 Name: _____

Section 1: Multiple Choice. 20 questions, 6 points each.

Instructions: For the following questions, circle the answer on the exam sheet **and** bubble in the correct answer on your Scantron sheet. **Unless you are specifically told that there might be more than one answer to a problem, assume that only one answer is correct. No credit will be awarded for partially-correct answers.**

1.) You are taking test version **A**. Please fill in bubble "**A**" on your Scantron sheet.

2.) Which of the following compounds exhibit a dipole moment? **Mark all that apply.**

A) CO_2 **B)** CO **C)** SF_6 **D)** CH_4 **E)** N_2

3.) At 300 K, argon atoms travel with an rms speed of 433 $m \cdot s^{-1}$. Which of the following gases has one-half the rms speed of argon at 300 K?

A) O_2 **B)** C_6H_8 **C)** N_2 **D)** Br_2 **E)** Ne

4.) 1.0 mole of sodium hydrosulfide, NaHS, (HS^- is the conjugate base of the weak acid H_2S, whose pK_a is 6.9) is dissolved in 1.0 L of water. HCl is then added until the pH is 6.4. Which of the following has the highest concentration?

A) H_3O^+ **B)** OH^- **C)** H_2S **D)** H_2 **E)** HS^-

5.) Which of the following species will oxidize Co, but not Br^- under standard conditions?

A) $Cl_2(g)$ **B)** Ag(s) **C)** Pb^{2+} **D)** Li^+ **E)** None of these.

6.) How many moles of Na_2SO_4 can be added to 1.0 L of an aqueous 0.10 M $Ca(NO_3)_2$ solution before a precipitate forms? Assume that Na_2SO_4 and $Ca(NO_3)_2$ dissociate completely in water. The K_{sp} for $CaSO_4$ is 2.4×10^{-5}.

A) 2.4×10^{-6} **B)** 2.4×10^{-5} **C)** 2.4×10^{-4} **D)** 4.8×10^{-4} **E)** 4.9×10^{-3}

7.) Which of the following can have the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^4$?

A) Ga^{3+} **B)** Te **C)** As^- **D)** Br **E)** None of these.

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

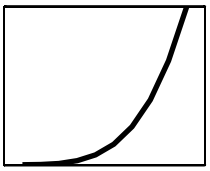
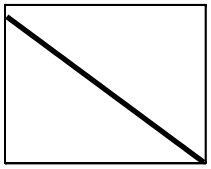
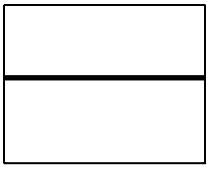
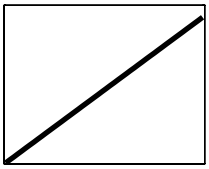
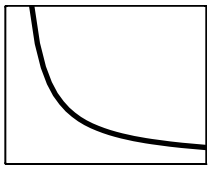
A) F **B)** F^- **C)** Ne **D)** Na **E)** Na^+

9.) How many ***atoms*** are there in 36 g of pure water?

A) 3.0×10^{25} **B)** 3.6×10^{24} **C)** 1.8×10^{24} **D)** 1.2×10^{24} **E)** 6.0×10^{23}

 Name: _____

10-13. In the next four problems, choose which of the following five graphs best describes the behaviors listed below.

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

10.) $[H_3O^+]$ as a function of NaOH(s) added to water.

11.) PV as a function of P for an ideal gas at 25 °C.

12.) The de Broglie wavelength, λ, as a function of speed for a sodium atom.

13.) lnK as a function of 1/T for an endothermic reaction.

14.) The work function, Φ, for chromium is 7.2×10^{-19} J. A photon of which energy (hν) will eject an electron with the lowest electron kinetic energy?

A) 2.0×10^{-19} J **B)** 5.3×10^{-19} J **C)** 1.3×10^{-18} J

D) 2.7×10^{-18} J **E)** 6.6×10^{-18} J

15.) A compound comprised of only oxygen and carbon is found to contain 27.29% carbon by mass. What is the empirical formula for the compound?

A) CO **B)** CO_2 **C)** C_2O_3 **D)** C_2O_2 **E)** $C_{27}O_{73}$

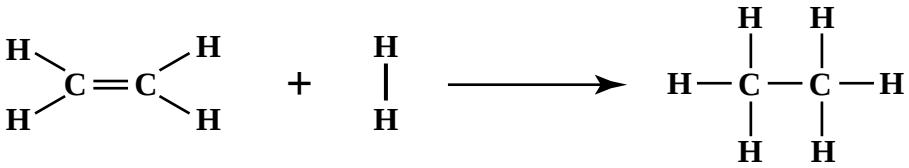
16.) 

