Part 1: Multiple Choice.
(5 pts each, 145 pts total)

Instructions: Bubble in the correct answer on your Scantron™ form AND circle the answer on your exam. Each question has one correct answer.

1.) The answer to question 1 is **A**. Bubble in **A** on your Scantron™ form.

2.) Hydrogen has two stable isotopes, ^{1}H and ^{2}H, and nitrogen has two stable isotopes, ^{14}N and ^{15}N. Which isotopic species of ammonia will give a peak at mass 19 in a mass spectrometer?

A.) $^{14}N^{1}H_2{}^{2}H$ B.) $^{14}N^{2}H_3$ **C.) $^{14}N^{1}H^{2}H_2$** D.) $^{15}N^{1}H^{2}H_2$ E.) $^{15}N^{1}H_3$

3.) An oxide of titanium contains 40% oxygen by weight. What is the empirical formula of titanium oxide?

A.) TiO B.) Ti_2O_3 C.) Ti_3O_2 D.) Ti_2O **E.) TiO_2**

4.) The vapor pressure of tungsten at 2500 °C is 7.0×10^{-9} atm. What is the number of gaseous tungsten atoms in a light bulb of volume 0.20 L operating at 2500 °C?

A.) 1.9×10^{10} **B.) 3.7×10^{12}** C.) 4.11×10^{12} D.) 5.4×10^{21} E.) 1.2×10^{23}

5.) For O_2 molecules at 100 K, v_{rms} = 8.8 m/sec. At what temperature does v_{rms} = 4.4 m/sec?

A.) 25 K B.) 50 K C.) 71 K D.) 141 K E.) 400 K

6.) HA_1 and HA_2 are two weak acids with dissociation constants K_{A_1} and K_{A_2}, respectively. If the equilibrium constant for the reaction,

$$HA_1 + A_2^- \rightleftharpoons HA_2 + A_1^-$$

is K > 1, which of the following must be true?

A.) $K_{A_1} = K_{A_2}$ **B.) $K_{A_1} > K_{A_2}$** C.) $K_{A_1} < K_{A_2}$

D.) $K_{A_1} / K_{A_2} = K_w$ E.) $K_{A_1} \times K_{A_2} = K_w$

7.) A solution of NaOH with pH = 10.00 is diluted with H_2O by a factor of 10. The resulting pH is:

A.) 1.00 **B.) 9.00** C.) 9.43 D.) 10.57 E.) 11.00

 Name: _____

8.) A solution of NH_3 with pH=10.00 is diluted with H_2O by a factor of 10. The resulting pH is:

A.) 1.00 B.) 9.00 **C.) 9.43** D.) 10.57 E.) 11.00

9.) Which compound could be added to the solution of sodium acetate (CH_3COONa) in order to make an acidic buffer?

A.) HCl B.) NaOH C.) H_2O D.) NaCl E.) NH_3

10.) A 0.1 M solution of which of the following species has the highest pressure of that species above the solution?

A.) He B.) N_2 C.) O_2 D.) CO_2 E.) NH_3

11.) Which of the following has the smallest atomic or ionic radius?

A.) S^{2-} B.) Cl^- C.) Ar D.) K^+ **E.) Ca^{2+}**

12.) Which of the following has the highest ionization energy?

A.) S B.) Cl **C.) Ar** D.) K E.) Ca

13.) Which of the following ground state atoms or ions is *not paramagnetic*?

A.) F **B.) O^{2-}** C.) Rb D.) Al E.) S^-

14.) Which atom or ion can have the following electron configuration $1s^2 2s^2 2p^6 3s^2 3p^5 4s^1$?

A.) Ar B.) K C.) Ca^+ D.) Ti^{2+} E.) Zn

15.) In which of the following orbitals is the electron probability density spherically symmetric, i.e. independent of the angles φ and θ?

A.) 9s B.) 8p C.) 7d D.) 6f E.) 5g

 Name: _____

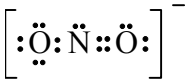
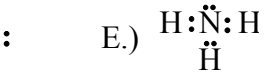
16.) For a neutral hydrogen atom, the radiation absorbed in the transition from n = 2 to n = 3 corresponds to a wavelength of 657 nm. What would be the wavelength of radiation absorbed in the transition from n =1 to n = 3?

A.) 103 nm B.) 657 nm C.) 1051 nm D.) 1314 nm E.) 4205 nm

17.) Which of the following has the lowest ionization energy?

A.) $He^+ 1s^1$ B.) $He^+ 4s^1$ C.) $He^+ 2s^1$ D.) $He\ 1s^1\ 2p^1$ **E.) $He\ 1s^1\ 4p^1$**

18.) Which one of the following is an *incorrect* Lewis electron dot structure?

