Chemistry 1A, Fall 2004

Midterm Exam I, Version 1

Sept 21, 2004

(90 min, closed book)

Name:___________________

SID:_____________________

TA Name:________________

Identification Sticker

- Write your name on every page of this exam.
- This exam has 40 multiple choice questions worth 3.4 points each. Fill in the Scantron form AND circle your answer on the exam.
- There is no penalty for guessing, so answer every question.
- There is only one correct answer per question.

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$E = h\nu$
$\lambda\nu = c$
$\lambda_{deBroglie} = h / p = h / mv$
E_{kin} (e-) $= h\nu - \Phi = h\nu - h\nu_0$

$$E_n = -\frac{Z^2}{n^2} R_\infty$$

$\Delta x \, \Delta p \sim h$
$p = mv$
Particle in a box (1-D Quantum):
$E_n = h^2n^2/8mL^2$; $n = 1, 2, 3...$

$PV = nRT$

$$E_{kin} = \frac{3}{2} RT$$

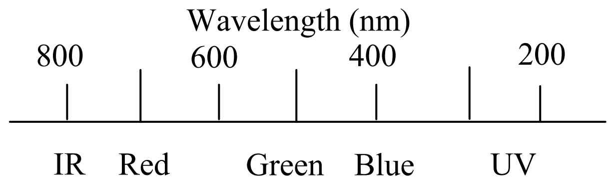
$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$\Delta E = q + w$
$w = -P_{ext}\Delta V$

$$\Delta E = \frac{3}{2} nR\Delta T$$

$N_0 = 6.02214 \times 10^{23}$ mol^{-1}
$R_\infty = 2.179874 \times 10^{-18}$ J
$R_\infty = 3.28984 \times 10^{15}$ Hz
$k = 1.38066 \times 10^{-23}$ J K^{-1}
$h = 6.62608 \times 10^{-34}$ J s
$m_e = 9.101939 \times 10^{-31}$ kg
$c = 2.99792 \times 10^{8}$ m s^{-1}
Gas Constant:
$R = 8.31451$ J K^{-1} mol^{-1}
$R = 8.20578 \times 10^{-2}$ L atm K^{-1} mol^{-1}
T (K) = T (C) + 273.15
F = 96,485 C / mol
1 V = 1 J / C 1 nm = 10^{-9} m
1 kJ = 1000 J

Color and Wavelength of Light



$\Delta G° = \Delta H° - T\Delta S°$
$\Delta H° = \Sigma \, \Delta H°_f$ (products) $- \Sigma \, \Delta H°_f$ (reactants)
$\Delta S° = \Sigma \, S°$ (products) $- \Sigma \, S°$ (reactants)
$\Delta G° = \Sigma \, \Delta G°_f$ (products) $- \Sigma \, \Delta G°_f$ (reactants)
$S = k_B \ln W$

for $aA + bB \rightleftarrows cC + dD$

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$ At equilibrium, Q = K

$\Delta G° = -RT\ln K$

$$\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$$

$\Delta G° = -nF\Delta\mathcal{E}^o$

$pX = -\log X$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

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SECTION 1: ATOMS, MOLECULES AND MOLES

Questions 1 - 4 refer to any of the various chlorofluorocarbon (CFC) molecules found as pollutants in the air. Each question may refer to a *different* CFC.

1.) What will the atomic number be of an individual chlorine atom that is removed from a chlorofluorocarbon ($C_xCl_yF_z$) pollutant in the air [hw 2.35]?

A) 16 ***B) 17*** C) 35 D) 37 E) can't tell

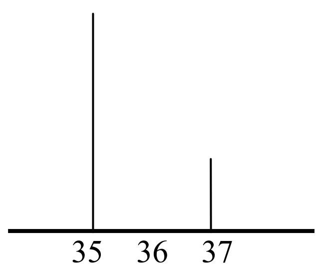
2.) What is the relative mass (amu) of an individual chlorine atom that is removed from a chlorofluorocarbon (CFC) pollutant in the air [hw 2.35, 2.29]?

A) 35 B) 36 C) 37 D) 35.45 ***E) can't tell***

3.) What is the empirical formula of a chlorofluorocarbon which is composed of 59% chlorine, 31% fluorine and 10 % carbon by weight [hw 3.49]?

