CHEM*1040
General Chemistry I
Midterm Examination, Fall 2010
University of Guelph, Department of Chemistry

VERSION 01 - RED

Family Name (print neatly): GRADING KEY
First Name (print neatly):
Signature:
Student ID Number:

Instructions: This examination consists of this cover page, 5 pages of questions and a data page. Please check that you have all pages. The data page may be removed and used for rough work, but it will not be graded.

No notes, printed material of any kind or communication with other students is permitted. Programmable calculators are not permitted. For page 5, only work in ink will be considered for re-grading.

You should have a RED coloured test scoring answer sheet.
Multiple choice answers must be recorded in PENCIL on the Test Scoring Answer Sheet within the time given for the examination. On side 1 of the Test Scoring Answer Sheet:

1. Print your family name and first name initial(s) in the appropriate boxes.
2. Fill in the circles with your name and first name initial(s).
3. Print your 7-digit STUDENT ID number in the appropriate boxes including leading zeros (e.g., 0123456).
4. Fill in the circles with your STUDENT ID number.
5. **Enter "01"** for the **"section number"** (to represent this version of exam)
6. Leave the E-mail ID section blank.
7. Record your answers within the examination period (i.e., 90 minutes).

Written Page (page 5)
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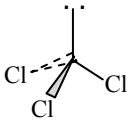
PART A: Multiple Choice Section [2 points each]

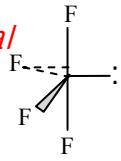
For each question, circle the letter of the one correct answer and enter the answer on the Test Scoring Sheet in pencil. The Test Scoring Answer Sheet will be considered final. Answers must be transferred to the Test Scoring Answer Sheet within the examination period. There is no penalty for incorrect answers.

1. Consider the molecules PCl_3 and SF_4. Comment on their polarity.

   A) PCl_3 is polar while SF_4 is nonpolar.
   B) SF_4 is polar while PCl_3 is nonpolar.
   C) Both PCl_3 and SF_4 are polar.
   D) Both PCl_3 and SF_4 are nonpolar.



PCl_3 V = 26e⁻ Framework: AB_3E Shape: trigonal pyramidal Polar



SF_4 V = 34e⁻ AB_4E seesaw Polar

2. Consider the reaction: $5O_{2(g)} + 4NH_{3(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(l)}$

   What are the limiting reactant and the number of moles of the other reactant remaining when 9.0 moles of oxygen and 9.0 moles of ammonia gas react?

   A) O_2 and 1.8 mol NH_3 remaining
   B) NH_3 and 2.2 mol O_2 remaining
   C) NH_3 and 1.8 mol O_2 remaining
   D) O_2 and 7.2 mol NH_3 remaining
   E) NH_3 and O_2 react with no excess

9.0 mol O_2 × 1 rxn/5 mol O_2 = 1.8 rxns — LR
9.0 mol NH_3 × 1 rxn/4 mol NH_3 = 2.25 rxns — Excess
1.8 rxns × 4 mol NH_3/1 rxn = 7.2 mol NH_3 will react
9.0 mol NH_3 - 7.2 mol NH_3 reacted = 1.8 mol remain

3. How many orbitals are there in the n = 2 energy level of any atom?

   A) 1 B) 3 C) 5 D) 2 E) 4

n = 2; ℓ = 0, 1
s = 1 orb; p = 3 orb

4. Which of the following pairs of species has the greatest difference in size?

   A) C and F — C > F (n = 2 (same row))
   B) Na and Mg — Na > Mg (n = 3 (same row))
   C) K^+ and Br — $K^+ < K$; $K > Br$ (n = 4 (same row))
   D) Li^+ and I^- — $Li^+ < Li$; $I^- > I$ (n = 2 & n = 5)
   E) O^{2-} and F^- — $O^{2-} < F^-$ (n = 2 (same row))

5. Iron is biologically important in the transport of oxygen by red blood cells from the lungs to the various organs of the body. In the blood of an adult human, there are ~2.60×10^{13} red blood cells with a total of 2.90 g of iron. On average, how many iron atoms are present in each red blood cell?

   A) 8.33×10^{-10}
   B) 1.20×10^{9}
   C) 3.12×10^{22}
   D) 2.60×10^{13}
   E) 5.19×10^{-2}

2.90 g Fe/ 2.60×10^{13} red blood cells × 1mol Fe/ 55.84 g Fe × 6.02×10^{23} Fe atoms/1 mol = 1.20×10^{9} Fe atoms per red blood cell

6. The following reactions occur at 500 K. Arrange them in order of increasing tendency to proceed to completion (least → greatest tendency).

