This test is closed book, closed notes, and closed neighbors. A periodic table and other useful information is available at the end of the test. When told to begin, read through the entire exam, and decide which questions you can answer quickly. After you have answered those questions, return to the more involved questions and answer them.

By signing below, I agree to abide by the University rules and regulations regarding honesty on exams. I understand that I am not to look at others' exams nor allow others to view mine. I hereby state that all answers on the answer sheet are my own.

I understand that Professor Martin considers academic honesty to be central to the goals of the University and that dishonest behavior will be dealt with very seriously.

Printed Name: _____________________________________________________________

Signature: __________________________________________________________________

As soon as you have your OpScan (answer) sheet:

1) Place your name where indicated.

2) Place your student ID number where indicated, starting at column A.

Fill in the bubbles corresponding to the above.

Failure to correctly enter any of the above items will result in the deduction of 5 points from your exam.

Tear this page off and return with your completed answer sheet.
Immediately place a “1” in column K of your OpScan Sheet.

\[ R = 0.082057 \text{ atm L / mol K} \]
\[ h = 6.626 \times 10^{-34} \text{ J sec/photon} = 3.99 \times 10^{-10} \text{ J sec/(mol photons)} \]
\[ N_0 = 6.02 \times 10^{23} \text{ “things”/mole} \]

** There are 40 questions on this exam **

1a. 2(5 points) The molar mass of NaNO\(_3\) is:
   (a) 24.0  (b) 34.0  (c) 42.0  (d) 69.0  (e•) 85.0

2a. 3•(9 points) An unknown amino acid is found to contain 34.29% C, 6.71% H, 45.67% O, and 13.33% N. What is the empirical formula for this amino acid?
   
   (a) Leucine  C\(_6\)H\(_{13}\)O\(_2\)N  54.94  9.99  24.39  10.68  
   (b) Valine  C\(_5\)H\(_{11}\)O\(_2\)N  51.3  9.46  27.3  11.96  
   (c) Alanine  C\(_3\)H\(_7\)O\(_2\)N  40.44  7.92  35.92  15.72  
   (d) Glycine  C\(_2\)H\(_5\)O\(_2\)N  32.00  6.71  42.63  18.66  
   (e•) Serine  C\(_3\)H\(_7\)O\(_3\)N  34.29  6.71  45.67  13.33

3a. 4•(9 points) The equation for one of the reactions in the process of reducing iron ore to the metal is:

\[ \text{Fe}_2\text{O}_3 (s) + 3 \text{CO} (g) \rightarrow 2 \text{Fe} (s) + 3 \text{CO}_2 (g) \]

What mass of CO\(_2\) is produced in reducing 454 g of Fe\(_2\)O\(_3\) to iron metal?

(a•) 375 g  (b) 454 g  (c) 239 g  (d) 79.6 g  (e) 39.8 g

\[
\text{# moles Fe}_2\text{O}_3 = \frac{454 \text{ g}}{159.69 \text{ g/mole Fe}_2\text{O}_3} = 2.84 \text{ mole Fe}_2\text{O}_3
\]

\[
\text{# moles CO}_2 = 2.84 \text{ mole Fe}_2\text{O}_3 \times \frac{3 \text{ mole CO}_2}{1 \text{ mole Fe}_2\text{O}_3} = 8.53 \text{ mole CO}_2
\]

\[
\text{g CO} = 8.529 \text{ mole CO} \times \frac{44.01 \text{ g CO/mole CO}}{1} = 239 \text{ g CO}
\]
4a. 4• (9 points) Balance the following reaction using only integral coefficients:

\[ \text{NH}_3 + \text{O}_2 \rightarrow \text{NO} + \text{H}_2\text{O} \]

What is the coefficient of stoichiometry for NO in the balanced reaction?
(a) 1  (b) 2  (c) 3  (d•) 4  (e) 5

\[ 4 \text{NH}_3 + 5 \text{O}_2 \rightarrow 4 \text{NO} + 6 \text{H}_2\text{O} \]

5a. 5• (9 points) Elemental gold (Au) is dissolved from rock by treating the rock with sodium cyanide (NaCN, a potent respiratory poison!) in the presence of O\(_2\).

\[ 4 \text{Au (s)} + 8 \text{NaCN (aq)} + \text{O}_2 (\text{g}) + 2\text{H}_2\text{O (l)} \rightarrow 4 \text{NaAu(CN)}_2 (\text{aq}) + 4 \text{NaOH (aq)} \]

