Exam 1A
Chem 1142
Spring 2019

Name: KEY

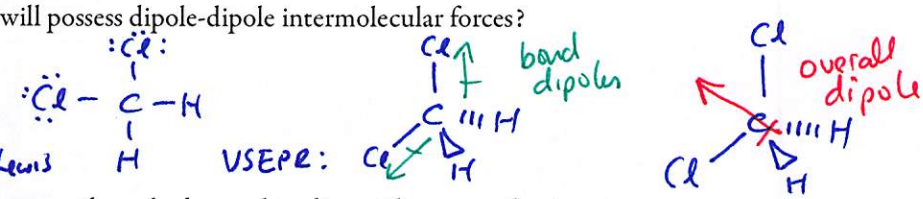
MULTIPLE CHOICE. [3 pts ea.] Enter the best response on your scantron sheet. [**60 pts total.**]

Q1. Which ~~intermolecular~~ force depends upon the total number of electrons in the substance?

A) London dispersion ← ∝ # e⁻s (~ ∝ molar mass)
B) Dipole-dipole
C) Hydrogen-bonds
D) Ion-dipole

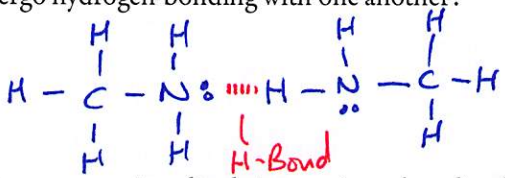
Q2. Which molecule will possess dipole-dipole intermolecular forces?

A) CH_2Cl_2
B) CO_2
C) F_2
D) BeF_2



Q3. Which molecules can undergo hydrogen-bonding with one another?

A) CH_3OCH_3
B) $CH_3CH_2CH_2F$
C) CH_3NH_2
D) CH_2O



Q4. Which ion will undergo the **strongest** ion-dipole interaction when dissolved in water?

∝ |charge on ion|

A) sodium ion Na^+
B) chloride ion Cl^-
C) oxide ion O^{2-}
D) aluminum ion Al^{3+}

Q5. ΔH_{vap} for water is +44.0 kJ/mol. How much heat is gained/lost (state which) when 5.0 g of water evaporates?

A) 12 kJ of heat is lost by water
B) 12 kJ of heat is gained by water
C) 160 kJ of heat is lost by water
D) 160 kJ of heat is gained by water

$$5.0\,g\,H_2O \times \frac{1\,mol\,H_2O}{18.02\,g\,H_2O} \times \frac{+44\,kJ}{1\,mol\,H_2O} = +12\,kJ$$

(+) means energy is gained by water

Q6. What is **always** true for a substance at its boiling point?

A) The vapor pressure is equal to 760 mmHg → only true for NORMAL bp
B) Air bubbles form inside the liquid and rise to the surface → this happens at temps < bp
C) Its temperature must be at or above 100 °C → only for pure H_2O @ 1atm!
D) The vapor pressure is equal to air pressure

Q7. When comparing the following enthalpies of phase transition, which is always true:

A) $\Delta H_{vap} < \Delta H_{fus} < \Delta H_{sub}$

B) $\Delta H_{vap} > \Delta H_{fus} > \Delta H_{sub}$

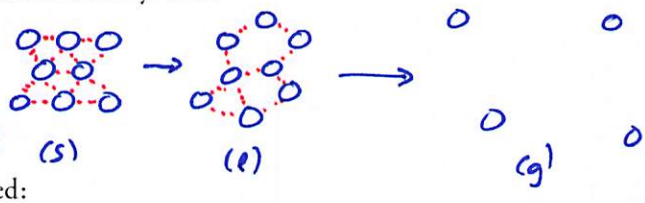
C) $\Delta H_{sub} > \Delta H_{vap} > \Delta H_{fus}$

D) $\Delta H_{sub} < \Delta H_{vap} < \Delta H_{fus}$

sub: s → g (break ALL IMFs)

vap: l → g (" most)

fus: s → l (" some)



Q8. The place on a phase-diagram where three phases coexist is called:

A) The triple point

B) The melting point

C) The critical point

D) The tertiary point

Q9. Experimentally, crystal structure can be best determined using which of the following techniques:

A) Nuclear magnetic resonance spectroscopy

B) Emission spectroscopy

C) X-ray diffraction

D) Cryogenic viscometry

X-ray λ ~ atomic spacing in crystal

Q10. The most efficient packing method for cubic unit cells is

A) Simple cubic

B) Face-centered cubic

C) Body-centered cubic

D) Corner-faced cubic

also known as cubic closest pack (ccp)

Q11. If an atom is present at the **corner** of a cubic unit cell, what fraction is inside the cell?

