Form

Detailed Key Exam 1 Fa 22

O_3: 3(6) = 18 e⁻

O_3 exhibits resonance, so all bonds are equivalent.

A/B
C/D

CHEMISTRY 102
Hour Exam I

Fall 2022
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1. Draw a Lewis structure for ozone, O_3. Which of the following statements regarding O_3 is **false**?

(Fa) A total of ~~three~~ two resonance structures can be drawn for O_3.
T b) All of the oxygen-oxygen bonds in O_3 are equivalent in length and strength.
T c) The central oxygen atom in O_3 is sp^2 hybridized. - trigonal planar about central O atom
T d) The electrons in the π bond(s) in O_3 are delocalized over the entire surface of the molecule. - this is how the equivalent bonds are explained.
T e) The bond angle in O_3 is approximately 120°. - trigonal planar about central O atom (120°) Each O atom has a p orbital perpendicular to the plane of the molecule. All three p orbitals combine to form delocalized π bonding.

2/18
27/14

2. How many of the following five elements has/have one (1) unpaired electron in the ground state?

Sc: [Ar] $4s^2 3d^1$ — 1 unpaired in 3d
Rb: [Kr] $5s^1$ — 1 unpaired in 5s
Cu: [Ar] $4s^1 3d^{10}$ — 1 unpaired in 4s
Ga: [Ar] $4s^2 3d^{10} 4p^1$ — 1 unpaired in 4p
I: [Kr] $5s^2 4d^{10} 5p^5$ — 1 unpaired in 5p

Rb, Sc, Cu, Ga, I

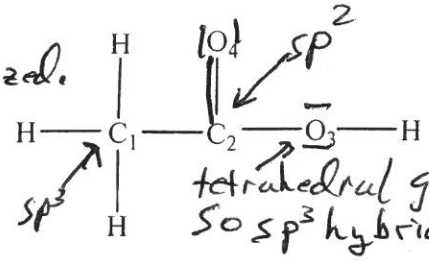
a) 1 b) 2 c) 3 d) 4 (e) 5 (All have one unpaired electron.)

All have 1 unpaired ~~valence~~ electron.

3/19
28/15

3. Acetic acid is an organic compound with the following skeletal structure.

C_1 exhibits tetrahedral geometry, so sp^3 hybridized.
C_2 exhibits trigonal planar geometry so sp^2 hybridized.



Follow organic rules to complete Lewis structure.

All single bonds are σ bonds. Double bonds are 1 σ and 1 π.

Complete the Lewis structure for acetic acid. Which of the following statements concerning acetic acid is **false**?

correct answer → T There is one π bond in acetic acid. - in the double bond
(F) b) The oxygen atom labeled 3 (O_3) is sp hybridized. - sp^3 hybridized; ~109° tetrahedral angles.
T c) The carbon-carbon bond is formed from overlap of an sp^3 hybrid orbital on C_1 with an sp^2 hybrid orbital on C_2.
T d) There are seven sigma bonds in acetic acid.
T e) C_2 uses an unhybridized p atomic orbital to form one of the bonds to the oxygen atom labeled 4 (O_4). - Unhybridized p atomic orbitals are always used to form π bonds.

4/20
29/16

4. Bismuth aluminate ($Al_6Bi_2O_{12}$) is a medication used to treat upset stomachs. If 0.500 g of bismuth aluminate is digested, calculate the mass of bismuth consumed. Bi is element #83.

molar mass = 6(26.98) + 2(209.0) + 12(16.00) = 771.9 g/mol

a) 0.500 g (b) 0.271 g c) 0.367 g d) 0.135 g e) 0.162 g

$$0.500\text{ g } Al_6Bi_2O_{12} \left| \frac{1\text{ mol } Al_6Bi_2O_{12}}{771.9\text{ g}} \right| \frac{2\text{ mol Bi}}{1\text{ mol } Al_6Bi_2O_{12}} \left| \frac{209.0\text{ g Bi}}{\text{mol Bi}} \right| = 0.271\text{ g Bi}$$

Moles caffeine = $\frac{3.01\times10^{23}\ \text{molecules}}{6.022\times10^{23}\ \text{molecules}} \left|\frac{1\ \text{mol caffeine}}{}\right. = 0.500\ \text{mol caffeine}$

