Section A: Multiple Choice: (1 mark each)
Write your answers on the multiple choice grid on page 3

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 =   (A) 2   (B) 6   (C) 8   (D) 9

A ○   B ●   C ○   D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ●   B ✖   C ○   D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word *correct* and drawing an arrow as follows.

correct

A ✖   B ✖   C ○   D ○

1. As the pH of a solution increases, phenolphthalein changes from colourless to dark pink in the pH range 8.6 to 10.0. By what factor does the hydrogen ion concentration of the solution change over this range?

   (A) the hydrogen ion concentration increases by a factor of 1.5
   (B) the hydrogen ion concentration decreases by a factor of 25
   (C) the hydrogen concentration increases by a factor of 25
   (D) the hydrogen concentration decreases by a factor of 1.5

2. What is the pH of a solution containing a mixture of 25.0 mL of 0.25 mol L^{-1} HNO_3 and 20.0 mL of 0.35 mol L^{-1} HCl ?

   (A) 0.3
   (B) 0.5
   (C) 1.8
   (D) 2.2

3. Which statement best represents Lavoisier's definition of an acid?

   (A).Acids contain oxygen.
   (B). Acids are proton donors.
   (C) Acids contain replaceable hydrogen.
   (D).Acids ionise in solution to form hydrogen ions.

4.   Which of the following is a use for manufactured esters?

      (A)   fats
      (B)   food colouring
      (C)   detergents
      (D)   food flavouring

5.   The pH of 0.001 mol L^{-1} solutions of Na_2O, CaO, SiO_2 and SO_2 are tested. Which would have the lowest pH?

      (A) CaO
      (B) Na_2O
      (C) SO_2
      (D) SiO_2

6.   Several factors can disturb a system at equilibrium.
        Which of the following changes will always shift the equilibrium to the right?

      (A)   change the concentration of the product(s)
      (B)   increase the concentration of one of the reactants
      (C)   cooling the equilibrium mixture
      (D)   changing the pressure of the reaction vessel

Section A. Multiple Choice Answer Grid

1.   A O   B O   C O   D O

2.   A O   B O   C O   D O

3.   A O   B O   C O   D O

4.   A O   B O   C O   D O

5.   A O   B O   C O   D O

6.   A O   B O   C O   D O

Section B: Short Answer Questions   MARKS

Question 7   (7 marks)

Acid rain is one of the major ecological problems in the world today and the main culprits are sulfur dioxide and nitrogen oxides from industrial processes.

(a)   Identify an industrial process which produces sulfur dioxide **or** nitrogen oxides and construct a chemical equation showing the formation of sulfur dioxide **or** an oxide of nitrogen.   **2**
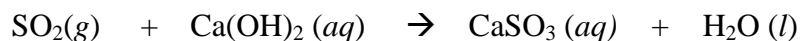
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(b)   Construct a chemical equation showing sulfur dioxide or an oxide of nitrogen forming acid rain.   **1**

…………………………………………………………………………………………

(c)   Identify two harmful aspects of acid rain.   **2**

…………………………………………………………………………………………

…………………………………………………………………………………………

(d)   A large industrial plant produces 750,000 litres of sulfur dioxide per day.
       The pollutant gas is neutralised with calcium hydroxide…

$$SO_2(g) \quad + \quad Ca(OH)_2 \ (aq) \quad \rightarrow \quad CaSO_3 \ (aq) \quad + \quad H_2O \ (l)$$

