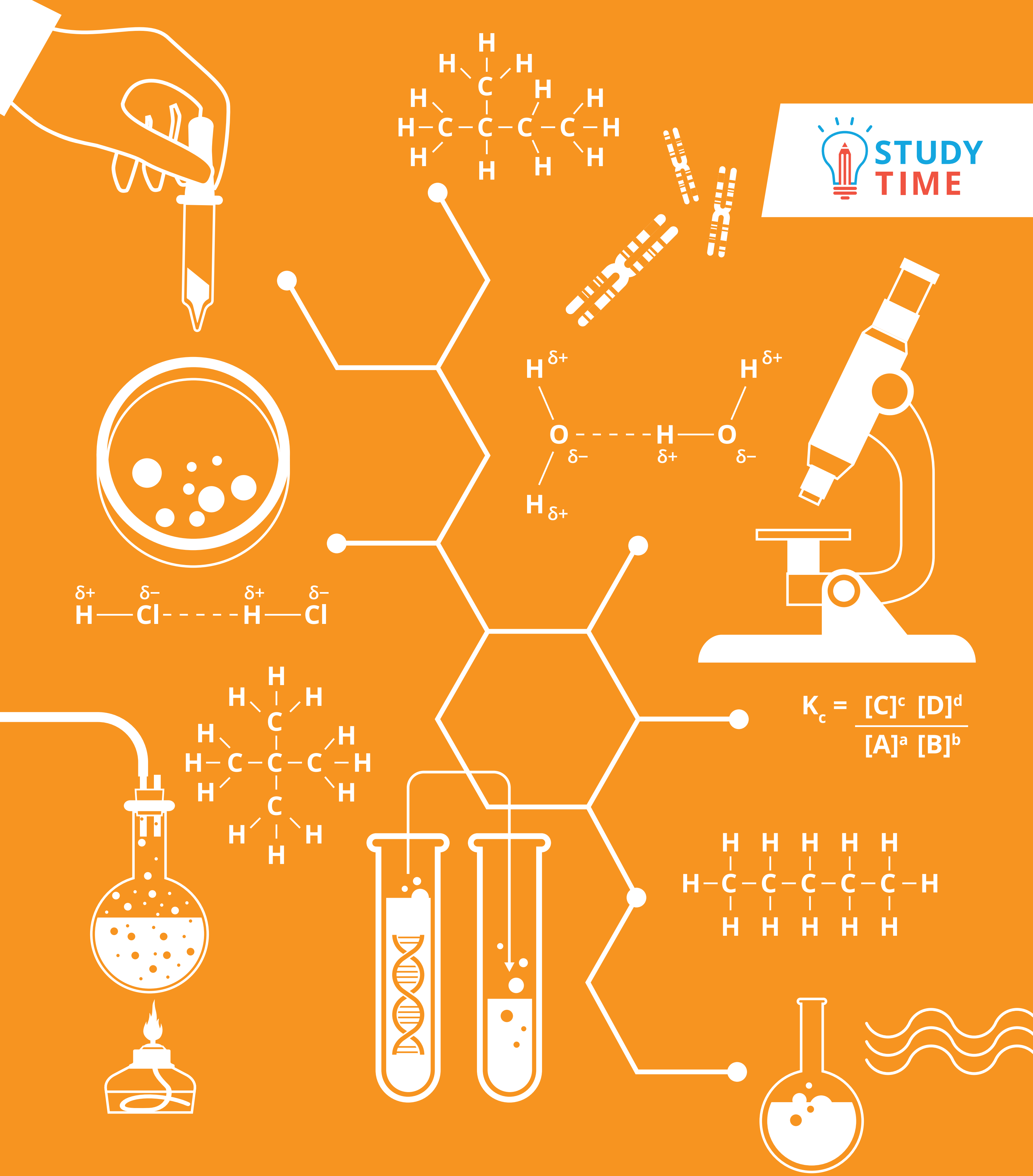


STUDY TIME

LEVEL 2 CHEMISTRY

STRUCTURE AND BONDING

NCEA Workbook Answers

Section One
Basic Skills

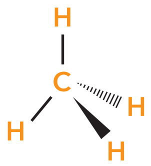
1. Molecular Shapes

a. A bond where two electrons are shared between two atoms

b. Covalent bonds have a negative charge because of the electrons, and since like charges repel, covalent bonds will repel each other to be as far apart as possible.

c. Degrees.

