Chemistry 1A, Spring 2008

Midterm Exam I, Version 1

Feb. 11, 2008

(90 min, closed book)

Name:________ KEY ___

SID:___________________________

TA Name:_______________________

1.) Write your name on every page of this exam.

2.) This exam has 15 multiple-choice questions and 3 short answer questions. Fill in the Scantron form AND circle your answer on the exam.

3.) There is no penalty for guessing, so answer every question.

4.) Some questions may require selecting more than one answer to receive credit.

5.) Show all work to receive credit on short answer questions.

Question	**Points**
MC	/60
#16	/15
#17	/10
#18	/15
TOTAL	/100

Name________________________________

$E = h\nu$

$\lambda\nu = c$

$\lambda_{deBroglie} = h / p = h / mv$

E_{kin} (e-) $= h\nu - \Phi = h\nu - h\nu_0$

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

$$E_{i \to f} = -R_\infty \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$\Delta x \, \Delta p \geq h/4\pi$

$p = mv$

Particle in a box (1-D Quantum):

$E_n = h^2 n^2 / 8mL^2$; 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}

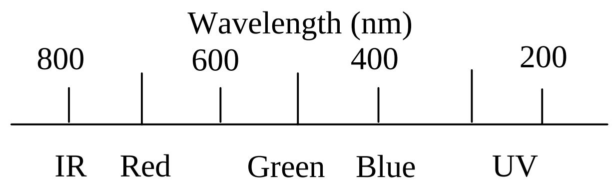
T (K) = T (C) + 273.15

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)

$S = k_B \ln W$

$\Delta G° = - RT\ln K$

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

$\Delta G° = - nF\Delta Є^o$

$pX = - \log X$

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

Name________________________________

Multiple Choice Questions (4 Points Each)

1) In class you observed the combustion of butane (C_4H_{10}). What is the coefficient of oxygen in the *balanced* chemical equation of two moles of butane?

$2C_4H_{10}\ (g) + \quad O_2\ (g) \rightarrow \quad CO_2\ (g) + \quad H_2O\ (l)$

Answer: $\mathbf{2C_4H_{10}\ (g) + 13O_2\ (g) \rightarrow 8CO_2\ (g) + 10H_2O\ (l)}$

A) 2 B) 10 C) 7 $\boxed{\text{D) 13}}$ E) 5

2) In lab, the reaction of acetic acid and sodium bicarbonate produced CO_2 (g) to inflate your airbag.

$CH_3COOH\ (aq) + NaHCO_3\ (s) \rightarrow CH_3COO^-Na^+\ (aq) + CO_2(g) + H_2O\ (l)$

If 53 g of $NaHCO_3$(s) is mixed with CH_3COOH(aq) to produce 7.2 g of water, what is the limiting reactant?

Answer: 53 g of sodium bicarbonate = 0.63 moles, 7.2 g of water = 0.40 moles. Therefore, acetic acid must be the limiting reagent.

$\boxed{\text{A) } CH_3COOH}$
B) $NaHCO_3$
C) CO_2
D) H_2O
E) $CH_3COO^-Na^+$

3) How many electrons are there in the iodide (I^-) anion?

Answer: The atomic number of iodine is 53. So the number of electrons in the anion is 54.

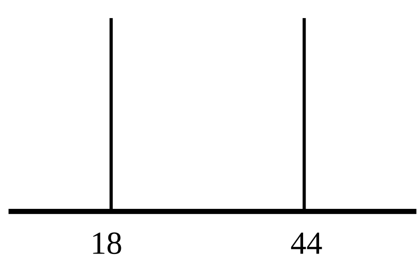
A) 52 B) 127 $\boxed{\text{C) 54}}$ D) 128 E) 53

4) How many protons are there in the nucleus of the sodium cation, Na^+?

Answer: The atomic number of sodium is 11. A cation is formed by the loss of electrons, not by a change in the number of protons.

A) 10 B) 24 C) 12 D) 23 $\boxed{\text{E) 11}}$

5) Combustion of a hydrocarbon with O_2 yields products with the mass spectrum shown. What is the hydrocarbon?



Name________________________________

Answer: C_2H_4. A balance equation yields 1 mole of carbon dioxide and 1 mole of water. The mass ratio is therefore 1:1.

A) $\boxed{C_2H_4}$
B) C_2H_2
C) C_4H_{10}
D) C_3H_8
E) CH_4

6) Carbon has two stable isotopes, C-12 and C-13. C-12 has a mass of 12.00 amu and the mass of C-13 is 13.00 amu. Use the atomic mass of carbon to calculate the relative abundance of the two isotopes.

Answer: 12*(x) + 13*(1-x) = 12.01, where x is the percentage of C-12. Solving for x we get 99% of C-12 and 1% of C-13.

A) 97% of C-12, 3% of C-13
B) 90% of C-12, 10% of C-13
C) 99% of C-12, 1% of C-13
D) 100% of C-12, 0% of C-13
E) Can't be determined.

