Mid1 review

1.

The electron in a hydrogen atom is excited to the $n = 6$ shell and emits electromagnetic radiation when returning to lower energy levels. Determine the number of spectral lines that could appear when this electron returns to the lower energy levels, as well as the wavelength range in nanometers.

( ) spectral lines

Wavelength range

( )nm to ( )nm

2.

The energy levels of one-electron ions are given by the equation

$$E_n = \left(-2.18 \times 10^{-18}\ \text{J}\right)\frac{Z^2}{n^2}$$ where Z is atomic number and n is the energy level.

e series in the He^+ spectrum that corresponds to the set of transitions where the electron falls from a higher level to the $n_f = 4$ state is called the Pickering series, an important series in solar astronomy. Calculate the Pickering series wavelength associated with the excited state $n_i = 7$.

λ= ( )m

What region of the electromagnetic spectrum does this transition fall in?

- infrared
- visible
- microwave
- gamma
- X ray
- ultraviolet
- radio

3.

A ground state hydrogen atom absorbs a photon of light having a wavelength of 92.05 nm. It then gives off a photon having a wavelength of 1736 nm. What is the final state of the hydrogen atom? Values for physical constants can be found here.

n_f = ( )

4.

The temperature of a black body can be estimated based on the wavelength of light that it is emitting. A star can be considered a black body. Find the surface temperature of a star where λ_{max} = 697 nm.

T = ( )K

5.

Data for the photoelectric effect of silver are given in the following table.

Frequency of incident radiation (10^{15} s^{-1})	Kinetic energy of ejected electrons (10^{-19} J)
2.00	5.90
2.50	9.21
3.00	12.52
3.50	15.84
4.00	19.15

Using these data, find the experimentally determined value of Planck's constant, *h*, and the threshold frequency, ν_0, for silver.

h = (   ) J · S   V0 = (   )s^{-1}

6.

Assuming that the smallest measurable wavelength in an experiment is 0.670 fm (femtometers), what is the maximum mass of an object traveling at 913 m · s^{-1} for which the de Broglie wavelength is observable?

m = (   ) kg

7.

To resolve an object in an electron microscope, the wavelength of the electrons must be close to the diameter of the object. What kinetic energy must the electrons have in order to resolve a protein molecule that is 3.20 nm in diameter? Take the mass of an electron to be 9.11×10^{-31} kg.

(   )J

8.

The average speed of a helium atom at 25 °C is 1360 m · s^{-1}. What is the average wavelength of a helium atom at this temperature?

λ = (   )m

9.

Consider a 2050-lb automobile clocked by law-enforcement radar at a speed of 85.5 mph (miles/hour). If the position of the car is known to within 5.0 feet at the time of the measurement, what is the uncertainty in the velocity of the car?

Δv >= (   )mph

If the speed limit is 75 mph, could the driver of the car reasonably evade a speeding ticket by invoking the Heisenberg uncertainty principle?

(   ) Yes

(   ) No

10.

Electrons in molecules are described by wavefunctions that can extend over multiple atoms. Answer the following questions about an electron that can extend over two adjacent carbon atoms.

a. Use the one-dimensional particle-in-the-box model to calculate the energy needed to promote an electron from the $n = 1$ to $n = 2$ level. Assume that the length of the box is equivalent to the length of the carbon–carbon bond, 139 pm.

( )J

b. Calculate the wavelength, in nanometers, of radiation that corresponds to the energy calculated in part a.

( )nm

c. Suppose that each atom in a linear chain of 6 carbon atoms contains one electron. Determine the minimum number of wavefunctions required to account for all of the electrons.

( )wavefunctions

d. For the linear chain of 6 carbon atoms, use the one-dimensional particle-in-the-box model again to calculate the energy needed to promote an electron from the $n = 5$ to $n = 6$ level. Assume that each carbon–carbon bond is 139 pm in length.

( )J

e. Calculate the wavelength, in nanometers, of radiation that corresponds to the energy calculated in part d.

( )nm

f. A compound with multiple carbon–carbon bonds is found to requires 314 nm light to promote an electron from the $n = 6$ to the $n = 7$ level. Determine the number of carbon atoms in this molecule. Round the answer to the nearest whole number.

( )carbon atoms

11. Which of these systems can exhibit degenerate energy levels? Select all that apply.

a. A particle in a 1-dimension box

b. A particle in a 1-dimension box

c. A particle in a 1-dimension box

12.

The wavefunction for a particle in a box of length 3.9 a.u. (arbitrary units) is given by:

$$\psi(x) = A\sin\left(\frac{n\pi x}{3.9}\right)$$

In the wavefunction n is an integer corresponding to the quantum number of the particle and A is a normalization constant used to ensure that the probability of finding the particle anywhere in the box is 1. Find the value of A.

