atom electron configuration is [Ar] $4s^1 3d^{10}$ (Auf Bau exception, due to opportunity to completely fill d-subshell), and when we remove an electron to form the Cu(I) ion, it comes out of the subshell with the largest principal quantum number (shell, n) - so Cu^+ is [Ar] $3d^{10}$

Q16. [10 pts.] Draw Lewis structures for the following compounds:

a) BrO_3^-

$7 + 6\times3 + 1 = 26e^-$

-6 (Bonds)

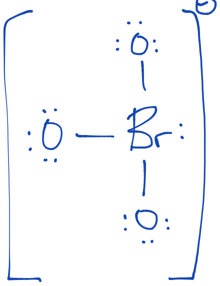
$20e^-$

$-18e^-$ (lp on O for octets)

$2e^-$

$-2e^-$ (all remaining e^-s → central atom.)

0



Don't forget to either: Put ion in [ ] + write charge, OR show FCs for all atoms!

b) $SOCl_2$ (sulfur is central atom)

$6 + 6 + 7\times2 = 26e^-$

$-6e^-$ (bonds)

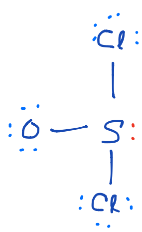
$20e^-$

$-18e^-$ (lp on Cl to complete octet)

$2e^-$

$-2e^-$ ← goes on central atom.

0



c) NO_2^+

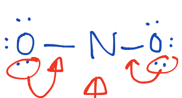
$5 + 6\times2 - 1 = 16e^-$

-4 (bonds)

12

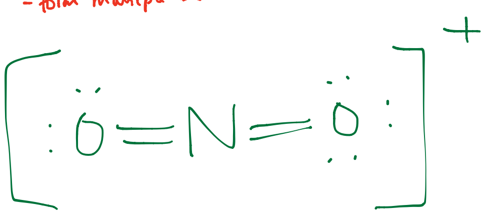
-12 (lp on O for octet)

0



- only $4e^-$
- not an exception

⇒ need 4 more e^-!
- form multiple bonds



Q17. [10 pts.] Use bond energies to estimate ΔH°_{rxn} for the combustion of two moles of acetylene:

$$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

Hint: Drawing the Lewis structures for each will help determine what types of bond are formed/broken.

H−C≡C−H
H−C≡C−H
+
O=O
O=O
O=O
O=O
O=O

⟶

O=C=O
O=C=O
O=C=O
O=C=O
+
H−O−H
H−O−H

Remember
It costs E to break a bond (+)

It releases E to make a bond (−)

BREAK (+)

$4 \times C{-}H = 4 \times 414$
$2 \times C{\equiv}C = 2 \times 812$
$5 \times O{=}O = 5 \times 498.7$
(+) 5773.5

MAKE (−)

$8 \times C{=}O = 799 \times 8$
$4 \times H{-}O = 460 \times 4$
(−) 8232

$$\Rightarrow \Delta H^\circ_{rxn} = +5773.5 - 8232$$
$$= -2458.5\ kJ/mol$$

BONUS: Is FBH_2 (boron is the central atom) polar or non-polar? Explain.

$7 + 3 + 2\times1 = 12$

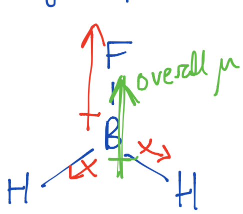
Lewis

```
  ..
 :F:
  |
H—B—H
```

B is e^- deficient!
- An exception to the Octet rule.

(Can make double bond between B+F, but this puts +ve formal charge on F, which is crazy since F is most electronegative element!)

VSEPR
3 reps ⇒ 120°
trigonal planar.



E_n: F = 4.0, B = 1.5, H = 2.1
Δ: F−B > 2.5, B−H > 0.6

δ+ → δ− = Bond Dipole

B−F bond is ≈ 4x as polar as B−H!

- $\mu_{molecule} = \sum \mu_{bond} \neq 0$

⇒ $\boxed{\text{POLAR}}$

Periodic Table

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.1	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.29
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac^** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
^	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Bond	Bond Enthalpy (kJ/mol)	Bond	Bond Enthalpy (kJ/mol)
H—H	436.4	C—C	347
H—O	460	C═C	620
C—O	351	C≡C	812
C═O	745 (average)	O—O	142
C═O	799 (in CO_2)	O═O	498.7
C—H	414		

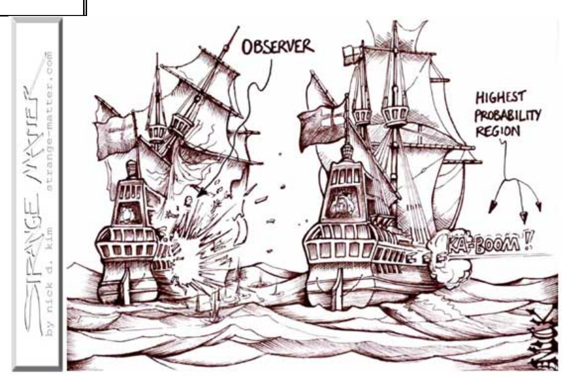


ILLUSTRATION FROM THE TEXTBOOK "CANNON-BALLS: A QUANTUM MECHANICAL TREATMENT."