CSSA

2021
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

MARKING GUIDELINES

Chemistry

Section I
20 marks

Questions 1-20 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Band
1	B	CH11/12-6, CH12-15	2-3
2	D	CH11/12-5	2-3
3	D	CH11/12-5, CH12-14	3-4
4	D	CH12-14	3-4
5	B	CH12-12	2-3
6	B	CH12-12	2-3
7	A	CH11/12-6, CH12-15	3-5
8	D	CH11/12-4	3-4
9	C	CH12-14	3-4
10	D	CH12-12	3-4
11	A	CH12-12	3-4
12	D	CH11/12-5	3-4
13	A	CH12-14	3-4
14	C	CH11/12-4	4-5
15	B	CH11/12-4	4-5
16	A	CH12-14	4-5
17	A	CH11/12-6, CH12-14	4-5
18	C	CH11/12-6, CH12-14	5-6
19	C	CH12-14	5-6
20	C	CH11/12-6, CH12-15	5-6

Section II
80 marks

Question 21 (4 marks)
Outcomes Assessed: CH12-4, CH12-12
Targeted Performance Bands: 4-5

Criteria	Marks
• Correct half equation AND • All calculations AND • Justified if the solution will precipitate based on calculations and data	4
• Correct calculations with one minor mistake	3
• Correct half equation written, with the equilibrium sign. AND • Some relevant working out	2
• Some relevant information	1

Sample answer:

$Cu(OH)_2\ (s) \rightleftharpoons Cu^{2+}(aq)\ + 2OH^-(aq)$

$n Cu^{2+} = 0.0150\ M \times 0.01L = 1.5 \times 10^{-4}$ moles

$[Cu^{2+}]$ initial $= 1.5 \times 10^{-4} / 0.01L + 0.02\ L = 0.005\ mol\ L^{-1}\ Cu^{2+}$

$n OH^{-} = 0.0300\ M \times 0.02L = 6.00 \times 10^{-4}$ moles

$[OH^-]$ initial $= 6.00 \times 10^{-4} / 0.01L + 0.02\ L = 0.02$ mol L OH^-

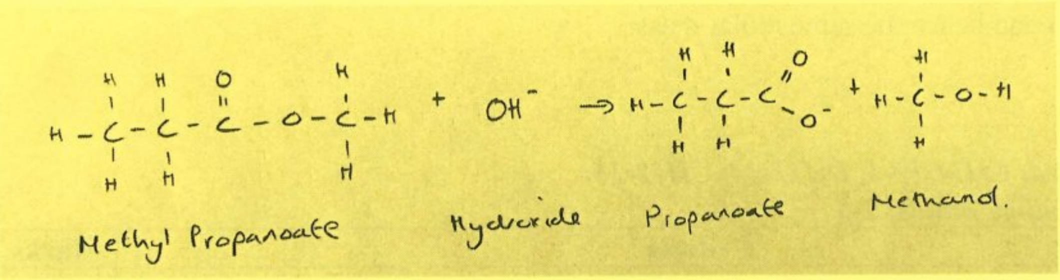
$Q_{sp} = [Cu^{2+}][OH^-]^2 = (0.005)(0.02)^2 = 2.00 \times 10^{-6}$

K_{sp} of $Cu(OH)_2 = 2.2 \times 10^{-20}$, since Q_{sp} is more than K_{sp}, $Cu(OH)_2$ will precipitate

Question 22 (5 marks)
(a) (2 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2-4

Criteria	Marks
• Provides a correct equation using structural formulae	2
• Shows some relevant understanding	1

Sample answer:



OR

$$CH_3CH_2COOCH_3 + H_2O \xrightleftharpoons{H^+(aq)} CH_3CH_2COOH + CH_3OH$$

Methyl propanoate — Propanoic acid — Methanol

(b) 3 marks
Outcomes Assessed:CH11/12-7, CH12-14
Targeted Performance Bands: 2-4

Criteria	Marks
• Explains the cleaning action of soap	3
• Describes the cleaning action of soap	2
• Shows some relevant understanding	1

Sample answer:
The non-polar end of the molecule dissolves in the oil (non-polar) via dispersion forces. The polar end of the molecule interacts with water molecules (polar) via hydrogen bonding. This produces a micelle. Agitation causes the oil to be lifted from the surface and remain suspended within the water as an emulsion.

