THE UNIVERSITY OF BRITISH COLUMBIA

CHEMISTRY 123 Midterm 9 February 2010

This examination consists of **7** numbered pages. **TIME LIMIT:**

PLEASE CHECK THAT YOU HAVE A COMPLETE PAPER **1.0 HOURS**

GIVEN NAME(S): ______________________ (IN INK) SURNAME: ______________________ (CAPITALS) (IN INK)

STUDENT NUMBER: ______________________ (IN INK) SIGNATURE: ______________________ (IN INK)

The only calculator allowed is the Sharp EL-510R. All other calculators will be confiscated. Cell phones or other electronic communication devices are not permitted. Molecular models are allowed.

Lecture Section (check √ your section)

___ 201 (MWF 1:00) Bizzotto/Love
___ 202 (MWF 2:00) MacFarlane/Ruddick
___ 203 (MWF 3:00) MacFarlane/Ruddick
___ 210 (MWF 10:00) Patey/Sherman
___ 211 (MWF 11:00) Patey/Sherman
___ 299 (T,Th 9:30) Monga
___ 266 (T,Th 11:00) Lekhi/Stewart
___ 222 (T,Th 2:00) Lekhi/Stewart

Question	Maximum	Obtained	Initials
1	10		
2	14		
3	6		
TOTAL	30		

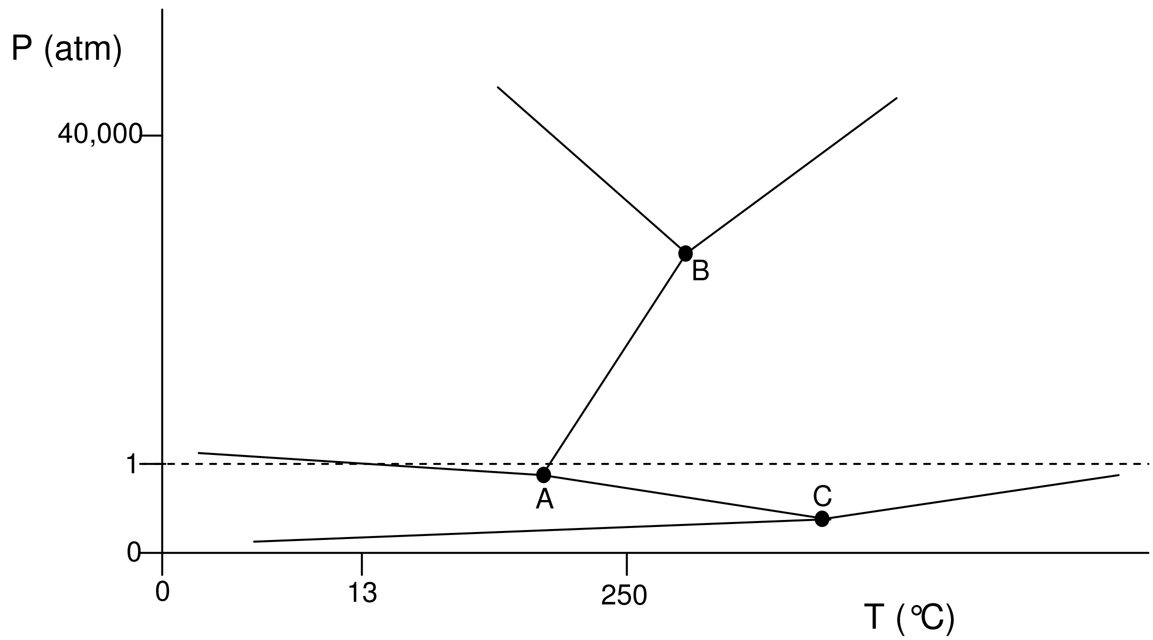
1. $\Delta E = q + w$ or $\Delta U = q + w$
2. $H = E + PV$ or $H = U + PV$
3. $G = H - TS$
4. $\Delta G_{reaction} = \Delta G^0_{reaction} + RT \ln Q$
5. $\Delta G^0_{reaction} = -RT \ln K$
6. $\ln\left(\frac{K_1}{K_2}\right) = \frac{\Delta H^0}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$
7. $\Delta G = w_{el} = -nF\Delta\mathcal{E}$
8. $\Delta\mathcal{E} = \Delta\mathcal{E}^0 - \frac{RT}{nF}\ln Q$
9. $\Delta\mathcal{E}^0 = \frac{RT}{nF}\ln K$
10. $R = 8.314\ J\ K^{-1}\ mol^{-1} = 0.0821\ L\ atm\ K^{-1}\ mol^{-1}$
11. $1\ L\ atm = 101.3\ J$
12. $F = 96,500$ coulombs mol^{-1}
13. $1\ J = 1$ volt coulomb
14. $K_w = 1.00 \times 10^{-14}$ at 25°C (298.15°K)
15. Kelvins = degrees Celsius + 273.15