A) 1

B) 1/2

C) 1/4

D) 1/8

Q12. An example of a network covalent solid is

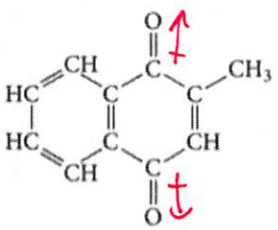
A) diamond(s)

B) sodium chloride(s)

C) aluminum(s)

D) xenon(s)

Q13. What type of solvent would vitamin K_3 (shown below) be most likely to dissolve in?



C–C } non-polar
C–H } bonds.

C=O } polar, but: (1) dipoles may cancel out!

(2) It is a large molecule, so even if the C=O dipoles do not cancel, overall molecule is mostly non-polar.

A) Polar solvents

B) Non-polar solvents

C) Both polar and non-polar solvents

D) Not possible to determine

"like-dissolves-like"

Q14. In general, gas solubility _____ as the temperature is increased

A) increases
B) decreases
C) is unchanged

ex: Warm pop goes "flat" quickly!

Q15. Oxygen gas has a Henry's law constant of 1.3×10^{-3} M·atm^{-1} at 25 °C in water. What pressure of oxygen would be required above water for the oxygen concentration to be 0.013 M?

A) 10. atm
B) 0.10 atm
C) 1.0×10^{2} atm
D) 13 atm

$C = K_H \cdot P \Rightarrow P = C/K_H = \frac{0.013\ M}{1.3 \times 10^{-3}\ M \cdot atm^{-1}} = 10.\ atm$

Q16. A sample of water that contains 15 mg of $PbCl_2$ in 150 g of solution would have a mass concentration of

A) 10 %
B) 1.0 %
C) 100 ppm
D) 0.10 ppb

$\frac{15\ mg}{150\ g} = \frac{15 \times 10^{-3}\ g}{150\ g} = 1.0 \times 10^{-4}$

ppm: $1.0 \times 10^{-4} \times 10^{6} = 100\ ppm$

%: $1.0 \times 10^{-4} \times 100 = 0.010\%$

ppb: $1.0 \times 10^{-4} \times 10^{9} = 100{,}000\ ppb$

Q17. What is the **molal concentration** of 25.0 g of CH_2O dissolved in 75.0 g of water? The final solution volume is 99.5 mL.

A) 8.37 M
B) 25.0 M
C) 8.33 m
D) 11.1 m

molal = mol solute / kg solvent (solute, solvent)

$75.0\ g \times \frac{kg}{10^3\ g} = 0.0750\ kg\ H_2O$

$25.0\ g\ CH_2O \times \frac{1\ mol\ CH_2O}{30.03\ g\ CH_2O} = 0.8325\ mol\ CH_2O$

$\Rightarrow m = \frac{0.8325\ mol}{0.0750\ kg} = 11.1\ \frac{mol}{kg}$ (3 s.f.)

Q18. Which solution will have the greatest osmotic pressure at 37 °C?

A) 0.10 M glucose $i = 1$ molecular
B) 0.10 M $FeCl_3$(aq) $i = 4$ $Fe^{3+}, 3Cl^-$
C) 0.10 M NH_4NO_3(aq) $i = 2$ NH_4^+, NO_3^-
D) 0.10 M NaCl(aq) $i = 2$ Na^+, Cl^-

$\Pi = i \cdot M \cdot R \cdot T$ ⇒ if four sol'ns have same M, T then largest i will have largest Π!

Q19. What is the theoretical value for the van't Hoff factor for the soluble ionic compound, $Sr(OH)_2$?

