Exam 1A
Chem 1142
Spring 2017

Name: KEY

MULTIPLE CHOICE. [3 pts ea.] Circle the best response. [**45 pts total.**]

Q1. Which ionic compound will likely have the highest melting point?

a) NaCl 1+/1−
b) Na_2S 1+/2−
c) MgS 2+/2−
d) AlP 3+/3− (*)
e) $MgCl_2$ 2+/1−

charges on ions

Coulomb's law: $F \propto \frac{q_1 \times q_2}{r^2}$ (r: distance between ions)

Q2. Which substance will have the **greatest** London dispersion forces?

a) CH_4
b) CCl_4
c) H_2
d) I_2
e) CI_4

LDF ∝ #e⁻s

Q3. Which substance will possess dipole-dipole interactions between its molecules?

a) CO_2
b) Br_2
c) BF_3
d) CF_4
e) SO_2

Lewis: O=S=O

VSEPR: bent

overall dipole ≠ 0 ⇒ POLAR!

bond dipoles

Q4. Which substance will possess hydrogen-bond interactions between its molecules?

a) CH_3NH_2
b) NF_3
c) CH_3OCH_3
d) NO_2
e) CH_4

H-Bond

Q5. A cubic unit cell contains tungsten (W) ions at each corner and body, and oxide ions at each face. What is its chemical formula?

a) W_2O_3
b) W_9O_6
c) W_3O_2
d) WO_2
e) W_3O_4

W: corners: $8 \times \frac{1}{8} = 1$
body: $1 \times 1 = 1$
2 W

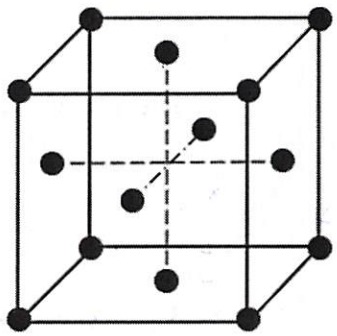
O: faces: $6 \times \frac{1}{2} = 3$ O

$\Rightarrow W_2O_3$

Q6. An example of a network covalent solid is:

a) brass
b) ice
c) quartz
d) gold
e) sucrose

Q7. What type of unit cell is shown below:



a) simple cubic
b) face-centered cubic
c) body-centered cubic
d) tetragonal
e) orthorhombic

Q8. A solution of NaCl(aq) has a molal concentration of 2.0 m. How many moles of NaCl are present if there are 125-g of $H_2O(l)$?

a) 16-mol
b) 0.016 mol
c) 0.25 mol
d) 63 mol
e) 2.0 mol

$$125\,g\,H_2O \left| \frac{1\,kg\,H_2O}{1000\,g\,H_2O} \right| \frac{2.0\,mol\,NaCl}{1\,kg\,H_2O} = 0.25\,mol\,NaCl$$

Q9. Which aqueous solution will have the **largest** boiling point? Assume ideal behavior.

a) 0.100 m glucose ($i = 1$)
b) 0.100 m sucrose ($i = 1$)
c) 0.300 m lithium phosphate ($i = 4$) ← $Li_3PO_4 \rightarrow 3Li^+ + PO_4^{3-}$
d) 0.400 m sodium chloride ($i = 2$) ← $NaCl \rightarrow Na^+ + Cl^-$
e) 0.500 m ethanol ($i = 1$)

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

(c) $4 \times 0.300\,m = 1.20\,m$ (*)
(d) $2 \times 0.400\,m = 0.800\,m$
(e) $1 \times 0.500\,m = 0.500\,m$

Q10. A solution of LiCl(aq) has an osmotic pressure of 1.8 atm at a temperature of 35 °C. Calculate the concentration of the solution, assuming ideal behavior.