Question 23 (5 marks)
(a) 1 mark
Outcomes Assessed: CH11/12-6, CH12-15
Targeted Performance Bands: 2-5

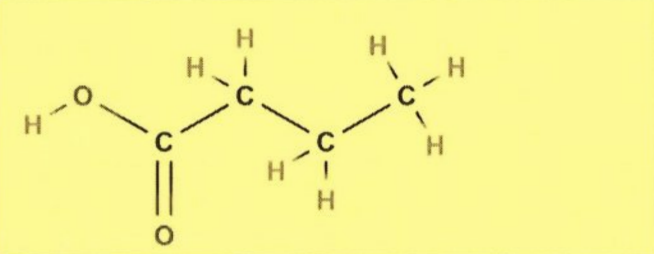
Criteria	Marks
• Correctly identifies the reason for the peak	1

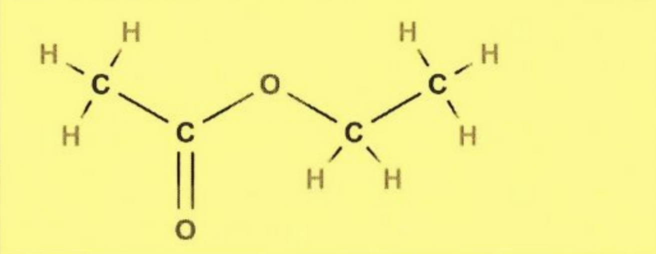
Sample answer:
Both have a peak at about 88, which is the peak for their molecular ion. They both have the same molecular formula and hence the same molar mass.

(b) 3 marks
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15
Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly identifies the fragments for BOTH molecules	3
• Correctly identifies the fragment for ONE molecule	2
• Correctly describes the structure of ONE compound	1

Sample answer:
Butanoic acid and ethyl acetate have the following structures (created with Molview):





For butanoic acid, the –COOH fragment would correspond to the m/z = 45 peak. For ethyl acetate, the CH3CH2O- fragment would correspond to the m/z = 45 peak.

(c) 3 marks

Outcomes Assessed: CH11/12-2, CH11/12-3, CH11/12-5, CH11/12-6, CH12-14, CH12-15

Targeted Performance Bands: 3-5

Criteria	Marks
• Outlines a suitable method, with approximate quantities • Identifies the expected results	3
• Outlines a suitable method, with approximate quantities OR • Outlines a suitable method and identifies the expected results	2
• Identifies some relevant feature	1

Sample answer:

A simple chemical method to distinguish between butanoic acid and ethyl acetate is a reaction with sodium bicarbonate (bicarb soda):

1. Conduct the experiment in a fumehood, with appropriate PPE.
2. Pour 1 cm of bicarb soda into two test tubes.
3. Add about 1 cm of one compound into one test tube, and 1 cm of the other compound into the other test tube.
4. The test tube with the butanoic acid should fizz/produce gas.
5. Dispose of both solutions in an appropriate container for organic waste.

Question 24 (4 marks)
***Outcomes Assessed:* CH12-4**

Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly calculates moles of butanol AND • Correctly calculates heat transferred AND • Correctly calculates 20% heat loss AND • Correctly calculate final temperature, including units	4
• As above with one error	3
• As above with two errors	2
• Demonstrates some relevant understanding	1

Sample answer:
n (butanol) = m/M = 1.8/74.121 = 0.024 mol

$\Delta H_c = q/n$, so $q = \Delta H_c \times n$

q = 2871 x 0.024 = 69.7 kJ

20% is lost to the environment, so available q is 69.7 x 80/100 = 55.8 kJ

$\Delta T = q/mC$ where m is the mass of water and C is its specific heat capacity.