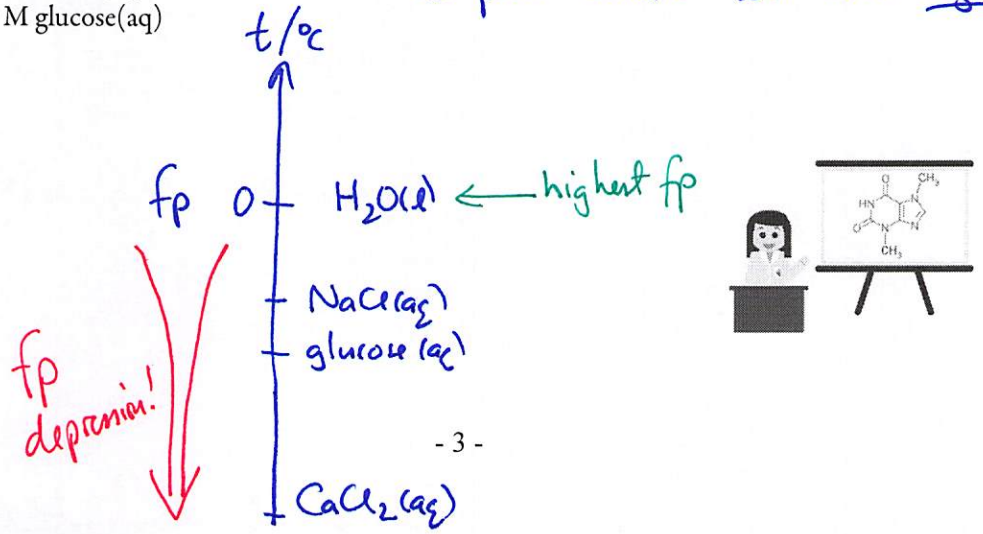
A) 1
B) 2
C) 3
D) 4
E) 5

$Sr^{2+}, 2OH^-$ → 3 particles / formula unit

Q20. Which solution would be expected to have the **highest** freezing point?

A) pure H_2O(l)
B) 0.10 M NaCl(aq)
C) 0.20 M $CaCl_2$(aq)
D) 0.30 M glucose(aq)

Dissolving solutes in solvents will depress fp ⇒ pure solvent will have highest fp!



Short Response.

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

Q21. [10 pts.] 12.0 g of an unknown substance (non-electrolyte) is dissolved in 95.0 g of water, forming a solution that freezes at −1.40 °C. What is the molar mass of this substance? $k_f(H_2O) = 1.86\ °C/m$

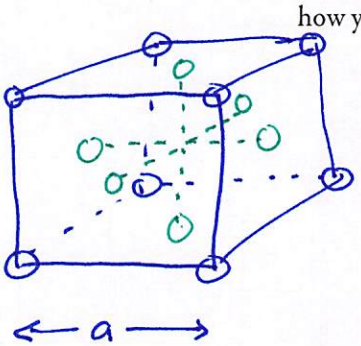
$\Delta T_f = (0°C) - (-1.40°C) = +1.40°C$ (2d.p.)

$\Delta T_f = K_f \cdot m \Rightarrow m = \frac{\Delta T_f}{K_f} = \frac{1.40°C}{1.86°C/m} = 0.7527m$

#mol unknown? $95.0g\ H_2O \times \frac{kg}{10^3 g} \times \frac{0.7527 mol\ unknown}{1\ kg\ H_2O} = 0.07151\ mol\ unknown$

Molar mass? $M = \frac{\#g\ unknown}{\#mol\ unknown} = \frac{12.0g}{0.07151 mol} = 168 g/mol$ (3s.f.)

Q22. [10 pts.] Calculate the density (in units of g/cm^3) of scandium (Sc) if it crystallizes in a face-centered cubic unit cell with an edge length of 464 pm. As part of your answer, sketch the unit cell and explain how you determine the number of atoms inside of it!



8 @ corners = $8 \times 1/8$

6 @ faces = $6 \times 1/2$

4 atoms/cell

$d = m/V$

$V = a^3 = \left(464pm \times \frac{10^{-12} m}{pm} \times \frac{cm}{10^{-2} m}\right)^3$

$= 9.9897 \times 10^{-23} cm^3$ (3s.f.)

$m = 4\ atoms\ Sc \times \frac{1\ mol}{6.022 \times 10^{23} atoms} \times \frac{44.96g\ Sc}{1\ mol\ Sc}$

$= 2.986 \times 10^{-22} g$ (4s.f.)

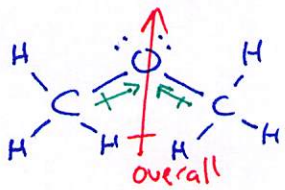
$\Rightarrow d = \frac{m}{V} = \frac{2.986 \times 10^{-22} g}{9.9897 \times 10^{-23} cm^3} = 2.99 g/cm^3$ (3s.f.)

