CHM 1311 - F **First Midterm** **Oct 22 – 2019**

(Prof. S. Gambarotta)

Your Name: ____________________ **Student #: ______________**

Please do not un-staple the booklet

1. The solution key will be posted on the web on Wednesday.
2. You must respond to all exercises.
3. Periodic Table, Electronegativity Table and relevant values are at the end.
4. A few scratch sheets are at the very end. Report in the booklet the minimum amount of calculations to show your reasoning.

Read carefully:

Cellular phones, unauthorized electronic devices or course notes (unless an open-book exam) are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, the following may occur: academic fraud allegations will be filed which may result in your obtaining a **0** (zero) for the exam.

By signing below, you acknowledge that you have read and ensured that you are complying with the above statement.

Signature: ______________________________

1	**/2**	**6**	**/1**
2	**/3**	**7**	**/2**
3	**/2**	**8**	**/1**
4	**/4**	**9**	**/1**
5	**/3**	**10**	**/2**

Total/21 =
Total/10 =

1. (2 points) Terephthalic acid, used in the production of polyester fibers and films, is composed of carbon, hydrogen, and oxygen. When 0.6943 g of terephthalic acid was subjected to combustion analysis it produced 1.471 g CO_2 and 0.226 g H_2O. What is its empirical formula?

Grams of C in the sample: 1.471/44 x 12 = 0.40
Grams of H in the sample: 0.226/18 x 2 = 0.025
Grams of O in the sample = 0.6943 – 0.40 – 0.025 = 0.269

Moles of C = 0.40/12 = 0.033
Moles of H = 0.025/1 = 0.025
Moles of O = 0.269/16 = 0.0168

The ratio would give $C_2H_{1.5}O_1$ and which should be multiplied by 2 yielding:

Anw. $C_4H_3O_2$

2. (3 points) Balance the following equation:

$Ca_3(PO_4)_2(s) + SiO_2(s) + C(s) \rightarrow CaSiO_3(s) + CO(g) + P_4(s)$

P exchanges 10 electrons to get into P_4 and C exchanges 2 and the electron balance yields:

$2Ca_3(PO_4)_2(s)$ + $SiO_2(s)$ + $10C(s)$ → $CaSiO_3(s)$ + $10CO(g)$ + $P_4(s)$

the subsequent mass balance yields:

$2Ca_3(PO_4)_2(s)$ + $6SiO_2(s)$ + $10C(s)$ → $6CaSiO_3(s)$ + $10CO(g)$ + $P_4(s)$

Answ. $2Ca_3(PO_4)_2(s)$ + $6SiO_2(s)$ + $10C(s)$ → $6CaSiO_3(s)$ + $10CO(g)$ + $P_4(s)$

3. (2 points)
Aluminum metal dissolved in hydrochloric acid as follows:

$2Al(s)$ + $6HCl(aq)$ → $2AlCl_3(aq)$ + $3H_2(g)$

a. What is the minimum volume of 6.0 *M* HCl(*aq*) needed to completely dissolve 3.20 g of aluminum in this reaction?
b. What mass of $AlCl_3$ would be produced by complete reaction of 3.20 g of aluminum?

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Moles of Al = 3.2/26.98 = 0.118

$Al + 3\ HCl \rightarrow AlCl_3 + 3/2\ H_2$

Thus moles HCl needed: 0.118 x 3 = 0.356 which, divided by the molarity, corresponds to 59.3 mL

The mass of AlCl3 = 0.118 moles x molar mass AlCl3 = 15.8 g

Answ. a) 59.3 mL
b) 15.8 g

4. (4 points)

When light of frequency $1.30 \times 10^{15}\ s^{-1}$ shines on the surface of cesium metal, electrons are ejected with a maximum kinetic energy of 5.2×10^{-19} J. Calculate (a) the wavelength of this light; (b) the binding energy of electrons

to cesium metal; and (c) the longest wavelength of light that will eject electrons. $E_{photon} = E_{binding} + E_{kinetic}$