What is oxidized in this reaction?
(a) H\(_2\)O  (b) O\(_2\)  (c) Na\(^+\)  (d) CN\(^-\)  (e•) Au

6a. 5• (5 points) Although many of the transition metal cations prefer charges of +2 or +3, other charges are sometimes observed. In the compound NaMnO\(_4\), the Mn has a formal charge (oxidation number) of:
(a) +3  (b) +4  (c) +5  (d) +6  (e•) +7

7a. 5• (9 points) You are manufacturing expensive, hand-built automobiles. You currently have 8 cars ready for delivery to customers, except that they lack tires (each car requires 4 tires and one "skinny" spare). You have in stock 25 regular tires and 9 skinny spares. How many complete cars can you deliver without ordering more tires?
(a) 5  (b•) 6  (c) 7  (d) 8  (e) 9

Limiting "reagent" - tires. Can only build 25/4=6 cars
8a. 6• (9 points) Hydrogen and oxygen can be used as a fuel, according to the following reaction:

\[ 2 \text{H}_2 (g) + \text{O}_2 (g) \rightarrow 2 \text{H}_2\text{O} (l) \quad \Delta H = -483.6 \text{ kJ/mol} \]

This reaction is:

(a) endothermic    (b•) exothermic

9a. 6• (9 points) How much heat is provided by burning 1.5 lbs of propane (681 gms) in a propane stove? The MW of propane C\textsubscript{3}H\textsubscript{8} is 44.1, and the reaction which occurs in the combustion is:

\[ \text{C}_3\text{H}_8(g) + 5\text{O}_2 (g) \rightarrow 3\text{CO}_2 (g) + 4\text{H}_2\text{O}(l) \quad \Delta H = -2220 \text{ kJ} \]

(a) 45,700 kJ    (b•) 34,280 kJ    (c) 22,900 kJ
(d) 11,430 kJ    (e) 56,400 kJ

10a. 6• (5 points) A small pool of water is sitting on your arm on a hot, dry day. If the water is considered the system and your arm the surroundings, which best describes the spontaneous process which occurs?

(a) no heat is transferred

(b•) heat is transferred from the surroundings to the system
my arm cools down

(c) heat is transferred from the system to the surroundings
my arm heats up

(d) heat is transferred from the system to the surroundings
my arm cools down

(e) heat is transferred from the surroundings to the system
my arm heats up
11a. 6• (9 points) A 40.0 g piece of metal is heated in boiling water to a temperature of 100°C. It is then dropped into 225 g of water in an insulated beaker. The initial temperature of the water in the beaker was 20°C. The final temperature of the metal and water is 24°C. What is the specific heat of the metal? (Assume there is no heat transfer through the walls of the beaker; the specific heat of water is 4.184 J/g K)

(a•) 1.24 J/g K  (b) 8.37 J/g K  (c) 1.65 J/g K  
(d) 0.826 J/g K  (e) 4.184 J/g K

12a. 6• (5 points) Both hydrogen (H₂) and ethanol (C₂H₅OH) have been proposed as alternate fuels for automobiles. ΔH° for the complete combustion of H₂ is -285.8 kJ/mol, while that for ethanol is -1,367 kJ/mol. Remembering that weight contributes to overall fuel efficiency, combustion of which fuel produces more heat per gram?

(a•) hydrogen produces more heat per gram  
(b) ethanol produces more heat per gram

H₂: heat per gram = \(-285.8 \text{ kJ/mol} \times \left(\frac{\text{mol}}{2.016 \text{ g}}\right)\) = 141.8 kJ/g

C₂H₅OH: heat per gram = \(-1,367 \text{ kJ/mol} \times \left(\frac{\text{mol}}{46.07 \text{ g}}\right)\) = 29.7 kJ/g

13a. 6• (5 points) You hold a gram of aluminum in one hand and a gram of copper in the other. Each metal was originally at 0°C, and both metals are perfectly spherical balls. If they take up heat at the same rate, which reaches your body temperature first?

