CH103 General Chemistry II

2018 Fall semester Quiz 4

Date: Dec. 3rd (Mon) ***Time: 19:00~19:45***

Professor Name	Class	Student I.D. Number	Name

1. **Circle on the correct answer in underlined parentheses. (1 point each. Total 12 points)**

a) Cisplatin, *cis*-$[PtCl_2(NH_3)_2]$, has (tetrahedral / **square planar**) geometry.

b) Selection rule for rotational IR spectroscopy is (**$\Delta J = \pm 1$** / $\Delta J = \pm 2, 0$).

c) Larger population difference between nuclear spin states causes (**stronger** / weaker) intensities in NMR spectra.

d) The formation of 'hard acid/soft base pair' is (**unfavorable than** / preferred over) 'hard acid/hard base' or 'soft acid/soft base' pair.

e) $[Co(en)_2Br_2]^+$ has (**three** / four) isomers, including optical isomer (en = ethylene diamine).

f) In MOs associated with the ethylene C=C double bond, π* orbital has (higher / **lower**) energy than σ* orbital.

g) In rigid rotor model, the required energy for J=0 to 1 transition and that for J=1 to 2 transition are (same / **different**).

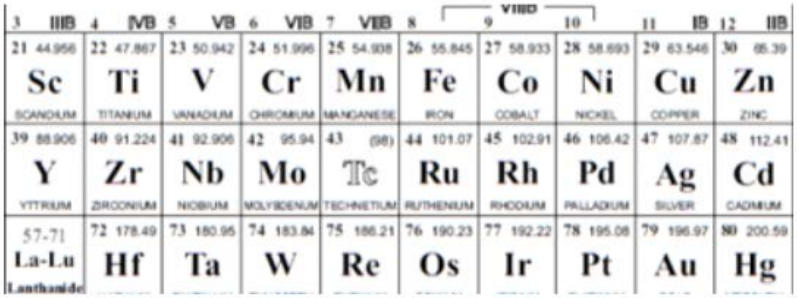
h) In harmonic oscillator model, the required energy for v=0 to 1 transition and that for v=1 to 2 transition are (**same** / different).

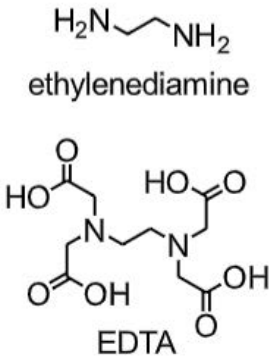
i) $[Co(NH_3)_6]Cl_2$ is (**paramagnetic** / diamagnetic).

j) EDTA is (tetradentate / **hexadentate**) ligand.

k) More shielded proton shows its NMR signal at more (**upfield** / downfield) region.

l) The atomic radius of Sc is (**larger** / smaller) than that of Fe.





2. Write the terminology most relevant to each statement from the Hint box below. (1 point each, total 6 points)

a) The atomic radius of rhodium (Rh) is slightly larger than that of iridium (Ir).

ans)__**Lanthanide contraction**_____

b) The energy of a magnetic dipole moment μ aligned along the z-axis of external magnetic field B_0 is proportional to its dipole moment and the gyromagnetic ratio.

ans)___**Zeeman effect**_____

c) ^{1}H NMR signal of aromatic C–H bonds appear at significantly downfield due to the ring current along the π-electrons of the aromatic system.

ans)___**Anisotropic effect**_____

d) The energy of electron can be considered as independent to the nuclear motion due to the significant difference in the mass of electron and that of nucleus.

ans)___**Born-Oppenheimer approximation**

e) A molecule having two or more electron pair on distant moieties can bind on a metal via two or more separate coordination.

ans)___**Chelation**_____

f) At thermal equilibrium, the population ratio between two energy level is proportional to $\exp(-\Delta E/k_B T)$, where $k_B = R/N_A$.

ans)___**Boltzmann distribution**_____

Hint box (Order in A-Z order)

