Exam II Makeup Questions

H. Ryott Glayzer 26th February 2024

Notice of ADA Accommodation and Methods

I have an ADA accommodation to do my assignment on paper. This document is a utilization of that accommodation. This assignment will utilize the makeup questions for Exam II provided by Dr. Moulder. Reasoning will be provided within the context of this class, and at times, within the context of concepts outside of the scope of this class. Each problem will appear on a new page.

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1	H				Dorio	lic Tab						He						
1	Hydrogen	2 IIA			renoc	iic rab	ie di Ci	ileililea	Lienie	iils Via	11111		13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	Helium
	3 6.941	4 9.0122	1										5 10.811	6 12.011	7 14.007	8 15.999	9 18.998	10 20.180
2	Li	Be											В	С	N	0	F	Ne
	Lithium	Beryllium											Boron	Carbon	Nitrogen	Oxygen	Flourine	Neon
	11 22.990	12 24.305											13 26.982	14 28.086	15 30.974	16 32.065	17 35.453	18 39.948
3	Na	Mg	2 111 4	4.11.70	E \/D	C \ //ID	7.//ID	0.1/1110	0.1/11/0	10 \ ////	11 ID	10 UD	Al	Si	Р	S	CI	Ar
	Sodium	Magnesium	3 IIIA	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB		11 IB 29 63.546	12 IIB	Aluminium	Silicon	Phosphorus	Sulphur 34 78 96	Chlorine	Argon 36 83.8
	19 39.098 K	20 40.078 Ca	21 44.956 Sc	22 47.867 Ti	23 50.942 V	24 51.996 Cr	25 54.938 Mn	26 55.845 Fe	27 58.933 Co	28 58.693 Ni	Cu	30 65.39 Zn	31 69.723 Ga	32 72.64 Ge	33 74.922 As	34 78.96 Se	35 79.904 Br	Kr 83.8
4					_													
	Potassium 37 85.468	Calcium 38 87.62	Scandium 39 88.906	Titanium 40 91.224	Vanadium 41 92.906	Chromium 42 95.94	Manganese 43 96	Iron 44 101.07	Cobalt 45 102.91	Nickel 46 106.42	Copper 47 107.87	Zinc 48 112.41	Gallium 49 114.82	Germanium 50 118.71	Arsenic 51 121.76	Selenium 52 127.6	Bromine 53 126.9	Krypton 54 131.29
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	1.0.5	Xe
5	Rubidium	-		Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium		
	55 132.91	Strontium 56 137.33	Yttrium : 57-71	72 178.49	73 180.95	74 183.84	75 186.21	76 190.23	77 192.22	78 195.08	79 196.97	80 200.59	81 204.38	82 207.2	83 208.98	84 209	lodine 85 210	Xenon 222
6	Cs	Ba	La-Lu	Hf	Та	w	Re	Os	lr	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
-	Caesium	Barium	: Lanthanide	Halfnium	Tantalum	Tungsten	Rhenium	Osmium	'Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
	87 223	88 226	89-103	104 261	105 262	106 266	107 264	108 277	109 268	110 281	111 . 280	112 285	113 284	114 289	115 288	116 293	117 292	118 294
7	Fr	Ra	Ac-Lr	RF	Dв	Sc	Вн	Hs	Мт	Ds	Rg	Си	Nн	FL	Mc	Lv	Ts	OG
	Francium	Radium	Áctinide	Rutherfordium	Dubnium	Seaborgium	Bohrium	Hassium	Meltnerium	Darmstadtium	Roentgenium	Copernicium	Nihonium	Flerovium	Moscovium	Livermorium	Tennessine	Oganesson
	Alkali Met	Wali Metal														*********		
	Alkaline Earth Metal			57 138.91	58 140.12	59 140.91	60 144.24	61 145	62 150.36	63 151.96	64 157.25	65 158.93	66 162.50	67 164.93	68 167.26	69 168.93	70 173.04	71 174.97
	Metal Metalloid			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	Non-meta	I		Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	. Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium
	Noble Gas	Halogen Noble Gas																
	Lanthanide/Actinide			89 227	90 232.04	91 231.04	92 238.03	93 237	94 244	95 243	96 247	97 247	98 251	99 252	100 257	101 258	102 259	103 262
	Z ma			Ac	Th	Pa	U	NP	Pu	Ам	См	Вк	CF	Es	Fм	Mp	No	LR
	Symb	ol MAI		Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium
	Name																	

