Form A/B C/D

Detailed Key Exam I Fall 2023

NH4MnO4 is composed of two different ions, NH4+ and MnO4-.

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1 mol NH_4MnO_4 ($\frac{2 \text{ mol ions}}{1 \text{ mol } NH_4MnO_4}$)($\frac{6.022\times10^{23} \text{ ions}}{\text{mol ions}}$) = 1.2×10^{24} ions

1/27 18/23

1. Consider the ionic compound NH_4MnO_4 (ammonium permanganate). How many ions (total) are there in 1.0 mole of ammonium permanganate?

a) 1.8×10^{24} ions b) 6 ions c) 6.0×10^{23} ions

(d) 1.2×10^{24} ions e) 3.6×10^{24} ions

$\Delta E = -R_H\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$, $\Delta E = -2.178\times10^{-18}\text{ J}\left(\frac{1}{8^2} - \frac{1}{1^2}\right) = 2.144\times10^{-18}\text{ J} = E_{photon}$

2/28 19/24

2. What is the wavelength of a photon of light that can excite the electron in a hydrogen atom from the n = 1 to the n = 8 energy level?

$E_{photon} = \frac{hc}{\lambda}$, or $\lambda = \frac{hc}{E} = \frac{6.626\times10^{-34}\text{ J}\cdot\text{s}\,(2.998\times10^{8}\text{ m/s})}{2.144\times10^{-18}\text{ J}} = 9.265\times10^{-8}\text{ m}$

(a) 92.65 nm b) 104.2 nm c) 729.7 nm d) 1261 nm e) 5837 nm = 92.65 nm

3/29 20/25

3. Consider the following five molecules/ions which all have selenium as the central atom.

32e- SeO_4^{2-} sp3 hybridized

34e- SeF_4 dsp3 hybrids

36e- SeF_4^{2-} d2sp3 hybrids

40e- SeF_5^+

18 SeO_2 + 1 more — sp2 hybridized

In how many of the above molecules/ions is the central selenium atom sp^3 hybridized?

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

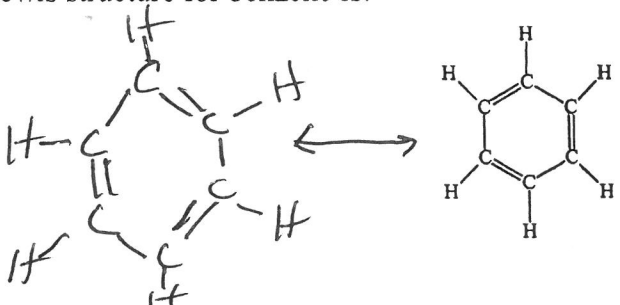
e) 5 (All exhibit sp^3 hybridization by the central selenium atom.)

Only SeO_4^{2-} exhibits tetrahedral 109° bond angles, so only SeO_4^{2-} is sp^3 hybridized.

dsp^3 hybridized

4/30 21/26

4. A Lewis structure for benzene is:



Benzene = C_6H_6

6(4) + 6(1) = 30 valence electrons

Has 2 resonance structures

Which of the following statements concerning benzene is **false**?

T a) Another equivalent (resonant) Lewis structure can be drawn for benzene.

(F) b) As predicted from the Lewis structure(s), three of the six carbon-carbon bonds are shorter than the other three C-C bonds.

T c) The carbon-carbon sigma bonds are formed from overlap of sp^2 hybrid orbitals from each carbon.

T d) The electrons in the π bonds can be thought of as delocalized above and below the entire ring surface.

T e) Each carbon in benzene has one unhybridized p atomic orbital.

All six C–C bonds are equal in length and strength. The actual carbon-carbon bond is an average of the 2 resonance structures (about a 1.5 bond).

with resonance, all 6 carbon-carbon bonds are equivalent.

Each carbon has trigonal planar geometry (120° bond angles), so each C is sp^2 hybridized.

