Carleton UNIVERSITY

CHEM 1006 A
Winter 2018

<u>Midterm #1:</u> Thursday, February 1st, 2018

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.

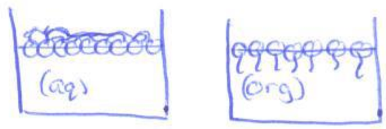
Part A: Short Answer (5 marks each)

5/5

1. Name, describe and sketch the 3 ways surfactants will interact in solution. Identify the region of the surfactant that will interact with aqueous solutions.

Each:
(0.5) name
(0.5) description
(0.5) sketch

(1) Monolayer (single layer of molecules)



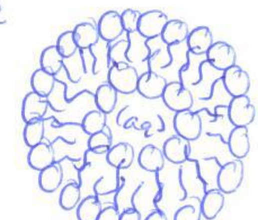
hydrophilic, (aq) interaction
hydrophobic

(0.5) Aq interact ω hydrophilic head

(2) Micelles (grouping "like" tails together)

aqueous interaction outside

(3) Vesicle (pocket protecting "like" tails between layers)



aqueous interaction outside and in inside pocket/cavity

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2. For the following compounds, write the reaction showing their dissolution in water:
   a. $NaHCO_{3(s)}$
   b. $CH_3(CH_2)_{13}CH_{3(s)}$

a) $NaHCO_{3(s)} \longrightarrow Na^+_{(aq)} + HCO_3^-{}_{(aq)}$

(1) Na
(0.5) +1 charge
(0.25) phase (aq)

(1) HCO_3
(0.5) −1 charge
(0.25) phase (aq)

b) $CH_3(CH_2)_{13}CH_{3(s)} \longrightarrow CH_3(CH_2)_{13}CH_{3(aq)}$

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

5/5

3. Using the structures provided and explaining your reasoning, determine if the two species below would be miscible.

1,4-pentadiene

1,5-pentanediol

(to self/pure)
· dispersion

(1) explain pure intermolecular forces

(to self / pure)
· dispersion
· dipole - dipole
· H-bonding

(1) explain pure intermolecular forces

(1) explain shared interaction

Combined / shared interaction:

· dispersion

(1)

∴ NOT miscible (insoluble) because 1,5-pentanediol has very high intermolecular forces to itself, with only weak dispersion to 1,4-pentadiene when mixed.

(1) Explain

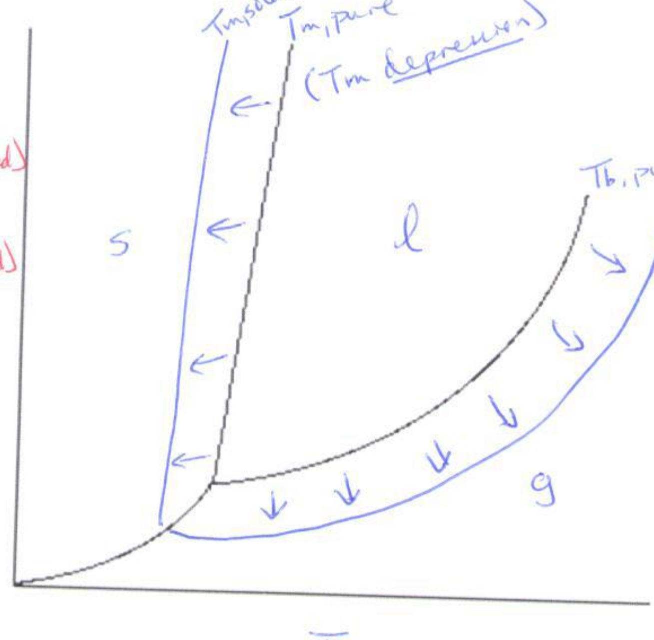
5/5

4. On the phase diagram below, draw the effect on boiling and freezing points of a pure solvent when a solute is added.

(2) Tm moved to left (depressed)

(2) Tb moved to right (elevated)

(1) Tm and Tb labels (or s, l, g labels)



Part B: Long Answer Problems (10 marks each)

