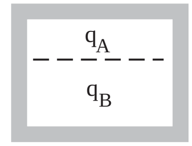
VERSION A

SHORT ANSWER/ MULT CHOICE	______	(OUT OF 10)
TRUE / FALSE	______	(OUT OF 2)
COLD SEA WATER - ELEC	______	(OUT OF 8)
COLD SEA WATER – AIR CON	______	(OUT OF 9)
COLD SEA WATER - DRINK	______	(OUT OF 8)
NEURON K+	______	(OUT OF 5)
GIANT SQUID	______	(OUT OF 15)
UV-OPEN ION CHANNEL	______	(OUT OF 15)
COLUMBIA DISASTER	______	(OUT OF 12)
MAPLE SYRUP	______	(OUT OF 13)
KBr ROCK SALT TO CsCl	______	(OUT OF 8)
TOTAL	______	(OUT OF 105)

1) Short Answer / Multiple Choice ***(2 pt. each = 10 points total)***

Choose the single best answer.

i) Two blocks (A and B) are in equilibrium, can freely exchange heat at constant E and V, and are isolated from the surroundings. The number of particles of A and B are constant. What can you conclude about this equilibrium system?



_____ dE = 0 _____ dH = 0 _____ dA = 0 _____ dG = 0 _____ dS = 0

ii) Examples of phases of carbon are a gas, a molten liquid, solid graphite, and solid diamond. The temperature in my laboratory varies between the summer and the winter. What is the maximum number of phases of carbon that can coexist over the whole range of summer and winter temperatures?

_____ phases

iii) For an endothermic reaction, what can you say about the equilibrium constant K_1 measured at a low temperature T_1 with respect to K_2 measured at a high temperature T_2?

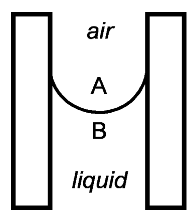
_____ $K_1 < K_2$ _____ $K_1 = K_2$ _____ $K_1 > K_2$

iv) Typically, activity for a *solvent* is …

_____ pressure (P) _____ concentration (c) _____ mole fraction (x)

v) Points A and B are separated by the very thin interface between the air and liquid.

What can you say about the pressures at points A and B?



_____ $P_A < P_B$ _____ $P_A = P_B$ _____ $P_A > P_B$

2) True / False: ***(2 pt. each = 2 points total)***

Mark if the statement is true as stands, or write how the underlined text must be corrected.

i) As you heat water on the stove, bubbles start to form in the pan below the boiling temperature because gas comes out of solution. You can conclude that the enthalpy of dissolution of the gas is <u>exothermic</u>.

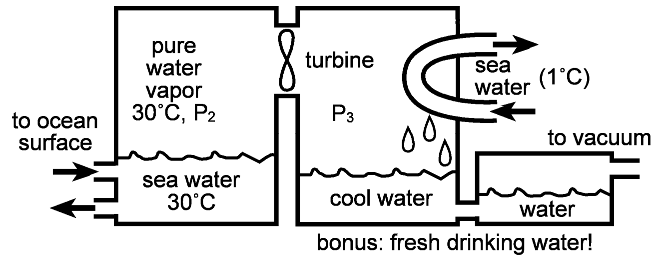
_____ True as stands _______ True when replaced by "________________________"

3) This question is #1 of a set of 3 that all use the same text in the box:

In June 2005, *Wired* reported on plans by John Piña Craven of the Common Heritage Corp. to produce electricity, drinking water, and air conditioning in Hawaii and Saipan by using cold water pumped from 1000m below sea level. The molar mass of water is 18.0 g/mol.

A plausible generator is at the right. Assume that the area of the turbine is $1m^2$, and that $\Delta\overline{H}_{vaporization}(water)$ is constant in all processes.

