THE UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
CHEMISTRY 201, WINTER 2017
TERM TEST 2
Version 1

Date: Monday March 6th, 2017 Time: 7:00pm – 9:00pm

FIRST NAME: _____ **LAST NAME:** _____ **Lab Section:** _____

Lecture Section: Please check one, then fill in ID # on next page!

❑	L01	MWF	11:00 am	Dr. E. Sullivan
❑	L02	MWF	12:00 pm	Dr. E. Sullivan
❑	L03	TR	8:00 am	Dr. V. Mozol

Statement about the use of electronic devices / examination aids: This is a closed-book examination. The use of camera devices, MP3 Players and headphones, or wireless access devices such as cell phones, Blackberries, etc., during the examination will not be allowed. Only non-programmable calculators and molecular model kits are permitted for this examination. A Chemical Data Sheet is on the final page of this exam.

Instructions: This test consists of **14 multiple choice** questions worth 2 marks each (total 28 marks) and **5 long answer** questions (total 32 marks). The total value for the test is 60 marks. The exam has 15 pages make sure you have all 15 pages.

All questions must be answered to obtain full marks. The answers to the multiple choice section must be entered on the optical score sheet. The time limit includes the time necessary to fill in the answers on the optical score sheet. The answers to the long answer questions must be written in the space provided on the question sheets AND **written in non-erasable ink** to be eligible for re-grading. All required work must be shown in order to obtain full marks on long answer questions.

AT THE END OF THE EXAMINATION, HAND IN THE OPTICAL SCORE SHEET AND THE ENTIRE EXAM PAPER

Failing to encode this Exam Booklet or your Optical Score Sheet correctly, for your name, ID and lecture section, will result in the loss of two marks

ID……	Q15…… Q16……. Q17……. Q18……. Q19……. DO NOT WRITE IN THIS BOX, FOR GRADING PURPOSES ONLY!

SECTION I - Machine graded section (Total value 28)
To be answered on provided Optical Score Sheet

Below please see the learning outcomes for each question. Besides in lecture, we have highlighted other places where you would have seen the material for each question.

1. Maleic acid is a diprotic acid. It can be titrated for total acid content like the citric and ascorbic acids in Experiment 3.

   If a solution is prepared that contains 1.5 mol of Maleic acid in 1.0 L of water, how many moles of OH^- will be needed to titrate this solution to an endpoint?

   a) 4.5 mol
   b) 3.0 mol
   c) 2.0 mol
   d) 1.5 mol
   e) 0.75 mol

Learning outcome(s):

-Determine the theoretical and percent yield of a chemical reaction.

Seen in Lab #3 and Stoichiometry review quiz on D2L.

2. For which of the atom/ions below, is the given electron configuration correct?

	Species	Electron Configurations
i.	Cr	[Ar] $4s^2\ 3d^4$
ii.	V^{3+}	[Ar] $4s^2$
iii.	Sc^+	[Ar] $4s^2$

   a) i & ii are correct
   b) ii & iii are correct
   c) Only i is correct
   d) All of them are correct
   e) None of them are correct

Learning outcome(s):

-Determine the e- configurations for stable ions of the elements.

-Recognize and explain the reason for exceptions to ground state configurations.

Seen on Term Test #1 in Questions 6 & 13.

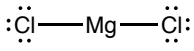
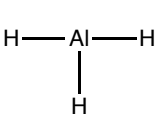
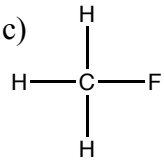
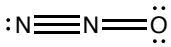
3. Which lists the ions in order of increasing size?

a) $Na^+ < Al^{3+} < P^{3-} < Cl^-$
b) $Cl^- < P^{3-} < Al^{3+} < Na^+$
c) $Al^{3+} < Na^+ < Cl^- < P^{3-}$
d) $Na^+ < Al^{3+} < Cl^- < P^{3-}$
e) None of the above are organized correctly

Learning outcome(s):
-Explain changes in size, ionization energy and electron affinity for an atom and its ions.
-Order a given series of elements or ions by size, ionization energy and/or electron affinity then justify the answer.

Seen in Question 7 of Term Test #1

4. Which of the following is a correct best Lewis structure?

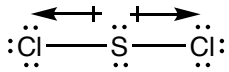
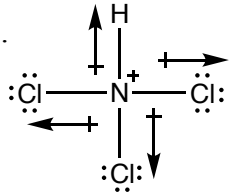
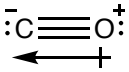
a) 
b) 
c) 
d) 

e) None of the above structures are correct best Lewis structures.

