Instructions:

1. **<u>Put your name on this exam paper!!!</u>** Questions are to be answered directly on these papers.
2. Allowed external materials: calculator (any type)
3. Print or write legibly!
4. The final 2 sheets of this exam paper are a periodic table and a formula sheet. Feel free to remove them if desired.
5. There are xxx points on the exam. Time allowed = 55 minutes.
6. Multiple choice to be answered on the 1st page (like Midterm 1)

NOTE: Almost all of these could be asked as multiple choice. Obviously, on the real exam, you will have more room to fill in the full solution! These examples will take longer than the actual midterm.

1. A particular X-ray microscope can measure the position of a particle to within 5.0×10^{-11} m. What is the minimum error in the momentum (mv)?

   (a) 1.1×10^{-24} kg m s^{-1}

   (b) 4.2×10^{-23} kg m s^{-1}

   (c) 1.1×10^{-44} kg m s^{-1}

   (d) 2π

   (e) $h/2\pi$

2. Draw Lewis structures for the following (including resonance and formal charges if necessary). Note that in both cases, the central atom does not obey the octet rule.

   (a) $POCl_3$ (b) SO_3^{2-}

3. Predict the Valence-Shell Electron-Pair Repulsion (VSEPR) Theory shape of the molecules in #2. For 2(b), predict the direction of the dipole moment (if any).

4. What is this orbital?

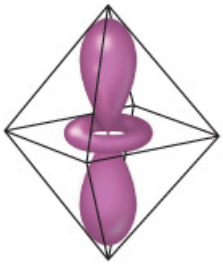
   (a) $3p_y$

   (b) $3p_x$

   (c) $3d_{z2}$

   (d) $3d_{xy}$

   (e) $3s$



5. Explain the term “bidentate” (referring to a ligand).

6. Give a valid set of quantum numbers for an *electron* (4 quantum numbers!) in the following orbitals: 3*d*, 5*f*, 2*s*.

7. Predict the colour of the hydrogen emission line for the transition between the n = 4 and n = 2 energy levels.

8. Balance the following nuclear equations by supplying the missing particle (in these cases, only 1 particle is missing). Note the following shorthand conventions:
   ${}^{0}_{1}e$ (positron), ${}^{0}_{-1}e$ (β-particle), ${}^{1}_{0}n$ (neutron), ${}^{4}_{2}He$ (α-particle).
   Note that the solution isn't necessarily one of these 4 particles!

   (a) $^{222}Rn \rightarrow {}^{218}Po + \_\_\_\_\_$

   (b) $^{238}U + {}^{12}C \rightarrow \_\_\_\_\_ + 6\ {}^{1}n$

9. Calculate the energy released in the nuclear reactions given in Question 8. Nuclear exact masses are as follows: ^{222}Rn (222.0175777), ^{218}Po (218.0089730), ^{4}He (4.002603254), ^{238}U (238.0507882), ^{12}C (12 (exact)), ^{244}Cf (244.066001), ^{1}n (1.00866).

10. What is the oxidation state of vanadium in $H_2V_2O_5$?

    (a) -2
    (b) 0
    (c) 2
    (d) 4
    (e) 5

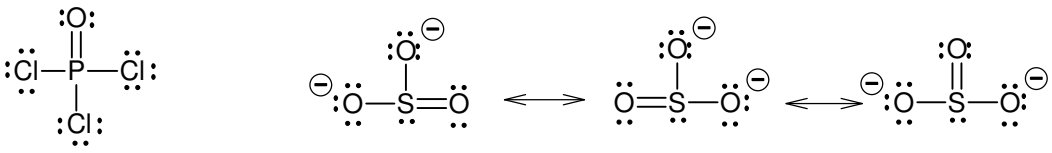
11. $CoCl_6^{4-}$ is a high spin octahedral complex. Show the *d*-orbital splitting in an octahedral complex, and say how many unpaired electrons the complex has.

12. Explain why atomic radius decreases as you go left to right across the periodic table.

13. Arrange the following in order of *increasing* electronegativity: N, Zr, F, Cu

SOLUTIONS

1. (a)

2. 

3. 

"tetrahedral" geometry "trigonal pyramidal" geometry

4. (c)

5. "Bidentate" refers to a ligand that has two binding sites (lone pairs) on two different atoms.

