Chemistry 1A, Fall 2002

Final Exam, Version A
December 11, 2002

(3 hours, closed book)

Name:________________________ **TA:**________

SID:__________________________ **Section:**_____

Please read this first: Write your name and that of your TA on all pages; On the **Scantron™**, bubble in Form A.

Test-taking Strategy

This test consists of two parts: multiple choice (**answers to be circled and entered on the Scantron™ sheet**) and short answer. In order to maximize your score on the exam:

- Do the questions you know how to do first.
- Then, go back and spend more time on the questions you find more challenging.
- Budget your time carefully -- don't spend too much time on one problem.
- Show all work for which you want credit and don't forget to include units.

Page	**Score**
10	
11	
12	
13	
14	
SA Total	
MC Total	

Name________________________
TA __________________________

Potentially Useful Information

$E=h\nu$

$\lambda\nu = c$

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

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

$E_{kin} = ½mv^2$

$E_{kin} = 3RT/2$

$v_{rms} = \sqrt{(3RT/M)}$

$E_n = -R_\infty(Z^2/n^2)$

$\Delta E = -R_\infty(Z^2/n_2^2 - Z^2/n_1^2)$

$R_\infty = 2.18 \times 10^{-18}$ J

$k_B = 1.381 \times 10^{-23}$ J/K

$m_e = 9.11 \times 10^{-31}$ kg

$h = 6.626 \times 10^{-34}$ J s

$c = 3.0 \times 10^8$ m/s

1 nm = 10^{-9} m

1 kJ = 1000 J

1 Torr = 1 mmHg

1 atm = 760 mmHg

J = (kg m^2)/s^2

1 eV = 1.602×10^{-19} J

PV = nRT

MM = mRT / (PV)

T(K) = T(C) + 273.15

R = 0.0821 L·atm / (mol·K)

R = 8.314 J / (mol K)

A = elC

$P_a = X_a P_{tot}$

P = F/A

$\Delta E = q + w$

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G = \Delta G° + RT \ln Q$

$\Delta G° = -RT \ln K$

$q = mC_s\Delta T$

$w = -P_{ext}\Delta V$

$\Delta H° = \Sigma\Delta H°_f(\text{products}) - \Sigma\Delta H°_f(\text{reactants})$

$N_A = 6.022 \times 10^{23}$

1 cal = 4.18 J

101.3 J = 1 L atm

$K_aK_b = K_w$

$K_w = 10^{-14}$

pX = -log X

$pK_a + pK_b = pK_w$

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

Bond Energies (kJ/mol)

C-H	412
N-H	388
H-H	436
N≡N	944
C-C	348
C=C	612
C≡C	837
C≡N	89

Name________________________
TA ___________________________

Part I-Multiple Choice (4 pts each, 160 pts total) Bubble in the correct answer on your Scantron™ form AND circle your answer on the exam. There is only one correct answer for each question, so you should circle and fill in one and only one answer for each question. There is no penalty for an incorrect response.

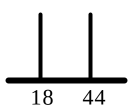
1.) Which neutral atom could have the configuration $1s^2 2s^2 2p^6 3s^2 3p^4 4s^1$?

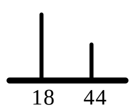
A) K $\boxed{\text{B) Cl}}$ C) Na D) Rb E) S

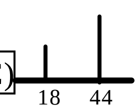
2.) What wavelength of light (in nm) is emitted by a hydrogen atom that undergoes a transition from n=4 to n=1?

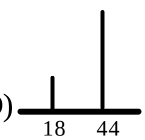
$\boxed{\text{A) 97}}$
B) 365
C) 823
D) 1460
E) 240

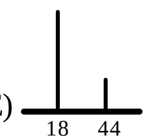
3.) Which would be the mass spectrum of the products when acetylene (C_2H_2) is burned in oxygen?

A) 

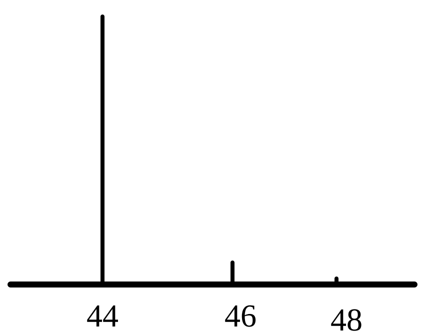
B) 

$\boxed{\text{C)}}$ 

D) 

E) 

4.) An expansion of the mass spectral region around 44 mass units for the products of acetylene combustion in oxygen shows the following. What is the likely explanation of the peak at mass number 46?



