Lakehead
UNIVERSITY

DEPARTMENT OF CHEMISTRY
Sample Midterm Questions
Chemistry 1110 (Modern Chemistry I)

Name: _____

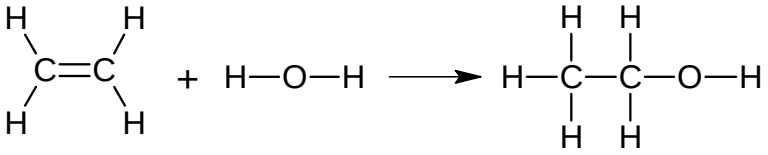
Student ID Number:_____

Instructions:

1. **Put your name on this exam paper!!!** 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.

NOTE: Some of these could be asked as multiple choice too. Obviously, on the real exam, you will have more room to fill in the full solution! These questions are longer than the actual midterm would be!

1. Water-free ethanol can be made by the following synthetic route,

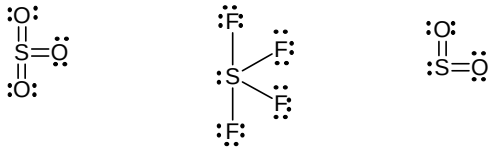


estimate $\Delta H°$ for the reaction from the bond enthalpies supplied (see Table 8.4).

2. Draw Lewis structures for the following (including resonance and formal charges if necessary),

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

3. Predict the Valence-Shell Electron-Pair Repulsion (VSEPR) Theory shape of the following:



4. Draw the following orbitals (include the axis system you are using): p_x, s, d_{xz}.

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

6. 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! (4 points)

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

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

7. Calculate the energy released in the nuclear reactions given in Question 6. 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).

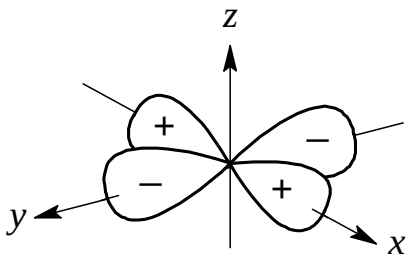
8. Predict the colour of the hydrogen emission line for the transition between the n = 4 and n = 2 energy levels.

9. Iron workers temper their metals by repeatedly heating the metal (in a charcoal flame) and cooling in a bucket of water. A wrought-iron candelabra, mass 550. g at a temperature of a charcoal flame (1400. K) is dunked into a bucket containing 10.00 L of water at 0°C. Recalling that water has a density of (exactly) 1 g/mL, what is the final temperature of the water and iron? Specific heats are: $s_{water} = 4.18\ J\ K^{-1}\ g^{-1}$; $s_{iron} = 0.45\ J\ K^{-1}\ g^{-1}$.

Okay, here's some real multiple choice questions:

Question 10:

(i) What is this orbital?



(a) $3p_y$

(b) $3p_x$

(c) $3d_{x^2-y^2}$

(d) $3d_{xy}$

(e) $3s$

(ii) 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) $h/2\pi$

(iii) Radon-222 ($^{222}_{86}\mathrm{Rn}$) has a half-life of 3.82 minutes and decays by α-emission. What is the daughter nucleus?

(a) not enough information given (need to know the angular momentum)

(b) $^{218}_{84}\mathrm{Po}$

(c) $^{222}_{85}\mathrm{At}$

(d) $^{222}_{86}\mathrm{Rn}$ $\quad (+\ ^{0}_{0}\gamma)$

(e) $^{222}_{87}\mathrm{Fr}$

(iv) Element number 116 has been temporarily named ununhexium (Uuh). It has an electron configuration [Rn]5f^{14} 6d^{10} 7s^2 7p^4. What is likely to be the most stable ion?

(a) Uuh^{+3}

(b) Uuh^{+2}

(c) Uuh^{+1}

(d) Uuh^{-1}

(e) Uuh^{-2}

(v) Iron ore (hematite) is converted to iron metal by the reaction:

$$2\ Fe_2O_3\ (s)\ +\ 2\ C\ (s)\ \rightarrow\ 4\ Fe\ (s)\ +\ 3\ CO_2\ (g)$$

Calculate the standard enthalpy of the reaction (as written) if ΔH_f° of Fe_2O_3 (*s*) is -826 kJ/mol and that of CO_2 (*g*) is -393.5.

