Chemistry 4A, Exam I
September 16, 2019
Professor R. J. Saykally

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GSI 3034774549

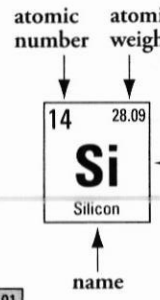
1. (20) _____
2. (20) _____
3. (20) _____
4. (40) _____

TOTAL EXAM SCORE (100) _____

Rules:

- Work all problems to 2 significant figures
- No lecture notes or books permitted
- No programmable or graphing calculators permitted
- Time: 50 minutes
- Show all work to get partial credit
- All answers must be written in the boxes provided
- Periodic Table, Tables of Physical Constants, and Conversion Factors included

Periodic Table of the Elements



symbol: **black** solid
blue liquid
red gas
white synthetically prepared *most stable isotope*
grey synthetically prepared; later found in trace amounts in nature

- alkali metals
- alkaline earth metals
- transition metals
- other metals
- metalloids
- noble gases
- halogens
- other non-metals
- unknown chemical properties
- discovery claimed

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1 1.01 H Hydrogen																	2 4.003 He Helium
3 6.94 Li Lithium	4 9.01 Be Beryllium											5 10.81 B Boron	6 12.01 C Carbon	7 14.01 N Nitrogen	8 15.999 O Fluorine	9 18.998 F Fluorine	10 20.18 Ne Neon
11 22.99 Na Sodium	12 24.31 Mg Magnesium											13 26.98 Al Aluminum	14 28.09 Si Silicon	15 30.97 P Phosphorus	16 32.06 S Sulfur	17 35.45 Cl Chlorine	18 39.95 Ar Argon
19 39.10 K Potassium	20 40.08 Ca Calcium	21 44.96 Sc Scandium	22 47.90 Ti Titanium	23 50.94 V Vanadium	24 51.996 Cr Chromium	25 54.94 Mn Manganese	26 55.85 Fe Iron	27 58.93 Co Cobalt	28 58.69 Ni Nickel	29 63.55 Cu Copper	30 65.41 Zn Zinc	31 69.72 Ga Gallium	32 72.64 Ge Germanium	33 74.92 As Arsenic	34 78.96 Se Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton
37 85.47 Rb Rubidium	38 87.62 Sr Strontium	39 88.91 Y Yttrium	40 91.22 Zr Zirconium	41 92.91 Nb Niobium	42 95.94 Mo Molybdenum	43 (98) Tc*** Technetium	44 101.07 Ru Ruthenium	45 102.91 Rh Rhodium	46 106.42 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.71 Sn Tin	51 121.76 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.29 Xe Xenon
55 132.91 Cs Cesium	56 137.33 Ba Barium	57 138.91 La ▸ Lanthanum	72 178.49 Hf Hafnium	73 180.95 Ta Tantalum	74 183.84 W Tungsten	75 186.21 Re Rhenium	76 190.23 Os Osmium	77 192.22 Ir Iridium	78 195.08 Pt Platinum	79 196.97 Au Gold	80 200.59 Hg Mercury	81 204.38 Tl Thallium	82 207.2 Pb Lead	83 208.98 Bi Bismuth	84 (209) Po Polonium	85 (210) At* Astatine	86 (222) Rn Radon
87 (223) Fr Francium	88 226.03 Ra Radium	89 227.03 Ac ▸ Actinium	104 (261) Rf* Rutherfordium	105 (262) Db* Dubnium	106 (266) Sg* Seaborgium	107 (264) Bh Bohrium	108 (277) Hs Hassium	109 (268) Mt Meitnerium	110 (281) Ds Darmstadtium	111 (272) Rg Roentgenium	112 (285) Cn Copernicium	113 — Uut Ununtrium	114 (298.19) Fl Flerovium	115 — Uup Ununpentium	116 (293) Lv Livermorium	117 — Uus Ununseptium	118 — Uuo Ununoctium

Lanthanide series ▸	58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.36 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.93 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.26 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium	71 174.97 Lu Lutetium
Actinide series ▸	90 232.04 Th Thorium	91 231.04 Pa Protactinium	92 238.03 U Uranium	93 237.05 Np* Neptunium	94 (244) Pu* Plutonium	95 (243) Am** Americium	96 (247) Cm* Curium	97 (247) Bk* Berkelium	98 (251) Cf* Californium	99 (252) Es* Einsteinium	100 (257) Fm* Fermium	101 (258) Md* Mendelevium	102 (259) No* Nobelium	103 (262) Lr* Lawrencium

* Discovered at Lawrence Berkeley National Laboratory
** Discovered in Chicago by Berkeley team
*** Discovered in Italy using a sample from Berkeley cyclotron bombardment

