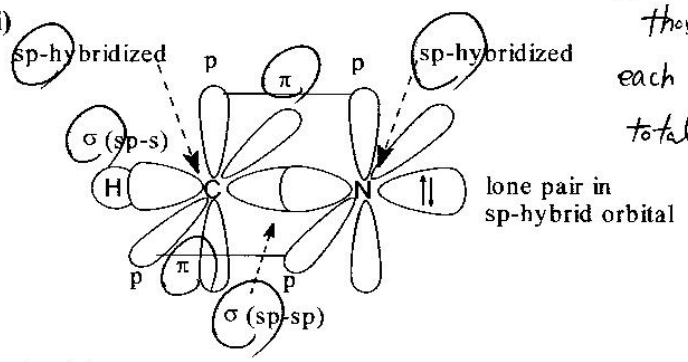
SOLUTIONS

you have to mention those six
each one points 1.5
total → 6 x 1.5 = 9 pts

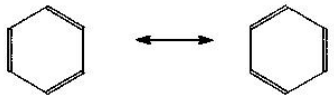
1 (i)



(9 points) (x,y,z axes are not necessary)

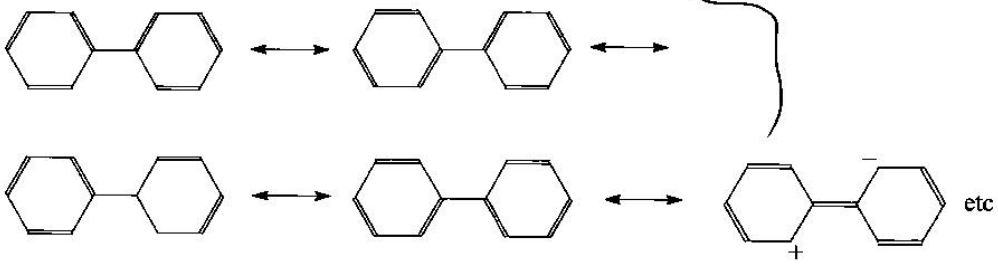
(ii)

There are only two major resonance structures for benzene:



3 pts

Biphenyl has more:



Give 5 points if correct explanation + some resonance structures (i.e. equiv

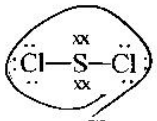
Biphenyl is more effectively stabilized than two separate (unbonded) benzene rings RE(biphenyl) > RE(benzene) [RE = resonance energy]. In effect the π system in biphenyl is more delocalized than that in benzene.
(6 points; 5 points if last resonance structure is omitted)

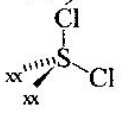
explanation points 3 pts

2. (i)

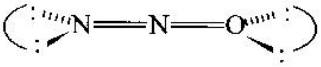
Note for all of these, only lone pairs on central atom need be shown.

drawing structure ✓ : 1 pt
types : 1 pt

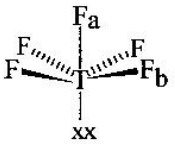
(a) Lewis diagram for SCl_2 is  SN of S = 4: tetrahedral arrange of electrons

Actual shape: "V" or bent  ∠ClSCl < 109.5° (or tetrahedral angle) (distorted)

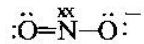
(b) Lewis diagram for N_2O is  SN of central N = 2: linear arrangement of electrons

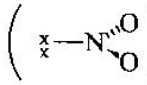
Actual shape: linear 

(c) Lewis diagram for IF_5 is  SN of central I = 6: octahedral arrangement of electrons

Actual shape: square pyramidal (distorted)  $\angle F_aIF_b < 90^o$

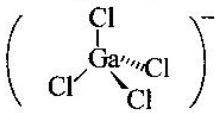
$\angle$ lone pair$IF_b > 90^o$

(d) Lewis diagram for NO_2^- is  SN of central N = 3: trigonal planar arrangement of electrons

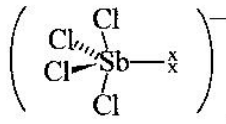
Actual shape: "V" shape or bent (distorted)  ∠ONO < 120°

(4 x 2 points)

(ii) (a) In $GaCl_4^-$, the central atom (Ga, group 3) has a steric number (SN) of 4 and is tetrahedral: 2 pts



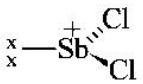
Sb (group 5) in $SbCl_4^-$ has SN = 5, with a trigonal bipyramidal arrangement of electrons. Its actual shape is "seesaw", with distorted ClSbCl bond angles:

 2pts

(2 x 2 points)

(b) The cation $GaCl_2^+$ is linear, whereas $SbCl_2^+$ is bent:

(SN =2)