   1. $N_2O_4 \rightleftharpoons 2NO_2$ K = 1.5×10^{3} *large #*
   2. $2SO_3 \rightleftharpoons 2SO_2 + O_2$ K = 1.3×10^{-5} *smallest #* *$K_2 < K_3 < K_1$*
   3. $2NO_2 \rightleftharpoons 2NO + O_2$ K = 5.9×10^{-5} *small #*

   A) 2 < 1 < 3 B) 1 < 2 < 3 C) 2 < 3 < 1 D) 3 < 2 < 1 E) 3 < 1 < 2

7. How many unpaired electrons are in an atom of zirconium, Zr (V = 40 for Zr)?

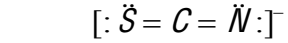
A) 0 B) 1 C) 2 D) 3 E) 4

Zr: [Kr] $4d^2\ 5s^2$ ↑ ↑ — — —

8. For the Lewis structure of the thiocyanate ion, SCN^-, in which carbon has a double bond with both sulfur and nitrogen atoms, the formal charges on the S, C and N atoms are, respectively,

A) 0, 0, -1
B) -1, 0, 0
C) -2, +1, 0
D) -1, +1, -1
E) -2, 0, +1

V = 6 + 4 + 5 + 1 = 16 e⁻

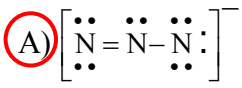


# of valance (V) e⁻'s: 6 4 5

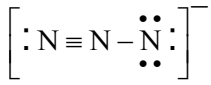
 # e⁻'s in diagram: 6 4 6

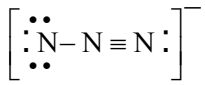
Formal Charges: 0 0 -1

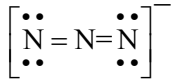
9. Which of the following is not a valid resonance structure for N_3^-? *V = 3(5)+1 = 16 e⁻'s*

A) 

This structure has 18e⁻'s

B) 

C) 

D) 

E) all are correct

10. What is the concentration of sulfate ions in a 250-mL volumetric flask labelled "0.22 M iron(III) sulfate"?

A) 0.055 M
B) 0.11 M
C) 0.16 M
D) 0.44 M
E) 0.66 M

$Fe_2(SO_4)_3(s) \rightarrow 2Fe^{3+}(aq) + 3SO_4^{2-}(aq)$

0.22 M 2 × 0.22 M = 0.44 M 3× 0.22 M = 0.66 M

11. What is the ground-state electron configuration of the nickel (II) ion, Ni^{2+} (V = 28 for Ni)?

A) [Ar] $3d^7 4s^1$
B) [Ar] $3d^8$
C) [Ar] $3d^6 4s^2$
D) [Ar] $3d^8 4s^2$
E) [Ar] $3d^{10} 4s^2$

Ni: [Ar] $3d^8\ 4s^2$

Ni^{2+}: [Ar] $3d^8$ ~~$4s^2$~~ = [Ar] $3d^8$

12. All the following species are isoelectronic EXCEPT

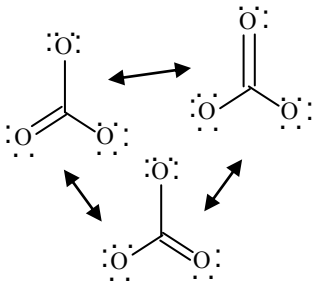
A) Ca^{2+} B) Mg^{2+} C) Cl^- D) Ar E) S^{2-}

V = 20 – 2 = 18 e⁻ V = 12 – 2 = 10 e⁻ V = 17 + 1 = 18 e⁻ V = 18 e⁻ V = 16 + 2 = 18 e⁻

13. Sulfur trioxide is known to be planar with all the oxygen atoms equidistant from the central sulphur atoms. On the bases of these facts, which conclusion(s) may be drawn concerning this molecule?

1. It can be represented by three equivalent resonance structures.
2. The dipoles associated with each S–O bond are equal in magnitude.
3. The sulphur atom is sp^2 hybridized.

