Form ~~A/B~~ C/D

Detailed key Sp24 Exam 1

CHEMISTRY 102 Spring 2024
Hour Exam I

$Vol = \frac{1000g \mid 1cm^3}{22.57g} = 44.31 cm^3$

$4.00cm \times 4.00cm \times height = volume = 44.31 cm^3$

1/25 17/9

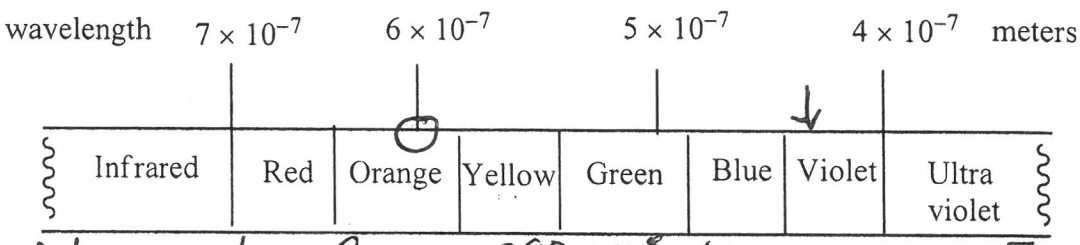
1. The density of osmium (the densest metal) is 22.57 g/cm³. If a 1.00 kg rectangular block of osmium has two dimensions of 4.00 cm × 4.00 cm, calculate the third dimension of the rectangular block. The volume of a rectangle is length × width × height.

height = $44.31 cm^3 / 16.0 cm^2 = 2.77 cm$

a) 44.3 cm b) 16.0 cm c) 2.77 cm

d) 1.41 cm e) 3.97 cm

Use the figure below to answer the next two questions.



$\nu\lambda = c, \lambda = \frac{c}{\nu} = \frac{2.998 \times 10^8 m/s}{5.0 \times 10^{14} s^{-1}} = 6.0 \times 10^{-7} m$

2/26 18/10

2. What color is electromagnetic radiation having a frequency of 5.0×10^{14} sec⁻¹?

From figure, $\lambda = 6.0 \times 10^{-7} m$ is orange light

a) red b) orange c) yellow d) green e) violet

$\Delta E = -R_H\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) = -2.178 \times 10^{-18} J \left(\frac{1}{2^2} - \frac{1}{5^2}\right) = -4.574 \times 10^{-19} J$, $E_{photon} = 4.574 \times 10^{-19} J$

3/27 19/11

3. In the emission spectrum for hydrogen, what color is the n = 5 to n = 2 electronic transition?

$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} J \cdot s (2.998 \times 10^8 m/s)}{4.574 \times 10^{-19} J} = 4.34 \times 10^{-7} m$

a) red b) orange c) yellow d) green e) violet

From figure, $\lambda = 4.34 \times 10^{-7} m$ is violet or blue-violet light. Only violet light listed as an answer.

4/28 20/12

4. Consider the compound butane, which has a formula of C_4H_{10}. If a sample of butane contains 2.59×10^{23} atoms of hydrogen, what mass of butane is present?

molar mass $C_4H_{10} = 4(12.01) + 10(1.008) = 58.12 g/mol$

a) 25.0 g b) 6.25 g c) 5.00 g

$2.59 \times 10^{23} atoms H \left(\frac{1 mol H}{6.022 \times 10^{23} atoms H}\right)\left(\frac{1 mol C_4H_{10}}{10 mol H}\right)\left(\frac{58.12 g}{mol C_4H_{10}}\right) = 2.50 g C_4H_{10}$

d) 1.25 g e) 2.50 g

5/29 21/13

5. An unknown element E forms a covalent compound with fluorine having the formula EF_4. The shape of the EF_4 molecule is see-saw. Which of the following elements could be E? The see-saw shape has 34 valence electrons.

Group 6 Group 5 Group 6 Group 5 Group 7

a) O b) N c) Se d) P e) I

See-saw shape

$34 e^- = x + 4(7)$, $x = 6$ = valence electrons of the unknown element E.

E is a group 6 element. But EF_4 has 10 e⁻ around central E atom. E can't be O since row 2 elements never have more than 8 e⁻ around it. Must be Se.