Q23. [5 pts.] There are two structural isomers of C_2H_6O with condensed formulas of CH_3OCH_3 and CH_3CH_2OH.

weaker IMFs (so easier to vaporize)

Which isomer would be expected to have the **greatest vapor pressure**? Explain! *Draw out valid Lewis structures as part of your answer.*

CH_3OCH_3

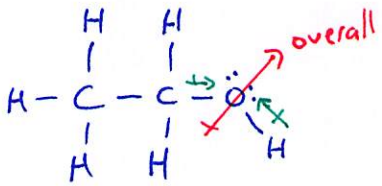


IMFs: LDF, d-d

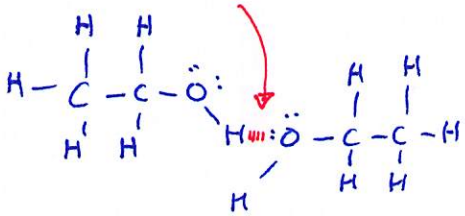
□ weaker set of IMFs

⇒ Greater vp!

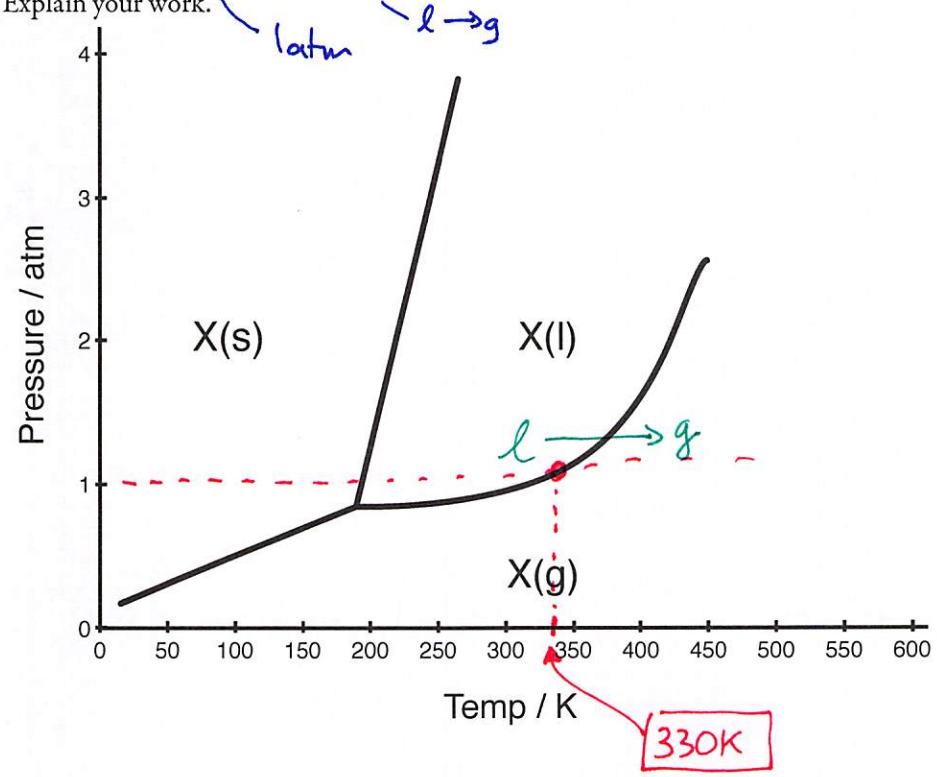
CH_3CH_2OH



IMFs: LDF, d-d, H-Bonds



Q24. [5 pts.] Estimate the normal boiling point of the substance whose phase diagram is reproduced below. Explain your work.



Q25. [10 pts.] Concentrated HCl(aq) is 36.0 % by mass. Convert this to **molar concentration** given the density of the solution is 1.20 g/mL.

molar conc HCl = $\frac{\#\text{mol HCl}}{\#\text{L soln}}$ = [HCl]

Assume 100g: (36.0%) $36.0\text{g HCl} \times \frac{1\text{mol HCl}}{36.46\text{g HCl}} = 0.9874\text{ mol HCl}$ (#mol)

volume? $d = m/V \Rightarrow V = \frac{m}{d} = \frac{100\text{g}}{1.20\text{g/mL}} = 83.33\text{mL} \times \frac{1\text{L}}{1000\text{mL}} = 0.08333\text{L}$

$\Rightarrow [HCl] = \frac{0.9874\text{mol}}{0.08333\text{L}} = 11.8\frac{\text{mol}}{\text{L}}$ (3 s.f.)

BONUS Question:

For two substances to mix and dissolve in one another, what can you say about the strengths of the interactions between the solute and solvent molecules? (solute-solute, solvent-solvent, solute-solvent)

solute-solvent interactions > solute-solute, solvent-solvent

(when solute dissolves, the IMFs it makes w/ the solvent must be stronger than the IMFs that are broken between solute-solute + solvent-solvent)