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YEAR 12 CHEMISTRY

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SAMPLE HSC EXAMINATION 1

Try to complete these papers as if they are the real thing. These are the instructions you need to follow in the HSC Exam:

General instructions

- Reading time: 5 minutes
- Working time: 3 hours
- Write using black pen.
- NESA approved calculators may be used.
- Use the Data Sheet and Periodic Table in this book.

Total marks: 100

Section I: 20 marks

Section II: 80 marks

- Attempt all questions.

Section I: 20 marks

Attempt Questions 1–20.
Allow about 35 minutes for this section.

1 **A solution of barium chloride is sprayed into a blue Bunsen burner flame. Identify the colour that the flame will turn.**

A orange-red
B yellow
C bright green
D pale yellow-green

2 **Name the hydrocarbon shown in Figure E1.1.**

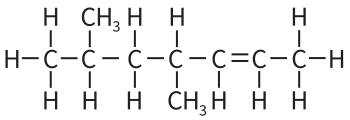

Figure E1.1 Hydrocarbon

A dimethylheptene
B hept-2-ene
C 4,6-dimethylhept-2-ene
D 2,4-dimethylhept-5-ene

3 **Identify the weak acid.**

A sulfuric acid
B hydrochloric acid
C sulfurous acid
D nitric acid

4 **Calculate the pH of a 0.000 50 mol/L solution of sulfuric acid.**

A 5.00
B 3.30
C 11.00
D 3.00

5 **Identify which of the following aqueous mixtures would act as a buffer.**

A propanoic acid + potassium propanoate
B phosphoric acid + sodium carbonate
C sulfurous acid + sodium sulfate
D formic acid + potassium hydroxide

6 **Three solutions X, Y and Z were tested with universal indicator. The indicator changed colour as recorded below:**

X = violet; Y = yellow; Z = red

Use this information to classify the acidity or basicity of the three solutions.

A X = acidic; Y = basic; Z = basic
B X = basic; Y = acidic; Z = acidic
C X = basic; Y = basic; Z = acidic
D X= acidic; Y = acidic; Z = basic

7 **Consider the following equilibrium involving copper (II) ions in water:**

$$Cu(H_2O)_4^{2+}(aq) + 4Cl^-(aq) \leftrightharpoons CuCl_4^{2-}(aq) + 4H_2O(l)$$

blue **green**

The equilibrium solution is a blue-green colour. Identify which of the following statements is true.

A The solution will become more green if additional water is added.
B The solution will become more green if crystals of NaCl are dissolved in the solution.
C The solution will become more blue if concentrated sodium nitrate is added to the solution.
D The colour of the solution will not change if hydrochloric acid is added.

8 **The pH of soda water in an unopened bottle is 4. The pH of the soda water rises when the bottle is opened. Select the correct statement about this change.**

A The pH rises to 7 as all the gas is lost from the water.
B Additional carbonic acid forms on opening the bottle.
C The rise in pH is due to a temperature increase.
D The concentration of hydrogen ions decreases as carbonic acid decomposes due to the loss of carbon dioxide from the bottle.

9 **Identify the true statement about nitrous acid (HNO_2).**

A The conjugate base of nitrous acid is the nitrite ion.
B Nitrous acid is a strong acid.

C Nitrous acid is completely dissociated in water.
D The pH of 0.0010 mol/L nitrous acid is 3.0.

10 Ammonia gas is manufactured from hydrogen and nitrogen gas:

$N_2(g) + 3H_2(g) \leftrightarrows 2NH_3(g)$

At 500 °C, the equilibrium constant (K_{eq}) is 0.060. The reaction is exothermic.

Select the correct statement about this equilibrium.

A The equilibrium constant will increase if a catalyst is used.
B The yield of ammonia at 500 °C is not changed if helium gas is injected into an equilibrium mixture in the constant volume reaction vessel.
C The equilibrium constant will increase if the temperature is raised.
D The yield of ammonia will increase if the volume of the reaction vessel is increased.

11 A solution of a weak monoprotic acid, HA, is 8% dissociated at 25 °C. Its pH is 4.10. Calculate the concentration of the weak acid (HA) in the solution.

A 0.080 mol/L
B 2.13 mol/L
C 9.93×10^{-3} mol/L
D 9.93×10^{-5} mol/L

12 Identify which of the following solutions will cause precipitation when added to a potassium chloride solution.

A barium nitrate
B silver nitrate
C copper (II) nitrate
D zinc bromide

13 The solubility product (K_{sp}) for lead (II) bromide is 6.6×10^{-6}. Determine the concentration of bromide ions in a saturated solution.

A 0.0236 mol/L
B 0.0118 mol/L
C 2.57×10^{-3} mol/L
D 0.0189 mol/L

14 Name the molecule shown in Figure E1.2.

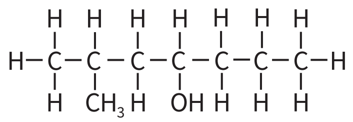

Figure E1.2 Alkanol

A 2-methylheptan-4-ol
B 6-methylheptan-4-ol
C methylheptanol
D 2-methylheptan-4-one

15 A flame atomic absorption spectrometer (AAS) uses a slot burner. The purpose of the flame is to:

A generate light of specific wavelengths to be absorbed by metal ions.
B atomise the material.
C diffract the light waves.
D absorb light from the hollow cathode lamp.

16 The equilibrium constant for an equilibrium reaction in the gaseous state is:

$K_{eq} = [CH_4][H_2O]/[CO][H_2]^3$

Select the equilibrium equation that is consistent with the equilibrium constant.

A $CH_4(g) + H_2O(g) \leftrightarrows CO(g) + H_2(g)$
B $CH_4(g) + H_2O(g) \leftrightarrows CO(g) + 3H_2(g)$
C $CO(g) + 3H_2(g) \leftrightarrows CH_4(g) + H_2O(g)$
D $CO(g) + 3H_2(g) \leftrightarrows CH_4(g) + H_2O(l)$

17 Hexan-2-ol burns with a yellow, smoky flame. Identify which equation is consistent with that observation.

A $C_6H_{13}OH(l) + 9O_2(g) \rightarrow 6CO_2(g) + 7H_2O(l)$
B $C_6H_{15}OH(l) + 9O_2(g) \rightarrow 5CO_2(g) + CO(g) + 8H_2O(l)$
C $2C_6H_{13}OH(l) + 15O_2(g) \rightarrow 6CO_2(g) + 6CO(g) + 14H_2O(l)$
D $C_6H_{13}OH(l) + 6O_2(g) \rightarrow 2CO_2(g) + 2CO(g) + 2C(s) + 7H_2O(l)$

18 Saturated solutions of the following salts were prepared. The solubility product constant for each salt is included. Identify the solution that has the lowest sulfate ion concentration.

A $SrSO_4$ ($K_{sp} = 3.44 \times 10^{-7}$)
B $CaSO_4$ ($K_{sp} = 4.93 \times 10^{-5}$)
C $PbSO_4$ ($K_{sp} = 2.53 \times 10^{-8}$)
D $BaSO_4$ ($K_{sp} = 1.08 \times 10^{-10}$)

19 A student stirred a mixture of red cobalt (II) chloride crystals and water to produce a saturated solution. Identify a procedure that could be used to determine when the system had reached equilibrium.

A Use a colourimeter to analyse the colour of the solution.
B Titrate the solution with sodium hydroxide.
C Use an electronic balance to measure the mass of the system.
D Evaporate samples of the solution and measure the mass of solid formed.

20 Select the true statement about C-13 NMR spectra of organic molecules.

A One peak will be observed for ethanol.
B Methyl acetate and propanoic acid are both three-carbon molecules and their C-13 NMR spectra will be identical.

C The chemical shift for the C=O bond in ketones is typically in the range 205–220 ppm.

D Two peaks will be observed for ethane.

Section II: 80 Marks

Attempt Questions 21–36.
Allow about 2 hours and 25 minutes for this section.

Instructions
- In the HSC Exam you will answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.

