Name:____ **Score:**______**/100**

Part I. Multiple choice. Write the letter of the correct answer for each problem. 3 points each

1. Which of the following contains the greatest number of moles of O?
   A) 2.3 mol H_2O
   B) 1.2 mol H_2O_2
   C) 0.9 mol $NaNO_3$
   D) 0.5 mol $Ca(NO_3)_2$
   Answer ___D____

2. Argon gas is enclosed in a 10.2 L tank at 12.01 atm. Which of the following is a reasonable value for the pressure when the argon is transferred to a 30.0 L tank at constant temperature?
   A) 3.0 atm
   B) 4.0 atm
   C) 36.0 atm
   D) 120.0 atm
   Answer ___B____

3. Which intermolecular force is most significant in accounting for the high boiling point of water relative to other substances of similar molar mass?
   A) dispersion forces
   B) dipole-induced dipole interactions
   C) hydrogen bonding interactions
   D) ion-dipole interactions
   Answer ___C____

4. The fundamental law that energy cannot be created or destroyed is:
   A) The first law of thermodynamics
   B) The second law of thermodynamics
   C) The third law of thermodynamics
   D) The law of the jungle
   Answer ___A____

5. Which of the following pairs of substances is *least likely* to form a solution?
   A) An ionic compound in a nonpolar solvent
   B) An ionic compound in a polar solvent
   C) A nonpolar compound in a nonpolar solvent
   D) A polar compound in a polar solvent
   Answer ___A____

6. That energy goes spontaneously from more useful forms to less useful forms is a statement of the:
   A) first law of thermodynamics
   B) second law of thermodynamics
   C) third law of thermodynamics
   D) standard law of energy conversion
   Answer ___B____

7. According to the kinetic-molecular theory of gases, in collisions between gas particles, the total energy
   A) decreases slightly.
   B) decreases considerably.
   C) increases slightly.
   D) remains the same.
   Answer ___D____

8. One 1.00L flask (flask A) contains CO gas and another 1.00 L flask (flask B) contains CO_2 gas. If both flasks are at the same temperature and pressure, flask A contains
   A) less mass and fewer molecules than flask B.
   B) less mass but the same number of molecules than flask B.
   C) more mass but the same number of molecules than flask B.
   D) more mass and more molecules than flask B.
   Answer ___B____

9. Molecules are farthest apart in a(n)

A) ionic solid
B) liquid
C) covalent solid
D) gas

Answer ___D____

10. Consider the reaction below. How many moles of CO_2 are produced if 75 moles of O_2 react?

$$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$$

A) 50
B) 100
C) 48
D) 32

Answer ___C____

11. Which of the following is likely to require the greatest input of energy to melt, therefore having the highest melting point?

A) $C_6H_{12}O_6$
B) N_2O
C) NaCl
D) Ar

Answer ___C____

12. Of CH_3OH, H_2, HF, and H_2O, which molecule(s) can participate in hydrogen bonding?

A) H_2 only
B) H_2O only
C) CH_3OH, HF, and H_2O
D) CH_3OH, H_2, HF, and H_2O

Answer ___C____

13. Reactions tend to proceed faster at higher temperatures because

A) there are more molecules available to react.
B) reactant molecules collide more frequently.
C) the energy of the products has increased.
D) the pressure in the reaction vessel has decreased.

Answer ___B____

14. How many grams of sulfur are in 0.20 mol of $Cr(SO_4)_3$?

A) 3.20 g
B) 6.40 g
C) 12.8 g
D) 19.2 g

Answer ___D____

15. In the reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, with all the substances at the same temperature and pressure, what volume of ammonia is produced when 4.50 L of nitrogen reacts with excess hydrogen?

A) 2.25 L
B) 4.50 L
C) 9.00 L
D) 13.5 L

Answer ___C____

Part II. Complete each of the following. Point values are noted by each question.

