PART I – Multiple Choice) ***Select the*** **BEST** ***response for each question below.*** **[Total marks = 30]**

1. This is exam Version A. **Mark "A" as the answer to question 1 on the optical sense form.**

2. In which one of the following species is the octet rule **NOT** followed?

   A. NH_3 B. NH_4^+ C. I_2 D. BH_4^- E. NO_2

3. What is the total number of non-bonding **pairs of electrons** in the SF_3^+ cation?

   A. 1 B. 6 C. 4 D. 10 E. 5

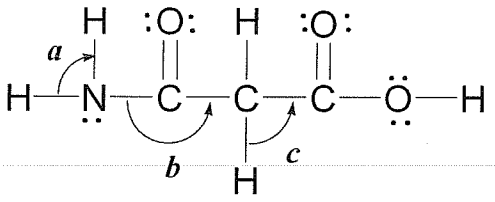
5. In the molecule $POCl_3$ the central atom is P, what is the formal charge on the P atom in the **best** electron dot structure (Lewis structure)? (Note: Phosphorus is a third row element.)

   A. +1 B. +2 C. -1 D. 0 E. +3

6. Triiodomethane, CHI_3, is a yellow solid with a normal melting point of 120°C. What is the main intermolecular force in CHI_3? Which of the listed intermolecular forces is/are at work in this substance?
   (i) Ion-dipole attraction
   (ii) Hydrogen bonding
   (iii) Dipole-dipole attraction
   (iv) London dispersion forces

   A. all of them B. ii, iii, & iv only C. ii & iii only D. iii & iv only E. iv only

7. To a close approximation, the bond angles marked ***a, b, c*** in the molecule below are _____, _____, and _____ respectively.



A. 90°, 180°, 90° B. 109.5°, 120°, 109.5° C. 120°, 120°, 109.5°
D. 120°, 120°, 90° E. 109.5°, 90°, 120°

8. The molecule in **question 7** has _____ sigma (σ) and _____ pi (π) bonds, respectively.

A. 11, 2
B. 9, 2
C. 11, 0
D. 9, 0
E. 5, 4

9. Which of the following molecules is square planar in molecular shape?

A. SF_4 B. XeF_4 C. $SiCl_4$ D. BF_4^- E. $SnCl_3^-$

10. Which of the following has a trigonal bipyramidal electron domain geometry?

A. SF_4 B. XeF_4 C. $SiCl_4$ D. BF_4^- E. $SnCl_3^-$

11. Three monosulfur fluorides are observed: SF_2, SF_4 and SF_6. Of these, _____ is/are polar.

A. SF_2 only B. SF_2 and SF_4 only C. SF_4 only
D. SF_6 only E. SF_2, SF_4 amd SF_6

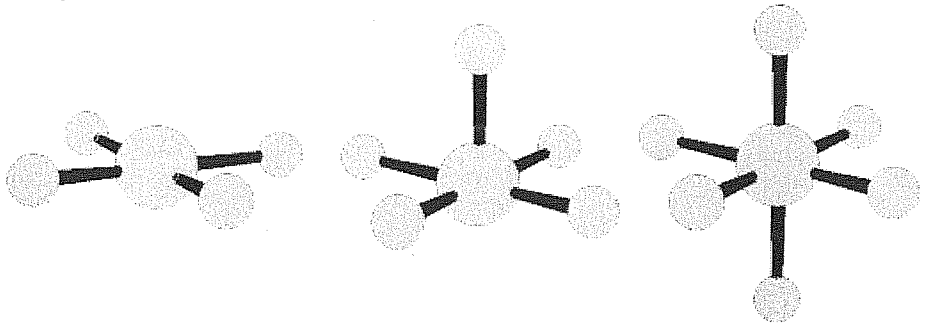
12. Which of these statements about benzene is FALSE?