21 An analytical chemist determines the concentration of zinc minerals in the soil on a farm. Five soil samples were collected for analysis. Each sample was heated with nitric acid to dissolve the zinc minerals.

a Discuss the use of gravimetric analysis, volumetric analysis and AAS in determining the zinc levels in the soil. (2 marks)

b Describe the steps of the method and calculation used to determine the zinc concentration in the soil. (5 marks)

22 You are provided with a punnet of blueberries and asked to evaluate the use of the blueberry extract as an acid–base indicator. Describe your investigations and the procedures you will use to evaluate the effectiveness of the indicator. (6 marks)

23 Write balanced equations for the following reactions and name the organic reaction product(s):

a esterification of pentanoic acid and ethanol (2 marks)

b addition reaction of HI and pent-2-ene (4 marks)

24 An alkanol has a molar mass of 102.172 g/mol. Draw structural formulas for isomeric molecules that have this molar mass. Name these molecules systematically. (7 marks)

25 Figure E1.3 shows the structural formula of a halogenated alkene.

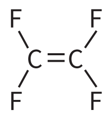

Figure E1.3 Halogenated alkene

a Name this molecule. (1 mark)

b This molecule is polymerised using a catalyst. The product is called Teflon or PTFE.

i What type of polymerisation occurs? (1 mark)

ii Draw the repeating structure of Teflon. (1 mark)

26 A common polyester used to make clothing is PET (polyethylene terephthalate). This polymer is manufactured from two monomers. Figure E1.4 shows the PET polymer structure.

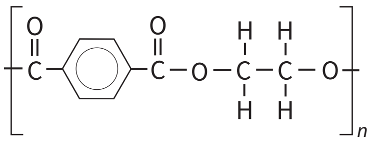

Figure E1.4 PET

a Identify the type of polymerisation that produces this polymer. (1 mark)

b Draw structural formulas of the monomers. (2 marks)

c What property of PET makes it useful in creating textile products? (1 mark)

27 25.00 mL of hard water from a lake was pipetted into a conical flask. The solution was titrated with a standard solution of 0.0100 mol/L EDTA using Eriochrome Black T indicator. At the end point the titre was 13.75 mL:

$$Ca^{2+}(aq) + EDTA^{4-}(aq) \rightarrow CaEDTA^{2-}(aq)$$

a Explain how lake water can become hard. (1 mark)

b How can hard water be used to clean dirty clothing if soap will not lather? (2 marks)

c Calculate the total hardness of the lake water. Assume the hardness is totally due to calcium ions. (5 marks)

28 A colourless solution contains lead (II) nitrate and calcium nitrate. The solution was given to a student as an unknown in a practical exam. The student is told that two cations from the following list are present in the unknown:

Ca^{2+}, Ba^{2+}, Fe^{3+}, Pb^{2+}, Cu^{2+}

Describe the steps required to ensure that the student correctly identifies the two cations in the mixture. (4 marks)

29 Solutions of sodium hydrogen carbonate exhibit both acidic and basic properties. The hydrogen carbonate ion is amphiprotic. Write net ionic equations to demonstrate that it is amphiprotic. (2 marks)

30 Polymers can be foamed to reduce their density. One method of introducing gas bubbles into the polymer is to add a 'blowing agent' such as sodium hydrogen carbonate, which decomposes to form sodium carbonate on heating to form bubbles in the foam.

a Write a balanced equation for the thermal decomposition of sodium hydrogen carbonate. (1 mark)

b Calculate the volume of carbon dioxide (at 25 °C/100 kPa) produced by the decomposition of 8.41 g of sodium hydrogen carbonate. (Molar volume of a gas = 24.79 L/mol) (3 marks)

c Identify the change in property that results by introducing gas bubbles into a plastic such as polystyrene or polypropene. (1 mark)

31 A student performed a simple fermentation experiment in the school laboratory. Dried yeast and a glucose solution were placed in a stoppered side arm flask. The flask was kept warm in a water bath at 37 °C. The carbon dioxide evolved was collected in a weighed U-tube containing powdered calcium oxide.

- **a** Explain why the flask is kept at 37 °C. (1 mark)
- **b** Explain why calcium oxide was used to collect the carbon dioxide. (1 mark)
- **c** Write a balanced equation for the fermentation of glucose. (1 mark)
- **d** Calculate the maximum mass of carbon dioxide that can be formed by the complete fermentation of 18.0 g of glucose. (2 marks)
- **e** In one experiment, 18.0 g of glucose was dissolved in the water. After two days the calcium oxide tube had increased in mass by 7.0 g. What percentage of the theoretical yield of carbon dioxide has been reached after two days? (3 marks)

32 Octadecanoic acid ($C_{17}H_{35}COOH$) is a weak organic acid. 15.0 g of octadecanoic acid dissolves in 6.0 mol/L potassium hydroxide solution to form potassium octadecanoate and water. Potassium octadecanoate is a white insoluble solid with a soapy feel.

- **a** Write the chemical formula of potassium octadecanoate. (1 mark)
- **b** Write a balanced equation for this reaction. (1 mark)
- **c** Calculate the volume of potassium hydroxide required to completely react with the octadecanoic acid. (3 marks)

33 A piece of white phosphorus (P_4) is burnt in pure oxygen. The phosphorus burns with a yellow flame to produce clouds of a white smoke containing tetraphosphorus decaoxide.

- **a** Write a balanced equation for this combustion reaction. (1 mark)
- **b** The white powder is dissolved in water and purple litmus added. The litmus turned red. Account for this observation, with the aid of a balanced equation. (2 marks)
- **c** Sodium hydroxide solution is now carefully added to the solution in part **b** until the indicator turns purple. Write an equation for the reaction occurring and name the salt formed in this reaction. (2 marks)

34 Sulfurous acid is one of the acids present in acid rain.

- **a** Explain how sulfurous acid is formed in rainwater, with the aid of a balanced equation. (1 mark)
- **b** Marble is composed of calcium carbonate. The acid rain attacks a marble statue. Write a balanced equation for this reaction. (1 mark)
- **c** A sample of the acid rain was tested and found to have a hydrogen ion concentration of 1.0×10^{-5} mol/L. Calculate the pH of the rain. (1 mark)
- **d** What colour would each of the following indicators turn in samples of this acid rain?
  i phenolphthalein **ii** bromothymol blue (1 mark)

35 Determine whether or not silver sulfate will precipitate when 60 mL of 0.010 mol/L silver nitrate and 30 mL of 0.010 mol/L sodium sulfate are mixed at 25 °C. (K_{sp}(silver sulfate) = 1.20×10^{-5}) (3 marks)

36 An unknown alkanol X and an unknown alkanoic acid Y have the same molar mass but different melting and boiling points as shown below:

X: m.p = –45 °C; b.p = 158 °C

Y: m.p = –34 °C; b.p = 186 °C

- **a** Explain why the melting and boiling points of Y are greater than those of X. (1 mark)
- **b** The molecular formula of Y is $C_5H_{10}O_2$. Name molecule Y. (1 mark)
- **c** When X is oxidised it is converted to the next member of Y's homologous series. Suggest a name for X. (1 mark)

SAMPLE HSC EXAMINATION 2

Section I: 20 Marks

Attempt Questions 1–20.
Allow about 35 minutes for this section.

1 Figure E2.1 is a C-13 NMR spectrum of an organic molecule.

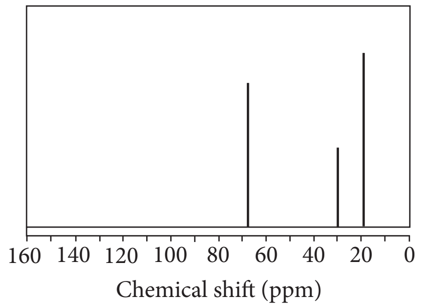

Figure E2.1 C-13 NMR spectrum

Use the Data Sheet in the inside cover of this book to identify which one of the listed molecules would produce this C-13 NMR spectrum.

- **A** butan-1-ol
- **B** butane
- **C** 2-methylpropan-1-ol
- **D** butanone

2 Figure E2.2 is an infrared spectrum of an organic molecule.

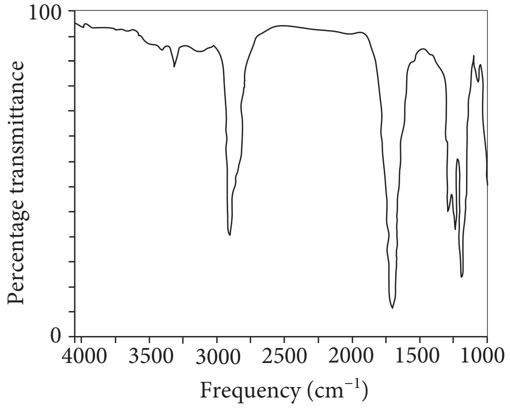

Figure E2.2 IR spectrum

Use the Data Sheet on the inside cover of this book to identify which one of the listed molecules would produce this infrared spectrum.

