Final Exam

Chem 111, Section 2 (10:10 am) Fall 1998

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..

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Immediately place a "2" in column K of your OpScan Sheet.

R = 0.082057 atm L / mol K = 8.3145 J / mol K

h = 6.626×10^{-34} J sec/photon = 3.99×10^{-10} J sec/(mol photons)

N_o = 6.02×10^{23} "things"/mole

** There are 40 questions on this exam **

1b. **2**(5 points) The molar mass of $NaNO_2$ is:

(a) 24.0 (b) 34.0 (c) 42.0 (d•) 69.0 (e) 85.0

2b. **3**•(9 points) An unknown amino acid is found to contain 40.44% C, 7.92% H, 35.92% O, and 15.72% N. What is the empirical formula for this amino acid?

(a) Leucine	$C_6H_{13}O_2N$	54.94	9.99	24.39	10.68
(b) Valine	$C_5H_{11}O_2N$	51.3	9.46	27.3	11.96
(c•) Alanine	$C_3H_7O_2N$	40.44	7.92	35.92	15.72
(d) Glycine	$C_2H_5O_2N$	32.00	6.71	42.63	18.66
(e) Serine	$C_3H_7O_3N$	34.29	6.71	45.67	13.33

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

$$Fe_2O_3\,(s) + 3\,CO\,(g) \rightarrow 2\,Fe\,(s) + 3\,CO_2\,(g)$$

What mass of CO is required to reduce 454 g of Fe_2O_3 to iron metal?

(a) 1360 g (b) 454 g (c•) 239 g (d) 79.6 g (e) 39.8 g

moles Fe_2O_3 = (454 g) (1/ 159.69 g Fe_2O_3/mole Fe_2O_3) = 2.84 mole Fe_2O_3

moles CO = 2.84 mole Fe_2O_3 (3 mole CO/1 mole Fe_2O_3) = 8.53 mole CO

g CO = 8.529 mole CO (28.01 g CO/mole CO) = 239 g CO

4b. 4•(9 points) Balance the following reaction using only integral coefficients:

$$NH_3 + O_2 \rightarrow NO + H_2O$$

What is the coefficient of stoichiometry for O_2 in the balanced reaction?

(a) 1 (b) 2 (c) 3 (d) 4 (e•) 5

$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$

5b. 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.

$4\ Au\ (s) + 8\ NaCN\ (aq) + O_2\ (g) + 2H_2O\ (l) \rightarrow 4\ NaAu(CN)_2\ (aq) + 4\ NaOH\ (aq)$

What is reduced in this reaction?

(a) H_2O (b•) O_2 (c) Na^+ (d) CN^- (e) Au

6b. 5•(5 points) Although many of the transition metal cations prefer charges of +2 or +3, other charges are sometimes observed. In the ionic compound $NaCrO_3$, the Cr has a formal charge (oxidation number) of:

(a) +3 (b) +4 (c•) +5 (d) +6 (e) +7

7b. 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 28 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 28/4=7 cars

8b. 6•(9 points) Hydrogen and oxygen can be used as a fuel, according to the following reaction:

$$2\ H_2\ (g)\ +\ O_2\ (g)\ \rightarrow\ 2\ H_2O\ (l) \quad \Delta H = -483.6\ kJ/mol$$

This reaction is:

(a) endothermic (b•) exothermic

9b. 6•(9 points) How much heat is provided by burning 0.5 lbs of propane (227 gms) in a propane stove? The MW of propane C_3H_8 is 44.1, and the reaction which occurs in the combustion is:

$$C_3H_8(g) + 5O_2\ (g) \rightarrow 3CO_2\ (g) + 4H_2O(l) \qquad \Delta H = -2220\ kJ$$

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

10b. 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

11b. 6•(9 points) A 30 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) 0.826J/g K (e)4.184J/g K

12b. 6•(5 points) Both hydrogen (H_2) and ethanol (C_2H_5OH) have been proposed as alternate fuels for automobiles. $\Delta H°$ for the complete combustion of H_2 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
H_2 : heat per gram = -285.8 kJ/mol x (mol/2.016g) = 141.8 kJ/g
C_2H_5OH : heat per gram = -1,367 kJ/mol x (mol/46.07g) = 29.7 kJ/g

13b. 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•) copper (b) aluminum

Specific Heat Capacity (J / g K)	
Aluminum	0.902
Copper	0.385

14b. 7(5 points) Analogous to the coordinates x,y,z, n, *l*, m can independently take on any real integer values.

(a•) False (b) True

15b. 7(5 points) What is the number of orbitals available for an atom with the quantum number $l = 2$?

(a) 2 (b) 3 (c) 4 (d•) 5 (e) 6

16b. 7•(5 points) Which best describes the node in a $2p_z$ orbital?

(a) spherical (b•) in the xy plane (c) in the yz plane
(d) in the xz plane (e) there is no node

17b. 7•(5 points) Which of the following photons has the highest energy?