(a) 433 kJ/mol

(b) 472 kJ/mol

(c) -433 kJ/mol

(d) -472 kJ/mol

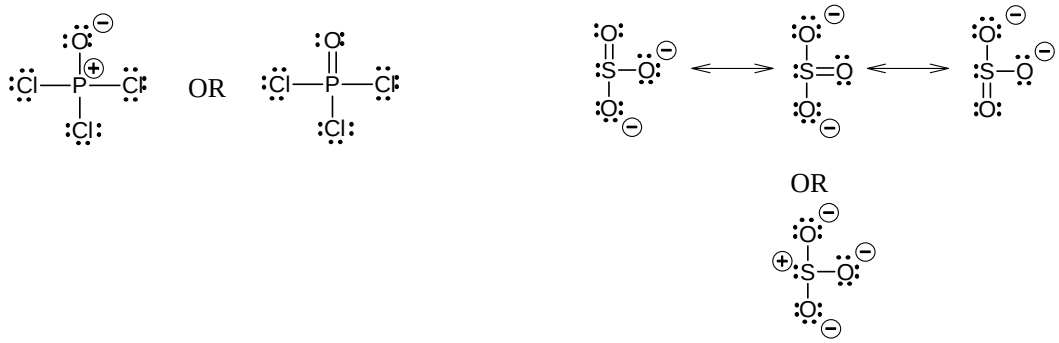
(e) -1220. kJ/mol

SOLUTIONS

1. (using the textbook values from Table 8.4)

Bonds "broken" =	4 C-H	1 C=C	2 O-H	
=	4(413) +	614 +	2(467) =	3200 kJ/mol
Bonds "created" =	5 C-H	1 C-C	1 C-O	1 O-H
	5(-413) +	(-347) +	(-358) +	(-467) = -3237 kJ/mol

Therefore, $\Delta H° \approx 3200 + (-3237) = -37$ kJ/mol

2. 

3. (a) effectively 3 pairs (double bonds = 1 pair), no lone pairs = trigonal planar

(b) 5 electron pairs, 1 lone pair = see-saw

(c) effectively 3 pairs, 1 lone pair = bent

4. see Figure 7.14, 7.15, and 7.17

5. 3*d*: $n = 3$, $l = 2$; m_l can be any of -2, -1, 0, 1, or 2; m_s can be either ½ or -½
5*f*: $n = 5$, $l = 3$; m_l can be any of -3, -2, -1, 0, 1, 2, or 3; m_s can be either ½ or -½
2*s*: n = 2, l = 0, $m_l = 0$; m_s can be either ½ or -½

6. (a) $^{4}_{2}\text{He}$ (b) $^{244}_{98}\text{Cf}$

7. (a) $\Delta m = 218.0089730 + 4.002603254 - 222.0175777 = -0.0060014$ g/mol $= -6.0014 \times 10^{-6}$ kg
$E = mc^2 = (-6.0014 \times 10^{-6}\text{ kg/mol})(2.998 \times 10^{8}\text{ m/s})^2 = -5.394 \times 10^{11}$ J/mol

(b) $\Delta m = 244.066001 + 6(1.00866) - 238.0507882 - 12 = 0.06719$ g/mol $= 0.00006719$ kg/mol
$E = mc^2 = (0.00006719\text{ kg/mol})(2.998 \times 10^{8}\text{ m/s})^2 = 6.039 \times 10^{12}$ J/mol

8. $$\Delta E = -2.178 \times 10^{-18}\,\text{J}\left(\frac{1}{n_{\text{final}}^2} - \frac{1}{n_{\text{initial}}^2}\right) = -2.178 \times 10^{-18}\,\text{J}\left(\frac{1}{4^2} - \frac{1}{2^2}\right) = 4.084 \times 10^{-19}\,\text{J}$$

$E = hc/\lambda$ or $\lambda = hc/E = (6.626\times10^{-34})(2.998\times10^{8})/4.084\times10^{-19} = 4.86\times10^{-7}$m=486nm=blue or green

9. The two final temperatures must be the same (if they weren't there would be a temperature gradient and heat would continue to flow between them!). Thus, using $q = sm\Delta T$, and noting that $q_{H2O} = -q_{Fe}$,

10.00 L of water = 10 000 mL = 10 000 g H_2O

note that this can be done in °C or K (actually in °C is easier because you cancel a term with the 0°C). In K,
(4.18 J/Kg)(10000 g)(T_f - 273.K) = -(0.45 J/Kg)(550. g)(T_f - 1400.K)

rearranged and solved for T_f = 280 K (or 6.6°C)

10. (i) c (ii) a (iii) b (iv) e (v) b

Formula Sheet:

$V \propto \frac{1}{P}$

$V \alpha n$

$V \alpha T$

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

$PV = nRT$

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

$q = s\, m\, \Delta T$

$q = C_p\, \Delta T$

$\Delta H = q_p = \Delta E + P\Delta V$

$E = mc^2$

$t_{½} = (\ln 2) / k$

$\ln\left(\frac{N}{N_0} \right) = -kt$

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

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

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

$\lambda = \frac{h}{mv}$ (v = velocity)

$\Delta x \cdot \Delta mv \geq \frac{h}{4\pi}$

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

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

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

$\hat{H}\Psi = E\Psi$

<u>constants</u>:

R = 0.08206 L atm/(mol K) = 8.315 kPa dm^3/(mol K) = 8.315 J/(mol K) = 62.36 Torr L/(mol K)

