Chemistry 14A
Dr. Scerri
Final exam
March, 2022

3 hours.

PROBLEM	SCORE	POINTS
1		18
2		16
3		18
4		21
5		18
6		22
7		15
8		15
total		143

Name Grace Reimer

Signature [signature]

ID # 505687969

Please note:

Some questions carry more points than others.

Instructions: **This exam has 8 questions plus a periodic table at end of exam. Verify you have the right number of pages before you begin. Write your name on each page.** Raise your hand if you don't understand a question. **SHOW YOUR WORK!** No credit will be given for an unsubstantiated or illegible answer. Write legibly, use proper units throughout and use significant figures in all answers. **If you exceed the line limit any additional material will not be read by graders** Good luck!

Possibly useful information:

$h = 6.63 \times 10^{-34}$ J sec $N_o = 6.02 \times 10^{23}$ mol^{-1} $c = 3.00 \times 10^{8}$ m sec^{-1}

$m_e = 9.11 \times 10^{-31}$ kg   1 a.m.u. = 1.66×10^{-27} kg   1 Å = 10^{-10} m

g = 9.81 m/s   R = 0.0821 liter·atm/mol·K = 8.3145 J/mol·K

1 eV = 1.602×10^{-19} J   K.E. $= 1/2mv^2 = p^2/2m$

$\lambda\nu = c$ $\Delta E = E_f - E_i = \varepsilon_{photon} = h\nu$ $h\nu = h\nu_0 + $ K. E.(electron)

$\lambda_{mass} = \frac{h}{mv} = h/p$ $m\Delta v\Delta x = \Delta p\Delta x \geq \frac{h}{4\pi}$

$E_n = -(2.18 \times 10^{-18}\ J)Z^2/n^2$ n-ℓ-1 spherical (radial) nodes; ℓ angular nodes; n-1 total nodes

Bond order = (# bonding electrons - # antibonding electrons)/2

To solve a quadratic equation, $ax^2 + bx + c = 0$,

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

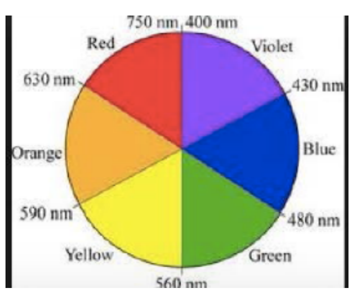
$p_A = \chi_A \times P_T$

$K_p = K_c (RT)^{\Delta n}$

For ΔH + $\ln K \propto -1/T$

$[H^+][OH^-] = 10^{-14}$ at 25^0C and 1 atmo,   pH + pOH = 14 at 25^0C.

$K_a \times K_b = K_w = 10^{-14}$ at 25^0C.



$+0.6\ \Delta$

$-0.4\ \Delta$

Spectrochemical series (abbreviated) $Cl^- < F^- < H_2O < NH_3 < en < CN^-$

1a. The Russian chemist Mendeleev was one of six discoverers of the periodic system. However he is given the most credit for the discovery. Briefly explain why. (2)

Mendeleev was successful at predicting a couple of elements that were discovered later on.

1b. The element helium can be placed in groups 2 or 18 of the periodic table. Explain the basis for each of these options. (3)

Group 18 : He forms no compounds, Noble gases, Has full outer shell which is like noble gases

Group 2: He has 2 e's Group 2's elements have 2 outer e's

1c. A compound which weighing 200 grams contains only carbon, hydrogen, oxygen and nitrogen. By analysis, it is found to contain 97.56 grams of carbon, 4.878 g of hydrogen, 52.03 g of oxygen and 45.53 g of nitrogen. Find its empirical formula. (5)