Absorption	Jahn-Teller distortion
Anisotropic effect	Lanthanide contraction
Boltzmann distribution	Phosphorescence
Born-Oppenheimer approximation	Polarizability
Chelation	Rigid rotor
Ferromagnetic	Selection rule
Fluorescence	Spin-orbit coupling
Franck-Condon principle	Splitting
Harmonic oscillator	Vibrational relaxation
Internal conversion	Zeeman effect
Intersystem crossing	Zero-point energy

3. **The octahedral complex ions $[FeCl_6]^{3-}$ and $[Fe(CN)_6]^{3-}$ were prepared. One of them is high spin and another one is low spin complex. The spectrochemical series is given below. (Total 8 points)**

$I^- < Br^- < SCN^- < Cl^- < H_2O < py < NH_3 < en < PPh_3 < CN^- \sim CO$

(a) Choose correct statement among below. (2 points) ans) **(i)**

(i) Both $[FeCl_6]^{3-}$ and $[Fe(CN)_6]^{3-}$ are paramagnetic.

(ii) $[FeCl_6]^{3-}$ is paramagnetic while $[Fe(CN)_6]^{3-}$ is diamagnetic.

(iii) $[FeCl_6]^{3-}$ is diamagnetic while $[Fe(CN)_6]^{3-}$ is paramagnetic.

(iv) Both $[FeCl_6]^{3-}$ and $[Fe(CN)_6]^{3-}$ are diamagnetic.

(b) Write the electron configuration of each compound in the form of $t_{2g}^{x}e_g^{y}$. (3 points)

$[FeCl_6]^{3-}$: **$t_{2g}^3e_g^2$**

$[Fe(CN)_6]^{3-}$: **t_{2g}^5** **$t_{2g}^5e_g^0$ is also correct.**

No correct answer : 0 point / 1 correct answer : 2 points / 2 correct answers : 3 points

(c) Write the crystal field stabilization energy of each compound using Δ_0. (3 points)

$[FeCl_6]^{3-}$: **0** **0 Δ_0 is also correct.**

$[Fe(CN)_6]^{3-}$: **$-2\ \Delta_0$**

No correct answer : 0 point / 1 correct answer : 2 points / 2 correct answers : 3 points

4. The microwave absorption spectrum of gaseous $^{23}Na^{1}H$ has been measured experimentally; microwaves with wavelengths of 1.02 mm excite the transition from J=0 to J=1. (Planck's constant, h = 6.626x10^{-34} J·s; speed of light, c = 3.00x10^{8} m/s; mass of ^{23}Na = 22.9898 amu; mass of ^{1}H = 1.0078 amu; 1 amu = 1.6605x10^{-27} kg) (Total 8 points) **Correct answer of each: full point.**

(a) Calculate the energy of the microwave that is used for the excitation in Joule. (2 points)

ans) **1.95 x 10^{-22} J**

$$E = h\nu = \frac{hc}{\lambda}$$
$$= \frac{(6.626\times10^{-34}\,J\cdot s)\cdot(3.00\times10^{8}\,m/s)}{1.02\times10^{-3}\,m} = 1.95\times10^{-22}\,J$$

E=hc/λ : 1 point; E=hν only : no point.

(b) Calculate the reduced mass μ of $^{23}Na^{1}H$ in kilogram. (2 points)

ans) **1.603 x 10^{-27} kg**

$$\mu = \frac{m_1 m_2}{m_1 + m_2} = \frac{1.0078\cdot22.9898}{1.0078+22.9898} = 0.9655\,amu$$
$$= 0.9655amu\cdot\frac{1.6605\times10^{-27}\,kg}{amu} = 1.603\times10^{-27}\,kg$$

μ=0.9655 amu : 1 point (unit amu is required for the partial point).