(8 points total)



i) The generator uses two ocean water sources, warm from the surface at 30˚C, and cold from the ocean floor at 1˚C. What would be the efficiency of a heat pump using the same resources?

place your answer here:

ii) Instead of using a heat pump, the warm water evaporates to steam inside a vacuum chamber. What is the pressure (P_2) required to make pure water boil at 30˚C?

place your answer here:

iii) The purpose of the condenser on the right hand side is to lower the vapor pressure P_3. Assuming that P_3. is 1.0×10^{-3} atm ≈ 1.0×10^{2} Pa, what is the force across the turbine?

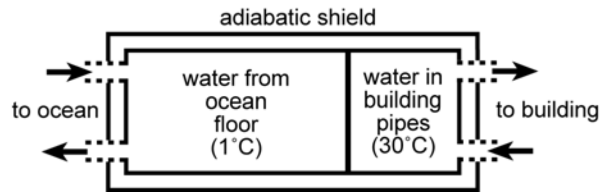
place your answer here:

Not needed for this problem: *Wired* June 2005 p113 “The Mad Genius at the Bottom of the Sea” by Carl Hoffman.

4) This question is #2 of a set of 3 that all use the same text in the box: ***(9 points total)***

In June 2005, *Wired* reported on plans by John Piña Craven of the Common Heritage Corp. to produce electricity, drinking water, and air conditioning in Hawaii and Saipan by using cold water pumped from 1000m below sea level. The molar mass of water is 18.0 g/mol.

i) 2 liters of water from the ocean floor (1˚C) are put in contact with 1 liter of water from the building's cooling pipes (30˚C) and then the water flow is turned off. The whole system is adiabatically isolated from the surroundings. What is the final equilibrium temperature, T_f?



place your answer here:

ii) What is the change of entropy for the scenario in step i?

place your answer here:

Not needed for this problem: *Wired* June 2005 p113 "The Mad Genius at the Bottom of the Sea" by Carl Hoffman.

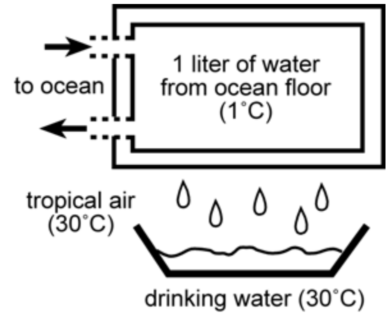
5) This question is #3 of a set of 3 that all use the same text in the box:

In June 2005, *Wired* reported on plans by John Piña Craven of the Common Heritage Corp. to produce electricity, drinking water, and air conditioning in Hawaii and Saipan by using cold water pumped from 1000m below sea level. The molar mass of water is 18.0 g/mol.

Drinking water is produced by the condensation of water. Assume that ocean water at 1˚C is pumped into a 1 liter container and then the water flow is turned off.

The container is in thermal contact with humid warm air. For each liter of ocean water that warms from 1˚C to 30˚C, what volume of drinking water condenses (always at 30˚C)?

(8 points total)



place your answer here:

Not needed for this problem: *Wired* June 2005 p113 “The Mad Genius at the Bottom of the Sea” by Carl Hoffman.

6) Consider a neuron at rest at 37˚C with ion concentrations inside and outside the cell as at right. ***(5 points total)***

	inside	outside
Na^+	10 mM	150 mM
K^+	70 mM	5 mM

i) What is the voltage due to *only* the difference in concentrations of K^+ across the membrane (outside – inside) under these conditions?

place your answer here:

ii) What voltage must be applied to the membrane to open a K^+ channel? In other words, at what voltage are there equal concentrations of (only) K^+ across the membrane?

place your answer here:

7) Recently, in 2005, the first videos were made of a live, deep-sea giant squid, *Architeuthis.* The squid was ~8m long! At sea level, air is ~21 mole% O_2 and ~79 mol% N_2, and is at 20˚C. The Henry's Law constant for aqueous N_2 is 1.55×10^5 Pa m^3 / mol. The surface tension of water is 0.072 N/m. Assume squid blood ≈ water. The vapor pressure above pure water is 3.13×10^{-2} atm. ***(15 points total)***

i) At sea level, what is the concentration of N_2 dissolved in water?

