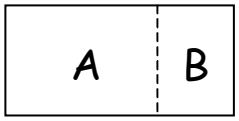
Last Name:_____ First Name_____ ID_____

This is a set of practice problems for the final exam. It is not meant to represent every topic and is not meant to be equivalent to a 2-hour exam. These problems have not been carefully tested and there may be errors and inconsistencies. For practice, work the problems closed book.

1. Four distinguishable atoms are confined to a box with two sections, as shown. The atoms can move between the sections. Section A has twice the volume of section B. In equilibrium, what is P_b, the probability that all of the atoms will be found in section B?



(a) $P_b = 1/81$
(b) $P_b = 1/64$
(c) $P_b = 1/16$

2. An ideal Carnot engine acting as a refrigerator extracts Q_C joules of heat from the food in the fridge and gives out Q_H joules of heat to the outside world. The **increase** of entropy of the outside world is exactly equal to the **loss** of the entropy by the food.

(a) True
(b) False

3. Show explicitly the relation of how an ideal Carnot engine leads to the answer you gave for question 2, i.e. show that the **increase** of entropy of the outside world is [or is not] exactly equal to the **loss** of the entropy by the food.

This will be discussed in the review.

4. Two bricks with the same mass, M = 2 kg, and heat capacity, C = 2100 J/K, but different initial temperatures, T_1 = 20° C and T_2 = 50° C, are put in thermal contact with each other (but are isolated from the rest of the world). After the two-brick system reaches thermal equilibrium, by how much, ΔS_{tot}, has their total entropy changed?

a. ΔS_{tot} = 0.0 J/K
b. ΔS_{tot} = 5 J/K
c. ΔS_{tot} = 10 J/K
d. ΔS_{tot} = 15 J/K
e. ΔS_{tot} = 20 J/K

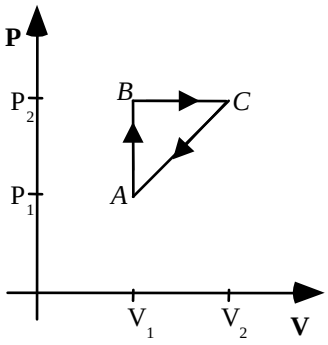
5. The chemical potential is a measure of

a. the change of free energy as a particle is added to a system.
b. the change of free energy as energy is added to a system.
c. the change of potential energy when chemicals are mixed.

6. If you double the absolute temperature of an ideal classical gas (at fixed volume), by what factor do you change the number of times per second that molecules hit the walls?

(a) 1
(b) 1.41
(c) 2
(d) 2.82
(e) 4

The next two questions pertain to the following figure.



A student performs an experiment with 0.10 moles of an ideal monatomic gas that is confined to a cylinder with a piston. The gas is taken through the cycle A→B→C as shown above.

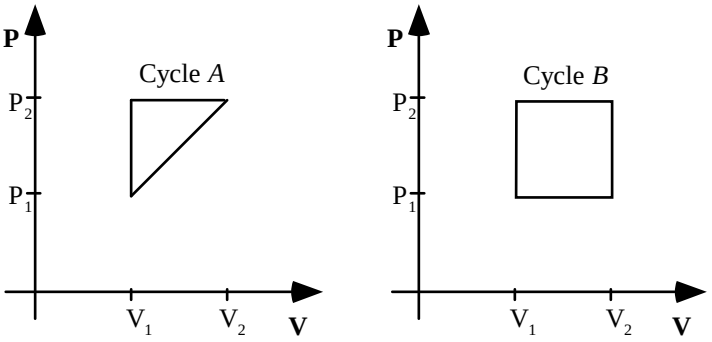
7. During which of the processes is positive work done by the gas?

(a) A→B only
(b) B→C only
(c) C→A only
(d) A→B and B→C
(e) B→C and C→A

8. During which of the processes is heat added to the gas?

(a) A→B only
(b) B→C only
(c) C→A only
(d) A→B and B→C
(e) B→C and C→A

9. The PV diagrams shown below represent cycles used in two different heat engines.



Compare W_A, the work of cycle A, to W_B, the work of cycle B.

(a) $W_A < W_B$
(b) $W_A = W_B$
(c) $W_A > W_B$

10. At high temperatures, an HCl gas molecule can dissociate to form individual hydrogen and chlorine atoms according to the reaction $HCl \rightarrow H + Cl$. Which of the following correctly expresses the relationship between the chemical potentials of all three species?

a) $\mu_{HCL} = \mu_H + \mu_{Cl}$
b) $\mu_{HCL}^2 = \mu_H + \mu_{Cl}$
c) $\mu_{HCL} + \mu_H = \mu_{Cl}$
d) $\mu_{HCL} + \mu_H + \mu_{Cl} = 0$
e) $\mu_{HCL} = \mu_H = \mu_{Cl}$

11 . Hydrogen atoms can combine to form an H_2 molecule according to the reaction $H + H \rightarrow H_2$. By what factor would the equilibrium constant $K_H = n_H^2/n_{H2}$ change if the isotope deuterium were used ($D + D \rightarrow D_2$)? Note that $m_D = 2m_H$ and D_2 and H_2 have the same binding energy. $K_D/K_H =$

a) 0.02
b) 0.17
c) 0.34
d) 1.0
e) 2.8

12. A block of material has a temperature-dependent heat capacity given by $C(T) = A\,T^3$ where A is a constant.. How much does the entropy of this object change as its temperature is increased from T_i to T_f?

a) $\frac{1}{2} A (T_i - T_f)^2$
b) $A (T_i - T_f)$
c) $(1/3) A (T_f^3 - T_i^3)$

The next two questions pertain to the following.