Which of the following energy level diagrams could give rise to the emission spectrum pictured to the left?

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

 Name: _____

17.) Using bond enthalpies, estimate $\Delta H°$ for the following reaction (in $kJ \bullet mol^{-1}$).



A) -550 **B)** -350 **C)** -100 **D)** 350 **E)** 550

18.) A gaseous mixture of $NO_2(g)$ and $N_2O_4(g)$ is in equilibrium:

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$$

If the volume is suddenly doubled without changing the temperature, which of the following will be true once the system regains equilibrium (compared to the original system before the volume was changed)?

A) The total pressure will be higher.
B) The partial pressure of $N_2O_4(g)$ will be higher.
C) The mole fraction of $NO_2(g)$ will be higher.
D) The equilibrium constant, K, will be lower.
E) The equilibrium constant, K, will be higher.

19.) Which of the following reactions/processes has a negative $\Delta S°$?

A) $LiCl(s)$ -----> $Li^+(aq) + Cl^-(aq)$
B) $H_2O(\lambda)$ -----> $H_2O(g)$
C) $2\ MgO(s) + C(s)$ -----> $CO_2(g) + 2\ Mg(s)$
D) $BF_2Cl(g) + BCl_2F(g)$ -----> $BCl_3(g) + BF_3(g)$
E) $PCl_5(g)$ -----> $PCl_3(g) + Cl_2(g)$

20.) A 50 g iron block (specific heat = 0.449 $J \bullet g^{-1} \bullet K^{-1}$) is heated to 100 °C and placed in a calorimeter containing 50 mL of water (specific heat = 4.18 $J \bullet g^{-1} \bullet K^{-1}$) initially at 0 °C. After several minutes, the final temperature of the water will be approximately:

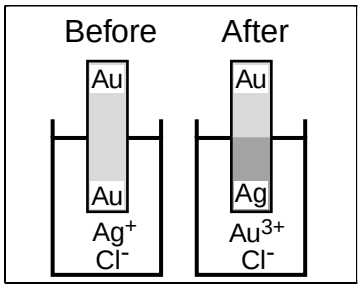
A) Below 0 °C.
B) Between 0 °C and 40 °C.
C) Around 50 °C.
D) Between 60 °C and 100 °C.
E) Above 100 °C.

 Name: _____

Section 2: *What's Wrong*. 8 questions, 10 points each.

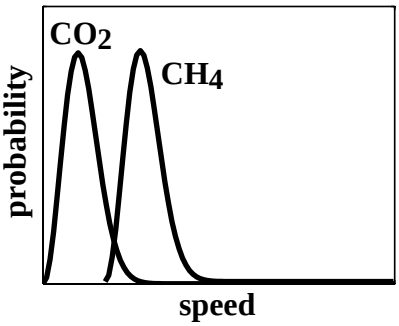
For this section, in no more than twenty words per response, **explain** what is wrong with the following pictures. **Note: only the first 20 words of each answer will be read!**

1.) For the plating of silver onto a gold plate:



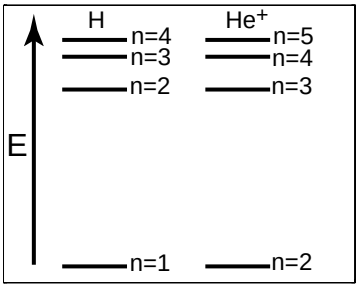
Answer:

2.) For two ideal gases at 25 °C:



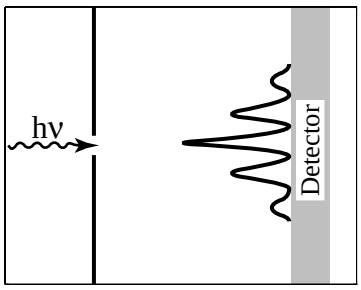
Answer:

3.) Energy level diagrams for the one electron species H and He^+, where $E_n = -\frac{Z^2}{n^2}R_y$:



Answer:

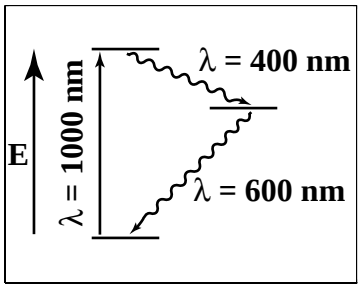
4.) For the diffraction of light through a slit:



Answer:

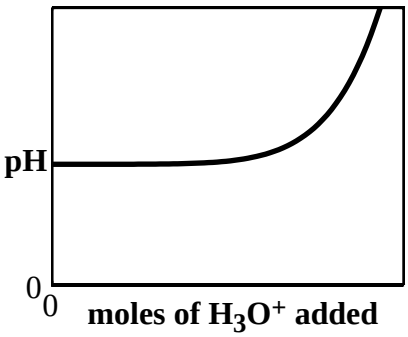
 Name: _____

5.) An energy level diagram for absorption and emission:



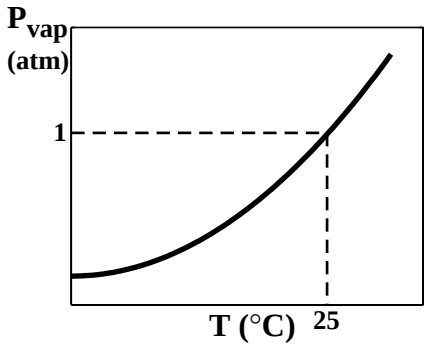
Answer:

6.) For the addition of 0.1 M HCl to a solution in which initially [HA] = [A^-]:



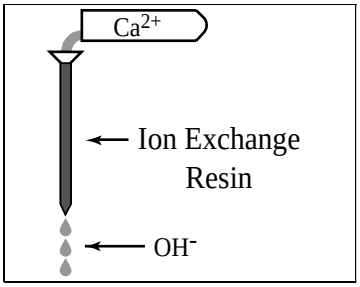
Answer:

7.) For the vapor pressure of water:



Answer:

8.) An ion exchange column with Ca^{2+} ions exchanging with OH^- ions:



Answer:

 Name: _____

Section 3: Short Answer. 10 questions, 20 points each.

Answer the following ten short answer questions. Partial credit will be given, so show your work whenever possible. Your final answers **must** be written in the boxes provided.

1.) Consider an ideal gas at a volume of 1 L and a pressure of 1 atm. The gas is expanded **adiabatically** and **irreversibly** against a constant external pressure of 0.1 atm until it reaches a volume of 2 L.

For each quantity below, indicate (by checking the box) whether it is =0, >0, or <0 for the overall adiabatic and irreversible expansion.

Quantity	= 0	> 0	< 0
ΔP_{sys}			
ΔV_{sys}			
ΔT_{sys}			
w			
q			
ΔE_{sys}			
ΔE_{surr}			
ΔS_{sys}			
ΔS_{surr}			
ΔS_{tot}			

2a.) Using the table on page 14, calculate $\Delta H°$ and $\Delta S°$ for the following reaction:

$$CO(g) + 2\,H_2(g) \rightleftharpoons CH_3OH(g)$$

$\Delta H°$=
$\Delta S°$=

b.) Is this reaction spontaneous under standard conditions at 25 °C? Circle your answer.

Yes **No**

c.) Assuming $\Delta H°$ and $\Delta S°$ are independent of temperature, at which temperature will this reaction be at equilibrium? Assume all the pressures are 1.0 atm.

Answer:

 Name: _____

3a.) Formic acid (HCOOH) has a $K_a=1.8x10^{-4}$, $pK_a=3.74$. If 0.050 moles of formic acid are dissolved in 1.0 L of water, what will the pH be?

pH=

b.) How many mL of 0.10 M NaOH should be added to the solution in **a)** in order to raise the pH to 3.74?

Answer:

c.) The solution in **a)** is titrated to the equivalence point with 500 mL of 0.10 M NaOH. This solution now has the same pH as which of the following. Circle your answer.

0.10 moles of $HCOO^-Na^+$ (sodium formate) in 3.0 L of water.

$1.0x10^{-5}$ moles of NaOH in 1.0 L of water.

0.050 moles of formic acid and 0.10 moles of NaOH in 1.5 L of water.

 Name: _____

4a.) Draw the Lewis electron dot structure for XeF_4. Include all the lone pairs.

Lewis Dot Structure:

b.) Which of the following best describes the geometry of the electron pairs (including bonds) around the central atom? Circle your answer.