A) $CClF_3$ B) $C_2Cl_2F_2$ C) CCl_3F ***D) CCl_2F_2*** E) C_3Cl_2F

4.) Which is an explanation for the peaks in the following region of the mass spectrum of a fragmented chlorofluorocarbon [hw 2.27, cq 2.1]?



A) ^{35}Cl and ^{37}Cl in 1:1 ratio
B) ^{19}F and ^{35}Cl in 1:1 ratio
C) ^{19}F and ^{18}F in 2:1 ratio
D) ^{35}Cl and ^{37}Cl in 1:3 ratio
E) ^{35}Cl and ^{37}Cl in 3:1 ratio

Continue with the next question:

5.) What is the identity of an atom with atomic number 35 and mass number 81 [hw 2.32]?

A) Br B) Cl C) Ti D) Tl E) Pb

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For questions 6 and 7, consider the industrial production of hydrogen cyanide (HCN) by reaction of ammonia (NH_3), oxygen gas (O_2) and methane (CH_4). Water is also produced as a byproduct of the reaction.

6.) What is the stoichiometric coefficient of water in the balanced chemical equation for the production of 2 moles of HCN [hw 3.55]?

A) 1 B) 3 C) 5 ***D) 6*** E) 8

7.) How many moles of HCN are produced when 10 kg of NH_3 reacts completely [hw 3.67]?

A) 255 B) 401 C) 588 D) 911 E) 1213

Continue with the next question:

8.) How many moles of ethanol (C_2H_5OH) are contained in 12.0 mL pure ethanol (ethanol density: 0.90 g/mL) [hw 3.31, cq 3.3]?

A) 0.14 B) 0.24 C) 0.55 D) 1.2 E) 37

9.) What is the molar concentration (M) of an alcoholic beverage which is 12% ethanol (C_2H_5OH) by volume in water (ethanol density: 0.90 g/mL) [hw 4.13, cq 3.4]?

A) 10 B) 5.5 C) 2.4 D) 0.12 E) 0.56

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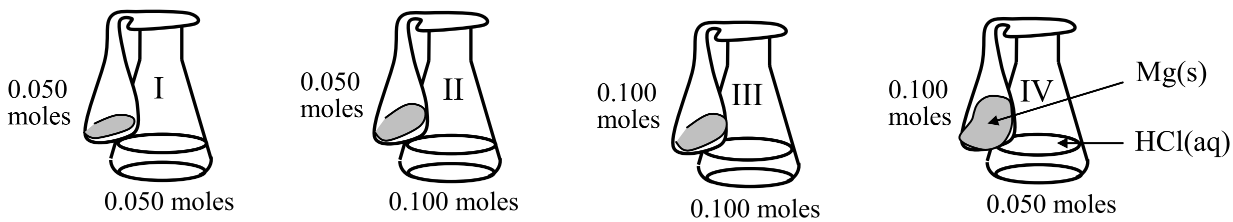
Consider the reaction of magnesium powder (Mg) and hydrochloric acid (HCl) to generate hydrogen gas:

$$Mg\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$$

Aqueous HCl liquid is placed in an Erlenmeyer flask and the solid Mg powder is placed in a balloon stretched over the neck of the flask in the various combinations shown below.

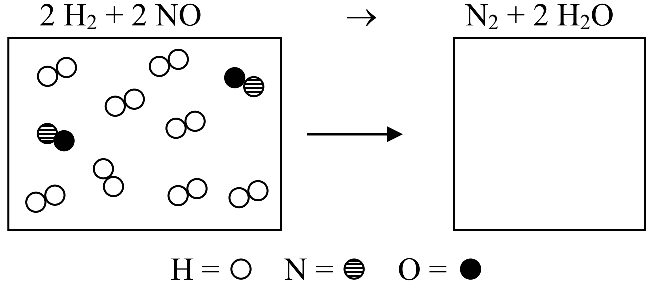


10.) What is the relative order of the balloon sizes after the reagents are mixed and the reaction is complete?

