Carleton UNIVERSITY

# CHEM 1006 A
# Winter 2018

## Midterm #1: Deferred Midterm

*Test duration: 80 minutes*
*Instructor: Alyssa Nause*

**Student Name:** Solutions

**Student Number:** _____

*Answer the questions on the exam paper.*

*If more space is needed, use reverse of exam pages.*

## Part A: Short Answer (5 marks each)

/5

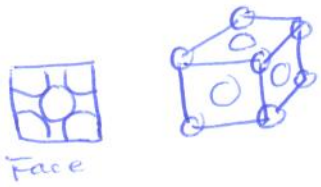
1. Name, describe and sketch the 3 main types of cubic unit cells. List how many atoms are contained within each type of unit cell.

Each
(0.5) name
(0.5) describe / face
(0.5) sketch 3D

(1) Simple cubic

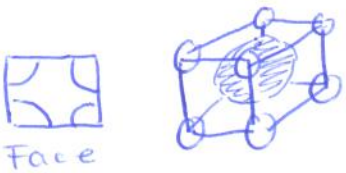

# Atoms $= (\frac{1}{8})(8) = 1$

(2) Face-centered Cubic




# Atoms $= (\frac{1}{8})(8) + (6)(\frac{1}{2})$
$= 4$

(3) Body-centered Cubic




# atoms $= (\frac{1}{8})(8) + 1$
$= 2$

all # atoms correct (0.5)

/5

2. For the following compounds, write the reaction showing their dissolution in water:
   a. $CH_3CH_2CHOH_{(l)}$
   b. $CaO_{(s)}$

a) $CH_3CH_2CHOH_{(l)} \rightarrow CH_3CH_2CHOH_{(aq)}$

(1) no dissociation
(0.5) phase (aq)

b) $CaO_{(s)} \rightarrow Ca^{2+}_{(aq)} + O^{2-}_{(aq)}$

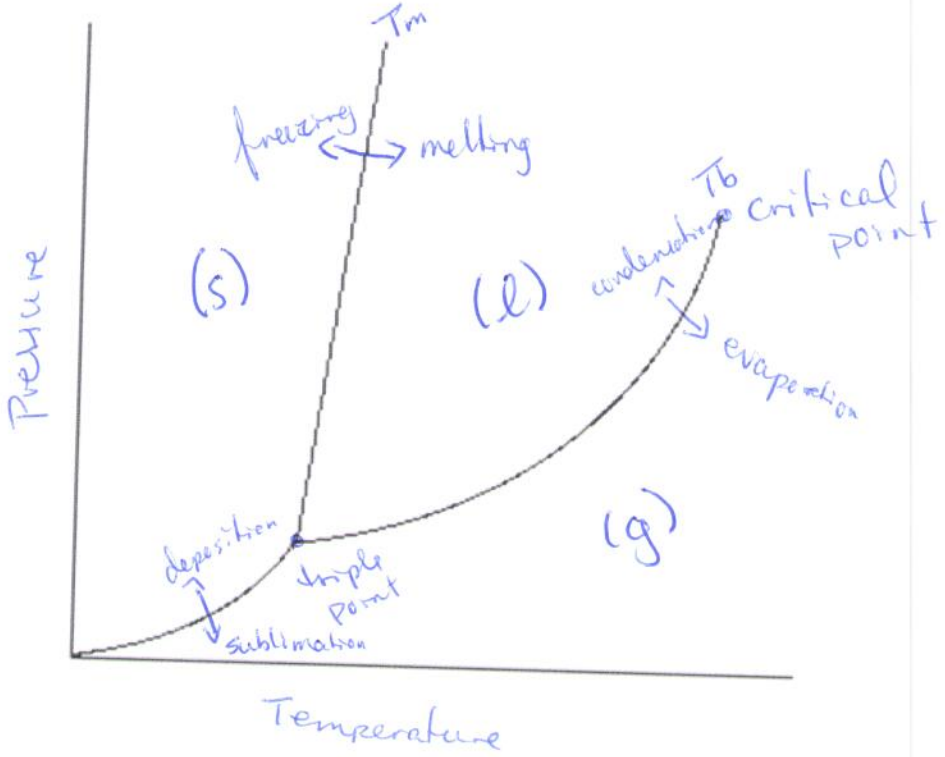
(1) Ca
(0.5) +2 charge
(0.25) phase (aq)