REGULATIONS FOR EXAMINATIONS

1. Each candidate must be prepared to produce upon request, a Library/AMS card for identification.
2. Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions.
3. No candidates shall be permitted to enter the examination room after the expiration of one half hour from the scheduled starting time, or to leave during the first half hour of the examination.
4. Candidates guilty of any of the following, or similar, dishonest practices shall be immediately dismissed from the examination and shall be liable to disciplinary action:
   (a) Having at the place of writing any books, papers or memoranda, calculators, audio or visual cassette players or other memory aid devices, other than those authorized by the examiners.
   (b) Speaking or communicating with other candidates.
   (c) Purposely exposing written papers to the view of other candidates. The plea of accident or forgetfulness shall not be received.
5. Candidates must not destroy or mutilate any examination material; must hand in all examination papers; and must not take any examination material from the examination room without permission of the invigilator.

ANSWER ALL QUESTIONS

1. [10 points] The phase diagram for tin (not to scale) is shown below. This is a system which has three solid phases (Sn-I, Sn-II and Sn-III) in addition to a liquid phase (L) and a vapour phase (V). At point A, Sn-I, Sn-II and the liquid phase are in equilibrium. At point B, Sn-I, Sn-III and the liquid phase are in equilibrium. The transition from each of the solid phases to the liquid phase is endothermic. Vapour (V) is one of the phases in equilibrium at point C. (The dotted line is indicating P = 1 atm)



a) Label the diagram indicating the phase that is stable in each region.

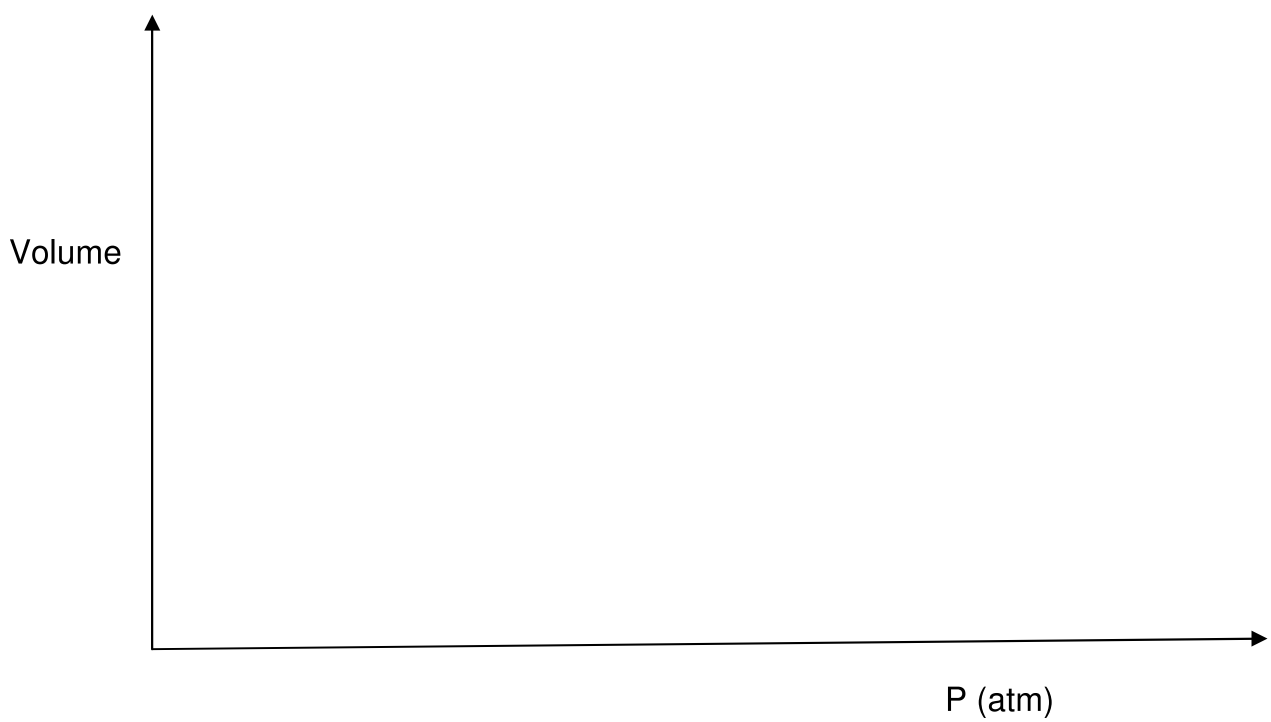
b) One of the solid phases has a diamond-like structure while the other two solid phases have metallic lattices in which the atoms are more closely packed giving higher densities. **Which of the three solids has the diamond-like structure?**

