CHM 2045
FIRST PROBLEM SET

INSTRUCTOR: DON SWIETER **OFFICE: K–223** **PHONE: 395–5303**

MATH REVIEW and SIGNIFICANT FIGURE QUESTIONS

1. Perform the indicated algebra: (For help see the appendices in your text.)

   a. $a^m \times a^n =$ b. $a^{(m+3)} \div a^{(2m+2)} =$ c. $a^0 =$ d. $a^{-2} =$

   e. Since $a^{1/4} = \sqrt[4]{a}$, what does $a^{1/n} = ?$

2. How many significant figures are in each of the following?

   a. 9 baseballs   b. 90 baseballs   c. 9,000,000 baseballs
   d. 3 dozen ostrich eggs   e. 0.1 cm   f. 100.10 cm
   g. 1.01 in.   h. 0.005 g   i. 0.00500 g

3. Rewrite the values in problem 2 e-i in suitable scientific notation.

4. Do the indicated arithmetic paying strict attention to significant figures and units.

   a. 0.034 cm + 0.0340 cm   b. 0.034 cm × 0.0340 cm   c. 0.034 cm – 0.0340 cm
   d. 0.034 cm ÷ 0.034 cm   e. 0.034 cm – 0.0034 cm

5. Perform the following calculations and report the answer to the proper number of significant figures (without the aid of a calculator):

   a. 9.75 in + 0.326 in   b. 1.025 sec – 0.09 sec   c. $(1.61 \times 10^{15}\ \text{A}) + (1.61 \times 10^{16}\ \text{A})$

   d. $(5.6 \times 10^{-2}\ \text{m})^2$ e. $\sqrt[3]{4 \times 10^5\ \text{g} \times 3 \times 10^{-3}\ \text{g}}$

6. Perform the following SI conversions making proper use of unit conversion analysis:

   a. 971 mg = kg   b. 82 s = ms   c. $12.3\ \text{cm}^2 = \text{mm}^2$

   d. $0.213\ \text{L} = \text{cm}^3$ e. $6.50\ \text{m}^{-1} = \text{cm}^{-1}$ f. 7.61 kg/L = mg/mL

7. You are given 1000 equal sized gem stones with a total mass of exactly 3 g. These gems are valued at $1000 per oz. (Note: 1.00 oz = 28.35 g) Answer the following using unit – factor analysis.

   a. How much money are you out if you lose 50 stones?

   b. If you now receive an additional handful of these gems, how would you determine the value of this handful by weighing? Tell exactly how you would go about it.

   c. Could you determine the value of this handful by a counting procedure? What assumption would the counting procedure depend upon?

8. A circular cheese pizza with a 10" diameter sells for $5.00. The same pizza with a 14" diameter sells for $10.00. Which is the better buy? (Remember: area of a circle = πr^2)

9. Medium thin-rind grapefruit (diam. = 2.0") sell for 10¢ each. Large thin-rind grapefruit (diam. = 3.0") sell for 20¢ each. Consider the fruit to be spherical. Which is the better buy? (Remember: volume of a sphere = $4/3\pi r^3$)

QUESTIONS ON MATTER and ENERGY

10. What are the general properties of metals and where are they found in the periodic table?

11. What are the general properties of nonmetals and where are they found in the periodic table?

12. Characterize each of the following as a physical or chemical process:
    a. copper wire produced from a bar of copper
    b. the attraction of an iron nail by a magnet
    c. dissolving sugar in water
    d. vaporization of water from a lake
    e. combustion of coal
    f. heating the filament of an incandescent lamp to provide light
    g. crystallization of sodium carbonate from water
    h. dissolving an Alka-Seltzer in water
    i. silver tarnishing in air

13. Suppose I define a new temperature scale (Hokie, °H) where the freezing point of H_2O is –40°H and the boiling point of H_2O is 320°H.

    To what temperature in °C does 100°H correspond? From a significant figure standpoint, which scale the °H or the °C more precisely defines the temperature? Why?