A.) B.)  **C.)**  D.) E.) 

19.) What is the H–C–H angle in CH_3^+?

A.) 60° B.) 90° C.) 109.5° **D.) 120°** E.) 180°

20.) Which molecule *does not* have an electric dipole moment?

A.) $CHCl_3$ B.) CH_2Cl_2 C.) CH_3Cl D.) CO **E.) CS_2**

21.) For a certain metal, orange light does not eject electrons, but yellow light does. Light of which range will eject electrons from the same metal with the lowest kinetic energy?

A.) infrared B.) red **C.) green** D.) blue E.) ultraviolet

22.) One mole of an ideal gas is compressed *isothermally*. Which of the following inequalities is true?

A.) $\Delta P < 0$ B.) $q > 0$ **C.) $\Delta S < 0$** D.) $\Delta V > 0$ E.) $\Delta T < 0$

23.) Which is true for the following spontaneous reaction?

$$CH_3OH\ (l) + 3/2\ O_2\ (g) \longrightarrow CO_2\ (g) + 2\ H_2O\ (l)$$

A.) $\Delta H° > 0$ B.) $\Delta H° = 0$ **C.) $\Delta H° < 0$** D.) $\Delta S° > 0$ E.) $\Delta G° > 0$

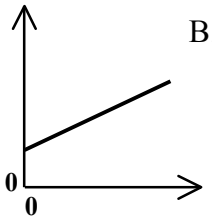
24.) Given that $E_{O=O} > 2\ E_{O-O}$ where the E's refer to bond energies, which is true for the conversion of ozone to oxygen?

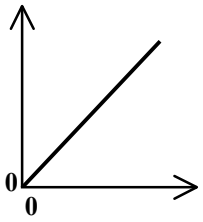
$$2\ O_3 \longrightarrow 3\ O_2$$

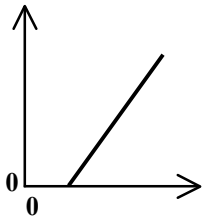
A.) $\Delta H° > 0$ B.) $\Delta H° = 0$ **C.) $\Delta H° < 0$** D.) $\Delta S° < 0$ E.) $\Delta G° > 0$

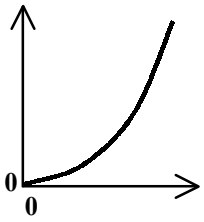
 Name: _____

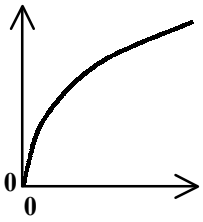
For each of the problems **25-30**, select the graph that best describes the behavior listed.

A.) 

B.) 

C.) 

D.) 

E.) 

25.) Solubility of $Mg(OH)_2$ as a function of $[H_3O^+]$.

A.) A B.) B C.) C **D.) D** E.) E

26.) PV as a function of T (°C) for an ideal gas.

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

27.) ln(K) as a function of 1/T for the combustion of C (s) to CO (g).

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

28.) The kinetic energy of an ideal gas (E_{kin}) as a function of T (K).

A.) A **B.) B** C.) C D.) D E.) E

29.) The kinetic energy of photoelectrons (E_{kin}) as a function of $1/\lambda$ where λ is the wavelength of the light impinging on Cs metal.

A.) A B.) B **C.) C** D.) D E.) E

30.) The solubility of O_2 (g) in H_2O (l) as a function of P_{O_2} at low pressure.

A.) A **B.) B** C.) C D.) D E.) E

 Name: _____

Part 2: Short Answer Problems (205 pts total)
Instructions: Enter answers in the boxes provided. Show your work. Explain your answer when requested in 15 words or less.

(10 pts)
1.) Hypochlorous acid, HClO, can be formed from the following chemical reaction. Balance the chemical reaction.

$$\mathbf{2}\ Cl_2 + \mathbf{1}\ O_2 + \mathbf{2}\ H_2O \rightarrow \mathbf{4}\ HClO$$

If 4 moles Cl_2, 2 moles O_2, and 1 mole H_2O are mixed and the reaction proceeds until one or more of the reactants is completely consumed, how many moles of hypochlorous acid will be produced?

Answer:

2 moles

(15 pts)
2.) A 10.0 L bulb is maintained at 30.0 °C. After evacuating, 1.00 g H_2O (g) is injected into the bulb.

a) If the water vapor acts like an ideal gas, what is the pressure inside the bulb?

$P V = n R T$,
$P = n R T / V = 0.138$ atm

Answer:

0.138 atm

b) Given the vapor pressure of H_2O at 30.0 °C is 0.0418 atm. Compare this value to your answer in part a). Describe what happens in the bulb. (Use 15 words or less.)