place your answer here:

ii) During the day, the giant squid hunts at a depth of 900m below sea level. What is the pressure at this depth?

place your answer here:

iii) At a depth of 900m below sea level, what is the concentration of N_2 dissolved in water, assuming the ratios of O_2 and N_2 are the same as at sea level?

place your answer here:

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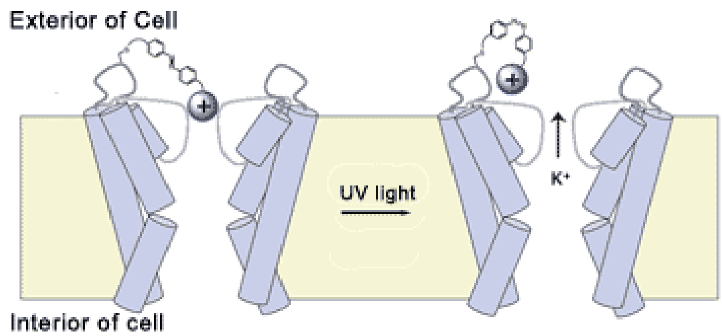
iv) The researchers ripped a 5.5m tentacle arm off of the poor squid and brought the arm to the surface. If the tentacle was brought to the surface too quickly, N_2 bubbles formed in the bloodstream. At the surface, what is the volume of N_2 gas in bubbles in the tentacle blood? The arm probably contains ~0.05 liters of squid blood.

place your answer here:

v) What is the Laplace pressure across a spherical N_2 bubble stuck in a squid blood capillary that is ~1μm in diameter?

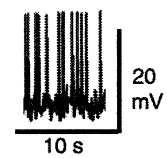
place your answer here:

Not needed for this problem: *Data from T. Kubodera and K. Mori "First-ever observations of a live giant squid in the wild" Proc. R. Soc. B. (2005) doi: 10.1098. In divers, the formation of nitrogen bubbles in the bloodstream is called "the bends", a painful and sometimes fatal condition.*



8) Researchers at Berkeley recently induced neurons to "see" light by modifying a potassium channel in the neuronal cell membrane. A voltage of –90mV is always across the membrane. The channel goes from the closed, blocked state to the open state by the application of UV light of wavelength 380 nm. Temperature ≈ 20˚C. Mol. weight of K = 39.1 g/mol. ***(15 points total)***

i) Even in the "blocked" state, the channel allows some K^+ to flow as at the right.



If K^+ flows 1/4 of the time, what is $\Delta\overline{G}^0(K^+\ no\ flow \rightarrow K^+\ flow)$ in the blocked state?

place your answer here:

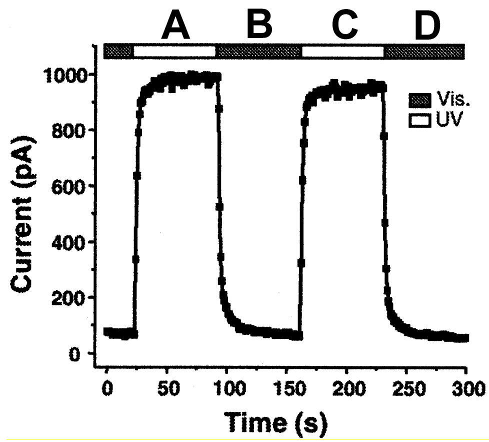
ii) The channel switches to the open state when one photon of UV light falls on it. What is the energy per mole of channels to switch channels from the blocked state to the open state?

place your answer here:

Continued...