14. Classify the following processes as endothermic or exothermic:
    a. melting of ice   b. evaporation of alcohol   c. combustion of methane
    d. frying an egg   e. carbohydrates metabolized by the body

15. When washing soda (Na_2CO_3) is stirred into H_2O initially at 25°C the temperature of the resulting solution is greater than 25°C. Is the dissolution process exothermic or endothermic? Explain.

QUESTIONS ON DENSITY

16. A cube with edge = 1.00" of an unknown pure substance has a mass of 10.0 oz. What is the density of this substance in g/mL? In kg/L? (Remember: 1 mL = 1 cc exactly and 1.00 oz = 28.35 g)

17. Osmium is the densest element known. What is the density of osmium if 2.72 g of osmium has a volume of 0.121 mL?

18. What is the mass of 125 mL of chlorine gas if the density of chlorine gas is 3.16 g/L?

19. What is the volume of 11.3 g of graphite (carbon) which has a density of 2.25 g/cm^3?

20. Determine the density of a block of metal weighing 20.12 g which when immersed in water contained in a graduated cylinder causes the water level to rise from 15.5 mL to 21.6 mL.

21. A graduated cylinder has a mass of 57.832 g. An organic liquid, toluene, with a density of 0.866 g/cm^3 is added until the combined mass reads 87.127 g. What is the volume of the liquid in the graduated cylinder?

QUESTIONS ON FUNDAMENTAL LAWS OF CHEMISTRY

22. If 16.0 g of oxygen react completely with 2.0 g of hydrogen to produce water, what mass of water is produced? What natural law are you using to determine the mass of the water?

    If 4.0 g of oxygen are reacted with 2.0 g of hydrogen to produce water and leftover hydrogen, what mass of hydrogen is leftover? What is the mass of water produced? On what natural laws are your responses based?

23. Consider these hypothetical examples of the work of John Dalton on the mythical elements Gazook (G) and Mudd (M) under differing experimental conditions:

    a. 1.00 g G + 3.00 g M $\longrightarrow$ 4.00 g of a new pure stuff, Compound I

    b. 1.00 g G + 6.00 g M $\longrightarrow$ 7.00 g of another pure stuff, Compound II

    c. 1.00 g G + 9.00 g M $\longrightarrow$ 10.00 g of yet another pure stuff, Compound III

    i) What natural law can be used to derive simplest formulas for the products from these data?

    ii) Now, for a, b, and c respectively, what are the SIMPLEST formulas for the products that are consistent with the data?

    iii) If GM_2 is an acceptable formula for compound I, what are acceptable formulas for the other products?

    iv) If G_2M_5 is an acceptable formula for compound I, what are acceptable formulas for the other products?

    v) If GM is an acceptable formula for compound II, what are acceptable formulas for the other products?

QUESTIONS ON FUNDAMENTAL SUBATOMIC PARTICLE

24. J. J. Thomson showed that cathode ray tubes could be constructed using many different metals as the cathodic electrode material.

    How do the results of the Thomson experiments support the theory that cathode rays (or electrons as they are known today) are fundamental particles of all matter?

    What did his experiments show about canal rays?

25. Why could neutrons not be isolated and detected by the same methods that had been used to characterize electrons and protons?

26. A student repeats Millikan's oil drop experiment in order to determine the charge on the electron. The results were:

Droplet	Calculated charge
A	-9.6132×10^{-19} C
B	-14.4198×10^{-19} C
C	-4.8066×10^{-19} C
D	-19.2264×10^{-19} C

a. From these four pieces of data, what is the **LARGEST** acceptable value for the charge on the electron? Explain.

b. Now reconsider the data. Could the value of -2.4033×10^{-19} C also be an acceptable value? Explain.

27. The charge/mass (e/m) ratio for an electron is -1.76×10^{8} C/g and this ratio for a proton is $+9.58 \times 10^{4}$ C/g. Use these data to show why chemists may consider an electron to be essentially massless. (Hint. Calculate the ratio of the mass of an electron to the mass of a hydrogen atom.)

28. It is now known that static electric charges are caused by the transfer of electrons.

a. How many excess electrons are present on an object with a charge of -5.5×10^{-15} C?

b. How many electrons are deficient from an object with a net charge of $+6.4 \times 10^{-12}$ C?

