Exam 1A (2-hour)
Chem 1142
Spring 2015

Name: KEY

MULTIPLE CHOICE. [3 pts ea.] Choose the best response on the scantron sheet. **[45 pts total.]**

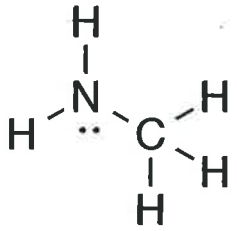
Q1. Which of the following substances will have a dipole-dipole intermolecular force?
a) CCl_4 b) BF_3 c) H_2O d) NaCl e) N_2

Q2. Predict which ionic compound should have the highest melting point:
a) LiF b) NaCl c) MgO d) CaS e) AlP

3+/3-

Q3. True or False: Hydrogen-Bonds are stronger than ionic-bonds.
a) TRUE b) FALSE

Q4. Pick the correct statement about the following molecule:



a) it can hydrogen-bond donate, but not accept **b) it can hydrogen-bond accept, but not donate**
c) it can neither accept not donate hydrogen-bonds **d) it can both accept and donate hydrogen-bonds**

Q5. An example of a network covalent crystal is:
a) ice b) quartz c) tar d) aluminum e) sodium chloride

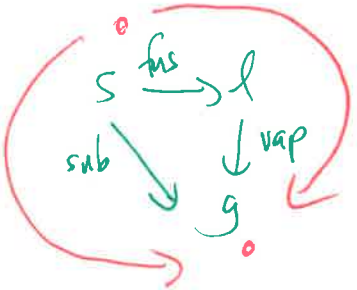
Q6. The enthalpy of fusion, vaporization, and sublimation for a substance X has been determined. Which of the following possible sets of values is most likely to be correct?

	ΔH°_{fus} / kJ·mol^{-1}	ΔH°_{vap} / kJ·mol^{-1}	ΔH°_{sub} / kJ·mol^{-1}
a)	–10	–5	+15
b)	–20	+30	–10
c)	+5	+12	+14
d)	+10	+25	+35
e)	+20	+15	+5

$\Delta H_{vap} > \Delta H_{fus}$

↑ break all remaining IMF $\ell \to g$

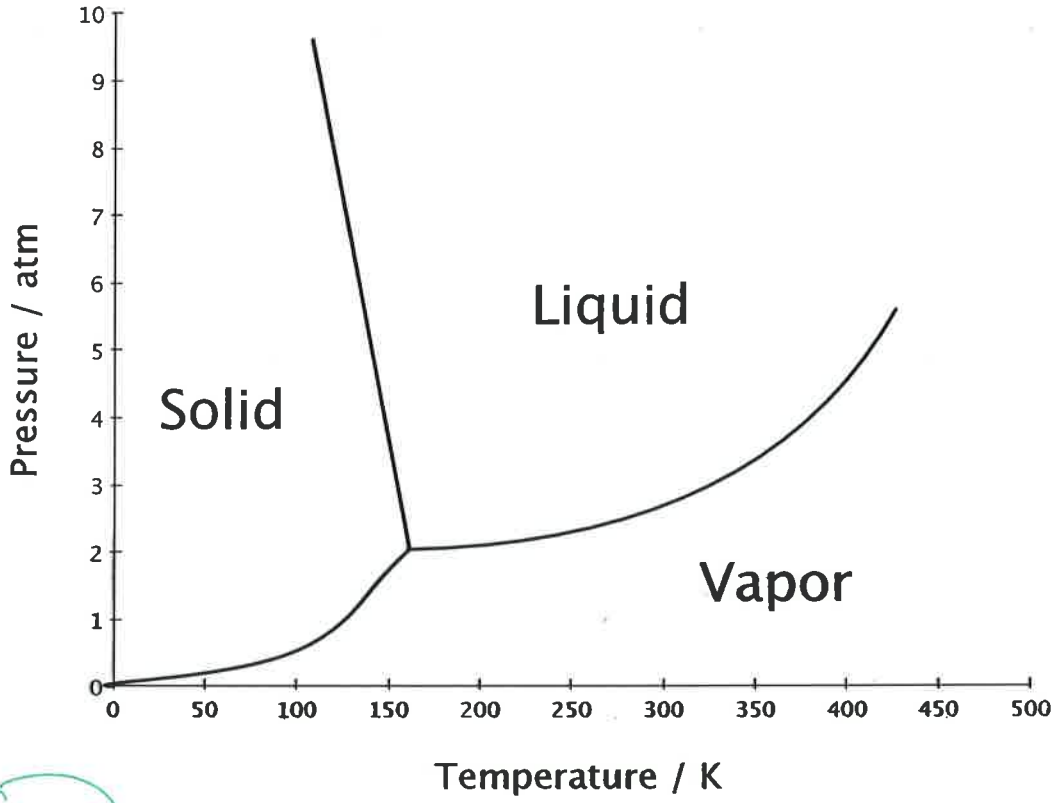
↑ break some IMF $s \to \ell$



$\Delta H_{sub} = \Delta H_{fus} + \Delta H_{vap}$

since H is state fxn!