7) What is the molar concentration (M) of an alcoholic beverage that is 42% ethanol (C_2H_5OH) by volume in water (ethanol density: 0.90 g/mL)?

Answer: 42% ethanol = 42 mL ethanol in 100 mL solution. 42 mL*(0.90 g/mL) / 46.07 g/mol) = 0.820 moles in 100 mL. [ethanol] = 8.20 M

A) 19.5 M
B) 8.20×10^{-3} M
C) 1.95×10^{-2} M
D) 8.20 M
E) 9.13 M

8) Consider a two-slit experiment using monochromatic light. Which statements are true? (Mark all that apply.)

Answer, A, C, and D are all correct and all must be selected to receive full credit.

A) Constructive interference results in bright spots.
B) Constructive interference results in dimmed or no intensity.
C) Changing the frequency of light affects the interference pattern.
D) Destructive interference results in dimmed or no intensity.
E) Destructive interference results in bright spots.

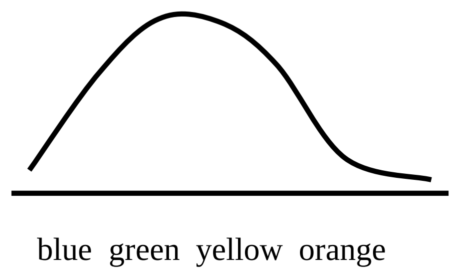
9) What is the frequency of light with a wavelength of 532 nm?

Answer: $\nu = c / \lambda$. $\nu = (3 \times 10^8$ m/s$) / (532 \times 10^{-9}$ m$) = 5.64 \times 10^{14}$ s^{-1} (Hz)

A) 5.64×10^{14} Hz

B) 1.77×10^{-6} Hz
C) 1.77×10^{-15} Hz
D) 5.64×10^{5} Hz
E) 1.60×10^{11} Hz

10) The absorption spectrum of an object is shown below. What color is the object?



Answer: Most of the colors are absorbed, except red.

A) Blue   B) Red   C) Green   D) White   E) Yellow

11) Which of the following are possible quantum numbers for an electron in a 3s orbital?

A) $n = 3$, $l = 0$, $m_l = 0$
B) $n = 3$, $l = 0$, $m_l = 2$
C) $n = 2$, $l = 1$, $m_l = 1$
D) $n = 2$, $l = 1$, $m_l = 0$
E) $n = 3$, $l = 1$, $m_l = 1$

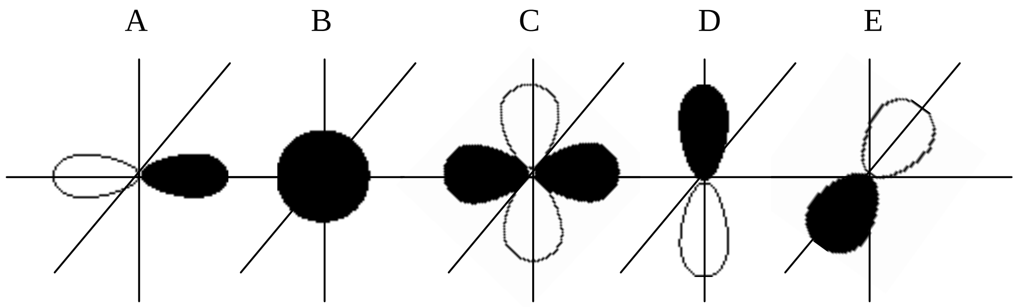
12) In a hydrogen atom, which of the following arrangements of the electron and the proton has the lowest energy?

Answer: Of the given choices, the PE is smallest for the ground state. As in discussion, moving a proton and electron further from one another results in an increase in energy.

A) The electron is infinitely spaced from the proton.
B) The ground state.
C) The excited state.
D) The nucleus.
E) None of the above.

Name________________________________

For the next *three* questions, consider the following set of five orbitals:



13) Which of these represents a *d* orbital?
Answer: Orbital 'C' depicts a d orbital.

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

14) How many nodes are displayed in orbital 'E'?
Answer: There is one node evident in orbital 'E'

A) 0 B) 1 C) 2 D) 3 E) 4

15) Which orbital has the lowest energy?
Answer: Orbital 'B' shows the least number of nodes suggesting it has the lowest energy.

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

Name________________________________

Short Answer Questions

16) Glucose is an important sugar because it is an energy source for living cells. Elemental analysis of glucose gave the following mass percent composition: 40.00% C, 6.72% H, and 53.28% O. The molar mass is 180 g/mol.

A) What is the molecular formula? Show your work. (15 points)

Answer:
In a 100g sample, we would have 40.00 g C, 6.72 g H, and 53.28 g O.
Using molar masses of 12.01 g/mol, 1.008 g/mol and 16.00 g/mol for C, H, and O, respectively, we obtain 3.33 moles of C, 6.66 moles of H, and 3.33 moles of O.

Dividing by the lowest common denominator, the empirical formula is CH_2O.