(1) O
(0.5) 2- charge
(0.25) phase (aq)

/5

3. Label all parts of the solvent phase diagram below.

(0.5) each:
- y-axis
- x-axis
- s phase
- l phase
- g phase
- s↔l transition
- s↔g transition
- l↔g transition
- Triple point
- Critical point

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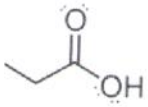
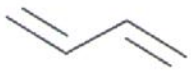
4. Using the structures provided and explaining your reasoning, determine which of these two species would likely be miscible with water.

ethanoic acid 

- dispersion
- dipole-dipole
- H-bonding

butadiene 

- dispersion

$H_2O$ 

- dispersion
- dipole-dipole
- H-bonding

(1) x 3 explain + compare pure intermolecular forces

(1) explain
Ethanoic acid has more intermolecular forces in common with water (compared to common forces between butadiene and water), so ethanoic acid is likely miscible with water (1) miscible = ethanoic acid (butadiene likely insoluble with water).

## Part B: Long Answer Problems (10 marks each)

/10

5. Using the constants provided on the Equations and Constants page, for a solution made by mixing 5.25g of sodium hydroxide ($NaOH_{(s)}$) in 400.0mL of acetic acid ($C_2H_4O_{2(l)}$) at 25.0°C.
   a. determine the boiling point of the solution.
   b. determine the vapour pressure (in kPa) of the solution.

a) Note: solvent = acetic acid, solute = NaOH  Use Equations: $\Delta T_b = i k_b b$, $b = \frac{n}{m}$, $\rho = \frac{m}{V}$, $n = \frac{m}{M}$

$m_{solvent} = m_{acetic\ acid} = (\rho_{acetic})(V_{acetic}) = (1.049\ g/mL)(400.0\ mL) = 419.6\ g$

$m_{acetic\ acid} = 419.6\ g \times \frac{1\ kg}{1000\ g} = 0.4196\ kg$ (0.5 calc, 0.5 convert)

$M_{NaOH} = 22.990\ g/mol + 1.008\ g/mol + 15.999\ g/mol = 39.997\ g/mol$ (0.5 calc)

$n_{solute} = n_{NaOH} = \frac{m_{NaOH}}{M_{NaOH}} = \frac{5.25\ g}{39.997\ g/mol} = 0.131259\ mol$ (0.5 calc)

$b = \frac{n_{solute}}{m_{solvent}} = \frac{0.131259\ mol}{0.4196\ kg} = 0.31282\ \frac{mol}{kg}$ (0.5 calc)

Solution: $NaOH_{(s)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$ (1 equation)

$i = \frac{1+1}{1} = 2$ (1 calc)

$\Delta T_b = i (k_b)_{acetic} b = (2)(3.07\ °C\ kg/mol)(0.31282\ \frac{mol}{kg})$

$\Delta T_b = 1.92072\ °C$ (1 calc)  (+'ve for $T_b$ elevation) (0.5 +'ve)

$T_{b,soln} = T_{b,acetic} + \Delta T_b$

$T_{b,solution} = 118°C + 1.92072\ °C$

$T_{b,solution} = 119.92072\ °C$

$T_{b,solution} = 120.\ °C = 1.20 \times 10^2\ °C$ (1 calc/result) (0.5 sig. figs.)

(part b) on reverse, pg 8)

(5.) b) Use equations: $P_{vap,sol^n} = X_A(P_{vap,A})$

$$X_A = \frac{n_A}{n_{total}} \quad , \quad n = \frac{m}{M}$$

$M_{acetic} = (2 \times 12.011 g/mol) + (4 \times 1.008 g/mol) + (2 \times 15.999 g/mol) = 60.052 g/mol$ (0.5) calc

$$n_{acetic} = \frac{m_{acetic}}{M_{acetic}} = \frac{419.6g}{60.052 g/mol} = 6.98728 mol$$ (0.5) calc

$n_{total} = n_{acetic} + n_{NaOH} = 6.98728 mol + 0.1312598 mol = 7.11854 mol$ (0.5) calc

$$X_{acetic} = \frac{n_{acetic}}{n_{total}} = \frac{6.98728 mol}{7.11854 mol} = 0.98156117$$ (0.5) calc

