

THE UNIVERSITY OF BRITISH COLUMBIA

CHEMISTRY 123 MID-TERM EXAM

9 February 2006

This examination consists of **8** numbered pages.

PLEASE CHECK THAT YOU HAVE A COMPLETE PAPER

TIME LIMIT:
1.0 HOUR

GIVEN NAME(S): _____ (IN INK)	SURNAME: _____ (CAPITALS) (IN INK)
STUDENT NUMBER: _____ (IN INK)	SIGNATURE: _____ (IN INK)

NO CALCULATORS ALLOWED PREPROGRAMMED WITH ANY CHEMISTRY OR PHYSICS FORMULAE OR TEXTUAL MATERIAL. MOLECULAR MODELS ARE ALLOWED.

Lecture Section (check \checkmark your section)

- ___ 201 (MWF 1:00) Drs. Wang/Ruddick
- ___ 202 (MWF 2:00) Drs. Wang/Ruddick
- ___ 209 (MWF 9:00) Dr. Sauer
- ___ 210 (MWF 10:00) Dr. Comisarow
- ___ 211 (MWF 11:00) Dr. Liu
- ___ 299 (T,Th 9:30) Dr. Herring
- ___ 222 (T,Th 2:00) Dr. Sherman

Question	Maximum	Obtained	Initials
1	5		
2	10		
3	20		
4	10		
TOTAL	45		
MARK	15		

REGULATIONS FOR EXAMINATIONS

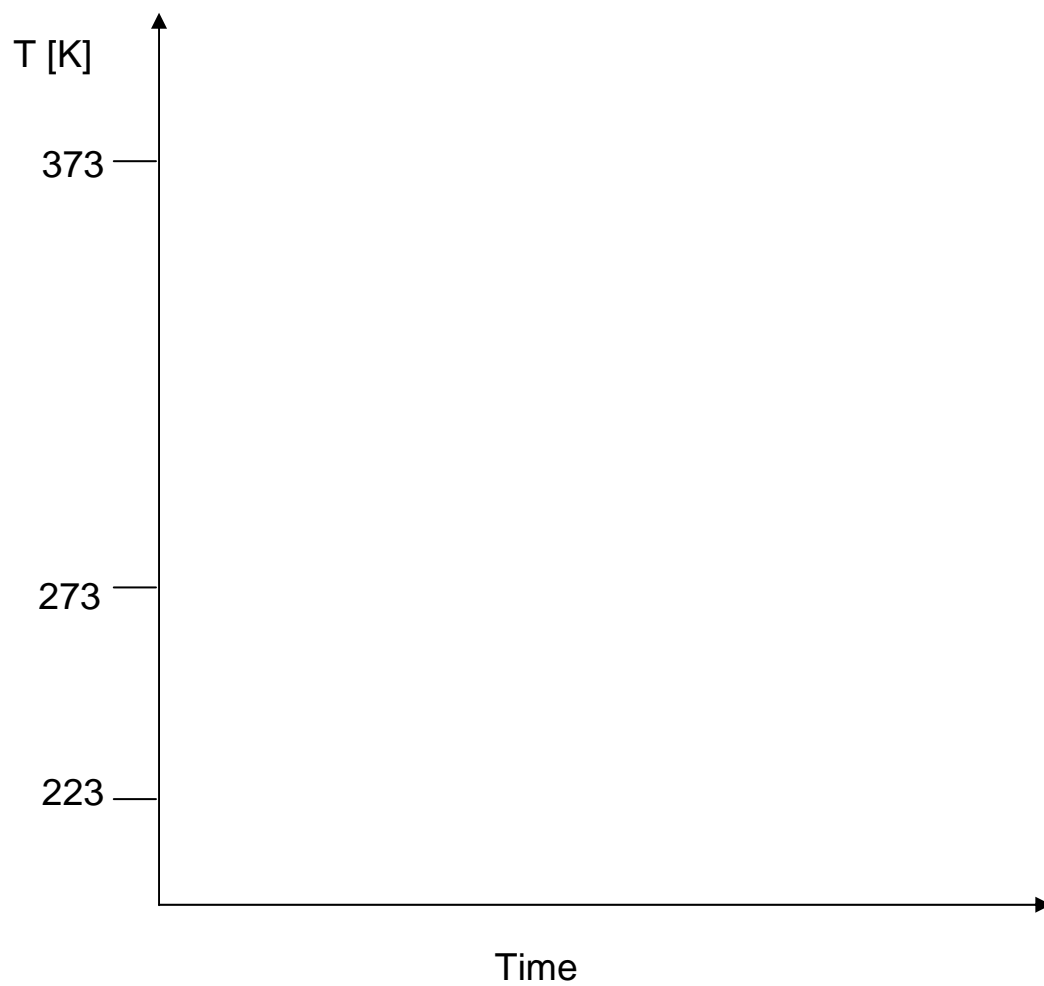
- Each candidate must be prepared to produce upon request, a Library/AMS card for identification.
- Candidates are not permitted to ask questions of the invigilators, except in cases of supposed errors or ambiguities in examination questions.
- No candidates shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half hour of the examination.
- 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:
 - Making use of any books, papers or memoranda, calculators, audio or visual cassette players or other memory and devices, other than those authorized by the examiners.
 - Speaking or communicating with other candidates.
 - Purposely exposing written papers to the view of other candidates. The plea of accident or forgetfulness shall not be received.
- 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