Form A/B C/D

radii trend

Radius trend works for neutral atoms, but not for ions. From trend, I is bigger than F. Te^- is isoelectronic with I. Since Te^- has fewer proton in the nucleus, Te^- is bigger than I. Ne^+ is isoelectronic with F. Since F has 1 fewer proton in the nucleus, F is bigger than Ne^+. Putting this all together gives an order of $Te^- > I > F > Ne^+$.

6|20 1|25

6. Place the following atoms/ions in order of **decreasing** size (largest to smallest).

F, Te^-, I, Ne^+

a) $Te^- > I > F > Ne^+$ b) $F > Te^- > I > Ne^+$ c) $I > Te^- > F > Ne^+$

d) $Te^- > F > Ne^+ > I$ e) $Ne^+ > F > Te^- > I$

Si, P, O, N, and As are the elements. IE trend

7|21 2|26

7. Which of the following ground state electron configurations is associated with the atom having the **largest** ionization energy?

From IE trend, expect O to have the largest IE value.

a) $[Ne]3s^23p^2$ = Si b) $[Ne]3s^23p^3$ = P c) $[He]2s^22p^4$ = O

But there is a decrease in ionization energy when

d) $[He]2s^22p^3$ = N e) $[Ar]4s^23d^{10}4p^3$ = As

going from N to O. So N has largest IE value.

8|22 3|27

8. The ground state electron configuration for an atom or ion has 2 electrons in the $n = 1$ orbital, 8 electrons in $n = 2$ orbitals, 18 electrons in $n = 3$ orbitals, and 12 electrons in $n = 4$ orbitals. Which of the following could be this atom or ion?

notice: no n = 5 electrons

electrons = 2 + 8 + 18 + 12 = 40 e^-; Answers a, b, and c have 40 electrons

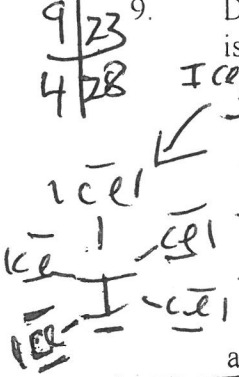
a) Zr, 40 e^- b) Mo^{2+}, 40 e^- c) Sr^{2-} 40 e^- d) Cd, 48 e^- e) Pd^{2-} 48 e^-

Zr = Sr^{2-} = $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^2$ ← can't be Zr or Sr^{2-} since these have n = 5 electrons. Mo^{2+} is correct. Transition metal ions lose the s electrons before the d electrons. Mo^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^0 4d^2$

9|23 4|28

9. Draw the Lewis structure for ICl_5. How many of the following four statements (I-IV) is/are **true** regarding ICl_5?

ICl_5: 6(7) = 42 electrons.



I. The central atom in ICl_5 has one lone pair of electrons.

II. Some of the Cl–I–Cl bond angles are approximately 90°. – has octahedral geometry

III. ICl_5 is polar. – not symmetric; bond dipoles do not all cancel each other out.

IV. The shape of ICl_5 is square pyramid.

a) 0 (None are true.) b) 1 c) 2 d) 3 e) 4 (All are true.)

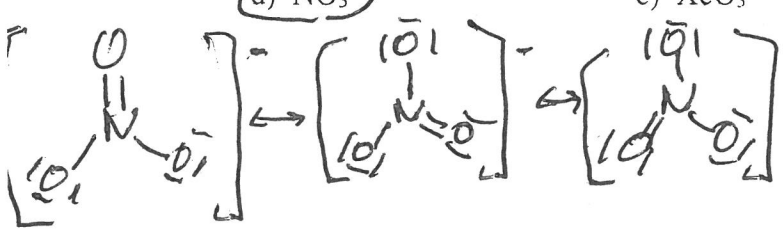
$\bar{O}=C=\bar{O}$, $[\bar{O}-N=\bar{O}]^+$; both CO_2 and NO_2^+ have 2 other resonance structures. But the average bond is a double bond to central atom.

10|24 5|29

10. A compound or ion has delocalized π electrons resulting in equivalent bonds to oxygen. All of the bonds in this compound or ion are stronger than single bonds yet are significantly weaker than double bonds. Which of the following could be this compound or ion?

a) CO_2 (16 e^-) b) NO_2^+ (16 e^-) c) SO_3^{2-} (26 e^-)

d) NO_3^- (24 e^-) e) XeO_3 (26 e^-)



XeO_3 and SO_3^{2-} are both composed of only single bonds.