Q7. Given the following phase diagram, what is the boiling point of the substance at 3 atm?



a) 350 K b) 425 K c) >500 K d) <150 K e) 160 K

Q8. Which pair of substances would be most likely to mix and form a homogeneous solution?

a) $NaCl/C_4H_{10}$ b) C_8H_{18}/H_2O c) CH_3CH_2OH/CO_2

d) CH_3OH/NH_3 e) CH_4/NaH

Q9. 4.25 mL of a 0.281 M aqueous solution at 35 °C contains 0.117-g of an unknown solute. What is the molar mass of the solute?

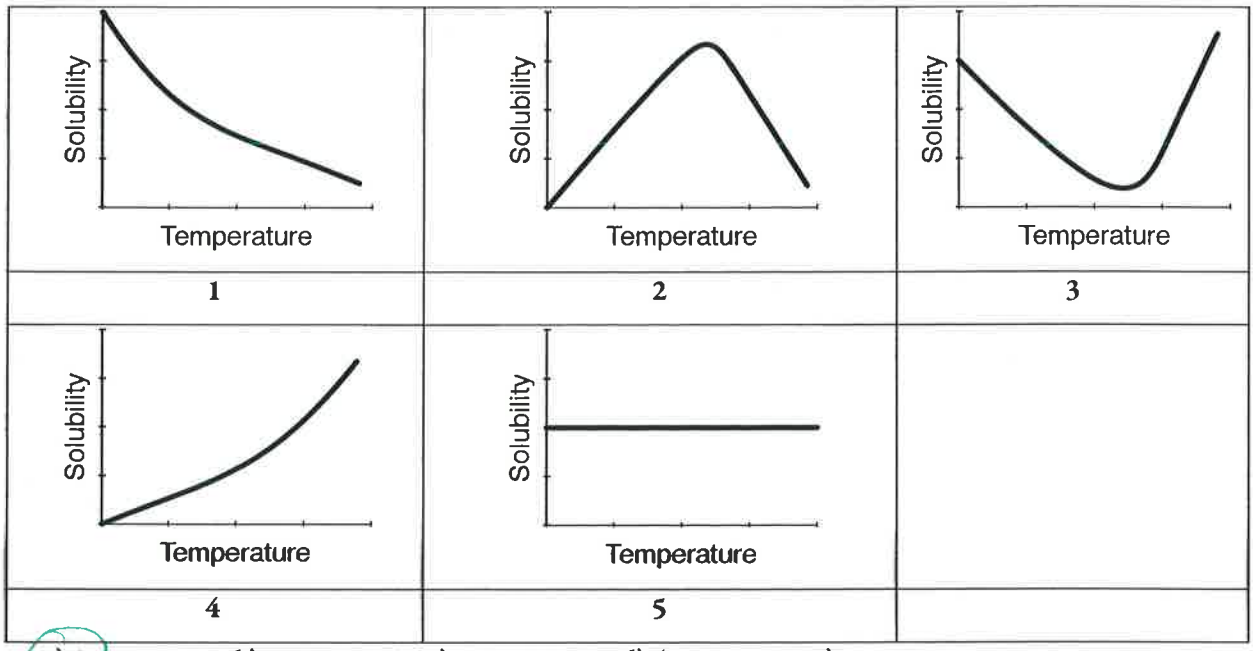
a) 98.0 g/mol b) 0.416 g/mol c) 10.2 g/mol

d) 0.0980 g/mol e) 102 g/mol

$$M = \frac{\#g}{\#mol} = 98.09\ g/mol.$$

$$\frac{4.25\,mL \mid 1\,L \mid 0.281\,mol}{1000\,mL \mid L} = 1.194 \times 10^{-3}\ mol$$

Q10. Which numbered graph shows the typical solubility of a **gas** in a liquid with changing temperature?



a) 1 b) 2 c) 3 d) 4 e) 5

Q11. If the solubility of He(g) in water at 25 °C is 6.6×10^{-4} M at a pressure of 1.75 atm, then what is the solubility when the pressure is changed to 9.8 atm?

a) 1.2×10^{-4} M b) 3.7×10^{-3} M c) 2.9×10^{-3} M
d) 3.7×10^{-2} M e) 4.7×10^{-6} M

$C = kP$

$\Rightarrow k = \frac{C}{P} = \frac{6.6 \times 10^{-4} M}{1.75 atm} = 3.77 \times 10^{-4} \frac{M}{atm}$

$\Rightarrow C = k \cdot P = 3.77 \times 10^{-4} \frac{M}{atm} \times 9.8 atm = 3.7 \times 10^{-3} M$

Q12. Which one of the following aqueous solutions would have a *different* boiling point than the other four?