A) 1 only
B) 2 only
C) 3 only
D) 1 and 2 only
E) 1, 2 and 3



SO_3: V = 24 e⁻
Framework: AB_3
Three resonance structures (moving double bond)
Shape: Trigonal planar
Non-polar
Hybridization: sp^2

14. Phosphoric acid is commercially produced by the three step "furnace method":

$2Ca_3(PO_4)_2(s) + 6SiO_2(s) + 10C(s) \rightarrow 4P(s) + 10CO(g) + 6CaSiO_3(s)$

$4P(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$

If 2.16×10^4 moles of H_3PO_4 (*aq*) are to be produced (~ 2 metric tonnes), how many moles of carbon (graphite) must have been added if all other reagents are in excess?

A) 2.16×10^5 mol
B) 1.38×10^5 mol
C) 5.40×10^4 mol
D) 8.64×10^3 mol
E) 3.38×10^3 mol

2.16×10^4 mol $H_3PO_4 \times \frac{1\ mol\ H_3PO_4}{4\ mol\ H_3PO_4} \times \frac{4\ mol\ P}{1\ mol\ P_4O_{10}} \times \frac{10\ mol\ C}{4\ mol\ P} = 5.40\times10^4$ mol C

15. If two gases exhibit identical lines in their emission spectra when excited,

A) the two samples must contain identical gases. *Identical emission lines means identical compound.*
B) the two samples must be at the same temperature.
C) the samples must contain a mixture of gases.
D) the absorption spectra must be examined before any conclusions can be made.
E) the two samples contain equal concentrations of at least two gases.

16. The measure of the attraction that an atom has for the electrons in a chemical bond is called

A) ionization energy
B) electronegativity
C) hybridisation
D) electron affinity
E) London forces

17. With what volume of 5.0 M HF will 0.100 moles of calcium hydroxide react completely?

A) 20. mL
B) 50. mL
C) 30. mL
D) 40. mL
E) 1.0×10^2 mL

$Ca(OH)_2(aq) + 2HF(aq) \rightarrow CaF_2(aq) + 2H_2O(l)$
0.100 mol × 2 mol HF/1 mol Ca(OH)2) = 0.200 mol HF
0.200 mol HF × 1L/5.0 mol HF = 0.040 L = 40. mL

18. Consider the following equilibrium: $2HgO_{(s)} + \text{heat} \rightleftharpoons 2Hg_{(l)} + O_{2(g)}$

The amount of Hg could be increased by:

1. adding some HgO. *No change*
2. removing some O_2. *Rxn moves L → R*
3. increasing the temperature. *Rxn moves L → R*

A) 1 only
B) 2 only
C) 3 only
D) 1, 2 and 3
E) 2 and 3 only

19. Consider the following orderings:

I. Al < Si < P < Cl
II. Be < Mg < Ca < Sr
III. I < Br < Cl < F
IV. $Na^+ < Mg^{2+} < Al^{3+} < Si^{4+}$

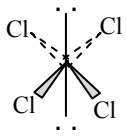
Which of these give(s) a correct trend in ionization energy?

A) III
B) I, II
C) I, IV
D) I, III, IV
E) II, IV

Ionization energy increases L → R across a row
& from bottom to top within a column

20. After evaluating the Lewis structure for the ion $TeCl_4^{2-}$, what is its final shape?

A) tetrahedral
B) octahedral
C) square pyramidal
D) square planar
E) seesaw



V = 36 e⁻'s
Framework: AB_4E_2
Shape: square planar

PART B. [Total of 20 points] Name: _____

1. Write the balanced net ionic equation for any reaction that occurs when the following aqueous solutions are mixed. Include states and clearly identify your final answer. If no reaction occurs, write no reaction.

(i) potassium phosphate and calcium chloride:

-1 for each mistake

$NIE: 3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s)$ (2 marks) (charges, states, balancing)

(ii) chromium(III) nitrate and ammonium sulfate:

No Reaction (2 marks)

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2. Gasoline (C_8H_{18}; MM = 114.22 g/mol) burns in oxygen to produce carbon dioxide and water. Balance the combustion equation below. What volume of oxygen at STP (i.e., 0°C and 1atm) is necessary to react with 1 gal of gasoline? The density of gasoline is 0.81 g/mL and 1 gal = 3.78 L. Show your work!

$$\underline{2\ (or\ 1)}\ C_8H_{18}(l) + \underline{25\ (or\ 25/2)}\ O_2(g) \rightarrow \underline{16\ (or\ 8)}\ CO_2(g) + \underline{18\ (or\ 9)}\ H_2O(l)$$

1 gal C_8H_{18} = 3.78 L C_8H_{18} = 3780 mL × 0.81 g/ 1 mL = 3062 g C_8H_{18} (1 mark)

