CH301H – Principles of Chemistry I: Honors
Spring 2014, Unique 51880

Exam 1
13 February 2014

Name: Key

You may use any material you wish provided it does not have a heartbeat nor does it connect to a wireless or cellular network.

Honor Code:

"The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community."

I certify that the work on this exam is entirely my own.

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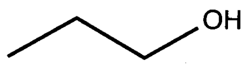
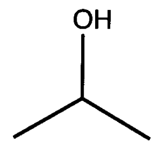
Signature Date

1. (8 points) Determine whether the following statements are true or false.

a. True False S^0_m(propanol) > S^0_m(isopropanol).



propanol



isopropanol

b. True False When the heat a system produces is divided by the temperature at which that heat is produced, the result is a state function.

c. True False The formation enthalpy of O(g) is 0 J.

d. True False When two pure substances are mixed, intermolecular forces in the mixture will always be more attractive than in the pure forms.

2. (18 points) In each of the following transformations, determine the sign of ΔS_{sys}:

a) Honey sitting in a jar in your pantry crystallizes over the course of a year. $\Delta S_{sys} < 0$

b) Sodium chloride salt melts. $\Delta S_{sys} > 0$

c) Solid carbon dioxide (i.e. dry ice) sublimes. $\Delta S_{sys} > 0$

d) A balloon full of helium gas slowly deflates as gas leaks through a small hole in the material. $\Delta S_{sys} > 0$

e) Glucose ($C_6H_{12}O_6$) is metabolized by the body to water and carbon dioxide. $\Delta S_{sys} > 0$

f) A hot iron is plunged into a large vat of water held at room temperature. $\Delta S_{sys} < 0$

3. (10 points) The Henry's law constant for $O_2(g)$ ($K_{H,O2}$) dissolved in water at 25°C is 4.34 x 10^4 atm. When water is cooled to 4°C, $K_{H,O2}$ = 2.41 x 10^4 atm. In clear, comprehensible English, discuss the reason for this observation.

The decreasing k_{H,O_2} means that the solubility of O_2 in water increases as temperature decreases, and the mixture becomes more ideal. Because nothing changes w/ intermolecular forces as a function of T, this must be purely an effect of kinetic energy. As T decreases, fewer O_2 molecules have the necessary KE to escape to the vapor phase.

4. (10 points) Which is larger, ΔH^0_{fus} or ΔH^0_{sub} for liquid water? Justify your answer.

$H_2O(s) \xrightarrow{\Delta H_{sub}} H_2O(g)$

$H_2O(s) \xrightarrow{\Delta H_{fus}} H_2O(l) \xrightarrow{\Delta H_{vap}} H_2O(g)$

$\Delta H_{sub} = \Delta H_{fus} + \Delta H_{vap}$

$\Delta H_{sub} > \Delta H_{fus}$ always

5. (14 points) A cylinder of helium gas held at 50 atm and room temperature is used to inflate a balloon to a diameter of 25 cm, where the pressure of the helium is 2.0 atm (and still at room temperature). What is the change in entropy of the helium? $C_{v,m} = \frac{3}{2}R$

$P_i = 50\text{atm}$

$T_i = 298\text{K}$

$P_f = 2.0\text{atm}$

$T_f = 298\text{K}$

$V_f = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{25\text{cm}}{2}\right)^3 = 8181\text{cm}^3\left(\frac{1\text{dm}}{10\text{cm}}\right)^3\left(\frac{1\text{L}}{1\text{dm}^3}\right) = 8.18\text{L}$

$n = \frac{P_f V_f}{RT_f} = \frac{(2.0\text{atm})(8.18\text{L})}{(0.082\frac{\text{L atm}}{\text{mol K}})(298\text{K})} = 0.670\text{mols}$

$\Rightarrow V_i = \frac{nRT_i}{P_i} = \frac{(0.670\text{mols})(0.082\frac{\text{L atm}}{\text{mol K}})(298\text{K})}{(50\text{atm})}$

$V_i = 0.327\text{L}$

$\Delta S_{sys} = nR\ln\left(\frac{V_f}{V_i}\right)$

$= (0.67\text{mols})(8.314\text{J/K mol})\ln\left(\frac{8.18\text{L}}{0.327\text{L}}\right)$

$\Delta S_{sys} = 17.9\text{J/K}$

OR $\Delta S_{sys} = nR\ln\left(\frac{P_i}{P_f}\right) = 17.9\text{J/K}$ also

both are acceptable solns.