a) 0.036 M
b) 0.071 M
c) 23 M
d) 45 M
e) 0.31 M

$LiCl \rightarrow Li^+ + Cl^-$, $i = 2$

$\Pi = iMRT$

$$\Rightarrow M = \frac{\Pi}{iRT} = \frac{1.8\,atm}{2 \times 0.08206 \frac{L \cdot atm}{mol \cdot K} \times 308\,K}$$

$$= 0.036\,M$$

$\Delta T_b = 1.2°C = i \cdot K_b \cdot m$

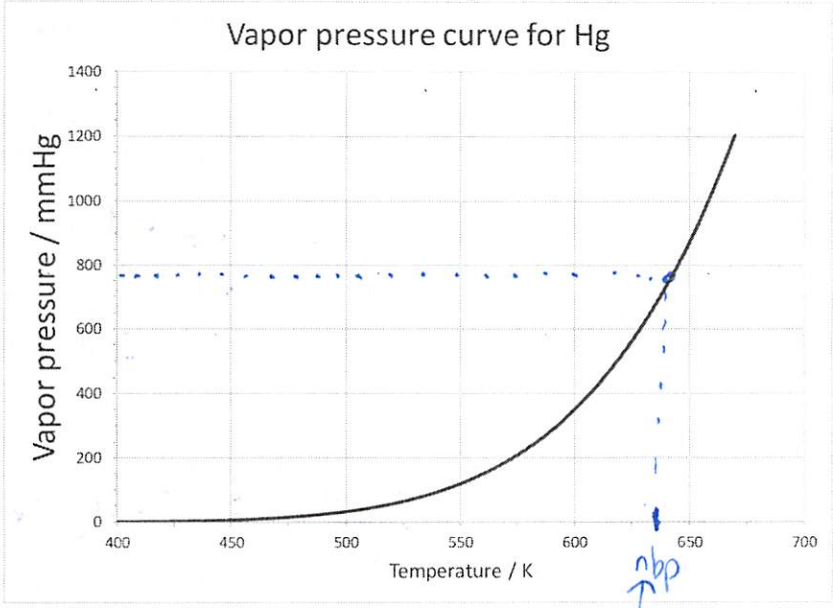
Q11. The boiling point of 1.0 m $FeCl_3(aq)$ is 101.2 °C. Calculate the van't Hoff factor for $FeCl_3$ from this data. Note: $k_b(H_2O) = 0.52$ °C/m.

$\Rightarrow i = \frac{\Delta T_b}{K_b \cdot m} = \frac{1.2°C}{0.52°C/m \times 1.0m} = 2.3$

a) 4.0
b) 3.8
c) 2.3
d) 1.2
e) 0.60

bp @ 1atm (760mmHg)

Q12. Given the vapor pressure curve for mercury shown below, estimate its normal boiling point.



a) 575 K
b) 640 K
c) 400 K
d) 530 K
e) 670 K

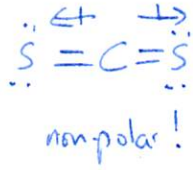
Q13. For most substances, when you are below the critical temperature it is possible to convert the gas phase into either a solid or liquid phase by compression. Above the critical temperature, this is not possible because:

a) the substance is a plasma in this region
b) the substance has extremely large IMF in this region
c) the substance is a crystal in this region
d) the substance is a supercritical fluid in this region
e) the substance is volatile in this region

Q14. Predict which two liquids will likely be miscible:

like-dissolves-like!
polar/polar or non-polar/non-polar

a) CS_2 / C_8H_{18} — both non-polar
b) C_8H_{18} / CH_3OH — polar/non-polar
c) $CH_3CH_2NH_2$ / C_6H_{14}
d) C_8H_{18} / C_7H_{16} — both non-polar
e) CH_3NH_2 / C_5H_{12}



Q15. $N_2(g)$ has a Henry's law constant of 8.2×10^{-4} M·atm^{-1} for water at 4 °C. If the concentration of N_2 in water is found to be 0.100 M, what must the pressure of $N_2(g)$ be?

a) 120 atm
b) 8.2×10^{-3} atm
c) 0.10 atm
d) 0.19 atm
e) 10. atm

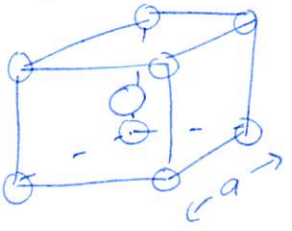
$C = k \cdot p \Rightarrow p = \frac{C}{k}$

$= \frac{0.100\,M}{8.2\times10^{-4}\,M\cdot atm^{-1}} = 120\,atm$

Short Response.

Show ALL work to receive credit. Be sure to use the conversion-factor (dimensional-analysis) method for all problems involving conversions!

Q16. [11 pts.] Cesium (Cs) crystallizes in a body-centered cubic unit cell with an edge length of 614.1 pm. Being careful to show all work—including units and significant figures—calculate its density in units of g/cm^3.