d. *i.* CH_4



Molecular shape: Tetrahedral

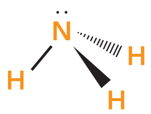
Bond angles: 109.5°

ii. H_2

Molecular shape: Linear

Bond angles: 180°

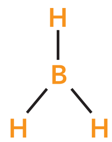
iii. NH_3



Molecular shape: Trigonal pyramidal

Bond angles: 109.5°

iv. BH_3



Molecular shape: Trigonal planar

Bond angles: 120°

v. CO_2

Molecular shape: Linear

Bond angles: 180°

vi. HCN

Molecular shape: Linear

Bond angles: 180°

vii. HBr

Molecular shape: Linear

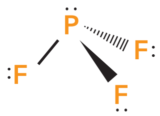
Bond angles: 180°

viii. N_2

Molecular shape: Linear

Bond angles: 180°

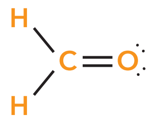
ix. PF_3



Molecular shape: Trigonal pyramidal

Bond angles: 109.5°

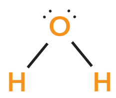
x. H_2CO



Molecular shape: Trigonal planar

Bond angles: 120°

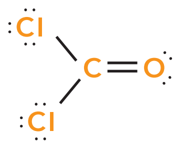
xi. H_2O



Molecular shape: Bent

Bond angles: 109.5°

xii. $COCl_2$



Molecular shape: Trigonal planar

Bond angles: 120°

xiii. O_2

Molecular shape: Linear

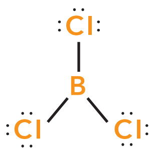
Bond angles: 180°

xiv. BeF_2

Molecular shape: Linear

Bond angles: 180°

xv. BCl_3



Molecular shape: Trigonal planar

Bond angles: 120°

xvi. HCl

Molecular shape: Linear

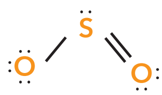
Bond angles: 180°

xvii. CO

Molecular shape: Linear

Bond angles: 180°

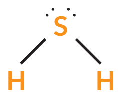
xviii. SO_2



Molecular shape: Bent

Bond angles: 120°

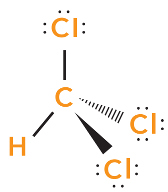
xix. H_2S



Molecular shape: Bent

Bond angles: 120°

xx. $CHCl_3$



Molecular shape: Tetrahedral

Bond angles: 109.5°

2. Polarity

a. Electronegativity is the tendency of an atom to attract a bonding pair of electrons.

b. A nonpolar covalent bond occurs when two atoms of the same element form a covalent bond. This is due to no difference in electronegativity.

c. A polar covalent bond occurs when two different atoms form a covalent bond. This is due to a difference in electronegativity.

d. Yes. If the polar bonds are symmetrically arranged throughout the molecule, their dipoles will cancel, resulting in a nonpolar molecule.

3. Types of Solids

a. *i.* Co

Type of solid: Metal.
Type of particle: Atoms.
Attractive forces between particles: Metallic bonds.

ii. Ag

Type of solid: Metal.
Type of particle: Atoms.
Attractive forces between particles: Metallic bonds.

iii. NaCl

Type of solid: Ionic solid.
Type of particle: Ions.
Attractive forces between particles: Ionic bonds.

iv. $MgCl_2$

Type of solid: Ionic solid.
Type of particle: Ions.
Attractive forces between particles: Ionic bonds.

v. C (graphite)

Type of solid: Covalent network.
Type of particle: Atoms.
Attractive forces between particles: Covalent bonds.

vi. Fe

Type of solid: Metal.
Type of particle: Atoms.
Attractive forces between particles: Metallic bonds.

vii. SiO_2

Type of solid: Covalent network.
Type of particle: Atoms.
Attractive forces between particles: Covalent bonds.

viii. Na

Type of solid: Metal.
Type of particle: Atoms.
Attractive forces between particles: Metallic bonds.

ix. CaF_2

Type of solid: Ionic solid.
Type of particle: Ions.
Attractive forces between particles: Ionic bonds.

x. ZnI_2

Type of solid: Ionic solid.
Type of particle: Ions.
Attractive forces between particles: Ionic bonds.

xi. S_8

Type of solid: Covalent.
Type of particle: Molecules.
Attractive forces between particles: Intermolecular forces.

xii. PCl_3

Type of solid: Covalent.
Type of particle: Molecules.
Attractive forces between particles: Intermolecular forces.

xiii. Zn

Type of solid: Metal.