- **A** butan-1-ol
- **B** butan-1-amine
- **C** 2-methylpropan-1-ol
- **D** butanone

3 Figure E2.3 is a simplified mass spectrum of an organic molecule.

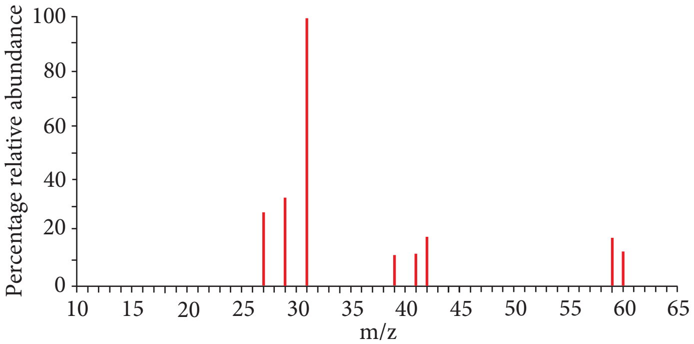

Figure E2.3 Mass spectrum

Identify which one of the listed molecules would produce this mass spectrum.

- **A** propan-1-ol
- **B** propane
- **C** propanoic acid
- **D** but-2-ene

4 Three code-labelled bottles X, Y and Z are known to contain an alkanol, an ester and an alkanoic acid with the same molecular weights. The boiling points of each liquid were determined. Use the following results to identify the component in each bottle:

X (141 °C); Y (118 °C); Z (57 °C)

	X	Y	Z
A	alkanol	ester	alkanoic acid
B	alkanoic acid	ester	alkanol
C	alkanoic acid	alkanol	ester
D	ester	alkanol	alkanoic acid

5 A sample of high density polyethylene (HDPE) has a molar mass of 1.00×10^6 g/mol. Determine the approximate number of monomers that have undergone addition polymerisation to form this polymer.

- **A** 33 258
- **B** 36 977
- **C** 17 824
- **D** 35 648

6 The condensed structural formulas of three molecules X, Y and Z are:

$X = CH_3CHFCHF_2$
$Y = CHCl_2CH_2CHBr_2$
$Z = CH_3CH_2CH_2CHBrCH_2CBr_3$

Identify the correct IUPAC names of these molecules.

	X	Y	Z
A	1,1,2-trifluoropropane	1,1-dibromo-3,3-dichloropropane	1,1,1,3-tetrabromohexane
B	trifluoropropane	dibromodichloropropane	tetrabromohexane
C	2,3,3-trifluoropropane	1,1-dichloro-3,3-dibromopropane	4,6,6,6-tetrabromohexane
D	1,1,2-trifluoropropane	1,1-dichloro-3,3-dibromopropane	1,1,1,3-tetrabromohexane

7 Three bottles X, Y and Z contain the following solutions:

X = ammonia cleanser; Y= sea water; Z = lemonade

The solutions were tested with universal indicator and a pH meter.

Identify which answer correctly identifies the colour of the indicator and the pH.

	X	Y	Z
A	violet (pH 11.5)	green-blue (pH 7.9)	red (pH 2.5)
B	violet (pH 9.0)	green (pH 7.0)	orange (pH 4.8)
C	blue (pH 10.0)	green (pH 7.0)	orange-red (pH 4.0)
D	violet (pH 10.0)	yellow (pH 6.0)	red (pH 3.8)

8 30.0 mL of 0.0250 mol/L HNO_3 is added to 220.0 mL of water to form 250.0 mL of solution.

Identify the response that has correctly calculated the pH and pOH of the solution.

	pH	pOH
A	1.60	12.40
B	2.52	11.48
C	11.48	2.52
D	2.47	11.53

9 Acetic acid dissociates according to the following equation:

$$CH_3COOH(aq) + H_2O(l) \leftrightharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

The K_a value for acetic acid is 1.77×10^{-5}. Determine the pH of a 0.15 mol/L solution.

A 4.8

B 2.8

C 5.6

D 2.0

10 Esters have many uses in society. 1-propyl acetate is a volatile solvent used in cosmetics and aerosol sprays. 1-pentyl propanoate is a slow-evaporating solvent used in enamels and car refinishing. Identify the response that correctly identifies the condensed structural formula of each ester and the likely boiling point consistent with its use.

	1-propyl acetate	b.p (°C)	1-pentyl propanoate	b.p (°C)
A	$CH_3COOC_3H_7$	102	$CH_3CH_2COOC_5H_{11}$	165
B	$CH_3CH_2COOC_2H_5$	102	$CH_3CH_2CH_2CH_2COOC_3H_7$	165
C	$CH_3COOC_3H_7$	165	$CH_3CH_2COOC_5H_{11}$	102
D	$CH_3CH_2COOC_2H_5$	165	$CH_3CH_2CH_2CH_2COOC_3H_7$	102

11 Concentrated sulfuric acid is added to hexan-1-ol. Select the true statement about this reaction.

A Hex-1-ene is a product.

B Hexane is a product.

C The hexan-1-ol is oxidised to form hexanoic acid.

D Formic acid and pentanoic acid are formed.

12 Select the true statement about mass spectrometry.

A The vapourised sample is ionised using pulses of high frequency radio waves.

B The parent molecular ion always forms a peak that has the highest intensity.

C The mass spectrum of methane will have a peak with an m/z value of 16.

D The mass spectrum of ethylene will have a peak at a frequency of 28 cm^{-1}.

13 A solution of silver ions was tested with the following reagents:

- dilute hydrochloric acid
- dilute sodium hydroxide
- dilute sulfuric acid
- dilute potassium iodide solution

Select the response that correctly shows the observations recorded.

	HCl(aq)	NaOH(aq)	H_2SO_4(aq)	KI(aq)
A	white precipitate	brown precipitate	no reaction	no reaction
B	no reaction	white precipitate	no reaction	white precipitate
C	white precipitate	white precipitate	white precipitate	yellow precipitate
D	white precipitate	brown precipitate	faint white precipitate	yellow precipitate

14 As part of the refining of nickel, impure nickel is reacted with carbon monoxide gas to form nickel tetracarbonyl gas:

$$Ni(s) + 4CO(g) \leftrightharpoons Ni(CO)_4(g); \Delta H = -163 \text{ kJ/mol}$$

An increase in the concentration (or partial pressure) of carbon monoxide causes the equilibrium to shift towards the product. Impurities in the crude nickel do not react and are removed.

Select the response that correctly explains how pure nickel can now be obtained.

A Decompose the nickel tetracarbonyl by heating the compound and recycle the carbon monoxide.

B Decrease the partial pressure of carbon monoxide.

C Cool the gaseous product till solid nickel forms.

D Reduce the volume of the vessel to raise the total pressure.

15 **In the industrial manufacture of soap the blended fats (e.g. beef tallow and coconut oil) are mixed with concentrated sodium hydroxide in large vats and steam jets are used to heat the mixture. Following saponification, hot brine is added. The soap curd separates from the aqueous layer. The aqueous layer is pumped out and processed to extract the glycerol. Water is added to the soap curd. The soap is then vacuum dried before processing into soap bars, flakes or powders.**

Select the correct response about the soap-making process.

A The hot brine is added to precipitate the soap curd.

B The glycerol extracted is used to manufacture more soap.

C Saponification is an example of the acidic hydrolysis of a fat.

D Water is added to hydrate the soap before processing to form bars of soap.

16 **In the industrial preparation of sodium carbonate an important step is to recover the ammonia used in the industrial process. Calcium carbonate can be used to recover ammonia gas from solutions of ammonium chloride. The calcium carbonate is first thermally decomposed to form calcium oxide solid. This solid is dissolved in water to form calcium hydroxide solution. The calcium hydroxide solution is mixed with the ammonium chloride solution and on heating ammonia is formed.**

Identify the correct response concerning these industrial reactions.

A The conversion of calcium carbonate to calcium oxide is an exothermic process.

B Sodium carbonate will also form in the reaction that produces the ammonia.

C The ammonia is recovered and recycled to reduce costs and avoid pollution of the atmosphere if released.

D Calcium carbonate decomposes to form calcium hydroxide.