c) In early cathedrals (where it often tended to be much colder than 20°C) the tin organ pipes, constructed at 20°C, developed growths which were thought to be the work of the devil.

i. What phase transition was the devil bringing about?

ii. Is this transition endothermic or exothermic?

d) Sketch (not to scale) on the axis below the isotherm curve as tin is compressed from P = 0 atm to P = 40,000 atm at 250°C. Label the phases on the curve.



2. [14 points] Your objective is to synthesize some hydrogen cyanide (HCN) from commonly available gases. Consider the following reaction that you might use:

Reaction (1) $$CH_4(g) + NH_3(g) + \frac{3}{2}O_2(g) \longrightarrow HCN(g) + 3H_2O(g)$$

For this reaction $\Delta G^0 = -493.9$ kJ at 25°C.

a) Write the standard formation reaction for HCN(g). For this reaction, $\Delta H_{reaction}$ (at 25°C, P = 1 atm) is 135.1 kJ mol^{-1}

b) Using the additional data below, determine if Reaction (1) is exothermic or endothermic under standard conditions at 25°C. Justify your answer with calculations.

	$\Delta H^0_{f,298\ K}$ kJ mol^{-1}	**$S^0_{298\ K}$ J $mol^{-1}K^{-1}$**
$CH_4(g)$	−74.81	186.3
$NH_3(g)$	−46.11	192.5
$H_2O(g)$	−241.8	188.8
$H_2(g)$		130.7
O_2 (g)		205.1
N_2 (g)		191.6
C(s, graphite)		5.74

c) Calculate ΔS^0 for Reaction (1) at 25°C in J K^{-1}.

d) Consider the alternative reaction for producing HCN:

Reaction (2) $\quad CH_4(g) + NH_3(g) \longrightarrow HCN(g) + 3H_2(g)$

Reaction (2) has $\Delta H^0_{298\ K} = +256.0$ kJ and $\Delta S^0_{298\ K} = +215.6$ J K^{-1}. At 25°C would Reaction (2) be a better choice thermodynamically than Reaction (1) for producing HCN? Justify your answer with calculations.

e) Suppose that Reaction (1) and Reaction (2) are carried out at the same temperature. Assuming the enthalpy and entropy changes are independent of temperature, above what temperature would Reaction (2) be more thermodynamically favourable than Reaction (1) for the production of HCN?

3. [6 points] Solid ammonium perchlorate dissociates according to the equation

$$NH_4ClO_4(s) \longrightarrow NH_3(g) + HClO_4(g)$$

At 520 K the ΔG^0 for this reaction is 88.9 kJ. For calculation purposes, assume that all gases are ideal.

a) Write out an exact expression for the equilibrium constant of this reaction in terms of activities.

b) If $NH_4ClO_4(s)$ is placed in a closed, previously evacuated container and the reaction is allowed to reach chemical equilibrium at 520 K, what is the total equilibrium vapour pressure in the container?

END OF EXAMINATION