Physical Constants

Standard Acceleration of terrestrial gravity	$g = 9.80665$ m s^{-2} (exactly)
Avogadro's number	$N_0 = 6.022137 \times 10^{23}$
Bohr radius	$a_0 = 0.52917725$ Å $= 5.2917725 \times 10^{-11}$ m
Boltzmann's constant	$k_B = 1.38066 \times 10^{-23}$ J K^{-1}
Electron Charge	$e = 1.6021773 \times 10^{-19}$ C
Faraday constant	$\mathcal{F} = 96{,}485.31$ C mol^{-1}
Masses of fundamental particles:	
Electron	$m_e = 9.109390 \times 10^{-31}$ kg
Proton	$m_p = 1.672623 \times 10^{-27}$ kg
Neutron	$m_n = 1.674929 \times 10^{-27}$ kg
Ratio of proton mass to electron mass	$m_p/m_e = 1836.15270$
Permittivity of vacuum	$\epsilon_0 = 8.8541878 \times 10^{-12}$ C^2 J^{-1} m^{-1}
Planck's constant	$h = 6.626076 \times 10^{-34}$ J s
Speed of light in vacuum	$c = 2.99792458 \times 10^8$ m s^{-1} (exactly)
Universal gas Constant	$R = 8.31451$ J mol^{-1} K^{-1} $= 0.0820578$ L atm mol^{-1} K^{-1}
Rydberg Constant	$R_\infty = e^4 m_e/(8\epsilon_0^2 h^2)$

Conversion Factors

Standard Atmosphere	1 atm = 1.01325×10^5 Pa = 1.01325×10^5 kg m^{-1} s^{-2} (exactly)
Atomic mass unit	1 u = 1.660540×10^{-27} kg
	1 u = 1.492419×10^{-10} J = 931.4942 MeV (energy equivalent from E = mc2)
Calorie	1 cal = 4.184 J (exactly)
Electron volt	1 eV = $1.6021773 \times 10^{-10}$ J = 96.48531 kJ mol^{-1}
Foot	1 ft = 12 in = 0.3048 m (exactly)
Gallon (U.S.)	1 gallon = 4 quarts = 3.78541 L (exactly)
Liter-atmosphere	1 L atm = 101.325 J (exactly)
Metric ton	1 metric ton = 1000 kg (exactly)
Pound	1 lb = 16 oz = 0.45359237 kg (exactly)

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Question 1 (10 points each)

A) What mass (g) of CO_2 is made when 2.0 L of a stoichiometric mixture of *gaseous* propanol (C_3H_7OH) and oxygen at 1.0 atm, 300 K is combusted?

$P_{O_2} + P_{C_3H_7OH} = 1\ atm$

$C_3H_7OH + \frac{9}{2}O_2 \rightarrow 3CO_2 + 4H_2O$

$2C_3H_7OH + 9O_2 \rightarrow 6CO_2 + 8H_2O$

$\frac{2}{9} = \frac{P_{C_3H_7OH}}{P_{O_2}}$

$P_{C_3H_7OH} = \frac{2}{9}P_{O_2}$

$P_{O_2} + \frac{2}{9}P_{O_2} = 1$

$\frac{11}{9}P_{O_2} = 1$

$P_{O_2} = \frac{9}{11}\ atm$

$mol\ O_2 = \frac{P_{O_2}V_{O_2}}{RT}$

$mol\ O_2 = \left(\frac{9}{11}atm\right)(2.0L)$

$\frac{0.08206\ L \cdot atm}{mol \cdot K} \times 300K$

$mol\ O_2 = 0.0665\ mol$

$0.0665\ mol\ O_2 \times \frac{6\ mol\ CO_2}{9\ mol\ O_2} \times \frac{44.009\ g\ CO_2}{1\ mol}$

molar mass of $CO_2 = 12.011 + 4(15.999) = 44.009$

$2.0\ g\ CO_2$

B) Calculate the mass of CO_2 produced by complete surface combustion of 0.70 L of a 4.0 M solution of propanol (C_3H_7OH) in water.

$C_3H_7OH + \frac{9}{2}O_2 \rightarrow 3CO_2 + 4H_2O$

$2C_3H_7OH + 9O_2 \rightarrow 6CO_2 + 8H_2O$

$mol\ C_3H_7OH = 0.70L \times 4.0\frac{mol\ C_3H_7OH}{L}$

$mol\ C_3H_7OH = 2.8\ mol$

$2.8\ mol\ C_3H_7OH \times \frac{6\ mol\ CO_2}{2\ mol\ C_3H_7OH} \times \frac{44.009\ g\ CO_2}{1\ mol\ CO_2}$

$370\ g\ CO_2$

$3.7 \times 10^2\ g\ CO_2$

Question 2 (10 points each)

The Iodine Clock Reaction involves the reaction of iodate (IO_3^-) with iodide (I^-) in acidic solution (H^+) to produce iodine (I_2) and water.

A) Calculate the volume of 0.100 M IO_3^- solution that will exactly react with 20.0 mL of 0.300 M I^- solution.

