Review Packet for Exam 1

Sample exam cover sheet:

Name: Answer key!

WARNING: The only calculator that you may have during the exam is a Texas Instruments TI-30X IIS or similar non-graphing scientific calculator previously approved by the instructor.

WARNING: For the computational part of the exam, you may only use departmental laptops running Matlab. Running any other application (email client, internet browser, etc) will be considered a breach of the honor code with a minimum sanction of failure for the work involved.

By signing my name below, I affirm that this exam represents my work only, without aid from outside sources. In all aspects of this course, I perform with honor and integrity.
Signature: ____________________

Information you may need:

$h = 6.626 \times 10^{-34}$ J s
$k = 8.99 \times 10^{9}$ N m^2/C^2
$e = 1.602 \times 10^{-19}$ C

$hc = 1240$ eV nm
1 eV $= 1.602 \times 10^{-19}$ J
$R = 8.31$ J/(K mol)

$k_B = 8.62 \times 10^{-5}$ eV / K
$k_B = 1.38 \times 10^{-23}$ J / K
$k_B = R / N_A$

$$E(r) = -\frac{e^2 M}{4\pi\varepsilon_0 r} + \frac{B}{r^m}$$

$$E(r) = -2\varepsilon\left[A\left(\frac{\sigma}{r}\right)^6 - B\left(\frac{\sigma}{r}\right)^{12}\right]$$

$$n_v = 4\pi N\left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-mv^2/(2kT)}$$

$$n_E = \frac{2N}{\pi^{1/2}}\left(\frac{1}{kT}\right)^{3/2} E^{1/2} e^{-E/(kT)}$$

	Points
Questions	/40
Derivation	/15
Problem 1	/20
Problem 2	/20
Computation	/25
TOTAL	/120

Equations / constants you should know:

$c = 3 \times 10^8$ m/s

$$\Delta KE = q\Delta V \qquad PE = -\frac{kZ_1eZ_2e}{r} \qquad KE = \frac{1}{2}mv^2$$

$$k = \frac{1}{4\pi\varepsilon_0} \qquad E = h\upsilon = \frac{hc}{\lambda} \qquad \overline{E} = \overline{KE} + \overline{PE}, \quad \overline{KE} = -\frac{1}{2}\overline{PE}$$

$$PV = \frac{N}{N_A}RT \qquad PV = \frac{2}{3}N\left(\frac{1}{2}m\overline{v^2}\right) \qquad U = \frac{1}{2}kT \times \begin{pmatrix} \#\, quadratic \\ terms \end{pmatrix} \qquad C_m = \frac{dU}{dT}$$

Topics covered:

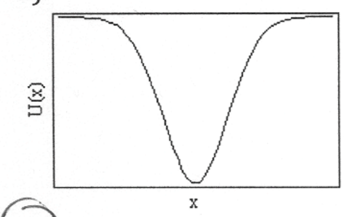
- Rutherford experiment
- Atomic spectra
- Bohr model of the atom
- Quantum numbers
- Virial theorem, potential energy, kinetic energy
- Definition of eV
- Covalent, Ionic, Metallic, and Secondary bonding
- Kinetic molecular theory
- Heat capacity, molar heat capacity
- Maxwell's principle of equipartition of energy
- Dulong-Petit rule
- Maxwell-Boltzmann velocity distribution
- Maxwell-Boltzmann energy distribution

Note: This review packet is not meant to be comprehensive. For the exam you should also review your class notes, HW, and ABCD questions (posted with the PPT slides in the course website).

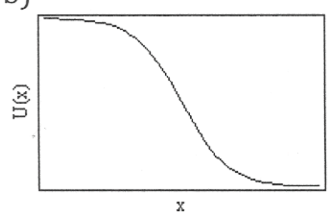
Note: For multiple choice questions, choose the best answer to each question. Show what equations you use, make a drawing, or write one sentence **explaining why** you chose that answer. You must have both the correct answer and correct reasoning to earn all possible points in the exam.

1. A ball is rolling along a flat surface when it encounters a hill. It rolls up and over the hill and then keeps rolling along a flat surface on the other side of the hill. Which of the following could be a plot of the potential energy of the ball as a function of position?

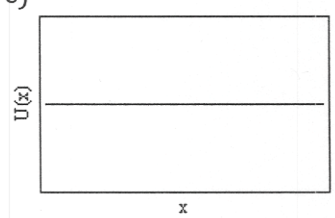
a)



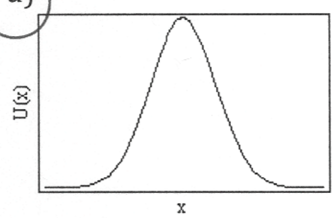
b)



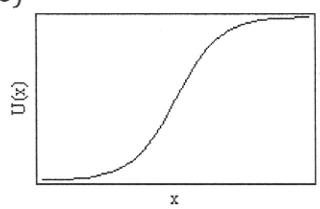
c)



d)



e)

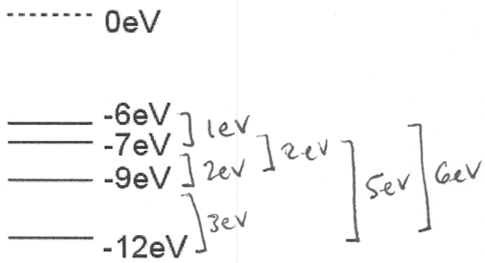


Potential energy is highest when the ball is on top of the hill.

2. How much kinetic energy (in eV) is gained by an electron when accelerated through a potential difference of 6 V?

6 eV since the definition of 1 eV is the amount of K.E. gained by an e^- when accelerated through a ΔV of 1 V.