6. 3*d* must have $n = 3$ and $l = 2$; m_l can be any of -2, -1, 0, +1, or +2; m_s can be +½ or -½

   5*f* must have $n = 5$ and $l = 3$; m_l can be any of -3, -2, -1, 0, 1, 2, or 3; m_s can be +½ or -½

   2*s* must have $n = 2$, $l = 0$, and $m_l = 0$; m_s can be +½ or -½

7. $$\Delta E = -2.178 \times 10^{-18}\,\text{J}\left(\frac{1}{n_{\text{final}}^2} - \frac{1}{n_{\text{initial}}^2}\right) \quad = -2.178\times10^{-18}\text{J}(1/4^2 - 1/2^2) = -4.08\times10^{-19}\text{J}$$

   (note, the way the question is worded, either + or – answer is correct)

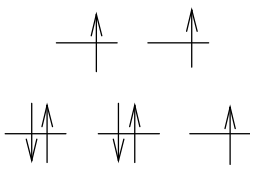
8. (a) ${}_2^4\text{He}$ (or ${}^4\text{He}$ is sufficient) (b) ${}^{244}\text{Cf}$

9. (a) $E = (0.004002603254 + 0.2180089730 - 0.2220175777)(3.00\times10^8)^2 = -5.40\times10^{11}$

   (b) $E = (0.24406600 + 6*0.00100866 - 0.2380507882 - 0.0120000000)(3.00\times10^8)^2$
   $= 6.05\times10^{12}$

10. (d)

11. Co is 2+, therefore 7 electrons remaining in the *d*-orbitals; this will give it 3 unpaired electrons, as drawn.



12. Electrons in each shell will shield the electrons of higher energy, but they do not effectively shield electrons of the same energy. Therefore, as you go right to left, you have the same number of core electrons but increasing charge on the nucleus (called increasing effective nuclear charge). The electrons in the valence shell therefore see increasing nuclear charge (and don't see each other), so they are drawn closer to the nucleus, therefore size decreases.

13. Zr < Cu < N < F

Appendix 1: Formula Sheet

$PV = nRT$

$P_{total} = P_1 + P_2 + ...$

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

$$\bar{u} = \sqrt{\frac{3RT}{M_m}}$$

$$\frac{\text{rate}_A}{\text{rate}_B} = \frac{\bar{u}_A}{\bar{u}_B} = \frac{\sqrt{M_{mB}}}{\sqrt{M_{mA}}}$$

$$\ln \frac{N_t}{N_0} = -kt$$

$$t_{1/2} = \frac{\ln 2}{k}$$

$E = mc^2$

$c = \lambda\nu \ (= \lambda f)$

$E = h\nu \ (= hf)$

$$\bar{E}_k = \frac{1}{2} m \bar{u}^2$$

$$\Delta E = -2.178 \times 10^{-18} \text{J} \left(\frac{1}{n^2_{\text{final}}} - \frac{1}{n^2_{\text{initial}}} \right)$$

$$\lambda = \frac{h}{mv}$$

$A = \epsilon bc$

$(\Delta x)(\Delta(mv)) \geq {}^{h}/_{4\pi}$

Constants:

$h = 6.626 \times 10^{-34}$ J s

$c = 2.9979 \times 10^{8}$ m/s

joules = kg m^2 s^{-2}

0EC = 273.15 K

$N_A = 6.022 \times 10^{23}$ mol^{-1}

1 atm = 101.325 kPa = 760.00 Torr

mass of an electron: 0.000549 amu (g/mol)

