

# 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 non-multiple choice 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 =  $6.022 \times 10^{23}$  units/mol

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

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

$\lambda = h/mv$

1 foot = 12 inches

1 J = 1 kg (m/sec)<sup>2</sup>

1 inch = 2.54cm (exactly)

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

1 pound = 453.6 g = 16 ounces

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

1 amu =  $1.6605 \times 10^{-24}$  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 = 0.001 Calorie

1 <b>H</b> 1.0079																	2 <b>He</b> 4.0026
3 <b>Li</b> 6.941	4 <b>Be</b> 9.0122											5 <b>B</b> 10.811	6 <b>C</b> 12.011	7 <b>N</b> 14.007	8 <b>O</b> 15.999	9 <b>F</b> 18.998	10 <b>Ne</b> 20.180
11 <b>Na</b> 22.990	12 <b>Mg</b> 24.305											13 <b>Al</b> 26.982	14 <b>Si</b> 28.086	15 <b>P</b> 30.974	16 <b>S</b> 32.066	17 <b>Cl</b> 35.453	18 <b>Ar</b> 39.948
19 <b>K</b> 39.098	20 <b>Ca</b> 40.078	21 <b>Sc</b> 44.956	22 <b>Ti</b> 47.88	23 <b>V</b> 50.942	24 <b>Cr</b> 51.996	25 <b>Mn</b> 54.938	26 <b>Fe</b> 55.847	27 <b>Co</b> 58.933	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.546	30 <b>Zn</b> 65.39	31 <b>Ga</b> 69.723	32 <b>Ge</b> 72.61	33 <b>As</b> 74.922	34 <b>Se</b> 78.96	35 <b>Br</b> 79.904	36 <b>Kr</b> 83.80
37 <b>Rb</b> 85.468	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.906	40 <b>Zr</b> 91.224	41 <b>Nb</b> 92.906	42 <b>Mo</b> 95.94	43 <b>Tc</b> (98)	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29
55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	71 <b>Lu</b> 174.97	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
87 <b>Fr</b> (223)	88 <b>Ra</b> 226.03	103 <b>Lr</b> (260)	104 <b>Rf</b> (261)	105 <b>Db</b> (262)	106 <b>Sg</b> (263)	107 <b>Bh</b> (262)	108 <b>Hs</b> (265)	109 <b>Mt</b> (266)	110 <b>Ds</b> (269)	111 <b>Rg</b> (272)	112 <b>Cn</b> (277)	113	114	115	116	117	118

57 <b>La</b> 138.91	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.97	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.94	70 <b>Yb</b> 173.04
89 <b>Ac</b> 227.03	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> 237.05	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (258)	101 <b>Md</b> (258)	102 <b>No</b> (259)

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

- The First Law of Thermodynamics states that:
  - Kinetic energy is stored in chemical bonds
  - Electrostatic energy is another name for electricity
  - An element in its “standard” state has no energy
  - Energy cannot be created or destroyed**
  - Potential energy is a measure of the speed of molecular movement
- The specific heat capacity of any substance is:
  - The amount of energy required to increase the temperature of one mole of the substance 1°C
  - The amount of energy required to increase the temperature of one gram of the substance 1°C**
  - 4.184 J/g°C
  - The amount of energy required to increase the temperature of one pound of the substance 1°C
  - The amount of energy required to increase the temperature of one gram of the substance 1°F
- Each of the following describes an *endothermic* process *except*:
  - Chemical bonds are broken
  - The reactants have a lower energy than the products of a reaction
  - The system absorbs heat from the surroundings
  - $\Delta H$  is positive
  - The system liberates heat to the surroundings**

**Problems:**

4. The specific heat capacity of wood is 1.76 J/g°C. How much energy is needed to heat 450.0g of wood from 7.61°C to 29.19°C? (15pts)

$$q = (1.76 \text{ J/g}\cdot\text{C})(450.0\text{g})(29.19-7.61\text{C}) = 1.71 \times 10^4 \text{ J}$$

Answer 4:

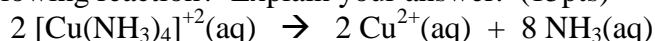
5. How much energy is released when 800.0g of acetone is frozen at its freezing point (-94°C)? ( $\Delta H^\circ_{\text{fusion}} = 5.691 \text{ kJ/mol}$  for acetone) (15pts)

$$E = (5.691 \text{ kJ/mol})(1\text{mol} / 58.079\text{g})(800.0\text{g}) = 78.39\text{kJ}$$

Answer 5:

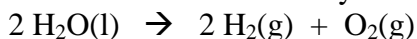
6. You have determined that  $\Delta H^\circ_{\text{reaction}}$  for the reaction of copper(II) ions with ammonia is  $-28.16 \text{ kJ/mol}$ .
- $$\text{Cu}^{2+}(\text{aq}) + 4 \text{NH}_3(\text{aq}) \rightarrow [\text{Cu}(\text{NH}_3)_4]^{+2}(\text{aq})$$