Type of particle: Atoms.

Attractive forces between particles: Metallic bonds.

xiv. Ca

Type of solid: Metal.

Type of particle: Atoms.

Attractive forces between particles: Metallic bonds.

xv. C (diamond)

Type of solid: Covalent network.

Type of particle: Atoms.

Attractive forces between particles: Covalent bonds.

xvi. KBr

Type of solid: Ionic solid.

Type of particle: Ions.

Attractive forces between particles: Ionic bonds.

xvii. CO_2

Type of solid: Covalent.

Type of particle: Molecules.

Attractive forces between particles: Intermolecular forces.

xviii. H_2O

Type of solid: Covalent.

Type of particle: Molecules.

Attractive forces between particles: Intermolecular forces.

xix. I_2

Type of solid: Covalent.

Type of particle: Molecules.

Attractive forces between particles: Intermolecular forces.

xx. BF_3

Type of solid: Covalent.

Type of particle: Molecules.

Attractive forces between particles: Intermolecular forces.

4. Thermochemistry

a. Enthalpy is the energy involved in bond formation and breaking, usually in the form of "heat energy". The symbol ΔH is used, where the 'Δ' (uppercase delta) symbol means "change in" and the H represents enthalpy or heat energy.

b. An exothermic reaction releases energy (negative enthalpy) while an endothermic process uses energy (positive enthalpy).

c. *i.* The enthalpy change is -3897kJ/mol: Exothermic, a negative ΔH means energy is released so the process is exothermic.

ii. Water freezes to ice: Exothermic, as water freezing requires the formation of bonds between water molecules, which releases energy.

iii. The reaction vessel becomes very warm: Exothermic, as warming shows that heat energy is being released into the system, so must be exothermic.

iv. The enthalpy change is 264kJ/mol: Endothermic, as a positive ΔH means energy is absorbed so the process is endothermic.

v. Butter softens when left out on the bench: Endothermic, as softening is a very similar process to melting, where the strength of bonds between particles is decreasing or breaking, and to do this requires an input of energy.

vi. Ignition of a car engine: Exothermic because igniting your car engine releases huge amounts of energy, which is then harnessed to make your wheels spin.

vii. Leavening agents such as baking powder and baking soda in action during baking cookies: Exothermic, these reactions release energy into the cookies causing them to rise.

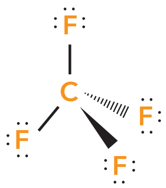
viii. Burning wood for a campfire: Exothermic as large amounts of heat are released so the process must be exothermic.

ix. Dry ice sublimes to gaseous carbon dioxide: Endothermic because intermolecular bonds are being broken during the transition of states from solid to gas, and breaking bonds requires energy so must be endothermic.

x. Snow melting: Endothermic, as intermolecular bonds are being broken during state change from solid to liquid which requires energy so must be endothermic.

Section Two
Exam Skills & Mixed Practice

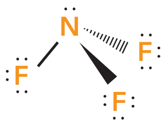
Lewis Structures, Shape and Polarity

a. i. 

ii. Tetrahedral. There are four bonding areas of electron density around the central (carbon) atom.

iii. Yes. There is a difference in electronegativity in the two atoms.

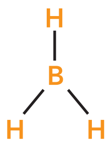
iv. Nonpolar. The polar bonds are arranged evenly around the central atom.

b. i. 

ii. Trigonal pyramidal. There are four areas of electron density around the central (nitrogen) atom. But only three of these are bonding. The other is a lone pair.

iii. Yes. There is a difference in electronegativity in the two atoms.

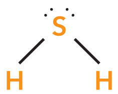
iv. Polar. The bonds are not arranged evenly around the central atom.

c. i. 

ii. Trigonal planar. There are three bonding areas of electron density around the central (boron) atom.

iii. Yes. There is a difference in electronegativity in the two atoms.

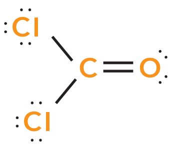
iv. Nonpolar. The polar bonds are arranged evenly around the central atom with no lone pairs of electrons.

d. i. 

ii. Bent. There are four areas of electron density around the central (sulfur) atom. Two bonding and two non-bonding (lone pairs).

iii. Yes. There is a difference in electronegativity in the two atoms.

iv. Polar. The bonds are not arranged evenly around the central atom.

e. i. 

ii. Trigonal planar. There are three areas of electron density around the central (carbon) atom, all bonded covalently.

iii. Yes. There is a difference in electronegativity in the two atoms of both the C=O bond and the C-Cl bonds.