Always the case with resonance.

sp^2 hybridization has 1 unhybridized p atomic orbital. All 6 of the unhybridized p atomic orbitals all overlap together to give the delocalized π bonding electrons above and below the surface of the molecule.

Form A/B C/D

SF_4, 34 e^-
The S-F individual bond dipoles do not cancel each other.
SF_4 is a polar molecule.

Shape = see-saw

5|19 9|19

5. Draw the Lewis structure for SF_4. Which of the following statements concerning SF_4 is **false**? Central S atom exhibits trigonal bipyramid geometry, so sulfur is dsp^3 hybridized.

T a) The hybridization of sulfur in SF_4 is dsp^3.
F b) The molecular shape of SF_4 is ~~square pyramid~~. see-saw
T c) The smallest bond angle in SF_4 is approximately 90°.
T d) SF_4 is polar.
T e) It is impossible to satisfy the octet rule for all atoms in SF_4.

6|20 10|20

6. Consider the following three reactions:

I. $F(g) \rightarrow F^+(g) + e^-$ $\Delta H_I = ?$ ionization energy for F

II. $F(g) + e^- \rightarrow F^-(g)$ $\Delta H_{II} = ?$ electron affinity for F

III. $S(g) \rightarrow S^+(g) + e^-$ $\Delta H_{III} = ?$ ionization energy for S

IE trend ↑

From IE trend, F has a larger ionization energy than S.
So $\Delta H_I > \Delta H_{III}$.

Which of the following statements (a-c) concerning these reactions is/~~are~~ **true**?

F a) ΔH for reaction I is equal to the first electron affinity for fluorine.
F b) ΔH for reaction II is equal to the first ionization energy for fluorine.
F c) ΔH for reaction III is larger (more positive) than ΔH for reaction I ($\Delta H_{III} > \Delta H_I$).
d) All of the above statements (a-c) are true.
e) None of the above statements (a-c) are true.

7|21 11|21

7. A compound has a formula of $NaClO_x$ where x is some whole number. A 100.00 g sample of this compound contains 21.6 g of sodium. Which of the following is the formula of this compound?

$\text{mol } NaClO_x = 21.6\text{ g Na}\left(\frac{1\text{ mol Na}}{22.99\text{ g}}\right)\left(\frac{1\text{ mol } NaClO_x}{1\text{ mol Na}}\right) = 0.9395\text{ mol } NaClO_x$

a) NaClO b) $NaClO_2$ c) $NaClO_3$ d) $NaClO_4$ e) $NaClO_6$

$\text{Molar mass} = \frac{100.00\text{ g}}{0.9395\text{ mol}} = 106.4\text{ g/mol}$; $106.4 = 22.99 + 35.45 + x(16)$

solving: $x = 3$ ($NaClO_3$ is formula.)

8|22 12|22

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

Brass = solid mixture, Air = gaseous mixture } both are homogeneous mixtures.

T a) A homogeneous mixture can be a solid mixture or a gaseous mixture.
T b) It is not possible for five measurements of the same object to be described as accurate but imprecise. If all measurements are accurate, then they are all close to the true value. If all measurements are close to each other, then they are precise.
T c) An atom is mostly empty space.
F d) One would expect the undiscovered element 122 to be an alkaline earth metal.
T e) A compound is a substance with constant composition that can be broken down into elements by chemical processes. definition

Element 120 would be the next alkaline earth metal. Just count over from 112 in periodic table.

Form A|B C|D

Atomic masses are all average masses of the various isotopes that make up the element. No one isotope has the average atomic mass. But a large sample size of the element behaves as if each atom had the average mass.

9|1 22|14

9. Bromine consists of two isotopes and the average mass of a bromine atom is 79.90 amu. Assuming you were able to pick up only one bromine atom, what are the chances that you would pick a bromine atom having a mass of 79.90 amu?

a) 0% b) 35% c) 50% d) 65% e) 100%

2+2+6+2+6+0+5 = 23 electrons; only V and Cr+ have 23 electrons,

10|2 23|15

10. Consider the following ground state electron configuration:

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$ → so not V, must be Cr^+.