NO_3^- has 3 resonance structures. Average bond is (2 + 1 + 1)/3 = 4/3 or 1 1/3 bond. This fits the data in the problem.

Form
A|B
C|D

11|16
22|5

11. Which of the following statements is **false**?

T a) When a metal reacts with a nonmetal, an ionic compound is generally produced.
T b) Nonmetals generally form anions when reacted with a metal to form a compound.
T c) Alkaline earth metals generally form stable +2 charged ions when in ionic compounds.
F d) Transition metals generally gain electrons to form stable ions when in ionic compounds. Metals lose electrons to form cations when in ionic compds.
T e) When two nonmetals react with each other, a covalent compound is generally produced.

12|17
23|6

12. The most stable ion of a certain isotope contains 15 protons and has a mass number of 33. Which of the following statements (a-d) about this ion is **true**? Note: the most stable ion is the ion that forms when this isotope is in an ionic compound.

Phosphorus has 15 protons. P forms P^{3-} ions in ionic compounds.

T a) The net charge of the ion is –3.
F b) The ion contains 10 electrons.
F c) The ion contains 33 neutrons.
F d) The ion is sulfur.
F e) All of the above statements (a-d) are false.

Ion has 15+3 = 18 electrons for 3 − charge.

neutrons = 33 − 15 = 18 neutrons

13|18
24|7

13. When the following calculation is performed, how many significant figures are in the correct answer? 1.00866 − 1.00776 = 0.00090 ← by subtraction rule, this is known to 2 sig figs

$$(1.00866 - 1.00776) \times (6.022 \times 10^{23})$$

Answer known to 5 decimal places.

A 2 sig fig number multiplied by a 4 sig fig number gives a 2 sig fig answer by multiplication rule.

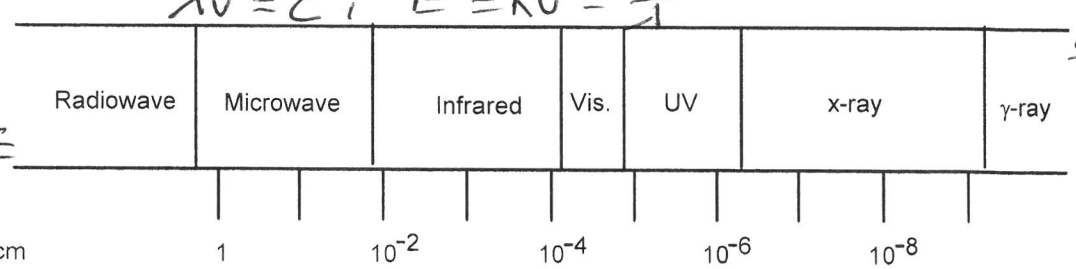
a) 1 b) 2 c) 3 d) 4 e) 6

14|19
25|8

14. Which of the following statements (a-d) about the electromagnetic spectrum is **true**? Note that wavelengths are given in units of cm.

$\lambda\nu = c$, $E = h\nu = \frac{hc}{\lambda}$

long λ
low ν
small E



short λ
high ν
large E

F a) Ultraviolet (UV) radiation has a ~~longer~~ shorter wavelength than visible (Vis.) radiation.
F b) The frequency of microwave radiation is ~~higher~~ lower than the frequency of visible (Vis.) radiation.
F c) Gamma (γ) ray radiation travels faster than radiowaves because it has a shorter wavelength. Both travel a c, the speed of light.
T d) A photon of x-ray radiation is more energetic than a photon of microwave radiation.
e) None of the above statements (a-d) are true.

Form A|B C|D

nonpolar, d^2sp^3 — bond dipoles cancel, nonpolar d^2sp^3 hybrid

polar, dsp^3 — bond dipoles do not cancel

nonpolar dsp^3 — bond dipoles cancel

Consider the following five compounds for the next two questions.

$36e^-$	$34e^-$	$40e^-$	16 e	$18e^-$
XeF_4	SF_4	PCl_5	COS	SO_2

$\bar{S}=C=\bar{O}$ polar, sp

$\bar{S}=O$ + 1 other polar, sp^2 — bond dipoles do not cancel

15|11 6|20

15. How many of these five compounds are polar? SF_4, COS, SO_2 are polar.

a) 1 b) 2 c) 3 d) 4 e) 5 (All are polar.)

