Chapter 13: Nitrogen and sulfur

Homework marking scheme

1 a i

lone pairs on each nitrogen [1]
three bonds per nitrogen, each dot-cross [1]
N–N bond, dot-cross. [1]

ii 107° [1]

iii Hydrazine has hydrogen bonds between the molecules, which are stronger than other intermolecular forces [1]
due to the electronegative nitrogen atom and the electron deficient hydrogen. [1]
Oxygen is a non-polar molecule and therefore the only intermolecular forces present are induced dipoles (van der Waals forces). [1]

iv $N_2H_4 + O_2 \rightarrow N_2 + 2H_2O$ [1]

v

$N_2H_4 + O_2$	$N_2 + 2H_2O$
1 × N–N, 4 × N–H, 1 × O=O	1 × N≡N, 4 × O–H
160 + (4 × 390) + 496 = 2216	994 + 4 × 460 = 2834

list of bonds [1]
list of enthalpies [1]
total energy change = +2216 − (+2834) = −618 kJ mol^{-1}
correct value [1]
units [1]

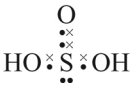
vi 6.4 kg = 6400 g
number of moles of hydrazine = $\frac{6400}{32}$ = 200 mol [1]
enthalpy change = 200 × −618 kJ mol^{-1} [1]
= –123 600 kJ mol^{-1} [1]

vii It is a liquid at room temperature, therefore easily stored and transported. [1]
Gives a large enthalpy change when it burns in air. [1]

b It has a lone pair of electrons on each nitrogen [1]
therefore, can accept protons [1]
by forming dative covalent bonds. [1]

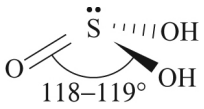
c In this reaction, one of the nitrogen atoms uses its lone pair to accept a proton. [1]
The nitrogen accepting the proton has an N–N bond, three N–H bonds and no lone pair [1]
therefore, it has an H–N–H bond angle of 109.5°. [1]
The other nitrogen still has its N–N bond, two N–H bonds and a lone pair and therefore has an H–N–H bond angle of 107°. [1]

2 a i



one lone pair on sulfur [1]
one dot-cross pair of electrons on two oxygen atoms (those attached to an H atom) [1]
two dot-cross pairs of electrons on one of the oxygen atoms [1]

ii

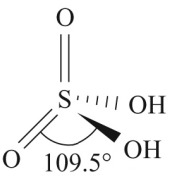


correct three-dimensional representation of molecule [1]
1 if give 118° or 119° for bond angle [1]

b i

one dot-cross pair of electrons on two oxygen atoms (those attached to an H atom) [1]
two dot-cross pairs on one of the oxygen atoms [1]

ii



correct three-dimensional representation of molecule [1]
109.5° for bond angle [1]

c i Cl^- ions are formed. [1]
This is shown by the white precipitate with silver nitrate solution that is soluble in ammonia solution. [1]
SO_4^{2-} ions are formed. [1]
This is shown by the white precipitate with acidified barium chloride solution. [1]
H^+ ions are formed. [1]
This is shown by the red colour with universal indicator solution. [1]

ii $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
all reactants and products [1]
state symbols [1]
$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
all reactants and products [1]
state symbols [1]

iii $Cl_2 + SO_3^{2-} + H_2O \rightarrow 2Cl^- + 2H^+ + SO_4^{2-}$
all reactants and products [1]
balancing [1]
The chlorine is reduced because its oxidation state has decreased from 0 to −1. [1]
The sulfur has been oxidised because its oxidation state has increased from +4 to +6. [1]

d i $Cu \rightarrow Cu^{2+} + 2e^-$ [1]
$H_2SO_4 + 4H^+ + 2e^- \rightarrow 2H_2O + SO_2$ [1]

ii $Cu + H_2SO_4 + 4H^+ \rightarrow Cu^{2+} + 2H_2O + SO_2$
all reactants and products [1]
balancing. [1]