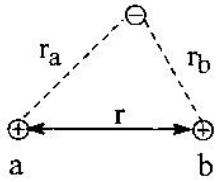
(SN =3)

Hence $(SbCl_2^+)(GaCl_4^-)$ is the correct formulation. **(3 points)**

3pts

3 (i)

For H_2^+, there are just two attractive potentials and one repulsive potential:

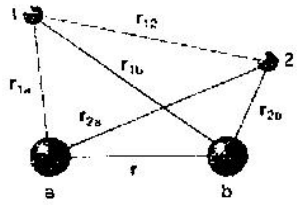


$$V = -\frac{e^2}{r_a} - \frac{e^2}{r_b} + \frac{e^2}{r}$$

(2 points)

For H_2, there are four attractive and two repulsive potentials:

$$V = -\frac{e^2}{r_{1a}} - \frac{e^2}{r_{2b}} - \frac{e^2}{r_{1b}} - \frac{e^2}{r_{2a}} + \frac{e^2}{r_{12}} + \frac{e^2}{r}$$

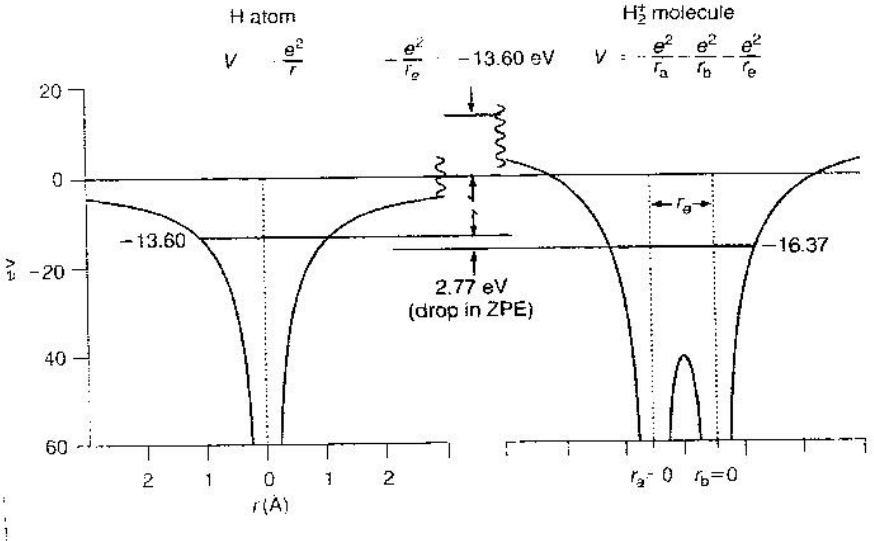


(3 points)

H_2^+ was chosen as the model for MO theory, because it is a single electron system and thus can be solved exactly using the Schrödinger equation. **(2 points)**

(ii)

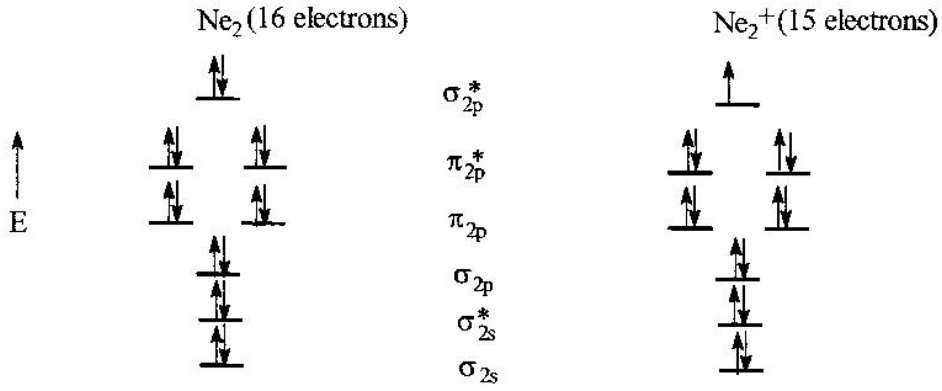
A diagram like the one below is needed, but it is not necessary to include either the x or y axis scales. A sketch showing the shape of the potential curves for H and H_2^+ with approximate lines for –13.60 eV and –16.37 eV is fine.



The driving force behind bond formation (overlap of atomic orbitals) is greater volume for the electron in which to exist, or greater delocalization.