Bond dipoles do not cancel in SCO.

16|12 7|21

16. Which of the following statements about these five compounds is **false**?

F a) In XeF_4, the central Xe atom is ~~sp^3~~ d^2sp^3 hybridized.

T b) In SF_4, the central S atom is dsp^3 hybridized.

T c) In PCl_5, the central P atom is dsp^3 hybridized.

T d) In COS, the central C atom is sp hybridized.

T e) In SO_2, the central S atom is sp^2 hybridized.

117: [Rn] $7s^2\ 5f^{14}\ 6d^{10}\ 7p^5$ — Element 117 is the next halogen under At.

17|13 8|22

17. Which of the following statements (a-d) is **true** regarding element 117 (symbolized as X)? Halogen forms −1 charged ion. K forms +1 charged ion. KX is the formula.

F a) Element 117 would form a stable compound with potassium having the formula ~~KX~~.

F b) Element 117 has ~~2~~ 1 unpaired electrons in the ground state.

F c) Element 117 has ~~one~~ 7 valence electron in the ground state. $7s^2 7p^5$

F d) Element 117 has ~~14~~ 28 electrons in various f orbitals in the ground state. 4f and 5f orbitals are filled.

e) None of the above statements (a-d) are true.

1s 1s 1 — 7p (1 unpaired electron)

18|14 9|23

18. Which of the following statements is **false**? From periodic table, 8s orbitals fill for elements 119 + 120. The 8s orbitals are higher in energy than the 6d.

F a) The periodic table predicts that the 8s atomic orbital ~~will~~ be ~~lower~~ higher in energy that the 6d atomic orbitals. 6d orbitals fill for elements 89 – 112.

T b) The quantum mechanical model assumes that the electron has wave properties.

T c) The Heisenberg uncertainty principle implies that we cannot know the exact location of an electron in an atom.

T d) DeBroglie hypothesized that all matter exhibits both particulate and wave properties.

T e) The quantum mechanical model tells us that there are seven degenerate (same energy) 4f atomic orbitals.

19|15 10|24

19. Draw the Lewis structures for the following four compounds: BH_3 ($6e^-$), PS_2 ($17e^-$), BrF_3 ($28e^-$), and OCl_2 ($20e^-$). These 3 can't satisfy octet rule. How many of these four compounds can **satisfy** the octet rule (duet rule for H) for all elements in the compound? BH_3 with 6 electrons can't satisfy octet rule. PS_2 with odd # of electrons, can't satisfy octet rule.

a) 0 (none) b) 1 c) 2 d) 3

only OCl_2

e) 4 [All satisfy the octet rule (duet rule for H)].

BrF_3 can't satisfy octet rule.

OCl_2 can satisfy octet rule.

Form balanced rxn is: $2\,NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O$

2:1 mol ratio between $NaHCO_3$ and Na_2CO_3

A	B
C	D

20	7
26	1

20. When heated, baking soda (commonly called sodium bicarbonate) reacts to form solid sodium carbonate, carbon dioxide gas and water vapor. How many moles of sodium carbonate are produced for every 2.0 moles of sodium bicarbonate that are reacted? Assume the only reactant is sodium bicarbonate. (HCO_3^- is the bicarbonate ion formula.)

a) 1.0 mol sodium carbonate
b) 1.5 mol sodium carbonate
c) 2.0 mol sodium carbonate
d) 2.5 mol sodium carbonate
e) 3.0 mol sodium carbonate

From balanced reaction, 1.0 mol Na_2CO_3 is produced for every 2 mol $NaHCO_3$ reacted.

21	8
27	2

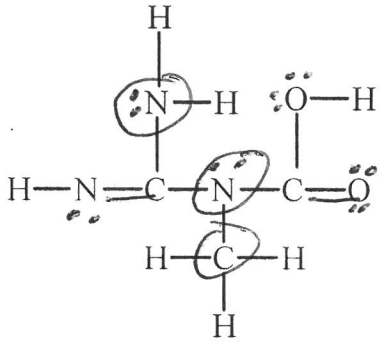
21. Which of the following statements (a-c) is/are **true**?

Positive charge in tiny dense nucleus.

