

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

$c = \lambda\nu = 3.00 \times 10^8$ m/sec

$32.00^\circ\text{F} = 0.000^\circ\text{C} = 273.15\text{K}$

$E_{\text{photon}} = h\nu$

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 $1.00728\text{amu} = 1.6726 \times 10^{-24}$ g

Neutron $1.00866\text{amu} = 1.6749 \times 10^{-24}$ g

Electron $0.000549\text{amu} = 9.1094 \times 10^{-28}$ g

Density of Water = $1.000^{\text{g}}/\text{mL}$

$R = 0.08206$ L \cdot atm/mol \cdot K

$PV = nRT$

1 calorie = 4.184 J = 0.001Calorie

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

$\lambda = h/mv$

1 J = 1 kg (m/sec)²

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)

Multiple Choice: Circle the letter of the most correct response. (5pts. per question)

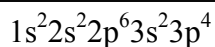
- The First Law of Thermodynamics states that:
 - Electrostatic energy is another name for electricity
 - An element in its “normal” state has no energy
 - Energy cannot be created or destroyed**
 - Potential energy is a measure of the speed of molecular movement
 - Kinetic energy is stored in chemical bonds

- The specific heat capacity of a substance is:
 - The amount of energy required to increase the temperature of one mole of the substance one degree Celsius
 - The amount of energy required to increase the temperature of one gram of the substance one degree Celsius**
 - $4.184 \text{ J/g}\cdot^\circ\text{C}$
 - The amount of energy required to increase the temperature of one pound of the substance one degree Celsius
 - The amount of energy required to increase the temperature of one gram of the substance one degree Fahrenheit

- Each of the following describes an *exothermic* process *except*:
 - Chemical bonds are formed
 - The reactants have a higher energy than the products of a reaction
 - The system releases heat to the surroundings
 - ΔH is negative
 - The system absorbs heat from the surroundings**

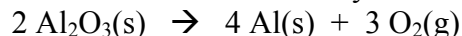
- Which of the following is *not* a possible set of quantum numbers?
 - $n = 1, \ell = 0, m_\ell = 0$
 - $n = 2, \ell = 1, m_\ell = -1$
 - $n = 2, \ell = 2, m_\ell = -1$**
 - $n = 3, \ell = 0, m_\ell = 0$
 - $n = 3, \ell = 2, m_\ell = 2$

- Write out the correct electron configuration for a sulfur atom (6pts)



Multiple Choice Calculations: (10pts each)

6. Alumina (Al_2O_3) can be converted to aluminum metal by the following reaction:



What is $\Delta H^\circ_{\text{reaction}}$ for this process? ($\Delta H^\circ_f = -1675.7 \text{ kJ/mol}$ for Al_2O_3 .)

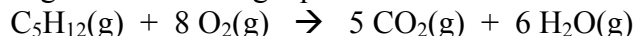
- a. -3351.4 kJ/mol
b. -1675.7 kJ/mol
c. -837.85 kJ/mol
d. 1675.7 kJ/mol
e. **3351.4 kJ/mol**
7. The specific heat capacity of liquid water is $4.184 \text{ J/g}\cdot^\circ\text{C}$. How much energy is required to heat 126.49g of liquid water from 10.34°C to 61.92°C ?
a. 32.77 kJ
b. **27.30 kJ**
c. 5.472 kJ
d. 1559 J
e. $6.413 \times 10^{-4} \text{ J}$
8. A green laser pointer emits light with a wavelength of 512nm. What is the energy of a single photon of light from a green laser pointer?
a. $5.86 \times 10^5 \text{ J}$
b. **$3.88 \times 10^{-19} \text{ J}$**
c. $1.99 \times 10^{-25} \text{ J}$
d. $3.88 \times 10^{-28} \text{ J}$
e. $3.39 \times 10^{-40} \text{ J}$
9. Palmitic acid ($\text{C}_{16}\text{H}_{32}\text{O}_2$) is a saturated fatty acid found in palm oil that melts at 60.48°C . How much energy is required to melt 50.612g of stearic acid at 60.48°C ? ($\Delta H^\circ_{\text{fusion}} = 163.93 \text{ J/g}$ for palmitic acid)
a. $5.0179 \times 10^5 \text{ J}$
b. **8296.8 J**
c. 3.2390 J
d. 0.30874 J
e. 0 J
10. You have determined that $\Delta H^\circ_{\text{reaction}}$ for the following reaction is -311.2 kJ/mol .
$$3 \text{Ca}(\text{OH})_2(\text{s}) + 2 \text{H}_3\text{PO}_4(\text{s}) \rightarrow \text{Ca}_3(\text{PO}_4)_2(\text{s}) + 6 \text{H}_2\text{O}(\text{l})$$

What is $\Delta H^\circ_{\text{reaction}}$ for the reaction:
$$2 \text{Ca}_3(\text{PO}_4)_2(\text{s}) + 12 \text{H}_2\text{O}(\text{l}) \rightarrow 6 \text{Ca}(\text{OH})_2(\text{s}) + 4 \text{H}_3\text{PO}_4(\text{s})$$

a. **622.4 kJ/mol**
b. 311.2 kJ/mol
c. 155.6 kJ/mol
d. -311.2 kJ/mol
e. -622.4 kJ/mol

Problems:

11. Pentane burns according to the following equation:



You perform an experiment in which you burn 12.913g of pentane and determine that the reaction generated 585.6kJ of heat. Based upon this experiment, what is the value of ΔH_f° for pentane? (20pts)