A) Presence of ^{13}C in acetylene burned.
B) Presence of ^{18}O in the water formed.
C) $\boxed{\text{Presence of } ^{18}\text{O in oxygen burned}}$.
D) Presence of ^{2}H in the water formed.
E) None of these.

Name________________________
TA __________________________

5.) What is the maximum number of electrons with the same spin quantum number (m_s) for the principle quantum number 3?

A) 4 B) 8 $\boxed{\text{C) 9}}$ D) 14 E) 19

6.) A longer wavelength of light is required to break an oxygen-oxygen bond in ozone (O_3) than the oxygen-oxygen bond in diatomic oxygen (O_2). Which of the following is the best explanation for this.

A) Random differences between different molecules
B) Ozone is bigger so the bonds are weaker
$\boxed{\text{C) Diatomic oxygen has a higher bond order than ozone}}$
D) There are three oxygen atoms in ozone
E) Diatomic oxygen has no dipole moment

7.) What is the conjugate acid of OH^-?

A) H^+
B) H_3O^+
$\boxed{\text{C) } H_2O}$
D) O^{2-}
E) none of these

8.) Which of the following acids has the strongest conjugate base (pK_a values are given in parenthesis)?

A) Iodic acid, HIO_3 (0.77)
B) Hydrofluoric acid, HF (3.45)
C) Lactic acid, $CH_3CH(OH)COOH$ (3.08)
D) Acetic acid, CH_3COOH (4.75)
$\boxed{\text{E) Carbonic Acid, } H_2CO_3 \text{ (6.37)}}$

Consider a flask containing the following mixture of gases at 300 K for the next three questions.

Gas	Pressure
Neon	1 atm
Argon	1 atm
Krypton	_atm
Xenon	2 atm

9.) The total pressure in the flask is 4.5 atm. What is the partial pressure of Krypton in atmospheres?

A) 0.10
B) 0.25
$\boxed{\text{C) 0.50}}$
D) 0.75
E) 1.0

Name________________________
TA __________________________

10.) Which gas has the greatest root mean square velocity?

A) Neon
B) Argon
C) Krypton
D) Xenon
E) All have the same mean velocity.

11.) Which gas has the greatest molar mean energy?

A) Neon
B) Argon
C) Krypton
D) Xenon
E) All have the same molar mean energy.

12.) If 2 grams of hydrogen gas and 16 grams of oxygen gas react to form water, how many moles of water will form?

A) 2 moles B) 16 moles C) 1 mole D) 18 moles E) 14 moles

13.) Ideally, under identical conditions the molar density of O_2 gas is _________ that of H_2 gas.

A) less than
B) greater than
C) the same as
D) need more info

14.) How much energy is lost if all of the atoms in 1.0 g of H emit a photon with a wavelength of 656.3 nm?

A) 215 kJ
B) 182.3 kJ
C) 3.03×10^{-19} J
D) 3.03×10^{-19} kJ
E) 2.79×10^{-14} J

15.) What is the de Broglie wavelength (in nm) of an electron traveling 1.5×10^5 m s^{-1} ?

A) 7.1 B) 4.9 C) 3.2 D) 2.0 E) 5.5

16.) How many nodes are there in a 5f orbital?

A) 3 B) 4 C) 5 D) 6 E) 7

Name________________________
TA __________________________

17.) If the quantum numbers for an electron of hydrogen are n = 4, l = 3, m_l = -2, in what type of orbital is the electron?

A) 3d B) 4d C) 4p $\boxed{\text{D) 4f}}$ E) 4g

18.) Why is it harder to remove an electron from phosphorus than it is from silicon?

all answers were accepted because the question was poorly worded

A) silicon has more electrons than phosphorus
B) half filled orbitals are more stable than partly filled orbitals
C) phosphorous has more protons than silicon
D) silicon is larger than phosphorous
E) none of these

19.) Which of the following statements about bond formation is TRUE?