C $97.56g \times \frac{1}{12g} = 8.13 = 2.5$ 5

H $4.878g \times \frac{1}{1g} = 4.878 = 1.5$ 3

O $52.03g \times 1/16g = 3.252 = 1$ 2

N $45.53 \times 1/14g = 3.252 = 1$ 2

$C_5H_3O_2N_2$

1d. Consider the following reaction

3 Cu(s) + 8 HNO_3(aq) ---------> 3 $Cu(NO_3)_2$(aq) + 2 NO(g) + 4 H_2O(l)

i) How many moles of NO are produced by the reaction of 4.0 moles of copper with excess HNO_3? (2)

$4 \text{ mol Cu} \times \frac{2 \text{ mol NO}}{3 \text{ mol Cu}} = 2.66$ mol or 2.7 (2 sig fig)

ii) How many moles of HNO_3 are required to react completely with 20.0 g of copper? (3)

$20 g \times \frac{1 \text{ mol Cu}}{63.55 g} \times \frac{8 \text{ mol } HNO_3}{3 \text{ mol Cu}} = 0.839$ mol (3 sig fig)

iii) How many grams of NO are produced by the reaction of 6.35 grams of Cu with excess HNO_3? (3)

$6.35 \div 63.546 = .099928$ moles Cu

$(0.099928 \times 2) \div 3 = 0.0222$ moles of NO

2. The work function for lithium is 4.60 x 10^{-19} J.

(a) Calculate the lowest frequency of light that will cause photoelectric emission. (2)

$\Phi = h\nu_0$

$4.6 \times 10^{-19}\ J = h\nu_0$

$\nu_0 = \frac{4.6 \times 10^{-19} J}{h} = \frac{4.6 \times 10^{-19} J}{6.63 \times 10^{-34} J/sec}$

$\nu_0 = 6.9 \times 10^{14} sec^{-1}$

(b) What is the maximum energy of the electrons emitted when light of 7.35 x 10^{14} Hz is used? (2)

$E = \Phi + KE$

$h\nu = h\nu_0 + KE$

$KE = h\nu - \Phi$

$KE = (6.63 \times 10^{-34})(7.35 \times 10^{14} Hz) - 4.6 \times 10^{-19} J$

$KE = 2.7 \times 10^{-20} J$

(c) What is the wavelength of these electrons? (2)

$KE = \frac{1}{2}mv^2$

$V = \sqrt{\frac{2KE}{m}}$

$V = \sqrt{\frac{2(2.7 \times 10^{-20} J)}{9.11 \times 10^{-31} Kg}}$

$V = 2.435 \times 10^5$

$\lambda = \frac{h}{mv}$

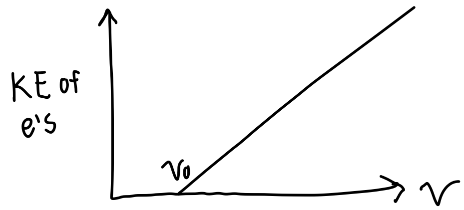
$\lambda = \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31})(2.435 \times 10^5)}$

$\lambda = 3.0 \times 10^{-9} m$

(d) How does the Pauli Principle help to explain why electrons don't collapse into the nucleus in an atom such as Neon? (3)

Because only 2 electrons can fill the 1s orbital, it provides the repulsive forces essential to prevent collapse into the nucleus. These 2 electrons have opposing spin in the 1s orbital.

(e) Sketch a graph of kinetic energy of ejected electrons against frequency of light that strikes the metal. Comment on the importance of the threshold frequency for the development of quantum theory of light. (4)



Threshold energy states the minimun energy which is threshold energy of $h\nu_0$ is also known as quantum light energy, particle of light, or photon of light

(f) An electron has an uncertainty in velocity of 10.5 m/s. Calculate the uncertainty in it's position. (3)

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x \Delta mv \geq \frac{h}{4\pi}$$

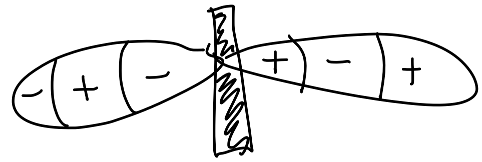
$$\Delta x \geq \frac{h}{4\pi} \times \frac{1}{m\Delta v}$$

$$\Delta x \geq \frac{6.63 \times 10^{-34}}{4\pi} \Bigg| \frac{1}{(9.11 \times 10^{-31})(10.5 m/s)}$$

$$\Delta x \geq 5.52 \times 10^{-6} m$$

3a. Draw the 3-D contour surfaces for a 4p orbital, including any phases and nodes. (4)

