Chemistry 150 Exam 3

Be sure to put your name on each page. This page can be removed from your exam so that you will have a Periodic Table handy throughout the exam, it does not need to be turned in. Show all your work for problems which require any sort of calculation, no credit will be given for answers without work shown. If you have shown a significant amount of work or multiple drawings for a problem, draw a box around what you consider your final answer.

Avogadro's Number = 6.022×10^{23} units/mol
$32.00^{o}F = 0.000^{o}C = 273.15K$
1 foot = 12 inches
1 inch = 2.54cm (exactly)
1 pound = 453.6 g = 16 ounces
1 amu = 1.6605×10^{-24} g
Masses of subatomic particles:
- Proton 1.00728amu = 1.6726×10^{-24} g
- Neutron 1.00866amu = 1.6749×10^{-24} g
- Electron 0.000549amu = 9.1094×10^{-28} g

Density of Water = 1.000 g/mL
R = 0.08206 L•atm/mol•K
PV=nRT
1 calorie = 4.184 J = 0.001Calorie

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.922	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.03	89 **Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		114		116		

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.94	70 **Yb** 173.04	71 **Lu** 174.97
90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (258)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Score

Multiple Choice: Circle the letter of the most correct response. (6pts. per question)

1. The First Law of Thermodynamics states that:
   a. Kinetic energy is stored in chemical bonds
   b. Electrostatic energy is another name for electricity
   c. An element in its "standard" state has no energy
   d. Energy cannot be created or destroyed
   e. Potential energy is a measure of the speed of molecular movement

2. The specific heat capacity of a substance is:
   a. The amount of energy required to increase the temperature of one mole of the substance 1°C
   b. The amount of energy required to increase the temperature of one gram of the substance 1°C
   c. 4.184 $^{J}/_{g \cdot °C}$
   d. The amount of energy required to increase the temperature of one pound of the substance 1°C
   e. The amount of energy required to increase the temperature of one gram of the substance 1°F

3. Each of the following describes an ***endothermic*** process *except*:
   a. Chemical bonds are broken
   b. The reactants have a lower energy than the products of a reaction
   c. The system absorbs heat from the surroundings
   d. ΔH is positive
   e. The system liberates heat to the surroundings

4. Is each of the following processes endothermic or exothermic? (3pts each)

Splitting water to form H_2(g) and O_2(g)	***Endothermic***	*Exothermic*
Burning butane in air	*Endothermic*	***Exothermic***
Boiling liquid methanol	***Endothermic***	*Exothermic*
Freezing water	*Endothermic*	***Exothermic***

Problems:

5. Beryllium oxide (BeO) can be converted to strontium metal by the following reaction:

$$2\,BeO(s) \rightarrow 2\,Be(s) + O_2(g)$$

What is $\Delta H°_{reaction}$ for this process? ($\Delta H_f° = -609.4\ ^{kJ}/_{mol}$ for BeO.) How many kJ of energy must be transferred to produce 15.00g of Be(s)? Is the energy transferred *in* or *out* of the system? Explain. (20pts)

$$\Delta H°_{rxn} = 2(-\Delta H°_f(BeO(s))) + 2(\Delta H°_f(Be(s))) + (\Delta H°_f(O_2(g)))$$

$$\Delta H°_{rxn} = 2(-(-609.4\ ^{kJ}/_{mol})) + 2(\ 0\ ^{kJ}/_{mol}) + (\ 0\ ^{kJ}/_{mol}) = 1218.8\ ^{kJ}/_{mol}$$

$$(15.00\text{g Be(s)})\left(\frac{1\text{ mol Be(s)}}{9.0122\text{g Be(s)}}\right)\left(\frac{1\text{ mol rxn}}{2\text{ mol Be(s)}}\right)\left(\frac{1218.8\text{ kJ}}{1\text{ mol rxn}}\right) = 1014\text{ kJ}$$

Since $\Delta H°_{rxn}$ is positive, this reaction is endothermic, therefore the energy is being transferred *from* the system *to* the surroundings, *out* of the system

Score

6. The specific heat capacity of liquid water is 4.184 J/g•°C. How much energy is needed to heat 450.0g of liquid water from 7.61°C to 29.19°C? (20pts)

$$\left(\frac{4.184\ \text{J}}{\text{g}\bullet{}^{\circ}\text{C}}\right)(450.0\text{g})(29.19^{\circ}\text{C} - 7.61^{\circ}\text{C}) = 40630\ \text{J} \Rightarrow 40.63\text{kJ}$$

7. How much energy is released when 800.0g of water is condensed at its boiling point (100°C)? ($\Delta H^o_{vaporization}$ = 40.64 kJ/mol for water) (15pts)

$$(800.0\text{g})\left(\frac{1\ \text{mol}\ H_2O}{18.015\text{g}\ H_2O}\right)\left(\frac{40.64kJ}{1\ \text{mol}\ H_2O}\right) = 1805\text{kJ}$$