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

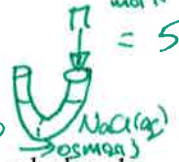
$\propto i \cdot m$

a) 0.60 m NaCl $i=2$, $i \cdot m = 1.2m$ b) 0.30 m $Fe(NO_3)_3$ $i=4$, $i \cdot m = 1.2m$ c) 0.60 m NH_4NO_3 $i=2$, $i \cdot M = 1.2m$
d) 1.2 m $C_6H_{12}O_6$ $i=1$, $i \cdot m = 1.2m$ e) 0.40 m $LiHCO_3$ $i=2$, $i \cdot m = 0.80m$

Q13. A semi-permeable membrane separates pure water from a solution of 1.0 M NaCl(aq) at 32 °C. In order to **stop** osmotic flow, what must be done?

$\Pi = i \cdot M \cdot R \cdot T = 2 \times 1.0 \frac{mol}{L} \times 0.08206 \frac{atm \cdot L}{mol \cdot K} \times 305 K = 50. atm.$

a) An additional pressure of 25 atm must be applied to the water side of the apparatus
b) An additional pressure of 25 atm must be applied to the NaCl side of the apparatus
c) An additional pressure of 50. atm must be applied to the water side of the apparatus
d) An additional pressure of 50. atm must be applied to the NaCl side of the apparatus



Q14. An aqueous solution of 3.0 m sodium phosphate boils at 105.3 °C. From this information, calculate the van't Hoff factor.

a) 67 b) 18 c) 3.4 d) 3.0 e) 0.85

$\Delta T_b = 5.3 °C = i \cdot K_b \cdot m$

$\Rightarrow i = \frac{5.3}{K_b \cdot m} = \frac{5.3 °C}{0.52 \frac{°C}{m} \times 3.0m} = 3.4$

Q15. Which of the following aqueous solutions would have the greatest osmotic pressure at the same temperature?

$\Pi = i \cdot M \cdot RT$

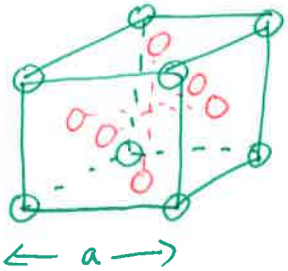
$\propto i \cdot M$

a) 0.10 M NaCl $i=2$, $iM = 0.20M$ b) 0.20 M $C_6H_{12}O_6$ $i=1$, $iM = 0.20M$ c) 0.060 M $CaCl_2$ $i=3$, $i \cdot M = 0.18M$
d) 0.050 M $(NH_4)_2CO_3$ $i=3$, $iM = 0.15M$ e) 0.20 M NH_4NO_3 $i=2$, $iM = 0.40M$

Short Response.

Show ALL work to receive credit.

Q16. [11 pts.] Silver crystallizes in a face-centered-cubic (FCC) unit cell and has a density of 10.50 g/cm^3. Calculate the edge length of the unit cell in picometers. Be sure to sketch the FCC unit cell as part of your answer.



O = face
O = corner.

$\#\text{ atoms/cell} = 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$
(corners) (faces)

$d = \frac{m}{V} = 10.50\ g/cm^3$

$V = a^3$

$$m = \frac{4\text{ atoms Ag} \mid 1\text{ mol Ag} \mid 107.87\text{ g Ag}}{6.022\times10^{23}\text{ Ag} \mid 1\text{ mol Ag}} = 7.165\times10^{-22}\text{ g}$$

$$V = \frac{m}{d} = \frac{7.165\times10^{-22}\text{ g}}{10.50\text{ g/cm}^3} = 6.824\times10^{-23}\text{ cm}^3$$

$$a = \sqrt[3]{V} = \frac{4.086\times10^{-8}\text{ cm} \mid 10^{-2}\text{ m} \mid \text{pm}}{\text{cm} \mid 10^{-12}\text{ m}} = 408.6\text{ pm}$$

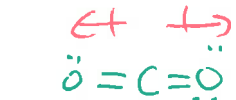
Q17. [11 pts.] Order the following compounds by predicted melting points. Explain in detail how you arrived at the ordering. As part of your answer, be sure to identify the intermolecular forces that each substance contains, and be prepared to draw Lewis/VSEPR diagrams to support your answer.

CaO, CH_3NH_2, CH_3Cl, CO_2, LiF

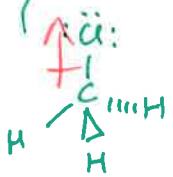
low mp — high mp

$CO_2 < CH_3Cl < CH_3NH_2 < LiF < CaO$

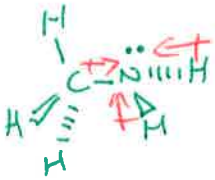
IMF: london | london, d-d | london, d-d, H-Bond | london, ionic 1+/1− | London, ionic 2+/2−



net dipole = 0



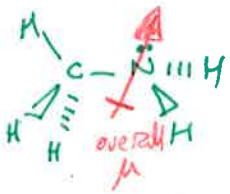
net dipole ≠ 0



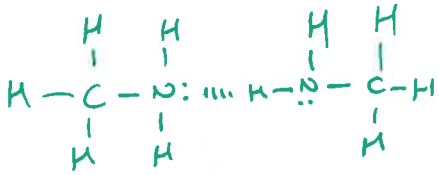
net dipole ≠ 0

Coulomb: $f \propto \frac{q_+ \cdot q_-}{r^2}$

ionic >> london, d-d, H-Bond



can H-Bond!