(4 points for diagram, 4 points for explanation)

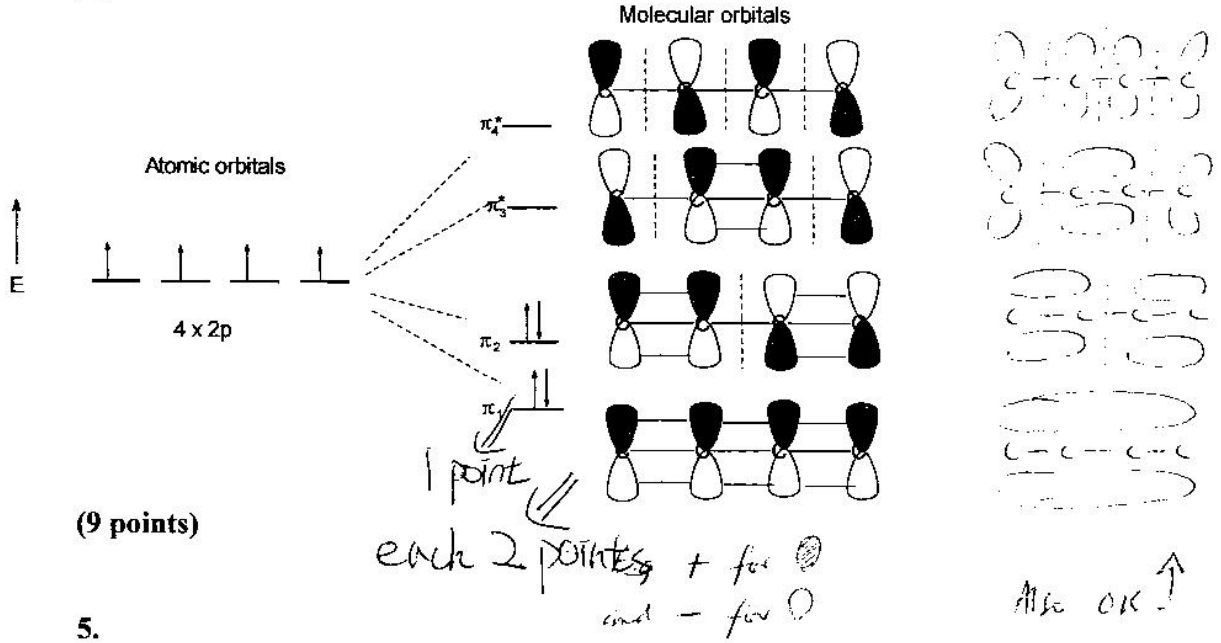
4(i)



Bond order: 1/2(8-8) = 0 4 points Bond order: 1/2(8-7) = 0.5

A weak bond exists between the Ne atoms in Ne_2^+, but Ne_2 is not chemically bonded. **(6 points)** explain 2 points

(ii)



1 point each 2 points + for ⊗ and − for ○ Also ok ↑

(9 points)

5.

Since this process is isothermal, $\Delta E = \Delta H = 0$ **(4 points)** ~~Sign~~ - each 2pts

At constant T and n, Boyle's law holds:

$$\frac{V_2}{V_1} = \frac{p_1}{p_2} = \frac{10.0\ (atm)}{1.00\ (atm)}$$

$$= 10$$

Hence, since $w = -nRT \ln (V_2/V_1)$,

$w = -5.00\ (mol) \times 8.315\ (J\ K^{-1}\ mol^{-1}) \times 298\ (K) \times \ln (10)$

$= -28500\ J$ **(8 points)** sign. unit. caculation mistake 4pts

$\therefore q = 28500\ J$ **(3 points)** 1 2pts

Coupling these two equations, where all the oxygen from the first reaction is used up in combustion of carbon, gives

$2Fe_2O_3(s) \longrightarrow 4Fe(s) + 3O_2(g)$; $\Delta G = +840$ kJ

$3C(s) + 2Fe_2O_3(s) \rightarrow 3CO_2(g) + 4Fe(s)$; $\Delta G = 840 - 1200 = -360$ kJ **(4 points)** unit. sign. calculation mistake ⇒ 2pts no answer just equation ⇒ 2pts

If ferrous oxide and carbon (ratio 2:3) are heated together, conversion of ferrous oxide to iron is spontaneous.

(ii)

The process is

$CHCl_3(l) \rightarrow CHCl_3(g)$; $\Delta H^o = 31.4$ kJ/mol , $\Delta S^o = 93.8$ J/K/mol, for which

$\Delta G = \Delta H - T\Delta S$.

At the boiling point, liquid is equilibrium with gas and $\Delta G = 0$ (reversible)

$0 = \Delta H^o - T_b\Delta S^o$, where T_b is the boiling point and ΔH^o, $\Delta S^o \sim \Delta H$, ΔS

(3 points) $\Delta G < 0 \Rightarrow$ no points

Hence, boiling point = 31400 (J/mol)/93.8 (J/K/mol)

= 335 K (62 °C) **(4 points)**