29. What is the net charge, in coulombs, associated with 1.00×10^{12}:

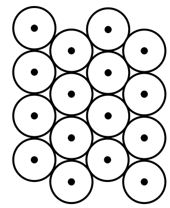
a. hydrogen atoms ($^{1}_{1}H$)? b. fluoride ions (F^{-})? c. $^{22}_{10}Ne^{+2}$ ions?

30. Why is it important to use a very thin foil for the Rutherford experiment?

31. Calculate the density of matter in a proton using Rutherford's estimate of the diameter of a proton of 1.5×10^{-13} cm. The mass of a free proton is about 1.67×10^{-24} g. Assume the nucleus is a sphere ($V = 4/3\pi r^3$). Compare this density with the density of osmium metal (the densest element) which is 22 g/cm^3). Comment about the amount of "empty space" in an atom.

32. Consider that the gold foil used in the Rutherford experiment was 4×10^{-4} cm thick. If Au has an atomic radius of 1.4 Å, on the average through how many Au atoms did each alpha particle (α) pass? (Refer to diagram at right.)

Packing of Atoms in gold foil



33. Complete the following table:

Elemental Symbol	Number of Protons	Number of Neutrons	Number of Electrons	Charge on Species	Name
$^{190}_{78}\text{Pt}$					
$^{41}_{20}\text{Ca}^{+2}$					
$^{223}_{87}\text{Fr}$					
$^{139}_{53}\text{I}^{-1}$					
$^{3}_{2}\text{He}$					
		7	6		Carbon Thirteen
	14	15		0	
		18	18	–2	
	26	30	23		
		118	76	+3	

34. Although the symbol $^{35}_{17}\text{Cl}$ may be preferred to the simpler ^{35}Cl, can you explain why the two actually convey the same information? Do the symbols $^{35}_{17}\text{Cl}$ and $_{17}\text{Cl}$ have the same meaning?

35. Are the two atoms described by ^{60}X and ^{60}Y atoms of the same element?

36. The mass numbers of the isotopes of hydrogen, called protium, deuterium, and tritium, are 1, 2, and 3, respectively. What are the basic differences in these types of hydrogen atoms?

37. Explain why ^{18}O and ^{16}O have essentially identical chemical properties.

38. The mass of a $^{12}_{6}\text{C}$ atom is taken to be exactly 12 amu. Are there likely to be any other nuclides with an exact integral (whole number) mass, expressed in amu? Explain.

39. Determine the average atomic mass of the following elements given the natural isotopic distributions and absolute isotopic masses:

   a. Potassium, only two natural isotopes:
   ^{39}K; 38.9637 amu, 93.12% and ^{41}K; 40.974 amu, 6.880%

   b. Neon, three natural isotopes:
   ^{20}Ne, 19.99244 amu, 90.92% , ^{21}Ne, 20.99395 amu, 0.2570% and ^{22}Ne, 21.99138 amu, 8.820%

   c. Do any potassium or neon atoms exist with your calculated masses?

40. The element silver consists in nature of two isotopes, ^{107}Ag, with isotopic mass of 106.905 amu, and ^{109}Ag, with isotopic mass of 108.905 amu. The accepted atomic mass of Ag is 107.870 amu. From this calculate the relative amounts of ^{107}Ag and ^{109}Ag in nature.

QUESTIONS ON BONDING, IONS AND MOLECULES

41. What is the difference between an atom and a molecule?

42. What is the difference between an atom, a simple cation, and a simple anion?

43. What is the difference between a molecule and a polyatomic ion?

44. What is the difference between a covalent bond and an ionic bond?

45. Which of the following bonds are likely to be ionic and which covalent?

   a) Na to Cl bond b) C to H bond c) B to Cl bond d) O to Fe bond

46. Correct the following mis–statements.

   a) The formula for carbon dioxide is CO2.

   b) The molecule of H_2O contains one atom of hydrogen and two atoms of oxygen.

   c) The molecules of sodium chloride (table salt) have the formula of NaCl.

   d) Mg^{+2} is an anion.

   e) NH_3 (ammonia) is a polyatomic ion.