4.17 (a) $\lambda = \frac{c}{\nu} = \frac{2.998 \times 10^{8} \text{ m/s}}{1.30 \times 10^{15} \text{ s}^{-1}} = 2.31 \times 10^{-7} \text{ m}$

(b) First determine the energy of the photon, then use $E_{binding} = E_{photon} - E_{kinetic}$

$E_{photon} = h\nu = (6.626 \times 10^{-34} \text{ J s})(1.30 \times 10^{15} \text{ s}^{-1}) = 8.61 \times 10^{-19} \text{ J}$

$E_{binding} = (8.61 \times 10^{-19} \text{ J}) - (5.2 \times 10^{-19} \text{ J}) = 3.4 \times 10^{-19} \text{ J}$

(c) The longest wavelength that will eject electrons corresponds to a photon with energy equal to the binding energy: $\lambda = \frac{hc}{E_{binding}}$

$$\lambda = \frac{(6.626 \times 10^{-34} \text{ J s})(2.998 \times 10^{8} \text{ m/s})}{3.4 \times 10^{-19} \text{ J}} = 5.8 \times 10^{-7} \text{ m}$$

5. (3 point)

Determine the frequencies that hydrogen atoms emit in transitions from the n = 6 and n = 5 levels to the n = 3 level. ($E_n = -2.18 \times 10^{-18} / n^2$)

Energies and frequencies for transitions in hydrogen atoms can be calculated from the equation for hydrogen atom energy levels:

$$E_n = \frac{-2.18 \times 10^{-18}\ \text{J}}{n^2}$$

$$\Delta E_{6-3} = E_6 - E_3 = \left(\frac{-2.18 \times 10^{-18}\ \text{J}}{6^2}\right) - \left(\frac{-2.18 \times 10^{-18}\ \text{J}}{3^2}\right) = 1.817 \times 10^{-19}\ \text{J}$$

$$v = \frac{E}{h} = \frac{1.817 \times 10^{-19}\ \text{J}}{6.626 \times 10^{-34}\ \text{J s}} = 2.74 \times 10^{14}\ \text{s}^{-1}$$

$$\Delta E_{5-3} = E_5 - E_3 = \left(\frac{-2.18 \times 10^{-18}\ \text{J}}{5^2}\right) - \left(\frac{-2.18 \times 10^{-18}\ \text{J}}{3^2}\right) = 1.550 \times 10^{-19}\ \text{J}$$

$$v = \frac{E}{h} = \frac{1.550 \times 10^{-19}\ \text{J}}{6.626 \times 10^{-34}\ \text{J s}} = 2.34 \times 10^{14}\ \text{s}^{-1}$$

These photons lie in the IR, just short of the visible spectral region (see Figure 4-4).

6. (1 point)

For the following sets of quantum numbers, determine which describe actual orbitals and which are non-existent. For each one that is non-existent, list the restriction that forbids it:

	n	l	m_l	m_s
(a)	5	3	−2	−1
(b)	5	3	−3	+1/2
(c)	3	3	−3	+1/2
(d)	3	0	0	−1/ 2

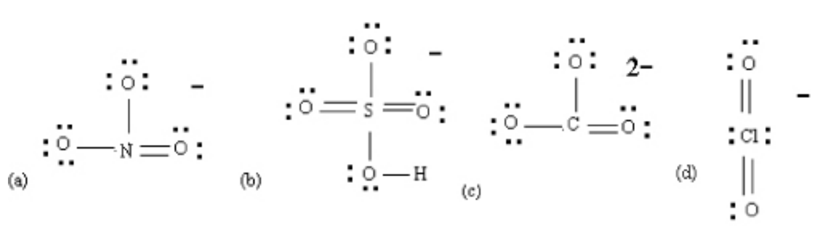
Remember that n must be a positive integer, l is restricted to zero and positive integers less than n, m_l is restricted to integers between $-l$ and $+l$, and $m_s = +\frac{1}{2}$ or $-\frac{1}{2}$.

