Q1) 12 points (2 points each)

Arrange the following (Use ">" or "<" to show decreasing and increasing order, respectively. If two options have the same value, use "=" between them)

a) **Decreasing** order of *wavelength* of a photon for the following transitions in a H atom (assume all given transitions are possible):

2s to 3p 3d to 2p 1s to 3p 2p to 1s 3d to 1s

b) **Increasing** *boiling point*:

Hexane; 2,3-dimethylbutane; 2-methylpropane; $CH_3CH_2CH_2CH_2CH_2CH_2OH$

c) **Decreasing** number *delocalized* electrons

Benzene O_3 CO_2 HCOO-

d) **Increasing** number of *unpaired* electrons

Mo^{2+} Zn^{2+} Fe^{3+} Zr^{2+}

e) **Decreasing** *size*

Cs^{+} Sr^{2+} I^{-} Mg^{2+}

f) **Increasing** number of *valence electrons*

F In Mn Ru

Q2) 9 points

There are two possible ways to draw the Lewis structure of H_3PO_3 in both of which all of the atoms have zero formal charge, but each have different molecular geometry at the central atom (P).

a) Draw both Lewis structures for H_3PO_3 (there are no O-O bonds). Indicate and draw (show solid wedge-dashed bonds) the molecular geometry around phosphorous atom for both the Lewis structures. **8 points**

Structure 1:	Structure 2:
Molecular Geometry around P:	Molecular Geometry around P:

b) Are these Lewis structures resonance structures of each other? Why or why not? **1 points**

Q3) 8 points

The **ionization energy (in kJ/mol)** for a given period 2 element are the following:

	IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7	IE_8
X	1314	3388	5296	7467	10987	13320	71320	84070

a) What is element X? Briefly explain your reasoning. **3 points**

b) Using the ionization energy values given above, calculate the **<u>lowest frequency</u>** (3 sig. figures) of a photon that can remove an electron from the ground state atom X? Show calculations. **5 points**

Q4) 11 points

a) A photon of wavelength 300 nm strikes an electron in a metal. The work function of the metal is 3.5×10^{-19} J. What is the velocity (ms^{-1}; 2 significant figures) of the electron ejected, assuming it was initially at rest? Show calculations. **7 points**

b) Without doing any calculations, predict the change (increase, decrease, or no change) for the following, if the wavelength of the photon was changed to 200 nm. **4 points**

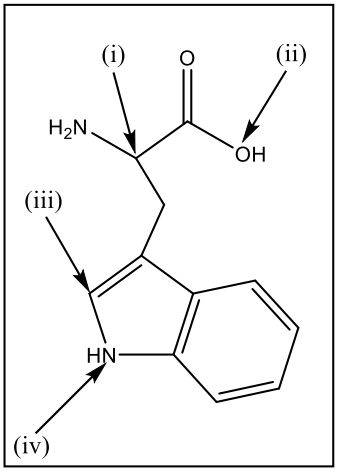
1. Work function of the metal:

2. Velocity of the electron:

3. Number of electrons ejected:

4. Kinetic energy of the electron:

Q5) 10 points



For the indicated atoms (denoted with an arrow), (i) to (iv), answer the following questions. Lone pairs are **not** indicated in the structure. All atoms have formal charge of 0.

a) **(2 points)** Describe the orbitals involved in all bonds formed by C(i). Designate sigma and pi bonds.

b) **For (ii)**

1. **(1 point)** Indicate the **molecular geometry** at O:
2. **(1 point)** Circle the one value that best describes the C-O-H bond angle.

>90° to <109.5° 109.5° >109.5° to <120° 120° >120° to <180

c) **For (iii)**

1. **(1 points)** Indicate the **hybridization** at C(iii):
2. **(3 points)** Consider x as the bond axis, how many p_x-p_x and p_y-p_y pi bonds does (iii) have?

p_x-p_x pi bonds = p_y-p_y pi bonds =

d) **For (iv)**

1. **(1 point)** Indicate the **molecular geometry** at (iv):
2. **(1 point)** Circle the one value that best describes the H-N-C bond angle.