Calculate the Velocity of Electrons with de Broglie Wavelengths of 285 nm.

The equation

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

is accurate for non-relativistic velocities. For relativistic velocities, the equation

$$\frac{1}{\lambda_B} = \frac{mv}{h\sqrt{1 - \frac{v^2}{c^2}}}$$

is more accurate. I will determine the velocity of electrons with de Broglie wavelengths of 285 nm using both of these equations.

Calculating the de Broglie Wavelength with the Non-Relativistic Equation

For the non-relativistic equation, we will first consider that the mass of an electron is given to be 9.1094 \times 10⁻³¹ kg. The non-relativistic equation:

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

can be rewritten:

$$h = m v \lambda$$
.

To determine the velocity, we can rearrange the equation to give the velocity:

$$v=\frac{h}{m\lambda}$$
.

Substituting the variables with known values, with the knowledge that $1 \, \text{J} = 1 \, \text{kg m}^2 \, \text{s}^{-2}$, gives:

$$v = \frac{6.63 \times 10^{-34} \, kg \, m^2 \, s^{-2} \, s}{9.1094 \times 10^{-31} \, kg \times 2.85 \times 10^{-7} \, m}.$$

This gives:

$$vm \, s^{-1} = \frac{6.63 \times 10^{-34} \, kg \, m^2 \, s^{-1}}{2.596 \, 179 \times 10^{-37} \, kg \, m}$$

which provides the value:

$$\nu = 2.553\,753\,035\times 10^3\,\text{m}\,\text{s}^{-1} = 2.553\times 10^3\,\text{m}\,\text{s}^{-1}$$

This value is closest to multiple choice option **D**: $2.552 \times 10^3 \, \text{m s}^{-1}$.

Calculating the de Broglie wavelength using the Proper Relativistic Equation

The de Broglie wavelength of a particle is a wavelength that determines the probability density of the particle being found at a specific point q in its configuration space. This is important in quantum mechanics. In the context of General Chemistry I, the de Broglie wavelength is defined in our textbook only as a characteristic of particles and other bodies. The relativistic definition of the de Broglie wavelength is:

$$\lambda_B = \frac{h}{p}$$
,

where λ_B represents the de Broglie wavelength of the particle, h represents the Planck constant, which has the value $6.626\,070\,15\times10^{-34}\,\mathrm{J}\,\mathrm{s}$, and p represents the relativistic momentum of the particle, defined as

$$p=\frac{mv}{\sqrt{1-\frac{v^2}{c^2}}},$$

with m representing the mass of the particle, v representing the particle's velocity, and c representing the speed of light in a vacuum. The invariant mass of the electron is approximately $9.109\,383\,701\,5(28)\times 10^{-31}\,\mathrm{kg}$ according to the NIST. The speed of light in a vacuum is defined as $299\,792\,458\,\mathrm{m\,s^{-1}}$.