16. Complete the following table. (6 points)

_____**579**_____ g C_5H_{11}	=	8.14 mol C_5H_{11}	=	__**4.90×10^{24}**__ molecules C_5H_{11}

$$8.14\text{ mol } C_5H_{11} \times \frac{71.14\text{ g } C_5H_{11}}{1\text{ mol } C_5H_{11}} = 579\text{ g } C_5H_{11}$$

$$8.14\text{ mol } C_5H_{11} \times \frac{6.02\times10^{23}\text{ molecules } C_5H_{11}}{1\text{ mol } C_5H_{11}} = 4.90\times10^{24}\text{ molecules } C_5H_{11}$$

17. Match the term with its definition. (8 points)

__**I**__ thermodynamics
__**G**__ molarity
__**D**__ solute
__**A**__ exothermic
__**J**__ electronegativity
__**H**__ joule
__**F**__ enthalpy
__**C**__ state function

A. a process that releases heat energy
B. a process that absorbs heat energy
C. a thermodynamic concept that does not depend on pathway (or mechanism).
D. the substance that is dissolved in another substance to form a solution
E. the substance that dissolves another substance to form a solution
F. energy transferred as heat
G. concentration in terms of moles per liter
H. a quantity of energy
I. the study of energy and its changes
J. the tendency for an atom in a bond to attract electrons to itself.

18. In a laboratory experiment, you use 15 mL of 3.0 M sodium hydroxide solution to begin the alloy formation. How many grams of NaOH are present in 15 mL of 3.0 M NaOH? (6 points)

$$15\text{ mL solution} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{3.0\text{ mol NaOH}}{1\text{ L solution}} = 0.045\text{ mol NaOH}$$

$$0.045\text{ mol NaOH} \times \frac{39.997\text{ g NaOH}}{1\text{ mol NaOH}} = 1.7999\text{g NaOH} = \mathbf{1.8\text{ g NaOH (2 sig. figs.)}}$$

19. How does the statement "you can't break even" relate to the second law of thermodynamics? (6 points)

Any spontaneous process that involves an energy transfer cannot be 100 % efficient. Some energy is always lost to increase the entropy of the universe.

20. How would you prepare 250 g of an aqueous solution that is 4.50% glucose ($C_6H_{12}O_6$) by mass, starting with pure, solid glucose? (6 points)

$$250\text{ g solution} \times \frac{4.50\text{ g glucose}}{100\text{ g solution}} = 11.25\text{ g glucose}$$

So, weigh 11.25 g glucose and add 238.75 g water to make 250 g of 4.50% solution. Since we only have 2 significant figures, we should weigh 11 g glucose and add 239 g water.

Part III. ***<u>Complete 3 of the following 4 problems.</u>*** Clearly mark the problem you do not want graded. Each problem is worth eight (8) points. You must show you work on calculations to receive partial credit. Report numerical results to the correct number of significant figures and with the appropriate units.

21. Oxygen gas (O_2) and nitrogen gas (N_2) can react to form nitrogen dioxide. What mass of oxygen is needed to react with 1.50 grams nitrogen in this process?

$$2O_2 + N_2 \rightarrow 2NO_2$$

$$1.50 \text{ g } N_2 \times \frac{1 \text{ mol } N_2}{28.014 \text{ g } N_2} = 0.05354 \text{ mol } N_2$$

$$0.05354 \text{ mol } N_2 \times \frac{2 \text{ mol } O_2}{1 \text{ mol } N_2} = 0.1071 \text{ mol } O_2$$

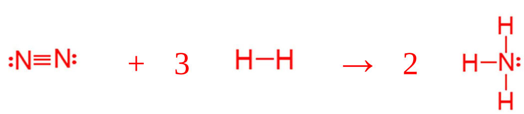
$$0.1071 \text{ mol } O_2 \times \frac{31.998 \text{ g } O_2}{1 \text{ mol } O_2} = 3.43 \text{ g } O_2$$

Therefore, 3.43 grams of oxygen are required.