$P_{vap,solution} = (X_{Acetic})(P_{vap,acetic})$

$P_{vap,sol^n} = (0.98156117)(2.07 kPa)$

$P_{vap,sol^n} = 2.0318 kPa$ (0.5) calc

$P_{vap,sol^n} = 2.03 kPa$ (0.5) sig fig

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6. For the following mechanism,
   a. write the overall reaction,
   b. label each compound as reactant, product, intermediate or catalyst

$HCOOH_{(aq)} + H^+_{(aq)} \rightarrow HCOOH_2^+{}_{(aq)}$ (fast)

$HCOOH_2^+{}_{(aq)} \rightarrow H_2O_{(l)} + HCO^+_{(aq)}$ (slow)

$HCO^+_{(aq)} \rightarrow CO_{(g)} + H^+_{(aq)}$ (fast)

a) overall: $HCOOH_{(aq)} \rightarrow H_2O_{(l)} + CO_{(g)}$

① overall, no errors
① phases

b) Reactant: $HCOOH_{(aq)}$ (1)

Products: $H_2O_{(l)}$ (1), $CO_{(g)}$ (1)

② all phases included

Intermediate: $HCOOH_2^+{}_{(aq)}$ (1), $HCO^+_{(aq)}$ (1)

Catalyst: $H^+_{(aq)}$ (1)

(optional work shown:)

$HCOOH_{(aq)} + H^+_{(aq)} \rightarrow HCOOH_2^+{}_{(aq)}$ (fast)

$HCOOH_2^+{}_{(aq)} \rightarrow H_2O_{(l)} + HCO^+_{(aq)}$ (slow)

$HCO^+_{(aq)} \rightarrow CO_{(g)} + H^+_{(aq)}$ (fast)

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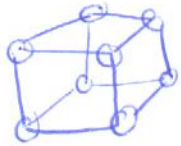
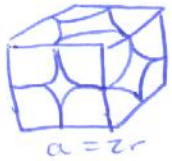
7. A Simple Cubic unit cell has a side length equal to two radii of the atoms making up the structure. What is the packing efficiency of a simple cubic unit cell (in percent)?






$\#atoms = \left(\frac{1}{8}\right)(8) = 1$ (2)

$V_{atoms} = \left(\frac{4}{3}\pi r^3\right) \times 1\,atom = \frac{4}{3}\pi r^3$ (2)

$V_{cell} = (a)^3 = (2r)^3 = 8r^3$ (2)

$\text{Packing Efficiency} = \frac{V_{atoms}}{V_{cell}} \times 100\%$ (1) formula

$= \frac{\frac{4}{3}\pi r^3}{8r^3} \times 100\%$

$= \frac{\frac{4}{3}\pi}{8} \times 100\%$

$= 52.36\%$ (2)