17 **Identify the response that shows the condensed structural formulas of functional group isomers.**

A $CH_3CH_2CH_2CH_2CH_3$ and $CH_3CH(CH_3)CH_2CH_3$

B $CH_3CH_2CH_2CH_2CHO$ and $CH_3COCH_2CH_2CH_3$

C $CH_3CHBrCHBrCH_2CH_3$ and $CH_2BrCH_2CHBrCH_2CH_3$

D CH_3CH_2COOH and $CH_3CH_2CH_2OH$

18 **Cetyl trimethyl ammonium bromide is the common name of a surfactant molecule. Its condensed structural formula is: $CH_3(CH_2)_{12}CH_2N(CH_3)_3{}^+Br^-$**

Select the true statement about such surfactants.

A The surfactant is anionic and can be used in dishwashing liquids.

B The types of surfactants are produced from biomass and readily biodegrade.

C The surfactant is weakly lathering in water and can be used to create stable emulsions in house paint.

D The surfactant is a cationic surfactant that can be used in hair conditioners.

19 **Select the statement that is true about photosynthesis.**

A Chlorophyll molecules selectively absorb green wavelengths of solar radiation.

B Water undergoes oxidation during the photosynthetic process.

C The Gibbs free energy change for photosynthesis is negative and therefore the reaction is spontaneous.

D The oxygen gas molecules liberated by the photosynthetic process are formed from oxygen atoms present in the carbon dioxide molecules.

20 **Figure E2.4 shows a map where chemical industries may be established at sites labelled W, X, Y and Z.**

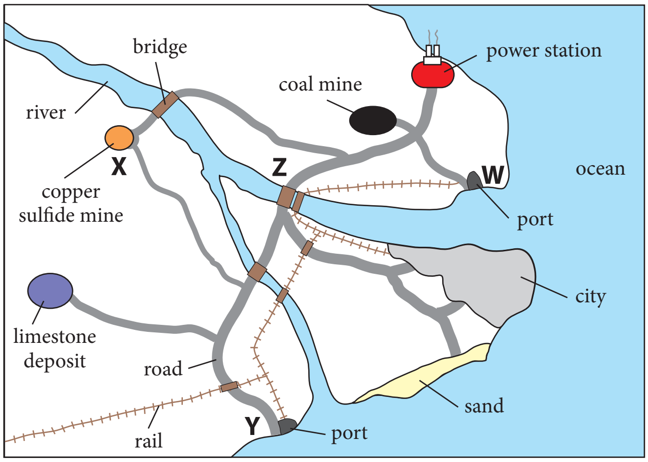

Figure E2.4 Possible sites for chemical industries

The possible industries to be established are:

- **Sodium carbonate production—the raw materials and feedstocks required are salt, limestone and ammonia; ammonia can be obtained by rail tanker from interstate.**

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- Sodium hydroxide production—salt is the raw material and electrical energy is required to electrolyse salt water.
- Sulfuric acid production—sulfur dioxide feedstock can be obtained from the roasting of sulfide ores.

Select the response that shows the best locations for each chemical plant.

	Sodium carbonate	Sodium hydroxide	Sulfuric acid
A	Y	W	X
B	Y	Z	X
C	W	X	Y
D	W	Y	Z

Section II: 80 Marks

Attempt Questions 21–36.
Allow about 2 hours and 25 minutes for this section.

Instructions
- In the HSC Exam you will answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.

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21 Hydrogen iodide gas was placed in a flask at 490 °C. It was allowed to decompose to form an equilibrium mixture of hydrogen gas and iodine vapour. The concentrations of each species were measured at equilibrium:

$[HI] = 1.76 \times 10^{-2}$ mol/L; $[H_2] = 2.60 \times 10^{-3}$ mol/L; $[I_2] = 2.60 \times 10^{-3}$ mol/L

a Write an equation for the equilibrium. (1 mark)

b Write an expression for K_{eq}. (1 mark)

c Calculate the value of K_{eq} at 490 °C and state the position of this equilibrium. (2 marks)

d The value of K_{eq} at 423 °C is 0.018. What can we conclude about this equilibrium from the K_{eq} values at two different temperatures? (1 mark)

22 Figure E2.5 is the pH titration graph for the reaction between 25.00 mL of a standardised 0.00245 mol/L sulfuric acid solution and an ammonia solution of unknown concentration.

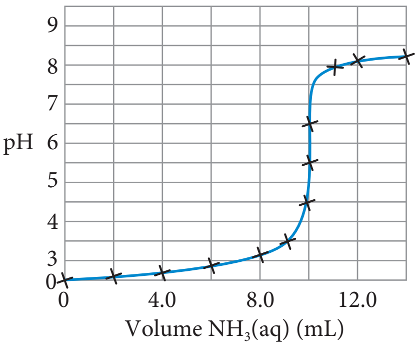

Figure E2.5 Acid–base pH titration

a Write a balanced whole formula equation for the neutralisation reaction. (1 mark)

b Identify which solution is placed in the burette. (1 mark)

c Determine the approximate pH at the equivalence point. (1 mark)

d Determine the titre for the titration. (1 mark)

e Calculate the concentration of the ammonia solution. (2 marks)

f Name an appropriate indicator if the titration had been performed using an indicator rather than a pH meter. (1 mark)

23 An insoluble white solid X is dissolved in nitric acid. An odourless gas is evolved and a colourless solution forms. Some of the gas is passed into a test tube containing universal indicator solution. The indicator turned pink. Some of the gas was passed into a solution of barium hydroxide and a faint white precipitate forms. The colourless solution was divided into three test tubes and tested with three reagents. The results are:

- Sodium iodide solution forms a bright yellow precipitate.
- Sulfuric acid forms a thick white precipitate.
- Sodium chloride solution forms a faint white precipitate that dissolves when the mixture is heated.

Analyse the information and identify the white solid X. Use equations as part of the explanation. (5 marks)

24 Atomic absorption spectroscopy (AAS) was used to measure the concentration of mercury in a sample of polluted water.

a Describe how a chemist could prepare a dilution standard with a mercury concentration of 20 ppm using crystalline mercury (II) nitrate that contains 61.80% mercury by weight. (3 marks)

b Further dilution standards were prepared and used to calibrate the atomic absorption spectrometer. Explain why this calibration was performed. (1 mark)

c The absorbance of the dilution standards was measured. The results are tabulated.

$[Hg^{2+}]$ (ppm)	0	5	10	15	20
Absorbance	0	0.095	0.190	0.290	0.385

The polluted water sample was diluted by a factor of 1 in 10 and its absorbance measured. The absorbance of the diluted sample was 0.120.

i Draw a calibration graph. (5 marks)

ii Use this data to determine the concentration of mercury in the original polluted water sample. (1 mark)

25 Bomb calorimeters are used to accurately measure enthalpies of combustion. An analytical chemist placed a 5.00 g sample of ethanol in a steel bomb calorimeter containing an excess of pure oxygen gas. The ethanol was vapourised and ignited. The heat released by the combustion was absorbed by the stainless steel calorimeter and its water bath that rose in temperature by 23.68 Celsius degrees. Calculate the molar enthalpy of combustion of ethanol from this data. Assume that the steel calorimeter and water bath were equivalent to 1.500 kg of water with a specific heat capacity of 4.18×10^3 J/kg/K. (3 marks)

26 Hydrogen sulfate ions are acidic in water solution due to the following equilibrium:

$$HSO_4^-(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + SO_4^{2-}(aq)$$

a A 0.100 mol/L solution of sodium hydrogen sulfate has a pH of 1.54 at 25 °C. Calculate the acid dissociation constant for the above equilibrium. (3 marks)

b Write a whole formula equation and a net ionic equation for the reaction of sodium hydrogen sulfate solution with potassium hydroxide solution. (2 marks)

27 Phosgene gas ($COCl_2$) is formed by the reaction of carbon monoxide and chlorine.

a Write an equilibrium equation for this reaction. (1 mark)

b The enthalpy change for the reaction is –108 kJ/mol. How will the position of the equilibrium change if the temperature is increased? (1 mark)

c One mole of CO and 1 mole of Cl_2 are mixed in a 2-litre vessel at a fixed temperature. The system is allowed to come to equilibrium. The amount of phosgene present at equilibrium was 0.30 mol.

i Write an expression for the equilibrium constant. (1 mark)

ii Calculate a value for the equilibrium constant. (3 marks)