QUESTIONS ON MOLES, FORMULAS AND PERCENT COMPOSITION

47. Determine the molar mass in grams (the mass of one mole) for each of the following species. Carry each calculation to the maximum number of significant figures allowed by the data.
   a. Fe b. N_2O_4 c. $(NH_4)_3AsO_4$ d. CO_3^{-2}

48. Calculate the formula mass (the mass of one formula unit) in amu <u>and</u> in grams for those materials in question 47. (1 amu = 1.66054×10^{-24} g) Make sure that you know the difference between questions 47 and 48!

49. Carry out each of the conversions indicated via the unit – factor analysis approach.

a. 37.5 g H_2O to moles H_2O

b. 3.25×10^{-2} moles F^{-1} to g F^{-1}

c. 4.2 g I_2 to molecules I_2

d. 39.6 g $(NH_4)_2SO_4$ to formula units $(NH_4)_2SO_4$

e. 4.5×10^{25} molecules $C_6H_{12}O_6$ to grams $C_6H_{12}O_6$

f. 0.25 moles $CaCl_2$ to number of formula units $CaCl_2$

g. 6.26×10^{-3} moles Mg^{+2} to ions of Mg^{+2}

h. 4.5×10^{25} molecules S_8 to moles S_8

50. Calculate the percentage by mass composition of each element in each of the following compounds.

a. $K_2Cr_2O_7$

b. $C_{12}H_{22}O_{11}$

51. a. Calculate the mass percent of water in $ZnSO_4 \bullet 7H_2O$

b. Calculate the mass of nitrogen in 30.0 g of the amino acid, glycine, $NH_2CH_2CO_2H$

52. a. A compound composed of xenon and fluorine, was found to be 63.3% Xe and 36.7% F by mass. Calculate the empirical formula.

b. A new organic compound gave the following elemental analysis:
60.59% C and 7.12% H. Further analysis revealed oxygen to be the only other element present. Compute the empirical formula for this compound.

c. Titanium forms two compounds with oxygen. Given the elemental analysis for each compound, calculate the empirical formulas.

Cpd. I: 59.9% Ti, 40.1% 0

Cpd. II: 66.6% Ti, 33.4% 0

53. Given the following empirical formulas and molecular masses, calculate the molecular formulas:

Empirical Formula	Molecular mass, amu(±3%)
CH_2	71
CH_2O	88
$AlCl_3$	267

54. Determine the empirical formula, molecular formula, and correct molecular mass for each compound listed below:

a. C, 85.69%; H, 14.31% ; MM ≈ 56 amu (± 2% error)

b. C, 38.7%; H, 9.7%; O, 51.6% ; MM ≈ 60 amu ± 3 amu

c. C, 59.0%; H, 7.1%; O, 26.2% ; N, 7.7%; MM ≈ 182 amu ± 4 amu

d. C, 49.5%; H, 5.15%; N, 28.9% ; O, 16.5%; MM ≈ 195 amu ± 2 amu

e. C, 1.640 g; H, 0.1032 g; ;N, 0.4780 g; O, 1.365 g ; MM ≈ 420 ± 20 amu

QUESTIONS ON STOICHIOMETRY AND WRITING SIMPLE EQUATIONS

55. Balance the following chemical reactions by inspection.
    a. $Mg\ (s) + N_2\ (g) \longrightarrow Mg_3N_2\ (s)$
    b. $Bi^{+3}\ (aq) + H_2S\ (g) + H_2O\ (\ell) \longrightarrow Bi_2S_3\ (s) + H_3O^+\ (aq)$
    c. $Al\ (s) + H_3O^+\ (aq) \longrightarrow Al^{+3}\ (aq) + H_2\ (g) + H_2O\ (\ell)$
    d. $C_8H_{18}\ (\ell) + O_2\ (g) \longrightarrow CO_2\ (g) + H_2O\ (\ell)$
    e. $CO_3^{-2}\ (aq) + NO\ (g) + O_2\ (g) \longrightarrow NO_2^-\ (aq) + CO_2\ (g)$
    f. $HCO_3^-\ (aq) + Cu^{+2}\ (aq) \longrightarrow CuCO_3\ (s) + CO_2\ (g) + H_2O\ (\ell)$
    g. $P_4O_{10} + H_2O \longrightarrow H_3PO_4$
    h. See handout on balancing for more and harder problems.

