Exam 1A
Chem 1142
Spring 2013

Name: KEY

Hybrid	Angle / Geom
sp	180° / linear
sp^2	120° / trigonal planar
sp^3	109.5° / tetrahedral
sp^3d	90°, 120° / trigonal bipyramidal
sp^3d^2	90° / octahedral

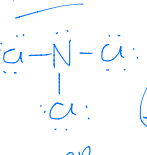
MULTIPLE CHOICE. [4 pts ea.] Choose the best response on the scantron sheet. **[48 pts total.]**

Q1. What angle do the sp^2 hybrid orbitals make with respect to each other?
a) 90° b) 109.5° c) 120° d) 180° e) 90° and 120°

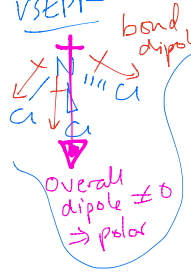
Q2. How many σ and π bonds are there in a molecule of acetylene: H–C≡C–H?
a) 3 σ, 1 π b) 3σ, 2 π c) 2 σ, 3 π d) 2 σ, 2 π e) 0 σ, 3 π

1st bond between pairs of atoms is always σ
2nd/3rd bonds are always π.

Lewis



VSEPR



Q3. Which one of the following substances would exhibit dipole-dipole intermolecular forces?
a) CCl_4 b) Cl_2 c) N_2 d) NCl_3 e) CH_4

Q4. At room temperature, which of the following compounds has the strongest intermolecular forces?
a) CO_2 b) H_2O c) NaCl d) CH_3CH_3 e) CH_3Cl

ionic >> London, d-d, H-Bonds!!

Q5. The boiling points of NH_3, PH_3, AsH_3, and SbH_3 follow a periodic trend except for
a) NH_3 which has an unexpectedly high boiling point
b) NH_3 which has an unexpectedly low boiling point
c) SbH_3 which has an unexpectedly high boiling point
d) SbH_3 which has an unexpectedly low boiling point
e) AsH_3 which has an unexpectedly high boiling point

← NH_3 can form STRONG H-Bonds! Even though London ∝ #e⁻s + NH_3 has few e⁻s...

Q6. What fraction of an atom occupying a face position of a cubic lattice is part of the unit cell?
a) 1 b) ½ c) ¼ d) 1/6 e) 1/8

Q7. For a pure substance, ΔH_{fus} is known to be +15.0 kJ/mol. Which of the following is most probably the ΔH_{vap} for this substance?
a) –15.0 kJ/mol b) –45.0 kJ/mol c) 0.0 kJ/mol
d) +15.0 kJ/mol e) +45.0 kJ/mol

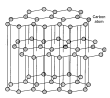
l→g : requires heat } ΔH > 0 ⇒ endothermic

{ fus: breaks some IMF
{ vap: breaks all remaining IMF ⇒ $\Delta H_{vap} > \Delta H_{fus}$

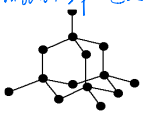
Q8. A substance at a temperature greater than its critical temperature is called
a) a solid b) a vapor c) a rheostatic liquid
d) a supercritical fluid e) an hydraulic fluid

Graphite, carbon sheets

Q9. Which of the following is an example of a covalent network solid?
a) C(graphite) b) MgO c) P_4 d) NaCl e) I_2



Diamond, sp^3 Carbon



Q10. If the pressure of a gas over a liquid increases, the amount of gas dissolved in the liquid will
a) increase b) decrease c) remain the same
d) have a higher vapor pressure e) depend on the polarity of the gas

Henry's law

Q11. Which of the following would have the **lowest** boiling point?
a) pure H_2O b) 1 *m* $C_6H_{12}O_6$(aq) c) 1 *m* KCl(aq)
d) 1 *m* $(NH_4)_2SO_4$(aq) e) 1 *m* Na_2SO_4(aq)

fp depression ∝ molal conc
bp elevation ∝ molal conc
} if we want lowest bp need lowest bp elevation ⇒ lowest solute conc! Pure water: m = 0!! $\Delta T_b = 0$

$\frac{\#\text{mol}}{\#\text{L soln}}$ ← no change w/ T

↑ usually increases w/ T ⇒ conc will change w/ T!

Q12. Which concentration will change as the temperature of a solution is increased?

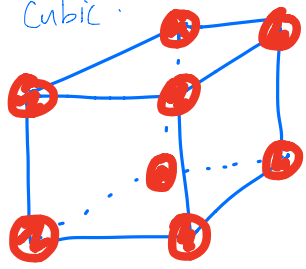
a) %(w/w) b) molality c) molarity d) morality e) mole-fraction

Short Response.

Show ALL work to receive credit.

Q13. [13 pts.] Describe the geometries of these cubic cells: simple cubic, body-centered cubic, and face-centered cubic. Which of these would give the highest density for the same type of atoms? Explain.