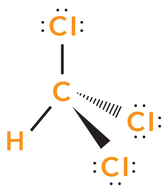
iv. Polar. Because the C=O has a different polarity to the C-Cl bond.

f. i. 

ii. Linear. There are two areas of electron density around the central atom.

iii. Yes. There is a difference in electronegativity in the two atoms.

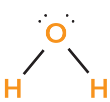
iv. Nonpolar. The bonds are arranged evenly around the central atom.

g. i. 

ii. Tetrahedral, there are four bonding areas of electron density around the central atom.

iii. Yes. There is a difference in electronegativity in the two atoms of the two types of bonds in the molecule.

iv. Polar. Because the C-H bond has a different polarity to the C-Cl bonds.

h. i. 

ii. Bent. Water has four areas of electron density around the central atom. Two of which are bonding, this leads to the bent shape.

iii. Yes. There is a difference in electronegativity in the two atoms.

iv. Polar. The bonds are not arranged evenly around the central atom.

Solids

a. i. Covalent network solid.

ii. Carbon (C)

iii. Diamond is a 3D covalent network solid with each carbon bonded to four other carbon atoms. These covalent bonds are very strong and take a large amount of energy to break. In order to break diamond, these strong covalent bonds would have to be broken and since this requires a lot of energy, diamond does not break easily.

b. i. Ionic solid.

ii. Magnesium chloride is an ionic solid. The ionic bond is an electrostatic attraction between positive and negative ions. In order to melt magnesium chloride, these strong ionic bonds need to be broken and so the melting point is high. However, due to the lattice structure, the layers of ions can be moved such that positive ions are next to positive ions and negative ions are next to negative ions which then causes the structure to break apart because of the repulsion, therefore, magnesium chloride is brittle.

c. i. Metallic solid.

ii. Copper is a metallic solid. The metallic bond is defined as an electrostatic attraction between positive nuclei and a sea of mobile electrons. Because of these mobile electrons, copper can conduct electricity (due to the free moving charged particles). This makes it suitable for electrical wires. Copper is also ductile because the layers in its lattice structure can slide over each other easily and so it is a malleable solid. These two properties allow copper to be effective in wires.

d. i. Covalent network solid.

ii. Silicon dioxide is a 3D covalent network solid. Each silicon is bonded to four oxygen atoms and each oxygen is bonded to two silicon atoms.

e. i. Covalent network solid.

ii. Carbon.

iii. Graphite is a 2D covalent network solid where each carbon is bonded to three other carbon atoms in hexagonal layers. There are strong covalent bonds within each layer but there are only weak intermolecular forces between the layers. Because of these weak intermolecular forces, it is easy to separate the layers so it can be used in pencils.

f. i. Molecular solid.

ii. Water is a covalent molecular solid. There are strong covalent bonds between the hydrogen and oxygen atoms in each water molecule. There are weak intermolecular forces between the water molecules. When boiling, it is the weak intermolecular forces that are broken, which separates the molecules, turning them into a gas. But the strong covalent bonds within the molecule are not broken.

Enthalpy

1. Combustion of Ethane

a. Reactant: 2 x C-C, 12 x C-H, 7 x O=O

Product: 8 x C=O, 12 x O-H

b. 2 x 348kJ/mol + 12 x 413kJ/mol + 7 x 495kJ/mol
= 696kJ/mol + 4956kJ/mol + 3465kJ/mol
= 9117kJ/mol

c. 8 x 799kJ/mol + 12 x 463kJ/mol
= 6392kJ/mol + 5556kJ/mol
= 11948kJ/mol

d. 9117kJ/mol - 11948kJ/mol = -2831kJ/mol (for 2 moles of ethane - see equation).