Calculate the mass of calcium hydroxide required to neutralise the sulfur dioxide at
100 kPa and 25^0C.   **2**
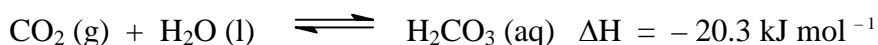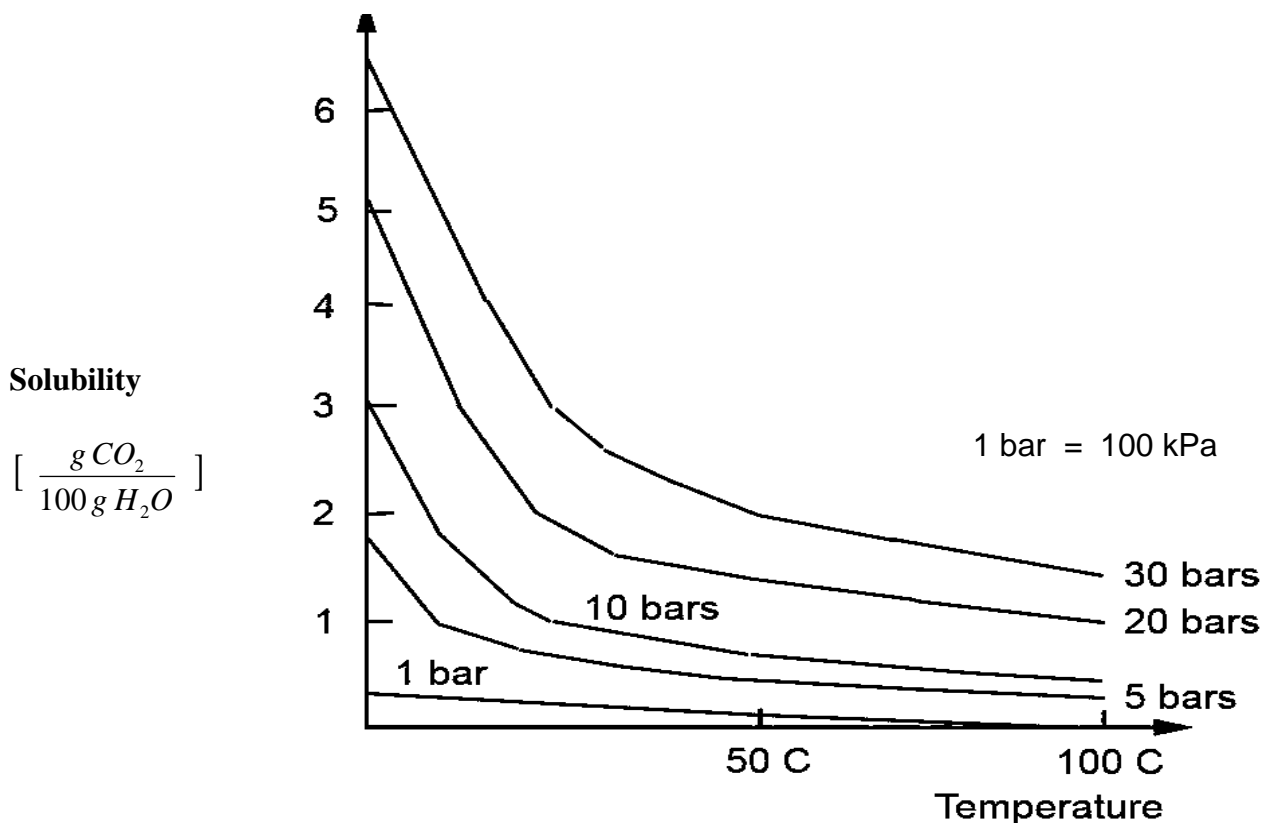
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Question 8   (4 marks)

Carbon dioxide dissolves in water according to the equilibrium…

$$CO_2 \ (g) \ + \ H_2O \ (l) \ \rightleftharpoons \ H_2CO_3 \ (aq) \quad \Delta H \ = \ -20.3 \ kJ \ mol^{-1}$$

The graph shows the solubility of carbon dioxide under changing conditions…

Solubility

$$\left[\ \frac{g \, CO_2}{100 \, g \, H_2O} \ \right]$$

Question 8 continues next page (page 5)

MARKS

Identify the trends in the solubility of CO_2 and explain them based upon Le Châtelier's principle.   **4**

………

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……….

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……….

Question 9   (4 marks)

Industrial chemistry processes have enabled scientists to develop replacements for natural products.

(a)   Complete the table…   **2**

Natural product (non-fossil fuel)	*Replacement material*

(b)   Discuss issues associated with shrinking world resources of the natural product you have identified.   **2**

……….