Learning outcome(s):
-Predict and rationalize the type of bonding that occurs between atoms by using electronegativity differences.
-Generate valid Lewis diagrams that show all non-zero formal charges.

Seen in Tutorial #2

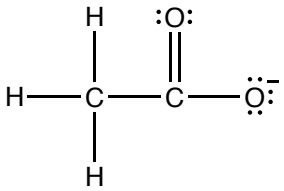
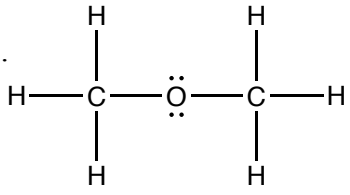
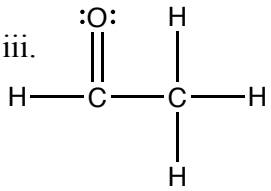
5. Which of the following have the bond polarity/dipoles drawn correctly?

i. 
ii. 
iii. 

a) i only
b) ii only
c) iii only
d) i and ii only
e) ii and iii only

Learning outcome(s):
-Identify bonds of significant polarity in a chemical species.

6. Rank, in order of increasing bond length, the carbon oxygen bonds for the following chemical species.

i. 
ii. 
iii. 
iv. 

a) iv < iii = i < ii
b) iv < iii < i < ii
c) ii < i = iii < iv
d) ii < i < iii < iv
e) iv < iii < ~~i~~ < ~~ii~~
ii i

Learning outcome(s):
-Determine bond orders within a chemical species.
-Generate and identify a valid resonance hybrid, which includes formal charges and bond orders, for a set of for a set of resonance structures.

Consider molecules i through iv when answering questions 7 to 10:

BF_3	SeO_2	NO_2^+	NO_2^-
i	**ii**	**iii**	**iv**

7. Which of the above species will have a tetrahedral electron-pair geometry?

a) ii only
b) ii and iii only
c) ii and iv only
d) All of the above
e) None of the above

Learning outcome(s) for 7-10:
-Generate valid Lewis diagrams that show all non-zero formal charges.
-Recognize when the octet rule can be violated.

Seen in Tutorial #2 & #3
SeO_2 same as SO_2, BF_3 same BH_3. NO_2^- similar to HNO. NO_2^+ similar to CO_2.

8. Which of the above species will have a bent molecular shape?

a) i only
b) i and ii only
c) ii and iv only
d) i and iii only
e) None of the above

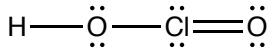
9. Which of the following gives the correct bond angles for each structure?

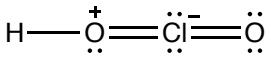
	i	ii	iii	iv
a)	<109.5°	180°	<120°	<109.5°
b)	120°	<120°	<109.5°	<120°
c)	<109.5°	<120°	180°	180°
d)	120°	<120°	180°	<120°
e)	120°	<109.5°	180°	<109.5°

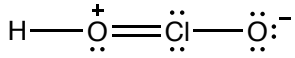
10. Which of the following species would have the shape shown to the right?

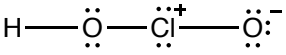
a) ii only
b) ii and iii only
c) ii and iv only
d) none of them
e) all of them

11. Rank the following resonance structures for $HClO_2^-$ from most to least stable.

i. 

ii. 

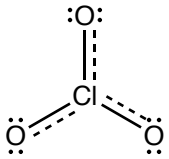
iii. 

iv. 

a) i > ii = iii = iv
b) iv > iii = ii > i
c) iv > iii > ii > i
d) i > iv > iii > ii
e) None of the above give the correct ranking.

12. Which of the following would be correct about an ion of ClO_3^-, for which formal charges have been minimized.?

i. The resonance hybrid before the identification of formal charge(s) and bond order(s) is:



ii. The chlorine oxygen bond orders are all 5/3 or 1 and 2/3.

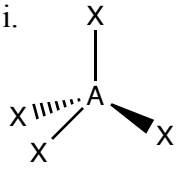
iii. Taking into consideration resonance, the overall formal charge of the ClO_3^- ion becomes –1/3.

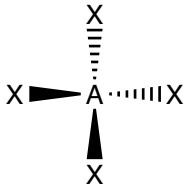
iv. The bond angles are 120°.