1.000 atm = 760. Torr = 101.3 kPa

kilo = 10^3

centi = 10^{-2}

milli = 10^{-3}

nano = 10^{-9}

pico = 10^{-12}

N_A = 6.022 x 10^{23} mol^{-1}

c = 2.998 x 10^8 m/s

h = 6.626 x 10^{-34} J s

Pa = N m^{-2}

N = kg m s^{-2}

J = N m = kg m^2 s^{-2}

STP = 1.0000 atm pressure and 273.15 K

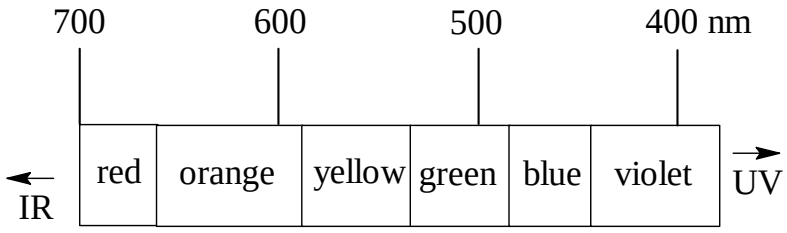
standard conditions = 1.00000 atm, 1.00000 M, and 298.15 K

rest mass of proton = 1.67262 x 10^{-27} kg

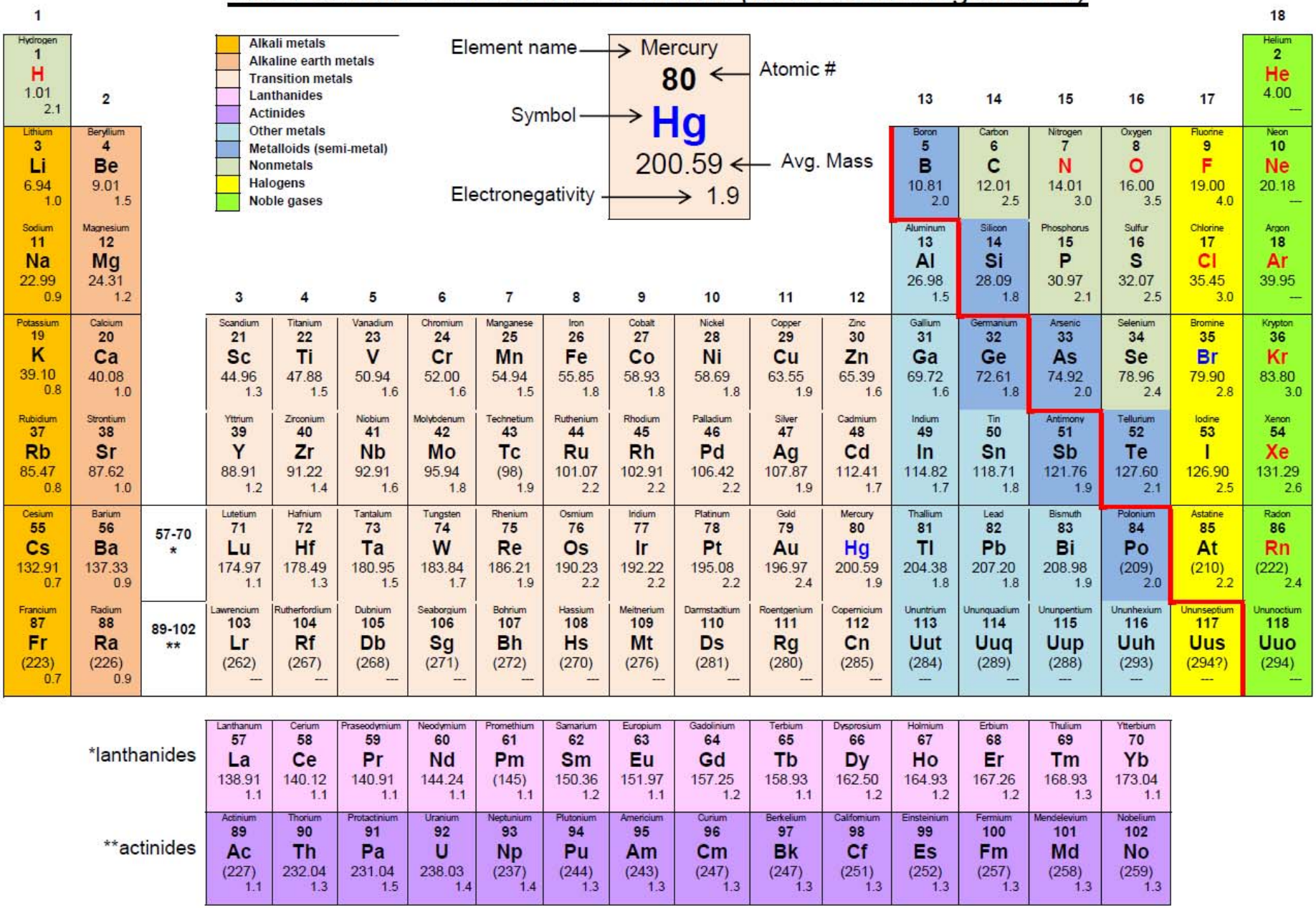
rest mass of neutron = 1.67493 x 10^{-27} kg

rest mass of an electron (m_e) = 9.10939 x 10^{-31} kg

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



The Periodic Table of the Elements (with Electronegativities)



1																	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	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	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