UNIVERSITY OF KELANIYA - SRI LANKA
FACULTY OF SCIENCE

Bachelor of Science (General) Degree Examination – 2022
Academic Year 2020/2021-Semester I

CHEMISTRY
CHEM 11612/CHEM 11612(R)- Atomic Structure, Periodic Table and Chemical Bonding

Number of Questions: Four (04)
Number of pages: Four (04)

Time: Two (02) hours
Answer **all** Four (04) questions.

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(1). Answer **all** parts.

(a) Briefly explain the following observations;

(i) The melting point of $MgCl_2$ is 714 °C and that of $AlCl_3$ is 192 °C.
(ii) $AlCl_3$ exists as a dimer.
(iii) A solution of sodium in liquid ammonia at -37 °C conducts electricity.

(3 x 20 Marks)

(b) (i) Arrange the following ions in the increasing order of their enthalpy of hydration.

Mg^{2+}, Sr^{2+}, Be^{2+}, Ca^{2+} and Ba^{2+}

(ii) Give reasons for your choice.
(iii) Among these ions, which one has the highest electrical conductivity in aqueous solution? Explain your answer briefly.

(20 Marks)

(c) Answer all parts.

(i) With the aid of a suitable diagram show how the valence electrons and orbitals of Xe involve in the formation of compound XeF_4.
(ii) What is the electron-pair geometry of XeF_4?
(iii) What is the molecular geometry (shape) of XeF_4?
(iv) What is the hybridization of valence orbitals of Xe in XeF_4?

(20 Marks)

(2) Answer **all** parts.

(a) Beryllium hydride is covalent and polymeric.
(i) Draw the polymeric structure of beryllium hydride.
(ii) What type of bonding is present in it?

(10 Marks)

(b) A common example of cyclic silicates or ring silicates is Beryl, ($Be_3Al_2Si_6O_{18}$). Draw the structure of the silicate ion of Beryl and clearly indicate the negatively charged positions. (15 Marks)

(c) The important allotropic forms of phosphorus are white phosphorus, and red phosphorus.

(i) Draw the structures of white phosphorous and red phosphorus.

(ii) Which one of these two types of phosphorus is more reactive and why?

(20 Marks)

(d) Phosphorus pentachloride (PCl_5) is prepared by passing an excess of dry chlorine into liquid trichloride (PCl_3).

(i) Explain why PCl_5 is considered a Lewis acid.

(ii) On hydrolysis, PCl_5 forms phosphoric acid. Write the balanced chemical equation for the hydrolysis reaction of PCl_5.

(iii) Draw the structure of pyrophosphorous acid ($H_4P_2O_5$) and indicate its bacisity.

(iv) What is the oxidation state of P in pyrophosphorous acid?

(25 Marks)

(e) Clathrates provide a convenient means of storing radioactive isotopes of Kr and Xe produced in nuclear reactors.

(i) What are clathrate compounds of noble gases?

(ii) Ar, Kr, and Xe can form clathrate compounds with 1,4- dihydroxybenzene, but He and Ne do not form clathrate compounds. Explain.

(30 Marks)

(3) Answer all parts.

(a) For the $4p_x$ and $5d_{z2}$ hydrogen-like atomic orbitals, sketch the followings:

i. The radial Function, R

ii. The radial probability function, $a_o r^2 R^2$

iii. Angular wave function, Y

(30 Marks)

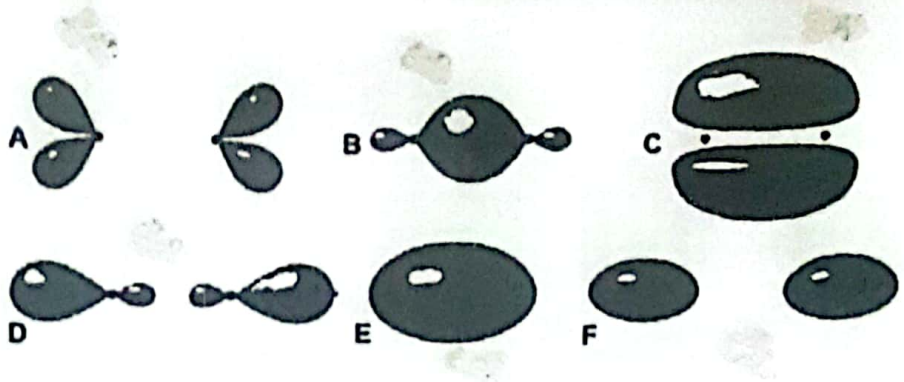
(b) Calculate the effective nuclear charge (Z*) experienced by the valence electrons in the three isoelectronic species: fluorine anion (F^-), neutral neon atom (Ne), and sodium cation (Na^+)?

(15 Marks)

(c) Give the formula of an anion comprised of iodine and fluorine in which the iodine atom is sp^3d^2 hybridized.