3. The following represents the electron energy levels diagram of a single-electrom atom that you want to detect in the lab using a flame where you detect the emission spectrum of the atom.



a) At what energy level is the electron when the atom is in its ground state?

−12 eV (lowest possible energy)

b) What colors will you expect to see emitted from the sample? (circle all that apply)

1eV 2eV 3eV 4eV 5eV 6eV 7eV 8eV 9eV 12eV

1240nm 620nm 413.3nm 248nm 206.7nm

$\Delta E = \frac{hc}{\lambda} = \frac{1240 \text{ eV nm}}{\lambda}$

c) What is the ionization energy?

12eV

4. Rutherford bombarded atoms with high energy alpha particles and observed that a small fraction of them were deflected nearly straight back. What makes the most sense to conclude from this observation?

a. that atoms have a small, massive positive core surrounded by a cloud of light electrons
b. that matter can act as both a wave and a particle
c. that electrons in atoms can only have certain energies
d. that alpha particles can excite electrons in atoms

5. Write three basic ideas that Bohr used in the formulation of his model of the hydrogen atom. – the electron is in a circular orbit around the nucleus which is much more massive and positively charged

- Coulom attraction provides the force for the circular orbit of the electron
- electrons can orbit without radiating energy
- electrons emit energy only during transitions between states
- the frequency of the emitted light corresponds to the energy difference between states
- electrons can only occupy orbits with fixed radii that correspond to allowed energies

6. What inference about the structure of atoms did Bohr make from the observation that if you excite a gas of atoms, it only emits certain colors? Explain how this inference follows from this observation. Bohr concluded that electrons can only occupy certain orbits with fixed radii that correspond to allowed energy levels. The color of the light (wavelength) corresponds to the difference between energy levels, so that if only certain energy levels are allowed, then only certain wavelengths of light could be emitted by the atom.

7. If an electron is orbiting a proton at a distance of 0.32 nm, how much potential energy does it have? Pick the closest answer following the sign conventions developed in class.

a. 14 eV
b. 4.5 eV
c. 0 eV
d. -4.5 eV
e. -14eV

$$P.E. = -\frac{ke^2}{r} = -\frac{9\times10^9\,Nm^2/C^2\,(1.602\times10^{-19}C)^2}{0.32\times10^{-9}\,m}\cdot\frac{1\,eV}{1.602\times10^{-19}\,J} = -4.5\,eV$$

8. Why doesn't the Bohr model work for predicting the spectral lines of neutral Helium?

a) Helium doesn't have quantized energies like Hydrogen does
b) Helium has more than one electron, and the Bohr model cannot describe the interactions between the electrons
c) Helium has neutrons as well as protons in nucleus, which are not included in the Bohr model
d) Helium is too heavy
e) Helium has doublet spectral lines

9. What do we mean by hydrogen-like atoms? What are the difficulties in applying Bohr's model to non-hydrogen-like atoms? Hydrogen-like atoms are those that have been ionized so that they only have one electron. The Bohr model does not account for electron-electron interactions so it cannot be applied to atoms with 2 or more electrons.

10. The Bohr model marks a step towards the behavior of matter on an atomic scale.

a) What are the biggest successes of the Bohr model?

- it predicts energy levels fairly precisely for one-electron atoms
- it predicts the approximate size of the hydrogen atom
- it explains (sort of) why atoms emit discrete spectral lines
- it explains (sort of) why electrons don't spiral into the nucleus

b) Describe the limitations of the Bohr model.

it cannot explain jumps between levels, atomic lifetimes, why some transitions are stronger than others, or atoms with multiple electrons

11. Give the electronic configuration of the following atoms or ions:

a) $^{9}F^{-}$ $1s^2 2s^2 2p^6$ $^{9}F + 1e$ (10 electrons)

b) $^{11}Na^{+}$ $1s^2 2s^2 2p^6$ $^{11}Na - 1e$ (10 electrons)

c) ^{18}Ar $1s^2 2s^2 2p^6 3s^2 3p^6$

12. The f-subshells have an *l* quantum number of 3. What is the maximum total number of electrons that can fit into the 4f (n=4, l=3) subshell? Explain your reasoning.

$n = 4$, $l = 3$

$m_l = -3, -2, -1, 0, 1, 2, 3$

$m_s = +1/2, -1/2$

m_l can take 7 values, m_s can take 2 values for a total of 14 possible combinations

13. Explain how ionic bonding occurs.

14. Explain how covalent bonding occurs.

15. Explain how metallic bonding occurs.

16. Explain how secondary bonding occurs for molecules with induced dipoles.

17. Explain how secondary bonding occurs for molecules with permanent dipoles.

18. The molar specific heat of a gas is measured at constant volume and found to be 11R/2. This gas is most likely:

a. monatomic
b. diatomic
(c.) polyatomic — since it has more than 7 degrees of freedom

19. Explain why we often neglect vibration when calculating the specific heat of a gas.

Because vibrational degrees of freedom are not typically excited at room temperature.

20. Using the Maxwell speed distribution n_v,

a) Write an integral expression for the number of atoms in an ideal gas that would have speed $v > c$ (where c is the speed of light) at T = 293 K (you do not need to evaluate this expression).

$$N_{v>c} = \int_c^\infty n_v \, dv = 4\pi N \left(\frac{m}{2\pi kT}\right)^{3/2} \int_c^\infty v^2 e^{-mv^2/2kT}$$

b) Explain why the numerical result of the expression you found in (a) is negligible.

we are looking at the tail of the distribution, so the probability that an atom would have $v>c$ is very small