University of Maryland
Department of Physics

Physics 132 **Drs. Antonsen & Buehrle**

Spring 2014 **Exam 1 (Sample Problems)** **February 2014**

(25 points) *1.1 (5 pts) If you flip a fair coin 12 times, which string of heads and tails are you more likely to get?*

I: HHHHHHHHHHHH
II: HTHTTHTHHTTH

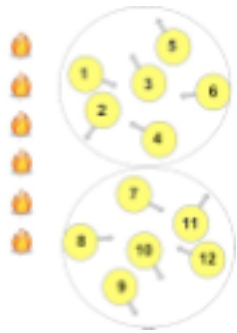
A. String I
B. String II
C. They are equally probable
D. You can't tell without being given more information.

1.2 (5 pts) If you flip a fair coin 12 times, which result are you more likely to get?

i: 12 heads
ii: 6 heads and 6 tails

A. Result i
B. Result ii
C. They are equally probable
D. You can't tell without being given more information.

1.3 (5 pts) You have 12 molecules in different locations in a two part box as shown in the figure and they are numbered as shown. If you add 6 packets of energy to the molecules at random, which result are you more likely to get?



I. Molecules 1, 2, 3, 4, 5, 6 get energy
II. Molecules 2, 5, 6, 9, 10, 12 get energy

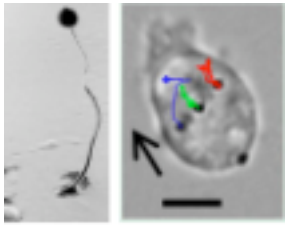
A. Set I
B. Set II
C. They are equally probable
D. You can't tell without being given more information.

1.4 (5 pts) You have 12 molecules in different locations in a two part box as shown in the figure and they are numbered as shown. If you add 6 packets of energy to the molecules at random, which result are you more likely to get?

i: 6 packets in the top box
ii: 3 packets in the top box and 3 packets in the bottom box

A. Result i
B. Result ii
C. They are equally probable
D. You can't tell without being given more information.

(15 points) *Slime mold cells feast on bacteria and yeast and essentially any food that comes their way. However, if they are out of food, they signal to each other and move together with about 100,000 of their best friends to form a spore. A typical spore is shown on the right. Unfortunately the image does not have a scale bar so we are not sure how large it is. Someone (Juan Lasheras, UCSD) did, however, take a picture of a single cell as shown on the right, with a scale bar of 5 microns. Estimate how heavy a spore is (in Newtons). (Note that the spores are just large enough to survive as a group yet light enough and high enough above the surface to be carried away by the wind!) Be sure to clearly state your assumptions and how you came to the numbers you estimated, since grading on this problem will be mostly based on your reasoning, not on your answer.*

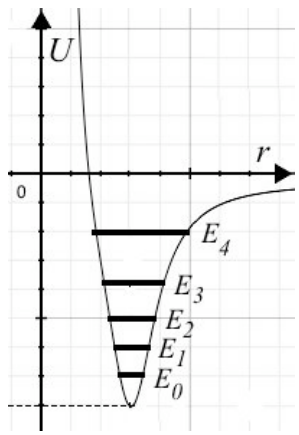


(10 points) *Three 132 students are discussing energy. Melanie says, "We don't need to talk about chemical energy at all. It's just the kinetic and potential energies of electrons and nuclei." Steve says, "We don't need to talk about thermal energy at all. It's just the kinetic and potential energy of atoms and molecules." Mike says, "But in biology, we sometimes talk about both chemical*

and thermal energy. I think it's useful." Who do you agree with and why? Note: This is an essay question. Your answer will be judged not solely on its correctness, but for its depth, coherence, and clarity.

(25 points)

A. A molecule that is a bound state of two atoms, A and B, has the potential energy between its atoms shown in the figure at the right. When it is in water at STP, it is typically in its ground state, E_0. When it is in this state, it does not react with an atom C that is also found in the water. But when it is in its excited state, E_1, the reaction AB + C → A + BC can take place. If $\Delta E = E_1 - E_0 = 500$ meV (milli-electron Volts), what is the probability that the AB molecule will be found in state E_1? Put your answer in the box and show your reasoning in the space below. (7 pts)



B. Consider the reaction $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$. The following bond energies have been determined experimentally:

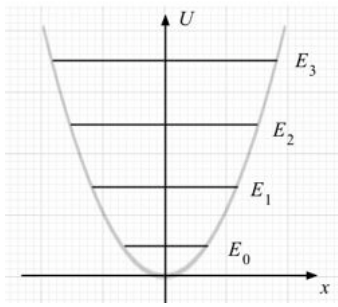
- *H-H 436 kJ/mol*
- *O=O 497 kJ/mol*
- *H-O 464 kJ/mol*

B.1 In this reaction, what is the difference in chemical energy between the reactants and the products? (8 pts)

B.2 Does your answer to part B.1 represent a net input of energy, or a net release (output) of energy if the reaction proceeds in the direction indicated? How do you know? (5 pts)

B.3 Assume this reaction takes place inside a thermally insulated container with hard walls. Since the energy of the universe has to be conserved (and in this case, energy can't enter or leave the system), where did the energy [input | output] you found in part B.2 [come from | go]? Be as specific as possible. (5 pts)

(10 pts) Real molecules have to be treated by quantum, not classical, mechanics. Although the classical treatment gives a correct description of the parameters involved and of the potential energy, there are differences. In the classical treatment, any energy is allowed; in the quantum treatment, only particular energy levels are allowed, as shown in the figure at the right.



The lowest level permitted (the ground state, E_0) is not at the bottom of the well but a little up from it. For a simple harmonic oscillator, the spacing between neighboring allowed levels is $\Delta E = hf$. According to our study of thermodynamics, we know that the relative probability of a molecule being excited by an amount $\Delta E = E - E_0$ in a medium at temperature, T, has the form

$$\frac{P(E)}{P(E_0)} = e^{-\Delta E/\varepsilon}$$

where ε is a parameter that has units of energy and depends on T.

2.1 (5 pts) If we are using ΔE to represent the excitation energy of a single diatomic molecule, and the molecule is in a human body at normal body temperature of 37 °C, what value should we take for ε?

A. 3.1 meV

B. 25 meV

C. 26 meV

D. 0.03 kJ

E. 2.4 kJ

F. 2.5 kJ

G. Something else (give it on your answer sheet).

2.2 (5 pts) If the value of *hf* for our diatomic molecule is ~ 0.22 eV, and the energy of the ground state is 0.11 eV, what is the probability of finding it in a living human body in its first excited state?

A. ~1

B. $\sim 1 \times 10^{-2}$

C. $\sim 2 \times 10^{-4}$

D. $\sim 8 \times 10^{-4}$

E. Something else (give it on your answer sheet).