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5. Using the constants provided on the Equations and Constants page, for a solution made by mixing 7.55g of potassium sulfate ($K_2SO_{4(s)}$) in 750.0mL of acetic acid ($C_2H_4O_{2(l)}$) at 25.0°C.
   a. determine the melting point of the solution.
   b. determine the osmotic pressure (in kPa) of the system.

a) Use equations: $\Delta T_m = i K_F b$ ($T_m = T_F$, "melt" = "freeze")

$b = \frac{n}{m}$, $\rho = \frac{m}{V}$, $n = \frac{m}{M}$

Solution: $K_2SO_{4(s)} \rightarrow 2K^+_{(aq)} + SO_4^{2-}{}_{(aq)}$ (1) equation (0.5 for phases + charges)

$i = \frac{2+1}{1} = 3$ (0.5) calc

$m_{solvent} = m_{acetic} = (V_{acetic})(\rho_{acetic}) = (750.0mL)(1.049 g/mL) = 786.75g$ (0.5) calc

$m_{acetic} = 786.75g \times \frac{1kg}{1000g} = 0.78675kg$ (0.25) convert

$M_{K_2SO_4} = (2 \times 39.098 g/mol) + 32.08 g/mol + (4 \times 15.999 g/mol)$

$M_{K_2SO_4} = 174.272 g/mol$ (0.5) calc

$n_{solute} = n_{K_2SO_4} = \frac{m_{K_2SO_4}}{M_{K_2SO_4}} = \frac{7.55g}{174.272 g/mol} = 0.043323 mol$ (1) calc

$b = \frac{n_{solute}}{m_{solvent}} = \frac{0.043323 mol}{0.78675 kg} = 0.0550658 mol/kg$ (1) calc

$\Delta T_m (= \Delta T_f) = i(K_{F,acetic})b = (3)(3.90°C\ kg/mol)(0.0550658 \frac{mol}{kg})$

$\Delta T_m = 0.64426986 °C$ (1) calc (w or w/out i = 3)

$\Delta T_m = -0.64426986°C$ (-'ve for Tm depression)

$T_{m,solution} = T_{m,acetic\ acid} + \Delta T_m$

$T_{m,solution} = 17.0°C - 0.64426986°C$ (0.5) -'ve used

$T_{m,solution} = 16.3557°C$

$T_{m,solution} = \underline{16.4°C}$ (1) result/calc

(0.5) sig figs

(reverse, pg 8, for b))

(5.) b) Use equations: $\Pi = iCRT$

$c = \frac{n}{V}$

$V_{solution} = V_{acetic\ acid} = 750.0\ mL \times \frac{1L}{1000mL} = 0.7500\ L$ (0.25) Convert

$n_{K_2SO_4}$ (from part a)) $= 0.043323\ mol$

$C = \frac{n_{K_2SO_4}}{V_{solution}} = \frac{0.043323\ mol}{0.7500L} = 0.057764\ \frac{mol}{L}$ (0.5) Calc

$T = 25.0°C + 273.15 = 298.15K$ (0.25) Convert

$i = 3$ (from part a))

$\Pi = iCRT = (3)(0.057764\ \frac{mol}{L})(8.314\ \frac{L\,kPa}{K\,mol})(298.15K)$

$\Pi_{solution} = 429.56\ kPa$

$\Pi_{solution} = \underline{430.\ kPa} = \underline{4.30 \times 10^2\ kPa}$

(1) calc/result

(0.5) sig figs.

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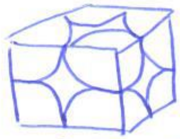
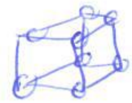
6. Neptunium (Np) was once thought to have a simple cubic unit cell. The side length of the unit cell was determined to be 400.pm.
   a. Determine the volume of the unit cell (in cm^3).
   b. Determine the mass of neptunium within the unit cell.
   c. Determine the volume of one neptunium atom (in cm^3).
   d. Determine the density of the neptunium packing structure (in g/cm^3).