Linear

Trigonal Planar

Tetrahedral

Trigonal Bipyramidal

Octahedral

c.) Name, describe, or draw the ***molecular*** geometry of the molecule.

Molecular Structure:

 Name: _____

5a.) Balance the following combustion equation:

_____ $C_3H_8(g)$ + _____ $O_2(g)$ --------> _____ $CO_2(g)$ + _____ $H_2O(g)$

b.) 1.0 atm of $C_3H_8(g)$ and 4.0 atm of $O_2(g)$ are sealed in a flask and ignited. How many **moles** of $O_2(g)$ remain once the reaction has gone to completion? Assume all the gases are ideal.

Answer:

c.) After the above reaction has run to completion, what is the total pressure in the flask?

Answer:

6.) An excited state of helium is created such that one electron is in the 1s orbital and one electron is in a 3p orbital.

a.) What is the ionization energy of the 3p electron in He(1s3p)?

IE=

b.) The first ionization energy for $He(1s^2)$ is found to be 2372 $kJ \cdot mol^{-1}$ (which is $1.8R_y$). What is the effective charge, Z_{eff}, for the ionization of a 1s electron?

Z_{eff}=

c.) Which one of the following is a possible ***excited state*** electronic configuration for lithium? Circle your answer.

$1s^2$ $1s^21p^1$ $1s^3$ $1s^22s^1$ $1s^23p^1$

 Name: _____

7a.) Write a balanced spontaneous ***net*** reaction in acidic solution based on the **unbalanced** and **incomplete** half-reactions below.

$$MnO_4^- + 5e^- \text{ --------> } Mn^{2+}$$

$$O_2(g) + 4e^- \text{ --------> } 2\ H_2O$$

Answer:

b.) Under standard conditions, what is $\Delta\varepsilon^\circ$ for this reaction?

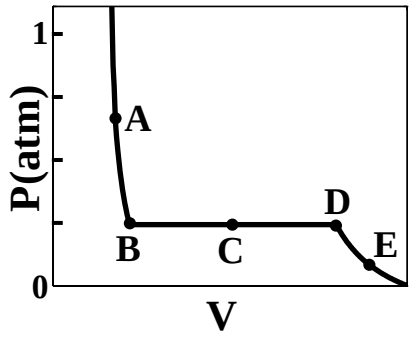
$\Delta\varepsilon^\circ =$

c.) What would happen to $\Delta\varepsilon$ if you lowered the pH of the solution? Limit yourself to 20 words or less.

Answer:

 Name: _____

8.) The graph pictured below is an isotherm for Br_2 at 25 °C.



For the following four questions, circle the point (or points) on the isotherm (A-E) which describes the statement given. **Circle all that apply**.

a.) **Only** gas is present. **A** **B** **C** **D** **E**

b.) **Only** liquid is present. **A** **B** **C** **D** **E**

c.) Gas and liquid are in equilibrium. **A** **B** **C** **D** **E**

d.) Point with the lowest compressibility. **A** **B** **C** **D** **E**

e.) What is the vapor pressure of $Br_2(\lambda)$ at 25 °C?

P_{vap}=

9.) At 25 °C, the equilibrium constant for the following reaction is 4.2×10^{-31}.

$$N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$$

K_p =

a.) Write the equilibrium expression for this reaction.

b.) NO(g) is placed in a vacuum at 25 °C and dissociates until it reaches its equilibrium partial pressure of 1.0×10^{-16} atm. What is the partial pressure of $N_2(g)$ at equilibrium?

P_{N_2}=

c.) If 1.0 atm of $N_2(g)$ is mixed with 1.0 atm of $O_2(g)$ at 25 °C, what will be the equilibrium partial pressure of NO(g) in equilibrium?

P_{NO}=

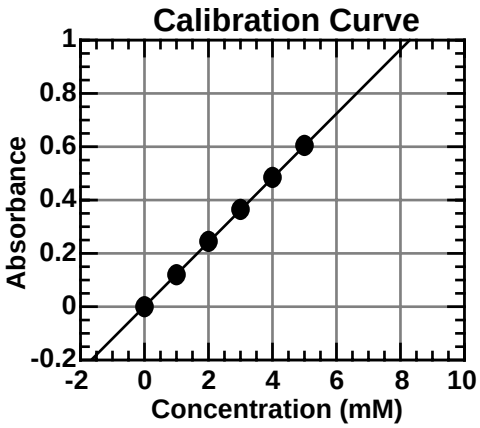
 Name: _____

10.) A student is doing an experiment to determine the amount of beta-carotene (a plant pigment) in a leaf using a UV-VIS spectrometer.