A) The potential energy of a compound is higher than that of the unbound atoms.
B) Ionic compounds share electrons equally between atoms.
C) The kinetic energy of a compound is lower than that of the unbound atoms.
D) Covalent bonds usually occur when the atoms have similar electronegativities.
E) All of the statements are correct.

Consider the ion CH_3^- for the following two questions:

20.) Using the Lewis Dot model, what is the predicted geometry of this ion?

A) square planar
B) trigonal pyramidal
C) tetrahedral
D) octahedral
E) see-saw

21.) What is the hybridization of the carbon atom in this ion?

A) s B) sp $\boxed{\text{C) } sp^3}$ D) sp^2 E) spd^2

22.) The initial temperature and pressure in a 1 L container are 1 atm and 300 K. Approximately what pressure is needed to compress the compartment to 0.1 L, if you also want the final temperature in the container to be 325 K.

A) 2 atm
B) 5 atm
C) 10 atm
D) 15 atm
E) 20 atm

Name________________________
TA ___________________________

23.) Which of the following statements best describes why ice cubes float in liquid water?

A) The solid is more densely packed than the liquid.
B) The crystal structure of ice allows the liquid water to flow through it.
C) Hydrogen bonding causes strong interaction between liquid and solid phases of water.
D) Liquid water is more compactly arranged than ice.
E) Ice cubes don't float.

24.) A typical hot tub has about 650 L of water in it. How much energy will it require to raise the temperature of the hot tub from 20ºC to 100 ºC. The heat capacity of water is 4.18 J/g·ºC; assume the density of water is 1.0 g/mL at all temperatures.

A) 220 kJ B) 2.5×10^{8} kJ C) 220 J D) 440 kJ E) 2.2×10^{5} kJ

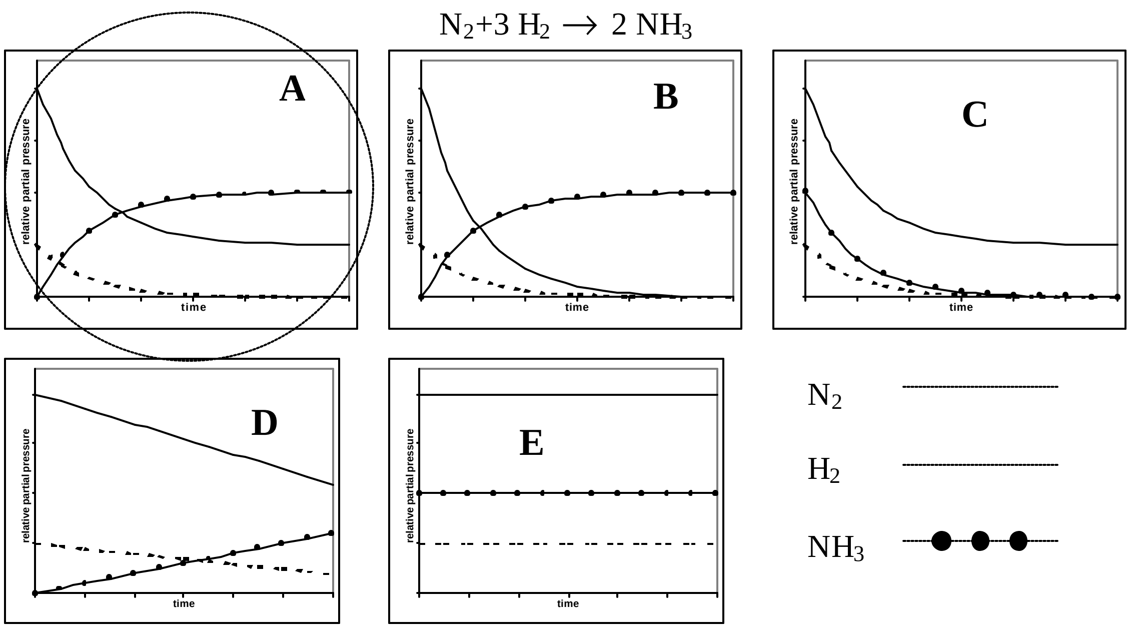
25.) In a calorimetry experiment a student determines the enthalpy for the reaction of magnesium with hydrochloric acid (shown below) to be -440 kJ/mol. The true enthalpy for this reaction is -450 kJ/mol. Which of the following errors would cause this falsely high (less negative) value for the enthalpy?

$$Mg + 2\,HCl \longrightarrow MgCl_2 + H_2$$

A) After recording the mass, some of the magnesium was dropped on the counter.
B) Some of the hydrogen gas escaped during the reaction.
C) The calorimeter was not tightly shut for the experiment.
D) The final temperature was recorded before the reaction was complete.
E) All of these errors would cause a falsely high value for the enthalpy.