8 atoms @ corners: $8 \times \frac{1}{8} = 1$

1 atom @ body: $1 \times 1 = 1$

2 atoms/cell.

$d = m/V$.

$V = a^3 = \left(\frac{614.1\,pm}{1}\left|\frac{10^{-12}\,m}{pm}\right|\frac{100\,cm}{1\,m}\right)^3 = 2.3159\times10^{-22}\,cm^3$

$m = \frac{2\ atoms\ Cs}{6.022\times10^{23}\ atoms}\left|\frac{1\,mol}{1\,mol\ Cs}\right|\frac{132.91\,g\ Cs}{1\,mol\ Cs} = 4.414\times10^{-22}\,g$

~~$d = 2.3159\times10^{-22}$~~

$d = \frac{m}{V} = \frac{4.414\times10^{-22}\,g}{2.3159\times10^{-22}\,cm^3} = \boxed{1.906\,g/cm^3}$

W

Q17. [11 pts.] i) List the intermolecular forces present between the following molecules:

a) NH_3 London, Dipole-dipole, Hydrogen bonding

b) CH_3F London, Dipole-dipole

c) CO_2 London

ii) Explain in detail why MgO has a much greater melting point than SO_2. Your answer should include complete sentences and diagrams where appropriate.

MgO is ionic, and composed of Mg^{2+} and O^{2-} ions that have a very strong attraction for each other. In general, ionic (+ covalent bonds) are hundreds of times greater than the intermolecular forces!

SO_2 is molecular : 

and possess London dispersion + dipole-dipole intermolecular forces. These are much weaker than the ionic attractions in MgO, and so it takes much less energy to melt, and hence SO_2 has a much lower melting point than MgO.

w

Q18. [11 pts.] Calculate the freezing point of 12.4 M NaBr(aq), given a solution density of 2.08 g/mL. What assumption are you making? Note, $k_f(H_2O) = 1.86\ ^\circ C/m$.
Hint: start by converting the molar concentration to a molal concentration!

$\Delta T_f = i \cdot k_f \cdot m$

Assume 1-L soln $\Rightarrow$ 12.4 mol NaBr.

$d = m/V \Rightarrow m = d \times V = 2.08\,g/mL \times 1000\,mL = 2080\,g$ soln

molal conc $= \frac{\#\,mol\ NaBr}{\#\,kg\ H_2O}$ $\Rightarrow$ need to find $\#\,kg\ H_2O$ + NaBr.

oops!

$12.4\,mol\ NaBr \left| \frac{1\,mol\ NaBr}{102.89\,g\ NaBr} \right. = 1275.8\,g\ NaBr.$

$\Rightarrow$ mass $H_2O = 2080\,g - 1275.8\,g = 804.164\,g\ H_2O$

$= 0.804164\,kg\ H_2O.$

$\Rightarrow$ molal conc $= \frac{12.4\,mol}{0.804\,kg} = 15.4\,m$

$\Delta T_f = i \cdot k_f \cdot m = 2 \times 1.86\,^\circ C/m \times 15.4\,m$

$= 57.36^\circ C$

$\Rightarrow T_f = 0 - \Delta T_f = \boxed{-57^\circ C}$

assume $i = 2$: $NaBr \xrightarrow{100\%} Na^+ + Br^-$

if ion-pairing occurs, expect $i < 2$ (and T_f to be $\uparrow$)

A

Q19. [11 pts.] The boiling point of an aqueous solution formed by adding 10.0-g of an unknown non-electrolyte to 150.0-g of water is found to be 100.715 °C. Show how to, and then calculate the molar mass of the unknown substance. Note: $k_b(H_2O) = 0.52\ ^\circ C/m$.