Form A/C B/D

Molar mass of caffeine = $\frac{\text{mass}}{\text{moles}} = \frac{97\text{g}}{0.500\text{mol}} = 194\ \text{g/mol}$

5/9 22/1

5. A 97-g sample of caffeine contains 3.01×10^{23} molecules of caffeine. If a typical 10-hour energy drink contains 420 mg of caffeine, how many moles of caffeine are present in the drink? $420\times10^{-3}\text{g caffeine} \left|\frac{1\ \text{mol caffeine}}{194\ \text{g}}\right. = 0.0022\ \text{mol caffeine}$

a) 1.1×10^{-3} mol b) 4.4 mol c) 1.1 mol d) 8.8 mol e) 2.2×10^{-3} mol

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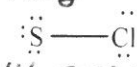
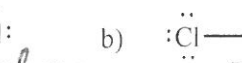
SCl: 6 + 7 = 13 valence e⁻; S_2Cl_2 = 2(6) + 2(7) = 26 e⁻

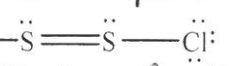
6/10 23/2

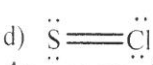
6. When molten sulfur reacts with chlorine gas, a vile smelling orange liquid forms. The formula of the compound is either SCl or S_2Cl_2. Which of the following Lewis structures could be the correct structure for this compound?

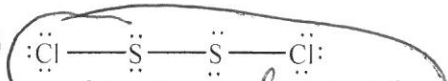
Only answer e is a possible correct answer.

a) 
14 e⁻ used - no

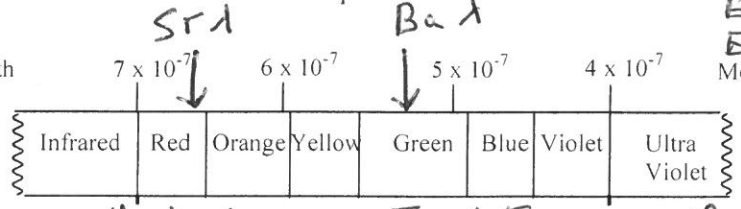
b) 
24 e⁻ used - no

c) 
22 e⁻ used - no

d) 
12 e⁻ used - no

e) 
26 e⁻ used - yes possible

Use the following figure to answer the next two questions:



$c = \lambda\nu$
$E = h\nu$
$E = hc/\lambda$

From diagram, $\lambda_{Sr} > \lambda_{Ba}$, so $E_{Sr} < E_{Ba}$ and $\nu_{Sr} < \nu_{Ba}$.

7/11 24/3

7. In the fireworks industry, strontium is used to produce red colors, while barium is used to produce green colors. Which of the following is **true** concerning the electronic transitions associated with these two colors?

F a) Strontium emits a photon of electromagnetic radiation having a ~~higher~~ lower frequency than barium.

b) Barium emits a photon of electromagnetic radiation having a larger energy than strontium.

F c) Strontium emits a photon of electromagnetic radiation having a ~~faster~~ same velocity than barium.

F d) Barium emits a photon of electromagnetic radiation having a ~~longer~~ shorter wavelength than strontium.

$\Delta E = -R_H\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) = -2.178\times10^{-18}\text{J}\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = -3.025\times10^{-19}\text{J}$

8/12 25/4

8. One of the visible lines in a hydrogen emission spectrum corresponds to the n = 3 to n = 2 electronic transition. Using the figure above, what color light is this transition?

$E_{photon} = |\Delta E| = 3.025\times10^{-19}\text{J}$

a) reddish-orange b) yellowish-green c) green d) blueish-green e) violet

$\lambda = \frac{hc}{E} = \frac{6.626\times10^{-34}\text{J}\cdot\text{s}\,(2.998\times10^{8}\ \text{m/s})}{3.025\times10^{-19}\text{J}} = 6.57\times10^{-7}\text{m}$

6.57×10^{-7} m is reddish-orange color (from spectrum above)

Form A/B C/D

$8.9250 - 8.905 = 0.020$

By subtraction rule, answer is known to the 3rd decimal place since 8.905 is only known to the 3rd decimal place.