26.) One mole of N_2 and four moles of H_2 are added to a closed container. Which of the following graphs best describes the progress of the following reaction with time?

$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$



Name________________________
TA __________________________

Use the following reaction for the next three questions:

$$2\ SO_2\ (g) + O_2\ (g) \rightleftarrows 2\ SO_3\ (g)$$

27.) What is the reaction quotient for the reaction?

A) $(P_{SO_3})/(P_{SO_2} \cdot P_{O_2})$
B) $(P_{SO_3}{}^2)/(P_{SO_2} \cdot P_{O_2})$
C) $(P_{SO_2}{}^2 \cdot P_{O_2})/(P_{SO_3}{}^2)$
D) $(P_{SO_3}{}^2)/(P_{SO_2}{}^2)$
E) $\boxed{(P_{SO_3}{}^2)/(P_{SO_2}{}^2 \cdot P_{O_2})}$

28.) Assuming that K increases with increasing temperature, which of the following statements is true?

A) The reaction is exothermic
B) $\boxed{\text{The reaction is endothermic}}$
C) The reaction favors the formation of products at all temperatures.
D) The reaction favors the formation of reactants at all temperatures.
E) The formation of products is entropically favored.

29.) At equilibrium 1 mol of argon (Ar) gas is pumped into the container; which of the following statements about the contents of the flask is true?

A) Heat will be absorbed.
B) The amount of SO_3 in the reaction vessel will increase.
C) The amount of SO_3 in the reaction vessel will decrease.
D) Heat will be released.
E) $\boxed{\text{None of these.}}$

Consider the following reactions for the next two questions:

$C(s) + \frac{1}{2} O_2\ (g) \rightleftarrows CO(g)$	$\Delta H^o = -110.5$ kJ	$K_1 = 1.057$
$CO(g) + \frac{1}{2} O_2\ (g) \rightleftarrows CO_2\ (g)$	$\Delta H^o = -283.0$ kJ	$K_2 =$ ________
$C(s) + O_2\ (g) \rightleftarrows CO_2\ (g)$	$\Delta H^o =$ ______kJ	$K_3 = 1.173$

30.) What is ΔH^o for the overall reaction?

A) 393.5 kJ $\boxed{\text{B) –393.5 kJ}}$ C) 172.5 kJ   D) –172.5 kJ   E) 0 kJ

31.) What is the value of K_2?

$\boxed{\text{A) 1.110}}$ B) 7.240   C) 0.776   D) 2.230   E) 0.901

Name________________________
TA ___________________________

Consider the reaction shown below for the following three questions:

$$HInd \rightleftharpoons H^+ + Ind^-$$

32.) Starting at equilibrium in water, the addition of HCl to the reaction vessel will result in which of the following?

A) Increase in the concentration of Ind^-
B) Increase in the concentration of HInd
C) Decrease in the concentration of H^+
D) Decrease in the concentration of Cl^-
E) No change will occur

33.) Starting at equilibrium in water, upon the addition of NH_3 the solution changes from yellow to blue. Which of the following statements can be concluded from this observation?

A) HInd is blue
B) HInd is yellow
C) NH_3 is blue
D) NH_3 is yellow
E) A contaminant must be present in the flask

34.) What can be said about the value of K for the HInd $\rightleftharpoons$ Ind^- + H^+ equilibrium reaction based on the observation made in the last question?

A) K>1   B) K<1   C) Q<K   D) Q>K   E) K=1

35.) Which of the following will result in a change in the solubility of silver chloride for the endothermic reaction shown below?