Continued...

iii) Switching between the blocked and open states results in the figure at the right. Approximately how many K^+ flow during the period marked “A”?



place your answer here:

iv) What is the approximate resistance of the blocked channel during the period marked “B”?

place your answer here:

Not needed for this problem: *Data and figures from M. Banghart, K. Borges, E. Isacoff, D. Trauner, and R.H. Kramer Nat. Neurosci. (2004) 7:1381-1386.*

9) The disaster of the space shuttle *Columbia* occurred in February of 2003. All seven members of the crew died. The disaster occurred because an air bubble in the insulating foam surrounding the fuel tank expanded when the temperature skyrocketed during liftoff. The expansion of the gas broke off a piece of foam, which hit a joint, damaging the heat shield. Foam is a good heat insulator, so let's explore whether the expansion of the gas could have occurred in an adiabatic transition. ***(12 points total)***

i) Initally the foam is very cold (100K), and the bubble radius is 1mm. After liftoff, the foam is hot (500K). Assume the transition is adiabatic and air is an ideal gas with Cv = 5/2nR. Find the bubble's final volume.

place your answer here:

ii) What can you say about the volume of the bubble before and after liftoff?

_____ $V_i < V_f$ _____ $V_i = V_f$ _____ $V_i > V_f$

iii) Could the expansion of the gas have occurred in this adiabatic transition?

_____ yep! _____ no way!

Not needed for this problem: *Photograph of astronauts Rick Husband, William McCool, Michael Anderson, Ilan Ramon, Kalpana Chawla, David Brown, and Laurel Clark from wikipedia.org.*

10) 40 liters of maple tree sap yields 1 liter of maple syrup. In the spring 2005 season, maple tree sap contained 3.5% of sugar (fructose) by weight (= weight sugar / weight water). There are two methods of making maple syrup investigated below. You may assume syrup is "dilute". Molecular weight fructose = 342.3 g/mol. ***(13 points total)***

i) What is the osmotic pressure of maple tree sap at room temperature = 20˚C?

place your answer here:

ii) In 1755 a group of Native Americans in Ohio captured and adopted young James Smith. Later he described the ingenious way the group concentrated sap *without* either metal or fire. They left sap in a trough outside overnight, discarded the ice that formed on top, and retained the concentrated liquid sap below. Assume night temperatures are –6˚C, and the ice was pure H_2O. If 1 liter of sap was left outside, what is the maximum volume of concentrated liquid sap formed?

place your answer here:

continued...

continued...

iii) The way we currently concentrate sap into syrup is to boil off the water. What is the boiling point of the syrup at the very end of the concentration process?

place your answer here:

iv) Once your syrup cools to room temperature, you want to verify that it really is the right sweetness (the right concentration), but your trusty hydrometer is broken. Luckily, your eBay order for a Wescor Model 5130 vapor pressure meter ($99!) arrives. By how much will the vapor pressure of water above your syrup differ from the vapor pressure above pure water?

place your answer here:

Not needed for this problem: *Source: H. McGee On Food and Cooking (2004) Collier Books, NYC.*
See also: "An account of the Remarkable Occurrences in the Life and Travels of Col. James Smith (1799).

11) KBr exists in two phases, a "rock salt" crystal, or a "CsCl structure" crystal. The volume of the "rock salt" is bigger by 4.17 x 10^{-6} m^3/mol. At room temp. (20˚C), "rock salt" becomes as stable as "CsCl structure" at a pressure of 18.0 x 10^3 atm, and $\Delta \overline{H}_{\textit{rock salt to CsCl structure}}$ = 7.65 x 10^3 J/mol.

(8 points total)

i) Using your intuition, which structure of KBr do you expect to find at low pressure?

_________ "rock salt" _________ "CsCl structure"

ii) What is the molar standard Gibbs Free Energy for the transition from rock salt to CsCl?

place your answer here:

iii) What is the molar standard entropy for the transition from rock salt to CsCl?

place your answer here:

Not needed for this problem: *Data from K.J. Rao and C.N.R. Rao (1966) J. Materials Sci 1:238.*
Data tabulated by A.R. West Solid State Chemistry and its Applications (1984) NYC, John Wiley, p. 429.