………

………

………
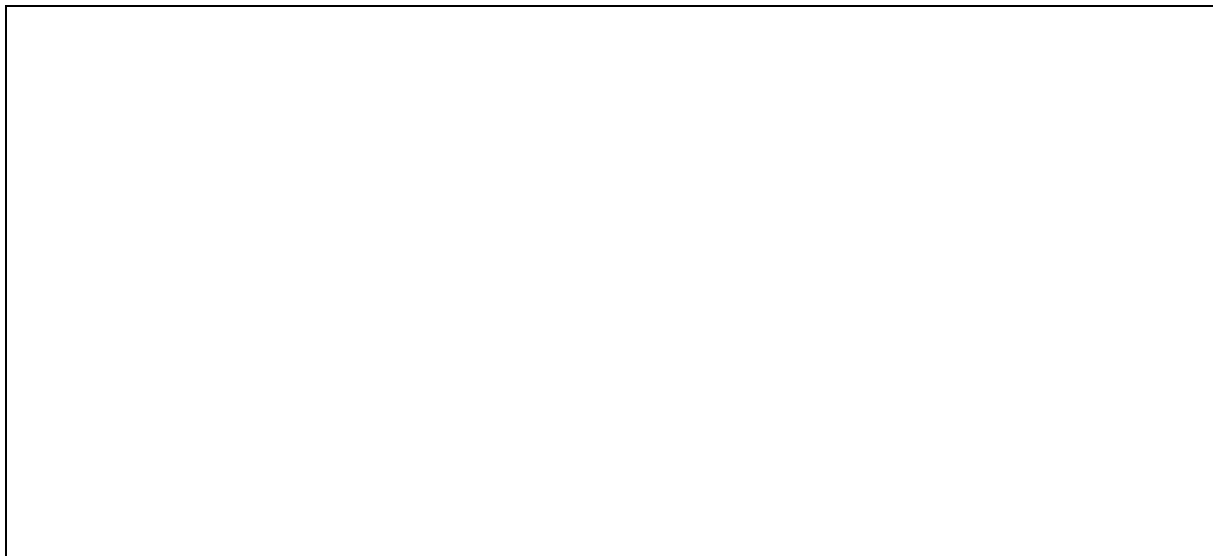
Question 10 ....(10 marks)

(a)   Use structural formulae to draw the reaction between 1-butanol and ethanoic acid.
        Show the conditions necessary for reaction and name all organic products.   **4**

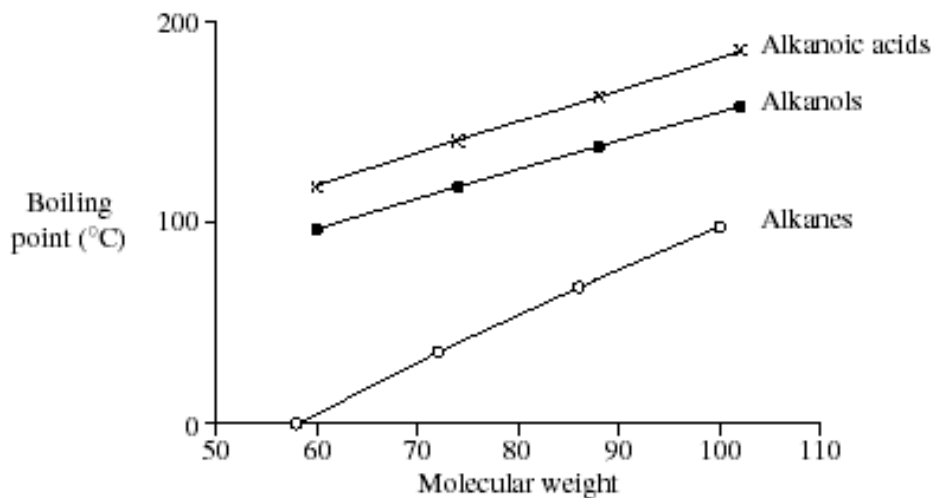(b)   Outline the advantages of using reflux to prepare an ester.   **2**

        ………………………………………………………………………………………………

        ………………………………………………………………………………………………

        ………………………………………………………………………………………………

Question 10 continues next page (page 7)

(c)   Explain trends in boiling points shown in the graph.   **4**

……

……

……

Question 11   .(4 marks)

Nuclear energy provides new elements. Some of these are transuranic elements

(a)   What are transuranic elements?   **1**

    ……………………………………………………………………………………………………..