Q18. [11 pts.] Calculate the boiling point of an aqueous 34.5 % (w/w) solution of KBr with a density of 1.82 g/mL.

$\Delta T_b = i \cdot K_b \cdot m$ ↑ do not need!

$i = 2$ ($KBr \xrightarrow{H_2O} K^+_{(aq)} + Br^-_{(aq)}$)

$K_b = 0.52\,^\circ C/m$

$m = ?$ $\quad m = \frac{\#\text{mol KBr}}{\#\text{kg } H_2O}$

100g soln → $34.5\text{g KBr} \left| \frac{1\text{mol KBr}}{119.0\text{g KBr}} \right| = 0.290\text{mol KBr}$

→ $65.5\text{g } H_2O \rightarrow 0.0655\text{kg } H_2O$

$\Rightarrow m = \frac{0.290\text{mol}}{0.0655\text{kg}} = 4.426\text{m}$

$\Rightarrow \Delta T_b = 2 \times 0.52\,^\circ C/m \times 4.426\text{m}$

$= 4.6\,^\circ C$

$\Rightarrow T_b = 100\,^\circ C + 4.6\,^\circ C =$ **104.6°C** (exact)

Q19. [11 pts.] A 12.8 % (w/w) aqueous solution of an unknown molecular compound X has a boiling point of 101.30 °C. Calculate the molecular weight of X.

molecular $\Rightarrow i = 1$

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

$\Rightarrow 1.30^\circ C = 1 \times 0.52^\circ C/m \times m$

$\Rightarrow m = \frac{1.30^\circ C}{0.52^\circ C/m} = 2.5 \frac{mol\ X}{kg\ H_2O}$

12.8% (w/w) $\longrightarrow$ 12.8 g X

$\searrow$ 87.2 g H_2O = 0.0872 kg H_2O.

$\Rightarrow 0.0872\ kg\ H_2O \times \frac{2.5\ mol\ X}{1\ kg\ H_2O} = 0.218\ mol\ X$

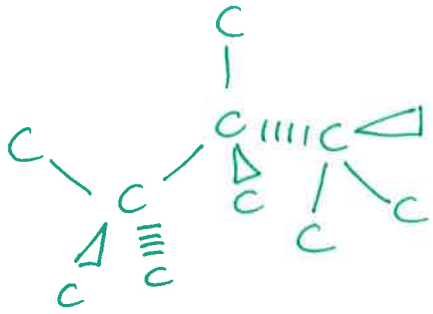
$M = \#g / \#mol = \frac{12.8\ g}{0.218\ mol} = \boxed{58.7\ g/mol}$

Q20. [11 pts. total]

a) [2 pts.] Give an example of a network covalent solid.

Diamond

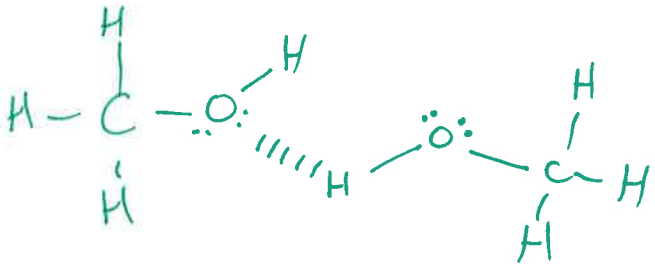
b) [3 pts.] Sketch the molecular structure of the substance you identified in part a) above.



c) [3 pts.] Using complete sentences, explain why the van't Hoff factor is 1.3, rather than 2.0 for 0.0500 M $MgSO_4(aq)$ at 25 °C.

if $MgSO_4$ completely dissociates into free Mg^{2+} and SO_4^{2-} ions, i will be 2. but... ion-pairing, which is the "sticking-together" of cations + anions will reduce the actual value of i between 1 (all ions-pair) and 2 (no ions-pair).

d) [3 pts.] Sketch the hydrogen bonds between molecules of CH_3OH.



BONUS Question:

In general, the enthalpy of vaporization of a substance is greater than its enthalpy of fusion. Why?

See exam 1B key.

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]	[258]	[259]

$1\ \text{atm} = 101{,}325\ \text{Pa} = 760\ \text{mmHg} = 760\ \text{torr}$

$$R = 0.08206 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}} \qquad R = 8.314\ \text{J/mol}\cdot\text{K}$$

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

$k_f(H_2O) = 1.86\ ^\circ\text{C/m}$ $\qquad k_b(H_2O) = 0.52\ ^\circ\text{C/m}$

$c = kP$

Exam 1B (2-hour)
Chem 1142
Spring 2015

Name: KEY (part) — see white key . . .