56. Write statements using the terms, atoms, ions, molecules, and/or formula units, as appropriate, to describe the information given to a chemist by equations (a), (b), and (c) in problem 55 above.

57. Produce the balanced chemical equation for each.
    a. Sodium metal and chlorine gas react to form solid sodium chloride.
    b. Carbon and oxygen gas react to yield carbon monoxide gas.
    c. Carbon and oxygen gas react to yield carbon dioxide gas.
    d. Potassium metal and liquid water react to form H_2 gas and aqueous potassium and hydroxide ions.
    e. Hydrogen and nitrogen gas react to form ammonia.
    f. The liquids, dichlorine heptoxide, Cl_2O_7, and H_2O combine to give aqueous H_3O^+ and ClO_4^- ions.
    g. Hydrogen gas reacts with Fe_3O_4 yielding iron metal and liquid water.
    h. Iron (II) persulfide (FeS_2) and oxygen gas yield iron (III) oxide and sulfur dioxide gas.

58. Write equations for the following transformations:
    a. Iron reacts with air to form Fe_2O_3 (a form of rust).
    b. Sulfur is burned in air to form gaseous sulfur dioxide.
    c. A water solution of sodium chloride is evaporated to dryness.
    d. Liquid ethyl alcohol (C_2H_5OH) reacts with O_2 gas to produce carbon dioxide gas and liquid water.
    e. Water is electrolyzed to form its constituent elements.
    f. A mixture of elemental hydrogen and oxygen is sparked to ignition.

59. Consider the following balanced equation: $4\ P_4 + 5\ S_8 \longrightarrow 4\ P_4S_{10}$

   a. How many moles of P_4S_{10} are produced when 0.50 mole of S_8 react?

   b. How many moles of P_4 are required to react with 16.0 g sulfur?

60. Consider the following balanced equation: $3\ NaN_3 \longrightarrow Na_3N + 4\ N_2$

   a. How many moles of N_2 are produced by the decomposition of 0.219 mol of NaN_3?

   b. How many moles of NaN_3 are required to produce 25.0 g N_2?

61. Consider this reaction: $2\ Al + 6\ HCl \longrightarrow Al_2Cl_6 + 3\ H_2$

   a. Calculate the mass of hydrogen formed when 25.0 g of the aluminum reacts with excess HCl.

   b. What mass of Al would react with excess HCl to produce 1.00×10^{24} molecules of H_2 gas?

62. Given that iron metal reacts with bromine to produce iron (III) bromide,

   a. Write the balanced equation.

   b. What mass of Br_2 would be required to react completely with 210 g Fe?

   c. What mass of $FeBr_3$ could be recovered from the reaction of 210 g Fe and excess Br_2?

   d. Calculate the percent yield of $FeBr_3$ if 974 g of $FeBr_3$ are produced in part c.

63. Into a sealed reaction flask were placed 1.00 g magnesium metal with 1.00 g of nitrogen gas. Heating drove the reaction to completion to yield only one product, magnesium nitride, Mg_3N_2.

   $3\ Mg + N_2 \longrightarrow Mg_3N_2$

   a. Identify the reactant present in excess.

   b. What is the theoretical yield of magnesium nitride?

   c. How many grams of the excess reagent remained after the reaction is completed?

64. Consider the following balanced equation:

   $6\ ClO_2 + 3\ H_2O \longrightarrow 5\ HClO_3 + HCl$

   a. How many moles of $HClO_3$ are produced from 14.3 g of ClO_2?

   b. How many grams of H_2O are needed to produce 5.74 g of HCl?

   c. How many grams of $HClO_3$ are produced when 4.25 g of ClO_2 are added to 0.853 g H_2O?

65. Hydrazine, N_2H_4, and hydrogen peroxide, H_2O_2, have been used as rocket propellents. They react according to the equation: $7\ H_2O_2 + N_2H_4 \longrightarrow 2\ HNO_3 + 8\ H_2O$

a. How many moles of HNO_3 are formed from 0.0250 mol N_2H_4?

b. How many moles of H_2O_2 react with 22.0 g N_2H_4?

c. How many grams of H_2O are formed if 1.87 mol HNO_3 are produced?

d. How many grams of H_2O_2 are needed to produce 45.8 g HNO_3?