(a) aluminum  (b•) gold

<table>
<thead>
<tr>
<th>Specific Heat Capacity (J/g K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum                    0.902</td>
</tr>
<tr>
<td>Gold                        0.128</td>
</tr>
</tbody>
</table>
14a. 7 (5 points) Analogous to the coordinates x,y,z, \( n, l, m \) can independently take on any real integer values.
   (a) True  (b•) False

15a. 7 (5 points) What is the number of orbitals available for an atom with the quantum number \( l = 2 \)?
   (a) 6  (b•) 5  (c) 4  (d) 3  (e) 2

16a. 7• (5 points) Which best describes the node in a 2p\(_x\) orbital?
   (a) spherical  (b) in the xy plane  (c•) in the yz plane  (d) in the xz plane  (e) there is no node

17a. 7• (5 points) Which of the following photons has the highest energy?
   (a) infrared (\( \lambda = 1000 \) nm)  (b•) near UV (\( \lambda = 250 \) nm)
   (c) microwaves (\( \lambda = 10^{-3} \) m)  (d) orange light (\( \lambda = 625 \) nm)
   (e) radio waves (\( \lambda = 0.5 \) m)

   Lowest wavelength -> highest energy
18a. (9 points) The frequency of microwaves in your microwave is 2.45 GHz. How many moles of photons (of microwave radiation) will it take to heat a cup of coffee (100 gms of coffee) from 25°C to 100°C (assume the heat capacity of coffee is 4.184 J/gm °C and ignore the coffee cup). (1 GHz = 1x10^9 s⁻¹, recall E = ħν)

(a) 2.36 x 10⁹ mol of photons  
(b) 21,400 mol of photons  
(c•) 32,100 mol of photons  
(d) 6860 mol of photons  
(e) 10,700 mol of photons

19a. (9 points) The Schroedinger equation was revolutionary in that:

(a) it introduced the concept of orbits and suggested that electrons circle an atom, much like planets circle the sun;  
(b) it explained the ejection of electrons from metals by light;  
(c•) it treated the electron as a wave and led to the concept of electron clouds or electron densities;  
(d) it suggested that the energy of a photon is related to its frequency by E = ħν  
(e) none of the above

20a. (9 points) The 4p electrons on Ga (gallium) "see" an effective nuclear charge of:

(a) 5  
(b) 15  
(c) 31  
(d) 6  
(e•) 3

The 4p electrons on Ga are screened by the 1s, 2s, 2p, 3s, 3p, and 3d electrons (a total of 28). Thus the total nuclear charge of +34 is reduced to +6.
Sodium azide (NaN$_3$) is used in automobile air bags. Two resonance forms for the azide anion are shown below.

\[ \begin{array}{c}
\text{N}\equiv\text{N}\equiv\text{N} \quad \leftrightarrow \quad \text{N}\equiv\text{N}\equiv\text{N} \end{array} \]

21a. **8• (9 points)** Assuming that these are the only valid resonance forms for the molecule, what is the net bond order of an N-N bond in azide?

(a) 3/2  (b) 1/3  (c) 1  (d•) 2  (e) 3

22a. **8• (5 points)** What net charge do these resonance forms predict for the central atom?

(a) –2  (b) –1  (c) 0  (d•) +1  (e) +2

23a. **8• (5 points)** What net charge do these resonance forms predict for the atoms at the ends?

(a) –2  (b•) –1  (c) 0  (d) +1  (e) +2

24a. **8• (9 points)** What molecular geometry do these resonance forms predict?

(a•) linear  (b) bent  (c) trigonal planar  
(d) tetrahedral  (e) none of the above

25a. **8• (9 points)** Additional resonance forms for azide are shown below.

\[ \begin{array}{c}
\text{N}\equiv\text{N}\equiv\text{N} \quad \leftrightarrow \quad \text{N}\equiv\text{N}\equiv\text{N} \end{array} \]

Assuming that these two are the only valid resonance forms for the molecule, what is the net bond order of an N-N bond in azide?

(a•) 3/2  (b) 1/3  (c) 1  (d) 2  (e) 3

26a. **8• (9 points)** What molecular geometry do these resonance forms predict?

(a) linear  (b•) bent  (c) trigonal planar  
(d) tetrahedral  (e) none of the above
27a. 9(5 points) Predict the enthalpy $\Delta H_{\text{rxn}}$ of the following reaction:

$$2 \text{CH}_3\text{-CH}_2\text{-OH} \rightarrow \text{O}_2 + 2 \text{CH}_3\text{-CH}_3$$

Which value below is closest to your value?