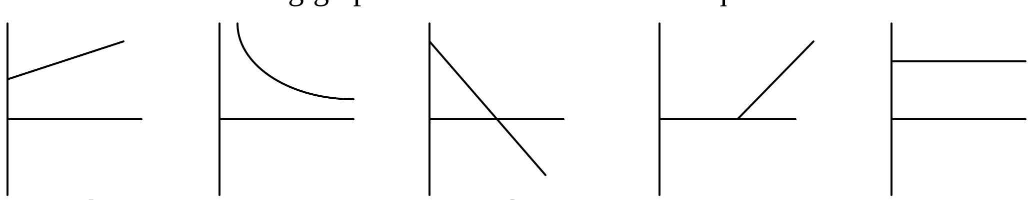
$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$$

A) Addition of NaCl
B) Heating the reaction vessel
C) Addition of AgCl
D) A & B but not C
E) A, B, & C

36.) Which of the following is true for any isothermal expansion of an ideal gas?

A) w = 0   B) w > 0   C) q = 0   D) ?E < 0   E) q > 0

Choose from the following graphs to answer the next four questions.



A   **B**   **C**   **D**   **E**

Name________________________
TA __________________________

37.) Which of the graphs is a plot of ln K vs. 1/T for an endothermic reaction where the change in entropy is positive? **C**

38.) Which of the graphs is a plot of pressure vs. volume for a real gas above its critical temperature? **B**

39.) Which of the graphs is a plot of kinetic energy vs. frequency of incident light for photoelectrons ejected from a metal? **D**

40.) Which of the graphs is a plot of the equilibrium constant vs. initial concentrations of reactants for a chemical reaction of the form A + B $\rightarrow$ C? **E**

Name________________________
TA ___________________________

Part 2: Short Answer Problems (140 pts total)
Instructions: Enter answers in the boxes where provided. Show all work for which you wish to receive credit.

For the following questions consider the two forms of the hydrogen cyanide molecule.

	H — C ≡ N:			:C ≡ N — H		
Formal Charge:	**0**	**0**	**0**	**-1**	**+1**	**0**

1.) Fill in the boxes for the formal charge of each atom in both forms.

2.) Which of the following would be the best classification for the pair of structures. (Circle your answer.)

A) Resonance structures B) Structural isomers C) Stereo isomers

D) Mirror images E) None of these

Consider the interconversion of the two forms for the next three questions.

$$HCN_{(g)} \rightleftharpoons HNC_{(g)}$$

3.) What is the size of the equilibrium constant? (Circle your answer.) Explain your reasoning in the box provided.

A) K = 1 B) K = 0 C) K > 1 D) K < 1 E) none of these

Explanation:

based on formal charge, HCN is more stable than HNC
equilibrium favors reactants so K<1

Calculate the approximate enthalpy for the forward interconversion reaction in kJ/mol. Put your final answer in the box provided.

H-C=N $\rightleftharpoons$ H-N=C evaluate the problem based on bond enthalpy

bonds broken: H-C and C=N bonds formed: H-N and C=N

net difference is between the strength of H-C (412 kJ/mol) and H-N(388 kJ/mol)

broken – formed = 412 – 388 kJ/mol = + 24 kJ/mol

Enthalpy: **+ 24 kJ/mol**

Name________________________
TA __________________________

4.) What value would you expect for the entropy of the interconversion? (Circle your answer.) Explain your answer.

A) ?S = 1 B) ?S ~ 0 C) ?S < 0 D) ?S > 0 E) None of these.

Explanation:
since both molecules are very similar in structure and both are in the gas phase, there should be no net change in entropy

5.) Write the reaction and an expression for K_a when HCN is added to water.

Reaction:

$$HCN + H_2O \leftrightarrows H_3O^+ + CN^-$$

K_a:

$$K_a = \frac{[H_3O^+][CN^-]}{[HCN]}$$

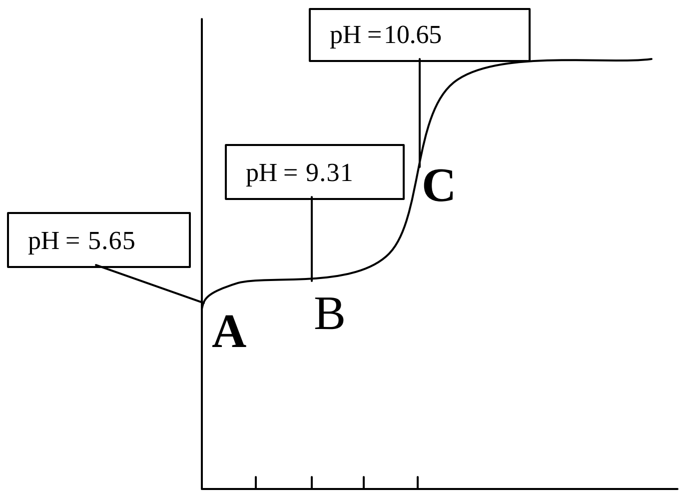
6.) The pK_a for HCN is 9.31. Is the acid-base reaction in the previous question spontaneous? Explain.