    ……………………………………………………………………………………………………

(b)   Identify one example of a transuranic element and describe how it is produced.   **2**

        …………………………………………………………………………………………………

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(c)   Identify one method of detecting nuclear radiation.   **1**

        ………………………………………………………………………………………………

Question 12 (2 marks)

In each of the following reactions, which reactant is the acid? What is its conjugate base?
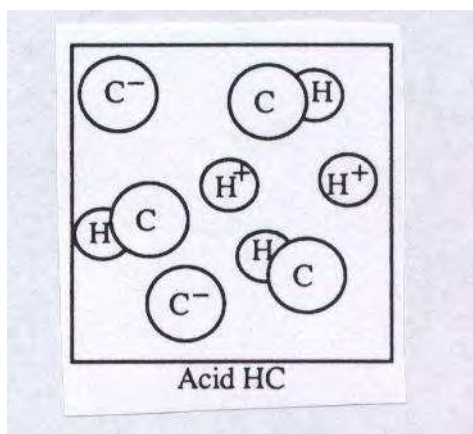Complete the table below **2**

(a) NH_4^+ *(aq)*   + $HCOO^-$ *(aq)* $\rightleftharpoons$ $NH_3(g)$ + $HCOOH$*(aq)*

(b) CO_3^{2-} *(aq)*   + HCN*(aq)* $\rightleftharpoons$ HCO_3^- *(aq)*   + CN^-
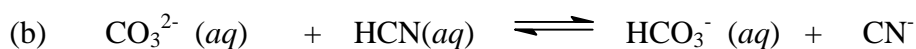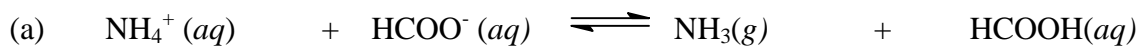
Equation	Acid	Conjugate base
(a)		
(b)		

Question 13   (7 marks)

The diagram below represents the number and type of chemical species (other than water molecules) present in a certain volume of an acidic solution, 'Acid HC'.

Acid HC

(a)   Draw separate diagrams of Acid HA and Acid HB assuming all acids are in the same volume as above and represent the chemical species in a similar way to the diagram above.

(i)   Acid HA is a weaker acid and more concentrated than Acid HC   **2**

Question 13 continues next page

Continuation of Question 13

(ii)Acid HB is stronger but the same concentration as Acid HC. **2**

(b) Describe the difference between Acid HB and Acid HC in terms of an equilibrium between the intact molecules and its ions. **2**

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End of Test

Section A: Multiple Choice: (1 mark each)
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Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

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2. What is the pH of a solution containing a mixture of 25.0 mL of 0.25 mol L^{-1} HNO_3 and 20.0 mL of 0.35 mol L^{-1} HCl ?

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Section A. Multiple Choice Answer Grid

1. A O B ● C O D O

2. A O B ● C O D O

3. A ● B O C O D O

4. A O B O C O D ●

5. A O B O C ● D O

6. A O B ● C O D O

Section B: Short Answer Questions   MARKS

Question 7   (7 marks)

Acid rain is one of the major ecological problems in the world today and the main culprits are sulfur dioxide and nitrogen oxides from industrial processes.

(a)   Identify an industrial process which produces sulfur dioxide **or** nitrogen oxides and construct a chemical equation showing the formation of sulfur dioxide **or** an oxide of nitrogen.   **2**

Possible Answer:

Smelting of metal sulphide ores or combustion of fuels with sulfur impurities.   (1 mark)

$S_{(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}$ *(1 mark)*

High temperature combustion of fuels.   (1 mark)
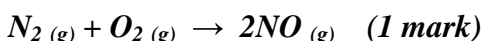
$N_{2\,(g)} + O_{2\,(g)} \rightarrow 2NO_{(g)}$ *(1 mark)*

(b)   Construct a chemical equation showing sulfur dioxide or an oxide of nitrogen forming acid rain.   **1**

Answer:

$SO_{2\,(g)} + H_2O_{(l)} \leftrightarrow H_2SO_{3\,(aq)}$ $2NO_{2\,(g)} + H_2O_{(l)} \leftrightarrow HNO_{3\,(aq)} + HNO_{2\,(aq)}$
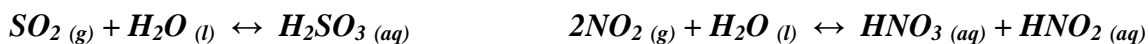
(c)   Identify two harmful aspects of acid rain.   **2**

- *leaching of nutrients from soil causing reduced fertility*
- *release of toxic metals (e.g. Al^{3+}) from minerals in the soil causing plant death*
- *corrosion of ferrous structures (e.g. bridges)*
- *deterioration of stonework and masonry*
- *reduced reproductive capacity & death of aquatic organisms in acidified lakes & rivers*
- *worsened attacks of bronchitis and asthma in city dwellers*