22. Calculate the amount of energy that is involved when 1 mol of nitrogen gas reacts with 3 mol hydrogen gas to produce 2 mol ammonia gas, given the information below. *(Hint: start with a Lewis structure for each compound.)*

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Bond	Bond Energy (kJ/mol)
N-N	163
N=N	418
N≡N	964
N-H	391
H-H	432



So, to deconstruct the reactants, we must break 1 N≡N bond and 3 H-H bonds. This requires

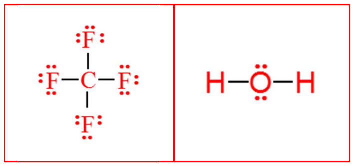
964 kJ + 3(432 kJ) = 2260 kJ of energy

So, to assemble the producs, we must form 6 N-H bonds (3 per molecule for 2 molecules). This releases

6(391 kJ) = 2346 kJ of energy

Therefore, the net energy change is: 2346 kJ – 2260 kJ = **86 kJ**

23. At a temperature of -100°C, tetrafluoromethane (CF_4) is a gas, while water is a solid. Use your understanding of the structure of these two compounds to explain this difference in their physical properties.



Consider the structures of each compound. CF_4 has polar bonds, but the geometry of CF_4 allows the bond dipoles to cancel, making CF_4 a nonpolar molecule, only able to participate in dispersion intermolecular forces. Water, on the other hand, has polar bonds and the geometry does not allow the bond dipoles to cancel, making water polar, allowing it to undergo not only dispersion forces, but also stronger dipole-dipole interactions. In addition, water can undergo hydrogen bonding interactions, which are particularly strong. The presence of these stronger intermolecular interactions in water make it more difficult to cause water to melt and boil, compared to the much weaker interactions in CF_4

24. Nitroglycerin, $C_3H_5(ONO_2)_3$, is a contact explosive that undergoes a rapid decomposition to form carbon dioxide, water vapor, nitrogen gas and oxygen gas.

a. Balance the reaction for the decomposition of nitroglycerin. I've given you a coefficient of 4 for nitroglycerin as a starting point.

$$4\ C_3H_5(ONO_2)_3\,(s) \rightarrow \underline{12}\ CO_2\,(g) + \underline{10}\ H_2O\,(g) + \underline{6}\ N_2\,(g) + \underline{1}\ O_2\,(g)$$

b. What is the molar mass of nitroglycerin?

$3(12.011) + 5(1.008) + 3(14.007) + 9(15.999) = 227.09$ g/mol

c. If 20.0 grams of nitroglycerin decomposes, how many total moles of gas are produced?
The reaction shows that for every 4 mol nitroglycerine (NG), 29 moles of gas are formed.

$$20.0\text{ g NG} \times \frac{1\text{ mol NG}}{227.09\text{ g NG}} \times \frac{29\text{ mol gas}}{4\text{ mol NG}} = 0.638\text{ mol gas}$$

d. Assuming the 20.0 grams of nitroglycerin from part c decomposes in a closed metal pipe with a volume of 0.200 L at a temperature of 5000°C (typical for nitroglycerin), what will the pressure be inside the pipe?

$$PV = nRT,\ T = 5000^{o}C + 273 = 5273\text{ K}$$

$$P = \frac{nRT}{V} = \frac{(29\text{ mol gas})(0.0821\text{ L atm mol}^{-1}\text{ K}^{-1})(5273\text{ K})}{0.200\text{ L}} = \mathbf{1380\ atm}$$

Note: the pipe probably cannot hold 1380 atm, so it will likely explode!

Please write legibly! If I can’t read it, I can’t grade it! Form A

% by mass = $\frac{\text{g component}}{\text{100 g mixture}}$	R = 0.0821 (L atm)/(mol K)	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
At STP, P = 1 atm, T = 25^{o}C	K = ^{o}C + 273.15	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	PV=nRT
Avogadro’s number: $N_A = 6.022 \times 10^{23}$ mol^{-1}	d = m/v	$P_1V_1 = P_2V_2$	

Periodic Table of the Elements

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]