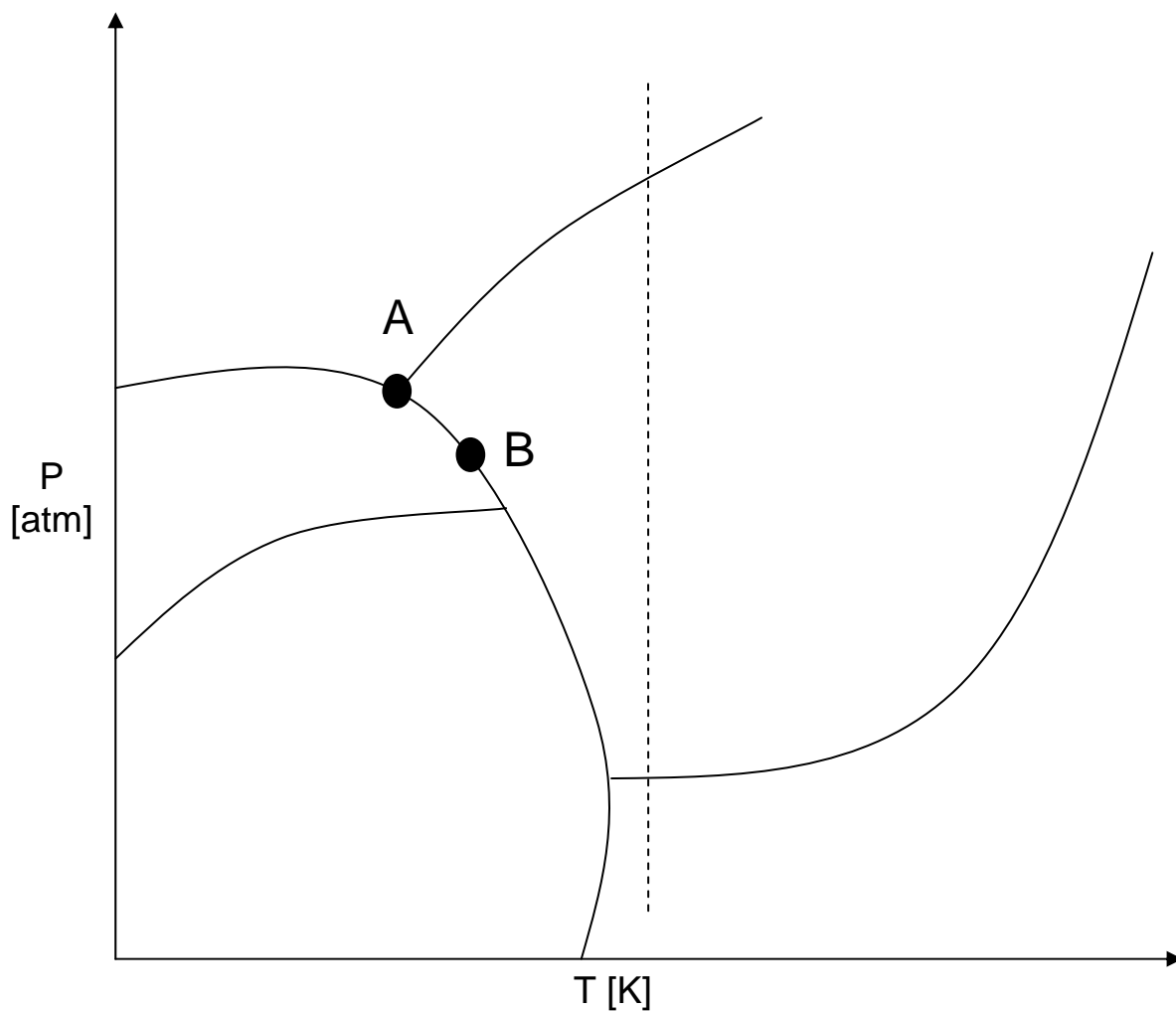
*** FORMULA & DATA ***

- $\Delta E = q + w$
- $H = E + PV$
- $G = H - TS$
- $\Delta G_{\text{reaction}} = \Delta G_{\text{reaction}}^0 + RT \ln Q$
- $\Delta G_{\text{reaction}}^0 = -RT \ln K$
- $\ln\left(\frac{K_1}{K_2}\right) = \frac{\Delta H^0}{R} \left(\frac{1}{T_2} - \frac{1}{T_1}\right)$
- $\Delta G = w_{\text{el}} = -nF\Delta\mathcal{E}$
- $\Delta\mathcal{E} = \Delta\mathcal{E}^0 - \frac{RT}{nF} \ln Q$
- $\Delta\mathcal{E}^0 = \frac{RT}{nF} \ln K$
- $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$
- $1 \text{ L atm} = 101.3 \text{ J}$
- $F = 96,500 \text{ coulombs mol}^{-1}$
- $1 \text{ J} = 1 \text{ volt coulomb}$
- $K_w = 1.00 \times 10^{-14} \text{ at } 25^\circ\text{C} (298.15^\circ\text{K})$
- $\text{Kelvins} = \text{degrees Celsius} + 273.15$

1. A substance has the following properties: boiling point = 75°C and melting point = -15°C . Sketch a heating curve for the substance from -50 to 100°C in the diagram shown below. Clearly label the phases present at each individual step (five steps).

