CHM 1311 - B **First Midterm** **Oct 21 – 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	**/1**	**10**	**/2**

Total/19 =
Total/10 =

1. (2 points)

The chemical formula for aluminum sulphate is $Al_2(SO_4)_3$. (a) Compute its molar mass. (b) Compute the number of moles contained in 25.0 g of this compound. (c) Determine its percent composition. (d) Determine the mass of this compound that contains 1.00 mole of O.

The chemical formula of a substance provides all the information needed to compute its molar characteristics:

(a) $M = 2(26.98 \text{ g/mol}) + 3[32.07 \text{ g/mol} + 4(16.00 \text{ g/mol})] = 342.17 \text{ g/mol}$

(b) $$n = \frac{m}{M} = 25.0 \text{ g}\left(\frac{1 \text{ mol}}{342.17 \text{ g}}\right) = 7.31\times10^{-2} \text{ mol}$$

(c) To determine the percent composition, work with 1 mole of substance. Take the ratio of the mass of each element that 1 mole contains to the mass of 1 mole (molar mass):

$$\%\text{Al} = (100\%)\left(\frac{2(26.98 \text{ g/mol})}{342.17 \text{ g/mol}}\right) = 15.77\%$$

$$\%\text{S} = (100\%)\left(\frac{3(32.07 \text{ g/mol})}{342.17 \text{ g/mol}}\right) = 28.12\%$$

$$\%\text{O} = (100\%)\left(\frac{12(16.00 \text{ g/mol})}{342.17 \text{ g/mol}}\right) = 56.11\%$$

(d) $$1.00 \text{ mol O}\left(\frac{1 \text{ mol } Al_2(SO_4)_3}{12 \text{ mol O}}\right)\left(\frac{342.17 \text{ g}}{1 \text{ mol}}\right) = 28.5 \text{ g}$$

2. (3 points) Balance the following equation:

$Se + Cr(OH)_3 \rightarrow Cr + SeO_3^{2-}$ (basic conditions)

$Se \rightarrow SeO_3^{2-}$

(1) Se is balanced; (2) add 3 H_2O on the left; (3) add 6 H_2O on the right and 6 OH^- on the left; (4) add 4 e^- on the right: $Se + 3\,H_2O + 6\,OH^- \rightarrow SeO_3^{2-} + 6\,H_2O + 4\,e^-$

Cancel duplicated species: $Se + 6\ OH^- \rightarrow SeO_3^{2-} + 3\ H_2O + 4\ e^-$

$Cr(OH)_3 \rightarrow Cr$

(1) Cr is balanced; (2 and 3) by inspection, add 3 OH^- on the right; (4), add 3 e^- on the left: $Cr(OH)_3 + 3\ e^- \rightarrow Cr + 3\ OH^-$

Multiply the first reaction by 3 and the second reaction by 4, and then add:

$$\begin{array}{r} 3\ [Se + 6\ OH^- \rightarrow SeO_3^{2-} + 3\ H_2O + 4\ e^-] \\ +\ 4\ [Cr(OH)_3 + 3\ e^- \rightarrow Cr + 3\ OH^-] \\ \hline 3\ Se + 4\ Cr(OH)_3 + 6\ OH^- \rightarrow 3\ SeO_3^{2-} + 4\ Cr + 9\ H_2O \end{array}$$

3. (2 points)
A student prepares a solution by dissolving 4.75 g of solid KOH in enough water to make 275 mL of solution. (a) Calculate the molarities of the major ionic species present. (b) Calculate the molarities of the major ionic species present if 25.00 mL of this solution is added to a 100 mL volumetric flask, and water is added to the mark.

The solution process is KOH (*s*) → K^+ (*aq*) + OH^- (*aq*). Each mole of solid generates 1 mole of each ion:

(a) Molarity is found using the equations, $c = \frac{n}{V}$ and $n = \frac{m}{M}$

M = 39.098 g/mol + 15.999 g/mol + 1.0079 g/mol = 56.11 g/mol

$$c = \frac{n}{V} = \left(\frac{4.75\ \text{g}}{275\ \text{mL}}\right)\left(\frac{1\ \text{mol}}{56.11\ \text{g}}\right)\left(\frac{10^3\ \text{mL}}{1\ \text{L}}\right) = 0.308\ \text{M} = c_{K^+} = c_{OH^-}$$

(b) In a dilution, the number of moles of solute remains constant whereas volume increases, so $c_f V_f = c_i V_i$. The starting volume is 25.00 mL and the final volume is 100.00 mL:

$$c_f = \frac{c_i V_i}{V_f} = \frac{(0.308\text{ M})(25.00\text{ mL})}{100.\text{ mL}} = 0.0770\text{ M} = c_{K^+} = c_{OH^-}$$

4. (4 points)
Neutrons, like electrons and photons, are particle–waves whose diffraction patterns can be used to determine the structures of molecules. Calculate the kinetic energy of a neutron with a wavelength of 75 pm.