(a) Non-existent: m_s must be $+\frac{1}{2}$ or $-\frac{1}{2}$; (b) actual; (c) non-existent: l must be less than n; and (d) actual.

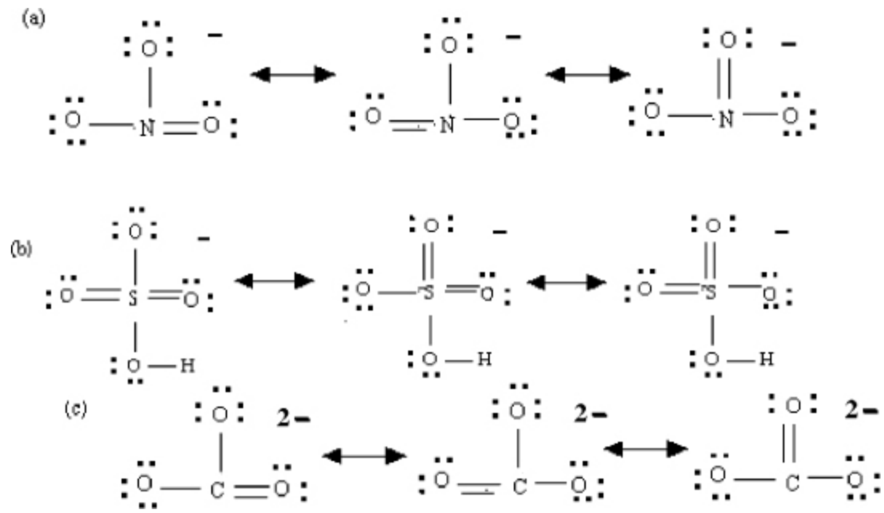
7. (2 points)

Determine the Lewis structure of each of the following polyatomic ions. Include all resonance structures and formal charges, where appropriate: (a) NO_3^-; (b) HSO_4^-; (c) CO_3^{2-}; and (d) ClO_2^-.

Optimize electron configurations of the inner atoms. The inner atoms in (a) and (c) are second row, so complete their octets. The inner atoms in (b) and (d) are third row, so reduce their formal charges to zero by making two double bonds to each:



. The outer oxygen atoms all are equivalent, so all but (d) have three equivalent structures.



8. (1 point)

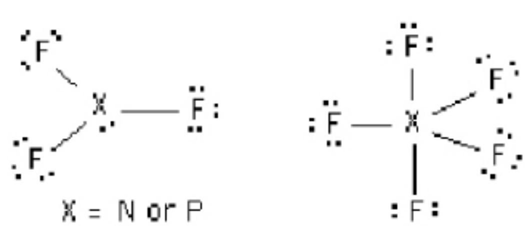
Identify the hybrid orbitals used by the inner atoms for: SO_3, SO_2, $CHCl_3$, PBr_3

Use the Lewis structure of the molecule: (a) *sp^2* hybrids; (b) *sp^2* hybrids; (c) *sp^3* hybrids (d) *sp^3* hybrids.

9. (1 point)

Both PF_3 and PF_5 are known compounds. NF_3 also exists, but NF_5 does not. Why is there no molecule with the formula NF_5?