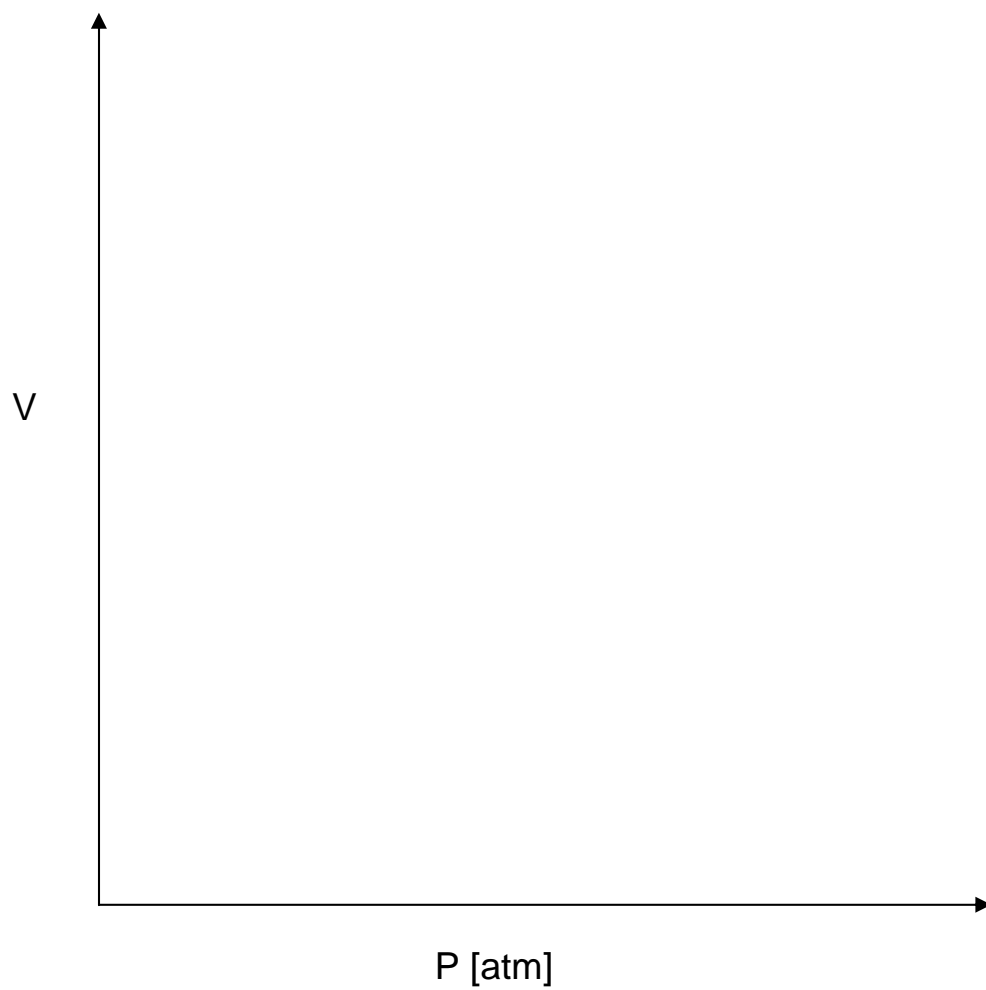


2. A phase diagram for an unknown substance is shown below. This substance has a vapour and liquid phase, and three solid phases (solid I, II and III). At point A on the diagram, solid III, solid II and the liquid phase are in equilibrium. Solid II is denser than solid III.



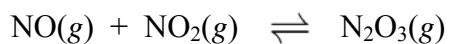
- (a) Label the states present in each of the five regions of the phase diagram.
- (b) Label all triple points with TP and the critical point with CP.
- (c) Which phase present at point B has the higher density?

- (d) Sketch (not to scale) on the axis below the effect of decreasing pressure on the volume of the substance along the dashed line on the phase diagram on page 2.



3. Assume that all gases are ideal. For ideal gases, $PV = nRT$, and $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$.

One possible way to make dinitrogen trioxide (N_2O_3) is through the following reaction:



At 298.15°K , the basic thermodynamic quantities are given below:

Substance	$\Delta H_f^\circ (\text{kJ mol}^{-1})$	$S^\circ (\text{J mol}^{-1} \text{K}^{-1})$	$\Delta G_f^\circ (\text{kJ mol}^{-1})$
$\text{NO}(g)$	91.3	210.8	87.6
$\text{NO}_2(g)$	33.2	240.1	51.3
$\text{N}_2\text{O}_3(g)$	82.8	314.6	

- (a) What is the heat of reaction under constant pressure at 298.15°K under standard conditions?

$q_p =$ _____

- (b) Calculate ΔS° , ΔE° , and ΔG° for this reaction at 298.15°K ?

$\Delta S^\circ =$ _____ $\Delta E^\circ =$ _____ $\Delta G^\circ =$ _____

- (c) Evaluate the standard Gibbs free energy of formation, ΔG_f° , of $\text{N}_2\text{O}_3(g)$ at 298.15°K .

$$\Delta G_f^\circ(\text{N}_2\text{O}_3) = \underline{\hspace{2cm}}$$

- (d) Evaluate the equilibrium constant, K , at 298.15°K .

$$K = \underline{\hspace{2cm}}$$