F a) The positive charge in an atom is uniformly distributed throughout the atom.
T b) In a neutral atom, the atomic number equals the number of electrons in the atom. # protons = # of electrons for neutral atom.
F c) Most of the mass of an atom is due to the ~~electrons~~. protons and neutrons.
d) Statements b and c are both true.
e) None of the statements (a-c) are true.

Creatine is an organic compound important to the building of muscle tissue in the body. The skeletal structure of creatine is below. Complete the Lewis structure and answer the next two questions.

Organic Rules
C: 4 bonds + 0 lone pairs
N: 3 bonds + 1 " "
O: 2 bonds + 2 " "



The circled N and C atoms all have tetrahedral geometry with 109° bond angles.

22	9
28	3

22. How many of the carbon and nitrogen atoms exhibit approximately 109°?

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

The other C and N atoms are trigonal planar with 120° bond angles.

23	10
29	4

23. How many double bonds are in the completed Lewis structure?

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

See above Lewis structure. Has 2 double bonds.

Form
A | B
C | D

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C_2^{2-}, 10 e⁻: [:C≡C:]²⁻ ; N_2^{2-}, 12 e⁻: [:N≡N:]²⁻
O_2^{2-}, 14 e⁻: [:O–O:]²⁻
F_2^{2+}; 12 e⁻: [:F–F:]²⁺

24 | 1
11 | 14

24. Draw the Lewis structures for the following four diatomic ions: C_2^{2-}, N_2^{2-}, O_2^{2-}, and F_2^{2+}. How many of these four diatomic ions must have a double or triple bond in order to satisfy the octet rule? C_2^{2-}, N_2^{2-}, and F_2^{2+} all have a double or triple bond. F_2^{2+} is a singly bonded species.

a) 0 (none) b) 1 c) 2 d) 3
e) 4 (All of these ions must have a double or triple bond in order to satisfy the octet rule.)

Br and Rb^{2+} both have 35 e⁻. But Rb^{2+} has 37 protons in the nucleus, while Br only has 35 protons. Rb^{2+} nucleus attracts the 35 e⁻ more strongly, so Rb^{2+} will be smaller than Br.

25 | 2
12 | 15

25. Which of the following statements is **true** concerning atoms of bromine?

T a) Br should have a larger radius (larger size) than Rb^{2+}.
F b) Br should have a ~~smaller~~ larger ionization energy than Br^{2-}. Br, with fewer electrons, will have the larger IE.
F c) Br should have a ~~smaller~~ larger electronegativity value than Ba (element #56). Apply EN trend.
F d) Br should have a smaller radius (smaller size) than Br^{2+}. Br^{2+}, with fewer electrons, will be smaller in size.
F e) Br should have a larger ionization energy than Ne.

Apply IE trend → IE trend ↑ → EN trend ↑

26 | 3
13 | 16

26. Which of the following bonds to selenium should be the most pure (nonpolar) covalent bond? Ga and In are metals, so expect Se-Ga and Se-In to be most ionic. From EN trend, Cl has an obviously larger EN value than Se, so Se-Cl will be a polar covalent bond. The trends are opposite each other going from Se-I, so I should have an EN value close to Se, so Se-I bond is most pure covalent.

a) Se – Ga b) Se – Cl c) Se – I d) Se – In

27 | 4
14 | 17

27. A pure substance that can be broken down into other substances by chemical change is classified as a(n): Compounds and elements are pure substances. Only compds can be broken down into other pure substances (elements).

a) mixture b) element c) phase d) solution e) compound

28 | 5
15 | 18

28. Sarin is a nerve gas whose chemical formula has 2 atoms of oxygen for each molecule of sarin. If 50.0 g of sarin contains 11.4 g of oxygen, calculate the molar mass of sarin.

mol Sarin = $11.4\text{ g O}\left(\frac{1\text{ mol O}}{16.00\text{ g O}}\right)\left(\frac{1\text{ mol sarin}}{2\text{ mol O}}\right) = 0.35625$ mol Sarin in 50.0 g sarin.

a) 280. g/mol b) 35.0 g/mol c) 70. g/mol
d) 210. g/mol e) 140. g/mol

Molar mass Sarin = $\frac{50.0\text{ g}}{0.35625\text{ mol}}$ = 140. g/mol

29 | 6
16 | 19

29. How many of the following four compounds is/are named **correctly**?

ok $MgCO_3$, magnesium carbonate
NO P_2O_5, phosphorus oxide — diphosphorus pentoxide is correct name for this covalent compound
NO $Co(ClO_2)_3$, cobalt(VI) perchlorate
ok HNO_3, nitric acid

ClO_2^- = chlorite ion, ClO_4^- = perchlorate ion

a) 0 (none) b) 1 c) 2 d) 3 e) 4 (All are correctly named.)