A = ( )

13.

In a one electron system, the probability of finding the electron within a shell of thickness δr at a radius of r from the nucleus is given by the radial distribution function $P(r) = r^2R^2(r)$.

An electron in a 1s hydrogen orbital has the radial wavefunction R(r) given by:

$$R(r) = 2\left(\frac{1}{a_0}\right)^{3/2} e^{-r/a_0}$$ where a_0 is the Bohr radius (52.9 pm).

alculate the probability of finding the electron in a sphere of radius $2.0a_0$ centered at the nucleus.

( )%

14.

Determine the most probable distance from the nucleus for an electron in the 2p orbital of a hydrogen atom. The radial wavefunction, $R_{nl}(r)$, for the 2p orbital is given by:

$$R_{2,1}(r) = \frac{1}{2\sqrt{6}}\left(\frac{Z}{a_0}\right)^{3/2}\left(\frac{Zr}{a_0}\right)e^{-\frac{Zr}{2a_0}}$$

Give your answer in terms of a_0.

( )a_0

15.

The equation for the angular part of the wave function of an electron in a hydrogen $2p_x$ orbital is

$$Y_{2p_x} = \sqrt{\frac{3}{4\pi}}\sin(\theta)\cos(\phi)$$

Suppose there is a small cubic box with a volume of 0.5 pm^3 centered at a point where r = 100 pm and θ = 0.7π, with a value of ϕ that can be varied. At what value(s) of ϕ is the probability of finding the electron inside the box maximized? You can assume that the numerical value of the wave function over the small volume in the box is constant, and equal to the value of the wave function at the center of the box.

a.3pi/4 b.pi/2 c.pi/3 d.0 e.2pi/3 f.pi g.pi/4

16.

Suppose you take a trip to a distant universe and find that the periodic table there is derived from an arrangement of quantum numbers different from the one on Earth. The rules in that universe are:

1. principal quantum number n = 1, 2, . . . (as on Earth);
2. angular momentum quantum number ℓ = 0, 1, 2,. . . , n – 1 (as on Earth);
3. magnetic quantum number m_ℓ = 0, 1, 2, . . . , ℓ (only positive integers up to and including ℓ are allowed);
4. spin quantum number m_s = – 1, 0, +1 (that is, three allowed values of spin).

(a) Assuming that the Pauli exclusion principle remains valid in the distant universe, what is the maximum number of electrons that can populate a given orbital there?

( )

(b) Write the electronic configuration of the element with atomic number 8 in the periodic table.
Formatting: superscript numbers where appropriate but omit parentheses.

( )

(c) What is the atomic number of the second noble gas?

( )

17. Rank these elements according to first ionization energy.

Li,Be,B,C,N,O,F,Ne

18.

A space probe identifies a new element in a sample collected from an asteroid. Successive ionization energies (in attojoules per atom) for the new element are shown below.

I_1	I_2	I_3	I_4	I_5	I_6	I_7
0.507	1.017	4.108	5.074	6.147	7.903	8.294

To what family of the periodic table does this new element probably belong?

- 1 (1A)
- 2 (2A)
- 13 (3A)
- 14 (4A)
- 15 (5A)
- 16 (6A)
- 17 (7A)
- 18 (8A)

19.

The electron affinity of thulium has been measured by a technique known as laser photodetachment electron spectroscopy. In this technique, a gaseous beam of the anions of an element is bombarded with photons from a laser. Electrons from the anion are then ejected and their energies are detected. The incident radiation had a wavelength of 1064 nm and the ejected electrons were found to have an energy of 0.137 eV. The electron affinity is the difference in energy between the incident photons and the energy of the ejected electrons. Determine the electron affinity of thulium in units of eV/atom and kJ/mol.

The electron affinity of thulium ( )eV/atom

Which is ( )KJ/Mol

20. Choose the compounds in which the central cation exhibits the inner-pair effect.

- $SnBr_4$
- Tl_2O
- In_2O
- $SnBr_2$
- Tl_2O_3
- In_2O_3
- $PbBr_2$
- $PbBr_4$

21.

The charges and sizes of the ions in an ionic compound affect the strength of the electrostatic attraction holding that compound together.

Based on ion charges and relative ion sizes, rank these ionic compounds by their expected melting points.

SrF_2, BrF, SrO, CsBr

22.

Azides of heavy metals explode when struck sharply, and are used in detonation caps. Write the Lewis structure for the most stable azide ion, N_3^-. Include lone pairs.

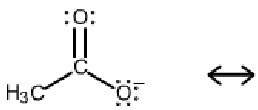
23.

