Chemistry 1B, Exam III
April 15, 1999
Professor R.J. Saykally

Name _____

TA _____

1. (15) _____
2. (15) _____
3. (25) _____
4. (15) _____
5. (10) _____
6. (10) _____
7. (10) _____

TOTAL EXAM SCORE (100) _____

Rules:
- Work all problems to 3 significant figures
- No lecture notes or books permitted
- No word processing calculators
- Time: 90 minutes
- Show all work to get partial credit
- Periodic Table, Tables of Physical Constants, Conversion Factors included

Inches 1 2 3 4 5 6

Periodic Table of the Elements

Key: Atomic number — 27; Atomic mass — 58.93; symbol — Co; name — Cobalt

symbol: **Black** naturally occurring; **White** synthetically prepared; *most stable isotope*

Legend: Metals; Metalloids; Nonmetals; Noble gases

1 1.01 H Hydrogen																	2 4.003 He Helium
3 6.94 Li Lithium	4 9.01 Be Beryllium											[illegible] B [illegible]	6 12.01 C Carbon	7 14.01 N Nitrogen	8 15.999 O Oxygen	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	[illegible] Si [illegible]	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 58.70 Ni Nickel	29 63.55 Cu Copper	30 65.37 Zn Zinc	31 69.72 Ga Gallium	[illegible] Ge [illegible]	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	46 106.40 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.69 Sn Tin	51 121.75 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.30 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	74 183.85 W Tungsten	75 186.21 Re Rhenium	76 190.20 Os Osmium	77 192.22 Ir Iridium	78 195.09 Pt Platinum	79 196.97 Au Gold	80 200.59 Hg Mercury	81 204.37 Tl Thallium	82 207.19 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) Ha Hahnium	106 (266) Sg Seaborgium	107 (262) Ns Nielsbohrium	108 (265) Hs Hassium	109 (266) Mt Meitnerium	110 (271)	111 (272)	112 (277)	(113)	(114)	(115)	(116)	(117)	(118)

Series														
Lanthanide series	58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.40 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 (260) Md Mendelevium	102 (259) No Nobelium	103 (262) Lr Lawrencium

Note: Atomic masses shown here are the 1983 IUPAC values (maximum of six significant figures).

Physical Constants

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

Values are taken from "Quantities, Units and Symbols in Physical Chemistry," International Union of Pure and Applied Chemistry, Blackwell Scientific Publications, 1988.

Conversion Factors

Standard atmosphere	$1\ \text{atm} = 1.01325 \times 10^5\ \text{Pa} = 1.01325 \times 10^5\ \text{kg m}^{-1}\ \text{s}^{-2}$ (exactly)
Atomic mass unit	$1\ \text{u} = 1.660540 \times 10^{-27}\ \text{kg}$
	$1\ \text{u} = 1.492419 \times 10^{-10}\ \text{J} = 931.4943\ \text{MeV}$ (energy equivalent from $E = mc^2$)
Calorie	$1\ \text{cal} = 4.184\ \text{J}$ (exactly)
Electron volt	$1\ \text{eV} = 1.6021773 \times 10^{-19}\ \text{J} = 96.48531\ \text{kJ mol}^{-1}$
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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1. (5 points each) Consider an electron confined to a 1–dimensional box of length 2.00 nm at 300K.

A. Calculate the energy of the n=3 state.

B. Sketch the probability for finding the electron in the n=3 state vs. position in the box.

C. Calculate the wavelength of the n=2 → 4 transition.

2. (3 points each) Aluminum is an important metal.

A. Predict its crystal structure.

_____

B. Sketch its energy bands, labeling the Fermi energy.

C. As temperature increases, its electrical conductivity _____.

D. If aluminum is doped into silicon, the resulting _____ semiconductor is _____ type, for which the majority carriers are _____.

E. The electrical conductance of A1–doped Si _____ if the temperature is raised.

3. (5+10+5+5 points)

A. Sketch the energy bands for A1–doped Si, labeling critical features.

B. Sketch the interface formed by an Al–doped Si crystal and an As–doped Si crystal. Label the fixed ions and majority carriers, label and show the direction of the recombination and generation currents.

C. What is the important physical property of a P–N junction?

D. Explain what happens when light with $h\nu > \Delta Eg$ is shined on a P-N junction.

4. (3 points each)

A. InP absorbs light only at wavelengths below 920 nm. Calculate the band gap.

B. Predict (qualitatively) the following properties of the ceramic silicon carbide:

electrical conductivity _____

hardness _____

melting point _____

C. Which has a higher packing fraction – fcc or bcc? _____

D. The number of nearest neighbors in a fcc lattice is _____.

E. Describe the crystal structure of silicon _____.

5. (10 points) One form of crystalline iron has a body–centered cubic lattice with an iron atom at every lattice point. Its density at 25°C is 7.86 g cm^{-3}. The length of the edge of the cubic unit cell is 2.87 Å. Use these facts to estimate Avogadro's number.

6. (10 points) For the following valence electron configurations of a homonuclear diatomic molecule or molecular ion, identify the element Z_2: $(\sigma_{2s})^2 (\sigma^*_{2s})^2 (\sigma_{2pz})^2 (\pi_{2p})^4 (\pi^*_{2p})^3$, determine the total bond order, and whether or not it is paramagnetic.

7. (10 points) Sketch and label the frontier occupied molecular orbitals of the valence shell for the N_2^+ molecule.