Use the equation for electrons from Table 4-1. The neutron mass is 1.6749×10^{-27} kg. First convert wavelength into metres:

$$\lambda = 75\text{ pm}\left(\frac{10^{-12}\text{ m}}{1\text{ pm}}\right) = 7.5 \times 10^{-11}\text{ m}$$

$$v = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34}\text{ J s}}{(1.6749 \times 10^{-27}\text{ kg})(7.5 \times 10^{-11}\text{ m})} = 5.3 \times 10^{3}\text{ m/s}$$

$$E_{\text{kinetic}} = \frac{1}{2}mv^2$$

$$E_{\text{kinetic}} = \frac{(1.6749 \times 10^{-27}\text{kg})(5.3 \times 10^{3}\text{ m/s})^2}{2} = 2.3 \times 10^{-20}\text{ kg m}^2\text{ s}^{-2} = 2.3 \times 10^{-20}\text{J}$$

5. (1 point)
The binding energy of electrons to a chromium metal surface is 7.21×10^{-19} J. Calculate (a) the longest wavelength of light that will eject electrons from chromium metal; (b) the frequency required to give electrons with kinetic energy of 2.5×10^{-19}; and (c) the wavelength of the light in Part (b).

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

$$\lambda = \frac{(6.626 \times 10^{-34}\ \text{J s})(2.998 \times 10^{8}\ \text{m/s})}{7.21 \times 10^{-19}\ \text{J}} = 2.76 \times 10^{-7}\ \text{m or 276 nm}$$

(b) First determine the energy of the photon, using $E_{\text{binding}} = E_{\text{photon}} - E_{\text{kinetic}}$; then calculate the frequency from $E_{\text{photon}} = h\nu$:

$$E_{\text{photon}} = E_{\text{binding}} + E_{\text{kinetic}} = (7.21 \times 10^{-19}\ \text{J}) + (2.5 \times 10^{-19}\ \text{J}) = 9.7 \times 10^{-19}\ \text{J}$$

$$\nu = \frac{E_{\text{photon}}}{h} = \frac{9.7 \times 10^{-19}\ \text{J}}{6.626 \times 10^{-34}\ \text{J s}} = 1.5 \times 10^{15}\ \text{s}^{-1}$$

(c) $$\lambda = \frac{c}{\nu} = \frac{2.998 \times 10^{8}\ \text{m/s}}{1.5 \times 10^{15}\ \text{s}^{-1}} = 2.0 \times 10^{-7}\ \text{m or 200 nm}$$

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)	3	–1	–1	$+\frac{1}{2}$
(b)	3	1	–1	$-\frac{1}{2}$
(c)	3	1	2	$+\frac{1}{2}$
(d)	3	2	2	$-\frac{1}{2}$

Remember that $\boldsymbol{n}$ must be a positive integer, $\boldsymbol{l}$ is restricted to zero and positive integers less than $\boldsymbol{n}$, $\boldsymbol{m_l}$ is restricted to integers between $-\boldsymbol{l}$ and $+\boldsymbol{l}$, and $\boldsymbol{m_s} = +\frac{1}{2}$ or $-\frac{1}{2}$. (a) Non-existent: $\boldsymbol{l}$ must be positive; (b) actual; (c) non-existent: $\boldsymbol{m_l}$ cannot be larger than $\boldsymbol{l}$; and (d) actual.

7. (2 points)

Draw the Lewis structures for the two possible arrangements of the N_2O molecule, NNO and NON. Experiments show that the molecule is linear and has a dipole moment. What is the arrangement of atoms? Justify your choice.

Determine the Lewis structures using standard procedures. Both molecules have 2(5) + 6 = 16 valence electrons. Two pairs are required for the bonding framework, and each outer atom receives three pairs:

Because these molecules contain only Row 2 atoms, we need to complete the octets. This can be accomplished by shifting two electron pairs to make double bonds:

N-N-O N-O-N

Molecules have dipole moments only if they are non-symmetrical. A linear N–O–N structure would not have a dipole moment, because the N–O dipole would exactly cancel the O–N dipole. Thus, N_2O must have the structure N–N–O if it is to have a dipole moment.