(d)   A large industrial plant produces 750,000 litres of sulfur dioxide per day.
       The pollutant gas is neutralised with calcium hydroxide…

$$SO_2(g) \quad + \quad Ca(OH)_2 \ (aq) \quad \rightarrow \quad CaSO_3 \ (aq) \quad + \quad H_2O \ (l)$$
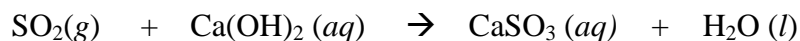
Calculate the mass of calcium hydroxide required to neutralise the sulfur dioxide at
100 kPa and 25^0C.   **2**

Answer

moles $Ca(OH)_2$ = moles SO_2 = V ÷ molar volume = 750,000 L ÷ 24.79 L mol^{-1}
moles $Ca(OH)_2$ = 30,254 moles   (1 mark)

mass $Ca(OH)_2$ = n × M = 30,254 mol × 74.096 g mol^{-1} = 2.2417 × 10^6 = 2.2 × 10^6 g
(1 mark)

Question 8   (4 marks)
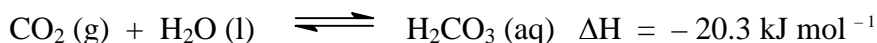
Carbon dioxide dissolves in water according to the equilibrium…

CO_2 (g) + H_2O (l) ⇌ H_2CO_3 (aq) ΔH = − 20.3 kJ mol^{-1}

The graph shows the solubility of carbon dioxide under changing conditions…

Solubility

$[\dfrac{g\ CO_2}{100\ g\ H_2O}]$
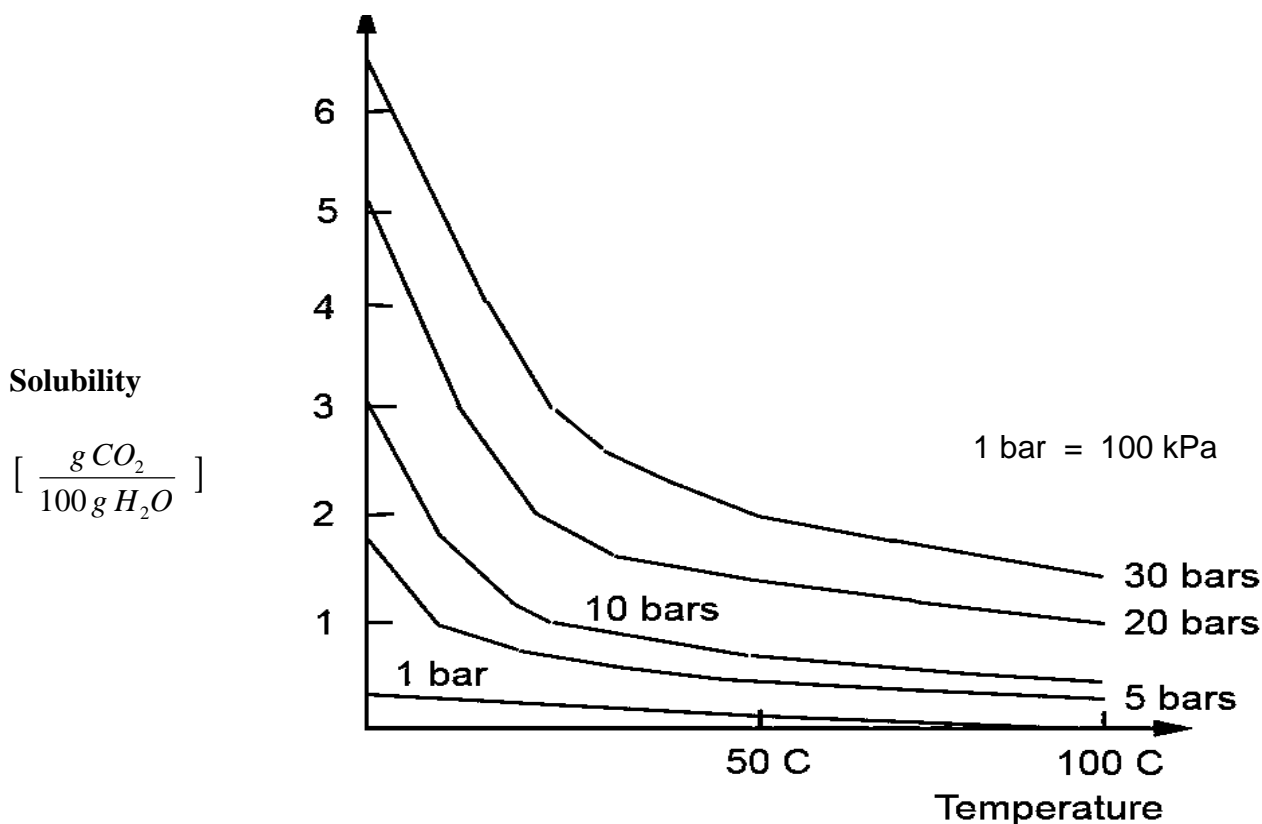
Question 8 continues next page (page 5)