First she obtains some pure beta-carotene and makes several dilutions using distilled water to obtain five standard solutions with known concentrations.

Next the student determines that the absorption maximum for beta-carotene is at 455 nm. She then blanks the spectrometer using pure distilled water, and measures the absorbance of her five standard solutions at 455 nm, obtaining the following results:

Concentration	Absorbance
0.0000 M (blank)	0.000
0.0010 M	0.120
0.0020 M	0.243
0.0030 M	0.364
0.0040 M	0.484
0.0050 M	0.605



Next she extracts **all** the pigments from 0.25 g of a leaf using 95% ethanol, some $CaCO_3$, and sea sand; grinding the leaf with a mortar and pestle. She then filters all of the **green** solution into a 100 mL volumetric flask, rinsing the filtrate with 95% ethanol until it is colorless, and brings the total volume to 100 mL using 95% ethanol.

Then, using the spectrometer, the student determines the absorbance to be 0.918 at 544 nm. Using the equation of the regression line from her calibration curve, she determines the concentration of her solution to be 0.0076 M. This corresponds to 163% of the mass of the leaf being beta-carotene!

There are at least 4 mistakes that the student made in this experiment. Find **3** of them. **Hint:** she did not make any math errors. Limit you answers to 20 words or less.

Mistake #1:
Mistake #2:
Mistake #3:

 Name: _____

Standard Reduction Potentials

Half Reaction	ε° (V)	Half Reaction	ε° (V)
$MnO_4^- + 8\ H_3O^+ + 5e^- \text{ -----> } Mn^{2+} + 12\ H_2O$	1.49	$Ag^+ + e^- \text{ -----> } Ag(s)$	0.80
$Au^{3+} + 3e^- \text{ -----> } Au(s)$	1.42	$2\ H_3O^+ + 2e^- \text{ -----> } H_2(g) + H_2O$	0.00
$Cl_2(g) + 2e^- \text{ -----> } 2\ Cl^-$	1.36	$Pb^{2+} + 2e^- \text{ -----> } Pb(s)$	-0.13
$O_2(g) + 4\ H_3O^+ + 4e^- \text{ -----> } 6H_2O$	1.23	$Co^{2+} + 2e^- \text{ -----> } Co(s)$	-0.28
$Br_2(\lambda) + 2e^- \text{ -----> } 2\ Br^-$	1.07	$Li^+ + e^- \text{ -----> } Li(s)$	-3.05

Bond Enthalpies

Bond	ΔH° (kJ • mol-1)	Bond	ΔH° (kJ • mol-1)
C - H	400	C = C	600
C - C	350	H - H	450

Standard Thermodynamic Properties

Substance	ΔH° (kJ • mol-1)	S° (J • mol-1 • K-1)	ΔG° (kJ • mol-1)
$Br_2(g)$	31	245	3.14
$Br(\lambda)$	0	152	0
$CO(g)$	-110	198	-137
$CH_3OH(g)$	-200	240	-162
$H_2(g)$	0	130	0
$H(g)$	225	115	203

Possibly Useful Information

Absolute T(K) = T(°C) + 273.15

$N_0 = 6.022 \times 10^{23}$

$PV = nRT$

$R = 0.0821\ L \cdot atm \cdot mol^{-1} \cdot K^{-1}$

$R = 8.31\ J \cdot mol^{-1} \cdot K^{-1}$

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

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

$K_w = [H_3O^+][OH^-]$

$\Delta E = q + w$

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

$\Delta E_{tot} = \Delta E_{sys} + \Delta E_{surr}$

$\Delta S_{tot} = \Delta S_{sys} + \Delta S_{surr}$

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

$\Delta G° = -RT\ln K$

$\Delta S_{sys} = nR\ln\frac{V_2}{V_1}$

$\Delta S_{surr} = -\frac{q_{rev}}{T}$

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

$E = h\nu = \frac{hc}{\lambda}$

$mu = p = \frac{h}{\lambda}$

$E_n = -\frac{Z^2}{n^2}R_y$, $R_y = 1312\ kJ \cdot mol^{-1}$

$\Delta E = -Z^2\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)R_y$

$IE = \frac{Z_{eff}^2}{n^2}R_y$

$E_{kinetic} = \frac{mu^2}{2}$

$E_{electron} = E_{photon} - \Phi$