A. The C-C bond lengths are all the same.
B. Benzene exhibits delocalized bonding.
C. The C-C bonds have a bond order of 1.5.
D. Three resonance structures are required to fully describe the bonding in benzene.
E. Each carbon atom contributes one electron to the π bonding in benzene.

13. Which of the following numbers of electron domains can give rise to a linear molecule?

A. 2 B. 3 C. 4 D. 5 E. 2 and 5

14. How are the central atoms in the molecules below hybridized? (The types of hybrid orbitals are listed in the same left-to-right order as the molecules.)



A. sp^3, sp^3d, sp^3d^2

B. sp^3, sp^3d^2, sp^3d^2

C. sp^3d, sp^3d, sp^3d^2

D. sp^3d^2, sp^3d, sp^3d^2

E. all sp^3d^2

15. Mercury is a liquid. Using your knowledge of metallic bonding, choose the best reason for this property.

A. Mercury has the configuration $6s^2\ 5d^{10}$, so it melts in a sea of electrons.

B. Mercury has no electrons in the bonding part of the d band, so the forces between atoms are weak.

C. Mercury has a large band gap, so has some of the properties of an insulator.

D. Mercury has as many antibonding electrons as bonding electrons, so the forces between atoms are weak.

E. Mercury has a large ionization energy, so will not form an ionic lattice.

16. Consider the intermolecular forces involved, and then arrange the following molecules in increasing order of boiling point (*i.e.* lowest b.p. first, highest b.p. last).

CH_3CH_2—OH CF_4 $HOCH_2CH_2OH$ $CH_3CH_2CH_2CH_3$

A. $HOCH_2CH_2OH < CH_3CH_2OH < CH_3CH_2CH_2CH_3 < CF_4$

B. $CF_4 < CH_3CH_2CH_2CH_3 < HOCH_2CH_2OH < CH_3CH_2OH$

C. $HOCH_2CH_2OH < CH_3CH_2CH_2CH_3 < CH_3CH_2OH < CF_4$

D. $CF_4 < CH_3CH_2CH_2CH_3 < CH_3CH_2OH < HOCH_2CH_2OH$

E. $CH_3CH_2CH_2CH_3 < CH_3CH_2OH < CF_4 < HOCH_2CH_2OH$

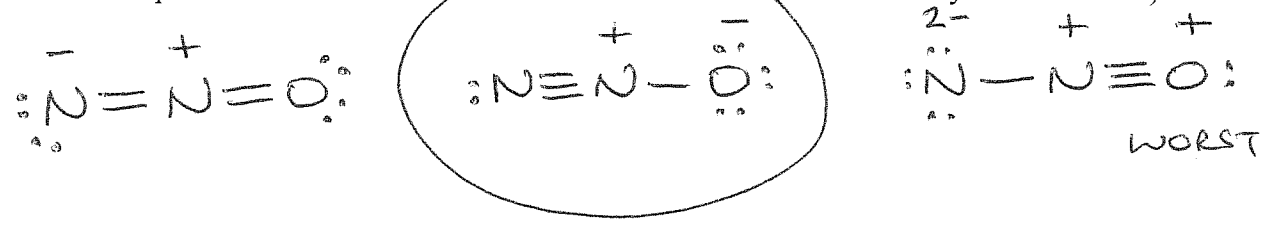
PART II – Written Answers to Questions. [Total Marks = 20]

Write your answers directly on this test paper. Show all your work. This helps us to award part marks instead of zero where appropriate. Hand in the entire test paper at the end of the test period.

1. **[5 Marks]**

1. In the molecule, N_2O, one of the nitrogen atoms is the central atom.

(a) Write three possible resonance structures for this molecule. (All must obey the octet rule.)



BEST – NEGATIVE CHARGE ON MOST ELECTRONEGATIVE ATOM

WORST

(b) Assign formal charges to each atom in every structure above. Write the non-zero formal charges beside the appropriate atoms in each structure.

(c) Which resonance form **(circle it)** is likely to contribute the most to the correct description of N_2O? Explain your reasoning.