Continuation of question 8

Identify the trends in the solubility of CO_2 and explain them based upon Le Châtelier's principle.   **4**

Outcome ~ H8
Answer:
The solubility of carbon dioxide is dependent upon temperature and pressure.

The graph shows the solubility increases with decreasing temperature. (1 mark)
The solvation reaction is exothermic, $\Delta H = -20.3$ kJ mol $^{-1}$. Le Châtelier's principle states that a decrease in temperature would shift the equilibrium to favour the exothermic reaction.
(1 mark)

The graph shows the solubility increases with increasing pressure. (1 mark)
The solvation reaction causes a reduction in gas volume from 1 unit to 0.
Le Châtelier's principle states that an increase in gas pressure would shift the equilibrium to the side with the least gas volume. (1 mark)

Question 9   (4 marks)

Industrial chemistry processes have enabled scientists to develop replacements for natural products.

(a)   Complete the table…   **2**

Natural product (non–fossil fuel)	*Replacement material*
nitrates in soil *OR* *phosphates in soil* ► *Others possible*	*nitrates derived from Haber process* *OR* *phosphates from super–phosphate* ► *Others possible*

(b)   Discuss issues associated with shrinking world resources of the natural product you have identified.   **2**

Nitrates and phosphates are essential for soil fertility and plant growth. Soils become leached naturally and the export of crops depletes the producer soil. If nitrates and phosphates were not replenished, soils would become infertile, crop yields would fall and global famine would result.

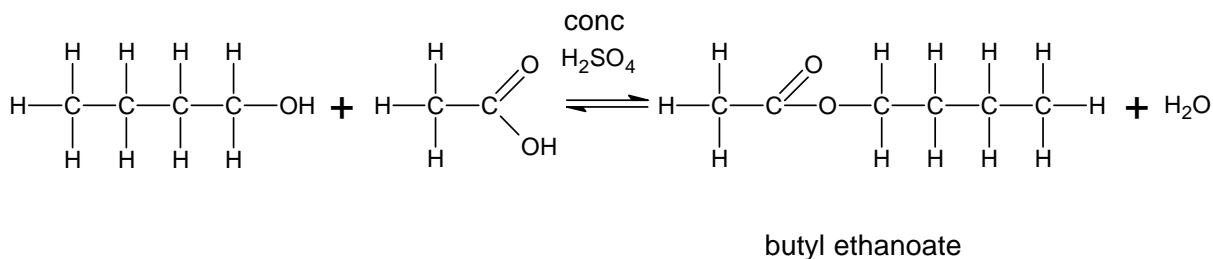► *Two valid points, e.g. cause and effect   (2 marks)*

► *One valid point.   (1 mark)*

Question 10 …….(10 marks)

(a)   Use structural formulae to draw the reaction between 1-butanol and ethanoic acid.
       Show the conditions necessary for reaction and name all organic products.   **4**

ANS

butyl ethanoate

Marking criteria	Marks
Correctly draws reactants and products, names product, indicates conditions	4
Three of the above	3
Two of the above	2
Correctly draws reactants or products or names product or describes conditions	1