Therefore:

$\frac{-2831}{2}$ kJ/mol

= -1415.5kJ/mol

2. Hydrogenation of Propene

a. Reactant: 1 x C-C, 1 x C=C, 6 x C-H, 1 x H-H

Product: 2 x C-C, 8 x C-H

b. 1 x C=C + 1 x 348 kJ/mol + 6 x 413 kJ/mol + 1 x 436 kJ/mol

= 1 x C=C + 348 kJ/mol + 2478 kJ/mol + 436 kJ/mol
= 1 x C=C + 3262 kJ/mol

c. 2 x 348 kJ/mol + 8 x 413 kJ/mol
= 696 kJ/mol + 3304 kJ/mol
= 4000 kJ/mol

d. C=C + 3262 kJ/mol - 4000 kJ/mol = -124 kJ/mol
C=C - 738 kJ/mol = -124 kJ/mol
C=C = 614 kJ/mol

3. Making Table Salt

a. $\Delta H = \frac{q}{n}$ $\frac{q}{\Delta H} = n$

$\frac{495}{57.6}$ = 8.59375 moles

b. M(Na) = 23g/mol M(Cl) = 35.5g/mol

M(NaCl): 23 + 35.5 = 58.5g/mol

c. m = n x M

m(NaCl): 8.59375 x 58.5 = 502.7kJ

Section Three
Practice Exam

Question One

a. i. Ionic solid

ii. In order for something to be conductive, it must have free moving charged particles. In the solid state, the positive and negative ions that makeup NaCl are not free to move, therefore it is not conductive. Two ways which NaCl can be made to conduct electricity are: melting into liquid state or dissolving in water. These two methods break the strong ionic bonds between the positive and negative charges allowing the positive and negative ions to move freely, thus making it conductive.

b. Graphite is a 2D covalent network where each carbon atom is bonded to three other carbon atoms, forming 2D hexagonal layers. The extra electron is delocalised within the individual layers. The forces between the layers are weak so they can be easily separated. Comparatively, diamond is a 3D covalent network where each carbon atom is bonded to four other carbon atoms. Therefore, the structure is held together by strong covalent bonds which cannot be easily broken making diamond unable to be separated into layers.

c. Quartz is a 3D covalent network solid, so to melt it you would need to break the covalent bonds (intramolecular forces). These bonds are very strong so this would take a large amount of energy hence the high melting point. $SiCl_4$, however, is a molecular solid, so to melt it you would need to break the weak intermolecular forces between individual $SiCl_4$ molecules. Breaking these weak intermolecular forces takes less energy, hence the much lower melting point of $SiCl_4$ compared with quartz.

Answers

Question Two

a. $H2O_{(l)} \longrightarrow H_2O_{(g)}$

Boiling water is an endothermic reaction, meaning the enthalpy change will have a positive value. Boiling water requires the breaking of intermolecular forces between water molecules in liquid water to form gaseous water. Breaking intermolecular bonds requires heat energy, meaning the process is endothermic.

b. $M(H_2O) = 18g/mol$

$n(water) = \frac{n}{M}$

$\frac{1000}{18} = 55.6mols$

$E = \Delta H \times n$

$= 40.8 \times 55.56 = 2267kJ$ (1 d.p.)

Question Three

a.

b. CS_2 - linear
$CSCl_2$ - trigonal planar

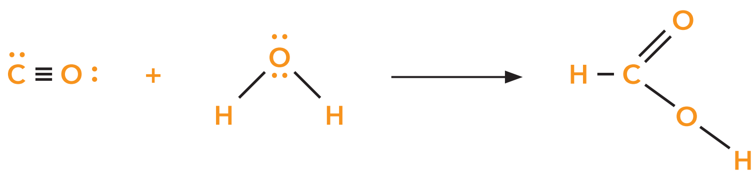
c. CS_2 - 180°
$CSCl_2$ - 120°

d. i.

ii. H_2 is nonpolar. The H-H bond is nonpolar because there is no electronegativity difference between atoms of the same element, resulting in a linear shape.

NF_3 is polar. There are four areas of electron density around the central atom. Three of which are occupied. This leads to the shape: trigonal pyramidal. The N-F bond is polar because there is a difference in electronegativity between the two atoms. Because of the trigonal pyramidal shape, these polar bonds are arranged unevenly around the central atom, making the molecule overall polar.

e. i.



ΔH = -41.5kJ/mol

ii. Using the ΔH of the reaction and the bond enthalpy data below, calculate the average bond enthalpy of the carbon-oxygen bond in carbon monoxide.

Call C≡O = x

Total energy on the reactants side:
X + (2 x 463) = X + 926

Total energy on the products side:
743 + 360 + 412 + 463 = 1978

Reactants - products = ΔH
(X + 926) - 1978 = -41.5
X - 1052 = -41.5
X = 1010.5kJ/mol

The average bond enthalpy for C≡O = 1010.5kJ/mol