$= 55\ 800/(0.250 \times 4.18 \times 10^{23}) = 53.4\ ^0C$

$T_{final} = 53.4 + 23 = 76\ ^0C$

Disclaimer

Question 25 (6 marks)

(a) 3 marks

Outcomes Assessed: **CH12-12**

Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculated solubility, with the correct sig fig	3
• Calculated solubility with one error	2
• Some relevant information	1

Sample answer:

Ksp = $6.4 \times 10^{-6} = [Ca^{2+}][OH^-]^2 = x(2x)^2$, where x = solubility

$x(4x^2) = 6.4 \times 10^{-6}$

$4x^3 = 6.4 \times 10^{-6}$

$x^3 = 6.4 \times 10^{-6}/4$

$$x = \sqrt[3]{\frac{6.4 \times 10^{-6}}{4}}$$

$x = 1.17 \times 10^{-2}$ mol L^{-1}

Molar mass is 40.08 + 2(16.00 + 1.008) = 74.096 $gmol^{-1}$

To convert mol L^{-1} to g L^{-1}

$1.7 \times 10^{-2} \times 74.096 = 8.7$

Therefore, the solubility of calcium hydroxide is 8.7 g L^{-1}

(b) 3 marks

Outcomes Assessed: CH11/12-7, CH12-12

Targeted Performance Bands: 3-6 **Criteria**	**Marks**
• Correctly calculated ΔH^o_f and explained the effect on quoted Ksp when temperature is increased	3
• Correctly calculated ΔH^o_f	2
• Some relevant information	1

Sample answer:

$Ca(OH)_2 (s) \rightleftharpoons Ca^{2+}(aq) + 2OH^- (aq)$

$\Delta H^o_f = \Sigma \Delta H^o_f$ products - $\Sigma \Delta H^o_f$ reactants

= [(-543) + 2(-230)] - (-986)

= -17 kJ mol^{-1}

According to LCP, when ΔH^o is less than 0 and temperature is increased, the equilibrium will shift to counteract the change in temperature, therefore Ksp will decrease.

Question 26 (7 marks)
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15
Targeted Performance Bands: 2-3
(a) 1 mark

Criteria	Marks
• Describes that different cations can have different colours and gives one example	2
• Provides some relevant information	1

Sample answer:
Different metal ions (cations) can be identified using a flame test, as they give different colours. For example, barium gives a yellowy-green flame and calcium gives a reddish flame.

(b) 5 marks
Outcomes Assessed: CH11/12-2, CH11/12-4, CH11/12-5, CH11/12-6, CH12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Outlines a clear method to correctly identify each of the solids • Presents correct expected results in a neat table	5
• Outlines a method to correctly identify TWO or more of the solids AND • Describes TWO or more correct expected results	4
• Outlines a method to correctly identify ONE or more of the solids OR • Describes ONE or more correct expected results	2-3
• Provides some relevant information	1

Sample answer:

Method

1. Place half a spatula of each solid onto four separate watchglasses.
2. Add a drop of hydrochloric acid to the solid on each watchglass (to identify the carbonate - fizzes).
3. Take a half a spatula of each of the remaining three solids and put them in three new test tubes. Dissolve each in a third of a test tube of distilled water.
4. Add 3 drops of sulfuric acid to each test tube (identifies the barium chloride).
5. Repeat Step 3. Add half of the barium chloride solution to the unknown test tubes. The potassium sulfate will react.

Results

Unknown	1.0 M HCl	0.1 M H_2SO_4	Barium chloride solution
Calcium carbonate	Fizzes		
Barium chloride	No reaction	White precipitate	
Potassium sulfate	No reaction	No reaction	White precipitate
Sodium chloride	No reaction	No reaction	No reaction

Question 27 (6 marks)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 3-6

Criteria	Marks
• Thoroughly explains, using the information provided and collision theory, the changes occurring within this closed system when the system was disturbed at both 1 and 7 minutes	5-6
• Explains, using the information provided and collision theory, one of the changes occurred within this closed system when the system was disturbed	3-4
• Describes the changes of the concentration of reactants and products over time in terms of Le Chatelier's Principle	2
• Describes one of the changes	1

Sample answer:

Cl_2 (g) + CO (g) ⇌ $COCl_2$ (g) $\Delta H = -108$ kJ mol^{-1}

At 1 minute, it is evident that the concentration of $COCl_2$ gradually decreases from 3 mol L^{-1} to 2 mol L^{-1} at 2.5 minutes, whereas the concentrations of CO and Cl_2 increase by1 mol L^{-1} in the same time interval. This is consistent with an increase in temperature within this closed system. Adding heat favours the backward, endothermic reaction rate in terms of collisions more than the forward rate, so the equilibrium shifts to the left, producing more CO and Cl_2. This then results in more collisions between these until eventually the forward and reverse rates are equal and concentrations remain constant. A new equilibrium position has been achieved.