A cylindrical pump contains one mole of an ideal gas. The piston fits tightly so that no gas escapes, but friction is negligible between the piston and the cylinder walls. The pump is (completely) thermally insulated from its surroundings.

The piston is slowly pressed inward.

13. What will happen to the temperature of the gas?

(a) The temperature of the gas increases.
(b) The temperature of the gas decreases.
(c) The temperature of the gas does not change.

14. What will happen to the entropy of the gas?

(a) The entropy of the gas increases.
(b) The entropy of the gas decreases.
(c) The entropy of the gas does not change.

The next 4 questions concern a system of <u>4 distinguishable spins</u>, each with magnetic moment $\mu = 9 \times 10^{-23}$ J/T.

15. How many available microstates are there for this spin system in zero magnetic field?

(a) 4
(b) 8
(c) 16

16. What is the entropy of the spins in the macrostate with zero total magnetic moment ?

(a) $\sigma = 0$
(b) $\sigma = 0.693$
(c) $\sigma = 1.386$
(d) $\sigma = 1.792$
(e) $\sigma = 3.584$

17. How many distinct energy levels are there for the 4-spin system in a magnetic field?

(a) 4
(b) 5
(c) 16

18. Now the spins are allowed to contact a thermal reservoir at T = 10 K, and the magnetic field is turned up to B = 1 Tesla. Calculate the following ratio of probabilities:

R = P(all spins parallel to B) / P(all spins antiparallel to B)

(a) R = 7.7
(b) R = 13.6
(c) R = 64
(d) R = 144
(e) R = 184

19. A Carnot heat engine is operated as a refrigerator operating between two reservoirs T_c and T_h. One must supply 250 J of work to move 1 kJ of heat from the cold reservoir. If the same engine is operated as a heat engine operating between temperatures T_h and T_c what is its efficiency?

a. $\varepsilon = 5\%$
b. $\varepsilon = 20\%$
c. $\varepsilon = 33\%$
d. $\varepsilon = 50\%$
e. $\varepsilon = 66\%$

20. If the average square of the velocity vector, i.e. the average square of the speed, of molecules with molecular weight 0.1 kg/mol in an ideal gas is 10^4 m^2/s^2, what is the temperature?

(a) 4 K
(b) 40 K
(c) 400 K
(d) 4000 K
(e) cannot be determined from this information

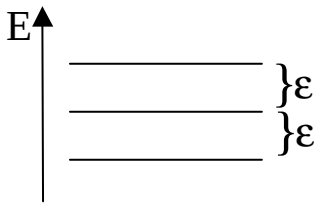
21. The latent heat of fusion for a particular liquid-solid transition is 0.35 J/kg. If the freezing temperature is 200 K, what is the entropy change $\Delta\sigma$ per kg when the material melts?

(a) 0
(b) 1.75×10^{14}
(c) 1.75×10^{16}
(d) 1.3×10^{20}
(e) 2.6×10^{22}

22. There is a 100 W heat leak from a room at temperature 22 °C into an ideal refrigerator. How much electrical power is needed to keep the refrigerator at -10 °C?

(a) 12 W
(b) 22 W
(c) 45 W
(d) 64 W
(e) 164 W

23. A particular molecule has three states, with energy spacing $\varepsilon = 10^{-20}$ J, as shown. At 1000K, what is P_0, the probability that the molecule is in the ground state?



(a) $P_0 = 0.33$
(b) $P_0 = 0.46$
(c) $P_0 = 0.58$
(d) $P_0 = 0.67$
(e) $P_0 = 1.00$

24. At what altitude is the atmospheric pressure of oxygen (molar mass = 32 g/mol) only 10% of that on the surface of the earth? (Assume T = 250K everywhere)

(a) 15.3 km
(b) 17.5 km
(c) 21.3 km
(d) 25.1 km
(e) 27.3 km

25. A sample of N_2 gas, initially with volume $V_i = 0.5\ m^3$ and temperature $T_i = 300$ K, expands adiabatically to $V_f = 1.2\ m^3$, pushing on a piston. What is T_f, the final temperature of the N_2? Assume that nitrogen is an α-ideal *diatomic* gas.

(a) $T_f = 125$ K
(b) $T_f = 211$ K
(c) $T_f = 258$ K
(d) $T_f = 367$ K
(e) $T_f = 426$ K

26. Six moles of an ideal monatomic gas is heated at constant volume from 300^0K to 600^oK. What is ΔS, the change in the entropy of the gas?

(a) $\Delta S = 51.8$ J/K
(b) $\Delta S = 98.7$ J/K
(c) $\Delta S = 149.6$ J/K
(d) $\Delta S = 212.4$ J/K
(e) $\Delta S = 1065$ J/K

Solutions for the Fa07 practice problems

1 a

2 a

3 discussion

4 b

5 a

6 b

7 b

8 d

9 a

10 a

11 e

12 c

13 a

14 c

15 c

16 d

17 b

18 e

19 b

20 b

21 d

22 a

23 c

24 a

25 b

26 a