Packing efficiency $= \underline{52\%}$ (1) rounded, units

## Equations and Constants:

$T_{b,\ acetic\ acid} = 118°C$

$T_{f,\ acetic\ acid} = 17.0°C$

$\rho_{acetic\ acid} = 1.049 g\ mL^{-1}$

$K_{f,\ acetic\ acid} = 3.90\ °C\ kg\ mol^{-1}$

$K_{b,\ acetic\ acid} = 3.07\ °C\ kg\ mol^{-1}$

$p_{vap,\ acetic\ acid,\ 25C} = 2.07\ kPa$

$R = 8.314\ L\ kPa\ K^{-1}\ mol^{-1}$

$R = 8.314 \times 10^{-2}\ L\ bar\ K^{-1}\ mol^{-1}$

$R = 62.36\ L\ Torr\ K^{-1}\ mol^{-1}$

$R = 8.206 \times 10^{-2}\ L\ atm\ K^{-1}\ mol^{-1}$

$N_{Av} = 6.022 \times 10^{23}\ mol^{-1}$

$n = m/M$

$c = n/V$

$b = n/m$

$\rho = m/V$

$V_{sphere} = (4/3)\pi r^3$

$[gas_{(aq)}] = K_H(p_{gas})$

$\Delta T_f = i(K_f)b$

$\Delta T_b = i(K_b)b$

$\Pi = icRT$

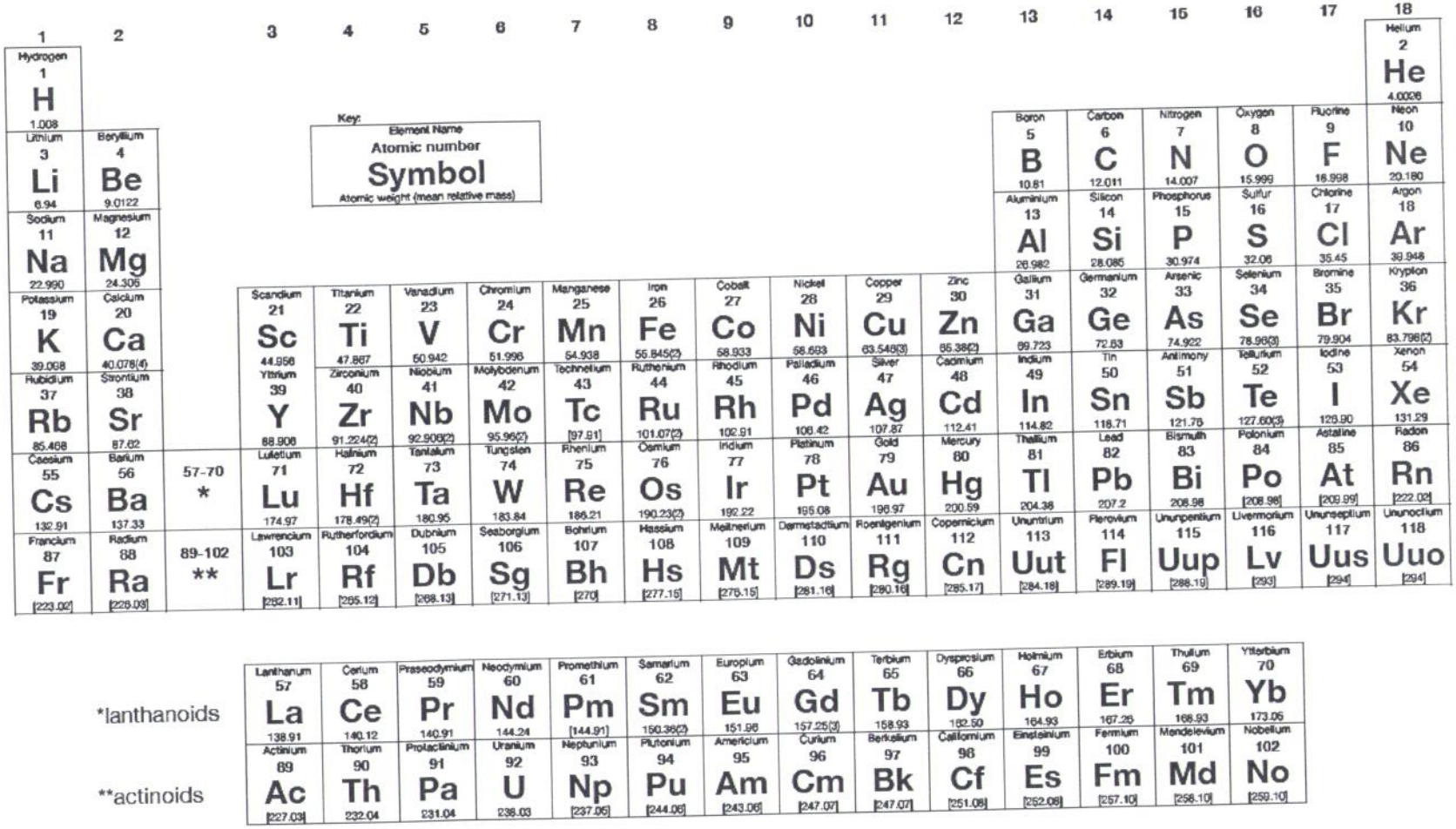
$p_{vap,soln} = X_A p_{vap,A}$

$p_{vap,soln} = X_A p_{vap,A} + X_B p_{vap,B}$

$X_C = n_C/n_{total}$

$1\ atm = 1.01325 \times 10^5\ Pa = 760\ Torr = 1.01325\ bar$

$T(K) = T(°C) + 273.15$


1
2
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10
11
12
13
14
15
16
17
18
Key:
Element Name
Atomic number
Symbol
Atomic weight (mean relative mass)
Hydrogen 1 H 1.008
Helium 2 He 4.0026
Lithium 3 Li 6.94
Beryllium 4 Be 9.0122
Boron 5 B 10.81
Carbon 6 C 12.011
Nitrogen 7 N 14.007
Oxygen 8 O 15.999
Fluorine 9 F 18.998
Neon 10 Ne 20.180
Sodium 11 Na 22.990
Magnesium 12 Mg 24.305
Aluminium 13 Al 26.982
Silicon 14 Si 28.085
Phosphorus 15 P 30.974
Sulfur 16 S 32.06
Chlorine 17 Cl 35.45
Argon 18 Ar 39.948
Potassium 19 K 39.098
Calcium 20 Ca 40.078(4)
Scandium 21 Sc 44.956
Titanium 22 Ti 47.867
Vanadium 23 V 50.942
Chromium 24 Cr 51.996
Manganese 25 Mn 54.938
Iron 26 Fe 55.845(2)
Cobalt 27 Co 58.933
Nickel 28 Ni 58.693
Copper 29 Cu 63.546(3)
Zinc 30 Zn 65.38(2)
Gallium 31 Ga 69.723
Germanium 32 Ge 72.63
Arsenic 33 As 74.922
Selenium 34 Se 78.96(3)
Bromine 35 Br 79.904
Krypton 36 Kr 83.798(2)
Rubidium 37 Rb 85.468
Strontium 38 Sr 87.62