MULTIPLE CHOICE. [3 pts ea.] Choose the best response on the scantron sheet. [**45 pts total.**]

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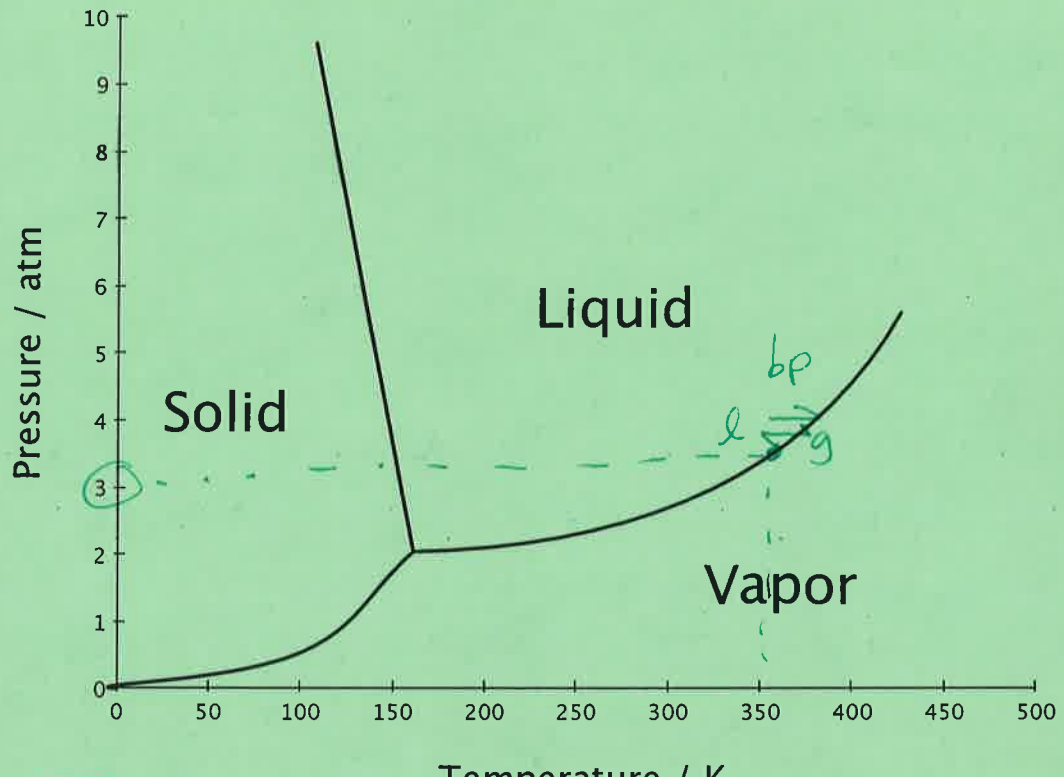

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a) 98.0 g/mol b) 0.416 g/mol c) 10.2 g/mol
d) 0.0980 g/mol e) 102 g/mol

$M = \frac{\text{g}}{\text{mol}}$

$0.00425\,\text{L} \times \frac{0.281\,\text{mol}}{\text{L}}$

Q3. Which pair of substances would be most likely to mix and form a homogeneous solution?

a) $NaCl/C_4H_{10}$ b) C_8H_{18}/H_2O c) CH_3CH_2OH/CO_2
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both polar.

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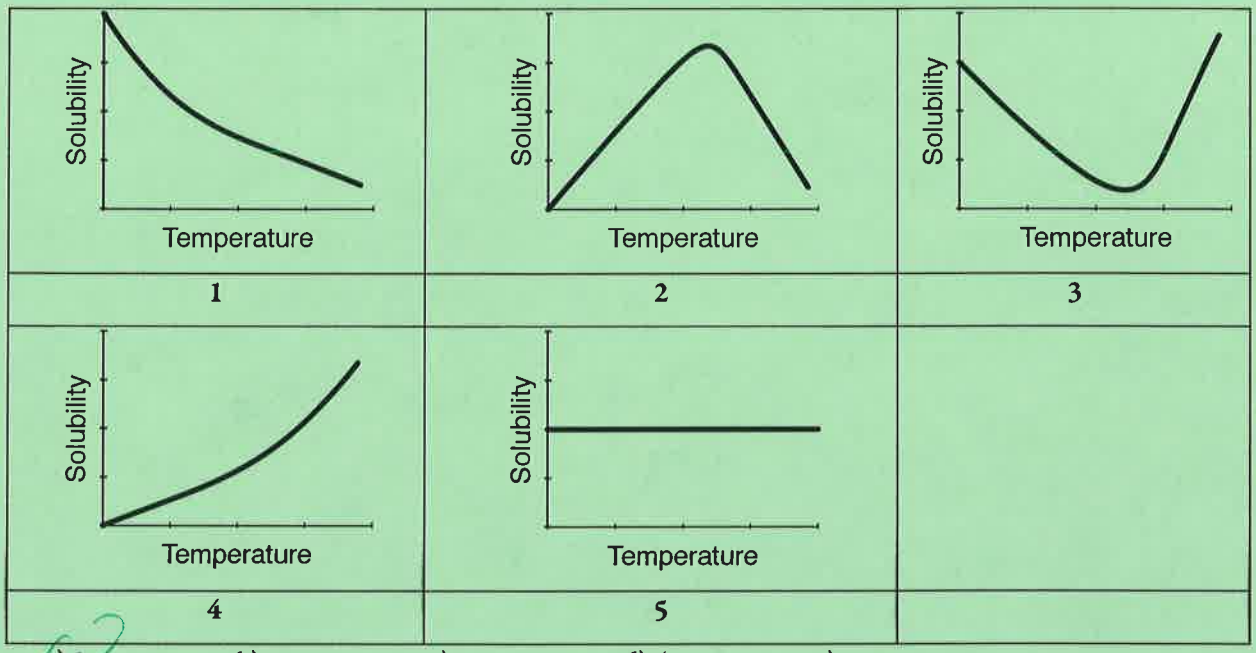

