

# *Chemistry 1B, Spring 2004*

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## Midterm 2

March 18, 2004

(90 min, closed book)

Name: \_\_\_\_\_

SID: \_\_\_\_\_

TA Name: \_\_\_\_\_

- This exam has 39 multiple choice questions.
- Fill in the Scantron form AND circle your answer on the exam.
- Each question is worth 4 points.

**Note:**

- The questions on the exam may be answered in any order.
- All the questions are equally weighted. Answer those you can quickly and go back to those that require more thought.
- Some questions may seem obvious or too simple. They are. There are no 'trick' questions.
- Questions that contain 'mark all that apply' may require you to mark more than one answer to get credit for that question.

- Potentially useful relations:

$$[A]_t = [A]_0 e^{-kt}$$

$$\ln[A]_t = \ln[A]_0 - kt$$

$$t_{1/2} = \ln 2/k$$

$$1/[A]_t = 1/[A]_0 + kt$$

$$k = A e^{(-E_a/RT)}$$

$$\ln(k_1/k_2) = E_a/R (1/T_2 - 1/T_1)$$

$$t_{1/2} = 1/[A]_0 k$$

$$t_{1/2} = [A]_0/k$$

$$PV = nRT$$

$$E_{kin} = \frac{3}{2} RT$$

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\Delta E = q + w$$

$$w = -P_{ext} \Delta V$$

$$\Delta E = \frac{3}{2} nR \Delta T$$

$$N_0 = 6.02214 \times 10^{23} \text{ mol}^{-1}$$

$$R_\infty = 2.179874 \times 10^{-18} \text{ J}$$

$$R_\infty = 3.28984 \times 10^{15} \text{ Hz}$$

$$k = 1.38066 \times 10^{-23} \text{ J K}^{-1}$$

$$h = 6.62608 \times 10^{-34} \text{ J s}$$

$$m_e = 9.101939 \times 10^{-31} \text{ kg}$$

$$c = 2.99792 \times 10^8 \text{ m s}^{-1}$$

Gas Constant:

$$R = 8.31451 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$R = 8.20578 \times 10^{-2} \text{ L atm K}^{-1} \text{ mol}^{-1}$$

$$T (\text{K}) = T (\text{C}) + 273.15$$

$$F = 96,485 \text{ C / mol}$$

$$1 \text{ V} = 1 \text{ J / C} \quad 1 \text{ nm} = 10^{-9} \text{ m}$$

$$1 \text{ kJ} = 1000 \text{ J}$$

$$\Delta G^\circ = \Delta H^\circ - T \Delta S^\circ$$

$$\Delta H^\circ = \sum \Delta H^\circ_f (\text{products}) - \sum \Delta H^\circ_f (\text{reactants})$$

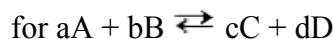
$$\Delta S^\circ = \sum S^\circ (\text{products}) - \sum S^\circ (\text{reactants})$$

$$\Delta G^\circ = \sum \Delta G^\circ_f (\text{products}) - \sum \Delta G^\circ_f (\text{reactants})$$

$$S = k_B \ln W$$

$$\Delta T = i k_{b,f} m$$

$$\Pi = i RTc$$



$$Q = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad \text{At equilibrium, } Q = K$$

$$\Delta G^\circ = -RT \ln K$$

$$\ln K = -\frac{\Delta H^\circ}{R} \frac{1}{T} + \frac{\Delta S^\circ}{R}$$

$$\Delta G^\circ = -nF \Delta \epsilon^\circ$$

$$\Delta \epsilon = \Delta \epsilon^\circ - RT/nF \ln Q$$

$$\ln K = nF \Delta \epsilon^\circ / RT$$

$$pX = -\log X$$

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

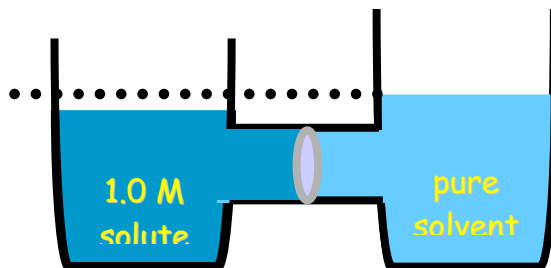
compound	vap press @ 25°C (torr) / BP°C	polarity
acetone, C <sub>3</sub> H <sub>6</sub> O	230 / 56	polar
benzene, C <sub>6</sub> H <sub>6</sub>	95 / 80	non-polar
carbon tetrachloride, CCl <sub>4</sub>	91 / 78	non-polar
methanol, CH <sub>3</sub> OH	100 / 65	polar
ethanol, CH <sub>3</sub> CH <sub>2</sub> OH	98 / 78	polar
water, H <sub>2</sub> O	23 / 100	polar

## SECTION 1: MIXTURES

All state functions refer to the system unless otherwise noted. A table with solvent data is found under the Potentially useful relations.

