BioE 103 Fall 2018
Final Exam
Dec. 13, 2018

Name: **Student ID:**

A. True/False (2 points each).

1.______ The Boltzmann constant x temperature sets energy scale for observing energy microstates

2.______ The force from a nonbonded interaction between two atoms at the energy minimum is zero

3.______ Conformational entropy favors the folded state over the unfolded state

4.______ Statistical entropy can be applied to isothermal ideal gas expansion and ideal DNA pulling

5.______ The natural log of multiplicity, ln(W), is not extensive

6.______ Heat capacity is inversely proportional to variance of the energy Gaussian distribution

7.______ The units of entropy are kJ/mol

8.______ The Helmholtz free energy is available energy to do mechanical or chemical work

9.______ The chemical potential, μ, is the tendency of system to realize concentration changes.

10.______ A reaction will proceed if the reaction quotient, Q is greater than equilibrium constant K

11.______ The standard enthalpy and entropy are always independent of temperature, pressure

12.______ The chemical potential is related to the mechanical (expansion) work of Gibbs free energy

13.______ Temperature signifies how multiplicity of bath grows with energy

14.______ A typical drug has a dissociation constant for its receptor in the nanomolar to picomolar range.

15.______ Hyperbolic responses are more sensitive to ligand concentration than a graded response.

16.______ The addition of a catalyst increases the rate of the reaction but not the equilibrium constant.

17.______ Einstein-Smoluchoski equation is the diffusion equation with dissipative forces

18.______ Debye-Huckel theory is an approximate solution to the Poisson equation

19.______ The probabilistic definition of entropy is only correct for small numbers of molecules

20.______ Atoms with favorable electronic configurations gain stability by forming covalent bonds

B. Multiple choice (5 pts each)

21. What is the probability of observing system with energy E_v at constant N,V,T

(a) $\exp(-\beta E_v^2)/Q$
(b) $1/Q$
(c) $\exp(-\beta E_v)/Q$
(d) all of the above

22. If a covalent bond vibrational excitation is ~25kJ/mole, is it significantly populated at 298K?

(a) yes
(b) no
(c) maybe
(d) all of the above

23. For an isolated system (constant N,V,E) all energy microstates

(a) have different Boltzmann probabilities
(b) are equally probable
(c) have different multiplicities
(d) all of the above

24. Direction of spontaneous change is when dN particles move from regions of

(a) low chemical potential to high
(b) equal chemical potential
(c) high chemical potential to low
(d) all of the above

25. The extent of a chemical reaction with large and negative values of $\Delta G°$ correspond to

(a) $K_{eq} >> 1$
(b) $K_{eq} \sim 1$
(c) $K_{eq} << 1$
(d) none of the above

26. To make a better drug, improvements in binding specificity relies on

(a) increasing hydrophobicity
(b) decreasing hydrogen-bonding
(c) decreasing pH
(d) increasing hydrogen-bonding

27. Because they bind to the same site as ATP, many kinase inhibitors are

(a) competitive
(b) substrate dependent non-competitive
(c) non-competitive
(d) all of the above

28. The order of this elementary reaction: $A + 2B \rightarrow C$ is

(a) can't be determined without experiment
(b) 1st order
(c) 3rd order
(d) none of the above

29. The units of the rate constant for a second-order elementary reaction is

(a) sec^{-1}
(b) $M^{-1}\cdot\text{sec}^{-1}$
(c) $M\cdot\text{sec}^{-1}$
(d) none of the above

30. Catalysts can work by changing the

(a) reaction mechanism
(b) decreasing the activation energy
(c) increasing the pre-exponential factor
(d) all of the above

C. Short problems (15 pts each)

31. The basis of proton NMR is that the hydrogen atom has a magnetic moment, so that in a magnetic field it can populate two states: spin up (S↑) and spin down (S↓). The energy difference measured between the states using a 300 MHz NMR spectrometer is 3.5×10^{-2} kJ/mol. For N=100 hydrogen atoms and T = 300 K

(a) Evaluate the relative population difference $|N_{S\uparrow} - N_{S\downarrow}| / (N_{S\uparrow} + N_{S\downarrow})$ using the partition function

(b) How does the population difference change with increasing temperature?

32. A bioengineer wants to develop a fuel by converting H_2O back to H_2 and O_2 using coupled ATP hydrolysis to drive the reaction. Given $\Delta_f G^o(H_2O)$ is -237 kJ•mol^{-1} and that 1 mole of ATP hydrolyzed to ADP + Pi yields -30 kJ•mol^{-1}, answer the following:

(a) write the balanced reaction for converting the gases to liquid water

(b) write the balanced reaction for converting H_2O back to H_2 and O_2 using X moles of ATP; how many moles of water need to be converted to get 3 moles of H_2 gas?

(c) how many moles of ATP is needed to yield the number of moles of H_2 gas given in (b)?

33. In your last homework of the semester you considered the inhibition of thrombin, a serine protease that catalyzes blood coagulation, as one of the important treatments of pathological blood clot formation. Two FDA approved anticoagulants drugs, Argatroban and Bivalirudin, are thrombin inhibitors which each act by a different inhibition mechanism. Another is Hirudin, which is one of the most potent natural inhibitors of thrombin known, but its continued use is being reevaluated due to a heightened risk of hemorrhaging. Variegin, was recently developed from the tropical bont tick. Given the binding data to the right, why might Variegin be a potential improvement over existing thrombin inhibitor drugs?

K_I (nM)	Anti-coagulant
3.2	**Argatroban**
2.3	**Bivalirudin**
0.2	**Variegin**
0.0002	**Hirudin**

34. The function of superoxide dismutase (SOD) is to convert superoxide radicals to more benign products of molecular oxygen and hydrogen peroxide. (a) Why is the sequence and structure of SOD important for the rate of diffusion of the superoxide radical to the active site (i.e. close to diffusion controlled?)

(b) Suppose we engineer mutations into SOD (SOD-M) that creates a net monopole charge of -5e and diminishes its quadrupole to zero (the zero dipole is the same for SOD and SOD-M). Would you expect the rate of scavenging of radicals to increase or decrease relative to wild type SOD? Explain.

(c) Would the molecular association rate of superoxide radical to SOD-M increase or decrease with salt concentration and why?

D. Extra Credit (25 pts)

35. Show the derivation for the more elaborate Michaelis-Menten mechanism from the following reaction

$$E+S\underset{k_{-1}}{\overset{k_1}{\rightleftarrows}}E\cdot S\underset{k_{-2}}{\overset{k_2}{\rightleftarrows}}E\cdot P\underset{k_{-3}}{\overset{k_3}{\rightleftarrows}}E+P$$

where dissociation of E·S and E·P is much faster than the interconversion between E·S and E·P, i.e. $k_{-1} >> k_2$ and $k_3 >> k_{-2}$. Show all work and assumptions.