9|21 17|21

9. Assuming 100 is an exact number in the following mathematical expression, what is the answer to the following percent calculation expressed to the correct number of significant figures?

$$\frac{8.9250 - 8.905}{8.9250} \times 100 = \frac{0.020}{8.9250} \times 100 = 0.22\%$$

apply division rule now, gives 2 sig fig answer due to 0.020.

a) 0.2% (b) 0.22% c) 0.224% d) 0.2241% e) 0.22409%

10|22 18|22

10. Consider the combustion reaction of ethanol, CH_3CH_2OH, an organic compound. How many moles of oxygen gas are required to react completely with one mole of ethanol? Hint: balance the equation. $CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

a) 7.0 mol b) 3.5 mol c) 2.5 mol (d) 3.0 mol e) 6.0 mol

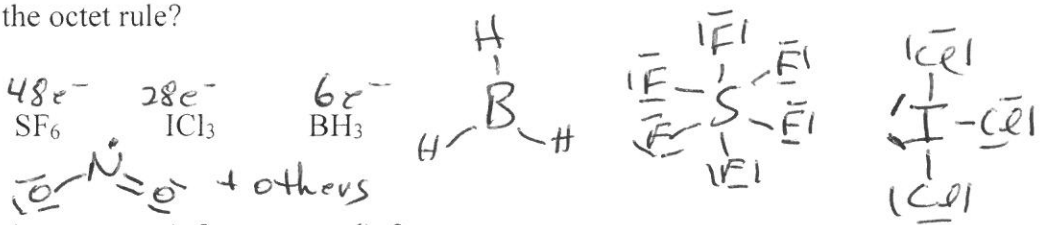
From balanced equation, 3 mol O_2 react with every 1 mol of CH_3CH_2OH.

11|23 19|23

11. How many of the following four compounds have at least one atom in the Lewis structure that **must** violate the octet rule?

17 e⁻ 48 e⁻ 28 e⁻ 6 e⁻

NO_2 SF_6 ICl_3 BH_3



+ others

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

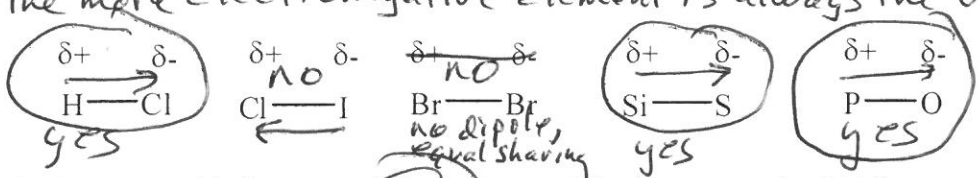
All must be exceptions to octet rule.

(e) 4 (All must violate the octet rule for at least one atom in the Lewis structures.)

12|24 20|24

12. In how many of the following bonds is the bond dipole correctly indicated?

The more electronegative element is always the δ- end of the bond dipole



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

13|25 21|25

13. Which of the following compounds has the largest molar mass?

approximate molar masses

a) ammonium chloride NH_4Cl: $14 + 4(1) + 35.5 = 53.5$ g/mol
b) iron(III) phosphate $FePO_4$: $56 + 31 + 4(16) = 151$ g/mol
c) potassium nitrate KNO_3: $39 + 14 + 3(16) = 101$ g/mol
(d) carbon tetrachloride CCl_4: $12 + 4(35.5) = 154$ g/mol
e) water H_2O: $2(1) + 16 = 18$ g/mol

CCl_4 has the largest molar mass.

From 2+ charge, # protons = 26 + 2 = 28 protons.
Element 28 is Ni.
mass number = 28p + 31n = 59
$^{59}_{28}Ni^{2+}$ is the ion.

Form A/B C/D

14|26
13|5

14. Identify the ion which has 31 neutrons, a 2+ net charge, and has 26 electrons.

a) $^{57}_{28}Ni^{2+}$ b) $^{57}_{31}Ga^{2+}$ c) $^{59}_{31}Ga^{2+}$ d) $^{59}_{28}Ni^{2+}$ e) $^{55}_{24}Cr^{2+}$

For consecutive ionization energies, there is always a big increase in IE values when going from the last valence electron removed to an inner core electron removed.

15|27
14|6

15. Consider the following sets of consecutive ionization energies (in some hypothetical units) for two unknown elements, X and Y (I.E. = ionization energy).

Look for big increase in

	X	Y
1st I.E.	1100	800
2nd I.E.	1900	1600
3rd I.E.	2900	3200
4th I.E.	5000	4400 ← big increase between 4 and 5
5th I.E.	6300	16,000
6th I.E	21,000	20,000
7th I.E.	29,000	25,000

Big increase between 5 and 6

So X has 5 valence electrons and Y has 4 valence electrons. Answer b fits data.