3062 g C_8H_{18} × 1 mol/114.22 g = 26.8 moles C_8H_{18} (1 mark)

26.8 moles C_8H_{18} × 25 mol O_2/ 2 mol C_8H_{18} = 335 moles O_2 (1 mark)

$$V = nRT/P = \frac{335\ moles\ O_2 \times 0.0821\ atm \cdot L \cdot K^{-1} \cdot mol^{-1} \times 273.15\ K}{1\ atm}$$

(1 mark for T conversion) (1 mark for substitution)

V = 7500 L (1 mark)

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3. For the reaction, $2P(s) + 3I_2(s) \rightarrow 2PI_3(s)$, determine the percent yield of the reaction if 28.2 g of PI_3 is obtained from the reaction of 38.7 g of phosphorous with excess iodine. Show your work!

38.7 g P × 1 mol P/30.97 g = 1.25 moles P (1 mark)

$$1.25\ moles\ P \times \frac{2\ mol\ PI_3}{2\ mol\ P} = 1.25\ moles\ PI_3 \times \frac{411.67\ g\ PI_3}{1\ mol\ PI_3} = 515\ g\ PI_3$$ (1 mark)

(MM PI_3 = 30.97 + 3(126.9) = 411.67 g/mol) (1 mark)

$$\%\ yield = \frac{actual}{theoretical} \times 100\%$$

$$\%\ yield = \frac{28.2\ g}{515} \times 100\%$$ (1 mark for substitution & 1 mark for answer)

$$\%\ yield = 5.48\%$$

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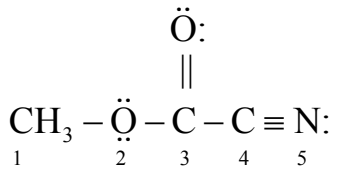
Complete the Lewis structure for the following molecule and fill in the blanks: (1 mark for each blank)



The C_1–O_2–C_3 bond angle is $< 109.5°$

This molecule has 8 sigma and 3 pi bonds. (must have < sign)

The types of orbitals that best describe the bond between atom (2) and (3) are $sp^3 - sp^2$.

Page Total

/20

Initials:

Name:

DATA SHEET (Any work on this page will NOT be graded.)

Gas constant, $R = 8.314\ J\ mol^{-1}\ K^{-1}$

$R = 8.314\ kPa\ L\ mol^{-1}\ K^{-1}$

$R = 0.0821\ atm\ L\ mol^{-1}\ K^{-1}$

$1\ atm = 101.3\ kPa = 760\ Torr$

$1\ nm = 1 \times 10^{-9}\ m$

Avogadro's Number $= 6.022 \times 10^{23}\ mol^{-1}$

$c = 2.998 \times 10^{8}\ m/s$

$h = 6.626 \times 10^{-34}\ J{\cdot}s$

$0°C = 273.15\ K$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds								

Molar Masses (g/mol)

H	1.01	Ne	20.18	Cl	35.45	Co	58.93
Li	6.94	Na	22.99	Ar	39.95	Ni	58.69
C	12.01	Mg	24.30	K	39.10	Cu	63.54
N	14.01	Al	26.98	Ca	40.08	Ag	107.87
O	16.00	P	30.97	Cr	52.00	I	126.90
F	19.00	S	32.06	Fe	55.84	Ba	137.33

Solubility Rules for some ionic compounds in water

1. All alkali metal and ammonium salts are SOLUBLE.
2. All nitrate, acetate, chlorate and perchlorate salts are SOLUBLE.
3. Most chloride, bromide & iodide salts are SOLUBLE -- EXCEPT for silver, lead or mercury (I) halides.
4. Most sulfate salts are SOLUBLE -- EXCEPT for silver, lead, mercury (I), calcium, strontium or barium sulfates.
5. Carbonate, phosphate & oxalate salts are NOT SOLUBLE -- EXCEPT for alkali metal or ammonium salts.
6. Hydroxides, oxides and sulfides are NOT SOLUBLE -- EXCEPT for alkali metal, ammonium, calcium, strontium or barium salts.
7. Chromate salts are NOT SOLUBLE -- EXCEPT for alkali metal, ammonium, calcium or magnesium chromates.

Circle how well you feel you did overall (out of 100%) on this exam.	80 – 100	70 – 79	60 – 69	50 – 59	0 – 49
	A	B	C	D	F