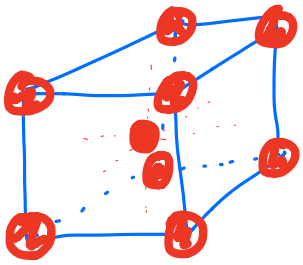
Simple Cubic:



$8 \times \frac{1}{8} = 1$ atom (corners)

1 atom/unit cell

Body-Centered Cubic

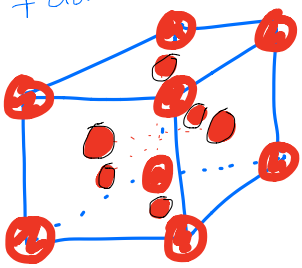


$8 \times \frac{1}{8} = 1$ atom (corners)

$1 \times 1 = 1$ atom (body)

2 atoms/unit cell

Face-Centered Cubic



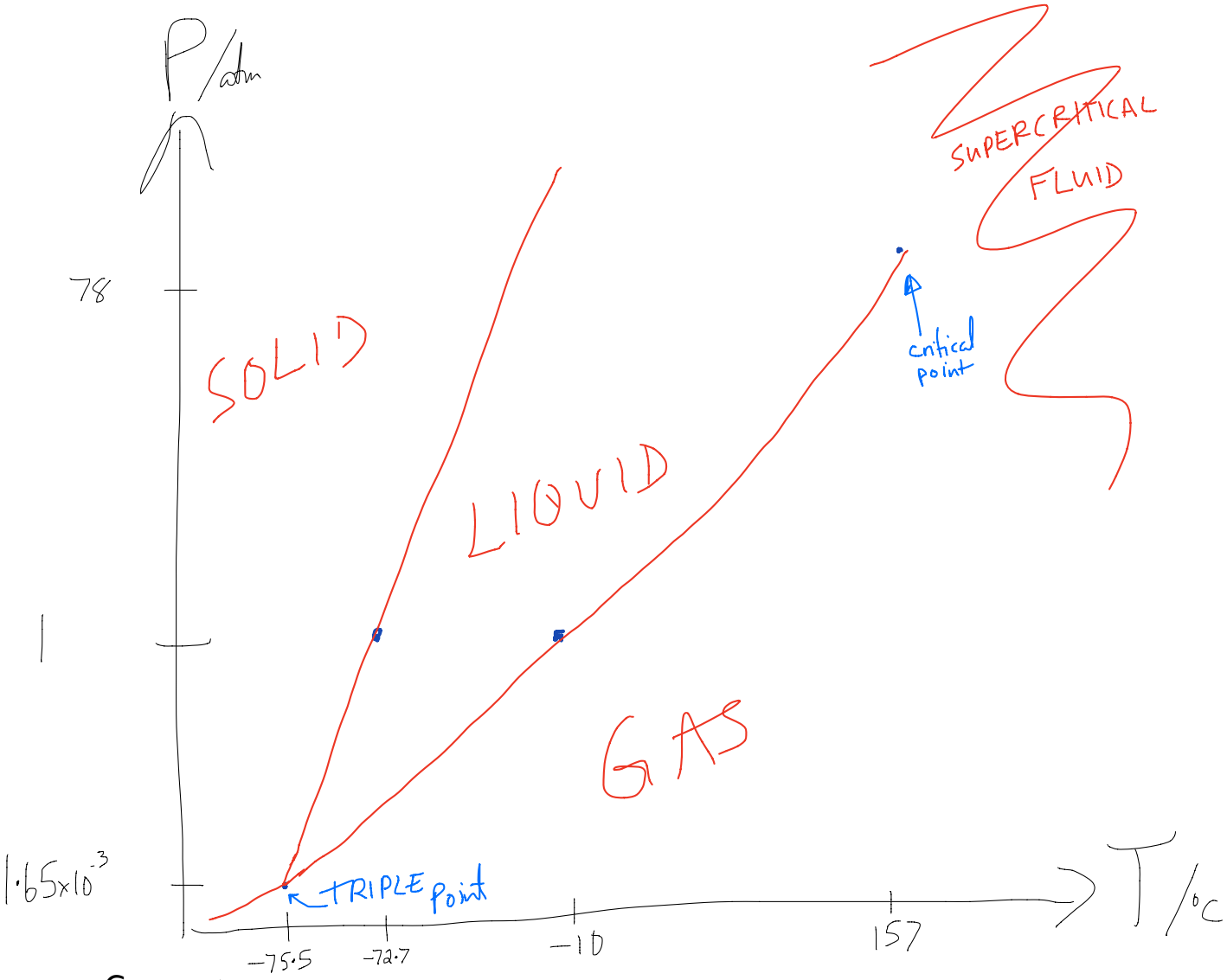
$8 \times \frac{1}{8} = 1$ atom (corners)

$6 \times \frac{1}{2} = 3$ atoms (faces)

4 atoms/unit cell

Assuming that all these unit cells have exactly the same edge length, *a*, then the face-centered cubic unit cell would contain the most number of atoms for the same volume, and hence would have the maximum density.