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$C = kP$

$\Delta T_b = i \cdot m \cdot k_b \Rightarrow i = \Delta T_b / m \cdot k_b$

Q6. An aqueous solution of 3.0 m sodium phosphate boils at 105.3 °C. From this information, calculate the van't Hoff factor.

a) 67 b) 18 c) 3.4 d) 3.0 e) 0.85

$= \frac{5.3^{\circ}C}{3.0m \times 0.52^{\circ}C/m}$

Q7. Which of the following aqueous solutions would have the greatest osmotic pressure at the same temperature?

$\Pi = i \cdot M \cdot RT$, $\propto i \cdot M$

a) 0.10 M NaCl $i=2, iM = 0.20M$ b) 0.20 M $C_6H_{12}O_6$ $i=1, iM = 0.20M$ c) 0.060 M $CaCl_2$ $i=3$ $iM = 0.18M$
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Q8. Which of the following substances will have a dipole-dipole intermolecular force?

a) CCl_4 b) BF_3 c) H_2O d) NaCl e) N_2

Q9. Predict which ionic compound should have the highest melting point:

a) LiF b) NaCl c) MgO d) CaS e) AlP $3+/3-$ ion

Q10. Which one of the following aqueous solutions would have a *different* boiling point than the other four?

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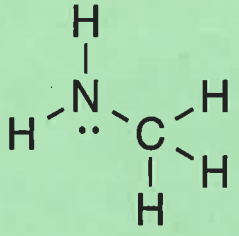

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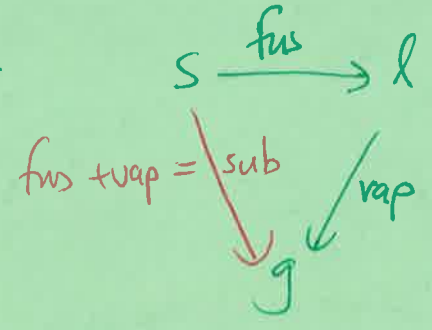
c)	+5	+12	+14
d)	+10	+25	+35
e)	+20	+15	+5

$\Delta H^\circ_{fus} < \Delta H^\circ_{vap}$

break some IMF

break all-remaining IMF

Since H is state fun:



Short Response.
Show ALL work to receive credit.

Q16. [11 pts.] A 21.8 % (w/w) aqueous solution of an unknown molecular compound X has a boiling point of 101.10 °C. Calculate the molecular weight of X.

$i = 1$

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

$K_b = 0.52\ ^\circ C/m$

$\Delta T_b = 101.10^\circ C - 100^\circ C_{\text{exact}} = 1.10^\circ C$

$\Rightarrow m = \frac{\Delta T_b}{i \cdot K_b} = \frac{1.10^\circ C}{1 \times 0.52^\circ C/m} = 2.115\ \frac{mol}{kg}$

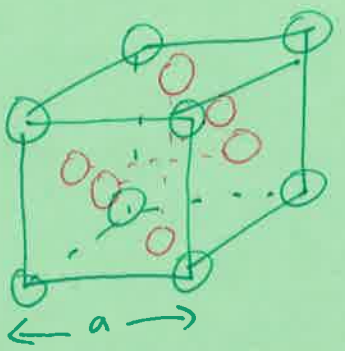
$\Rightarrow \frac{2.115\ mol\ X}{1\ kg\ H_2O}$.

21.8% $\rightarrow$ $21.8\ g\ X$

$\rightarrow 78.2\ g\ H_2O = 0.0782\ kg\ H_2O \mid \frac{2.115\ mol\ X}{1\ kg\ H_2O} = 0.1654\ mol\ X$

$\Rightarrow M = \#g / \#mol = \frac{21.8\ g\ X}{0.1654\ mol\ X} = 130\ g/mol$ (2 sf).

Q17. [11 pts.] Silver crystallizes in a face-centered-cubic (FCC) unit cell and has a density of 10.50 g/cm^3. Calculate the edge length of the unit cell in picometers. Be sure to sketch the FCC unit cell as part of your answer.



$V = a^3$

○ = face

○ = corner.