2|p has 2 radial nodes

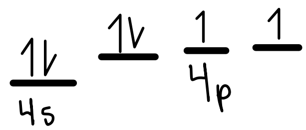


$4-1-1=2$

3b. Give the full configuration of the selenium atom. (No using noble gas cores). (3)
Also show the correct order or orbital occupation.

$1s^2 2s^2 3p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$

$_{34}Se$



3c. Give the full configuration of the molybdenum atom (hint: It shows an anomalous configuration). Show correct order of orbital occupation. (3)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^3 5s^1$

$_{42}Mo$

3d. Consider the 5th shell of an atom. How many orbitals does it contain and what are their labels? (no need to show individual orbital labels) (3)

5s 5p 5d 5f 5g
1 3 5 7 9 = 25

$5^2 = 25$

3e. How many electrons would be required to completely fill the 10th shell? (2)

$2n^2 \quad 2(10^2) = 200$

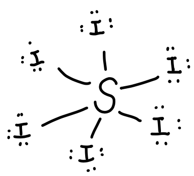
3f. Under what conditions do two waves produce destructive interference? (3)

One condition is when the path length difference is $0 = (2n-1)\frac{\lambda}{2}$

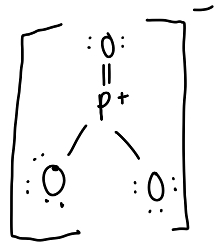
Another condition would be if the waves are in phase

4a. Draw the Lewis structures of the following molecules or ions **and show working,**

(i) SI_6 (ii) PO_3^- (6)



$V = 6 + 6(7) = 48$
$NG = 7 \times 8 = 56$
$B = 56 - 48 = 12$
$LP = 48 - 12 = 36$



$V = 5 + 3(6) + 1 = 24$
$NG = 4(8) = 32$
$B = 32 - 24 = 8$
$LP = 24 - 8 = 16$
charge P = 5 - 4 + 1
double bond O = 6 - 6 = 0 -1

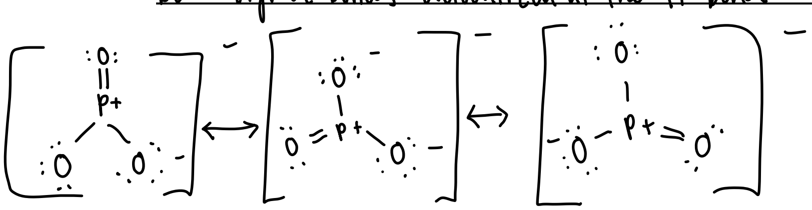
4b. What is 'wrong' with the Lewis structure in (ii) of the PO_3^- ion in the light of the experimental evidence on this ion which shows all bond lengths to be the same? (2)

The lewis structure of PO_3 shows that there are different lengths for double bonds and single bonds which is wrong.

4c. How can the Lewis structure be modified to attempt to correct the problem alluded to in 4b without appealing to any quantum concepts and why is this aproach unsatisfactory? (4)