Q14. [14 pts.] The normal boiling point and normal freezing point of sulfur dioxide are –10 °C and –72.7 °C respectively. The triple point is –75.5 °C and 1.65 x 10^{-3} atm, and its critical point is at 157 °C and 78 atm. On the basis of this information, draw a rough sketch of the phase diagram of SO_2. Be sure to carefully label your diagram.



Comments:

- Below triple point pressure (1.65 x 10^{-3} atm) CO_2 will sublime rather than melt as the temperature is increased.
- Above the critical temperature, the distinction between the liquid and gaseous phase disappears. We call this state of matter a *supercritical fluid*. Below Tc, the gas can be compressed and turned into a liquid.
- The melting point increases with increasing applied pressure. All substances whose d(solid) > d(liquid) have this behavior. Bismuth and water are two substances where d(solid) < d(liquid), resulting in opposite melting point behavior.

Q15. [15 pts.] A quantity of 7.480 g of an organic compound is dissolved in water to make 300.0 mL of solution. The solution has an osmotic pressure of 1.43 atm at 27 °C. The analysis of this compound shows it to contain 41.8 % C, 4.7 % H, 37.3 % O, and 16.3 % N. Calculate the molecular formula of the organic compound.

27 °C = 300 K

$\Pi = iMRT$

$i = 1$ (non-electrolyte)

$\Rightarrow M = \frac{\Pi}{RT} = \frac{1.43\ atm}{0.08206\ \frac{atm \cdot L}{mol \cdot K} \times 300.\ K} = 0.05809\ \frac{mol}{L}$

$M = \frac{\#_g}{\#_{mol}}$

$300.0\ mL \left| \frac{1\ L}{1000\ mL} \right| \left| \frac{0.05809\ mol}{1\ L} \right| = 0.01743\ mol$

$M = \frac{7.480\ g}{0.01743\ mol} = 429\ g/mol$ (3 s.f.)

Empirical formula?

Assume 100-g sample:

$41.8\ g\ C \left| \frac{1\ mol\ C}{12.01\ g\ C} \right| = 3.48\ mol\ C$

$4.7\ g\ H \left| \frac{1\ mol\ H}{1.008\ g\ H} \right| = 4.66\ mol\ H$

$37.3\ g\ O \left| \frac{1\ mol\ O}{16.00\ g\ O} \right| = 2.33\ mol\ O$

$16.3\ g\ N \left| \frac{1\ mol\ N}{14.01\ g\ N} \right| = 1.163\ mol\ N$

÷ 1.163 mol

2.99 C

4.01 H

2.00 O

1.00 N

$\Rightarrow C_3H_4O_2N$ empirical

$3 \times C = 3 \times 12.01$

$4 \times H = 4 \times 1.008$

$2 \times O = 2 \times 16.00$

$1 \times N = 1 \times 14.01$

86.07

$\frac{429}{86.07} = 4.98 \approx 5$

$\Rightarrow$ If we multiply empirical formula by 5, will get correct molecular mass!

$\Rightarrow (C_3H_4O_2N)_5 = \boxed{C_{15}H_{20}O_{10}N_5}$

Q16. [10 pts.] Calculate the van't Hoff factor of Na_3PO_4 in a 0.40 *m* aqueous solution whose boiling point is 100.78 °C.

$\Delta T_b = i \cdot K_b \cdot m$

$\Delta T_b = 100.78\ ^\circ C - 100\ ^\circ C$ (exact)

$= 0.78\ ^\circ C$

$\Rightarrow i = \frac{\Delta T_b}{K_b \cdot m} = \frac{0.78\ ^\circ C}{0.52\ ^\circ C/m \times 0.40\ m}$

$= \boxed{3.75}$

note: K_b (water) should be given on equation sheet!!

Comment:

Ideal van't Hoff factor would be 4 (since we might expect sodium phosphate to completely dissociate and form 3 sodium ions and 1 phosphate ion).

In reality, ion-pairing will reduce this number because oppositely charged ions can pair up in solution, reducing the number of particles actually formed per formula unit.

Useful Information

Periodic Table of the Elements

IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA
1																	*18*
1 H 1.01	*2*											*13*	*14*	*15*	*16*	*17*	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba* 137.33	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po [210]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra** [226]	103 Lr [262]	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [265]	109 Mt [268]	110 [269]	111 [272]	112 [277]	113	114 [285]	115	116 [289]	117	118 [293]

*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
**	89 Ac [227]	90 Th 232.04	91 Pa 231.04	92 U 238.03	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]

1 atm = 101,325 Pa = 760 mmHg = 760 torr

$R = 0.08206$ L·atm/mol·K $\qquad R = 8.314$ J/mol·K

$\Delta T_b = ik_b m \qquad \Delta T_f = ik_f m \qquad \Pi = iMRT$

$c = kP$

$K_b(H_2O) = 0.52^\circ C/m$