$\#\text{atoms/cell} = 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$ Ag atoms/cell.
(corners) (face)

$d = m/V \Rightarrow V = m/d.$

$$m = \frac{4\ \text{Ag} \mid 1\ \text{mol Ag} \mid 107.87\ \text{g Ag} \mid}{\mid 6.022 \times 10^{23}\ \text{Ag} \mid 1\ \text{mol Ag} \mid} = 7.1651 \times 10^{-22}\ \text{g}$$

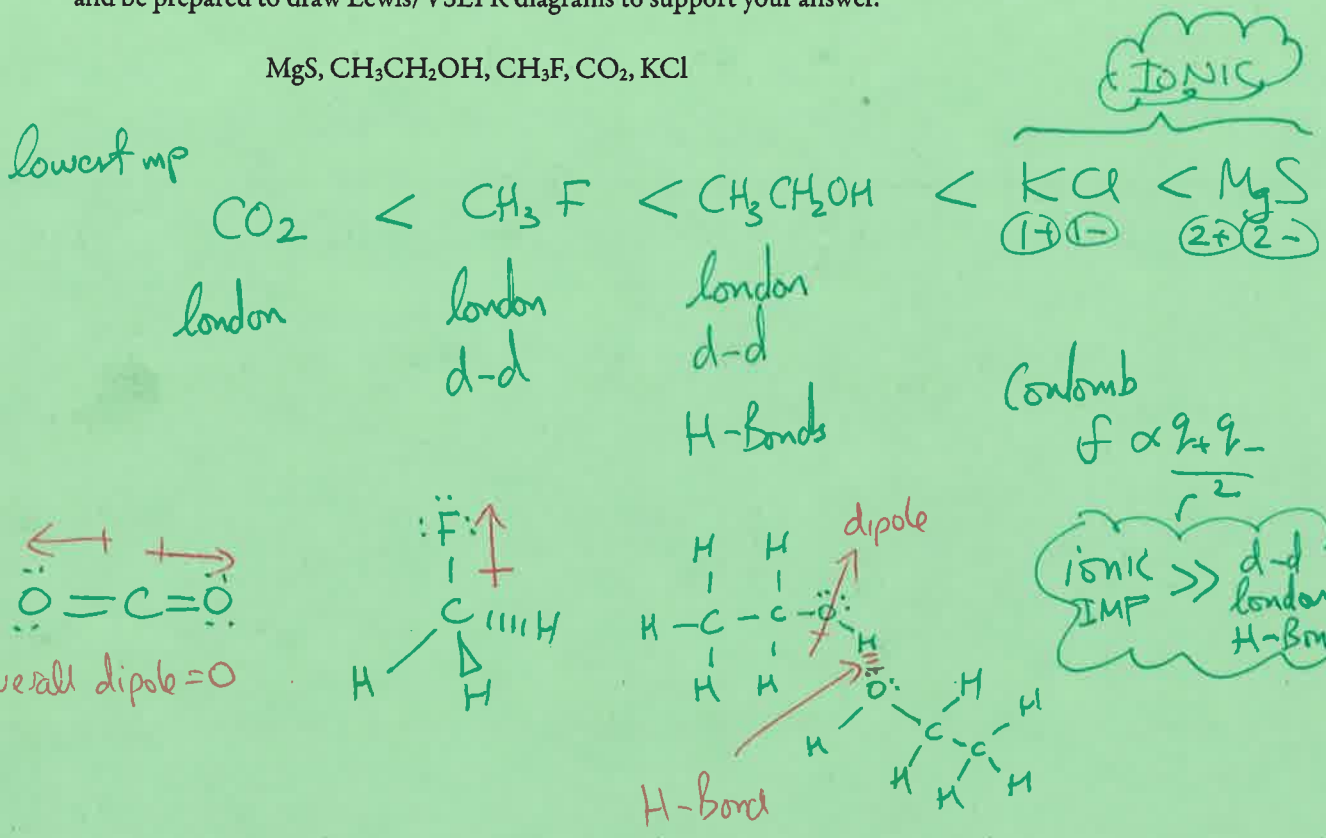
$$\Rightarrow V = \frac{7.1651 \times 10^{-22}\ \text{g}}{10.50\ \text{g/cm}^3} = 6.8239 \times 10^{-23}\ \text{cm}^3$$

$$a = \sqrt[3]{V} = 4.0865 \times 10^{-8}\ \text{cm}$$

$$a(\text{pm}) = \frac{4.0865 \times 10^{-8}\ \text{cm} \mid 10^{-2}\ \text{m} \mid \text{pm} \mid}{\mid \text{cm} \mid 10^{-12}\ \text{m} \mid} = \boxed{408.6\ \text{pm}}$$

Q18. [11 pts.] Order the following compounds by predicted melting points. Explain in detail how you arrived at the ordering. As part of your answer, be sure to identify the intermolecular forces that each substance contains, and be prepared to draw Lewis/VSEPR diagrams to support your answer.

MgS, CH_3CH_2OH, CH_3F, CO_2, KCl



$i = 2$

Q19. [11 pts.] Calculate the boiling point of an aqueous 39.5 % (w/w) solution of KBr with a density of 1.89 g/mL.

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

2 | 0.52°C/m

$KBr \rightarrow K^+(aq) + Br^-(aq)$.