(a) $-150 \text{ kJ/mol}$  (b) $-300 \text{ kJ/mol}$  (c) $+150 \text{ kJ/mol}$  (d*) $+300 \text{ kJ/mol}$
(e) can't tell from the data

$\Delta H = (\text{Bonds broken}) - (\text{Bonds formed})$

$$= [10x(\text{C-H}) + 2x(\text{C-C}) + 2x(\text{C-O}) + 2x(\text{O-H})] - [(\text{O=O}) + 12x(\text{C-H}) + 2x(\text{C-C})]$$

$$= -2x(\text{C-H}) + 2x(\text{C-O}) + 2x(\text{O-H}) - (\text{O=O})$$

$$= [-2x(413) + 2x(358) + 2x(463) - (498)] \text{ kJ/mol} = 318 \text{ kJ/mol}$$

28a. 6•(5 points) Re-calculate the enthalpy $\Delta H_{\text{rxn}}$ for the above reaction using the data at the right.

Which value below is closest to your value?

(a) $-150 \text{ kJ/mol}$  (b) $-300 \text{ kJ/mol}$  (c) $+150 \text{ kJ/mol}$  (d*) $+300 \text{ kJ/mol}$
(e) can't tell from the data

29a. 9(5 points) Which calculation do you think provides the more correct answer?

(a•) Using heats of formation  (b) Using bond energies  (c) they provide exactly the same estimate
30b. 9(9 points) What is the molecular geometry of PCl$_5$ (P is at the center)?

(a) T-shaped    (b) trigonal pyramid    (c) octahedral
(d) tetrahedral (e• ) triangular-bipyramid

The structure at right shows that there are 5 “groups” of electrons around As, resulting in a trigonal bipyramid electron-pair geometry. There are no lone pairs, resulting in a trigonal bipyramid molecular geometry.

31a. 9(9 points) What is the molecular geometry of the anion BrF$_4^-$?

(a) T-shaped    (b) trigonal planar    (c• ) square planar
(d) see-saw    (e) triangular-bipyramidal

There are 6 “groups” of electrons around Br resulting in an octahedral electron-pair geometry. Two are lone pairs, resulting in a square planar molecular geometry.

32a. 9(9 points) Which molecule below is not polar?

(a) CH$_2$Cl$_2$    (b) HF    (c) NH$_3$    (d) H$_2$O
(e• ) they are all polar

33a. 9(9 points) In which molecule below are the bonds most polar?

(a) SiH$_4$    (b) PH$_3$    (c• ) H$_2$S    (d) H$_2$    (e) O$_2$

34a. 10(9 points) Which resonance hybrid orbitals on P are used to form PCl$_5$?

(a) d$^5$    (b• ) sp$^3$d    (c) sp$^4$    (d) sp$^3$    (e) sp$^3$d$^2$

35a. 10(9 points) Which resonance hybrid orbitals on S are used to form the anion SO$_3$F$^-$?

(a) d$^5$    (b• ) sp$^3$    (c) sp$^4$    (d) sp$^3$d    (e) sp$^3$d$^2$
(For questions 36-39). You have two flasks of equal volume. Flask A contains H\textsubscript{2} at 0°C and 2 atm pressure. Flask B contains CO\textsubscript{2} gas at 0°C and 1 atm pressure.

36a. 12•(9 points) Which flask contains the larger number of molecules?
(a•) Flask A       (b) Flask B
(c) They have the same number of molecules

37a. 12•(9 points) Which flask has molecules with the larger kinetic energy per molecule?
(a) Flask A       (b•) Flask B
(c•) They have the same kinetic energy per molecule.

38a. 12•(9 points) Which flask has the larger total mass of gas?
(a) Flask A       (b•) Flask B
(c) They have the same total mass of gas.

39a. 12•(9 points) Argon gas is ten times more dense than helium gas at the same temperature and pressure. Which statement below is true?
(a) Argon gas and helium gas effuse at the same rate
(b) Argon gas effuses 10 times faster than helium gas
(c) Helium gas effuses 10 times faster than argon gas
(d) Argon gas effuses 3.2 times faster than helium gas
(e•) Helium gas effuses 3.2 times faster than argon gas
40a. **12• (9 points)** You have two gas-filled balloons, one containing He and the other H\(_2\). The H\(_2\) balloon is twice the size of the He balloon. The pressure of the gas in the H\(_2\) balloon is 1 atm, and that in the He balloon is 2 atm. The H\(_2\) balloon is outside in the snow (-5°C) and the He balloon is inside a warm building (25°C). Which balloon contains the greater number of molecules?

(a•) The H\(_2\) balloon       (b) The He balloon
(c) They have the same number of molecules.