- 1.) What is the driving force for colligative properties like freezing point depression?
  - A) **entropy**
  - B) enthalpy
  - C) internal energy
  - D) work
  - E) heat
  
- 2.) Which aqueous solution has the lowest freezing point (all compounds are ionic except glucose)?
  - A) 0.2 m glucose
  - B) 0.2 m NaCl
  - C) **0.2 m MgCl<sub>2</sub>**
  - D) 0.2 m CaCO<sub>3</sub>
  - E) all are the same
  
- 3.) Which has the lowest freezing point in the nonpolar solvent benzene (C<sub>6</sub>H<sub>6</sub>) (assume the concentration can be reached in each case)?
  - A) 0.2 m glucose
  - B) 0.2 m NaCl
  - C) 0.2 m MgCl<sub>2</sub>
  - D) 0.2 m CaCO<sub>3</sub>
  - E) **all are the same**
  
- 4.) What pressure (atm) is necessary to obtain drinking water from sea water (treat seawater as a 5 M NaCl solution) by reverse osmosis at 300 K?
  - A) 3
  - B) 10
  - C) 75
  - D) **200**
  - E) **300 both accepted**

- 5.) What will happen to the solution level on the left side of the system if the two sides are separated by a membrane permeable to only the solvent?

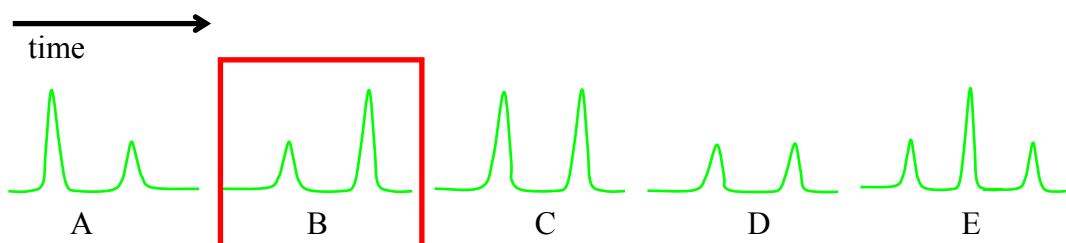


- A) rise  
B) no change  
C) fall  
D) cannot answer without solute information
- 6.) Which benzene ( $C_6H_6$ ) / acetone ( $CH_3COCH_3$ ) solution has the highest vapor pressure?  
A) Pure benzene  
B) 0.05 mole fraction acetone  
C) 0.1 mole fraction acetone  
D) 0.5 mole fraction acetone  
E) 0.75 mole fraction acetone
- 7.) What is the vapor pressure (torr) of a benzene ( $C_6H_6$ ) / acetone ( $CH_3COCH_3$ ) solution when the mole fraction of acetone is 0.5?  
A) 0.75  
B) 77  
C) 162  
D) 333  
E) 425
- 8.) Which are miscible (mix to a single phase) with water (mark all that apply)?  
A) Acetone  
B) Ethanol  
C) Carbon tetrachloride  
D) Methanol  
E) Benzene

9.) Which aqueous solution has the lowest vapor pressure at mole fraction 0.5 (note some of these may not be miscible with water)?

- A) Acetone
- B) Ethanol**
- C) Carbon tetrachloride
- D) Methanol
- E) Benzene

10.) Which is the appropriate trace for a 2:1 mixture of acetone and benzene from a gas chromatography experiment with a polar column?



11.) Which condition favors positive deviations from Raoult's Law?

- A) strong solute-solute interactions
- B) strong solute-solvent interactions
- C) weak solute-solvent interactions**
- D) strong solvent-solvent interactions
- E) weak solute-solute interactions

## SECTION 2: THERMODYNAMICS

All state functions refer to the system unless otherwise noted.