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



Reverse and double  $\rightarrow +56.32 \text{ kJ/mol}$

7. One potential source of hydrogen gas for use as a fuel is water by the following reaction:

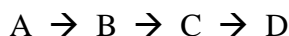


What is  $\Delta H^\circ_{\text{reaction}}$  for this process?  $\{\Delta H_f^\circ = -285.83 \text{ kJ/mol}$  for  $\text{H}_2\text{O}(\text{l})\}$  How many kJ of energy must be transferred to produce 15.00g of  $\text{H}_2(\text{g})$ ? Is the energy transferred *in* or *out* of the system? Explain. (20pts)

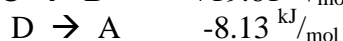
$$\Delta H_{\text{rxn}} = +571.66 \text{ kJ/mol}$$

$$(15.00 \text{g H}_2(\text{g})) (1 \text{mol H}_2 / 2.016 \text{g H}_2) (1 \text{mol rxn} / 2 \text{mol H}_2) (571.66 \text{ kJ/mol}) = 2126.7 \text{kJ in}$$

8. You have been studying a series of reactions:



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



What is  $\Delta H^\circ_{\text{rxn}}$  for the the third step,  $\text{C} \rightarrow \text{D}$ ? Is  $\text{C} \rightarrow \text{D}$  endothermic or exothermic? Draw a qualitatively correct reaction coordinate diagram for the entire stepwise process,  $\text{A} \rightarrow \text{B} \rightarrow \text{C} \rightarrow \text{D}$ . (20pts)

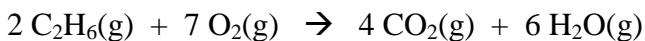
$$(+8.13 \text{ kJ/mol}) = (+13.38 \text{ kJ/mol}) + (-19.61 \text{ kJ/mol}) + (\Delta H^\circ \{\text{C} \rightarrow \text{D}\})$$

$$\Delta H^\circ \{\text{C} \rightarrow \text{D}\} = +14.36 \text{ kJ/mol}$$

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9. You have burned 25.00g of ethane gas {C<sub>2</sub>H<sub>6</sub>(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 copper initially at 6.38°C, what is the final temperature of the copper block? (The specific heat capacity of Cu(s) is 0.385<sup>J</sup>/g°C) (25pts)

Material	ΔH <sub>f</sub> <sup>o</sup> (kJ/mol)
C <sub>2</sub> H <sub>6</sub> (g)	-84.68
CO <sub>2</sub> (g)	-393.509
H <sub>2</sub> O(g)	-241.818



$$2(84.68) + 4(-393.509) + 6(-241.818) = -2855.58 \text{ kJ/mol}$$

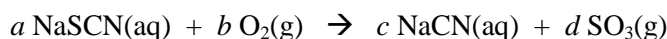
$$(25.00\text{g})(1\text{mol ethane} / 30.069\text{g}) (1\text{mol rxn} / 2\text{mol ethane}) (2855.58 \text{ kJ/mol}) = 1187\text{kJ}$$

$$1187\text{kJ} = (0.000385)(39670\text{g})(\Delta T)$$

$$\Delta T = 77.72^\circ\text{C}$$

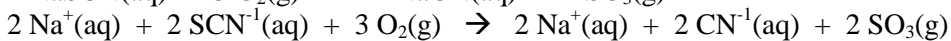
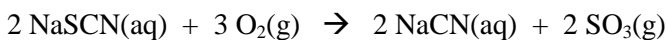
$$T_{\text{final}} = 6.38 + 77.72 = 84.10^\circ\text{C}$$

10. You have reacted 5.382L of oxygen at 37.32°C and 0.912atm with 250.0mL of 0.773M sodium thiocyanate solution by the following reaction:



How much heat is transferred by this reaction? Is the reaction endothermic or exothermic? (25pts)

Material	ΔH <sub>f</sub> <sup>o</sup> (kJ/mol)
Na <sup>+</sup> (aq)	-240.12
SCN <sup>-</sup> (aq)	-22.92
CN <sup>-</sup> (aq)	-183.62
SO <sub>3</sub> (g)	-395.72



$$2(+22.92) + 2(-183.62) + 2(-395.72) = -1112.84 \text{ kJ/mol}$$

Exothermic

$$\{(5.382\text{L})(0.912\text{atm}) / (0.08206)(310.47\text{K})\} (1\text{mol rxn} / 3\text{mol O}_2) (1112.84 \text{ kJ/mol}) = 71.5\text{kJ heat released}$$

$$\{(0.2500\text{L})(0.773\text{mols SCN}^- / \text{L})\} (1\text{mol rxn} / 2\text{mol SCN}^-) (1112.84 \text{ kJ/mol}) = 108 \text{ kJ heat released}$$

Oxygen is limiting, 71.5kJ heat released