Which of these molecules and polyatomic ions cannot be adequately described using a single Lewis structure? Check all that apply.

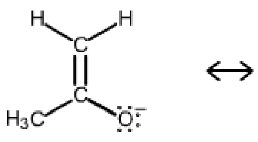
CO_3^{2-}
HCN
CH_2Cl_2
O_3
OF_2
NH_4^+

24.

Draw the other possible resonance structure of each organic ion in the spaces below. In each case, draw the structure that minimizes formal charges. Be sure to include all appropriate nonbonding electrons and charges.



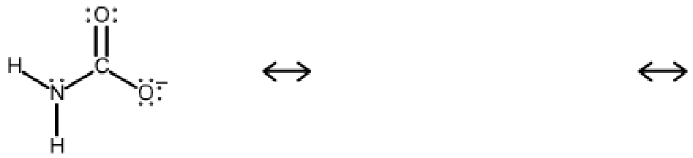
acetate ion



an enolate ion

25.

A Lewis structure of the carbamate ion is shown below. Draw the two other major resonance structures in the spaces to the right of the structure. Be sure to include all nonbonding electrons and formal charges where appropriate.



carbamate ion

Which of the Lewis structures would you expect to contribute the least to the overall structure of the carbamate ion?

The carbon–oxygen bonds have ample C=O bond character.

The carbon–oxygen bonds have overwhelmingly C–O bond character.

The carbon–nitrogen bond has ample C=N bond character.

The carbon–nitrogen bond has overwhelmingly C–N bond character.

Bond	Expected bond length, pm
C-O	143
C=O	112
C-N	152
C=N	127

Based on the bond lengths and bond character which of the Lewis structures actually contribute substantially to the overall structure of the carbamate ion?

All three Lewis structures contribute to the overall structure.

The Lewis structures on the right and on the left contribute to the overall structure.

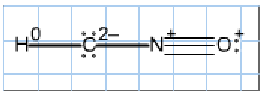
The Lewis structures on the left and in the center contribute to the overall structure.

The Lewis structures on the right and in the center contribute to the overall structure.

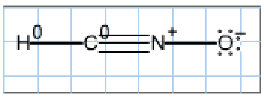
26.

Add formal charges to each resonance form of HCNO below.

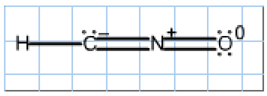
A.



B.



C.

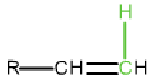


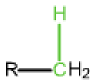
Based on the formal charges you added above, which structure is favored?

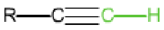
27.

Given the stretching frequencies for the C–H bonds shown in green, arrange the corresponding bonds in order of increasing strength.

Strength ranking( )

A.  3080 cm^{-1}

B.  2850 cm^{-1}

C.  3300 cm^{-1}

Explain your reasoning:

Stronger bonds absorb at higher wavenumber.
Stronger bonds absorb at lower wavenumber.
Bond strength is unrelated to wavenumber.

28. Draw the Lewis structure of $HBrO_2$, HIO_3, H_2SO_4, H3PO$_4$

29. (Not a question)

If the symbol X represents a central atom, Y represents outer atoms, and Z represents lone pairs on the central atom, the structure Y—$\ddot{\underset{\cdot\cdot}{X}}$—Y could be abbreviated as XY_2Z_2.

Classify these structures according to their shape.

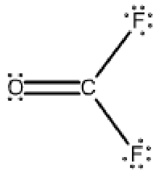
linear	bent (≈120°)	bent (≈109°)	trigonal pyramidal	T-shaped	see-saw	square planar	square pyramidal
XY_2Z_3	XY_2Z	XY_2Z_2	XY_3Z	XY_3Z_2	XY_4Z	XY_4Z_2	XY_5Z

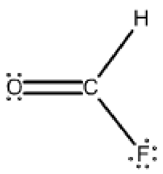
30. Which of these molecules are linear? Check al that apply.
BeCl2, SF2, NO2-, XeF2

31. Which of these molecules are polar? Check al that apply.
$PCl3$, $CO2$, $CH2Cl2$, $SO2$

32.

Where, approximately, is the negative pole on each of these molecules?





Which molecule should have the higher dipole moment, and why?

- COF_2 because it contains more F atoms.
- COFH because the polar bonds in COF_2 nearly cancel each other out.
- COF_2 because it contains more lone pairs.

33. (Not a question)

If the symbol X represents a central atom, Y represents outer atoms, and Z represents lone pairs on the central atom, the structure $Y-\ddot{\underset{\cdot\cdot}{X}}-Y$ could be abbreviated as XY_2Z_2.