$0.0418 < 0.138$

Answer:
0.0418 atm < 0.138 atm.
Q > K for $H_2O(l) \rightarrow H_2O(g)$, so the water vapor consenses.

 Name: _____

(16 pts)

3.) Draw the Lewis electron dot structure and sketch the molecular geometry of PCl_3 and IF_2^-.

PCl_3 IF_2^-

Lewis electron dot structure | Molecular geometry | Lewis electron dot structure | Molecular geometry

(14 pts)

4.) Given:

$2\ C_2H_2\ (g) + 5\ O_2\ (g) \longrightarrow 4\ CO_2\ (g) + 2\ H_2O\ (l)$ $\Delta H = -2602$ kJ

$2\ C_2H_6\ (g) + 7\ O_2\ (g) \longrightarrow 4\ CO_2\ (g) + 6\ H_2O\ (l)$ $\Delta H = -3123$ kJ

$H_2\ (g) + 1/2\ O_2\ (g) \longrightarrow H_2O\ (l)$ $\Delta H = -286$ kJ

What is the ΔH for the following reaction at 25 °C and 1 atm?

$$C_2H_2\ (g) + 2\ H_2\ (g) \longrightarrow C_2H_6\ (g)$$

Answer:

–311.5 kJ

(12 pts)

5.) 1000 mL of an ideal gas is compressed to 500 mL under a constant external pressure of 10 atm. During the compression, 500 J of heat flowed from the gas to the surroundings. What are q and w for the process, and ΔE for the gas?

q =

–500 J

w =

507 J

ΔE =

7 J

 Name: _____

(20 pts)

6.) What is the pH of each of the following solutions?

a) 0.10 M acetic acid (CH_3COOH)

Answer: **2.88**

b) 0.10 M sodium acetate (CH_3COONa)

Answer: **8.88**

c) A mixture prepared by adding 500 mL of solution (a) to 500 mL of solution (c).

Answer: **4.75**

(10 pts)

7.) Arrange the solutions in order of increasing pH. Place the appropriate letters in the boxes. (no pH calculations are needed)

A.) 0.2 M NaCl B.) 0.2 M CH_3COONa C.) 0.2 M NH_4Cl D.) 0.2 M HCl E.) 0.2 M NaOH

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

 Name: _____

(12 pts)

8.) 500 mL of a 2.0×10^{-3} M $AgNO_3$ solution are added to 500 mL of a 2.0×10^{-5} M NaCl solution. Determine whether or not a precipitate will form? Justify your answer.

$K_{sp} = 1.8 \times 10^{-10}$

$Q = [Ag^+][Cl^-] = (1.0 \times 10^{-3}\ M)(1.0 \times 10^{-5}\ M) = 1 \times 10^{-8}$

Q > K, therefore a precipitate will form.

Answer:

Yes, a precipitate will form.

(14 pts)

9.) The extinction coefficient (ε) with units of cm^2/g equals the absorbance (A) for a 1 g/mL solution for a path length (P) of 1.00 cm.

a) If an ethanol blank gives an intensity (I) of 2.0 μA at 400 nm and a 1 g/mL sample of Z dissolved in ethanol gives an intensity of 1.5 μA, what is the extinction coefficient for Z at 400 nm?

$A = -\log(I_o/I)$

Answer:

0.125 cm^2/g

b) The absorbance of a solution containing Z dissolved in ethanol is determined to be 0.40. What is the concentration of Z in the solution?

$A = \varepsilon\ \ell\ c$

Answer:

3.2 g/mL

 Name: _____

(14 pts)

10.) An air sample obtained on top of a mountain has a density of 1.00 g/L at 0.80 atm and 280 K. Calculate the mole fractions of oxygen and nitrogen in the air sample, assuming only nitrogen and oxygen are present and the gases are ideal under these conditions.

Answer:
0.82 N_2
0.18 O_2

(20 pts)

11.) Consider the following reaction:

$$PbO_2\,(s) \rightleftharpoons Pb(s) + O_2\,(g)$$

a) Calculate $\Delta G°$ for the reaction.

$\Delta G^o = \Delta H^o - T\Delta S^o$

Answer:
217 kJ/mole

b) Calculate the equilibrium constant for this reaction at 25 °C.

$\Delta G^o = -R\ T\ \ln K$

$K = e^{-\Delta G^o/RT} = 1.33 \times 10^{-39}$

Answer:
10^{-39}

c) Circle the temperature(s) at which the reaction is spontaneous at standard pressures and concentrations. Place an 'X' over (cross out) the temperature(s) at which the reaction is *not* spontaneous. Show your work.