$IO_3^- + I^- + H^+ \rightarrow I_2 + H_2O$

$2IO_3^- + 12H^+ \rightarrow I_2 + 6H_2O$

$2I^- \rightarrow I_2 + 2e^-) \times 5$

$10e^- + 2IO_3^- + 12H^+ \rightarrow 2I_2 + 6H_2O$

$10I^- \rightarrow 5I_2 + 10e^-$

$2IO_3^- + 10I^- + 12H^+ \rightarrow 6I_2 + 6H_2O$

$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$

mol $I^- = 0.020 \times 0.3$

$= 0.006$ mol I^-

$0.006 \text{ mol } I^- \times \frac{1 \text{ mol } IO_3^-}{5 \text{ mol } I^-} = 0.0012 \text{ mol } IO_3^-$

volume $IO_3^- = \frac{0.0012}{0.1} = 0.012$ L

$0.012 \times 1000 = 12$ mL

B) What volume of 0.100 M sulfite (SO_3^{2-}) solution would be required to exactly react with the iodine (I_2) produced in Part A above?

The balanced reaction is: $SO_3^{2-} + I_2 + H_2O \rightarrow SO_4^{2-} + 2I^- + 2H^+$

From part A

mol $I_2 = 0.006 \text{ mol } I^- \times \frac{3 \text{ mol } I_2}{5 \text{ mol } I^-}$

$0.0036 \text{ mol } I_2 \times \frac{1 \text{ mol } SO_3^{2-}}{1 \text{ mol } I_2}$

$= 0.0036$ mol SO_3^{2-}

Volume of $SO_3^{2-} = \frac{0.0036 \text{ mol}}{0.1 \text{ mol/L}} = 0.036$ L

$0.036 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}}$

36 mL of SO_3^{2-}

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Question 3 **(10 points each)**

A. 1.000-g mixture of cuprous oxide, Cu_2O, and cupric oxide, CuO, was quantitatively reduced to 0.839 g of metallic copper. What was the mass of CuO in the original sample?

$2Cu_2O \rightarrow 4Cu + O_2$

$2CuO \rightarrow 2Cu + O_2$

$x\,g\,Cu_2O \times \frac{1\,mol\,Cu_2O}{143.099\,g\,Cu_2O} \times \frac{4\,mol\,Cu}{2\,mol\,Cu_2O} \times \frac{63.55\,g}{1\,mol\,Cu} = 0.8884x$

molar mass of Cu_2O $= 2(63.55) + 15.999$

$= 143.099$

$y\,g\,CuO \times \frac{1\,mol\,CuO}{79.549\,g\,CuO} \times \frac{2\,mol\,Cu}{2\,mol\,CuO} \times \frac{63.55\,g}{1\,mol\,Cu} = 0.799y$

molar mass of CuO $= 63.55 + 15.999$

$= 79.549\,g$

$0.888x + 0.799y = 0.839$

$-0.888(x + y = 1)$

$-0.089y = +0.049$

$y = 0.55\,g$

0.55 g CuO

B) Four trials yield the following results for the mass of CuO produced in the above reactions:

0.538 g 0.716 g 0.815 g 0.920 g

Calculate the 95% confidence interval for these results.

Table 1: "t" Values for 95% confidence interval.

Degrees of freedom	Value of "t"
1	6.314
2	2.920
3	2.353
4	2.132
5	2.015
6	1.943

$\bar{x} = \frac{0.538 + 0.716 + 0.815 + 0.920}{4}$

$\bar{x} = 0.74725$

$S = \sqrt{\frac{(0.538 - 0.74725)^2 + (0.716 - 0.74725)^2 + (0.815 - 0.74725)^2 + (0.920 - 0.74725)^2}{3}}$

$S = 0.489 \quad df = 3 \quad t = 2.353$

$CI = 0.747 \pm \frac{(0.489)(2.353)}{\sqrt{4}}$

$CI = 0.747 \pm 0.569$

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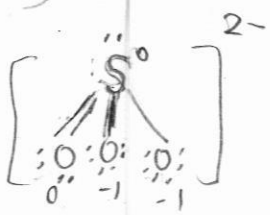
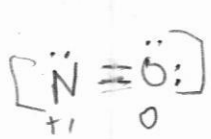
Question 4 (10 points each)

For the following compounds:
A. Draw the Lewis Structure, explicitly showing the formal charges and molecular geometry
B. Indicate the Electron Pair Geometry
C. Indicate the Molecular Geometry

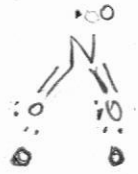
I. Sulfite Ion (SO_3^{2-})

A.	B.	C.
# of valence e⁻ = 6+6(3)+2 = 26 	tetrahedral	trigonal pyramidal

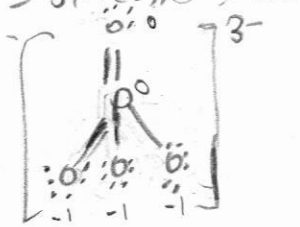
II. (NO^+) Ion

A.	B.	C.
# of valence e⁻ = 5+6-1 = 10 	linear	linear

III. NO_2 Molecule

A.	B.	C.
# of valence e⁻ = 5+2(6) = 17 	trigonal planar	bent

IV. Phosphate Ion (PO_4^{3-})

A.	B.	C.
# of valence e⁻ = 5+4(6)+3 = 32 	tetrahedral	tetrahedral