28 The Solvay process is used industrially to manufacture sodium carbonate. One of the steps in the process is the carbonation of ammoniated salt water (brine). Ammonia gas is first passed through saturated salt water to saturate the solution in ammonia. Inside the carbonation tower the ammoniated brine sprayed onto serrated plates arranged vertically in the tower. As the solution trickles over the plates the carbon dioxide is then pumped in at the base of the tower. The rising carbon dioxide gas is absorbed by the ammoniated brine and a solution of ammonium chloride and sodium hydrogen carbonate form. The carbonation tower is cooled during this process.

a Explain how the use of serrated plates increases the rate of reaction between the carbon dioxide and ammoniated brine solution. (1 mark)

b Write a balanced equation for the reaction between the carbon dioxide and the ammoniated brine solution. (1 mark)

c Sodium hydrogen carbonate crystals form under the conditions used. Explain what conditions lead to the crystallisation of sodium hydrogen carbonate. (2 marks)

29 25.00 mL of a nitric acid solution was pipetted into a beaker and a conductivity probe was clamped into position in the acid solution. A burette was cleaned and filled with a standardised 0.100 mol/L KOH solution. The conductivity of the solution was recorded as the titration was performed. The conductivity was plotted as a function of the volume of added KOH. The graph is shown in Figure E2.6. Determine the concentration of the nitric acid solution. (3 marks)

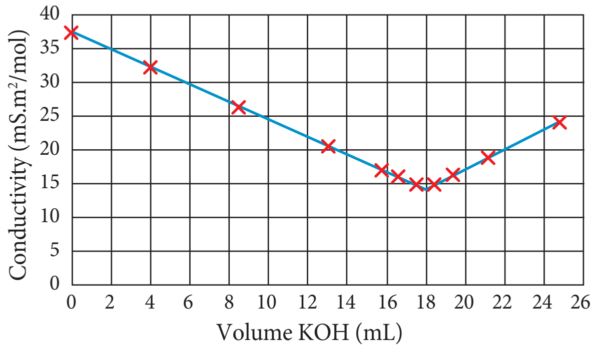

Figure E2.6 Conductivity graph versus volume KOH

30 One white salt and one green salt were mixed together and dissolved in water. A pale-green solution was formed. The tests in the table were performed on samples of this solution to identify the ions that may be present. Use the observations to identify the ions in the mixture. (4 marks)

Test	Observation
1 Dilute nitric acid was added.	no change
2 Barium nitrate solution was added to the solution from test 1.	no change
3 Silver nitrate solution was added to the solution from test 2.	white precipitate
4 A flame test was conducted on the original solution.	green flame
5 HCl was added to original solution.	no change
6 Sulfuric acid was added to the original solution.	white precipitate
7 Sodium hydroxide was added to the original solution.	pale-blue precipitate
8 Sodium fluoride was added to the original solution.	no change

31 Lauric acid is a straight chain alkanoic acid. Its molar mass is 200.312 g/mol.

a Determine the condensed structural formula of lauric acid. (2 marks)

b Lauric acid is a waxy solid that is insoluble in water. Explain why the acid is insoluble despite the presence of the carboxyl functional group. (1 mark)

c Lauric acid will dissolve in a hot solution of potassium hydroxide. Write an equation for this reaction. (1 mark)

32 Seawater contains a high concentration of chloride ions. A gravimetric analysis was performed by a student using a 100 mL sample of seawater. Excess silver nitrate was added to seawater and the precipitate produced weighed 7.56 g.

a The student assumed that the precipitate was silver chloride. Is this a valid assumption? Explain. (2 marks)

b Assuming that only chloride ions were precipitated, calculate the chloride ion concentration in the seawater in parts per million. (2 marks)

33 The molecule 6-aminohexanoic acid can undergo condensation polymerisation to form a polyamide called nylon-6.

a Draw the structural formula of 6-aminohexanoic acid. (1 mark)

b Draw a three-monomer section of the polymer chain to show the amide linkage. (1 mark)

34 A 100 mL bottle was completely filled with a sample of fresh, aerated water from a waterfall in the mountains. The water temperature was measured and the bottle was sealed. Back in the lab a Winkler titration was performed. A solution of manganese (II) ions reacted with the oxygen in the water and then an alkaline solution of potassium iodide was added. The mixture was acidified and the iodine that formed was titrated with a standard solution of 0.0100 mol/L sodium thiosulfate ($Na_2S_2O_3$). The titre was 12.35 mL.

a The net reaction in the titration is:

$$O_2(aq) + 4S_2O_3^{2-}(aq) + 4H^+(aq) \rightarrow 2H_2O(l) + 2S_4O_6^{2-}(aq)$$

Calculate the dissolved oxygen (DO) level in the water sample in the units of parts per million. (3 marks)

b Use the tabulated data to determine the temperature of the water sample, given that it was saturated in oxygen. (1 mark)

Temperature (°C)	10	15	20	25
DO (ppm)	11.1	9.9	9.0	8.2

35 The colours of thymol blue indicator at different concentrations of hydrogen ion are shown in the table.

$[H^+]$ mol/L	Colour	$[H^+]$ mol/L	Colour	$[H^+]$ mol/L	Colour
10^{-2}	red	10^{-5}	yellow	10^{-8}	yellow-green
10^{-3}	yellow	10^{-6}	yellow	10^{-9}	green
10^{-4}	yellow	10^{-7}	yellow	10^{-10}	blue

a What colour will thymol blue indicator turn if it is added to:

i 1 mol/L HCl? (1 mark) **ii** 1 mol/L NaOH? (1 mark)

b Thymol blue is added to a 1 mol/L sodium hydroxide solution and the solution slowly neutralised using sulfuric acid. Describe the colour changes of the indicator as neutralisation occurs. (3 marks)

c An unknown solution X was tested with bromothymol blue and thymol blue indicators. Bromothymol blue turned green. What colour will thymol blue turn? (1 mark)

36 The solubility of lead (II) carbonate was found by experiment to be 7.27×10^{-6} g/100 g water at 25 °C. Determine the solubility product constant for lead (II) carbonate. (Density of water = 1 g/mL) (3 marks)

37 An equimolar mixture of ammonium chloride and ammonia solution is prepared. The pH was measured and found to be 9.3.

a Write an equilibrium equation between ammonia and ammonium ions in water solution. (1 mark)

b The original ammonia solution had a pH greater than 9.3. Explain why the addition of ammonium chloride has caused the pH to drop to 9.3. (2 marks)

c Explain how this mixture can act as a buffer. (2 marks)

SAMPLE HSC EXAMINATION 1

Section I

1 **D.** Barium ions produce a yellow-green flame. **A** is incorrect as calcium ions produce an orange-red flame. **B** is incorrect as sodium ions produce yellow flames. **C** is incorrect as copper (II) ions produce bright-green flames.

2 **C.** The double bond has priority in numbering the chain. **A** is incorrect as no locants are shown. **B** is incorrect as the methyl groups are not named. **D** is incorrect as the double bond has not been given priority.

3 **C.** Sulfurous acid is a weak acid. Thus **A**, **B** and **D** are all incorrect as they are all strong acids.

4 **D.** Sulfuric acid is a strong acid that ionises completely when diluted:

$$H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

$[H^+] = 2 \times [H_2SO_4] = 2 \times 0.00050 = 0.0010$ mol/L

$pH = -\log_{10}[H^+] = -\log_{10}(0.0010) = 3.00$

Thus **A**, **B** and **C** are incorrect.

5 **A.** A buffer is a mixture of a weak acid and its conjugate base. **B** is incorrect as the carbonate ion is not the conjugate base of phosphoric acid. **C** is incorrect as sulfate is not the conjugate base of sulfurous acid. **D** is incorrect as KOH is a strong base.

6 **B.** Universal indicator is violet in strongly basic solutions but yellow or red in acidic solutions. **A** is incorrect because X is basic as the indicator turns violet. **C** is incorrect because Y is weakly acidic as the indicator is yellow. **D** is incorrect because Z is acidic as the indicator is red.

7 **B.** The chloride ion concentration increases and shifts the equilibrium to the right. **A** is incorrect as water will shift the equilibrium to the left and the solution becomes more blue. **C** is incorrect as the nitrate ion will have no effect. **D** is incorrect as the HCl will cause an increase in chloride concentration and the solution turns more green.

8 **D.** The system is open and carbon dioxide escapes and this leads to less carbonic acid in the water. **A** is incorrect as the water will be slightly acidic due to carbon dioxide partially dissolving in the water. **B** is incorrect as the loss of carbon dioxide will reduce the concentration of carbonic acid. **C** is incorrect as no temperature change has occurred.