>90° to <109.5° 109.5° >109.5° to <120° 120° >120° to <180

Q6) 10 points

a) Draw the molecular orbital (MO) diagram for N_2 (valence orbitals only). Label all the atomic and molecular orbitals (No need to show contribution/dotted lines from atomic orbitals). What is the bond order for N_2? **6 points**

b) Based on MO diagrams only, predict which of the following has the higher ionization energy (IE) in each case, and why? **4 points**

1. Higher IE: N_2 or N_2^{2-}

2. Higher IE: C_2 or C_2^{2-}

Q7) 11 points

a) Carbon can form bonds with itself as well as other elements. **5 points**

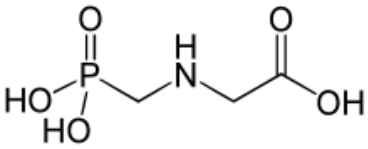
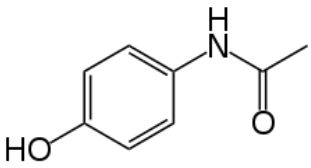
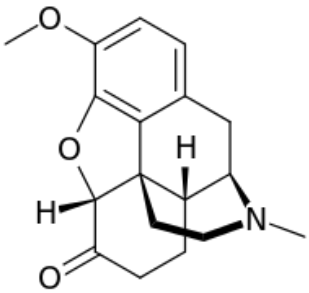
i. In addition to the halogens, what 5 other atoms most *commonly* bond to carbon in organic compounds? (symbols or names are accepted)

ii. Which of those 5 atoms in part *i* are heteroatoms?

iii. From the 5 atoms in part *i*, which elements are more electronegative than carbon?

iv. From the 5 atoms in part *i*, which elements are less electronegative than carbon?

b) Circle and name the type of functional groups in each compound below. Specify if each is primary, secondary, or tertiary. **6 points**

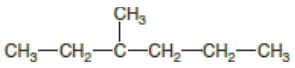
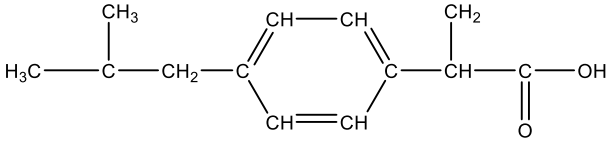
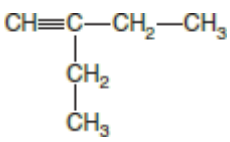
		
glyphosate (an herbicide)	acetaminophen (Tylenol)	hydrocodone

Q8) 17 points

a) Draw the following structures in the space provided. **3 points**

2-pentyne	*trans*-but-2-ene	1,4-dimethylcyclohexane

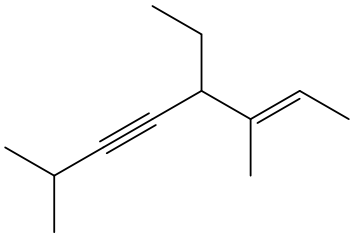
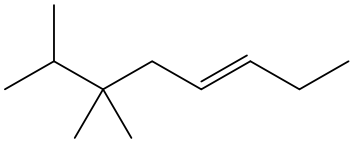
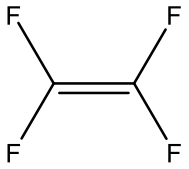
b) Circle any problems with the structures drawn below and draw the *corrected* structures as carbon skeletons. **6 points**

Question 8 continued on next page

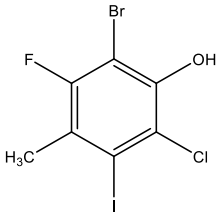
c) Provide the correct IUPAC names for the following structures. If necessary, specify *cis* vs *trans.*

6 points

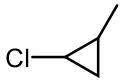
d) Taking the iodo as your reference, indicate the position of the other substituents as *ortho, meta, para*.

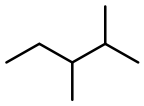
2 points

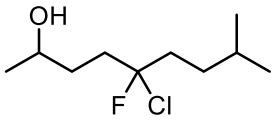
	Group	*ortho, meta, para*
	fluoro	
	bromo	
	hydroxyl	
	methyl	

Q9) 12 points

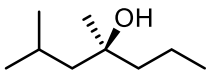
a) Circle all the chiral centres in the structures below. **3 points**

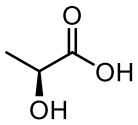


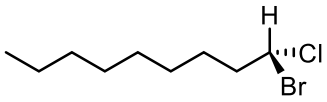




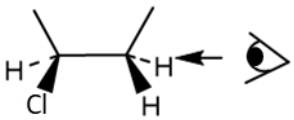
b) Give each molecule the appropriate stereochemical assignment (R vs S). Explain the steps you use to assign R vs S. **6 points**







c) Draw the Newman projection of the molecule below in the box provided, from the perspective indicated. **3 points**