$\Delta T_b = i \cdot K_b \cdot m$ (1)

$\Delta T_b = 100.715^\circ C - 100^\circ C$ (exact) $= 0.715^\circ C$. (1)

$i = 1$, non-electrolyte (1) $\Rightarrow \Delta T_b = K_b \cdot m$ (1)

set-up 3

$\Rightarrow m = \frac{\Delta T_b}{K_b} = \frac{0.715^\circ C}{0.52^\circ C/m} = 1.375\,m$

$= 1.375\,\frac{mol\ X}{Kg\ H_2O}$ (3)

solve molal conc 3

$150.0\,g\ H_2O \left| \frac{1\,Kg}{1000\,g} \right| \frac{1.375\,mol\ X}{1\,Kg\ H_2O} \Big| = 0.20625\,mol\ X$ (1) (2)

solve #mol 3

$M = \#g/\#mol = \frac{10.0\,g}{0.20625\,mol} = 48\,g/mol$ (2 s.f.) (1) (1)

solve M_b 2

-1 sf. (<2, >3)

A

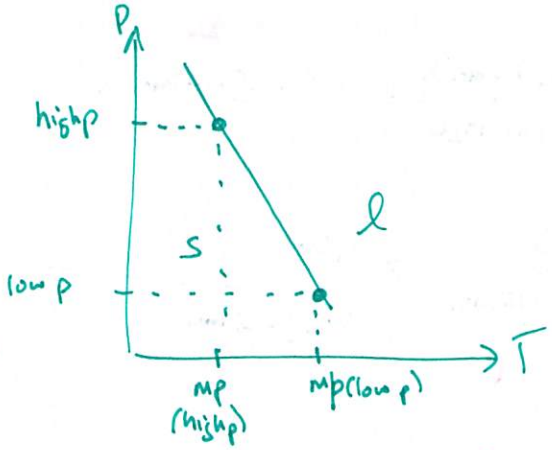
Q20. [11 pts.] Be sure to show all work!

a) How many moles of NaCl are contained in 325-g of a 1.00 %(w/w) aqueous solution?

$$325\,g\ soln \times \frac{1.00\,g\ NaCl}{100\,g\ soln} \times \frac{1\,mol\ NaCl}{58.44\,g\ NaCl} = 0.0556\,mol\ NaCl$$

1 1 1 (3)

b) Water has an unusual pressure-temperature phase diagram with a solid/liquid line that has a negative slope. What does this mean in terms of the melting point as we increase the pressure? You should sketch part of the phase diagram as part of your answer. Your explanation should be in the form of complete sentences.



- melting point decreases as pressure increases.

2

2 (up to) (4)

c) What happens to the following three types of concentrations as the temperature is increased? Be sure to explain your answer.

i) Molal concentration — No change 1

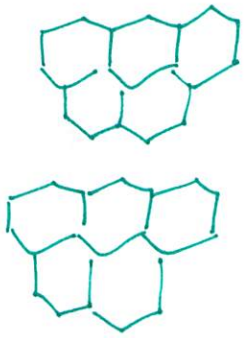
ii) Molar concentration — Concentration decreases if volume expands upon heating. 1 1 (4)

iii) Percent by mass, %(w/w) — No change. 1

A

BONUS Question:

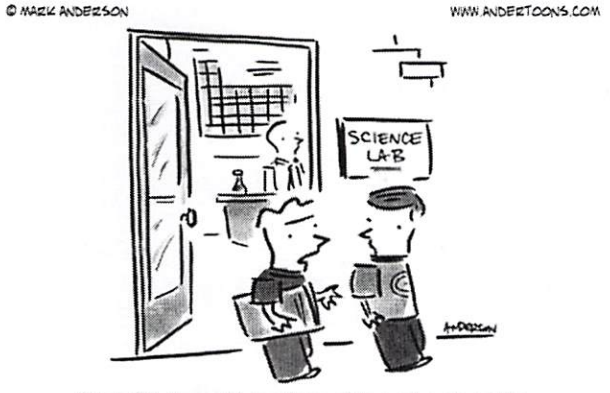
Sketch out the structure of graphite, and explain why it can act as an effective lubricant.



layers can slide
⇒ lubricant.

1.5

1.5



"Rats! I thought lanthanoids and actanoids were gonna be giant robots or something."

Useful Information

Periodic Table of the Elements

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

*	57	58	59	60	61	62	63	64	65	66	67	68	69	70
	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
**	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[256]	[259]

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

$T/\mathrm{K} = t/^{\circ}\mathrm{C} + 273.15$

$$R = 0.08206 \frac{\mathrm{atm \cdot L}}{\mathrm{mol \cdot K}}$$

$R = 8.3145\ \mathrm{J/mol \cdot K}$

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

$k_f(H_2O) = 1.86\ ^{\circ}\mathrm{C/m}$ $\quad$ $k_b(H_2O) = 0.52\ ^{\circ}\mathrm{C/m}$ $\quad$ $c = kP$