$\Delta G = 0$
$\Delta H = T\Delta S$

$\Delta H / \Delta S = T$

~~500 K~~ ~~1000 K~~

 Name: _____

(14 pts)

12.) Using average bond energies, estimate the change in enthalpy, ΔH, of the following (unbalanced) reaction.

$$CO\,(g) + O_2\,(g) \longrightarrow CO_2\,(g)$$

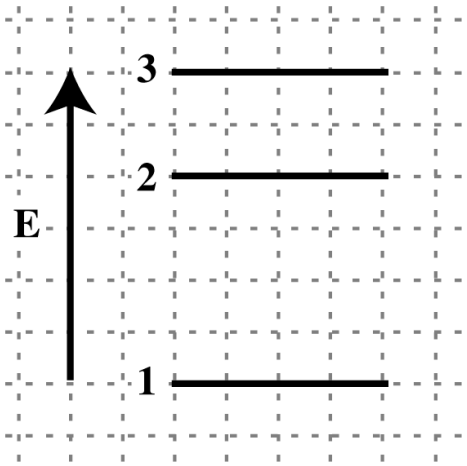
$\Delta H_{rxn} = \Sigma H_{bonds\ broken} - \Sigma H_{bonds\ formed}$

Answer:

–323 kJ/mole O_2

(14 pts)

13.) The emission from level 3 to level 2 corresponds to a photon wavelength of 800 nm; this line is indicated on the spectrum below. Sketch and label with appropriate wavelengths and transitions the remaining line(s) on the spectrum.

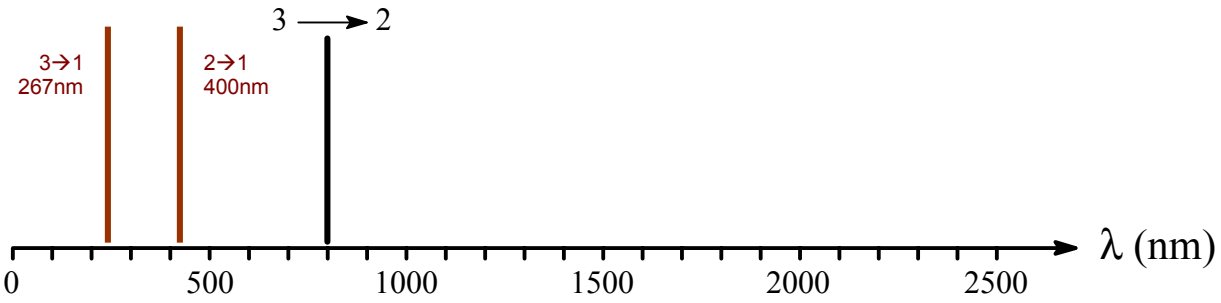


$E_{3\rightarrow 2} = hc/800nm$

$E_{2\rightarrow 1} = 2E_{3\rightarrow 2} = 2\ hc/800nm = hc/400nm$

$E_{3\rightarrow 1} = E_{2\rightarrow 1} + E_{3\rightarrow 1}$
$= (hc/800nm) + (hc/400nm)$
$= 3\ hc/800nm = hc/267\ nm$

Spectrum

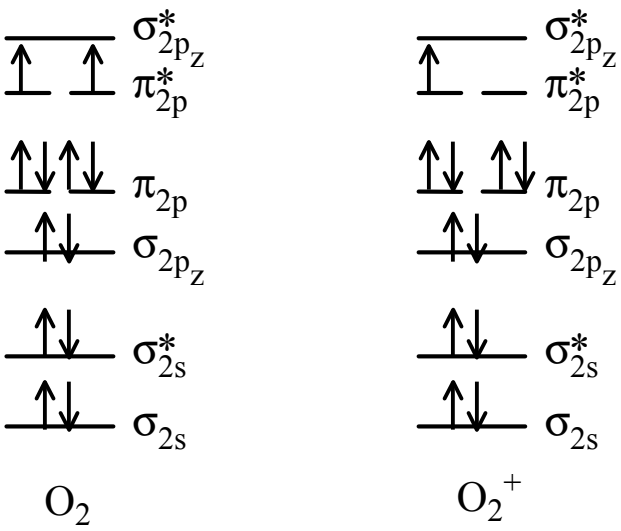


 Name: _____

(20 pts)

14.) Consider the molecule O_2 and the molecular ion O_2^+ in their respective ground states.

a) Fill in the electrons for the molecular orbital diagrams for O_2 and O_2^+.



b) Determine the bond orders for O_2 and O_2^+.

O_2:	O_2^+:
2	**2½**

c) Upon the ionization of O_2, how does the bond strength change? Circle the correct response.

decreases does not change **increases**

d) Upon the ionization of O_2, how does the paramagnetism change? Circle the correct response.

decreases does not change increases