Which of the following could be these two elements, X and Y?

a) X = C, Y = Ge b) X = P, Y = Si (5A 4A) c) X = B, Y = Be

d) X = Mg, Y = Al e) X = O, Y = F

16|28
15|7

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

NH_4^+ and NO_3^- are the ions

T a) NH_4NO_3, a component of fertilizers, is an example of an ionic compound.

T b) $CaCl_2$, a salt used to help melt ice in the winter time, contains an alkaline earth metal cation and halogen anions.

T c) $HC_2H_3O_2$, a component of vinegar, is an acid.

T d) C_3H_8, a component of natural gas, is an example of a covalent compound.

F e) N_2O, commonly known as laughing gas, is composed of N^+ and O^{2-} ions.

N_2O is a covalent compound between the two nonmetals N and O. No ions form when electrons are shared.

17|29
16|8

17. Each of the following are examples of:

Black coffee
Red table wine
Brass

All are homogeneous mixtures.

a) pure substances. b) heterogeneous mixtures. c) compounds.

d) homogeneous mixtures. e) elements.

18. Which of the following molecules or ions has the **largest** bond angle?

a) SF_2^{2-}, 22e⁻ b) SCl_3^-, 26e⁻ c) PF_2^-, 20e⁻ d) SO_3, 24e⁻ e) ClO_2^+, 18e⁻

a) 180° — has linear shape, 180° bond angle
b) ~109° — tetrahedral geometry, 109°
c) ~109°
d) 120° — trigonal planar geometry, 120°
e) ~120° — +1 other

19. Which of the following statements is **false** concerning the Bohr model of the hydrogen atom?

a) The model predicts that an electron can move from the n = 2 circular orbit to the n = 7 circular orbit by absorbing a photon of appropriate energy.

b) The model predicts that an electron moving from the n = 5 to the n = 1 circular orbit moves closer to the nucleus. — correct answer

c) The model accurately predicts the existence of the s, p, d, and f atomic orbitals. — This is the current quantum mechanical model.

d) According to the model, the energy emitted by an electron falling from the n = 6 energy level to the n = 4 energy level for hydrogen is given by the expression $\Delta E = -2.178 \times 10^{-18}\left(\frac{1}{4^2} - \frac{1}{6^2}\right)$. $\Delta E = -R_H\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$ $n_1 = 6$, $n_2 = 4$ $R_H = 2.178 \times 10^{-18}$ J

e) The model predicts that the energy of the photon absorbed to excite an electron from the n = 2 energy level to the n = 5 energy level is equal to the energy of the photon emitted when the electron moves from the n = 5 energy level back to the n = 2 energy level. — not a correct answer

IE trend ↑ From IE trend, ordering is expected to be Mg < N < O < F. But there is an exception between N and O (between 5A + 6A).

The next two questions concern the following series of elements: N, O, F, Mg

20. Which of the following correctly ranks these elements in order of **increasing** first ionization energy? So N and O are switched.

a) F < O < N < Mg b) Mg < O < N < F c) N < O < F < Mg
d) Mg < N < O < F e) F < N < O < Mg

Mg < O < N < F is correct.

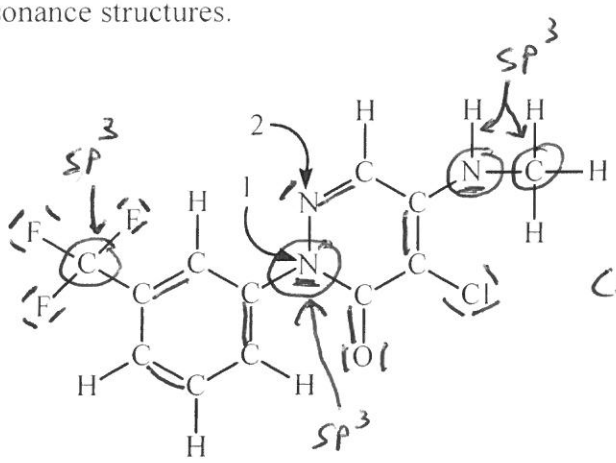
21. Now consider the ions these elements (N, O, F, Mg) are expected to form when in stable ionic compounds. Which of the following correctly ranks these **ions** in order of **increasing** atomic radius? Correct ions = N^{3-}, O^{2-}, F^-, Mg^{2+}

a) $F^- < N^{3-} < O^{2-} < Mg^{2+}$ b) $F^- < O^{2-} < N^{3-} < Mg^{2+}$
c) $Mg^{2+} < O^{2-} < N^{3-} < F^-$ d) $Mg^{2+} < F^- < O^{2-} < N^{3-}$
e) $N^{3-} < O^{2-} < F^- < Mg^{2+}$