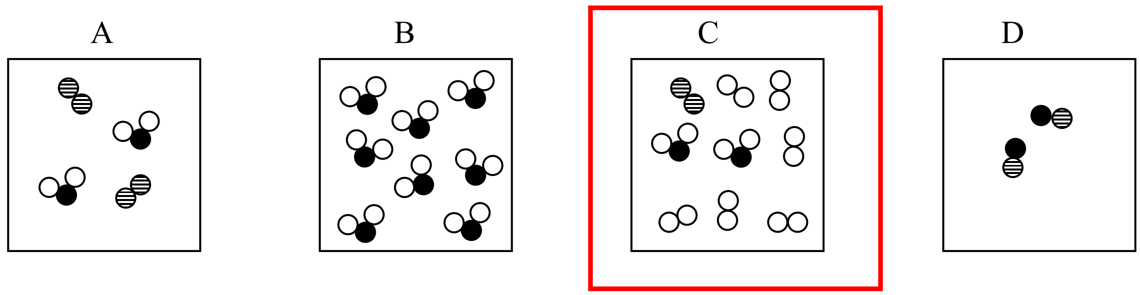
A) I = II = III = IV
B) III > IV = II > I
C) IV > III = II > I
D) II = III > I = IV

Consider the molecular picture shown below for the following reaction.

$$2\ H_2 + 2\ NO \rightarrow N_2 + 2\ H_2O$$



11.) Which of the diagrams below best represents the molecules after the reaction has taken place?



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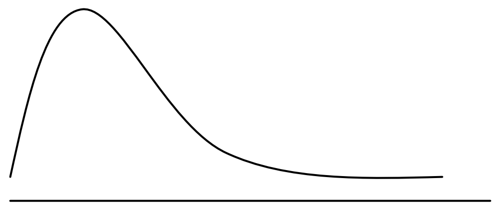
SECTION 2: PROPERTIES OF PARTICLES AND LIGHT

12.) What color does a normally orange object appear when viewed through a filter with the absorption profile shown here [cq 4.2]?

A) clear B) green C) blue D) black E) can't tell



red orange yellow green blue violet

Consider the following list of particles for questions 13-15.

A) 650 nm photons.
B) Electrons traveling at around 10^5m/s.
C) Buckminster Fullerenes (C_{60} 'Bucky Balls') traveling at around 300 m/s.
D) 170 g baseballs traveling at around 10 m/s.
E) 250 g soccer balls traveling at around 10 m/s.

13.) Which is the arrangement of the particles from smallest to largest de Broglie wavelength [12.37]?

A) A,B,C,D,E
B) B,C,A,D,E
C) C,B,A,D,E
D) E,D,C,B,A
E) E,D,A,B,C

14.) For which particle can a 'two-slit' type interference pattern be obtained in practice? (Hint: the slit spacing must be on the same order of magnitude as the wavelength).

A) A and B
B) A and C
C) B, C and D
D) D and E
E) All of the particles can display interference in practice.

15.) Which particles can have a 'zero-point' kinetic energy of zero?

A) A and B
B) A, B, and C
C) B, C and D
D) D and E
E) none of the particles have zero ground state energy.

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16.) How many photons of 150 nm light are required to approximately stop a Ti atom at a temperature of 80 K (de Broglie wavelength ~ 0.03 nm) [cq 6.1]?

A) 150 B) 1500 C) 2500 D) 5000 E) 1

Consider a metal that requires a minimum of 300 kJ to remove a mole of electrons for questions 17 – 20.

17.) What is the kinetic energy (kJ/mol) of a mole of ejected electrons if 400 kJ/mole of energy is supplied by photons in a beam of light [hw 12.29, 12.27]?

A) 20
B) 40
C) 100
D) 200
E) no electrons are ejected

18.) What is the kinetic energy (kJ/mol) of a mole of ejected electrons if 200 kJ/mole of energy is supplied by photons in a beam of light [hw 12.29]?

A) 20
B) 40
C) 100
D) 200
E) no electrons are ejected

19.) What is the kinetic energy (kJ/mol) of a mole of ejected electrons if the intensity of the beam of light in question 18.) is doubled [cq 5.2]?

A) 20
B) 40
C) 100
D) 200
E) no electrons are ejected

20.) What is the maximum photon wavelength (nm) required to eject a single electron from the metal [hw 12.27]?

A) 222 B) 398 C) 425 D) 567 E) 678

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SECTION 3: QUANTUM MECHANICS

21.) Which is true for a gaseous atom of any element, X, when an electron is removed according to the following equation:

$$X(g) \rightarrow X^{+}(g) + e^{-}$$

A) The reaction requires energy for all elements, because the initial state is less stable than the final state.