9 **A.** The nitrite ion (NO_2^-) is the conjugate base of HNO_2. **B** is incorrect as nitrous acid is a weak acid. **C** is incorrect as weak acids are partially dissociated in water. **D** is incorrect as 3.0 would be the pH of a strong acid with this concentration.

10 **B.** Helium is neither a reactant nor product and cannot react with any other gas as it is a noble gas. It cannot alter the position of the equilibrium as the concentration of reactants or products have not changed as the vessel volume is constant. **A** is incorrect as the value of K_{eq} depends only on temperature. **C** is incorrect as the equilibrium constant would decrease as the reaction is exothermic. **D** is incorrect as an increase in yield is caused by a total pressure increase as the result of reducing the volume of the reaction vessel.

11 **C.** $[H_3O^+] = 10^{-pH} = 10^{-4.10}$ mol/L

Degree of dissociation = 8 = $[H_3O^+]/[HA] \times 100$

$$[HA] = \left(\frac{10^{-4.10}}{8}\right) \times 100 = \left(\frac{7.94 \times 10^{-5}}{8}\right) \times 100 = 9.93 \times 10^{-3} \text{mol/L}$$

Thus **A**, **B** and **D** are incorrect.

12 **B.** Silver chloride is insoluble. **A** is incorrect as all products are soluble. **C** is incorrect as copper (II) chloride is soluble. **D** is incorrect as zinc chloride is soluble.

13 **A.** $PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Br^-(aq)$

$K_{sp} = [Pb^{2+}][Br^-]^2$

Let x be the mol of $PbBr_2$ dissolved per litre.

At equilibrium: $[Pb^{2+}] = x$; $[Br^-] = 2x$

$K_{sp} = (x)(2x)^2 = 4x^3 = 6.6 \times 10^{-6}$

Solve for x.

$x = 0.0118$ mol/L

$[Br^-] = 2x = 0.0236$ mol/L

Thus **B**, **C** and **D** are incorrect.

14 **A.** The hydroxyl functional group has numbering priority. **B** is incorrect as numbering is from left to right to give the lowest number to the methyl functional group. **C** is incorrect as no locants are shown. **D** is incorrect as the molecule is not an alkanone.

15 **B.** The metal ion solution is atomised in the flame. **A** is incorrect as the hollow cathode lamp generates the light. **C** is incorrect as the diffraction grating diffracts the light. **D** is incorrect as the flame does not absorb the light. The ions in the flame absorb the light.

16 **C.** The numerator of the equilibrium constant is the product of the methane and water vapour concentrations. **A** is incorrect as the equation is not balanced. **B** is incorrect as the quotient is inverted. **D** is incorrect as the water formed is in the gaseous state.

17 **D.** The yellow smoky flame is caused by carbon particles. **A** is incorrect as this is a complete combustion equation that would have produced a blue flame. **B** and **C** are incorrect as no carbon particles are present.

18 **D.** The smallest solubility product indicates the sulfate salt of lowest solubility and therefore the lower sulfate concentration. Thus **A**, **B** and **C** are incorrect as their K_{sp} values are larger.

19 **A.** The colourimeter can measure the colour of the solution and, when the equilibrium is attained, then the light absorbed by the solution will no longer change in intensity. **B** is incorrect because titrations are too long a procedure as samples would need to be removed and this would affect the attainment of equilibrium. **C** is incorrect as the mass remains constant. **D** is incorrect as the procedure is time consuming and could disturb the time to reach saturation equilibrium.

20 **C.** Ketones typically have chemical shifts at large downfield positions compared with the standard. **A** is incorrect as two peaks would be seen as the two carbon atoms are in different chemical environments. **B** is incorrect as the carbon atoms are in different chemical environments. **D** is incorrect as only one peak is observed because each carbon atom is in the same chemical environment.

Section II

21 EM Students need to determine which method can accurately measure low levels of zinc ions in soil. Students score full marks if they demonstrate the full experimental method.

a AAS is the only method that is sufficiently sensitive to detect the low concentrations of zinc minerals in a typical farm soil. ✓ Gravimetric and volumetric analysis are used in cases where concentrations are at molar levels. ✓

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b 1 Weigh each soil sample. Add nitric acid to each sample and heat to dissolve the zinc minerals. ✓
2 Filter and collect each filtrate. Transfer each filtrate to 100 mL volumetric flasks and add distilled water to the engraved mark. Stopper and mix. ✓
3 Prepare a stock zinc standard from a known mass of pure zinc dissolved in nitric acid. Prepare dilution standards from this stock standard. ✓
4 Use a zinc hollow cathode lamp. Aspirate the standards in the AAS flame and measure the absorbance of each. Create a calibration graph. Measure the absorbance of the soil extracts and use the calibration graph to determine the zinc concentrations. ✓
5 Calculate the zinc concentration of zinc in each soil sample (in ppm = mg/kg soil). Average the results of the five samples. ✓

22 **EM** Students must accurately describe the experimental method as well as explain how effective the indicator is for different types of titrations.

Preparation of indicator:

1 Use a mortar and pestle to squash the blueberries. Add the squashed berries to a beaker, cover with water and heat gently to extract the dyes. ✓
2 Filter the mixture and collect the filtrate. Use this filtrate as an indicator. ✓

Testing the indicator:

1 Prepare acid and base solutions of different pH levels between 0 and 14 using a pH meter and 1 mol/L HCl, 1 mol/L NaOH and water. ✓
2 Place the different pH solutions in test tubes and add drops of the blueberry indicator.

Record the colour of the indicator at each pH. ✓

3 Use these results to determine the pH range(s) of the blueberry indicator. ✓
4 Determine whether or not the indicator ranges would be suitable to be used in titrations involving strong/weak acids and bases. ✓

23 **EM** Students must demonstrate equation writing skills as well as a knowledge of possible reaction products. In part **b** students need to realise that two possible isomers can form.

a $CH_3CH_2CH_2CH_2COOH + CH_3CH_2OH \rightleftharpoons CH_3CH_2CH_2CH_2COOCH_2CH_3 + H_2O$ ✓
Ester = ethyl pentanoate ✓

b $CH_3CHHCH_2CH_3 + HI \rightarrow CH_3CH_2CHICH_2CH_3$ ✓
3-iodopentane ✓
$CH_3CHHCH_2CH_3 + HI \rightarrow CH_3CHICH_2CH_2CH_3$ ✓
2-iodopentane ✓

24 **EM** Students need to determine that a vast number of isomers can form. They also need to show that each isomer has a unique name.

These alkanols have six carbon atoms.

MF = $C_6H_{13}OH$

M = (6 × 12.01) + (14 × 1.008) + 16.00 = 102.172 g/mol

Figure AE1.1 shows the structural formulas and names of the isomers.

25 **EM** Students must demonstrate skills in naming alkenes. Students should show an understanding of the addition polymerisation process and the structure of the repeating unit.

a tetrafluoroethylene ✓

b i addition polymerisation ✓
ii Figure AE1.2 shows the structural formula of the polymer's repeating unit.