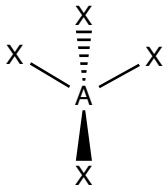
a) All of the options i-iv are correct
b) Only i and ii are correct
c) Only ii and iii are correct
d) Only ii, iii and iv are correct
e) Only ii is correct

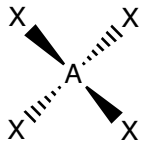
Learning outcome(s) for 11-12:
-Recognize when the octet rule can be violated.
-Distinguish equivalent from non-equivalent resonance structures.
-Generate and identify a valid resonance hybrid, which includes formal charges and bond orders, for a set of for a set of resonance structures.
Similar to last question in Tutorial #2 individual quiz

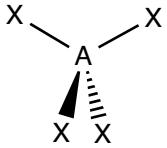
13. Which of the following orientations/representations is/are possible with a tetrahedral electron-pair geometry?

i. 

ii. 

iii. 

iv. 

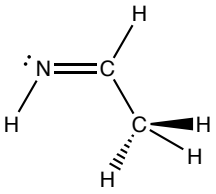
v. 

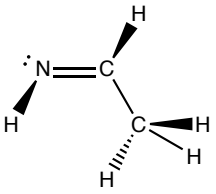
a) iv & v only
b) v only
c) i and ii only
d) i, ii, iii and v only
e) ii, iii and iv only

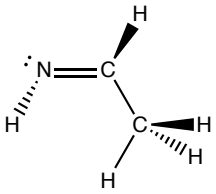
Learning outcome(s) for 13-14:
-Assign approximate bond angles.
-Recognize variations in orientation of VSEPR diagrams for the same geometries/shapes.

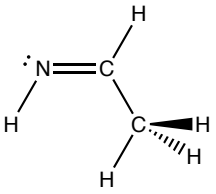
13 same as question #3 in group quiz for Tutorial #3.
14 similar to question #4 in group quiz for Tutorial #3.

14. Which of the following is a correctly drawn VSEPR structure for C_2H_5N?

a) 

b) 

c) 

d) 

e) none of the above are correctly drawn VSEPR structures.

**********END OF MULTIPLE CHOICE**********

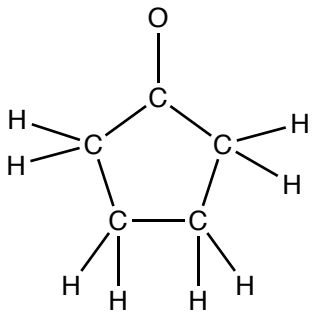
SECTION II: To be graded manually (Total value 32)

Answers must be written in non-erasable ink to be considered for re-grading!
Show all your work for full marks.

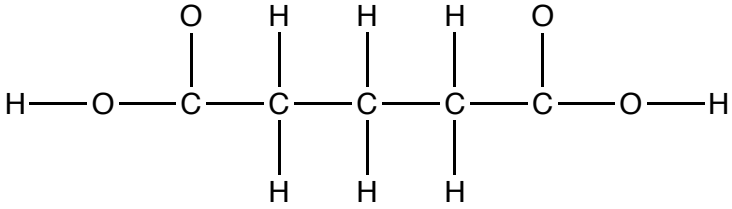
QUESTION 15 VALUE 7 MARKS

a) Complete the following Lewis structure skeletons by adding multiple bonds and/or lone pairs where needed:

Structure A:



Structure B:



b) Structure A (C_5H_8O) when mixed with CrO_3 in acidic conditions undergoes a redox reaction to make the corresponding Structure B ($C_5H_8O_4$) and Cr^{3+}, as shown in the unbalanced reaction shown below. Complete the steps to balance this reaction by drawing out both of the half reactions and then combining to get the overall balanced redox reaction.

$$C_5H_8O \quad + \quad CrO_3 \quad \rightarrow \quad C_5H_8O_4 \quad + \quad Cr^{3+}$$

Learning outcome(s) for 15:
-Balance a chemical reaction given the reactant(s) and product(s) (for example: acid/base or redox reactions).
-Identify the limiting and excess reagents given experimental data.
-Determine the theoretical and percent yield of a chemical reaction.

Balancing a Redox reaction under acidic conditions was seen in Lab #2 and completing a Lewis structure seen in Tutorial #2.
Determining Limiting reagent calculation seen in question #1 of Term Test #1.

c) If 0.22 moles of Structure A reacted with 0.37 moles of CrO_3, which would be the limiting reagent?

d) If 0.050 moles of Structure B were made when performing this reaction, what would be the percent yield for this reaction?

QUESTION 16 VALUE 4.5 MARKS

This question focuses on the species PO_2^-.

a) In the box to the right draw the best Lewis diagram for PO_2^-.

b) PO_2^- can have_____resonance structures.
equivalent / non-equivalent / both equivalent & non-equivalent / no

c) Explain your answer to b). Use diagrams as part of your explanation.