B) The reaction requires energy for all elements, because the initial state is more stable than the final state.

C) The reaction does not require energy for any element, because the initial state is the same energy as the final state.

D) The reaction requires energy for some elements, because sometimes the initial state is more stable than the final state.

22.) Which of the following statements is ***false*** about the potential energy between an electron and a proton in an atom?

A) The magnitude of the potential energy decreases as the electron gets closer to the nucleus.

B) The magnitude of the potential energy increases as the electron gets closer to the nucleus.

C) The potential energy approaches zero as the distance of the electron from the nucleus approaches infinity.

D) The sign of the potential energy is a negative number because the proton and electron have opposite charges.

23.) Which is the correct arrangement of particles from largest to smallest 1s orbital [hw 12.63]?

A) H, Li^{+2}, Be^{+3}, N^{+6}

B) N^{+6}, Be^{+3}, Li^{+2}, H

C) Li^{+2}, Be^{+3}, N^{+6}, H

D) H, N^{+6}, Be^{+3}, Li^{+2}

E) all have the same 1s orbital size.

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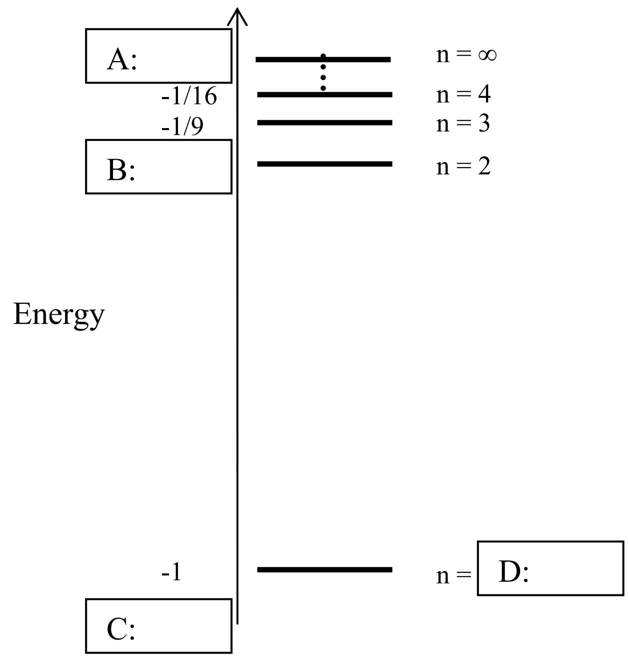
Consider the following diagram showing the energy levels of a Hydrogen atom for the following questions 24 - 29.



24.) In what units is the energy expressed?

A) Joules
B) Kilojoules
C) Hertz (frequency)
D) Rydbergs
E) Kelvins

25.) Which value belongs in box A?

A) -1 B) -1/4 C) 0 D) 1 E) none of these

26.) Which value belongs in box B?

A) -1 B) -1/4 C) 0 D) 1 E) none of these

27.) Which value belongs in box C?

A) -1 B) -1/4 C) 0 D) 1 E) none of these

28.) Which value belongs in box D?

A) -1 B) -1/4 C) 0 D)1 E) none of these

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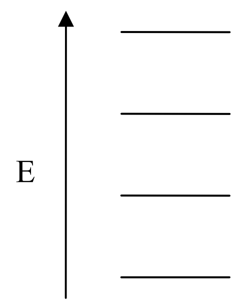
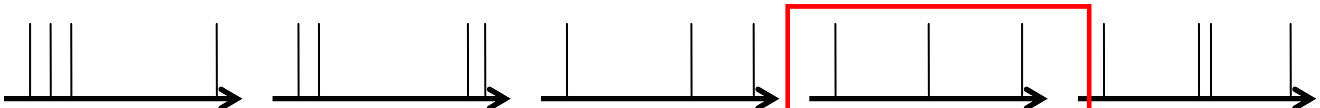
29.) An excited state of hydrogen emits a photon of energy ¾ u (where u are the units used in the figure). To which transition does this emission correspond [hw 12.35, cq 8.1, 8.2]?