- Add resonance structures to modify

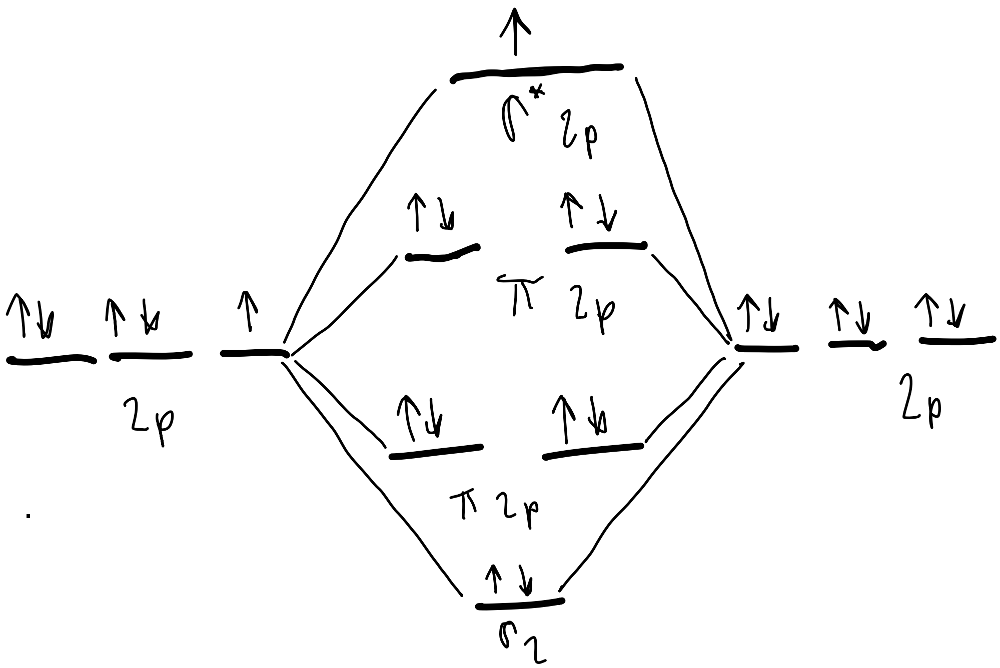
That approach doesn't work because it suggests double bonding jumping about, when it should be 3 signmet bonds delocalized at the pi bond



4(d) How can the Lewis structure of PO_3^- ion be modified according to the quantum theory of bonding? Give a diagram and explain briefly. (3)

This structure can be modified by making it PO_3^{3-}

4e. Draw a fully labeled molecular orbital diagram for the hypothetical Ne_2^{2+} ion and calculate its bond order (6)



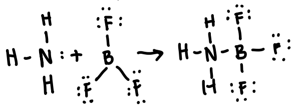
$$\text{Bond order} = \frac{(\text{no. of bonding } e^{-}\text{s}) - (\text{no. of antibonding } e^{-}\text{s})}{2}$$

$$= \frac{(10-8)}{2} = \frac{2}{2} = 1$$

Bond order = 1

5a. How does the Lewis theory define an acid and a base? (2)

A lewis acid is a molecule that accepts an electron pair, but a lewis base is a molecule that donates an electron pair.

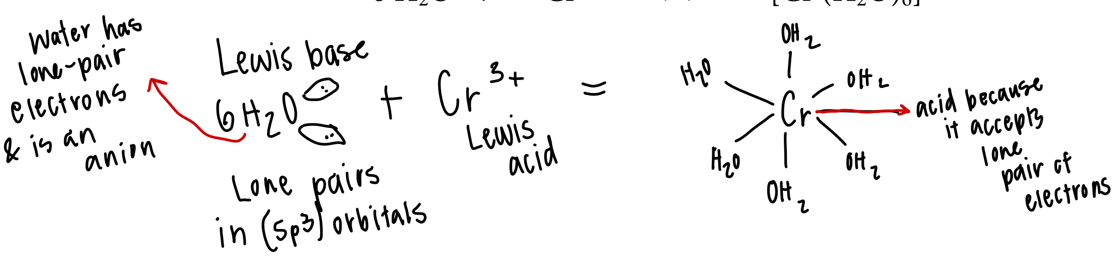


Boron trifluoride is Lewis Base

This example shows ammonia is a lewis acid

5b. Explain how the following reaction is an acid-base reaction of the Lewis type. (3)

$6\ H_2O + Cr^{3+} \Longleftrightarrow [Cr\ (H_2O)_6]^{3+}$



5(c) Explain how a sample of water can have a pH of 6 and yet can still be neutral Your response should include a reference to K_W values. (4)

