

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

Name _____

TA _____

1. (15) _____

2. (15) _____

3. (25) _____

4. (15) _____

5. (10) _____

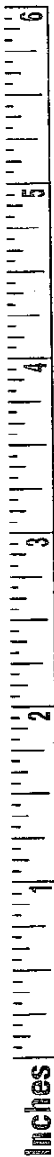
6. (10) _____

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



Periodic Table of the Elements

Atomic number		Atomic mass		symbol		name	
1	1.008	1	1.008	H	Hydrogen	Black naturally occurring	most stable isotope
2	4.003	2	4.003	He	Helium	White synthetically prepared	most stable isotope
3	6.94	4	9.01	Li	Be		
6	9.01	9	12.01	B	C		
7	12.01	12	24.31	Na	Mg		
11	22.99	20	40.08	K	Ca		
19	39.10	24	50.94	Sc	Ti		
23	47.88	28	58.93	V	Cr		
25	54.94	29	63.55	Mn	Fe		
26	55.85	30	65.37	Co	Ni		
27	58.93	31	69.72	Cu	Zn		
28	58.93	32	72.64	Ga	Ge		
39	88.91	40	91.22	K	Ca		
38	87.62	39	86.91	Rb	Sr		
37	85.47	36	84.24	Rb	Sr		
55	132.91	56	137.33	Cs	Ba		
72	175.04	73	180.95	Hf	Ta		
71	174.97	72	178.49	Hf	Ta		
104	261	105	262	Rf	Ha		
87	223	88	226.03	Fr	Ra		
89	227.03	90	232.04	Ac	Th		
91	231.04	92	238.03	Pa	U		
93	237.05	94	244	Np	Pu		
95	243	96	247	Am	Cm		
97	247	98	251	Bk	Cf		
99	251	100	257	Lr	103	262	103
101	259	102	265	103	262	103	262
104	261	105	262	106	266	107	268
108	265	109	266	110	271	111	272
112	277	113	284	114	289	115	294
116	294	117	304	118	304	119	315
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610	315	611	315	612	315	613	315
614	315	615	315	616	315	617	315
618	315	619	315	620	315	621	

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	$a_0 = 0.52917725 \text{ \AA} = 5.2917725 \times 10^{-11} \text{ m}$
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	$1 \text{ ft} = 12 \text{ in} = 0.3048 \text{ m}$ (exactly)
Gallon (U.S.)	$1 \text{ gallon} = 4 \text{ quarts} = 3.78541 \text{ L}$ (exactly)
Liter-atmosphere	$1 \text{ L atm} = 101.325 \text{ J}$ (exactly)
Metric ton	$1 \text{ metric ton} = 1000 \text{ kg}$ (exactly)
Pound	$1 \text{ lb} = 16 \text{ oz} = 0.45359237 \text{ kg}$ (exactly)

Chemistry 1B S'99, Exam III

Name _____ 1

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 $n=2 \rightarrow 4$ transition.

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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 Al-doped Si _____ if the temperature is raised.

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

A. Sketch the energy bands for Al-doped Si, labeling critical features.

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Name _____ 3

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 $h\nu > \Delta E_g$ 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.

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Name _____ 4

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.

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Name _____ 5

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.