- (e) Write an expression for the equilibrium constant in terms of activities and in terms of partial pressures.

- (f) Could this reaction be used to mass produce N_2O_3 at 298.15°K ? **Give reasoning for your answer.**

Yes or No

- (g) Will increasing the temperature favour the production of N_2O_3 ? **Give reasoning for your answer.**

Yes or No

- (h) If a chemical factory operating under standard conditions is built in a desert near the equator in Australia, where the temperature stays above 35°C during the entire year, will N_2O_3 be produced spontaneously by using this reaction? Assume that ΔS° and ΔH° do not change with the temperature. **Give reasoning for your answer.**

Yes_____ or No_____

4. Consider the galvanic cell based on the following half-reactions at 25°C



(a) Write the overall cell reaction in the direction of spontaneous change.

(b) Calculate the standard cell potential $\Delta\epsilon^{\circ}_{\text{cell}}$ and ΔG°

$$\Delta\epsilon^{\circ}_{\text{cell}} = \underline{\hspace{2cm}} \quad \Delta G^{\circ} = \underline{\hspace{2cm}}$$

(c) Calculate the cell potential $\Delta\epsilon_{\text{cell}}$ when the concentration of $\text{Cr}^{2+}(aq)$ and $\text{Cr}^{3+}(aq)$ are both 0.001 M.

- (d) Qualitatively (that is increase, decrease, or no change), what happens to the cell potential of a cell operating under standard conditions, when some NaOH solution is added to the compartment containing $\text{Cr}(s)$ and $\text{Cr}^{2+}(aq)$? The compound $\text{Cr}(\text{OH})_2$ precipitates: it is a sparingly soluble substance. **Provide a brief explanation of your choice.**

Increase_____ or Decrease_____ or No Change_____

- (e) Given that the standard cell potential goes down on raising the temperature, what is the sign of the enthalpy change for the cell reaction at 25°C ? **Provide a brief explanation of your choice.**

Plus_____ or Minus_____