**4.** (a) Benzocaine, C9H11O2N, is an aromatic compound which is used commercially in creams to alleviate sunburn.

* Benzocaine reacts with dilute acids to form the ion C9H12O2N+ and with ethanoyl chloride to form C11H13O3N.
* When benzocaine is heated under reflux with aqueous sodium hydroxide and the solution obtained is neutralised, two compounds **X** and **Y** are formed.
* **X** has a formula of C7H7O2N and is a solid with a melting temperature of 190 ºC. It is soluble in water.
* **Y** is a volatile liquid with a formula C2H6O which gives steamy fumes with phosphorus pentachloride.
* **X** reacts with sodium hydrogencarbonate solution to give a gas which turns lime water milky. It also reacts with a solution of sodium nitrite and hydrochloric acid between 0 ºC and 5 ºC to produce a substance which reacts with phenol in NaOH to give an orange precipitate, **Z**.

These reactions are summarised as follows.



(i) Deduce a structural formula for benzocaine and explain its three reactions shown above. You may either describe the types of reaction or write the equations for the reactions.

(6)

(ii) Write equations for the two reactions of **X**. Include in your answer the structural formula of **Z**.

(3)

(iii) Explain why substance **X** has a fairly high melting temperature and why it is soluble in water.

(3)

(b) Substance **X** is a weak monobasic acid and for the purpose of the remainder of this question you may write its formula as **HA**. **X** has a relative molecular mass of 137, with a p*K*a value of 4.92 at 25 ºC.

(i) Calculate the pH of a solution containing 21.37g of **X** per dm3 at a temperature of 25 ºC.

(4)

(ii) 50.0 cm3 of this solution was mixed with 50.0 cm3 of a 0.100 mol dm–3 solution of sodium hydroxide. Calculate the concentration of the salt of **X** produced, and the concentration of the acid **X** left unreacted.  
Hence calculate the pH of the mixed solution.

(4)

(c) The standard enthalpy change at 25 ºC for the neutralisation of a strong acid by a strong base is –57.2 kJ mol–1.

The standard enthalpy change for the ionisation of the weak acid **HA** in water is +8.3 kJ mol–1.

(i) Write the ionic equation for the neutralisation of a strong acid by a strong base and hence calculate the standard enthalpy of neutralisation of the acid **HA**.

(3)

(ii) State and explain how the value of *K*a of the acid **X** and hence the pH of the solution in (b)(i) would change if the temperature of the solution were increased.

(2)

(Total 25 marks)