8. (1 point)

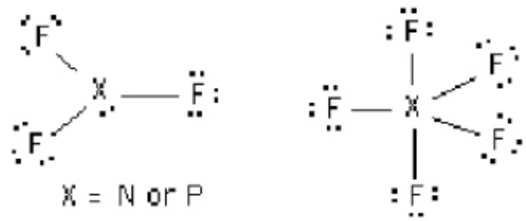
Identify the hybrid orbitals used by the inner atoms for: SO_3, SO_2, $CHCl_3$, PBr_3

. 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:



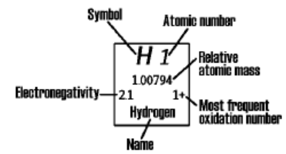
10. (2 points)

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

H_2, H_2^- and H_2^{2-}

H_2^{2-} H_2^- H_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
1	*H 1* 1.00794 2.1 1+ Hydrogen								
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium							
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium							
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
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** 101.07 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium
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
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

	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1									*He 2* 4.002602 - - Helium
2				**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				**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	**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	**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	**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	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
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

6	**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	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}	$J \cdot s$
Speed of Light	c	2.99792458×10^{8}	$m \cdot s^{-1}$

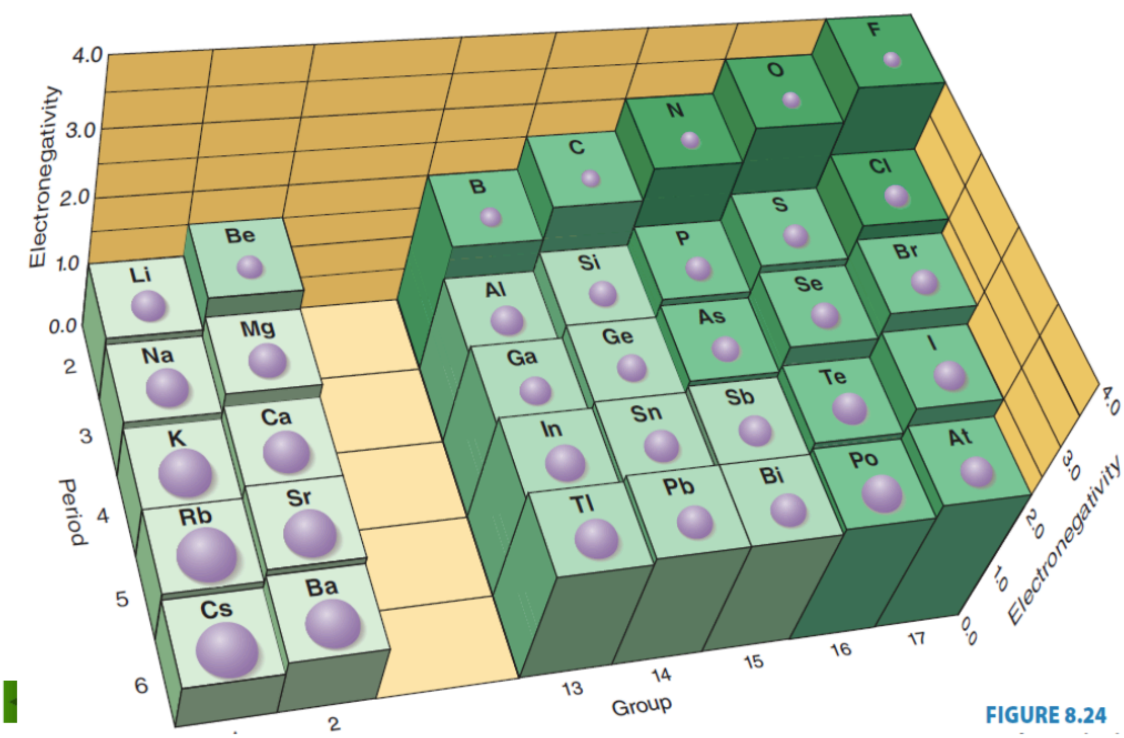


FIGURE 8.24

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

$\Delta U = q + W$

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

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

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

$q = ms\Delta T$

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

The atom

$E = h\nu$

$c = \nu\lambda$

$E = -B/n^2$

Kinetics

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

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

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

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

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