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^5$

Cr: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ ← exception to know.

Which of the atoms or ions below has this ground state electron configuration?

For Cr^+, the 4s electron is lost first (another exception to know),

a) V^- (24 e⁻) b) V (23 e⁻) c) Mn (25 e⁻)

d) Mn^+ (24 e⁻) e) Cr^+ (23 e⁻)

Cr^+: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^5$

11|3 24|16

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

Group 5A: $ns^2 np^3$ = valence shell

np: ↑ ↑ ↑ ← All have 3 unpaired electrons.

T a) Elements in group 5A of the periodic table have a total of 3 unpaired electrons in the ground state.

I: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^5$ 6+6+6+5 = 23 p electrons

T b) Iodine has a total of 23 electrons in various p orbitals in the ground state.

F c) Element 114 should have a total of 4 valence electrons in the ground state. → under Pb in group 4

F d) The periodic table predicts that iridium (element #77) should have a total of 7 unpaired electrons in various d orbitals (in the ground state).

T e) Mercury (element #80) has a total of 14 electrons in various f orbitals (in the ground state).

Hg: [Xe] $6s^2 4f^{14} 5d^{10}$; Hg has 14 e⁻ in f orbitals.

Ir: [Xe] $6s^2 4f^{14} 5d^7$ 5d: ↑↓ ↑↓ ↑ ↑ ↑ ← Ir has 3 unpaired e⁻.

12|4 25|17

12. A microwave oven emits 1.0×10^{28} photons of wavelength 4.0 cm each minute of operation. If a cup of coffee requires 77,000 J to bring it to boiling, how many seconds are required by this microwave oven to boil the coffee? Assume all the microwave energy is absorbed by the coffee.

4.0×10^{-2} m

$E = \frac{hc}{\lambda}$ $E = \frac{(6.626 \times 10^{-34}\ J \cdot s)(2.998 \times 10^8\ m/s)}{4.0 \times 10^{-2}\ m} = 4.966 \times 10^{-24}\ J$ = energy of 1 photon

a) 13 seconds b) 35 seconds c) 52 seconds

d) 70 seconds e) 93 seconds

$77{,}000\ J \left(\frac{1\ \text{photon}}{4.966 \times 10^{-24}\ J}\right)\left(\frac{60\ s}{1.0 \times 10^{28}\ \text{photons}}\right) = 93\ s$

13|5 26|18

13. A certain metal ion (M^{n+}) forms an ionic compound with phosphorus. The molar mass of the compound is 238.0 g/mol. If the charge on the metal ion is +2, which of the following is the identity of the metal, M? M^{2+} with P^{3-} gives M_3P_2 formula.

Let x = molar mass of M

a) Pb b) U c) Pm d) Ge e) Ni

$238.0 = 3x + 2(30.97)$, $x = 58.69$ g/mol

From periodic table, M = Ni.

Form A|B C|D

14|11 5|27

14. The successive ionization energies for an unknown element are:

IE_1 =	896 kJ/mol
IE_2 =	1,752 kJ/mol
IE_3 =	14,807 kJ/mol
IE_4 =	17,948 kJ/mol

Huge jump between IE_2 and IE_3. This indicates the element has 2 valence electrons. So this element is an alkaline earth metal.

In which group in the periodic table does this element belong?

a) alkali metal group
(b) alkaline earth metal group
c) boron group
d) nitrogen group
e) oxygen group

15|12 6|28

15. How many of the following five terms (I-V) did Dalton **not** discuss in his atomic theory? Dalton only proposed the idea of a generic atom. He had no idea what specific particles made up an atom. None of these terms were discussed in Dalton's atomic theory.

I. isotopes II. ions III. protons IV. electrons V. neutrons

a) 1 b) 2 c) 3 d) 4
(e) 5) Dalton did **not** discuss any of these terms in his atomic theory.