The Lewis structures of molecules with formula XF_3 show octets around the inner atom and $FC_X = 0$, making them stable. Compounds with formula XF_5 also have $FC_X = 0$ but have five electron pairs associated with the inner atom. This is possible for phosphorus, a third-row element that has *d* orbitals available for bonding. It is not possible for nitrogen, a second-row element that lacks valence *d* orbitals:



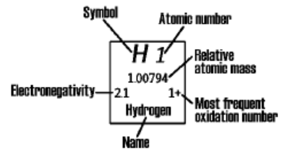
10. (2 points)

Use molecular orbital diagram to rank the bond energies of the following diatomic species from strongest to weakest:

He_2, He_2^+ and He_2^{2+}

He_2^{2+} He_2^+ He_2

Mokeur's Periodic table of the elements



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	*H 1* 1.00794 2.1 1+ Hydrogen																	*He 2* 4.002602 - - Helium
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium											**B 5** 10.811 2.0 3+ Boron	**C 6** 12.011 2.5 4+,4- Carbon	*N 7* 14.00674 3.0 3+,3- Nitrogen	*O 8* 15.9994 3.5 2- Oxygen	*F 9* 18.9984032 4.0 1- Fluorine	*Ne 10* 20.1797 - - Neon
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium											**Al 13** 26.981539 1.5 3+ Aluminum	**Si 14** 28.0855 1.8 4+ Silicon	**P 15** 30.973762 2.1 5+ Phosphorus	**S 16** 32.066 1.8 4+ Sulfur	*Cl 17* 35.4527 3.0 1- Chlorine	*Ar 18* 39.948 - - Argon
4	**K 19** 39.0983 0.8 1+ Potassium	**Ca 20** 40.078 1.0 2+ Calcium	**Sc 21** 44.955910 1.3 3+ Scandium	**Ti 22** 47.88 1.5 4+ Titanium	**V 23** 50.9415 1.6 5+ Vanadium	**Cr 24** 51.9961 1.6 3+ Chromium	**Mn 25** 54.93805 1.5 2+ Manganese	**Fe 26** 55.847 1.8 3+ Iron	**Co 27** 58.9332 1.8 2+ Cobalt	**Ni 28** 58.6934 1.8 2+ Nickel	**Cu 29** 63.546 1.9 2+ Copper	**Zn 30** 65.39 1.6 2+ Zinc	***Ga 31*** 69.723 1.6 3+ Gallium	**Ge 32** 72.61 1.6 4+ Germanium	**As 33** 74.92159 2.0 3+,3- Arsenic	**Se 34** 78.96 2.4 4+ Selenium	***Br 35*** 79.904 2.8 1- Bromine	*Kr 36* 83.80 - - Krypton
5	**Rb 37** 85.4678 0.8 1+ Rubidium	**Sr 38** 87.62 1.0 2+ Strontium	**Y 39** 88.90585 1.3 3+ Yttrium	**Zr 40** 91.224 1.4 4+ Zirconium	**Nb 41** 92.90638 1.6 5+ Niobium	**Mo 42** 95.94 1.8 6+ Molybdenum	Tc 43 98.9063 1.9 7+ Technetium	**Ru 44** 101.57 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium	**Pd 46** 106.42 2.2 2+ Palladium	**Ag 47** 107.8682 1.9 1+ Silver	**Cd 48** 112.411 1.7 2+ Cadmium	**In 49** 114.82 1.7 3+ Indium	**Sn 50** 118.71 1.8 4+ Tin	**Sb 51** 121.757 1.9 3+,3- Antimony	**Te 52** 127.60 2.1 4+ Tellurium	**I 53** 126.90447 2.5 1- Iodine	*Xe 54* 131.29 - - Xenon
6	***Cs 55*** 132.90543 0.7 1+ Cesium	**Ba 56** 137.327 0.9 2+ Barium	**La 57** 138.9055 1.1 3+ Lanthanum	**Hf 72** 178.49 1.3 4+ Hafnium	**Ta 73** 180.9479 1.5 5+ Tantalum	**W 74** 183.85 1.7 6+ Tungsten	**Re 75** 186.207 1.9 7+ Rhenium	**Os 76** 190.2 2.2 4+ Osmium	**Ir 77** 192.22 2.2 4+ Iridium	**Pt 78** 195.08 2.2 4+ Platinum	**Au 79** 196.96654 2.4 3+ Gold	***Hg 80*** 200.59 1.9 2+ Mercury	**Tl 81** 204.3833 1.8 1+ Thallium	**Pb 82** 207.2 1.8 2+ Lead	**Bi 83** 208.98037 1.9 3+ Bismuth	**Po 84** 208.9824 2.0 2+ Polonium	**At 85** 209.9871 2.2 1- Astatine	*Rn 86* 222.0176 - - Radon
7	***Fr 87*** 223.0197 0.7 1+ Francium	**Ra 88** 226.0254 0.9 2+ Radium	**Ac 89** 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Uun 110 269 - - Ununnilium	Uuu 111 272 - - Unununium	Uu 112 277 - - Ununbium		Uuq 114 289 - - Ununquadium		Uuh 116 289 - - Ununhexium		Uuo 118 293 - - Ununoctium