N^{3-} O^{2-} F^- Mg^{2+} ← 10 electrons → 7 protons 8p 9p 12p

These ions are isoelectronic (10 e⁻). The ion with the fewest protons attracting the 10 e⁻ is largest, while the ion with the most protons is smallest.
correct order = $Mg^{2+} < F^- < O^{2-} < N^{3-}$

Norflurazon is an organic molecule that is an effective herbicide. Below is an incomplete Lewis structure for norflurazon. Using the guidelines covered in class regarding Lewis structures for organic compounds, complete a Lewis structure and answer the following two questions. Ignore any possible resonance structures.



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

22|1 5|9

22. How many sp^3 hybridized carbon and nitrogen atoms are in the completed Lewis structure? the circled carbon and nitrogen atoms all have tetrahedral geometry (~109° bond angles), so they are all sp^3 hybridized

a) 2 b) 3 (c) 4 d) 5 e) 6

23|2 6|10

23. What are the approximate bond angles as predicted by the VSEPR model about the nitrogen atom labeled 1 and the nitrogen atom labeled 2, respectively?

N1 exhibits tetrahedral geometry, so ~109° bond angles.

(a) 109°; 120° b) 180°; 90° c) 120°; 90°

N2 exhibits trigonal planar geometry, so ~120° bond angles.

d) 120°; 120° e) 109°; 90°

24|3 7|11

24. Consider the ground state electron configurations for the following ions. Which ion has 19 electrons in various p atomic orbitals in the ground state?

From periodic table, elements/ions with 49 electrons have 19 p electrons, e.g., In has 49 e⁻; $2p^6 + 3p^6 + 4p^6 + 5p^1 = 19$ p electrons

Only Sb^{2+} has 49 e⁻, so it is the correct answer.

(a) Sb^{2+} b) Kr^+ c) I^- d) I^{2-} e) Sr^-

51 − 2 = 49 e⁻ 36 − 1 = 35 e⁻ 53 + 1 = 54 e⁻ 53 + 2 = 55 e⁻ 38 + 1 = 39 e⁻

25|4 8|12

25. When aluminum metal is heated with an element from Group 6A of the periodic table, an ionic compound forms. When the experiment is performed with an unknown Group 6A element, the product is 12.35% Al by mass. What is the formula of the compound?

Let X = Group 6A metal; formula of Al + X = Al_2X_3 ($Al^{3+} + X^{2-}$ ions).

a) Al_2O_3 b) Al_2S_3 c) Al_2Se_3 (d) Al_2Te_3 e) Al_3S_2

Assume 100.0 g of compound: mass of X = 100 − 12.35 g Al = 87.65 g X

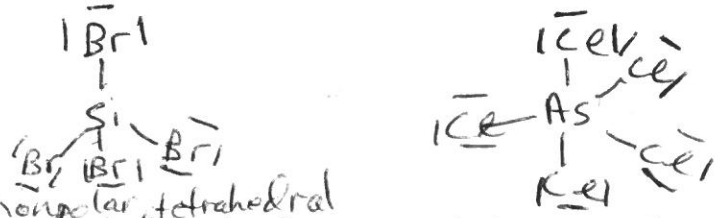
$$\text{mol X} = \frac{12.35\text{ g Al}}{26.98\text{ g}} \left| \frac{1\text{ mol Al}}{2\text{ mol Al}} \right| \frac{3\text{ mol X}}{} = 0.6886\text{ mol X}$$

$$\text{Molar mass} = \frac{\text{mass}}{\text{moles}} = \frac{87.65\text{ g X}}{0.6886\text{ mol X}} = 127.7\text{ g/mol}$$

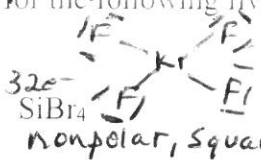
(X = Te) ← From periodic table

Form A/B C/D

Draw Lewis structures for the following five compounds then answer the next two questions.