Yttrium 39 Y 88.906
Zirconium 40 Zr 91.224(2)
Niobium 41 Nb 92.906(2)
Molybdenum 42 Mo 95.96(2)
Technetium 43 Tc [97.91]
Ruthenium 44 Ru 101.07(2)
Rhodium 45 Rh 102.91
Palladium 46 Pd 106.42
Silver 47 Ag 107.87
Cadmium 48 Cd 112.41
Indium 49 In 114.82
Tin 50 Sn 118.71
Antimony 51 Sb 121.76
Tellurium 52 Te 127.60(3)
Iodine 53 I 126.90
Xenon 54 Xe 131.29
Caesium 55 Cs 132.91
Barium 56 Ba 137.33
57-70 *
Lutetium 71 Lu 174.97
Hafnium 72 Hf 178.49(2)
Tantalum 73 Ta 180.95
Tungsten 74 W 183.84
Rhenium 75 Re 186.21
Osmium 76 Os 190.23(3)
Iridium 77 Ir 192.22
Platinum 78 Pt 195.08
Gold 79 Au 196.97
Mercury 80 Hg 200.59
Thallium 81 Tl 204.38
Lead 82 Pb 207.2
Bismuth 83 Bi 208.98
Polonium 84 Po [208.98]
Astatine 85 At [209.99]
Radon 86 Rn [222.02]
Francium 87 Fr [223.02]
Radium 88 Ra [226.03]
89-102 **
Lawrencium 103 Lr [262.11]
Rutherfordium 104 Rf [265.12]
Dubnium 105 Db [268.13]
Seaborgium 106 Sg [271.13]
Bohrium 107 Bh [270]
Hassium 108 Hs [277.15]
Meitnerium 109 Mt [276.15]
Darmstadtium 110 Ds [281.16]
Roentgenium 111 Rg [280.16]
Copernicium 112 Cn [285.17]
Ununtrium 113 Uut [284.18]
Flerovium 114 Fl [289.19]
Ununpentium 115 Uup [288.19]
Livermorium 116 Lv [293]
Ununseptium 117 Uus [294]
Ununoctium 118 Uuo [294]
*lanthanoids
Lanthanum 57 La 138.91
Cerium 58 Ce 140.12
Praseodymium 59 Pr 140.91
Neodymium 60 Nd 144.24
Promethium 61 Pm [144.91]
Samarium 62 Sm 150.36(2)
Europium 63 Eu 151.96
Gadolinium 64 Gd 157.25(3)
Terbium 65 Tb 158.93
Dysprosium 66 Dy 162.50
Holmium 67 Ho 164.93
Erbium 68 Er 167.26
Thulium 69 Tm 168.93
Ytterbium 70 Yb 173.05
**actinoids
Actinium 89 Ac [227.03]
Thorium 90 Th 232.04
Protactinium 91 Pa 231.04
Uranium 92 U 238.03
Neptunium 93 Np [237.05]
Plutonium 94 Pu [244.06]
Americium 95 Am [243.06]
Curium 96 Cm [247.07]
Berkelium 97 Bk [247.07]
Californium 98 Cf [251.08]
Einsteinium 99 Es [252.08]
Fermium 100 Fm [257.10]
Mendelevium 101 Md [258.10]
Nobelium 102 No [259.10]