16|13 7|29

16. Consider the calculation:

By subtraction/addition rule, the numerator is only known to the tenths place. So numerator is a 3 sig fig number.

$$\frac{39.0630 - 4.7 + 2.7392}{7.084 \times 3.1978} = \frac{37.1022}{7.084 \times 3.1978} = 1.64$$

For the remainder of the calculation, we have division and multiplication. A 3 sig fig number divided by a 4 sig fig number and a 5 sig fig number, results in 3 sig figs.

Which of the following is the answer to this calculation to the correct number of significant figures?

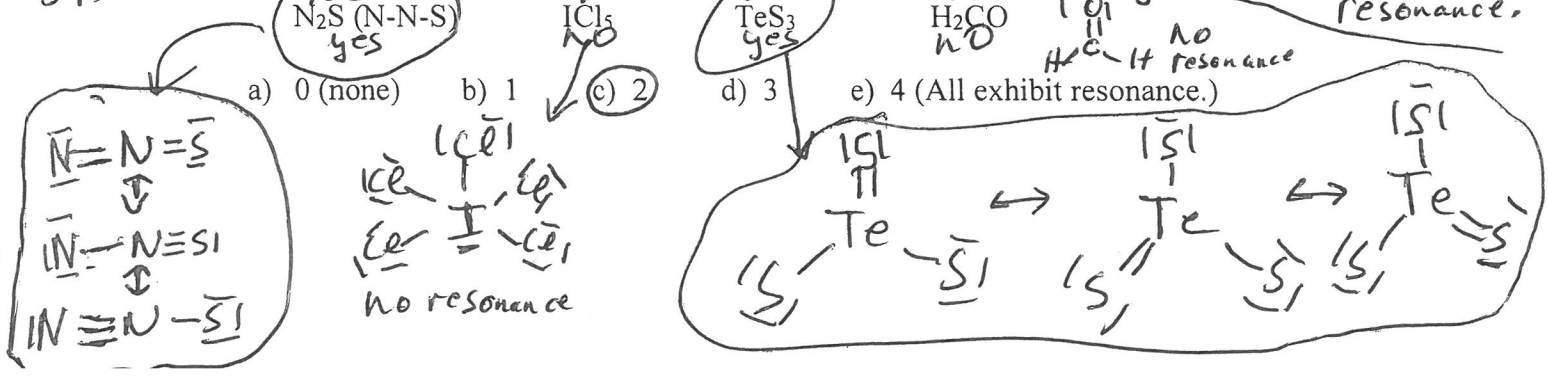
a) 1.6378 b) 1.638 (c) 1.64 d) 1.6 e) 2

17|14 8|30

17. How many of the following four compounds exhibit resonance? Only N_2S and TeS_3 have multiple bonds that can be placed in different locations. So only N_2S and TeS_3 exhibit resonance.

16e⁻ N_2S (N-N-S) yes — 42e⁻ ICl_5 no — 24e⁻ TeS_3 yes — 12e⁻ H_2CO no (H–C(=O)–H; no resonance)

a) 0 (none) b) 1 (c) 2 d) 3 e) 4 (All exhibit resonance.)



Form
A|B
C|D

18|23
1|10

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

T a) The Bohr model correctly predicts the energies of photons emitted by excited hydrogen atoms.
(F b)) The Bohr model correctly predicts the wavelengths of visible light emitted by excited neon (Ne) atoms. Bohr model only works for substances having 1 electron. Ne has 10 electrons. Bohr model doesn't work for Ne.
T c) The symbol **n** in the Bohr model represents allowed circular orbits in which an electron can be located.
T d) The simple, well-defined circular orbits for an electron in the Bohr model are not allowed by the Heisenberg uncertainty principle.
T e) As an electron in the Bohr model absorbs a photon of electromagnetic radiation, the electron moves farther away from the nucleus.

19|24
2|11

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

TiO_2 is composed of Ti^{4+} and O^{2-} ions. Ti^{4+} has 18 electrons and will have the argon electron configuration.