(15 Marks)

(d) The molecular orbitals depicted below are derived from n = 2 atomic orbitals.



(i) Give the orbital designations.
(ii) Rank the MOs in order of increasing energy for B_2.

(20 Marks)

(e) A single bond is almost always a sigma bond, and a double bond is almost always made up of a sigma bond and a pi bond. There are very few exceptions to this rule. Show that the C_2 molecule is an example for this exception.

(20 Marks)

(4) Answer all parts.

(a) Considering that there is a strong *s-p* mixing, sketch the molecular orbital energy diagram for NF and calculate the bond order. (Use appropriate labels for molecular orbitals and for starting atomic orbitals).

(30 Marks)

(b) Barium (atomic mass = 137.33 u) metal crystallizes in a body-centered cubic lattice. The unit cell edge length is 502 pm, and the density of the metal is 3.50 g/cm^3. Using this information, calculate
(i) Radius of the barium atom
(ii) Avogadro's number

(40 Marks)

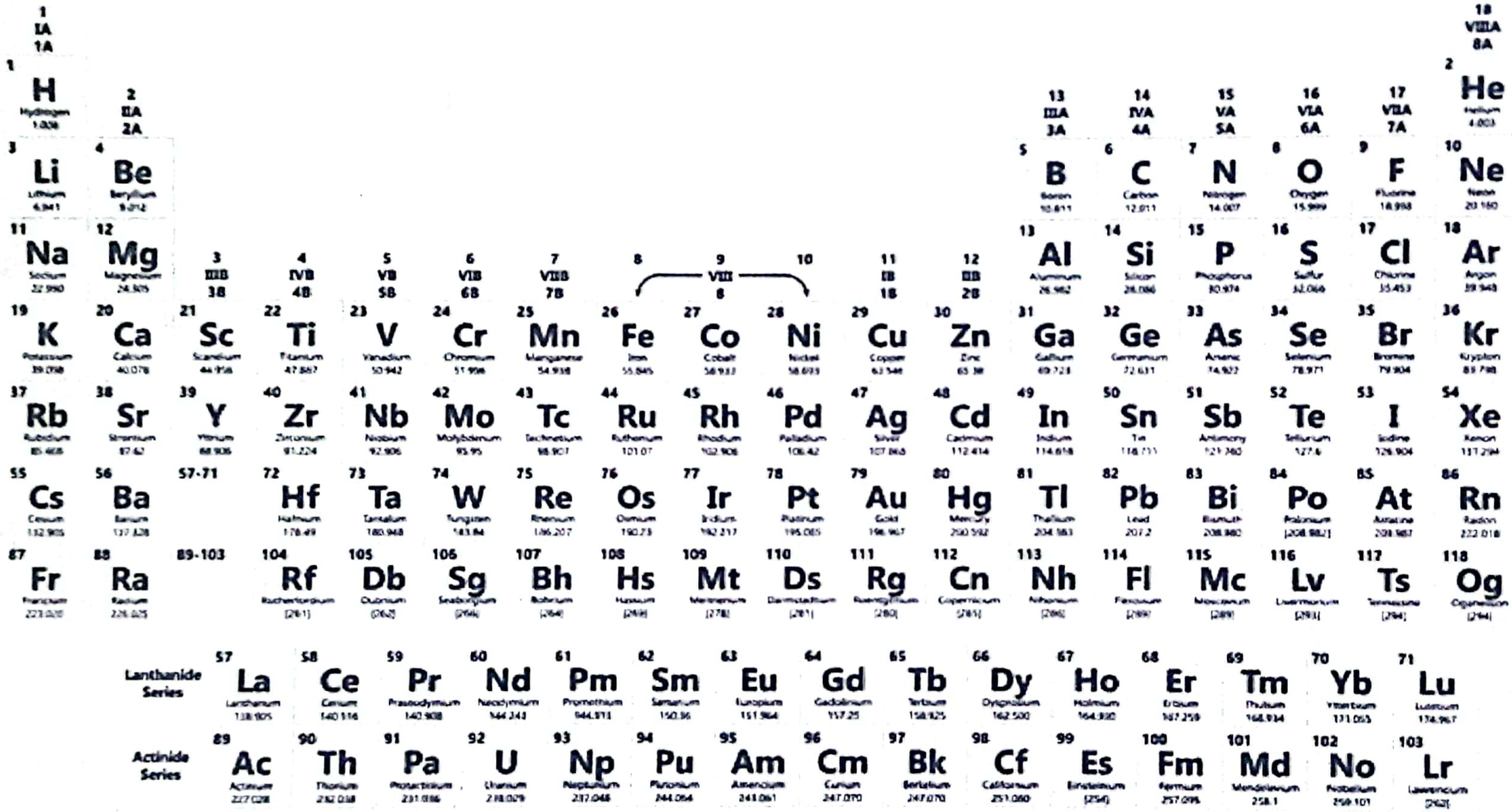
(c)
(i) Calcium sulfide adopts the sodium chloride crystal structure. How many S^{2-} ions are in the CaS unit cell?
(ii) A face-centered cubic cell contains 8 X atoms at the corners of the cell and 6 Y atoms at the faces. What is the empirical formula of the solid?