(a) radio waves (λ = 0.5 m) (b) orange light (λ = 625 nm)
(c) microwaves ($\lambda = 10^{-3}$ m) (d•) near UV (λ = 250 nm)
(e) infrared (λ = 1000 nm)

Lowest wavelength -> highest energy

18b. 7•(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 50°C to 75°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 $E=h\nu$)

(a) 2.36×10^9 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

19b. 7•(9 points) The Schroedinger equation was revolutionary in that:

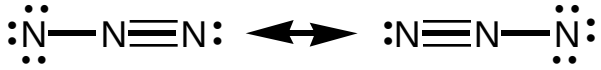
a) it explained the ejection of electrons from metals by light;
b) it introduced the concept of orbits and suggested that electrons circle an atom, much like planets circle the sun;
c) it suggested that the energy of a photon is related to its frequency by $E = h\nu$
d•) it treated the electron as a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

20b. 8•(9 points) The 4p electrons on Se (selenium) "see" an effective nuclear charge of:

(a) 5 (b) 15 (c) 31 (d•) 6 (e) 3

The 4p electrons on Se are screened by the 1s, 2s, 2p, 3s, 3p, and 3d electrons (a total of 28). Thus the total nuclear charge of +31 is reduced to +3.

Sodium azide (NaN_3) is used in automobile air bags. Two resonance forms for the azide anion are shown below



21b. 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) 1 (b•) 2 (c) 3 (d) 3/2 (e) 2/3

22b. 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

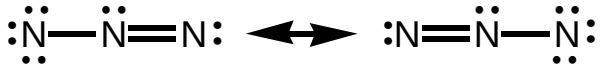
23b. 8•(5 points) What *net* charge do these resonance forms predict for the atoms at the ends?

(a) +2 (b) +1 (c) 0 (d•) –1 (e) –2

24b. 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

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



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) 1 (b) 2 (c) 3 (d•) 3/2 (e) 2/3

26b. 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

Bond Energies
$D_{C–H}$ = 413 kJ/mol
D_{C-O} = 358 kJ/mol
D_{O-O} = 146 kJ/mol
$D_{O=O}$ = 498 kJ/mol
D_{C-C} = 346 kJ/mol
D_{O-H} = 346 kJ/mol

27b. **9**(5 points) Predict the enthalpy ΔH_{rxn} of the following reaction:

$$2\ CH_3–CH_2–OH \rightarrow\ O_2\ +\ 2\ CH_3–CH_3$$

Which value below is closest to your value?

(a) +150 kJ/mol (b•) +300 kJ/mol (c) –150 kJ/mol (d) –300 kJ/mol
(e) can't tell from the data

ΔH = (Bonds broken) – (Bonds formed)

= [10x(C-H) + 2x(C-C) + 2x(C-O) + 2x(O-H)] – [(O=O) + 12x(C-H) + 2x(C-C)]

	ΔH_f^o
CH_3CH_2OH	–235 kJ/mol
CH_3CH_3	–85 kJ/mol

28b. **6**•(5 points) Re-calculate the enthalpy ΔH_{rxn} for the above reaction using the data at the right.

Which value below is closest to your value?

(a) +150 kJ/mol (b•) +300 kJ/mol (c) –150 kJ/mol (d) –300 kJ/mol
(e) can't tell from the data

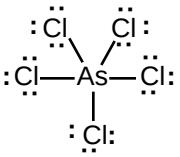
29b. **9**(5 points) Which calculation do you think provides the more correct answer ?

(a) Using bond energies (b•) Using heats of formation
(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 •) triangular-bipyramid (c) octahedral
(d) tetrahedral (e) trigonal pyramid

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.



31b. **9**(9 points) What is the molecular geometry of the cation BrF_4^+ ?

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

There are 5 "groups" of electrons aroundBr resulting in a trigonal bipyramid electron-pair geometry. One is a lone pair, resulting in a see saw-shaped molecular geometry.

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

(a) H_2O (b) NH_3 (c) HF (d•) CH_2Cl_2
(e) they are all polar

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

(a •) H_2S (b) PH_3 (c) SiH_4 (d) H_2 (e) O_2

34b. **10**(9 points) Which resonance hybrid orbitals on P are used to form PCl_5?

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

35b. **10**(9 points) Which resonance hybrid orbitals on S are used to form the anion SO_3F^- ?

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

(For questions 36-39). You have two flasks of equal volume. Flask A contains H_2 at 0°C and 2 atm pressure. Flask B contains CO_2 gas at 0°C and 1 atm pressure.

36b. 12•(9 points) Which flask contains the larger number of molecules?

(a) Flask B (b•) Flask A

(c) They have the same number of molecules

37b. 12•(9 points) Which flask has molecules with the larger kinetic energy per molecule?

(a) Flask B (b) Flask A

(c•) They have the same kinetic energy per molecule.

38b. 12•(9 points) Which flask has the larger total mass of gas?

(a•) Flask B (b) Flask A

(c) They have the same total mass of gas.

39b. 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 3.2 times faster than helium gas

(c•) Helium gas effuses 3.2 times faster than argon gas

(d) Argon gas effuses 10 times faster than helium gas

(e) Helium gas effuses 10 times faster than argon gas

40b. 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 He balloon (b •) The H_2 balloon

(c) They have the same number of molecules.