T a) The metal ion in TiO_2 has a noble gas electron configuration.
T b) A bond between two identical nonmetals will be a pure (nonpolar) covalent bond.
T c) An S–O bond is an example of a polar covalent bond.
(F d)) $Ca(NO_3)_2$ is an example of a compound that contains only ionic bonds. Bonding within NO_3^- is covalent.
e) The partial negative end of the bond dipole in the Se–Cl bond should be around the Cl atom. Se-Cl Cl is more electronegative than Se, so Cl is the partial negative end.

20|25
3|12

20. How many of the following are **correct** ground state electron configurations for the element or ion listed? Bi is element #83.

NO C: $1s^2 2s^2 2p^3$ $1s^2 2s^2 2p^2$
NO Mg: $[Ar]4s^2$ $[Ne]3s^2$
NO Si^{2-}: $[Ne]2s^2 2p^4$ $[Ne]3s^2 3p^4$
NO Bi: $[Xe]6s^2 5f^{14} 6d^{10} 6p^3$ $[Xe]6s^2 4f^{14} 5d^{10} 6p^3$

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

21|26
4|13

21. Apply the hybrid orbital theory to the bonding in a nitrogen molecule (N_2) and complete the following sentence. The nitrogen-nitrogen bonding in N_2 is best described as:

N_2, 10 e⁻'s. N≡N is Lewis structure. Each N has 2 sets of electrons about it so each N has linear geometry and sp hybrids.

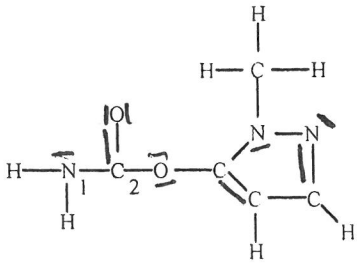
a) one σ bond due to overlap of an sp^2 hybrid orbital from each nitrogen and one π bond from overlap of unhybridized 2p atomic orbitals.
b) one σ bond due to overlap of an sp^2 hybrid orbital from each nitrogen and two π bonds from overlap of unhybridized 2p atomic orbitals.
(c) one σ bond due to overlap of an sp hybrid orbital from each nitrogen and two π bonds from overlap of unhybridized 2p atomic orbitals.
d) one σ bond due to overlap of an sp hybrid orbital from each nitrogen and one π bond from overlap of unhybridized 2p atomic orbitals.

The triple bond contains 1 σ and 2 π bonds. The sp hybrids from each N overlap head-to-head to form the sigma bond. The two unhybridized p atomic orbitals from each N overlap to form two π bonds.

Form
A|B
C|D

Isolan, an organic compound used as an insecticide, has the following skeletal structure. Complete a Lewis structure and answer the following two questions.

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



N_1 has tetrahedral geometry with 109 bond angles.
C_2 has trigonal planar geometry with 120° bond angles.

22/15
27/6
22. How many π bonds are in the complete Lewis structure?
There are 3 double bonds in the completed Lewis structure.
a) 0 b) 1 c) 2 (d) 3 e) 4
A double bond consists of 1 σ and 1 π bond. So there are 3 π bonds from the 3 double bonds.

23/16
28/7
23. What are the approximate bond angles about the nitrogen atom labeled 1 and the carbon atom labeled 2, respectively?

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

24/17
29/8
24. How many of the following formula/name combinations is/are **correct**?

NO	Al_2S_3	dialuminum trisulfate — aluminum sulfide is correct.
NO	$CuCO_3$	copper(II) carbonate — copper (II) carbonate is correct.
NO	$Fe(ClO_4)_2$	iron(IV) chlorate — iron(II) perchlorate is correct.
NO	CsBr	bromium ceside — cesium bromide is correct.
yes	S_2F_4	disulfur tetrafluoride

Carbonate = CO_3^{2-}
ClO_4^- is the anion.