Water can still be neutral because its capable of both donating and accepting protons. Even if waters ph changes there will always be an equal concentration of hydrogen to oxygen ions $K_w = [H_3O^+][OH^-] = 10^{-14}$

5(d) What is the pH of a solution of 0.060 M $Sr(OH)_2$ which is a strong base? (3)

$0.060 \times 2 = .12\ M\ OH^-$

$pOH = -\log[.12] = 0.92$

$pH = 13.08$

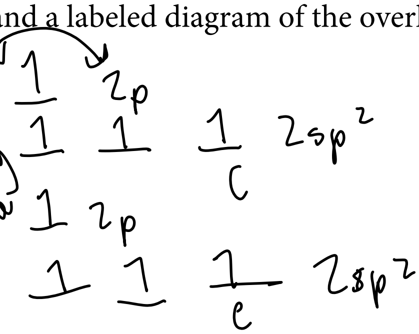
$pH + pOH = pK_w \quad 14 - .92 = 13.08$

at $25^{\circ}C$ $pK_w = 14$

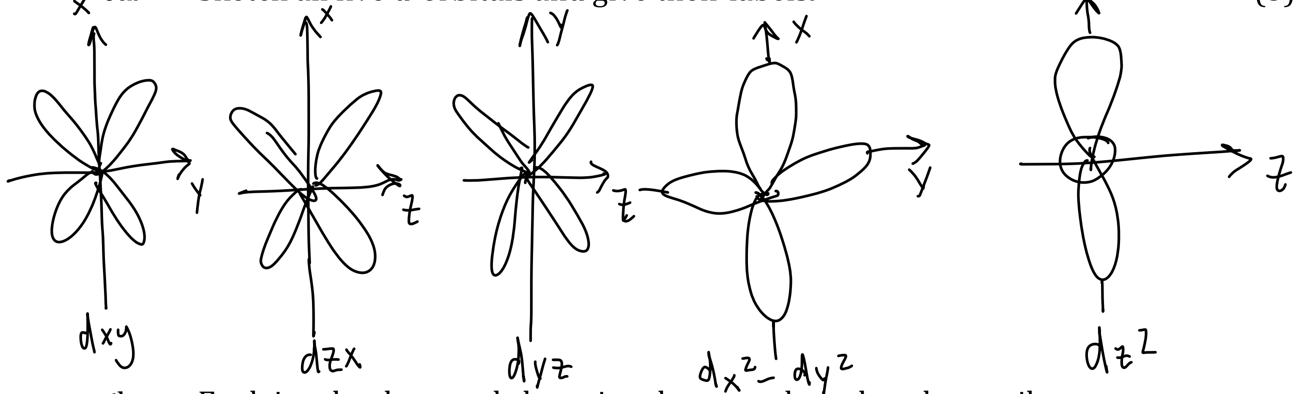
5(e) Use the concept of hybridization to explain the shape of the C_2 molecule. Your response should also include box diagrams to show which orbitals are being hybridized and a labeled diagram of the overlapping orbitals. (6)

its okay for the 4th electron to go here we it is interg etically favorable

These are the orbitals being hybridized



6a. Sketch all five d-orbitals and give their labels. (5)



6b. Explain why the metal chromium has no color other than a silvery appearance whereas compounds of nickel such as $[Ni(H_2O)_6]^{3+}$ have colors (4)

Because Chromium is not a transition metal. Transition metals

are able to do this because of the energy levels of the d block, electrons

are excited or moved between energy levels, when bonded to other elements

6c. What can you deduce about the ligands in a transition metal compound that appears orange ? (2)

This is a strong field ligand that caused a significant split within the energies of d orbitals within this compound.