A) n = 3 to n =2.
B) n = 2 to n = 1.
C) n = 4, n = 2.
D) n = 3, to n= 1.
E) Ionization.

Continue with the next question:

30.) Which is the emission spectrum (frequency increasing to the right) best associated with the energy level diagram shown [cq 6.3, 6.4]?





A B C D E

31.) Which combination of particle and box size has the highest ground state energy [cq 7.4]?

A) ^{1}H, 2 nm
B) electron, 0.01 cm
C) ^{2}H, 1 nm
D) electron, 1 nm
E) ^{1}H, 0.01 cm

32.) Which set of quantum numbers is not possible?

A) $n = 2, \ell = 0, m_\ell = 0, m_s = ½$
B) $n = 2, \ell = 1, m_\ell = 0, m_s = ½$
C) $n = 3, \ell = 3, m_\ell = 1, m_s = ½$
D) $n = 4, \ell = 0, m_\ell = 1, m_s = ½$
E) $n = 5, \ell = 4, m_\ell = 4, m_s = ½$

33.) Which has the fewest radial nodes [cq 8.4]?

A) 2s B) 4p C) 5d D) 6f E) 3d

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34.) Which set of numbers below corresponds respectively to the total number of electrons that can have the following designations 1p, $6d_{xy}$, 4f, $7p_y$, n=3 [hw 12.53]?

A) 6, 10, 14, 6, 18
B) 2, 2, 2, 6, 10
C) 2, 2, 14, 2, 18
D) 6, 2, 14, 2, 10
E) 0, 2, 14, 2, 18

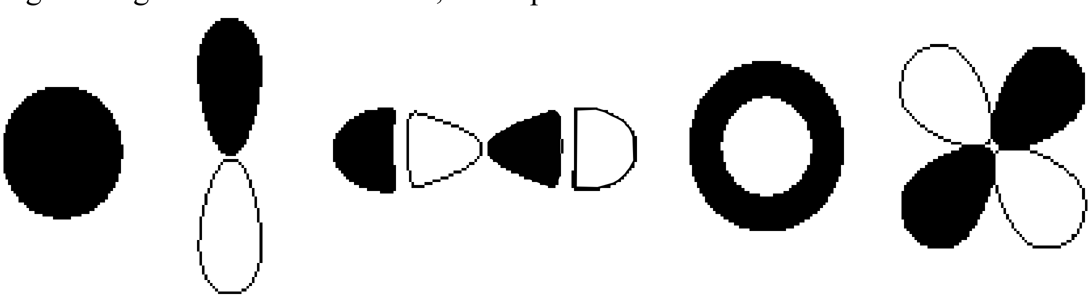
35.) Which is true for an *ion* that has the electronic configuration $1s^2 2s^2 3p^1$ [hw 12.78, 12.67]?

A) It is in its ground state.
B) It is neutral.
C) It has charge +2.
D) It is in an excited state.
E) Cannot be determined.

36.) Which is true for an *ion* that has the electronic configuration $1s^2 2s^2 3p^1$ [hw 12.67]?

A) The element is ionic boron.
B) The element is ionic carbon.
C) The element is ionic beryllium.
D) The element is ionic nitrogen.
E) Cannot be determined.

Consider the figure below for the following questions 37 and 38. Black represents a negative sign to the wave function, white positive.



A B C D E

37.) Which has the most angular nodes?

A) A B) B C) C D) D E) E

38.) Which would have designation 3p?

A) A B) B C) C D) D E) E

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SECTION 4: LABORATORY

39.) The atmosphere of earth has a volume of approximately 5.73×10^{23} L. The concentration of carbon dioxide (CO_2) in the atmosphere is 370 ppm. How many liters (L) of CO_2 are in the atmosphere?

A) 5.73×10^{17} L
B) 2.12×10^{26} L
C) 2.12×10^{20} L
D) 1.55×10^{21} L
E) 3.70×10^{8} L

40.) What assumption was *not required* in lab to calculate the amount of CO_2 generated by the world population?

A) For every O_2 molecule inhaled, you exhale one CO_2 molecule.
B) Everyone in the world takes the same number of breaths in a day.
C) Everyone in the world has the same volume in one breath.
D) All of the glucose eaten in a day is converted to CO_2.
E) The amount of CO_2 in the air is correlated to global warming.