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

25/18
30/9
25. How many neutrons and electrons are in $^{127}I^-$?
I is element 53, so has 53 protons, 127 − 53 = 74 neutrons
a) 128 neutrons and 53 electrons (b) 74 neutrons and 54 electrons
c) 127 neutrons and 54 electrons d) 127 neutrons and 52 electrons
e) 74 neutrons and 52 electrons
For the −1 charge on I, 54 electrons are present.

Form A/B C/D

IE trend ← radii trend

The trends apply to neutral charged atoms as in groups II and III. Apply the trends to Groups II and III, the IE order for Group II is Rb < Ca < Al and the IE order for Group III Sn < Se < Ar. The largest atom in Group II is Rb and the largest atom in Group III is Sn. For Group I, all have 7 protons. N^-, with the most electrons, has the smallest IE value and the largest size. N^+ has the largest IE and smallest size since it has the fewest electrons. Group III is an isoelectronic series where all ions have 10 electrons. O^{2-} with the fewest protons, will have the smallest IE value and the largest size. Na^+ with the most protons attracting the 10 electrons will have the largest ionization energy and smallest size. Only Group III is in order of increasing IE values. The other Groups are in the opposite order (largest IE → smallest).

Consider the following four groups (I-IV) of atoms/ions for the next two questions:

NO I. N^+, N, N^-
NO II. Al, Ca, Rb
YES III. Sn, Se, Ar
NO IV. Na^+, F^-, O^{2-}

26/6 13/1 26. How many of the four groups (I-IV) is/are in order of **increasing** ionization energy (smallest to largest IE)?

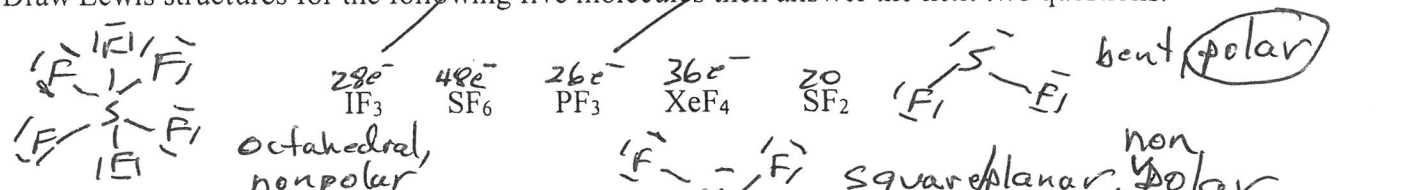
a) 0 (none) b) 1 c) 2 d) 3 e) 4 (All of the groups are in order of increasing ionization energy.)

27/7 14/2 27. In each group (I-IV), which atom/ion has the **largest** radius?

a) N^+; Al; Ar; Na^+ b) N^+; Rb; Ar; Na^+ c) N^-; Al; Ar; O^{2-}
d) N^-; Rb; Sn; O^{2-} e) N^-; Rb; Sn; Na^+

The circled atoms/ions in each group above have the largest size.

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



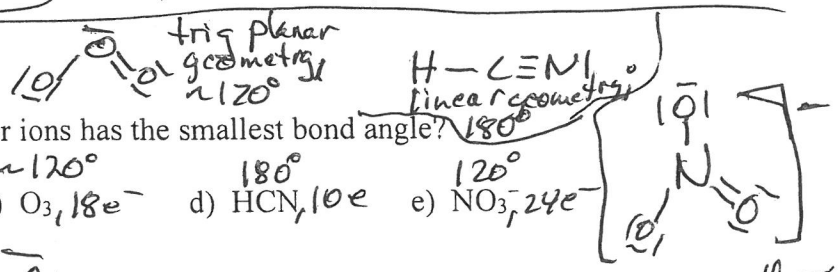
28/8 15/3 28. How many of these molecules are polar?

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

IF_3, PF_3, and SF_2 are polar (bond dipoles do not cancel out each other). SF_6 and XeF_4 are nonpolar since the bond dipoles cancel out each other.