12.) Which gas has the highest heat capacity?

- A) Ar
- B) CO
- C) CO<sub>2</sub>
- D) CH<sub>4</sub>**
- E) HCN

13.) What is the total motional contribution to the molar internal energy of gaseous HCN?

- A) 3RT
- B) 3.5RT
- C) 2.5RT**
- D) RT
- E) 1.5RT

- 14.) What is the total motional contribution to the molar internal energy (kJ/mol) of gaseous  $\text{H}_2\text{O}$  at  $25^\circ\text{C}$ ?
- A) 6.19
  - B) 7.43
  - C) 3.72
  - D) 12.4
  - E) 2.48
- 15.) A CD player and its battery together do 500 kJ of work, and the battery also releases 250 kJ of energy as heat and the CD player releases 50 kJ as heat due to friction from spinning. What is the change in internal energy (kJ) of the system, with the system regarded as the battery and CD player together?
- A) +100
  - B) +600
  - C) -800
  - D) -300
  - E) -450
- 16.) A system had 150 kJ of work done on it and its internal energy increased by 60 kJ. How much energy did the system gain or lose as heat?
- A) The system lost 90 kJ of energy as heat.
  - B) The system lost 210 kJ of energy as heat.
  - C) The system gained 60 kJ of energy as heat.
  - D) The system gained 90 kJ of energy as heat.
  - E) The system gained 210 kJ of energy as heat.
- 17.) When 2.00 kJ of energy is transferred as heat to nitrogen in a cylinder fitted with a piston at an external pressure of 2.00 atm, the nitrogen gas expands from 2.00 to 5.00 L against this constant pressure. What is  $q$  for the process (kJ)?
- A) -0.506
  - B) +2.00
  - C) -22.4
  - D) 0
  - E) +1.50
- 18.) When 2.00 kJ of energy is transferred as heat to nitrogen in a cylinder fitted with a piston at an external pressure of 2.00 atm, the nitrogen gas expands from 2.00 to 5.00 L against this constant pressure. What is  $w$  for the process (kJ)?
- A) -0.506
  - B) +2.00
  - C) -22.4
  - D) 0
  - E) +1.50
-

19.) When 2.00 kJ of energy is transferred as heat to nitrogen in a cylinder fitted with a piston at an external pressure of 2.00 atm, the nitrogen gas expands from 2.00 to 5.00 L against this constant pressure. What is  $\Delta U$  for the process?

- A) -0.506
- B) +2.00
- C) -22.4
- D) 0
- E) +1.50

20.) Which of the following are state functions (mark all that apply)?

- A) w
- B) V
- C) q
- D) P
- E) U

21.) What is the change in internal energy (kJ) when 2.50 kJ of energy is transferred as heat to 1.50 mol  $N_2$  at 298 K and 1 atm at constant volume?

- A) -2.50
- B) +2.50
- C) +1.00
- D) -1.50
- E) +1.50

22.) What is the change in enthalpy when 2.50 kJ of energy is transferred as heat to 1.50 mol  $N_2$  at 298 K and 1 atm constant pressure?

- A) -2.50
- B) +2.50
- C) +1.00
- D) -1.50
- E) +1.50

23.) What is the enthalpy change ( $\Delta H$ , kJ) that occurs when 0.5 lb (200 g) of mercury (MM 200 g/mol) freezes at its freezing point (234.3 K)? The standard enthalpy of fusion of mercury is 2.29 kJ/mol.