$m = \frac{\Delta T_b}{i \cdot K_b} = \frac{\#\text{ mol KBr}}{\#\text{ kg } H_2O}$

$100\text{g} \rightarrow 39.5\text{ g KBr} \left| \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \right| = 0.3319\text{ mol KBr}$

$\rightarrow 60.5\text{ g } H_2O = 0.0605\text{ kg } H_2O$

$m = \frac{0.3319\text{ mol}}{0.0605\text{ kg}} = 5.486\ \frac{\text{mol}}{\text{kg}}$ or (m)

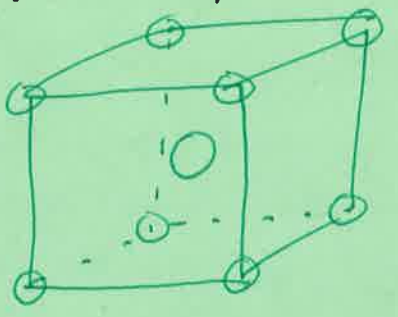
$\Delta T_b = i \cdot K_b \cdot m = 2 \times 0.52°\text{C/m} \times 5.486\text{m}$

$= 5.7°\text{C}$ (2 s.f.)

$\Rightarrow T_b = \underset{\text{(exact)}}{100°\text{C}} + 5.7°\text{C} = \boxed{105.7°\text{C}}$ 1dp.

Q20. [11 pts. total]

a) [2 pts.] Sketch the body-centered cubic (BCC) unit cell.



b) [3 pts.] If every lattice point in the BCC unit cell contains an atom, explain how to calculate how many atoms there are in the unit cell.

$8 \times \frac{1}{8} + 1 \times 1 = 2$ atoms/unit cell.

corners body

c) [3 pts.] Using complete sentences, explain why the van't Hoff factor is 1.3, rather than 2.0 for 0.0500 M $MgSO_4$(aq) at 25 °C.

i = #particles each formula unit breaks down into.

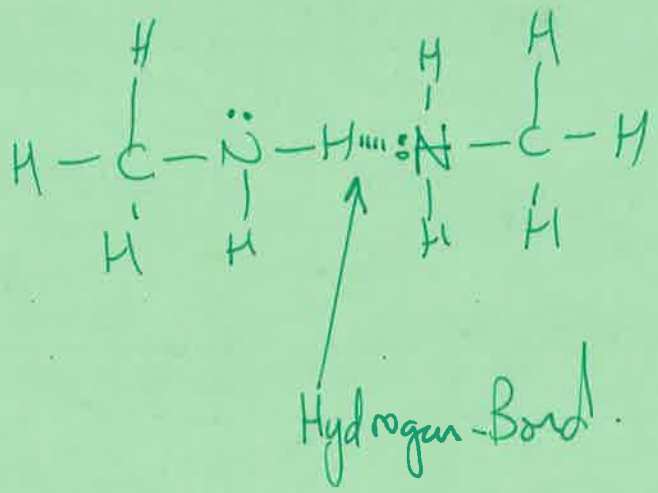
if $MgSO_4 \xrightarrow{H_2O} Mg^{2+}(aq) + SO_4^{2-}(aq)$, expect $i = 2$

In reality, some of the Mg^{2+} and SO_4^{2-} ions will pair (ion-pair) + reduce # particles, $\Rightarrow i < 2$.

if $MgSO_4$ doesn't dissociate, $i = 1$

$\Rightarrow$ expect i to be between 1 and 2.

d) [3 pts.] Sketch the hydrogen bonds between molecules of CH_3NH_2.



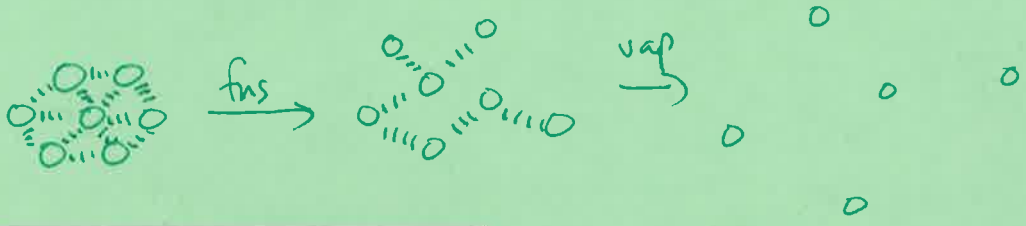
BONUS Question:

In general, the enthalpy of vaporization of a substance is greater than its enthalpy of fusion. Why?

$s \xrightarrow{fus} l \xrightarrow{vap} g$

fus: break some IMF

vap: break all-remaining IMF



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 [268]	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

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

$R = 8.314\ \text{J/mol·K}$

$\Delta T_b = ik_b m$

$\Delta T_f = ik_f m$

$\Pi = iMRT$

$k_f(H_2O) = 1.86\ ^\circ\text{C/m}$

$k_b(H_2O) = 0.52\ ^\circ\text{C/m}$

$c = kP$