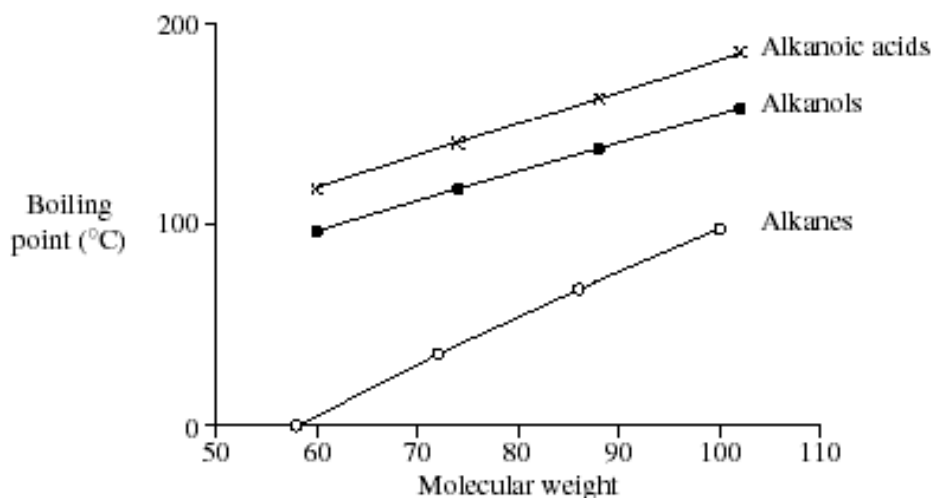(b)   Outline the advantages of using reflux to prepare an ester.   **2**

Marking criteria	Marks
Outlines two advantages of using reflux	2
Outlines one advantage of using reflux	1

Possible answer:
The reactants are volatile and yet need to be heated to reach their activation energy. Refluxing cools the reactant gases and condenses them returning them to the reaction mixture for continued heating. The gases would otherwise escape before they reacted.

(c)   Explain trends in boiling points shown in the graph.   **4**

Marking Criteria	Marks
Provides a thorough explanation of the trends in boiling points BETWEEN AND WITHIN the three series of compounds	4
Provides a thorough explanation of the trends in boiling points BETWEEN each series OR Provides a sound explanation of the trends in boiling points BETWEEN the three series of compounds and identifies an aspect of the trends in boiling points WITHIN each series	2-3
Identifies the relationship between boiling points and intermolecular forces OR Identifies that boiling points increase as molecular weight increases OR Identifies the following trend in boiling points: Alkanoic acids > Alkanols > Alkanes OR Identifies hydrogen bonding as a strong intermolecular force	1

Possible answer:
The boiling point of alkanes, alkanols and alkanoic acids all increase with increasing molecular mass because the increasing mass is due to increasing carbon chain length. The longer the carbon chain the more dispersion forces exist between molecules and the more energy is needed to separate them.

As you go from alkanes to alkanols to alkanoic acid the functional group becomes more polar. Only weak dispersion forces need to be overcome to boil alkanes. However alkanols have these as well as dipole-dipole forces and hydrogen bonds due to hydroxyl functional group. Alkanoic acids have similar dispersion forces and similar hydrogen bonds due to the hydroxyl group but they are more polar molecules owing to the double-bonded oxygen as part of the carbonyl functional group. This gives more polarity to the molecule and results in stronger dipole-dipole forces. These require the most energy to overcome.

Question 11 .(4 marks)

Nuclear energy provides new elements. Some of these are transuranic elements

(a)   What are transuranic elements?   **1**

Elements with atomic number greater than 92

(b)   Identify one example of a transuranic element and describe how it is produced.   **2**

Americium   *(*1 mark)

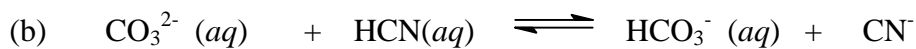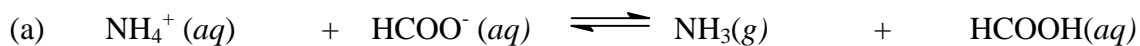***It is made by bombarding plutonium with neutrons (in a nuclear reactor)*** (1 mark)

(c) Identify one method of detecting nuclear radiation. (1 mark)

Ans   photographic film, cloud chamber, Geiger-Muller counter or scintillation counter (one only)

Question 12 (2 marks)

