**ATAR CHEMISTRY YEAR 11: Organic Chem and Intermolecular Forces**

**Name\_\_\_\_\_\_\_\_\_\_\_\_SOLUTIONS\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (39 marks)**

**Section A: Multiple Choice** *(please answer on the grid at the end of this section)*

1. Which of the following correctly identifies the number of lone pairs and single bonding pairs in the valence shell of a nitrogen atom in an ammonia molecule?

Lone pairs Single Bonds

* 1. 1 3
  2. 3 1
  3. 0 4
  4. 2 2

**2.** Which one of the following observations is explained in terms of hydrogen bonding?

A The melting point of H2Se is higher than that of H2S.

B The melting point of H2S is higher than that of CH4.

C The boiling point of HBr is higher than that of PH3.

D The boiling point of HF is higher than that of HCl.

1. Which of the following is most likely to be a polar molecule?
   1. A diatomic molecule of the same element.
   2. A diatomic molecule of different elements.
   3. A symmetrical molecule with polar bonds.
   4. A symmetrical molecule with non-polar bonds.
2. Which of the following lists the strength of intermolecular forces from weakest to strongest?
   1. Hydrogen bonding, Dispersion, Dipole-Dipole
   2. Hydrogen bonding, Dipole-Dipole, Dispersion
   3. Dipole-Dipole, Dispersion, Hydrogen bonding
   4. Dispersion, Dipole-Dipole, Hydrogen bonding
3. Which of the following molecules would have 3 zones of negativity around the central atom?
   1. CO2
   2. NH3
   3. BCl3
   4. CH4

6. Which of the following substances would contain dipole-dipole forces between the molecules?

A Bromine (Br2)

B Methane (CH4)

C Tetrachloromethane (CCl4)

D Chloromethane (CH3Cl)

7. Which one of the pairs of terms below correctly describes the electron pair geometry of the central nitrogen atom and the molecular shape of an NH3 molecule?

|  |  |  |
| --- | --- | --- |
|  | Electron pair geometry | Molecular shape |
| A | tetrahedral | trigonal planar |
| B | tetrahedral | trigonal-pyramidal |
| C | trigonal planar | V-shape |
| D | linear | Linear |

8 Which one of the following is a polar molecule?

A CCl4

B CO

C SiH4

D BH3

B *CO is a linear diatomic molecule between dissimilar atoms so they have different electronegativities and the bond will be polar.*

*While the C−Cl and Si−H bonds in CCl4 and SiH4 are polar, these molecules have a tetrahedral shape with the Cl and H atoms symmetrically placed around their central atom so these molecules are non-polar. The B−H bond in BH3 is polar, but the molecule has a trigonal planar shape with the H atoms symmetrically placed around the central B atom.*

9 Which one of the following molecules will have only dispersion forces and dipole–dipole forces between its molecules?

A H2S

B C2H4

C CO2

D SO3

A H2S is V-shaped with a dipole so has dispersion forces and dipole–dipole forces between its molecules.

*NH3 is trigonal-pyramidal with polar bonds and has a dipole so has dispersion forces, dipole–dipole forces and hydrogen bonding between its molecules. CO2 is linear with a symmetrical distribution of charge around the central C atom making it a non-polar molecule, so it will have only dispersion forces between its molecules. SO3 has polar bonds but is a trigonal planar molecule with the O atoms symmetrically distributed around the central S atom, making it a non-polar molecule, so it will have only dispersion forces between its molecules.*

10 The heat needed to vaporise 1 g of liquid ammonia (NH3) is 1.36 kJ, while that needed to vaporise 1 g of liquid methane (CH4) is 0.51 kJ. Which of the following statements help explain this?

I Only dispersion forces act between methane molecules.

II There are strong covalent bonds between N and H atoms in ammonia molecules.

III There is strong hydrogen bonding between ammonia molecules in liquid ammonia.

IV There is weak hydrogen bonding between methane molecules in liquid methane.

A I and II only

B III and IV only

C I and III only

D I, II and III only

*C Ammonia is a polar molecule with highly polar N−H bonds due to the large difference in electronegativity between N and H atoms, so there is hydrogen bonding between ammonia molecules, whereas methane is non-polar tetrahedral molecule with the H atoms symmetrically*

1. In which of the following are the covalent bonds ranked in order of decreasing polarity  
   (i.e. most polar to least polar)?