At 7 minutes, the sudden proportional decrease in the concentrations of product and reactants is evident. Cl_2 concentration dropped from 8.8 mol L^{-1} to 6.5 mol L^{-1}, CO decreased from 5 mol L^{-1} to 4 mol L^{-1} and $COCl_2$ decreased from 2 mol L^{-1} to 1.5 mol8L^{-1}. The decrease in volume of the system reduces the chances of collision between CO and Cl_2, favouring the rate of decomposition of $COCl_2$ molecules. Gradually, more CO and Cl_2 forms, resulting in more frequent collisions until the rate of the forward and reverse reactions become equal and concentrations remain constant. Equilibrium is re-established.

Question 28 (4 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2-6

Criteria	Marks
• Clearly explains why the three compounds have very different boiling points but similar molar masses in terms of their structure and bonding	4
• Outlines why the three compounds have very different boiling points but similar molar masses in terms of their structure and/or bonding	3
• Shows some understanding of the structure and/or bonding of the three compounds	2
• Shows some relevant understanding	1

Sample answer:

Butane – molar mass is 58 g mol^{-1}

Butane is an alkane and alkanes are nonpolar molecules. The forces of attraction between the molecules are only weak dispersion forces, resulting in a low boiling point as not much energy is required to overcome the forces.

Ethanoic acid – molar mass is 60 g mol^{-1}

Hydrogen bonding can occur between two carboxylic acid molecules resulting in the formation of a dimer. This increase in size also increases the strength of the dispersion forces between the neighbouring dimers. The stronger dispersion forces and the hydrogen bonds between molecules result in the higher boiling point observed for carboxylic acids.

Ethanamide – molar mass is 59 g mol^{-1}

The higher boiling point observed with amides occurs as they have more atoms that can donate or accept hydrogen bonds. As a result, hydrogen bonds form between the non-bonding electron pairs on the oxygen atom of one molecule and the partially positive hydrogen atom bonded to N on a neighbouring molecule. As this can happen at two sites, there is greater hydrogen bonding between ethanamide molecules than ethanoic acid, resulting in a higher boiling point.

The range of boiling points in these three compounds is due to the differences in intermolecular forces and cannot be linked to their molar masses.

Question 29 (4 marks)
Outcomes Assessed: 12-13
Targeted Performance Bands: 3-5

Criteria	Marks
• Defines a buffer AND • Clearly links the buffer to a named natural system AND • Describes what happens when conditions are changed (Addition of acid/base) AND • Equations include states.	4
• Defines a buffer AND • Clearly links the buffer to a named natural system AND • Describes what happens when conditions are changed (Addition of acid/base)	3
• Defines a buffer. • Clearly links the buffer to a named natural system OR • Describes what happens when conditions are changed (Addition of acid/base)	2
• Defines a buffer.	1

Sample answer:

A buffer is a solution that contains significant amounts of a weak acid and its conjugate base and which will resist a change in pH when small amounts of strong acid or base are added to it.

For example, blood contains carbonic acid and hydrogen carbonate ion in equilibrium in approximately equal concentrations and must maintain an approximately constant pH of 7.4.

$$H_2CO_3\ (aq) + H_2O\ (l) \rightleftharpoons HCO_3^-\ (aq) + H_3O^+\ (aq)$$

In acidic conditions, (when acid is added), the equilibrium shifts to consume the added acid:

$$HCO_3^-\ (aq) + H_3O^+\ (aq) \rightleftharpoons H_2CO_3\ (aq) + H_2O\ (l)$$

In basic conditions, (when some strong base is added), the equilibrium shifts to consume the added base:

$$H_2CO_3\ (aq) + OH^-\ (aq) \rightleftharpoons HCO_3^-\ (aq) + H_2O\ (l)$$

A buffer does resist the change in pH but there is a limit to a buffer's capabilities. If excess acid is added using up all the available HCO_3^- (aq), the resulting increase in H_3O^+ (aq) causes the pH to lower. The same is also applicable if excess OH^- (aq) is added; the carbonic acid will be consumed, resulting in an increase in pH. As a result, the body will be placed under stress as many cell processes are pH dependent.