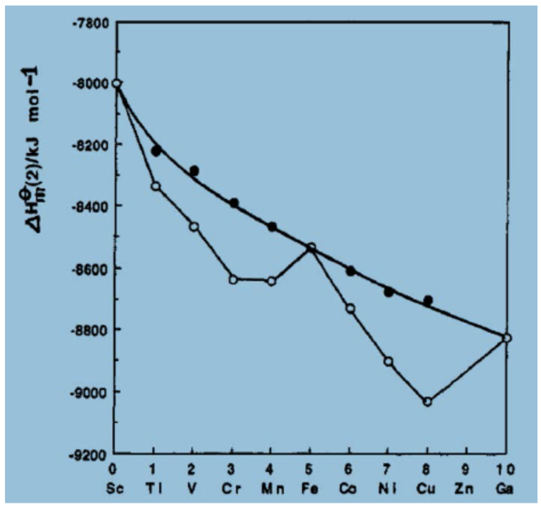
6d. Explain the nature of the bonding between the ligands and the metal ion in $[Fe(CN)_3(H_2O)_3]$. Also explain how the metal ion is able to accept six lone pairs of electrons. (4)

____

____

____

6e. Calculate the crystal field stabilization energy (CFSE) in the following compounds, d^7 (low field), d^5 (high spin). Show all working. (4)



6f. How is the above diagram connected with the CFSE of transition metal compounds? (3)

____

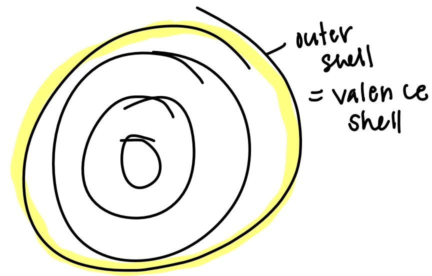
____

____

Multiple choice. Choose one best response by circling. When relevant show working in margins or an empty space. [for 7 iii - v incl' and 8 i, ii, v] (3 points each question).

7(i) The valence electrons of representative elements are

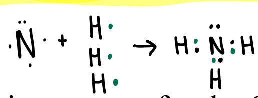
(a) in s orbitals only.
(b) located in the outermost occupied major energy level.
(c) located closest to the nucleus.
(d) located in d orbitals.
(e) located in the innermost occupied shell.



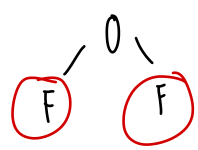
(ii) Which of the following does not have a noble gas electron configuration? (or which of the following is not isoelectronic with a noble gas?)
(a) S^{2-}
(b) Ba^{+}
(c) Al^{3+}
(d) Sb^{3-}
(e) Sc^{3+}

Ba+ alkaline earth metal
noble gas conf. of xenon
has 2 valence electrons whic lost when forming ionic compounds

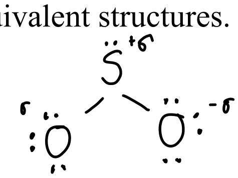
(iii) The correct Lewis structure for hydrogen cyanide shows:
(a) 2 double bonds and two lone pairs of electrons on the N atom.
(b) 1 C-H bond, 1 C=N bond, 1 lone pair of electrons on the C atom and 1 lone pair of electrons on the N atom.
(c) 1 C-H bond, 1 C-N bond, 2 lone pairs of electrons on the C atom and 3 lone pairs of electrons on the N atom.
(d) 1 triple bond between C and N, 1 N-H bond and 2 lone pairs of electrons on the C atom.
(e) 1 triple bond between C and N, 1 C-H bond and 1 lone pair of electrons on the N atom.



(iv) In the Lewis structure for the OF_2 molecule, the number of lone pairs of electrons around the central oxygen atom is
(a) 0
(b) 1
(c) 2
(d) 3
(e) 4



(v) The electronic structure of the SO_2 molecule is best represented as a resonance hybrid of ____ equivalent structures.
(a) 2
(b) 3
(c) 4
(d) 5
(e) This molecule does not exhibit resonance.



8(i)

What is the frequency of light having a wavelength of 4.50 x 10^{-6} cm?