mass of a proton: 1.00728 amu

mass of a neutron: 1.008665 amu

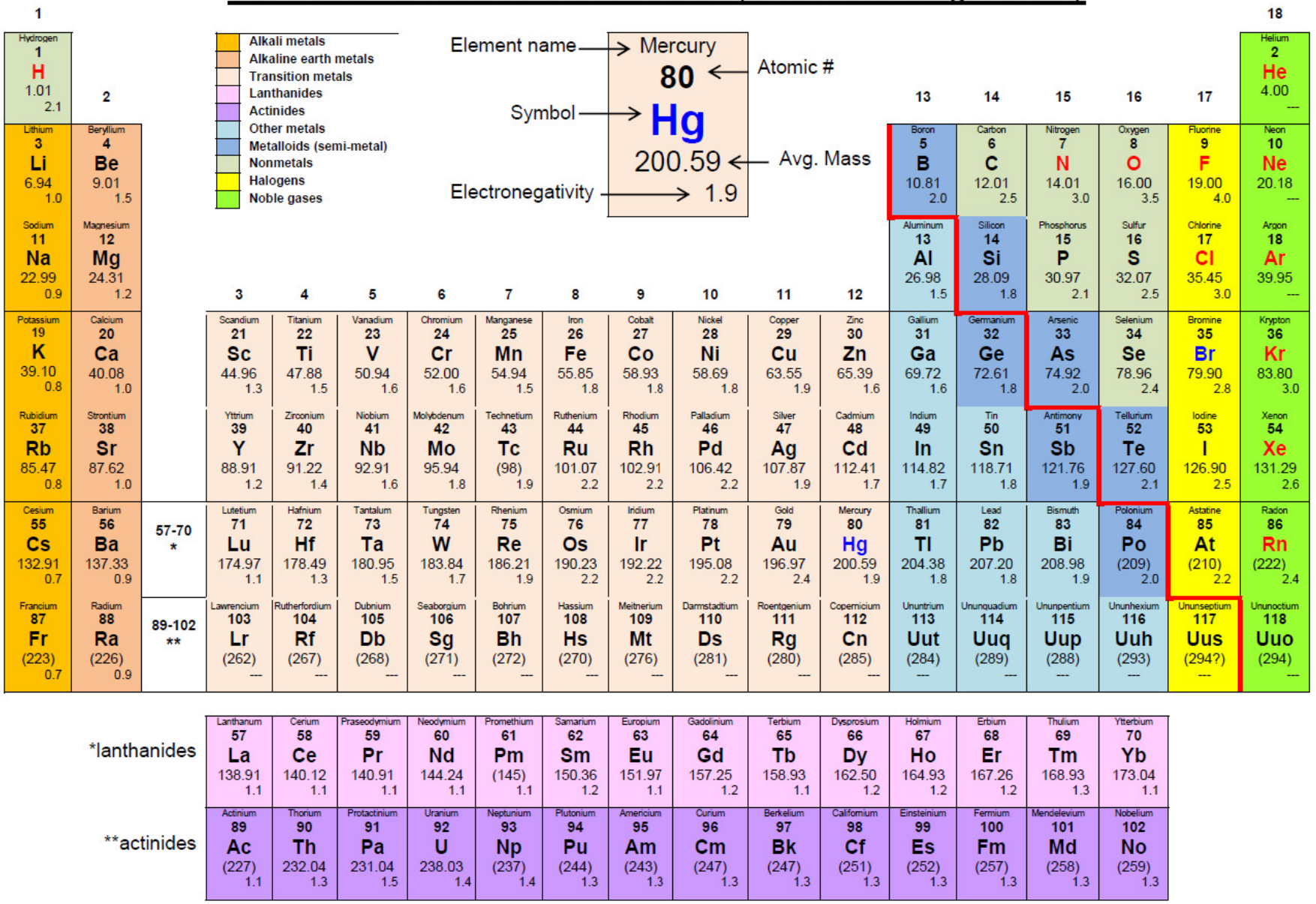
elementary charge (e) = 1.60218×10^{-19} C

$R = 8.314$ J mol^{-1} K^{-1} = 8.314 L Pa mol^{-1} K^{-1} = 0.08206 L atm mol^{-1} K^{-1}

STP = 1 atm, 0°C

kilo = 10^3 centi = 10^{-2} milli = 10^{-3} micro = 10^{-6} nano = 10^{-9} pico = 10^{-12}

The Periodic Table of the Elements (with Electronegativities)