Yes No

Explanation:
The higher the pKa the weaker the acid. HCN must be very weak so the equilibrium should favor products. K<1 so the reaction is not spontaneous.

Name________________________
TA __________________________

7.) Fill in the boxes on the diagram for the titration of 0.01 M HCN with 1.0 M strong base (ignore volume changes due to the added base). Show all work.



Point A- just weak acid in water before the titration begins

$$HCN + H_2O \rightleftarrows H_3O^+ + CN^-$$ pKa = 9.31 so Ka=4.9×10^{-10}

At equilibrium 0.01M-x +x +x

$$K_a = \frac{[H_3O^+][CN^-]}{[HCN]} = \frac{x^2}{0.01-x} = \frac{x^2}{0.01} = 4.9\times10^{-10}$$ x is negligible when K is small

x = $[H_3O^+]$ = 2.2×10^{-6} pH = -log$[H_3O^+]$ so $\boxed{\text{pH = 5.65}}$

Point B- in the buffer region at half equivalence point, half of the acid has been converted to its conjugate base, use the Henderson-Hasselbach to calculate pH of buffer solutions

$$\text{pH} = \text{pKa} + \log\frac{[\text{CN}^-]}{[\text{HCN}]}$$ Since [HCN] = [CN-] log term equals zero $\boxed{\text{pH=pKa= 9.31}}$

Point C – equivalence point of titration, all of the HCN has been converted to CN^- but CN- is a weak base so it reacts with water to from OH^- ions.

$$CN^- + H_2O \rightleftarrows OH^- + HCN$$ Ka×Kb=Kw Kb=2.0×10^{-5}

At equilibrium 0.01M-x +x +x

$$K_b = \frac{[HCN][OH^-]}{[CN^-]} = \frac{x^2}{0.01-x} = \frac{x^2}{0.01} = 2.0\times10^{-5}$$ x is negligible when K is small

x = $[OH^-]$ = 4.5×10^{-4} pOH = -log$[OH^-]$ so pOH = 3.35 pOH+pH=14 $\boxed{\text{pH = 10.65}}$

Name________________________
TA __________________________

Over what pH range would HCN act as a buffer?

A) 3.7-5.7 B) 10.3-12.3 C) 6.4-8.3 D) 5.7-7.7 E) 8.3-10.3

8.) Assuming all species are stable in solution, would you expect the pK_a for HNC to be greater, less than or equal to HCN? Explain.

Greater than Less than Equal to

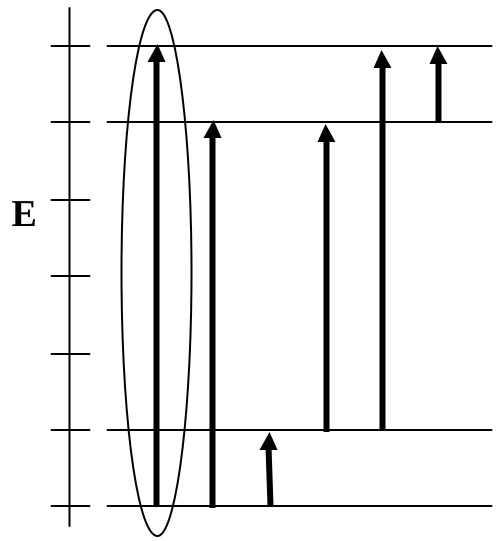
Explanation:

H-N bond is weaker than H-C bond so HNC is a stronger acid than HCN and would have a lower pKa

Name________________________

TA ___________________________

9.) Draw arrows indicating all of the possible transitions that occur upon absorption of a photon for an atom with the energy levels shown.



10.) Which of these transitions corresponds to absorption of a photon of the shortest wavelength? (Put a circle around the arrow of the transition.)

Shortest wavelength will be highest energy

11.) Which of the following is the best depiction of the spectrum obtained for this atom? (Circle your answer.)