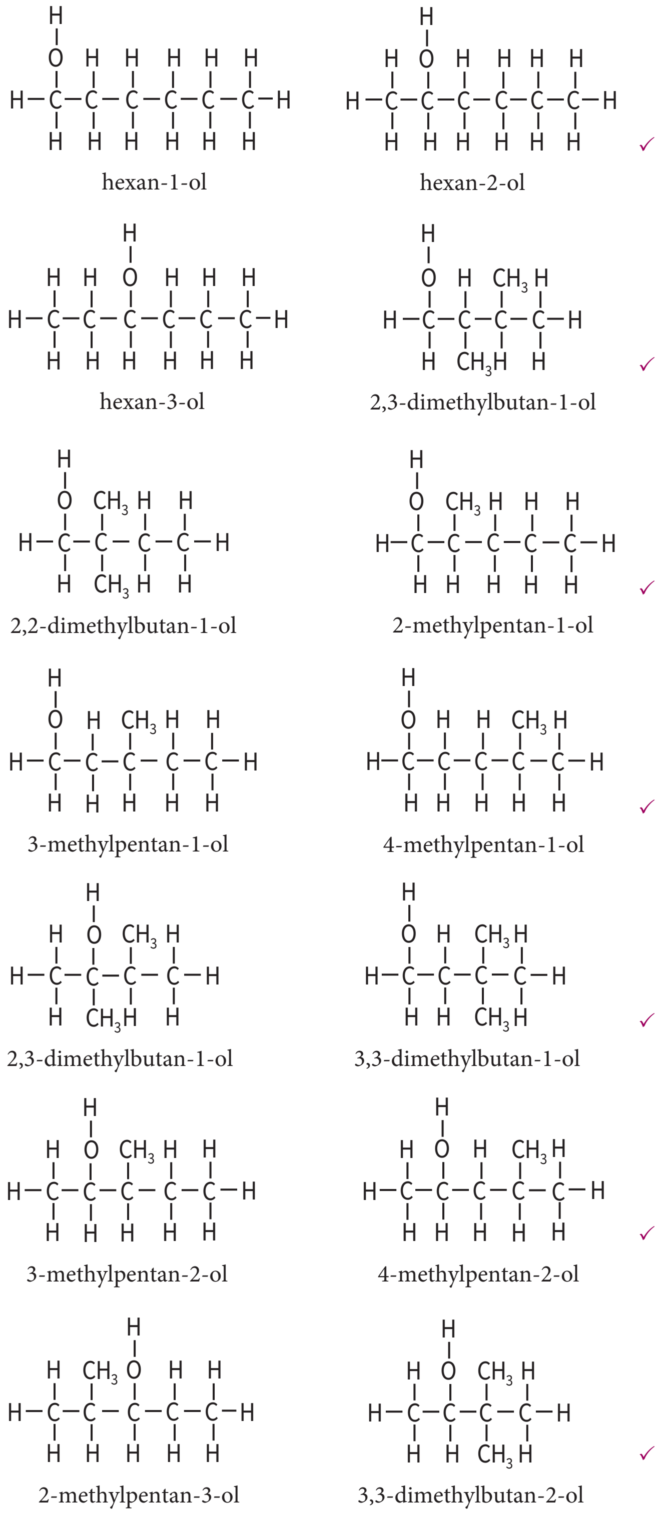

Figure AE1.1 Isomers

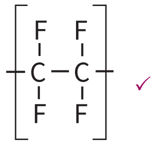

Figure AE1.2 Teflon repeating structure

26 **EM** Students must demonstrate an understanding of condensation polymerisation and how functional groups interact. Full marks are given to students who have a wide understanding of the social use of such polymers.

a condensation polymerisation ✓

b Figure AE1.3 shows the structural formulas of the two monomers.

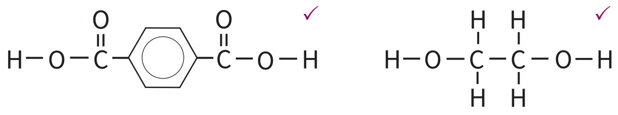

Figure AE1.3 Monomers

c PET has low water absorption and minimal shrinkage after washing. ✓

27 **EM** Students relate the social/environmental issues of hard water to the analysis of the water using an EDTA titration. Full marks require students to express hardness in the correct units.

a Limestone rocks bordering the lake are leached over time and calcium carbonate dissolves into the water. ✓

b Synthetic detergents (such as anionic detergents) are used. ✓ They lather and foam in hard water and can clean dirty clothes. ✓

c $n(\text{EDTA}) = cV = (0.0100)(0.010.75) = 1.075 \times 10^{-4}$ mol ✓
Reaction stoichiometry = 1 : 1
$n(Ca^{2+}) = 1.075 \times 10^{-4}$ mol ✓
The calcium ions are present due to calcium carbonate undergoing dissolution in the water.
$n(CaCO_3) = 1.075 \times 10^{-4}$ mol ✓
Calculate the mass of $CaCO_3$.
$M(CaCO_3) = 40.08 + 12.01 + 3(16.00) = 100.09$ g/mol
$m(CaCO_3) = n.M = (1.075 \times 10^{-4})(100.09) = 0.0108$ g = 10.8 mg ✓
$c(CaCO_3) = n/V = \frac{10.8}{0.0250} = 432$ mg/L = 432 ppm ✓

28 **EM** Students need to recall the order of elimination tests and describe confirmatory tests that confirm the presence of various cations.

1. Add excess HCl to a sample of the solution. If a white precipitate forms then lead (II) ions are indicated. This can be confirmed by adding sodium iodide to another sample and a bright yellow precipitate forms. ✓
2. If a precipitate formed when excess HCl was added, filter the mixture and keep the filtrate for testing. If no precipitate formed, then the next test can be conducted on the acidified solution. Add sulfuric acid to a sample of the filtrate or solution. A white precipitate indicates that calcium and/or barium ions are present. To another sample of filtrate, add sodium fluoride solution. If a white precipitate formed, then calcium ions are present. If no precipitate formed, then barium ions are present. ✓
3. Use a new sample of the unknown solution. Test the solution with potassium thiocyanate solution. A deep-red colouration demonstrates that iron (III) ions are present. ✓
4. Use a new sample of the unknown solution. Add ammonia solution in excess. A blue precipitate forms and then the precipitate dissolves to form a deep-blue solution if copper (II) ions are present. ✓

29 **EM** Students show an understanding of amphiprotic behaviour as well as choosing a strong base and a strong acid to demonstrate the amphiprotic property of the hydrogen carbonate ions.

HCO_3^- as an acid: $HCO_3^-(aq) + OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$ ✓
HCO_3^- as a base: $HCO_3^-(aq) + H_3O^+(aq) \rightarrow CO_2(g) + 2H_2O(l)$ ✓

30 **EM** Students are to use the stoichiometry of an equation to calculate the volume of a gaseous product. Students must then relate the use of the gas to produce a polymer foam and explain the properties of the polymer foam that makes it useful in a social context.

a $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$ ✓

b $M(NaHCO_3) = 22.99 + 1.008 + 12.01 + 3(16.00) = 84.008$ g/mol
$n(NaHCO_3) = m/M = \frac{8.41}{84.008} = 0.100$ mol ✓
$n(CO_2) = n(NaHCO_3)/2 = 0.0500$ mol ✓
$V(CO_2) = (0.0500)(24.79) = 1.24$L ✓

c The gas holes formed in the foam make the plastic foam a good thermal insulator. ✓

31 **EM** Students must show a deep understanding of the conditions required for fermentation and use supplied information to explain why calcium oxide can absorb carbon dioxide. For full marks students should demonstrate skills in mole calculations.

a At this temperature the yeast's biochemical processes are optimised. Enzymic processes occur at their optimal rate near 'blood temperature'. ✓

b Calcium oxide is a base and carbon dioxide is an acidic oxide. The calcium oxide reacts with the carbon dioxide to form solid calcium carbonate. Thus the carbon dioxide is effectively trapped. ✓

c $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$ ✓

d $M(\text{glucose}) = 6(12.01) + 12(1.008) = 6(16.00) = 180.156$ g/mol
$n(\text{glucose}) = m/M = \frac{18.0}{180.156} = 0.0999$ mol
$n(CO_2) = 2n(\text{glucose}) = 0.200$ mol
$M(CO_2) = 44.01$ g/mol
$m(CO_2) = 0.200 \times 44.01 = 8.80$ g ✓

e $m(CO_2)$ evolved in two days = 7.0 g
Percentage = $\left(\frac{7.0}{8.80}\right) \times \frac{100}{1} = 79.5\%$ ✓

32 **EM** Students should understand that the reaction involves neutralisation and be able to predict the formula of the fatty acid salt as well as perform a mole calculation to determine the volume of base for the complete reaction.

a $KC_{17}H_{35}COO$ ✓

b $C_{17}H_{35}COOH(s) + KOH(aq) \rightarrow KC_{17}H_{35}COO(s) + H_2O(l)$ ✓

c $M(C_{17}H_{35}COOH) = 18 \times 12.01 + 36 \times 1.008 + (2 \times 16.00)$
= 284.468 g/mol
$n(C_{17}H_{35}COOH) = m/M = \frac{15.0}{284.468} = 0.0527$ mol ✓
Stoichiometry = 1 : 1
$n(KOH) = 0.0527$ mol ✓
$V(KOH) = n/c = \frac{0.0527}{6.0} = 8.78 \times 10^{-3}$ L = 8.78 mL ✓

33 **EM** Students need to demonstrate the acidic properties of phosphorus oxides and write balanced equation for a neutralisation reaction.

a $P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$ ✓

b The solution is acidic due to the production of phosphoric acid: ✓
$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ ✓

c $H_3PO_4(aq) + 3NaOH(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$ ✓
Salt = sodium phosphate ✓

34 **EM** Students should recall the acidic oxides that can pollute the atmosphere and how acid rain can damage natural and built structures. Students need to calculate the pH of solutions and relate pH to colours of different indicators.

a SO_2 pollution of the atmosphere combines with water to form sulfurous acid:
$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ ✓

b $CaCO_3(s) + H_2SO_3(aq) \rightarrow CaSO_3(s) + H_2O(l) + CO_2(g)$ ✓

c $pH = -\log_{10}[H^+] = -\log_{10}[1.0 \times 10^{-5}] = 5.0$ ✓

d i colourless ii yellow ✓

35 **EM** Students must show mathematical skills in determining the concentration of ions on mixing solutions and determine whether the ionic product is greater or lesser than the solubility product constant.