1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 H 1.01 2.1																		Helium 2 He 4.00 ---
Lithium 3 Li 6.94 1.0	Beryllium 4 Be 9.01 1.5												Boron 5 B 10.81 2.0	Carbon 6 C 12.01 2.5	Nitrogen 7 N 14.01 3.0	Oxygen 8 O 16.00 3.5	Fluorine 9 F 19.00 4.0	Neon 10 Ne 20.18 ---
Sodium 11 Na 22.99 0.9	Magnesium 12 Mg 24.31 1.2												Aluminum 13 Al 26.98 1.5	Silicon 14 Si 28.09 1.8	Phosphorus 15 P 30.97 2.1	Sulfur 16 S 32.07 2.5	Chlorine 17 Cl 35.45 3.0	Argon 18 Ar 39.95 ---
Potassium 19 K 39.10 0.8	Calcium 20 Ca 40.08 1.0		Scandium 21 Sc 44.96 1.3	Titanium 22 Ti 47.88 1.5	Vanadium 23 V 50.94 1.6	Chromium 24 Cr 52.00 1.6	Manganese 25 Mn 54.94 1.5	Iron 26 Fe 55.85 1.8	Cobalt 27 Co 58.93 1.8	Nickel 28 Ni 58.69 1.8	Copper 29 Cu 63.55 1.9	Zinc 30 Zn 65.39 1.6	Gallium 31 Ga 69.72 1.6	Germanium 32 Ge 72.61 1.8	Arsenic 33 As 74.92 2.0	Selenium 34 Se 78.96 2.4	Bromine 35 Br 79.90 2.8	Krypton 36 Kr 83.80 3.0
Rubidium 37 Rb 85.47 0.8	Strontium 38 Sr 87.62 1.0		Yttrium 39 Y 88.91 1.2	Zirconium 40 Zr 91.22 1.4	Niobium 41 Nb 92.91 1.6	Molybdenum 42 Mo 95.94 1.8	Technetium 43 Tc (98) 1.9	Ruthenium 44 Ru 101.07 2.2	Rhodium 45 Rh 102.91 2.2	Palladium 46 Pd 106.42 2.2	Silver 47 Ag 107.87 1.9	Cadmium 48 Cd 112.41 1.7	Indium 49 In 114.82 1.7	Tin 50 Sn 118.71 1.8	Antimony 51 Sb 121.76 1.9	Tellurium 52 Te 127.60 2.1	Iodine 53 I 126.90 2.5	Xenon 54 Xe 131.29 2.6
Cesium 55 Cs 132.91 0.7	Barium 56 Ba 137.33 0.9	57-70 *	Lutetium 71 Lu 174.97 1.1	Hafnium 72 Hf 178.49 1.3	Tantalum 73 Ta 180.95 1.5	Tungsten 74 W 183.84 1.7	Rhenium 75 Re 186.21 1.9	Osmium 76 Os 190.23 2.2	Iridium 77 Ir 192.22 2.2	Platinum 78 Pt 195.08 2.2	Gold 79 Au 196.97 2.4	Mercury 80 Hg 200.59 1.9	Thallium 81 Tl 204.38 1.8	Lead 82 Pb 207.20 1.8	Bismuth 83 Bi 208.98 1.9	Polonium 84 Po (209) 2.0	Astatine 85 At (210) 2.2	Radon 86 Rn (222) 2.4
Francium 87 Fr (223) 0.7	Radium 88 Ra (226) 0.9	89-102 **	Lawrencium 103 Lr (262) ---	Rutherfordium 104 Rf (267) ---	Dubnium 105 Db (268) ---	Seaborgium 106 Sg (271) ---	Bohrium 107 Bh (272) ---	Hassium 108 Hs (270) ---	Meitnerium 109 Mt (276) ---	Darmstadtium 110 Ds (281) ---	Roentgenium 111 Rg (280) ---	Copernicium 112 Cn (285) ---	Ununtrium 113 Uut (284) ---	Ununquadium 114 Uuq (289) ---	Ununpentium 115 Uup (288) ---	Ununhexium 116 Uuh (293) ---	Ununseptium 117 Uus (294?) ---	Ununoctium 118 Uuo (294) ---

*lanthanides	Lanthanum 57 La 138.91 1.1	Cerium 58 Ce 140.12 1.1	Praseodymium 59 Pr 140.91 1.1	Neodymium 60 Nd 144.24 1.1	Promethium 61 Pm (145) 1.1	Samarium 62 Sm 150.36 1.2	Europium 63 Eu 151.97 1.1	Gadolinium 64 Gd 157.25 1.2	Terbium 65 Tb 158.93 1.1	Dysprosium 66 Dy 162.50 1.2	Holmium 67 Ho 164.93 1.2	Erbium 68 Er 167.26 1.2	Thulium 69 Tm 168.93 1.3	Ytterbium 70 Yb 173.04 1.1
**actinides	Actinium 89 Ac (227) 1.1	Thorium 90 Th 232.04 1.3	Protactinium 91 Pa 231.04 1.5	Uranium 92 U 238.03 1.4	Neptunium 93 Np (237) 1.4	Plutonium 94 Pu (244) 1.3	Americium 95 Am (243) 1.3	Curium 96 Cm (247) 1.3	Berkelium 97 Bk (247) 1.3	Californium 98 Cf (251) 1.3	Einsteinium 99 Es (252) 1.3	Fermium 100 Fm (257) 1.3	Mendelevium 101 Md (258) 1.3	Nobelium 102 No (259) 1.3