Combining these equations gives the formula:

$$\lambda_B = \frac{h}{\frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}}$$

which simplifies to

$$\lambda_B = rac{h\sqrt{1-rac{v^2}{c^2}}}{mv}.$$

This can be rearranged to

$$\lambda_B m v = h \sqrt{1 - rac{v^2}{c^2}}.$$

root -? The following steps will solve the equation for velocity:

$$\frac{\lambda_B m v}{h} = \sqrt{1 - \frac{v^2}{c^2}} \Rightarrow \left(\frac{\lambda_B m v}{h}\right)^2 = \left(\sqrt{1 - \frac{v^2}{c^2}}\right)^2 \Rightarrow \frac{\lambda_B^2 m^2 v^2}{h^2} = 1 - \frac{v^2}{c^2} \Rightarrow$$

$$1 = \frac{\lambda_B^2 m^2 v^2}{h^2} + \frac{v^2}{c^2} \Rightarrow 1 = \frac{\lambda_B^2 m^2 v^2 c^2 + v^2 h^2}{h^2 c^2} \Rightarrow h^2 c^2 = \lambda_B^2 m^2 v^2 c^2 + v^2 h^2 \Rightarrow$$

$$h^2c^2 = v^2(\lambda_B^2m^2c^2 + h^2) \Rightarrow v^2 = \frac{h^2c^2}{\lambda_B^2m^2c^2} \Rightarrow v = \sqrt{\frac{h^2c^2}{\lambda_B^2m^2c^2}}$$
 $v = \sqrt{\frac{h^2}{\lambda_B^2m^2}}$

And thus, we have arrived at the relativistic equation for the de Broglie wavelength solved for velocity. Using the values we defined earlier, we find the velocity to be:

$$v^2 = \frac{(6.626\,070\,15\times10^{-34}\,\mathrm{J\,s})^2}{(285\times10^{-9}\,\mathrm{m})^2\times(9.109\,383\,701\,5\times10^{-31}\,\mathrm{kg})^2}$$

$$v^2 = \frac{4.390\,480\,563 \times 10^{-67}\,\mathrm{kg^2m^4s^{-2}}}{6.740\,121\,281 \times 10^{-74}\,\mathrm{kg^2\,m^2}}$$

$$v^2 = 6.513948904 \times 10^6 \,\mathrm{m}^2 \,\mathrm{s}^{-2}$$

$$v = 2.552243896 \times 10^3 \,\mathrm{m \, s^{-1}}$$

which, upon applying significant figures, would come to

$$v = 2.552 \times 10^3 \,\mathrm{m \, s^{-1}}$$

This is exactly the multiple choice option **D**.

Solution

Both the non-relativistic approximation and the true relativistic equation give the answer

D.
$$2.552 \times 10^3 \,\mathrm{m \, s^{-1}}$$
.

What Element is Theoretically the Smallest of all on the Periodic Table?

The smallest theoretical element is Helium. This follows the periodic trends of atomic radius. As an element's group grows, its radius shrinks as there are more electrons in its shell, and the radius grows as the period increases, as there are more electron shells. Since Hydrogen has the most electrons and the least electron shells, Helium is the smallest element.

What wavelength would the hydrogen Rydberg line give for the electronic transition $n_1 = 2$ and $n_2 = 5$?

The Rydberg formula models the emission and absorption wavelengths for photons in jumps in electron energy levels. It is defined for hydrogen as follows:

$$\frac{1}{\lambda_{vac}} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

where R_H is defined in the handout as $1.097 \times 10^7 \,\mathrm{m}^{-1}$. This gives us the equation

$$rac{1}{\lambda_{vac}} = \left(1.097 imes 10^7 \, \mathrm{m}^{-1}
ight) \left(rac{1}{n_1^2} - rac{1}{n_2^2}
ight)$$

The problem is asking for the Rydberg line for $n_1 = 2$ and $n_2 = 5$. Plugging these into the formula gives us

$$rac{1}{\lambda_{vac}} = \left(1.097 imes 10^7 \, \mathrm{m}^{-1}
ight) \left(rac{1}{4} - rac{1}{25}
ight)$$

Fraction Subtraction rules tell us that we need to find a common denominator.

$$\frac{1}{\lambda_{vac}} = R_H \left(\frac{25}{100} - \frac{4}{100} \right) = R_H \left(\frac{21}{100} \right)$$

From this, we can see that

$$\lambda_{\textit{vac}} = \frac{100}{21 \times 1.097 \times 10^7 \, \text{m}^{-1}}$$

Which gives us

$$\lambda_{\textit{vac}} = 4.341 \times 10^{-7}\,\text{m}$$

which is approximately equal to 434.0 nm.