Material	ΔH_f° (kJ/mol)
CO ₂ (g)	-393.509
H ₂ O(g)	-241.818

Starting with the generic equation we'll use to calculate $\Delta H^\circ_{\text{rxn}}$:

$$\Delta H^\circ_{\text{rxn}} = 1\{-\Delta H_f^\circ(\text{C}_5\text{H}_{12}(\text{g}))\} + 8\{-\Delta H_f^\circ(\text{O}_2(\text{g}))\} + 5\{\Delta H_f^\circ(\text{CO}_2(\text{g}))\} + 6\{\Delta H_f^\circ(\text{H}_2\text{O}(\text{g}))\}$$

The problem gives us information to calculate the heat of the reaction, $\Delta H^\circ_{\text{rxn}}$:

$$\Delta H^\circ_{\text{rxn}} = \frac{-585.6\text{kJ}}{(12.912\text{g C}_5\text{H}_{12}) \left(\frac{1\text{mol C}_5\text{H}_{12}}{72.150\text{g C}_5\text{H}_{12}} \right) \left(\frac{1\text{mol rxn}}{1\text{mol C}_5\text{H}_{12}} \right)} = -3272 \frac{\text{kJ}}{\text{mol rxn}}$$

{NOTE: The negative sign is included because the problem states that the reaction generates heat, therefore it is exothermic.}

Using the ΔH_f° numbers provided in the problem, we can plug in to the $\Delta H^\circ_{\text{rxn}}$ expression:

$$-3272 \frac{\text{kJ}}{\text{mol rxn}} = 1\{-\Delta H_f^\circ(\text{C}_5\text{H}_{12}(\text{g}))\} + 8\{0 \frac{\text{kJ}}{\text{mol}}\} + 5\{-393.509 \frac{\text{kJ}}{\text{mol}}\} + 6\{-241.818 \frac{\text{kJ}}{\text{mol}}\}$$

Solving for the unknown:

$$\Delta H_f^\circ(\text{C}_5\text{H}_{12}(\text{g})) = -146 \frac{\text{kJ}}{\text{mol}}$$

12. Which has the longer deBroglie wavelength, the fastest recorded tennis serve, or the fastest recorded badminton smash? The mass of a standard tennis ball is 57g and the fastest serve was measured at 73.14 m/sec in 1931 by "Big Bill" Tilden. A badminton shuttlecock has a mass of 4.9g and the fastest smash was measured at 92.22 m/sec in 2005 by Fu Haifeng. Show your work. {Note: those speeds are 163 and 206mph. Yikes!} (16pts)

This problem involves plugging values into the deBroglie relationship:

$$\lambda = \frac{h}{mv}$$

For the tennis serve:

$$\lambda = \frac{6.626 \times 10^{-34} \frac{\text{kg} \cdot \text{m}^2}{\text{sec}}}{(0.057\text{kg})(73.14 \frac{\text{m}}{\text{sec}})} = 1.6 \times 10^{-34} \text{ m}$$

For the badminton smash:

$$\lambda = \frac{6.626 \times 10^{-34} \frac{\text{kg} \cdot \text{m}^2}{\text{sec}}}{(0.0049\text{kg})(92.22 \frac{\text{m}}{\text{sec}})} = 1.5 \times 10^{-33} \text{ m}$$

The badminton smash has the longer deBroglie wavelength. If you think about these wavelengths, they are both incredibly small, so there is no macroscopically observable wave character to the flight of a tennis ball or a shuttlecock.

13. The specific heat capacity of gold is $0.128 \text{ J/g}\cdot\text{C}$ and the specific heat capacity of iron is $0.449 \text{ J/g}\cdot\text{C}$. You have heated a 51.294 g block of gold to 49.318°C and placed it on an iron block at 21.516°C . When the system reaches thermal equilibrium, the temperature of the gold and iron is 34.468°C . If the system is perfectly insulated, what was the mass of the iron block in grams? (20pts)

The assumption that the system is perfectly insulated implies that all of the energy lost by the gold block is transferred to the iron block. Finding the energy lost by the gold block:

$$E_{\text{gold}} = (0.128 \text{ J/g}\cdot\text{C})(51.294 \text{ g Au})(14.850^\circ\text{C})$$

And the energy gained by the iron block:

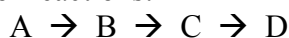
$$E_{\text{iron}} = (0.449 \text{ J/g}\cdot\text{C})(x \text{ g Fe})(12.952^\circ\text{C})$$

Setting these energies equal:

$$(0.128 \text{ J/g}\cdot\text{C})(51.294 \text{ g Au})(14.850^\circ\text{C}) = (0.449 \text{ J/g}\cdot\text{C})(x \text{ g Fe})(12.952^\circ\text{C})$$

$$x = 16.8 \text{ g Fe}$$

14. You have been studying a series of reactions:



So far, you have determined the following $\Delta H^\circ_{\text{rxn}}$ values:



And $\Delta H^\circ_{\text{rxn}}$ for the whole process ($A \rightarrow D$) is $+23.64 \text{ kJ/mol}$.

What is $\Delta H^\circ_{\text{rxn}}$ for the reaction $C \rightarrow D$? Draw a qualitatively correct reaction coordinate diagram for the entire stepwise process, $A \rightarrow B \rightarrow C \rightarrow D$. (18pts)