(d) Based on your answer to part (c) above, within which range of bond lengths would you expect the actual bond length of the N-to-N bond in N_2O to lie? Circle one.

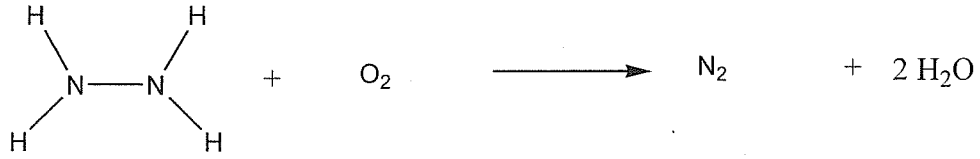
N≡N N=N N–N

< 110 pm | 110-124 pm | 124 | 125-140 pm | 140 | > 140 pm

IN BETWEEN N≡N AND N=N

2. **[4 Marks]**

Hydrazine, a component of rocket fuel, undergoes combustion to yield N_2 and H_2O according to the following gas-phase chemical equation:



hydrazine

Calculate the enthalpy of reaction (ΔH) for this combustion (in kJ/mol) using bond energies from the data sheet.

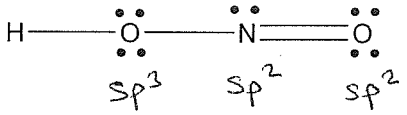
BREAK 4 × N–H
1 × N–N
1 × O=O
ENDOTHERMIC, +ve

FORM 4 × O–H
1 × N≡N
EXOTHERMIC, –ve

$(4 \times 388 + 1 \times 163 + 1 \times 495)$
$- (4 \times 463 + 1 \times 945)$
$= -587$ kJ/mol

3. **[4 Marks]**

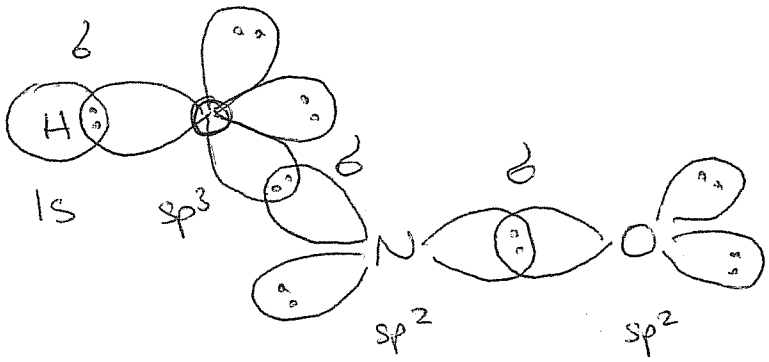
Consider the nitrous acid molecule HNO_2. The Lewis structure is shown below.



Draw (*i.e.* sketch) the bonding orbitals used in the formation of all the sigma (σ) and pi (π) bonds (including that to the H atom) for the nitrous acid molecule. Be sure to show clearly how the orbitals overlap to form the bonds. You will need to decide on the orbital hybridization for each atom. CLEARLY LABEL ALL THE ORBITALS AND SIGMA (σ) AND PI (π) BONDS, AND SHOW ALL THE BONDING AND NON-BONDING ELECTRONS.

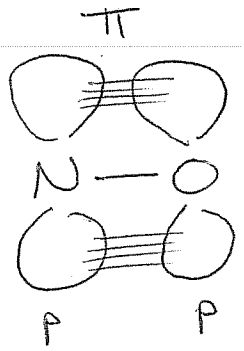
(Note: For clarity of presentation, you have the option of drawing the sigma (σ) and pi (π) bonds separately, using two diagrams if you wish.)

SIGMA (σ) BONDING



SIGMA = END-ON OVERLAP

PI (π) BONDING



PI = SIDE-ON OVERLAP OF UNHYBRIDIZED p-ORBITALS