(c) Calculate the moment of inertia, I, of $^{23}Na^{1}H$ in kg·m^2. Note that $\Delta E_{rot}=(h^2/8\pi^2 I)J(J+1)$. (2 points)

ans) **5.70 x 10^{-47} kg·m^2**

$$\Delta E = \frac{h^2}{8\pi^2 I}[1\cdot2-0\cdot1] = \frac{h^2}{4\pi^2 I}$$
$$I = \frac{h^2}{4\pi^2\Delta E} = \frac{(6.626\times10^{-34}\,J\cdot s)^2}{4\pi^2(1.95\times10^{-22}\,J)} = 5.70\times10^{-47}\,kg\cdot m^2$$

ΔE=h^2/4π^{2}I or I=h^2/4πΔE 1 point.

(d) Calculate the bond length R_e of $^{23}Na^{1}H$. Note that $I = \mu R_e^2$. (2 points)

ans) **1.89 x 10^{-10} m**

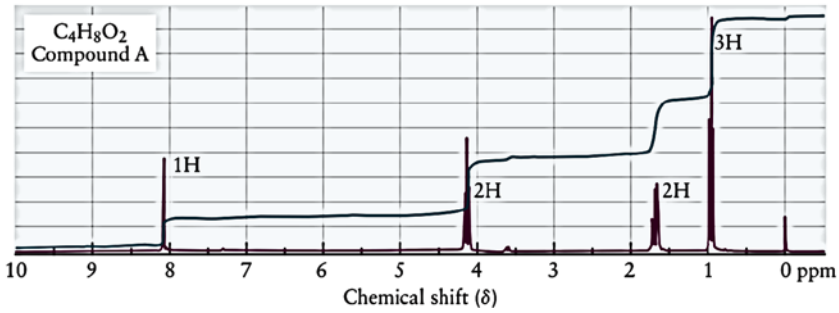
$$R_e = \sqrt{\frac{I}{\mu}} = \sqrt{\frac{5.70\times10^{-47}\,kg\cdot m^2}{1.603\times10^{-27}\,kg}} = 1.89\times10^{-10}\,m$$

1.89 Å is also possible.

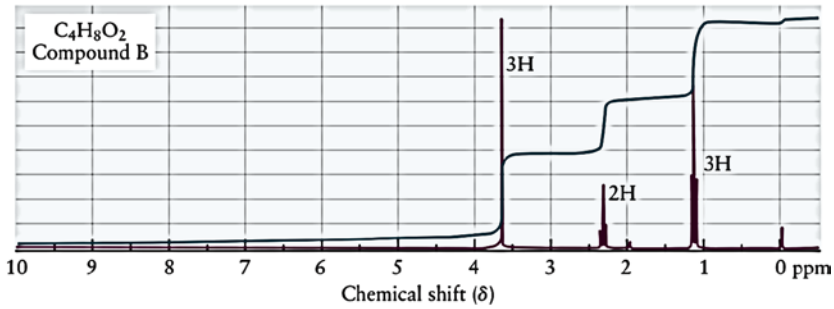
R_e^2=3.56x10^{-20}m^2 but calculation mistake: 1 point.
Correct calculation with wrong I and μ values : 1 point.
No partial point for just number substitution.

5. **Identify the three molecules with the molecular formula $C_4H_8O_2$ from their NMR spectrum below. Hint: They are all esters. (Each 2 points, Total 6 points)**

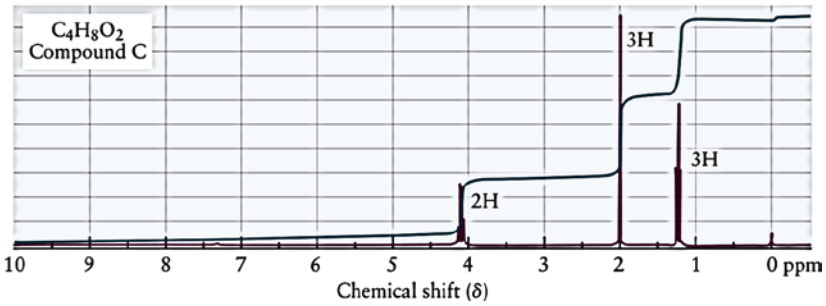
(a)



(b)



(c)



ans)