- A) -2.29
- B) +1.04
- C) +5.18
- D) +2.29
- E) -5.18

- 24.) What is the standard enthalpy of vaporization (kJ/mol) of liquid bromine if the standard enthalpy of sublimation of solid bromine is +40.1 kJ/mol and the standard enthalpy of fusion of solid bromine is +10.6 kJ/mol?
- A) -50.7
  - B) -29.5
  - C) +50.7
  - D) +14.8
  - E) +29.5
- 25.) How much heat (kJ) is required to vaporize 50.0 g of water (MM 18 g/mol) if the initial temperature of the water is 25°C and the water is heated to its boiling point where it is converted to steam? The specific heat capacity of water is 4.18 J/Kg and the standard enthalpy of vaporization of water at its boiling point is 40.7 kJ/mol.
- A) 129
  - B) 64.2
  - C) 40.7
  - D) 193
  - E) 23.5
- 26.) What mass of propane (g), C<sub>3</sub>H<sub>8</sub> gas (MM 44g/mol), must be burned to supply 2580 kJ of heat? The standard enthalpy of combustion of propane at 298 K is -2220 kJ/mol.
- A) 25.6
  - B) 51.2
  - C) 102
  - D) 75.9
  - E) 37.9
- 27.) Which is true of q (heat) when a gas expands rapidly (adiabatically) against a constant pressure?
- A)  $q = w$
  - B)  $q > 0$
  - C)  $q = 0$
  - D)  $q < 0$
  - E)  $q = \Delta U$
- 28.) Which is true when a gas expands rapidly (adiabatically) against a constant pressure?
- A)  $\Delta S_{\text{surr}} = 0$
  - B)  $\Delta S_{\text{sys}} = 0$
  - C)  $\Delta T = 0$
  - D)  $\Delta U = 0$
  - E)  $w = 0$
- 29.) Which is true when a gas expands rapidly (adiabatically) against a constant pressure?



- A)  $w = 0$
- B)  $\Delta S = 0$
- C)  $\Delta T < 0$
- D)  $\Delta U > 0$
- E)  $\Delta H > 0$

30.) Why are the entropies of vaporization of most liquids the same ( $\sim 90\text{J/Kmol}$ )?

- A) Enthalpies of vaporization are about the same.
- B) Boiling points have little variation.
- C) All are similar order to disorder transitions.
- D) The molar entropies of most liquids are about the same.
- E) The product of vapor pressure and boiling point are about the same.

31.) What is the best estimate for the enthalpy of vaporization (kJ/mol) of acetone (B.P.  $56.3^\circ\text{C}$ ) given entropies of vaporization for most liquids are about the same ( $\sim 90\text{J/Kmol}$ )?

- A) 0.30
- B) 5.0
- C) 30
- D) 44
- E) 101

32.) What is the maximum achievable efficiency of an engine that operates between two heat reservoirs at 450 K and 300 K?

- A) 0.25
- B) 0.33
- C) 0.55
- D) 0.60
- E) 0.75

33.) What is the change in entropy ( $\Delta S$ , J/K) of a large pail of water after 200 J of energy is reversibly transferred to the water at  $20^\circ\text{C}$ ?

- A)  $-0.733$
- B)  $+0.683$
- C)  $-0.683$
- D)  $+0.733$
- E)  $+200$

34.) What is the change in molar entropy ( $\Delta S$ , J/K) when 2.00 moles of ozone are compressed isothermally to one quarter of its original volume? Treat ozone as an ideal gas.

A) -23.1

B) -10.0

C) -1.39

D) +10.0

E) +23.1

35.) Which of the following processes leads to an increase in the entropy of the system? (Treat all gases as ideal.)

1. The pressure of one mole of oxygen gas is allowed to double isothermally.

2. Carbon dioxide is allowed to expand isothermally to 10 times its original volume.

3. The temperature of one mole of helium is increased  $25^\circ\text{C}$  at constant pressure.

4. Nitrogen gas is compressed isothermally to one half its original volume.

5. A glass of water loses 100 J of energy reversibly at  $30^\circ\text{C}$ .

A) 1 and 4

B) 5

C) 3 and 5

D) 2 and 3

E) 1 and 2

36.) What is the entropy (J/K) at  $T = 0$  of 1.00 mol chlorobenzene,  $\text{C}_6\text{H}_5\text{Cl}$ , where each molecule can be oriented in any of six ways?

A) 0

B) +15

C) +30

D) -30

E) -15

Consider the following plot of a Carnot cycle to answer the following questions:

37.) If the temperature at point 1 is  $T_H$  what is the temperature at point 2?

- A)  $T_H$
- B)  $> T_H$
- C)  $< T_H$
- D) 0
- E) not enough information.

38.) If the temperature at point 1 is  $T_H$  what is the temperature at point 4?

- A)  $T_H$
- B)  $> T_H$
- C)  $< T_H$
- D) 0
- E) not enough information.

39.) What does the shaded area represent?

- A) the net work
- B) the net heat
- C) the net energy change
- D) the net entropy change
- E) the net temperature change