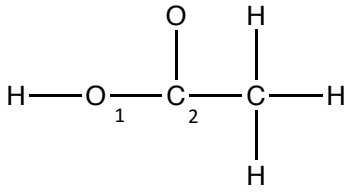
Learning outcome(s) for 16:
-Generate valid Lewis diagrams that show all non-zero formal charges.
-Recognize when the octet rule can be violated.
-Generate valid Lewis diagrams for a chemical formula or condensed formula and vice versa.
-Generate and identify valid resonance structures.
-Distinguish equivalent from non-equivalent resonance structures.
-Recognize when a chemical species is said to display resonance.

Similar P containing compounds were seen in Tutorial #2 and in the practice questions.

QUESTION 17 VALUE 10.5 MARKS

a) Complete the molecular skeletons for Structures A and B, by (i.e. add multiple bonds and/or lone pairs where needed). Use the information to then fill in the blanks and draw their VSEPR diagrams.

Structure A:



condensed formula _____ functional group _____

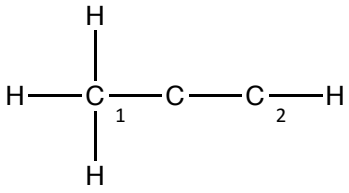
IUPAC name _____

VSEPR diagram:

Learning outcome(s) for 17:
-Generate valid Lewis diagrams.
-Identify functional groups
-Generate a name given the structure for an organic compound that possesses a single functional group and vice versa.

Similar compounds were seen in Labs #2 & #3, Tutorial #3 and within the available practice questions.

Structure B:



condensed formula _____ functional group _____

IUPAC name _____

VSEPR diagram:

b) Fill in the tables below to complete the VSEPR details for the atoms indicated in the molecular skeletons given in 17 a).

Atom	Electron-pair Geometry	Molecular Shape	Bond Angles
O_1			
C_2			

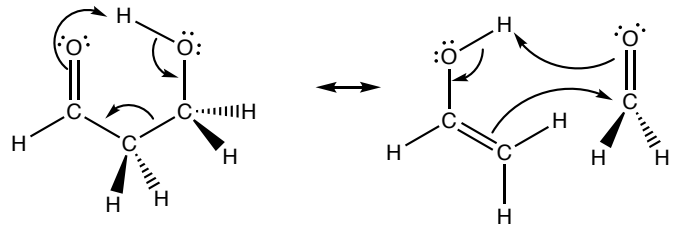
Atom	Electron-pair Geometry	Molecular Shape	Bond Angles
C_1 (in CH_3 group)			
C_2 (in CH group)			

QUESTION 18 VALUE 4 MARKS

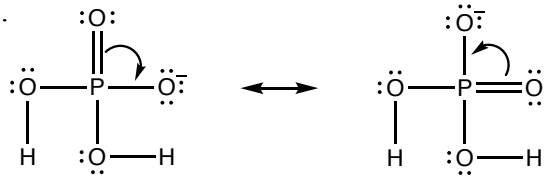
Curved arrows are tools that can be used to show electron movement involved in both resonance and chemical reactions.

Use examples i-iv to answer the following questions a) and b) below.

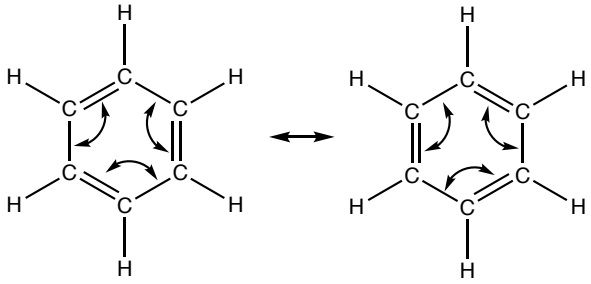
i.



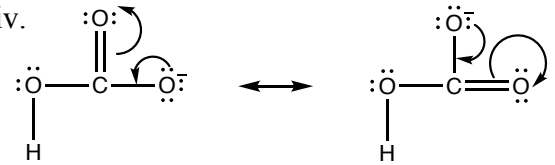
iii.



ii.



iv.



a) Identify which demonstrates an incorrect use of curved arrows and explain your reasoning (there may be more than one incorrect answer).

b) Identify which use arrows to explain the electron movement in a chemical reaction and how it differs from the electron movement in resonance.

Learning outcome(s) for 18:

-Use curly arrows to interconvert resonance structures.

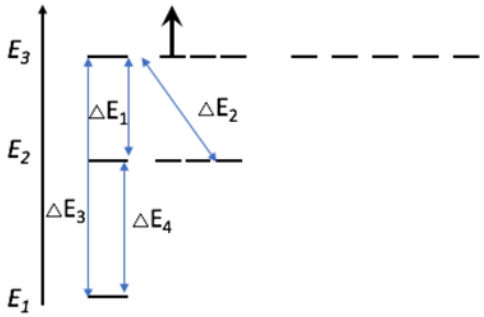
-Use structures and curved arrows to explain bond breaking and bond making.