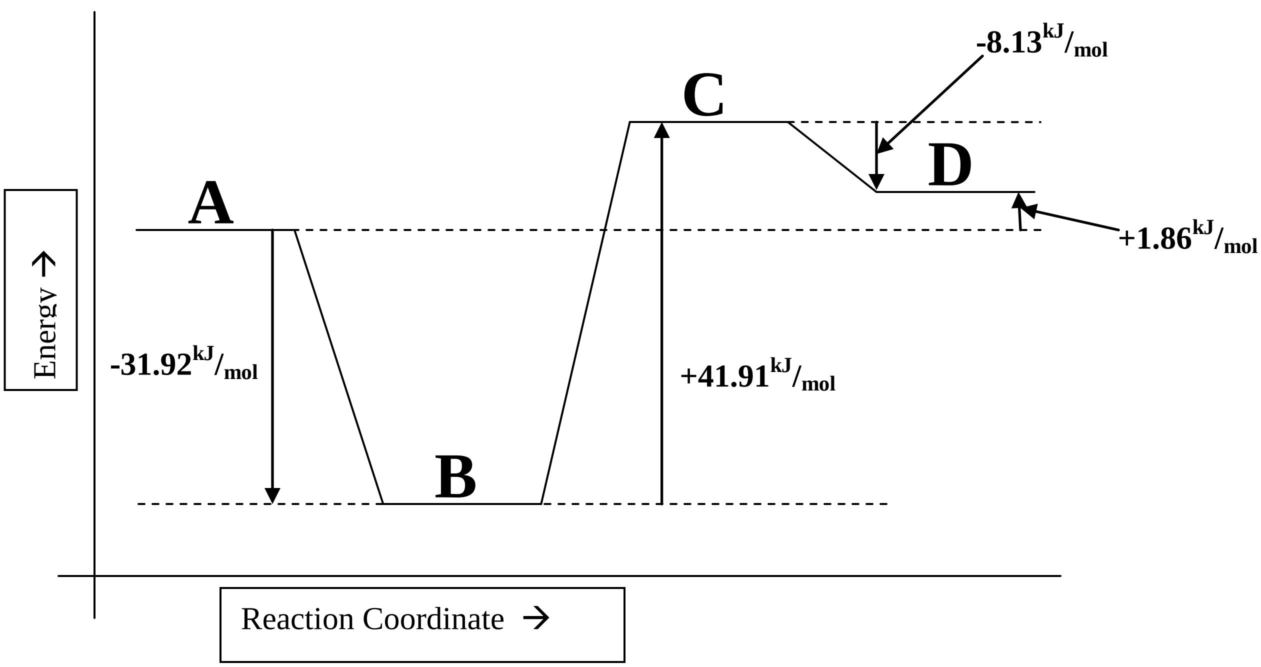
9. You have been studying a series of reactions:

A → B → C → D

So far, you have determined the following ΔH^o_{rxn} values:

A → B		-31.92 kJ/mol
C → B		-41.91 kJ/mol
C → D		-8.13 kJ/mol

What is ΔH^o_{rxn} for the overall reaction, A → D? Is A → D endothermic or exothermic? Draw a qualitatively correct reaction coordinate diagram for the entire stepwise process, A → B → C → D. (20pts)



Score

8. You have determined that $\Delta H^o_{reaction}$ for the reaction of calcium oxide with carbon dioxide gas is -178.3 $^{kJ}/_{mol}$.

$$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$$

What is $\Delta H^o_{reaction}$ for the following reaction? Explain your answer. (15pts)

$$3\ CaCO_3(s) \rightarrow 3\ CaO(s) + 3\ CO_2(g)$$

The reaction has been reversed and tripled, so

$$\Delta H^\circ_{rxn}(new) = -3\{\Delta H^\circ_{rxn}(original)\} = -3(-178.3\,^{kJ}/_{mol}) = 534.9\,^{kJ}/_{mol}$$

10. You have burned 25.00g of methane gas $\{CH_4(g)\}$ in excess oxygen to produce carbon dioxide and water. If all of the energy from this reaction is transferred to a 39.67kg block of iron initially at 12.83°C, what is the final temperature of the iron block? (The specific heat capacity of Fe(s) is 0.451 $^{J}/_{g\bullet°C}$) (30pts)

Material	ΔH_f^o ($^{kJ}/_{mol}$)
$CH_4(g)$	-74.61
$CO_2(g)$	-393.509
$H_2O(g)$	-241.818

Energy is coming from the combustion of methane, this is a reaction enthalpy problem.

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$$

$$\Delta H^\circ_{rxn} = (-\Delta H^\circ_f\{CH_4(g)\}) + 2(-\Delta H^\circ_f\{O_2(g)\}) + (\Delta H^\circ_f\{CO_2(g)\}) + 2(-\Delta H^\circ_f\{H_2O(g)\})$$

$$\Delta H^\circ_{rxn} = (-\{-74.61\,^{kJ}/_{mol}\}) + 2(-\{0\,^{kJ}/_{mol}\}) + (-393.509\,^{kJ}/_{mol}) + 2(-241.818\,^{kJ}/_{mol}) = -802.535\,^{kJ}/_{mol}$$

$$(25.00\text{g } CH_4(g))\left(\frac{1\text{ mol } CH_4}{16.043\text{g } CH_4}\right)\left(\frac{1\text{ mol rxn}}{1\text{ mol } CH_4}\right)\left(\frac{802.535\text{kJ}}{1\text{ mol rxn}}\right) = 1250.6\text{kJ heat liberated}$$

This heat is transferred to the block of iron, this is a heat capacity problem.

$$(1250.6\text{kJ})\left(\frac{1000\text{J}}{1\text{kJ}}\right)\left(\frac{\text{g}\bullet°\text{C}}{0.451\text{J}}\right)\left(\frac{1}{39.67\text{kg}}\right)\left(\frac{1\text{kg}}{1000\text{g}}\right) = 69.9°\text{C}$$

This is the ***change*** in temperature. Since the energy is being transferred ***to*** the iron block, the final temperature should be higher than the initial temperature, so:

$$T_{final} = 12.83°C + 69.9°C = 82.7°C$$

Score