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | H-O | > | H-F | > | H-Br | > | H-C |
|  | H-C | > | H- Br | > | H-O | > | H-F |
|  | H-F | > | H-C | > | H-O | > | H-Br |
|  | H-F | > | H-O | > | H-Br | > | H-C |

**12.** Which of these gives the correct shape for each of the covalent molecules?

**SO3 HCN F2O**

1. pyramidal linear bent / v-shaped
2. trigonal planar linear bent / v-shaped
3. trigonal planar bent / v-shaped linear
4. pyramidal trigonal planar linear

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |  | 7 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |
| 2 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |  | 8 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |
| 3 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |  | 9 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |
| 4 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |  | 10 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |
| 5 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |  | 11 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |
| 6 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |  | 12 | 🞏 a | 🞏 b | 🞏 c | 🞏 d |

**Section 2: Short Answer Section**

Question 13 (12 marks)

a Complete the table below by drawing the Lewis structure or sketching or naming the shape of the molecule. (6 marks)

|  |  |  |
| --- | --- | --- |
| Molecule | Lewis structure | Sketch and name the shape |
| PH3 |  | trigonal-pyramidal –pyramidal ok\* (and appropriate drawing)  (2 marks) |
| CS2 |  | linear\* (and appropriate drawing)  (2 marks) |
| CF4 | ( 1mark) | tetrahedral |
| OCl2 | ( 1 mark) | bent (V-shaped) |

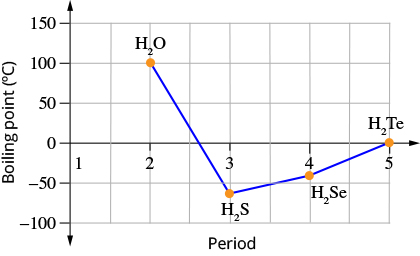
b Classify the following molecules into the table below. (6 marks)

|  |  |  |
| --- | --- | --- |
| HCN | SiCl4 | NCl3 |
| CH2F2 | Br2 | BF3 |

|  |  |  |
| --- | --- | --- |
| Non-polar molecule with polar bonds between atoms | Non-polar molecule with non-polar bonds between atoms | Polar molecule with polar bonds between atoms |
| SiCl4\*  BF3\* | Br2\* | HCN\*  NCl3\*  CH2F2\* |

Question 14 (6 marks)

The following graph shows the boiling points of the group 16 hydrides.



Explain by referring to intermolecular forces why the boiling point of H2S is so much lower than that of H2O. (6 marks)

*14 (solution)*

*The stronger the intermolecular forces, the higher the boiling point of a substance\*. (1)*

*Water (H2O) molecules are highly polar, so between water molecules there are hydrogen bonds (1) as well as weak dispersion forces\*.*

*H2S is much less polar, so between H2S molecules there are dipole-dipole interactions (1) and weak dispersion forces\* .*

*(+1 mark if recognises dispersion forces in both molecules)*

*Because H2S molecules are larger than water molecules, the dispersion forces between H2S molecules are more significant than those between water molecules (1) \*.*

*However,* ***hydrogen bonds are much stronger than dipole-dipole interactions****, so overall, the intermolecular bonds between H2S molecules are weaker than those between water molecules and the boiling point of H2S is consequently lower\*. (1)*

*1st point and last point may be combined*

Question 15 (4 marks)

Examine the structures and information for the compounds methanal and methanol shown below.

|  |  |
| --- | --- |
|  |  |
| Methanal  Molar mass = 30 g mol–1  Boiling point = –19°C | Methanol  Molar mass = 32 g mol–1  Boiling point = 65°C |

These compounds have similar molar masses but very different boiling points. Explain why their boiling points are different.

*Both compounds have dispersion forces between their molecules which will be of similar magnitude because the molecules have similar sizes (1).*

*Methanal will also have dipole–dipole forces between its molecules (1)*

*and methanol will also have hydrogen bonds between its molecules (1)*

*The hydrogen bonding in methanol is stronger than the dipole–dipole forces in methanal, so methanol has a higher boiling point* (1)\*. (4 marks)

**Question 16**

Identify the type of intermolecular forces (IMF) that exist between molecules of tetrachloroethene (C2Cl4). Clearly explain the steps taken to determine the type of IMF. [5]

Use of electron Dott diagram – 1

Polarity of bonds – 1

Overall symmetry – 1

Non-polar molecule – 1

**Dispersion – 1**