(a) 2.84 x 10^{-12} s^{-1}
(b) 2.10 x 10^{4} s^{-1}
(c) 4.29 x 10^{14} s^{-1}
(d) 1.06 x 10^{22} s^{-1}
(e) 6.67 x 10^{15} s^{-1}

$\lambda = \frac{c}{v} = \frac{3.00 \times 10^8}{4.50 \times 10^{-6}} = 6.66 \times 10^{13}$

$6.67 \times 10^{15} s^{-1}$

(ii)

The emission spectrum of gold shows a line of wavelength 2.676 x 10^{-7} m. How much energy is emitted as the excited electron falls to the lower energy level?

(a) 7.43 x 10^{-19} J
(b) 5.30 x 10^{-20} J
(c) 6.05 x 10^{-19} J
(d) 3.60 x 10^{-20} J
(e) 5.16 x 10^{-20} J

(iii)

Which of the responses contains all the statements that are consistent with the Bohr theory of the atom (and no others)?
(1) An electron can remain in a particular orbit as long as it continually absorbs radiation of a definite frequency.
(2) The lowest energy orbits are those closest to the nucleus.
(3) An electron can jump from the K shell (n = 1 major energy level) to the M shell (n = 3 major energy level) by emitting radiation of a definite frequency.

(a) 1,2,3
(b) 2 only
(c) 3 only
(d) 1,2
(e) 2,3

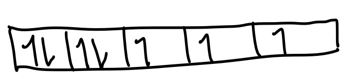
(iv) Which statement about the four quantum numbers which describe electrons in atoms is **incorrect**?

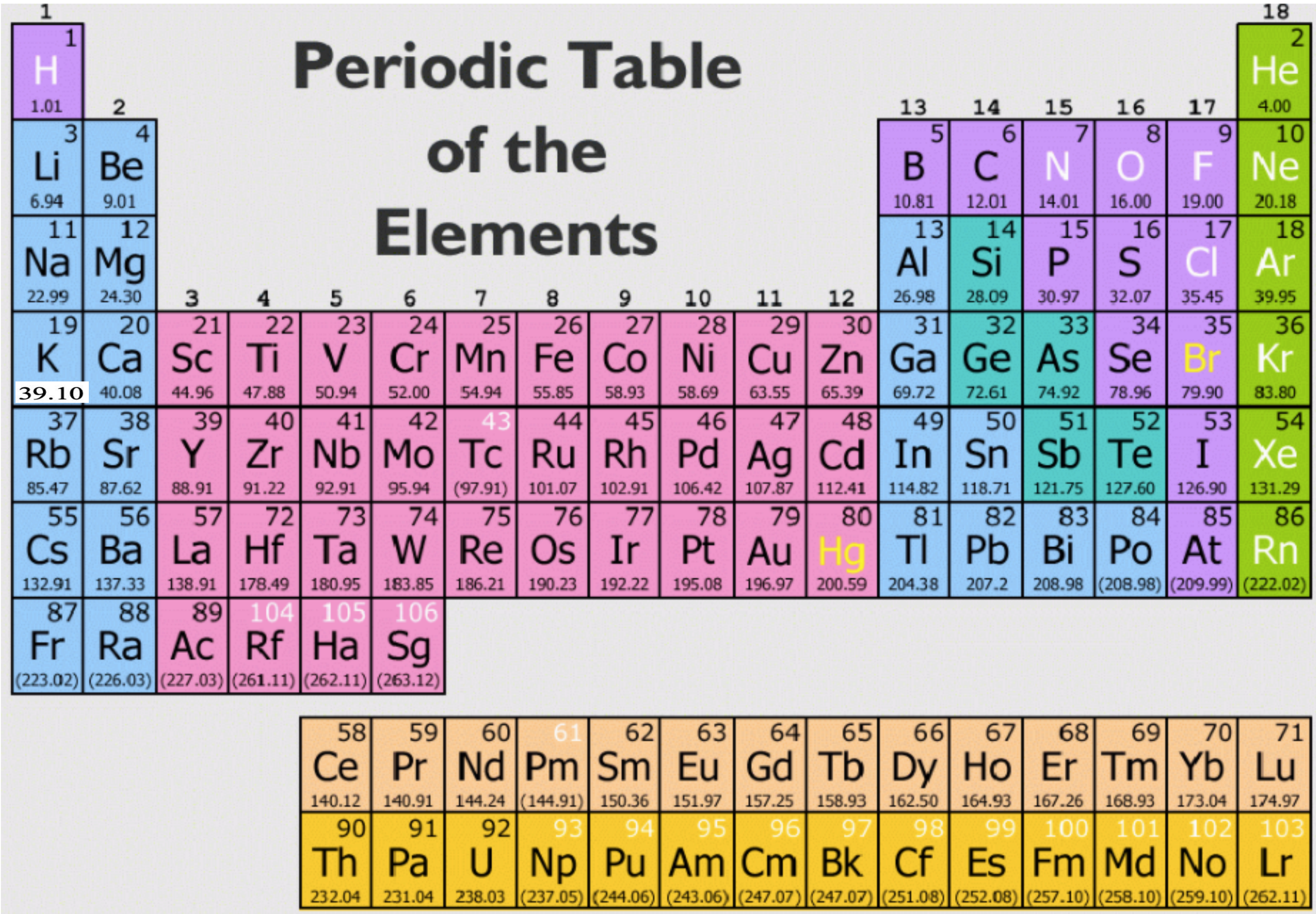
(a) n = principal quantum number, n = 1, 2, 3, ...
(b) l = subsidiary (or azimuthal) quantum number, l = 1, 2, 3, ... , (n+1)
(c) m_l = magnetic quantum number, m_l = (-l), ... , 0, ... , (+l)
(d) m_s = spin quantum number, m_s = +1/2 or -1/2.
(e) The magnetic quantum number is related to the orientation of atomic orbitals in space.