66. Compare the quantities of heat liberated per mole of iron formed when the oxides Fe_3O_4 and Fe_2O_3 are reduced by aluminum.

$3\ Fe_3O_4\ (s) + 8\ Al\ (s) \longrightarrow 4\ Al_2O_3\ (s) + 9\ Fe\ (s)$ $\Delta H° = -3.348 \times 10^3$ kJ

$Fe_2O_3\ (s) + 2\ Al\ (s) \longrightarrow Al_2O_3\ (s) + 2\ Fe\ (s$ $\Delta H° = -8.515 \times 10^2$ kJ

67. Calculate the amount of heat released when 10.0 g ethyl alcohol, C_2H_5OH burns in oxygen to CO_2 and H_2O and the products are cooled to 25.0°C.

$C_2H_5OH + 3\ O_2 \longrightarrow 2\ CO_2 + 3\ H_2O$ $\Delta H° = -1.367 \times 10^3$ kJ

68. How much heat energy is released when 6.00 lb (about one gallon) of gasoline with a composition that corresponds to octane is completely burned and the products are cooled to 25.0°C? Use the following equation and note that: 1 lb = 454 g.

$2\ C_8H_{18} + 25\ O_2 \longrightarrow 16\ CO_2 + 18\ H_2O$ $\Delta H° = -1.10 \times 10^4$ kJ

69. How much heat would be required in order to produce 562.0 g of mercury metal, Hg, from solid mercury(II) oxide, HgO.

$2\ HgO \longrightarrow 2\ Hg + O_2$ $\Delta H° = +1.817 \times 10^2$ kJ

QUESTIONS INVOLVING SOLUTIONS

70. In which physical state (solid, liquid, or gas) is it easiest to carry out chemical reactions? Explain.

71. What is the definition of the word "solution?"

72. What are the components of a solution? How are they distinguished?

73. Why are most chemical reactions carried out in liquid solution?

74. Generally, what is the most "convenient" concentration unit for chemists to use? Why?

75. What is the definition of "Molarity?"

76. What is the molarity of sugar, $C_{12}H_{22}O_{11}$, if 53.5 g of sugar are dissolved to give 746 mL of solution?

77. What is the molarity of KCl if 1.45 g of KCl are dissolved to give 50.0 mL of solution?

78. How many grams of $NaNO_3$ are there in 75.0 mL of 1.00 M $NaNO_3$ solution?

Periodic Table of the Elements

IA																	VIIIA
1 **H** 1.0079	IIA											IIIA	IVA	VA	VIA	VIIA	2 **He** 4.002602
3 **Li** 6.941	4 **Be** 9.012182											5 **B** 10.81	6 **C** 12.011	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.998403	10 **Ne** 20.180
11 **Na** 22.98977	12 **Mg** 24.305	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	13 **Al** 26.98154	14 **Si** 28.0855	15 **P** 30.97376	16 **S** 32.07	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.08	21 **Sc** 44.95591	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.996	25 **Mn** 54.93805	26 **Fe** 55.845	27 **Co** 58.93320	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.92159	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.90585	40 **Zr** 91.224	41 **Nb** 92.90638	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.90550	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.41	49 **In** 114.818	50 **Sn** 118.71	51 **Sb** 121.760	52 **Te** 127.60	53 **I** 126.90447	54 **Xe** 131.29
55 **Cs** 132.9054	56 **Ba** 137.33	57 **La*** 138.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.08	79 **Au** 196.96654	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.98037	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac†** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (268)	110 (269)	111 (272)	112 (277)		114 (289)		116 (289)		118 (293)

*	58 **Ce** 140.12	59 **Pr** 140.90765	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92534	66 **Dy** 162.50	67 **Ho** 164.93032	68 **Er** 167.26	69 **Tm** 168.93421	70 **Yb** 173.04	71 **Lu** 174.967
†	90 **Th** 232.0381	91 **Pa** 231.03588	92 **U** 238.0289	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

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