Classify these structures by the hybridization of the central atom.

sp	*sp*^{2}	*sp*^{3}	*sp*^{3}*d*	*sp*^{3}*d*^{2}
XY_2	XY_3	XY_2Z_2	XY_2Z_3	XY_6
	XY_2Z	XY_3Z	XY_3Z_2	XY_4Z_2
		XY_4	XY_4Z	XY_5Z
			XY_5	

34.(Not a question)

Use molecular orbital theory to complete this table.

Molecule	Ground state electron configuration	Bond order
NF	$(\sigma_{1s})^{2}(\sigma_{1s}^*)^{2}(\sigma_{2s})^{2}(\sigma_{2s}^*)^{2}(\pi_{2p})^{4}(\sigma_{2p})^{2}(\pi_{2p}^*)^{2}$	Number 2
NF^+	$(\sigma_{1s})^{2}(\sigma_{1s}^*)^{2}(\sigma_{2s})^{2}(\sigma_{2s}^*)^{2}(\pi_{2p})^{4}(\sigma_{2p})^{2}(\pi_{2p}^*)^{1}$	Number 2.5
NF^-	$(\sigma_{1s})^{2}(\sigma_{1s}^*)^{2}(\sigma_{2s})^{2}(\sigma_{2s}^*)^{2}(\pi_{2p})^{4}(\sigma_{2p})^{2}(\pi_{2p}^*)^{3}$	Number 1.5

0 1 2 3 4 *Drag a number into each of the blank boxes above.*

Classify these species according to their magnetic properties.

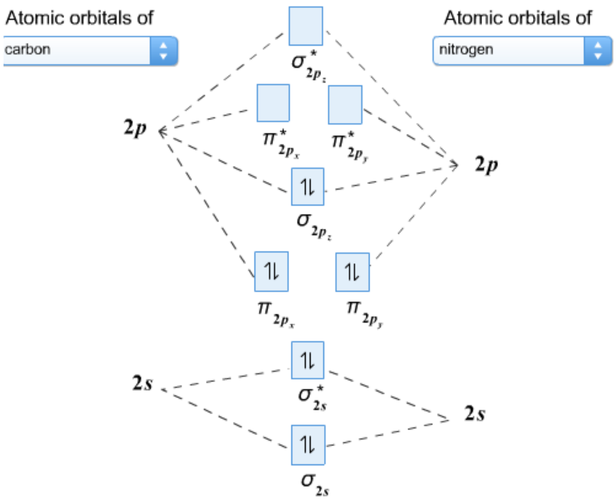
Diamagnetic	Paramagnetic
	NF^- NF NF^+

Correct.

35.(Not a question)

Complete this molecular orbital diagram for CN^- then determine the bond order. Note that the 1*s* orbital is not shown in this problem. To add arrows to the MO diagram, click on the blue boxes.

Molecular orbitals of CN^-



Bond order of CN^-

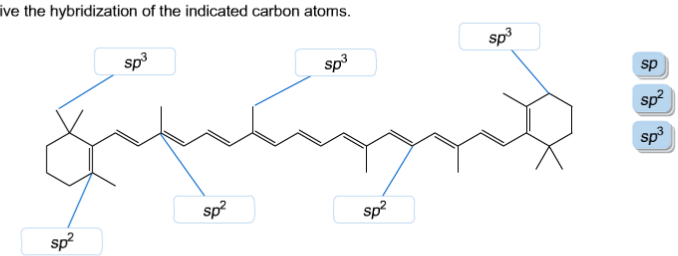
- ○ 0
- ○ 0.5
- ○ 1
- ○ 1.5
- ○ 2
- ○ 2.5
- ◉ 3

Correct.

36. (Not a question)

Beta-carotene, the structure of which is shown below, is an orange colored compound that gives carrots, sweet potatoes, and flamingo feathers their distinctive colors. Map

a) Give the hybridization of the indicated carbon atoms.



b) How many π molecular orbitals does beta-carotene have?

Number 22 π MOs

scroll down for full question

c) Considering only the π electron system, how many nodes does the HOMO have?

Number

10 nodes

d) Consider the conjugated π system of beta-carotene as a large box of length L. Calculate the length of the box if a C–C single bond is 1.52 Å and a C=C double bond is 1.35 Å.

Number

30.03 Å

e) What is the energy difference between the HOMO and LUMO?

Number

1.534×10^{-19} J

f) The actual λ_{max} for beta-carotene is about 470 nm. Calculate the actual energy difference between the HOMO and LUMO.

Number

4.23×10^{-19} J

orrect

37.

For which of these elements would the first ionization energy of the atom be higher than that of the diatomic molecule?

F, B, Li, He