

The University of Waterloo
Chemistry 254 Elementary Thermodynamics
April 16, 1992

FINAL EXAMINATION
NOW, CHEMISTRY 452D — ASSIGNMENT #1 [DUE: Sept 20, 2005]
DO #2 to #6

NAME I.D.
(surname first)

Instructions

- (1) Answer ALL six questions.
- (2) A standard, non-programmable calculator is allowed.
- (3) Total time permitted for this examination is THREE hours.

Some (possibly useful) Equations and Constants

The gas constant $R = 1.99 \text{ cal/mol/K} = 0.082 \text{ l-atm/mol/K} = 8.3 \text{ J/mol/K}$

Internal Energy: $dU = (\partial U/\partial T)_V dT + (\partial U/\partial V)_T dV$

$$(\partial U/\partial V)_T = T(\partial P/\partial T)_V - P$$

For an ideal gas: $P = nRT/V$

$$(\partial U/\partial V)_T = 0$$

$$C_p/n - C_v/n = R$$

For a van der Waals gas: $P = nRT/(V-nb) - n^2a/V^2$

$$(\partial U/\partial V)_T = n^2a/V^2$$

Gibbs Free Energy: $\Delta G^\ominus = -RT \ln K$

Gibbs-Helmholtz equation: $[\partial(G/T)/\partial T]_P = -H/T^2$

PLEASE SUBMIT BOTH THE EXAM PAPER (*this paper*) AND THE BOOKLET.

QUESTION	SCORE	MAXIMUM
1		20%
2		10%
3		20%
4		15%
5		15%
6		20%
TOTAL		100%

[1] Briefly discuss and/or define the following concepts in thermodynamics.

a. Phase equilibrium and reaction equilibrium. (Be sure to define all variables).

[5%]

b. Intensive and extensive properties. (Give an example for each).

[5%]

c. The second law of thermodynamics, from the system's point of view.

[5%]

d. The use of van't Hoff equation to determine thermodynamics quantities.

[5%]

[2] During a Grey Cup game, a football official inflated a football to the required pressure of 191 kPa prior to the game. The football had an volume of 2.65 l and the air was at room temperature (25°C) when the football was first inflated. The ball was then taken onto the field. By kick-off time, the air temperature had dropped to 0°C.

How much heavier would the football be if the official now had to re-inflate the football to the required pressure of 191 kPa? Hint: Molar mass of air is 28.97g/mol. We can assume air as a monatomic ideal gas.

[10%]

[3] One mole of a monatomic ideal gas expands isothermally at 300 K into an evacuated vessel so that the total pressure drops from 10 atm to 1 atm. i.e. It expands from a vessel of 2.463 l into a connecting vessel such that the total volume becomes 24.63 l.

a. Calculate w, q, ΔU and ΔH .

[10%]

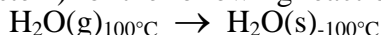
b. Now, calculate ΔS , ΔA and ΔG . Is this a spontaneous process?

[10%]

[4] Given the following data for H₂O:

$$\begin{array}{ll} C_p(l) = 75.3 \text{ J/K/mol} ; & C_p(s) = 2.05 \text{ J/K/mol} ; \\ \Delta H_{\text{vap}} = 40670 \text{ J/mol} ; & \Delta H_{\text{fus}} = 6008 \text{ J/mol} . \end{array}$$

Calculate S (of the system) for the following reaction.



[15%]

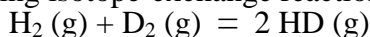
[5]a. The Gay-Lussac-Joule experiment indicates that the internal energy of an ideal gas is a function of temperature only. Use the appropriate Maxwell relation(s) to give a mathematical proof of this statement.

[10%]

b. By considering the temperature dependence of the Gibbs free energy and one of the six basic equations, derive the Gibbs-Helmholtz equation.

[5%]

[6] Suppose we put 0.3 mol of H₂ and 0.1 mol of D₂ into a 2.0 l flask at 25°C with a catalyst to promote the following isotope-exchange reaction:



For this reaction, $\Delta G^\circ = -2.928 \text{ kJ/mol}$.

a. Determine the equilibrium constant, K.

[10%]

b. Determine the amount (in mol) of HD produced.

Hint. For a quadratic equation $ax^2 + bx + c = 0$, the roots are given by the following:

$$x = [-b \pm (b^2 - 4ac)^{1/2}] / [2a].$$

[10%]