In each of the following reactions, which reactant is the acid? What is its conjugate base?
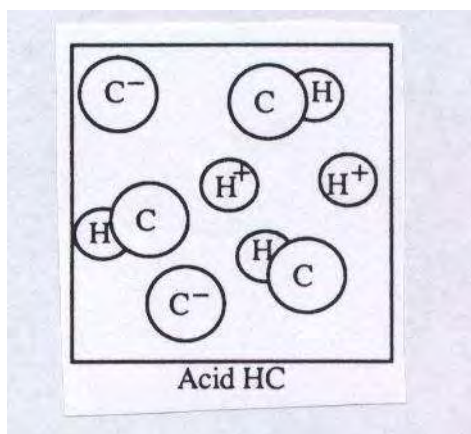Complete the table below **2**

(a) NH_4^+ (*aq*) + $HCOO^-$ (*aq*) $\rightleftharpoons$ NH_3(*g*) + $HCOOH$(*aq*)

(b) CO_3^{2-} (*aq*) + HCN(*aq*) $\rightleftharpoons$ HCO_3^- (*aq*) + CN^-

Equation	Acid	Conjugate base
(a)	NH_4^+	NH_3
(b)	HCN	CN^-

Question 13 (7 marks)

The diagram below represents the number and type of chemical species (other than water molecules) present in a certain volume of an acidic solution, 'Acid HC'.

Acid HC

(a) Draw separate diagrams of Acid HA and Acid HB assuming all acids are in the same volume as above and represent the chemical species in a similar way to the diagram above.

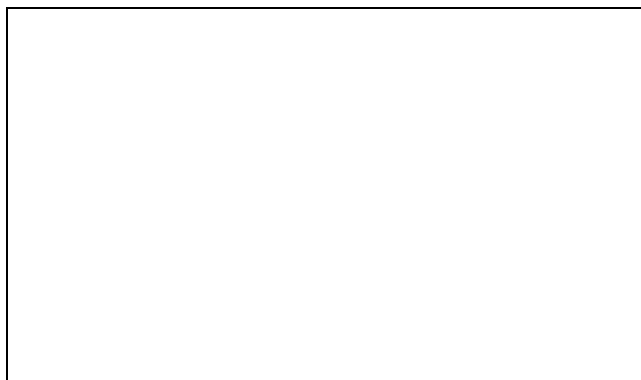(i) Acid HA is a weaker acid and more concentrated than Acid HC **2**

Question 13 continues next page

Continuation of Question 13

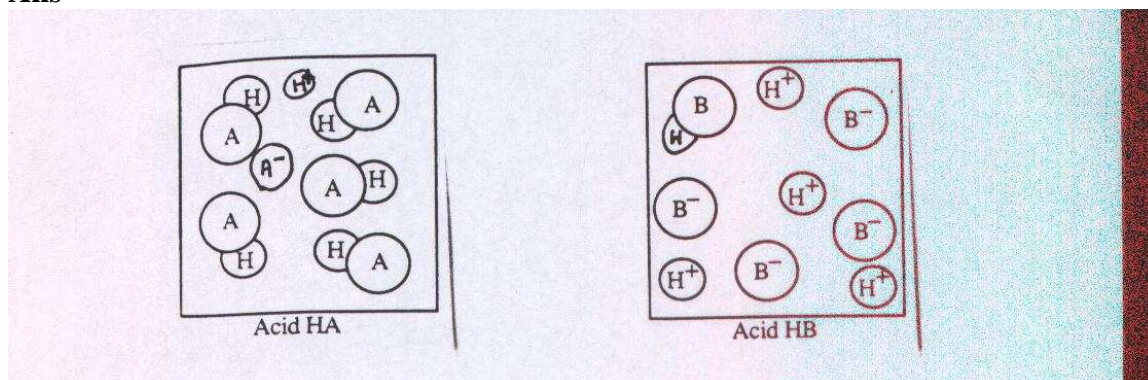(ii)Acid HB is stronger but the same concentration as Acid HC. **2**

(b)   Describe the difference between Acid HB and Acid HC in terms of an equilibrium
between the intact molecules and its ions. **2**

Ans

Acid HA   Acid HB

i.   1 Mark for greater number of HA molecules
1 Mark for less ions
(b) 1 Mark for more ions
1 Mark for same number of 'HB' species.
(ii) $HC_{(aq)} \leftrightarrow H^+_{(aq)} + C^-_{(aq)}$ (1 Mark)
(iii)Equilibrium in HC lies more to the left in favour of the intact molecules whereas in HB
equilibrium lies much more to the right in favour of the ions.(2 Marks)

End of Test