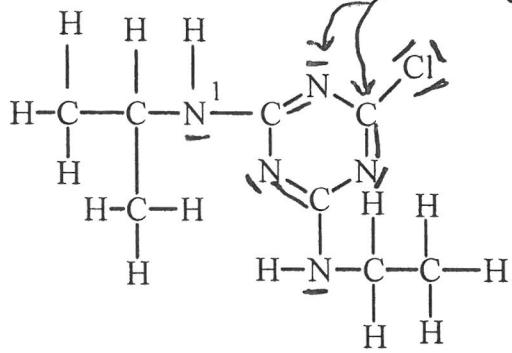
Cobalt(III) chlorite is correct name for $Co(ClO_2)_3$.

All single bonds are sigma bonds. All double bonds are 1 sigma and 1 π bond. Apply Lewis structure rules to complete Lewis structure.

30/30 30/30

30. A widely used herbicide is atrazine, $C_8N_5ClH_{14}$, whose skeletal structure is shown below. Complete a Lewis structure for this organic compound.

28 sigma bonds + 3 π bonds



The six C and N atoms in ring exhibit 120° bond angles (trigonal planar geometry), so all are sp^2 hybridized. The other C and N atoms have 109° bond angles (tetrahedral geometry), so they are sp^3 hybridized.

Which of the following statements concerning the Lewis structure for atrazine is **false**?

T a) Atrazine has zero atoms which are sp hybridized. There are no 180° bond angles, so no sp hybrids.

F b) ~~Eight~~ 6; The six C and N atoms in ring are all sp^2 hybridized, of the carbon and nitrogen atoms in atrazine have at least one unhybridized p atomic orbital. so there are 6 unhybridized p atomic orbitals. The other C and N atoms do not have unhybridized p orbitals since they are sp^3 hybridized.

T c) There are 28 sigma (σ) bonds and 3 pi (π) bonds in the Lewis structure.

T d) The nitrogen atom labeled 1 is sp^3 hybridized. Exhibits tetrahedral 109° bond angles, so sp^3 hybridized.

T e) All the carbon-hydrogen bonds in atrazine are formed from overlap of sp^3 hybrid orbitals from carbon with 1s orbitals from hydrogen. All C and N atoms with H bonded to them exhibit 109° bond angles, so they are sp^3 hybridized. H always uses 1s orbitals to form sigma bonds.

31/31 31/31

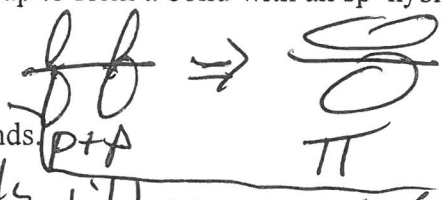
31. Which of the following statements about hybrid orbitals is **true**? Only valence orbitals form hybrids.

F a) Valence atomic orbitals always combine with inner core atomic orbitals to produce hybrid orbitals. We hybridize atomic orbitals to explain 109° and 120° bond angles.

F b) The orientation in space of the hybrid orbitals is identical to the orientation in space of the atomic orbitals from which they are formed.

T c) An sp^2 hybrid orbital from one atom can overlap to form a bond with an sp^3 hybrid orbital from another atom.

F d) Overlap of ~~hybrid~~ unhybridized atomic orbitals form π bonds.



F e) Atoms which are sp^2 hybridized form 1 pi bonds. sp^2 hybrid atoms have only 1 unhybridized p atomic orbital, so can only form 1 π bond.

32. My answers for this Chemistry 102 exam should be graded with the answer sheet associated with:

a) Form A b) Form B c) Form C d) Form D e) Form E

See the ring carbon bonded to N_1 in the structure above. This sigma bond is formed from an sp^2 hybrid orbital from the carbon with an sp^3 hybrid from N_1.