Q10) 11 points

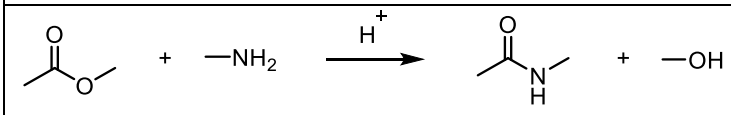
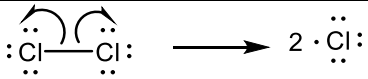
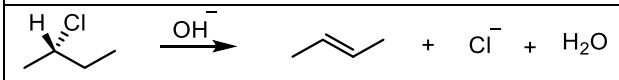
a) What is the definition of a nucleophile? **1 point**

b) Circle the stronger nucleophile in each pair, and explain why it is a stronger nucleophile. **6 points**

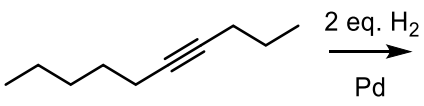
Nucleophiles	**Reason**
H_2O vs OH^-	
Br^- vs F^-	
NH_2^- vs NH_3	
CH_3^- vs NH_2^-	

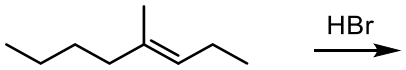
c) Label each reaction event below with either the bonding-breaking type or the specific reaction type. Choose the type that **<u>best</u>** describes the reaction event drawn. **4 points**

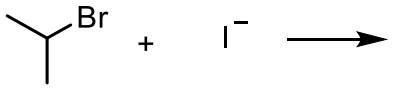
Choices: substitution, addition, elimination, rearrangement, heterolytic cleavage, homolytic cleavage

Reaction scheme	Reaction type (one **best** choice)
	
	
	
	

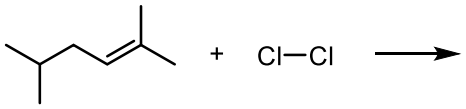
Q11) Draw the products of the reactions (carbon skeleton). **8 points**







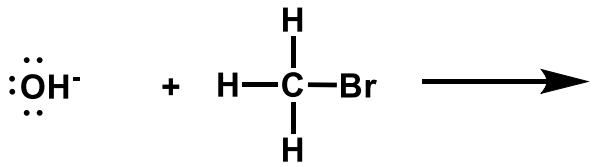
substitution



Q12) 10 points

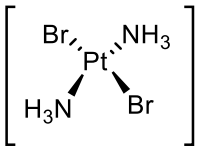
a) Draw a reaction energy diagram for a concerted, exothermic reaction. Include all the necessary labels. **5 points**

b) Complete the S_N2 reaction below. If there is a key intermediate or transition state, be sure to draw this and label if it is a transition state or an intermediate. Draw the curved arrows to show the movement of electrons (making and breaking bonds). **5 points**



Q13) 8 points

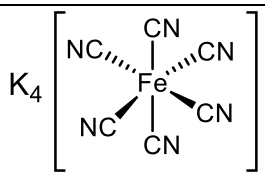
a) What is the coordination number of the complex and oxidation state of the transition metal in the following coordination complexes? **6 points**

Coordination complex	**Oxidation state**	**Coordination number**
$[Co(en)_2Cl_2]OH$		
		
tetraamminebromochloroplatinum(IV) chloride		

b) In $[Cr(OH)_6]^{3-}$, is the chromium ion diamagnetic or paramagnetic? Show the electron configuration to explain why chromium is either diamagnetic or paramagnetic. **2 points**

Q14) 8 points

a) Provide the systematic name for the following two coordination compounds. **2 points**

	$[Zn(H_2O)Cl(en)_2]Br$

b) If any of the following complexes can exist as isomers, state the type of isomerism and draw the structures. **6 points**

$[Zn(en)F_2]$	**$[Zn(H_2O)(NH_3)FCl]$**	**$[PtCl_2Br_2]^{2-}$ (square planar)**

Q15) 5 points

a) In each set of coordination complexes, circle which coordinate complex has the largest crystal field splitting energy. **2 points**

i.		**ii.**
Coordination complex	Maximum absorbance λ	
$[Fe(A)_6]^{3+}$	700 nm	$[Ti(NH_3)_6]^{3+}$
$[Ti(A)_6]^{3+}$	510 nm	$[TiF_6]^{3-}$
$[Cr(B)_6]^{3-}$	400 nm	$[Ti(CN)_6]^{3-}$
$[Fe(B)_6]^{3-}$	305 nm	$[Ti(H_2O)_6]^{3+}$

b) Why is the +2 oxidation state so common among transition elements? **1 point**

c) How does the variation in atomic size across a transition series contrast with the variation across the main group elements of the same period? Briefly explain why there is a difference for the transition series. **2 points**