(30 Marks)

Supporting Information

Slater's rules

1. For *ns* and *np* valence electrons:
   a. Each electron in the same group contributes 0.35 to the value of *S* for each other electron in the group.
      Exception: A 1*s* electron contributes 0.30 to *S* for another 1 *s* electron.
   b. Each electron in $n-1$ groups contributes 0.85 to *S*.
   c. Each electron in $n-2$ or lower groups contributes 1.00 to *S*.
2. For *nd* and *nf* valence electrons:
   a. Each electron in the same group contributes 0.35 to the value of *S* for each other electron in the group
   b. Each electron in groups to the left contributes 1.00 to *S*.


1 IA 1A
2 IIA 2A
3 IIIB 3B
4 IVB 4B
5 VB 5B
6 VIB 6B
7 VIIB 7B
8 9 VIII 8
10
11 IB 1B
12 IIB 2B
13 IIIA 3A
14 IVA 4A
15 VA 5A
16 VIA 6A
17 VIIA 7A
18 VIIIA 8A
H Hydrogen 1.008
He Helium 4.003
Li Lithium 6.941
Be Beryllium 9.012
B Boron 10.811
C Carbon 12.011
N Nitrogen 14.007
O Oxygen 15.999
F Fluorine 18.998
Ne Neon 20.180
Na Sodium 22.990
Mg Magnesium 24.305
Al Aluminum 26.982
Si Silicon 28.086
P Phosphorus 30.974
S Sulfur 32.066
Cl Chlorine 35.453
Ar Argon 39.948
K Potassium 39.098
Ca Calcium 40.078
Sc Scandium 44.956
Ti Titanium 47.867
V Vanadium 50.942
Cr Chromium 51.996
Mn Manganese 54.938
Fe Iron 55.845
Co Cobalt 58.933
Ni Nickel 58.693
Cu Copper 63.546
Zn Zinc 65.38
Ga Gallium 69.723
Ge Germanium 72.631
As Arsenic 74.922
Se Selenium 78.971
Br Bromine 79.904
Kr Krypton 83.798
Rb Rubidium 85.468
Sr Strontium 87.62
Y Yttrium 88.906
Zr Zirconium 91.224
Nb Niobium 92.906
Mo Molybdenum 95.95
Tc Technetium 98.907
Ru Ruthenium 101.07
Rh Rhodium 102.906
Pd Palladium 106.42
Ag Silver 107.868
Cd Cadmium 112.414
In Indium 114.818
Sn Tin 118.711
Sb Antimony 121.760
Te Tellurium 127.6
I Iodine 126.904
Xe Xenon 131.294
Cs Cesium 132.905
Ba Barium 137.328
57-71
Hf Hafnium 178.49
Ta Tantalum 180.948
W Tungsten 183.84
Re Rhenium 186.207
Os Osmium 190.23
Ir Iridium 192.217
Pt Platinum 195.085
Au Gold 196.967
Hg Mercury 200.592
Tl Thallium 204.383
Pb Lead 207.2
Bi Bismuth 208.980
Po Polonium [208.982]
At Astatine 209.987
Rn Radon 222.018
Fr Francium 223.020
Ra Radium 226.025
89-103
Rf Rutherfordium [261]
Db Dubnium [262]
Sg Seaborgium [266]
Bh Bohrium [264]
Hs Hassium [269]
Mt Meitnerium [278]
Ds Darmstadtium [281]
Rg Roentgenium [280]
Cn Copernicium [285]
Nh Nihonium [286]
Fl Flerovium [289]
Mc Moscovium [289]
Lv Livermorium [293]
Ts Tennessine [294]
Og Oganesson [294]
Lanthanide Series
La Lanthanum 138.905
Ce Cerium 140.116
Pr Praseodymium 140.908
Nd Neodymium 144.243
Pm Promethium 144.913
Sm Samarium 150.36
Eu Europium 151.964
Gd Gadolinium 157.25
Tb Terbium 158.925
Dy Dysprosium 162.500
Ho Holmium 164.930
Er Erbium 167.259
Tm Thulium 168.934
Yb Ytterbium 173.055
Lu Lutetium 174.967
Actinide Series
Ac Actinium 227.028
Th Thorium 232.038
Pa Protactinium 231.036
U Uranium 238.029
Np Neptunium 237.048
Pu Plutonium 244.064
Am Americium 243.061
Cm Curium 247.070
Bk Berkelium 247.070
Cf Californium 251.080
Es Einsteinium [254]
Fm Fermium 257.095
Md Mendelevium 258.1
No Nobelium 259.101
Lr Lawrencium [262]