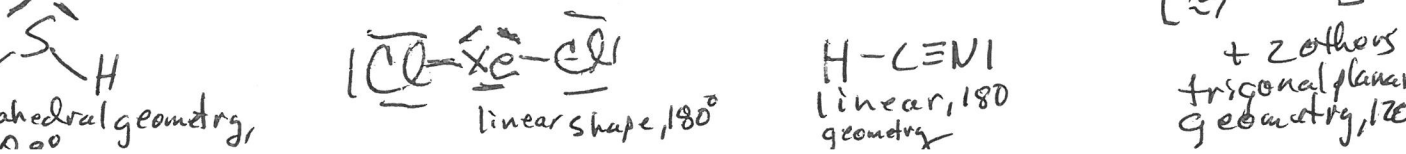
29/9 16/4 29. Which molecule has a trigonal pyramid shape? PF_3 has trigonal pyramid shape.

a) IF_3 b) SF_6 c) PF_3 d) XeF_4 e) SF_2



30/10 17/5 30. Which of the following molecules or ions has the smallest bond angle?

a) H_2S, 8e (~109°) b) $XeCl_2$, 22e⁻ (180°) c) O_3, 18e⁻ (~120°) d) HCN, 10e (180°) e) NO_3^-, 24e⁻ (120°)



Form
A | B
C | D

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

$1+3+2=6$ = sum of coefficients

31 | 31
31 | 31

31. When nitrogen gas reacts with hydrogen gas, gaseous ammonia is produced. Balance the equation for the reaction between nitrogen gas and hydrogen gas to produce ammonia. What is the sum of the coefficients in the best-balanced equation? Note that ammonia is the common name for nitrogen trihydride.

a) 4 b) 9 c) 8 d) 5 e) 6

$\lambda\nu = c$, $E = h\nu = \frac{hc}{\lambda}$; λ and ν are inversely related. Same is true for E and λ.

32 | 32
32 | 32

32. Assume Illini rays were recently discovered as a new type of electromagnetic radiation and assume that they possess extremely long wavelengths (λ = 100 km). Comparing Illini rays to microwaves (λ = 1.0 cm), which of the following statements (a-c) is/are **true**?

$\lambda_{Illini} > \lambda_{micro}$, so $\nu_{micro} > \nu_{Illini}$ and $E_{micro} > E_{Illini}$.

F a) A photon of Illini rays is more energetic than a photon of microwaves.
T b) The frequency of microwaves is higher than the frequency of Illini rays.
F c) Microwaves will have a faster velocity than Illini rays.
d) All of the above statements (a-c) are false.
e) All of the above statements (a-c) are true.

33 | 33
33 | 33

33. An element in the ground state has one unpaired electron in the 5p atomic orbitals. The element reacts with chlorine to form a covalent compound. Which of the following is this element?

In ($5p^1$) and I ($5p^5$) both have 1 unpaired electron

5p: ↑↓ ↑↓ ↑

In, a metal will react with a nonmetal to form an ionic compound. So not In. I, a nonmetal will react with the nonmetal Cl to form a covalent compound. So the element is I.

a) Tl b) At c) In d) I e) Ga

34 | 34
34 | 34

34. A 25.00 g sample of an unknown solid is placed in a graduated cylinder and then the cylinder is filled to the 50.0 mL mark with benzene. The mass of benzene and solid together is 58.80 g. Assuming that the solid is insoluble in benzene and the density of benzene is 0.880 g/cm^3, what is the density of the unknown solid?

$density = \frac{mass}{volume}$; mass of solid = 25.00 g; need to determine V_{solid}.

a) 2.16 g/cm^3 b) 0.651 g/cm^3 c) 4.25 g/cm^3 d) 1.18 g/cm^3 e) 3.68 g/cm^3

mass of benzene = 58.80 g − 25.00 g = 33.80 g benzene

volume of benzene = $38.80\,g\left(\frac{1\,cm^3}{0.880\,g}\right) = 38.41\,cm^3$

35. 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

volume of solid = 50.0 − 38.41 = 11.59 cm^3

$density = \frac{25.00\,g}{11.59\,cm^3} = 2.16\,g/cm^3$