6. (40 points) In class we discussed the catastrophic consequences of an imbalance in osmotic pressure in a hyperglycemic cell (i.e. a cell where the sugar concentration is too high). For this problem, assume that the cellular membrane can withstand an osmotic pressure inside the cell equal to 150% the pressure outside the cell, that the body is at physiological temperature of 37˚C, and that a 65 kg body is composed entirely of water. The following information my be useful for this problem (all given at a pressure of 1 bar and temperature of 37˚C):

i.e. P = 1.5 atm; T = 310 K; (≈1 atm)

	ΔH_f (kJ mol^{-1})	S_m (J K^{-1} mol^{-1})	$C_{P,m}$ (J K^{-1} mol^{-1})
$C_6H_{12}O_6$	-1284	215	53.1
$H_2O(l)$	-287.4	72.9	75.29
$O_2(g)$	0	211.2	29.4
$CO_2(g)$	-401.5	217.3	37.11

a) At what sugar concentration will the cell burst?

$$c = \frac{(1.5\,atm)}{(0.082\,\frac{L\,atm}{mol\,K})(310\,K)} = 0.059\ \frac{mol}{L}\ \text{sugar}$$

b) Further assume that 85% of the body's mass is contained inside cells, and 15% is in the so-called "extracellular matrix" (i.e. outside of cells). Assuming this sugar is in the form of glucose ($C_6H_{12}O_6$) and that it is contained entirely within cells, how much sugar is in the body when the cell bursts?

$$65\,kg = \frac{65000\,g}{1\,g/mL} = 65000\,mL = (65\,L)(0.85) = 55.25\,L\ H_2O\ \text{inside cells}$$

$$(0.059\,mol/L)(55.25\,L) = \underline{3.3\,mol\ sugar}(180\,g/mol) = \underline{594\,g\ sugar}$$

$$FW(C_6H_{12}O_6) = 180\,g/mol$$

c) Glucose is metabolized by the body in a complicated series of reactions. The overall reaction combines glucose with $O_2(g)$ to form the waste products $H_2O(l)$ and $CO_2(g)$. If 100% of the glucose from part b) is metabolized in this reaction, how much energy (in the form of heat) does this provide the body?

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

$$\Delta H_{rxn} = 6\Delta H_f(H_2O) + 6\Delta H_f(CO_2) - \Delta H_f(C_6H_{12}O_6)$$

$$= (6)(-287.4\,kJ/mol) + (6)(-401.5\,kJ/mol) - -1284\,kJ/mol$$

$$\Delta H_{rxn} = (-2849\,kJ/mol)(3.3\,mol) = \boxed{-9403\,kJ = \Delta H_{rxn}}$$

d) If the body did not have a way to cool itself, how much with the metabolism of glucose in part c) raise the body's temperature? *Identical problem to quiz 2!

$q_p = -9403\ kJ$

$m = 65\ kg$

$C_p(H_2O) = 75.29\ J/K\,mol$

$FW(H_2O) = 0.018\ kg/mol$

$n(H_2O) = \frac{65\ kg}{0.018\ kg/mol} = 3608\ mol$

$q_p = n C_p \Delta T$

$\Delta T = \frac{q_p}{n C_{p,m}} = \frac{(-9403 \times 10^3\ J)}{(3608\ mol)(75.29\ J/K\,mol)}$

$\Delta T = -34.6\ K$

e) The FDA recommends that a healthy adult consume, on average, 2000 calories of food a day to maintain normal metabolic activity. What fraction of this recommended daily intake is represented by the glucose in this problem? (1 dietary calorie = 1 kcal.)

2000 dietary cal $= (2000 \times 10^3\ cal)\left(\frac{4.18\ J}{1\ cal}\right) = 8.4 \times 10^6\ J$

as an aside, this is how I got the 10 MJ # on quiz 2

If $9403 \times 10^3 = 9.4 \times 10^6\ J$ are coming from sugar, then

- this amount of sugar represents 111% of a recommended daily diet of all foods.

- This # interests me for a couple reasons. American adults consume ≈13% of their calories as sugar (from a CDC 2010 survey). That means that the average American is within an order of magnitude of consuming a catastrophic amount of sugar. Obviously reality is much more complicated than this because the body regulates sugar very carefully, but I still find these #'s amazing.