Question 30 (7 marks)
Outcomes Assessed: CH11/12-5, 12-13
Targeted Performance Bands: 3-6
(a) 5 marks

Criteria	Marks
• Correctly calculates concentration to three significant figures, showing all relevant working	5
• As above, with one processing error	4
• As above, with two errors	3
• Calculates mol of oxalic acid added and finds total volume of NaOH added	2
• Finds total volume of NaOH added	1

Sample answer:

[lactucin] = mol lactucin in aliquot / volume of aliquot in L

mol lactucin = total mol of NaOH added – mol NaOH reacted with oxalic acid

Total NaOH added = 0.0150 x 0.00100 = 1.50×10^{-5} mole of OH^-

Reaction of NaOH with oxalic acid:

$$H_2C_2O_4\ (aq) + 2NaOH\ (aq) \rightarrow Na_2C_2O_4\ (aq) + 2H_2O\ (l)$$

Ratio is 2:1.

	NaOH	Oxalic Acid
c		0.000150 $molL^{-1}$
V		0.0143 L
n	0.00000429 mol	0.000002145 mol

Mole of OH^- reacted with oxalic acid = 0.00000429 mol = 4.29×10^{-5} mol

Moles of OH reacted with lactucin = $1.5 \times 10^{-5} - 4.29 \times 10^{-5}$ = 0.00001071

= 1.071×10^{-5} mol

Concentration of lactucin.

c = $1.071 \times 10^{-5} / 0.0100$ = 1.071×10^{-3} mol L^{-1} = 1.07×10^{-3} mol L^{-1}

(b) ***Outcomes Assessed: CH11/12-5***
Targeted Performance Bands: 3-6
2 marks

Criteria	Marks
• Calculates mass of lactucin and percent composition	2
• Finds molar mass of lactucin	1

Sample answer:

Concentration lactucin = 1.07×10^{-3} mol L^{-1}

Mol lactucin = 1.07×10^{-3} x 0.0500 = 5.35×10^{-5} mol

Lactucin MM = 292.24 g mol^{-1}

Mass = 5.35×10^{-5} x (12.01x14+12x1.008+16x7) = 0.0156g

Percent composition = (1.56×10^{-2} /1.2) x 100 = 1.3%

Question 31 (7 marks)
Outcomes Assessed: CH11/12-5, CH11/12-7, CH12-15
Targeted Performance Bands: 2-6

Criteria	Marks
• Identifies at least TWO different types of spectroscopy, including AAS, for monitoring the environment • Describes an example of monitoring the environment for each type of spectroscopy • Evaluates the role of each type of spectroscopy in monitoring the environment	6-7
• Identifies TWO different types of spectroscopy for monitoring the environment • Describes an example of monitoring the environment for each type of spectroscopy	4-5
• Identifies a type of spectroscopy for monitoring the environment • Describes an example of monitoring the environment for the identified type of spectroscopy	2-3
• Correctly identifies ONE relevant type of spectroscopy OR • Describes an example of monitoring the environment other than heavy metal contamination	1

Sample answer:

Heavy metal monitoring can be done accurately with Atomic Absorption Spectroscopy (AAS). Unlike previous wet chemistry techniques, AAS can be used to detect and measure to ppm and ppb levels, thus making it an excellent method of monitoring waterways, such as those around the Berrima mine.

Infrared (IR) spectroscopy can be used to identify organic chemicals in gas discharges, such as from factories or from vehicles. The volume of gas discharge does not need to be large and the concentrations can be quite low, making IR spectroscopy an excellent tool in monitoring waste organic gases in the atmosphere.

Question 32 (7 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly identifies ALL compounds and reagents	7
• As above but lose one mark for each incorrect unknown	1-6

Sample answer:

Compound B = ethane

Compound C= chloroethane

Compound D = ethanol

Reagent 1 = H_2/Ni

Reagent 2 = Cl2/UV light

Reagent 3 = sodium hydroxide (aq)

Reagent 4 = $Cr_2O_7^{2-}$ /H^+

Question 33 (6 marks)
(a) 1 marks
Outcomes Assessed: CH12-15
Targeted Performance Bands: 2-3

Criteria	Marks
• Correctly defines the term position isomer	1

Sample answer:
Position isomers have the same chemical formula and the same functional group, but the functional group is located on a different part of the carbon skeleton.