Thus, the wavelength of the hydrogen Rydberg line for the electronic transition from 2 to 5 would be $434.0 \, \text{nm}$, or multiple choice option \mathbf{C} .

Which is the most correct Lewis structure for N₂O

Both Nitrogen and Oxygen in N_2O can be the central atom, so we determine the central atom by determining the least electronegative atom and placing it in the middle. N has electronegativity 3.04, while O has electronegativity 3.44. Thus, Nitrogen will be the central atom.

There are five valence electrons in each nitrogen atom, and six in the oxygen atom. Thus, there are sixteen total valence electrons in N_2O .

Next, we must draw the skeleton structure for N_2O .

Now, we connect each atom with the central atom with a single bond.

$$\dot{N} - \dot{N} - \dot{O}$$

Now, we must create new bonds in the central atom to create double and triple bonds.

$$\dot{N} = \dot{N} = \dot{O}$$

The N atom on the end does not follow the octet rule. Thus, we must move around bonds to make it valid.

$$N = N - O$$

This works, but there are resonance structures:

and

Now, we must compute the formal charges of each of the above resonance structures. Formal Charge can be calculated via the following

$$\mathbf{Q}_{\mathsf{Formal}} = \mathbf{V}_{\mathsf{e}^-} - \mathbf{L}\mathbf{P}_{\mathsf{e}^-} - \frac{\mathbf{B}_{\mathsf{e}^-}}{2}$$

For the first structure, N = N - O, the Formal Charge is computed:

$$\mathbf{N}_{edge}: 5-2-\frac{6}{2}=0$$

$$\mathbf{N}_{\textit{central}}: 5-0-rac{8}{2}=+1$$

$$\mathbf{0}: 6-6-\frac{2}{2}=-1$$

Thus the formal charge of the first resonance structure, N = N - O, is 0 + 1 - 1 = 0. This has the negative charge on the Oxygen and the positive charge on the Nitrogen. The Oxygen is the more electronegative of the two, so this is the most correct structure for N_2O :

$$N \equiv N - O$$

This version is close to multiple choice option **D**.

What is the Frequency of Light that has a wavelength of 185 nm?

The frequency of a photon can be derived in a classical sense through

$$\lambda = rac{\mathsf{c}}{
u}$$

as such

$$u = \frac{c}{\lambda}$$

We can input the necessary values for c and λ .

$$\nu = \frac{3.00 \times 10^8 \, \mathrm{m \, s^{-1}}}{185 \times 10^{-9} \, \mathrm{m}}$$

this gives us the value

$$u = 1.62 \times 10^{15} \, \mathrm{s}^{-1}$$

This is the value of the multiple choice option ${\bf E}$.

Which element is most likely to present with the first five ionization energies specified below? (in $kJ \, mol^{-1}$)

589.8 | 1145 | 4912 | 6491 | 8153

These five ionization energies are increasing in order. Since the third ionization energy is exhibits a great increase, and it is greatly difficult to remove an electron from a full octet, one can assume that the atom has two valence electrons. Looking at the provided options, the only group 2 element in Calcium. Thus, one can assume the answer is Calcium, multiple choice option **B**.

What is the hybridization of all the carbon atoms in benzene (C_6H_6) ?

Based on their electronic configurations, which of the following elements or ions is paramagnetic in a vapor phase?

What is the maximum number of electrons that can have the following set of quantum numbers: n=4, I=3 $m_I=3$, $m_S=-\frac{1}{2}$

Order the following series of isoelectronic ions (Mg^{2+} , N^{3-} , F^- , Si^{4+}) from largest to smallest ionic radii.