The molar mass of CH_2O is 30 g/mol and the molar mass of glucose is 180 g/mol meaning the molecular formula is $C_6H_{12}O_6$.

B) Sucrose, $C_{12}H_{22}O_{11}$, is common table sugar. Write the balanced chemical reaction for the combustion of sucrose.

Answer: $C_{12}H_{22}O_{11}\ (s) + 12\ O_2\ (g) \rightarrow 12\ CO_2\ (g) + 11\ H_2O\ (l)$

C) If we start with 10.0 g of sucrose and an excess of oxygen (O_2), how many grams of CO_2 are produced from the reaction?

Answer:
moles of sucrose = 10.0 g/ (342 g/mol) = 0.029 moles

Stoichiometrically, for one mole of sucrose, we produce 12 moles of carbon dioxide. So we produce 12 x 0.029 moles = 0.348 moles.

Molar mass of CO_2 = 44 g/mol, so (0.348 moles)*(44 g/mol) = 15.3 g of CO_2 are produced.

D) If we start with 10.0 g of sucrose and 10.0 g of oxygen (O_2), what is the limiting reactant? Explain your reasoning.

Answer: 10 g of sucrose = 0.029 moles; 10 g of O_2 = 0.313 moles.

For 10 g of sucrose to react completely we need 12*(0.029 moles) = 0.348 moles of O_2.

But we only have 0.313 moles of O_2; therefore, O_2 is the limiting reactant.

17) Sodium metal requires light of 683 nm to eject electrons from the surface.

A) What is the minimum energy (J/mol) required to eject electrons? (10 points)

Answer: $E = hc/\lambda$

$= (6.626 \times 10^{-34}\ Js)(3 \times 10^{8}\ m/s)/(683 \times 10^{-9}\ m)$

$= 2.91 \times 10^{-19}\ J$;

$E/mol = E \times N_A$

$= (2.91 \times 10^{-19}\ J)(6.022 \times 10^{23}\ photons/mol)$

$= 1.75 \times 10^{5}\ J/mol$

B) How does reducing the intensity of 683 nm light affect the ejection of electrons? Explain your reasoning.

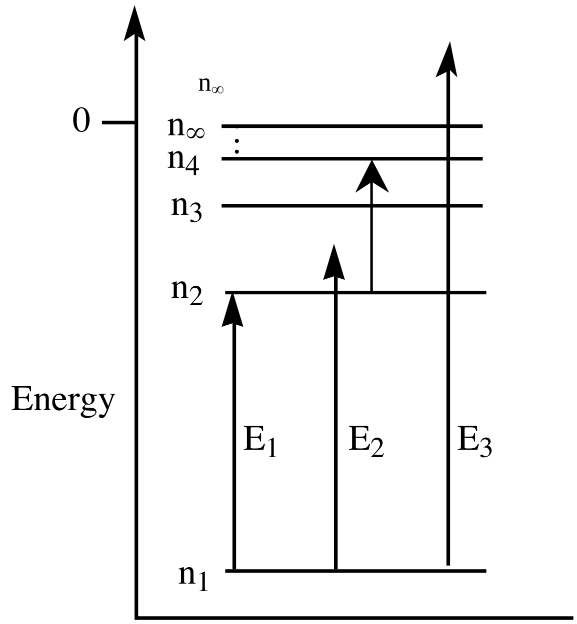
Answer: The wavelength of light does not change, so the photons still have enough energy to eject electrons. However, reducing the intensity of light results in fewer photons, meaning fewer electrons will get ejected.

C) Would electrons be ejected if 800 nm light was used in the experiment? Why or why not?

Answer: The wavelength of light has changed and in part (A) we calculated the minimum energy necessary to eject electrons was 1.75×10^{5} J/mol. Since wavelength and energy are inversely proportional, 800 nm light would not have enough energy to eject electrons.

Name________________________________

18) Consider the following energy level diagram for a hydrogen atom. (15 points)



A) Calculate the wavelength (nm) of light corresponding to the n = 2 → n = 4 transition. Show all work.

Answer: $E_n = -1/n^2(R_\infty)$ or $E = -R_\infty\,(1/n_f^2 - 1/n_i^2)$.
$E_2 = -\frac{1}{4}(R_\infty) = -5.45 \times 10^{-19}$ J and $E_4 = -1/16(R_\infty) = -1.36 \times 10^{-19}$ J.
$E_{2\rightarrow4} = 4.09 \times 10^{-19}$ J

$E = hc/\lambda$
$= 486$ nm.

B) Can an electron in state n = 1 absorb a photon of energy E_2?

Circle one: Yes $\boxed{\text{No}}$

If you answered yes, where does the excess energy go?

If you answered no, why not?

Energy is quantized, and E_2 does not correspond to an energy transition so it will not be absorbed.

C) Can an electron in n=1 absorb a photon of energy E_3?

Circle one: $\boxed{\text{Yes}}$ No

If you answered yes, where does the excess energy go?

The excess energy goes into kinetic energy of the unbound electron.

If you answered no, why not?