(v) In the ground state of a cobalt atom there are ___ unpaired electrons and the atom is ___

$27 - 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^7$

(a) 3, paramagnetic
(b) 5, paramagnetic
(c) 2, diamagnetic
(d) 0, diamagnetic
(e) 2, paramagnetic




Periodic Table of the Elements
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
1 H 1.01
2 He 4.00
3 Li 6.94
4 Be 9.01
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 24.30
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 65.39
31 Ga 69.72
32 Ge 72.61
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 (97.91)
44 Ru 101.07
45 Rh 102.91
46 Pd 106.42
47 Ag 107.87
48 Cd 112.41
49 In 114.82
50 Sn 118.71
51 Sb 121.75
52 Te 127.60
53 I 126.90
54 Xe 131.29
55 Cs 132.91
56 Ba 137.33
57 La 138.91
72 Hf 178.49
73 Ta 180.95
74 W 183.85
75 Re 186.21
76 Os 190.23
77 Ir 192.22
78 Pt 195.08
79 Au 196.97
80 Hg 200.59
81 Tl 204.38
82 Pb 207.2
83 Bi 208.98
84 Po (208.98)
85 At (209.99)
86 Rn (222.02)
87 Fr (223.02)
88 Ra (226.03)
89 Ac (227.03)
104 Rf (261.11)
105 Ha (262.11)
106 Sg (263.12)
58 Ce 140.12
59 Pr 140.91
60 Nd 144.24
61 Pm (144.91)
62 Sm 150.36
63 Eu 151.97
64 Gd 157.25
65 Tb 158.93
66 Dy 162.50
67 Ho 164.93
68 Er 167.26
69 Tm 168.93
70 Yb 173.04
71 Lu 174.97
90 Th 232.04
91 Pa 231.04
92 U 238.03
93 Np (237.05)
94 Pu (244.06)
95 Am (243.06)
96 Cm (247.07)
97 Bk (247.07)
98 Cf (251.08)
99 Es (252.08)
100 Fm (257.10)
101 Md (258.10)
102 No (259.10)
103 Lr (262.11)