(b) (i) (2 marks)
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15
Targeted Performance Bands: 3-4

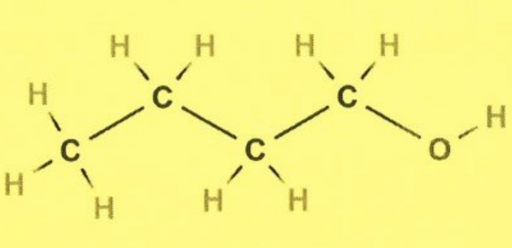
Criteria	Marks
• Correctly identifies the functional group with a specific band	2
• Identifies the functional group	1

Sample answer:
The spectrum shows the broad band near 3500 associated with an alcohol (-OH) group

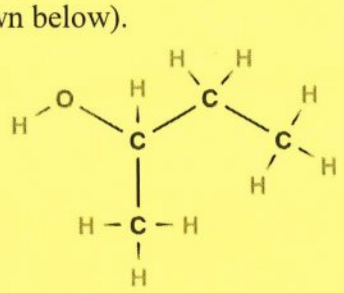
(b)(ii) (3 marks)
Outcomes Assessed: CH11/12-6, CH12-14, CH12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Identifies both possible isomers • Explains how splitting can be used to identify the isomer • Explains how relative area can be used to identify the isomer • Correctly identifies the isomer	3
• Identifies both isomers AND correctly explains ONE feature of the NMR spectrum OR • Shows a sound understanding of TWO features of NMR	2
• Identifies some relevant feature	1

Sample answer:
The two positional isomers are butan-1-ol and butan-2-ol (shown below).



butan-1-ol



butan-2-ol

butan-1-ol and butan-2-ol both have five different hydrogen environments, so their hydrogen NMR will have 5 peaks. This alone would not allow the isomers to be identified. However, the area and splitting of the peaks will be different. butan-1-ol cannot have a doublet but butan-2-ol can. The areas indicate the number of hydrogens in that environment. Only butan-2-ol has that pattern (eg two single hydrogens).

Question 34 (6 marks)
Outcomes Assessed: CH12-12, CH12-5
Targeted Performance Bands: 3-6

Criteria	Marks
• Identifies sodium fluoride as a basic salt AND • Identifies sodium hydrogen sulfate as amphiprotic AND • Provides relevant equations for both to clearly identify and explain similarity and differences.	5-6
• Identifies sodium fluoride as a basic salt AND • Identifies sodium hydrogen sulfate as amphiprotic AND • Explains similarity and differences. BUT • Missing relevant equations OR • Identifies basic and amphiprotic salt AND provides a relevant equation AND • Identifies similarities and differences between basic and amphiprotic salts.	3-4
• Identifies basic and amphiprotic salt AND provides a relevant equation. OR • Identifies salts, identifies a difference AND/OR a similarity.	2
• Identifies NaF as a basic salt OR identifies Hydrogen sulfate as amphiprotic.	1

Sample answer:

Sodium fluoride, a soluble salt, is the product of a strong base (NaOH) and a weak acid (HF). This means the fluoride, F^-, can act as a Bronsted – Lowry base, accepting a hydrogen ion from water and forming OH^- (aq) in solution, making it alkaline with a higher pH, as shown below. The sodium ion does not have the ability to accept hydrogen ions from water, so Na^+ has no pH effect on the water.

F^- (aq) + H_2O (aq) ⇌ HF (aq) + OH^- (aq)

Sodium hydrogen sulfate is soluble and is amphiprotic. It is able to donate and accept an H^+ ion.

In the presence of hydronium or hydroxide ion the following reactions occur:

(1) HSO_4^- (aq) + H_3O^+ (aq) ⇌ H_2SO_4 (aq) + H_2O (l) showing basic behaviour.
(2) HSO_4^- (aq) + OH^- (aq) ⇌ SO_4^{2-} (aq) + H_2O (l) showing acidic behavior.

In water the following reactions occur:

(1) HSO_4^- (aq) + H_2O (l) ⇌ H_2SO_4 (aq) + OH^- (l) showing basic behaviour.
(2) HSO_4^- (aq) + H_2O (l) ⇌ SO_4^{2-} (aq) + H_3O^+ (l) showing acidic behavior.

In water, reaction (2) is more likely, hence producing an acidic solution with a lower pH.

In summary, sodium fluoride, NaF is a basic salt, whereas sodium hydrogen sulfate is acidic. Both can accept hydrogen ions to produce some hydroxide ions in solution. However, hydrogen sulfate is able to donate hydrogen ions to water to produce H_3O^+. Hydrogen sulfate solutions are acidic.