This material was addressed in detail in lecture and within the available practice questions.

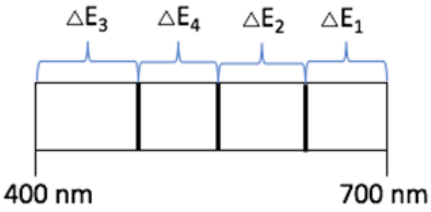
QUESTION 19 VALUE 6 MARKS

Students in a previous year were asked a certain set of questions. For each of the questions and the given responses, in the corresponding boxes, identify whether the student response is correct or incorrect and the corrections that need to be made.

a) **Question:** Use the energy diagram, given on the right, to draw the emission spectrum for a collection of Hydrogen atoms whose valence electrons have been excited to n=3 then emitted photons as they relaxed back down to their ground state.



Student response:



Correction to be made and why or why it is correct:

correct: ☐

incorrect: ☐

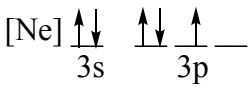
Learning outcome(s):

-Explain qualitatively how an atomic spectrum is obtained experimentally.
-Relate the energy, wavelength or frequency of any photon in an atomic spectrum to the difference between ground and excited states.

This question was question 12 on Term Test #1.

b) **Question:** What is the shorthand orbital box diagram for P?

Student response:



Correction to be made and why or why it is correct:

correct: ☐

incorrect: ☐

Learning outcome(s):

-Determine the ground state e- configurations for the first 36 elements using Aufbau, Pauli and Hund's principles.
-Generate e- configurations in spdf notation, using energy diagrams or orbital box diagrams, and rationalize when to use one type versus another.

This question was addressed in question 13 on Term Test #1.

c) **Question:**
$\Delta_{EA}H$ for O = -141 kJ/mol
$\Delta_{EA}H$ for Cl = -349 kJ/mol,
Explain why this difference exists.

Student response:
Because Cl has a higher n-value the electrons are further from the nucleus, giving the atom more room and the ability to add additional electron(s).

Correction to be made and why or why it is correct:

correct: ☐

incorrect: ☐

Learning outcome(s):
-Rationalize physical properties using the distance the valence e-s are from the nucleus (n) and the pull of the nucleus on these e-s (Z).*
-Explain changes in size, ionization energy and electron affinity for an atom and its ions.

This question was addressed in questions: 9, 10 & 13 on Term Test #1.

*********END OF WRITTEN ANSWER SECTION*********

PERIODIC TABLE

1 1A												13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H 1.008	2 2A																2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57* La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89** Ac (227)	104 Rf (261)	105 Ha (262)	106 Sg (263)	107 Ns (262)	108 Hs (265)	109 Mt (266)	110 Uun (269)	111 Uuu (272)							

Lanthanides *	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides **	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

Useful constants:

amu = 1.66054×10^{-27} kg

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

= 0.08205 L atm mol^{-1} K^{-1}

Avogadro's number, N_A = 6.022×10^{23} mol^{-1}

Speed of light, c = 2.998×10^{8} m s^{-1}

Planck's constant, h = 6.626×10^{-34} J s

STP = 0°C and 1 atm

Mass of an electron = 9.1094×10^{-31} kg

Useful conversions:

1 atm = 760 mmHg

= 760 torr

= 1.01325×10^{5} pascals

K = °C + 273.15

1J = 1kg.m^2/s^2

Electronegativities

1 1A												13 3A	14 4A	15 5A	16 6A	17 7A
H 2.2	2 2A															
Li 1.0	Be 1.6											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.3	3	4	5	6	7	8	9	10	11	12	Al 1.6	Si 1.9	P 2.2	S 2.6	Cl 3.2
K 0.8	Ca 1.0	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.8	Ge 2.0	As 2.2	Se 2.6	Br 3.0
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.3	Nb 1.6	Mo 2.2	Tc 1.9	Ru 2.2	Rh 2.3	Pd 2.2	Ag 1.9	Cd 1.7	In 1.8	Sn 2.0	Sb 1.9	Te 2.1	I 2.7
Cs 0.8	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 2.4	Re 1.9	Os 2.2	Ir 2.2	Pt 2.3	Au 2.5	Hg 2.0	Tl 1.6	Pb 2.3	Bi 2.0	Po 2.0	At 2.2