6	**Ce 58** 140.115 1.1 3+ Cerium	**Pr 59** 140.90765 1.1 3+ Praseodymium	**Nd 60** 144.24 1.1 3+ Neodymium	Pm 61 144.9127 1.1 3+ Promethium	**Sm 62** 150.36 1.2 3+ Samarium	**Eu 63** 151.965 1.2 3+ Europium	**Gd 64** 157.25 1.2 3+ Gadolinium	**Tb 65** 168.92534 1.2 3+ Terbium	**Dy 66** 162.50 1.2 3+ Dysposium	**Ho 67** 164.93032 1.2 3+ Holmium	**Er 68** 167.26 1.2 3+ Erbium	**Tm 69** 168.93421 1.2 3+ Thulium	**Yb 70** 173.04 1.1 3+ Ytterbium	**Lu 71** 174.967 1.2 3+ Lutetium
7	**Th 90** 232.0381 1.3 4+ Thorium	**Pa 91** 231.03588 1.5 5+ Protactinium	**U 92** 238.0289 1.4 6+ Uranium	Np 93 237.082 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.

Data For Water

Density = 1.00 g/mL (at 25°C)
s = 2.13 J g^{-1} K^{-1} (solid)
s = 4.184 J g^{-1} K^{-1} (liquid) $\Delta H°_{fus}$ = 6.02 kJ mol^{-1}
s = 2.01 J g^{-1} K^{-1} (gas) $\Delta H°_{vap}$ = 40.7 kJ mol^{-1}

Constants and Conversion Factors

1 mmHg = 1 torr 760 mmHg = 1 atm 1 atm = 101.325 kPa 1 atm = 1.013125 bar
1 cm^3 = 1 mL 1000 mL = 1 L 1000 L = 1 m^3

Avogadro's Number	*N*	6.022×10^{23} mol^{-1}	
Boltzmann's constant	*k*	1.30866×10^{-23} $J \cdot K^{-1}$	
Faraday's constant	*F*	96,485 $C \cdot mol^{-1}$	
Gas constant	*R*	8.31451 $J \cdot K^{-1} \cdot mol^{-1}$	
	R	0.08206 $atm \cdot L \cdot K^{-1} \cdot mol^{-1}$	
	R	8.31451 $m^3 Pa \cdot K^{-1} \cdot mol^{-1}$	
	R	0.0831451 bar $L \cdot K^{-1} \cdot mol^{-1}$	
Planck's constant	*h*	6.62608×10^{-34}	J·s
Speed of Light	*c*	2.99792458×10^{8}	$m \cdot s^{-1}$

