

# Sample Solutions

For instructor's use only

1	1c bonus	2	3	4	Si. D.	Total:
						/14

Name:

Student ID:

Rio is for 'significant digits' (possibly -1)

## UNIVERSITY OF MANITOBA, DEPARTMENT OF CHEMISTRY Chemistry 2290, Winter 2012, Dr. H. Georg Schreckenbach

### First Midterm Examination February 13, 2012

This exam has 4 (four) pages. *READ the question carefully!* Answer **ALL** questions, except possibly 1c, which is a bonus question that may earn you one extra mark. Most questions have *multiple* parts. Note that the questions aren't necessarily ordered by difficulty or by any other criteria.

If you use *pencil*, your exam will not be remarked! For numerical problems, all mathematical steps must be shown. Please answer all questions *on* the question sheets. Use *reverse* side or extra paper if more space is needed. On any extra sheet, please indicate your name and student ID number, please.

#### 1. Reversible and irreversible processes

3 marks (parts a and b; 1 bonus mark (part c))

(a) In the context of thermodynamics, what is a "reversible process"? (Definition.)

(b) Give an example of an irreversible process.

(c Bonus) Provide a formal proof of the Clausius inequality.

(a) reversible: infinitely slow process that goes through infinitely many infinitesimal steps such that system and surr. are always in equilibrium.

(b) any real, natural (finite) process

(c) See lecture notes:

• Any reversible cycle has the Carnot efficiency:  
 $-W_{rev} = q_{rev}$

• Irreversible cycle:  $-W_{irr} < -W_{rev}$  (max amount of work from rev.)  
 (otherwise, this could be used to create a perpetual mobile of the 2<sup>nd</sup> kind; violation of 2<sup>nd</sup> Law)

• hence:  $\delta W_{rev} < \delta W_{irr}$

$\Rightarrow \delta q_{rev} > \delta q_{irr}$  (1<sup>st</sup> Law)

$$\frac{\delta q_{rev}}{T} > \frac{\delta q_{irr}}{T}$$

$$dS = \frac{\delta q_{rev}}{T} \geq \frac{\delta q}{T}$$

## 2. Phase transition

4 marks

A certain material is observed to have a phase transition between the crystalline phase and the liquid crystalline phase at a temperature of 424.9 K. The observed enthalpy of the phase transition is 80.1 J/g (that's *Joules per gram*). The densities at this temperature are 0.8361 g/cm<sup>3</sup> for the crystalline phase, and 0.871 g/cm<sup>3</sup> for the liquid crystal phase.

Given atmospheric pressure (1.00 atm) and the equilibrium temperature of the phase transition (i.e. 424.9 K), calculate the volume change  $\Delta V$ , the entropy change  $\Delta S$ , the change in internal energy  $\Delta U$  and the change in enthalpy  $\Delta H$  for the phase transition of 2.50g of this substance from the crystalline state to the liquid crystal state.

$$T = 424.9 \text{ K}$$

$$m = 2.50 \text{ g}$$

$$\rho_{\text{cryst}} = 0.8361 \text{ g cm}^{-3}$$

$$\rho_{\text{lc}} = 0.871 \text{ g cm}^{-3}$$

$$\Delta H(g) = 80.1 \text{ J/g (per gram)}$$

$$P = 1.00 \text{ atm} = \text{const}$$

$$\Delta V = V_{\text{lc}} - V_{\text{cryst}}$$

$$= \frac{m}{\rho_{\text{lc}}} - \frac{m}{\rho_{\text{cryst}}}$$

$$= -0.120 \text{ cm}^3 \text{ (for 2.50 g)}$$

$$\Delta S = \frac{m \Delta H(g)}{T} = 0.471 \text{ J/K}$$

$$\Delta U = \Delta H - \Delta(PV)$$

$$= \Delta H - P \Delta V \text{ (const } P)$$

$$= m \Delta H(g) - 1 \text{ atm } \Delta V$$

$$= 200. \text{ J} \quad \left( = +0.0122 \text{ J, negligible as compared to } \Delta H \right)$$

$$\Delta H = m \Delta H(g) = 200. \text{ J}$$

### 3. Ideal gas

3 marks

Using the ideal gas law, calculate the average molar mass of air at sea level (assume 1.00 atm pressure and 0.00°C) if the density of air is 1.292 g L<sup>-1</sup> (value taken from Wikipedia.org).

$$P = 1.00 \text{ atm} = 101,325 \text{ Pa}$$

$$T = 0.00^\circ\text{C} = 273.15 \text{ K}$$

$$\rho = 1.292 \text{ g/L} = 1.292 \frac{\text{kg}}{\text{m}^3} \quad \left(\rho = \frac{m}{V}\right)$$

---

$$PV = nRT$$

$$M = \frac{m}{n}$$

$$n = \frac{m}{M}$$

$$PV = \frac{m}{M} RT$$

$$M = \left(\frac{m}{V}\right) \frac{RT}{P} = 0.0290 \frac{\text{kg}}{\text{mol}}$$
$$= 29.0 \frac{\text{g}}{\text{mol}}$$

#### 4. Entropy

4 marks

- (a) Give a *brief* description of the microscopic interpretation of the entropy. Illustrate your explanation using the change of entropy during the vaporization of a liquid as an example.
- (b) State how "entropy" could be used to find the direction of spontaneous change, for instance, whether a chemical reaction goes spontaneously in the forward or backward direction.

- (a)
- Measure of disorder
  - # of microstates available to the system:  
 $S \propto \ln[\text{\# of microstates}]$
  - liquid: short range order; high density  
(molecules close together)
  - gas  $\rightarrow$  no order (essentially)

- (b) use  $\Delta S_{\text{universe}} = \Delta S_{\text{sys}} + \Delta S_{\text{sur}}$
- $\Delta S_{\text{universe}} > 0$  for spontaneous change

Total marks in this exam: 14 (regular questions); bonus marks: 1 (question 1c)

---

--- END OF EXAM ---