CS_2, 16e⁻ $SiBr_4$, 32e⁻ KrF_4, 36e⁻ $AsCl_5$, 40e⁻ SeI_4 34e⁻



26. How many of the above five compounds are polar?

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

Only SeI_4 is polar; the bond dipoles do not cancel each other out. In the other molecules, the bond dipoles cancel out each other, so they are nonpolar

e) 5 (All five of these compounds are polar.)

27. Which compound has a see-saw shape (molecular structure)?

SeI_4 has see-saw shape.

a) CS_2 b) $SiBr_4$ c) KrF_4

d) $AsCl_5$ e) SeI_4

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28. How many of the following are **correct** ground state electron configurations for the atom or ion listed? Indium is element #49.

Cl: $[Ne]3s^23p^5$ (correct) Zn^{2+}: $[Ar]4s^23d^8$ (incorrect) In: $[Kr]5s^25d^{10}5p^1$ (4 incorrect [4d¹⁰, not 5d¹⁰]) At^-: $[Xe]6s^24f^{14}5d^{10}6p^6$ (correct)

Zn^{2+}: $[Ar]4s^03d^{10}$ is correct

a) 0 (None are correct.) b) 1 c) 2 d) 3

e) 4 (All four of these electron configurations are correct.)

29. Which of the following statements is **true**?

NO a) Dalton proposed that the atom is mostly empty space. This is Rutherford

NO b) Dalton discovered the electron. – This was after Dalton.

NO c) Dalton was the first to theorize that atoms consist of smaller particles called electrons, protons, and neutrons. – This was after Dalton. Dalton came up with idea of atoms, but had no idea of what atoms are made of.

NO d) Dalton disproved the plum pudding model of the atom by performing the alpha particle bombardment of metal foil experiment. – This was Rutherford

Yes e) Dalton's atomic theory didn't account for isotopes. – said all atoms of specific element are identical. We know now that all atoms of an element can have different number of neutrons (can have isotopes).

Most of the answers are ridiculous. Only answer b is plausible. The quantum mechanical model assumes wave properties for the electron. The allowed energy states (orbitals) have shapes that are 90% probability distributions.

Form A/B C/D

30|30 30|30

30. By considering electrons to have wave properties, we can better explain:

a) the existence of ionic bonds.

(b) the idea of orbitals as probability distributions.

c) why water is a bent molecule.

d) the need for resonance structures when drawing some Lewis structures.

e) the rationale for balancing chemical equations.

single bonds = σ bonds; double bond = 1σ + 1π; triple bond = 1σ + 2π

31|31 31|31

31. How many of the following four molecules have two pi (π) bonds and two sigma (σ) bonds?

$\ddot{O}=C=\ddot{O}$ + 2 others; all CO_2 resonance structures have 2σ + 2π bonds.

H–C≡N

2σ + 2π bonds

(HCN, 10e⁻) (CO₂, 16e⁻) SO_2, 18e⁻ C_2H_2 (H–C–C–H is the skeletal structure.) 10e⁻

5 + 4 (O) = 18 e⁻

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

SO_2 has 2σ + 1π bond.

H–C≡C–H Has 3σ + 2π bonds

e) 4 (All of these molecules have two pi bonds and two sigma bonds.)

32|32 32|32

32. Which of the following is an endothermic process?

F a) A reaction where heat is produced. exothermic rxn

F b) Combustion of natural gas in a furnace. produces heat so exothermic rxn

(T c) Adding an electron to a noble gas. heat + Ne + e⁻ → Ne⁻ EA > 0 Noble gases all have endothermic electron affinity values.

F d) The formation of an H_2 molecule from two H atoms. 2H → H_2, energy is released when a bond forms, so exothermic, Bonds form because they are more stable (lower energy) than the separate atoms.

F e) A reaction with a negative ΔH (enthalpy change) value. exothermic

33|33 33|33

33. Which of the following bonds has the **most** ionic character?

The bond with the most ionic character has the largest difference in electronegativity between the atoms in the bond. Since Be has lower electronegativity value than F, H, O, and N, the Be–F bond has the largest ΔEN.

(a) Be—F b) F—F c) H—F d) O—F e) N—F

34. 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