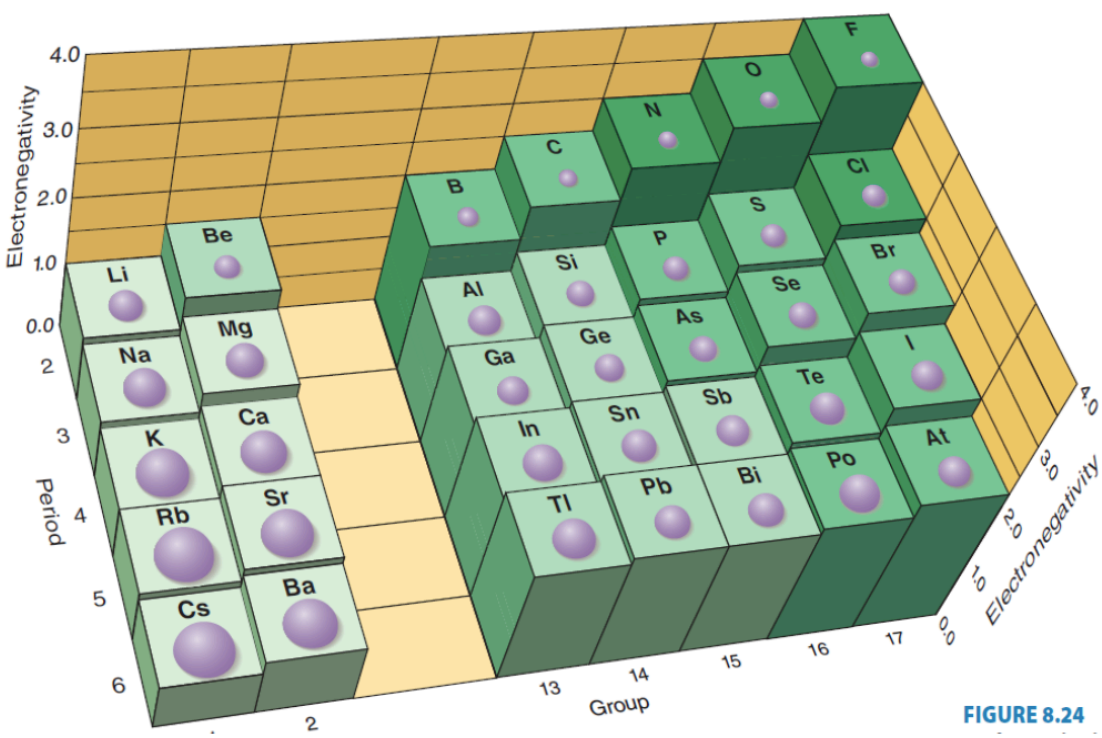


FIGURE 8.24

Gas Laws

$PV = nRT$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$P_T = P_1 + P_2 + P_3 + \ldots$

$d = \frac{m}{V} = \frac{P \cdot MM}{RT}$

$E_K = \frac{1}{2}mv^2$

$u_{rms} = \sqrt{\frac{3RT}{MM}}$

$\frac{Rate\ A}{Rate\ B} = \sqrt{\frac{MM_B}{MM_A}}$

$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$

Equilibrium

$K_P = K_C(RT)^{\Delta n}$

Acid/Base

$pOH = -\log[OH^{-1}]$

$pH = -\log[H^+]$

$pH + pOH = 14$

$K_a \times K_b = K_W$

$pH = pK_a + \log [A^-]/[HA]$

$pH = \frac{pK_{a1} + pK_{a2}}{2}$

Thermochemistry

$\Delta U = q + W$

$W_{system} = -P\Delta V = -\Delta nRT$

$\Delta H = \Delta U + P\Delta V$

$q_P = \Delta U + P\Delta V$

$q = ms\Delta T$

$\Delta H_{rxn}^\circ = \sum n\Delta H_f^\circ(pdts) - \sum n\Delta H_f^\circ(rxts)$

The atom

$E = h\nu$

$c = \nu\lambda$

$E = -B/n^2$

Kinetics

$[A]_t = [A]_o - kt$

$\ln[A]_t = \ln[A]_o - kt$

$1/[A]_t = 1/[A]_o + kt$

$k = Ae^{(-Ea/RT)}$

$\ln(k_2/k_1) = (-Ea/R)(1/T_2 - 1/T_1)$