Simple cubic



$V_{atoms} = (\frac{1}{8})(8) = 1 atom$ ① count

① convert

$a = 2r = 400.\,pm \times \frac{1\,m}{10^{12}\,pm} = 4.00\times10^{-10}\,m$ (or $= 4.00\times10^{-8}\,cm$)

a) $V_{cell} = a^3 = (4.00\times10^{-8}\,cm)^3 = 6.40\times10^{-23}\,cm^3$ ① calc ⓪.⑤ sig. figs.

b) $M_{Np} = 237.06\,g/mol$

$N_{AV} = 6.022\times10^{23}\,mol^{-1}$

$m_{1\,Np\,atom} = \frac{237.06\,g/mol}{6.022\times10^{23}\,atom/mol} = 3.93657\times10^{-22}\,g/atom$ ① calc

$m_{Np\,in\,cell} = (m_{1\,Np\,atom})(V_{atoms\,in\,cell})$

$m_{Np\,in\,cell} = (3.93657\times10^{-22}\,g/atom)(1\,atom)$

$m_{Np\,in\,cell} = 3.937\times10^{-22}\,g$ ① result ⓪.⑤ sig. figs.

c) $V_{Np\,atom} = \frac{4}{3}\pi r^3$

$a = 2r$

$400.\,pm = 2r$

$r = 200.\,pm \times \frac{1\,m}{10^{12}\,pm} = 2.00\times10^{-10}\,m$ (or $= 2.00\times10^{-8}\,cm$) ① Convert

$V_{Np\,atom} = \frac{4}{3}\pi(2.00\times10^{-8}\,cm)^3$

$V_{Np\,atom} = 3.35103\times10^{-23}\,cm^3$

$V_{Np,\,atom} = 3.35\times10^{-23}\,cm^3$ ① calc ⓪.⑤ sig. figs.

d) $\rho_{Np\,packing} = \frac{m_{Np,\,cell}}{V_{cell}} = \frac{3.93657\times10^{-22}\,g}{6.40\times10^{-23}\,cm^3} = 6.150891\,g/cm^3$

$\rho_{Np,\,packing} = 6.15\,g/cm^3$ ① calc ⓪.⑤ sig. figs

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

$$CH_{4(g)} + 2H_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 4H_{2(g)} \quad \text{(slow)}$$

$$CO_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)} \quad \text{(fast)}$$

$$2H_{(g)} + Pt_{(s)} \rightleftharpoons H_{2(g)} + Pt_{(s)} \quad \text{(fast)}$$

$$3H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_{(g)} + 2H_2O_{(g)} \quad \text{(fast)}$$

a) Overall: $CH_{4(g)} + 2H_{(g)} + O_{2(g)} \rightleftharpoons 3H_{2(g)} + CO_{2(g)}$

(1) overall, no errors
(1) all phases

b) Reactants: $CH_{4(g)}$ (1), $H_{(g)}$ (1), $O_{2(g)}$ (1)

Products: $H_{2(g)}$ (1), $CO_{2(g)}$ (1)

Intermediates: $CO_{(g)}$ (1)

Catalysts: $H_2O_{(g)}$ (1), $Pt_{(s)}$ (1)

(optional work shown:)

$CH_{4(g)} + 2H_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 2H_{2(g)}$ (slow)

$CO_{(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)}$ (fast)

$2H_{(g)} + Pt_{(s)} \rightleftharpoons H_{2(g)} + Pt_{(s)}$ (fast)

$3H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_{(g)} + 2H_2O_{(g)}$ (fast)

Equations and Constants:

$T_{b,\ acetic\ acid} = 118^{o}C$

$T_{f,\ acetic\ acid} = 17.0^{o}C$

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

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

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

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

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

$R = 8.314x10^{-2}\ L\ bar\ K^{-1}\ mol^{-1}$

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

$R = 8.206x10^{-2}\ L\ atm\ K^{-1}\ mol^{-1}$

$N_{Av} = 6.022x10^{23}\ mol^{-1}$

$n = m/M$

$c = n/V$

$b = n/m$

$\rho = m/V$

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

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

$\Delta T_f = i(K_f)b$

$\Delta T_b = i(K_b)b$

$\Pi = icRT$

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

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

$X_C = n_C/n_{total}$

$1\ atm = 1.01325x10^5\ Pa = 760\ Torr = 1.01325\ bar$

$T(K) = T(^{o}C) + 273.15$

Key: Element Name / Atomic number / **Symbol** / Atomic weight (mean relative mass)

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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]