Calculate the concentration of silver and sulfate ions on mixing.

$n(Ag^+) = cV\ (0.010)(0.060) = 6.0 \times 10^{-4}$ mol

$n(SO_4^{\ 2-}) = cV = (0.010)(0.030) = 3.0 \times 10^{-4}$ mol

Total volume on mixing = 60 + 30 = 90 mL = 0.090 L

$[Ag^+] = n/V = \left(\frac{6.0 \times 10^{-4}}{0.090}\right) = 6.67 \times 10^{-3}$ mol/L

$[SO_4^{\ 2-}] = n/V = \left(\frac{3.0 \times 10^{-4}}{0.090}\right) = 3.33 \times 10^{-3}$ mol/L ✓

Calculate the ionic product (IP). The ionic product is the product of concentration of ions of the electrolyte, each raised to the power of their coefficients in the balanced chemical equation in the dissolution equilibrium.

$IP = [Ag^+]^2[SO_4^{\ 2-}] = (6.67 \times 10^{-3})^2(3.33 \times 10^{-3}) = 1.48 \times 10^{-7}$ ✓

The ionic product is much less than the K_{sp}.

$IP = 1.48 \times 10^{-7} << 1.20 \times 10^{-5}$

Therefore no precipitate will form on mixing the solutions. ✓

36 **EM** Students should recall different types of intermolecular forces to explain differences in the properties of organic compounds. They also need to demonstrate an understanding of homologous series of organic compounds to score full marks.

a Alkanoic acids are more polar than alkanols and the hydrogen-bonding in alkanoic acids is stronger in short chain alkanoic acids than in similar alkanols. These stronger intermolecular forces result in higher melting and boiling points for alkanoic acids than alkanols. ✓

b pentanoic acid ✓

c The next member of Y's alkanoic acid series is hexanoic acid. Hexan-1-ol is oxidised to hexanoic acid. X = hexan-1-ol ✓

SAMPLE HSC EXAMINATION 2

Section I

1 **C.** 2-methylpropan-1-ol has three carbon atoms in different chemical environments. (Carbon 1 is attached to the OH group; C-2 is a CH_2 (methylene group); the remaining carbons are both methyl groups attached to C-2. **A** is incorrect as the spectrum would have four peaks. **B** is incorrect as butane would have two peaks. **D** is incorrect as butanone would have four peaks.

2 **D.** Butanone contains a carbonyl (C=O) group, which is consistent with the peak at 1705–1725 cm^{-1}. The other large peak is a C–H stretching frequency (typically 2850–2960 cm^{-1}). **A** is incorrect as butan-1-ol would have an O–H stretch at 3610–3640 cm^{-1}. **B** is incorrect as butan-1-amine would have an N–H stretch at 3300–3500 cm^{-1}. **C** is incorrect as 2-methylpropan-1-ol would have an O–H stretch at 3610–3640 cm^{-1}.

3 **A.** Propan-1-ol has a molar mass of 60.1 g/mol. This is consistent with the small peak at an m/z value of 60. The large peak at m/z = 31 is a fragment (CH_2OH^+). **B** is incorrect as propane would have a parent ion peak at m/z = 44. **C** is incorrect as propanoic acid would have a parent ion peak at m/z = 74. **D** is incorrect as but-2-ene would have a parent ion peak at m/z = 56.

4 **C.** Alkanoic acids have the highest boiling points as they are the most polar of the three molecules, and the ester has the lowest boiling point as it is the least polar. Therefore **A**, **B** and **D** are incorrect as the order is incorrect.

5 **D.** $M(CH_2CH_2) = (2 \times 12.01) + (4 \times 1.008) = 28.052$ g/mol

$n = \left(\frac{1.00 \times 10^6}{28.052}\right) = 35\ 648$ mol

Therefore **A**, **B** and **C** are mathematically incorrect.

6 **A.** In X the numbering is from right to left to give the lowest locant set. In Y the numbering is also right to left because the locant set numbers are the same from left to right as right to left, and so the alphabetical order of functional groups decides the numbering order. Z is also numbered from right to left to give the lowest locant set for the four bromo groups. **B** is incorrect as no locant positions are shown for the functional groups. **C** is incorrect as X and Z have been incorrectly numbered from left to right. **D** is incorrect as Y has been incorrectly numbered from left to right and priority has incorrectly been given to chloro groups instead of bromo groups.

7 **A.** Ammonia cleansers typically have a pH of 11.5 and universal indicator is violet at this pH. Sea water has a pH range of about 7.5–8.5 and universal indicator would be green-blue. Lemonades typically have a pH between 2 and 3 and the universal indicator would be red. Therefore **B**, **C** and **D** are incorrect.

8 **B.**

$n(HNO_3) = cV = (0.0250)(0.0300) = 7.50 \times 10^{-4}$ mol

After dilution:

$c(HNO_3) = n/V = \left(\frac{7.50 \times 10^{-4}}{0.250}\right) = 3.00 \times 10^{-3}$ mol/L

$[H^+] = c(HNO_3) = 3.00 \times 10^{-3}$ mol/L

$pH = -\log_{10}[H^+] = -\log_{10}(3.00 \times 10^{-3}) = 2.52$

$pOH = 14 - pH = 14 - 2.52 = 11.45$

Thus **A**, **C** and **D** are mathematically incorrect.

9 **B.** $K_a = [H_3O^+][CH_3COO^-]/[CH_3COOH]$

Hydronium ions and acetate ions have the same concentration according to the balanced equation. Let this concentration = x.

At equilibrium: $[H_3O^+] = [CH_3COO^-] = x$

$[CH_3COOH] = 0.150 - x$

$[H_3O^+][CH_3COO^-]/[CH_3COOH] = (x)(x)/(0.150 - x) = 1.77 \times 10^{-5}$

Solve for x.

$x = 1.6 \times 10^{-3}$ mol/L $= [H_3O^+]$

$pH = -\log_{10}[1.6 \times 10^{-3}] = 2.8$

Thus **A**, **C** and **D** are mathematically incorrect.

10 **A.** 1-propyl acetate is more volatile and will have the lower boiling point; the condensed structural formulas are correct. **B** is incorrect as the formulas are incorrect. **C** is wrong as the boiling points are incorrect. **D** is incorrect as both the formulas and boiling points are incorrect.

11 **A.** Hex-1-ene is produced in the dehydration reaction. **B** is incorrect as alkenes and not alkanes form on dehydration of alkanols. **C** and **D** are incorrect as oxidation does not occur.

12 **C.** Methane has an m/z value of 16 as the molar mass is 16.042 g/mol. **A** is incorrect as radio waves are not used in this instrument. **B** is incorrect as parent peaks are not necessarily the largest peak. **D** is incorrect as mass spectra do not have units of cm^{-1}.

13 **C.** HCl, NaOH and H_2SO_4 all form white precipitates, whereas KI produces a yellow precipitate. Therefore **A**, **B** and **D** are incorrect.

14 **A.** The reverse reaction is endothermic and therefore heating the nickel tetracarbonyl will decompose it to form pure nickel. **B** is incorrect as the reverse reaction will not go to completion. **C** is incorrect as the reverse reaction requires heat. **D** is incorrect because increasing the total pressure will promote the formation of nickel tetracarbonyl.

15 **A.** The high salt concentration causes the soap to precipitate. **B** is incorrect as the glycerol is used to manufacture other products but not soap. **C** is incorrect as the hydrolysis occurs under alkaline conditions. **D** is incorrect as water is used to wash alkali and salt out of the soap curd.

16 **C.** Ammonia is recycled to reduce costs. **A** is incorrect as this is an endothermic process. **B** is incorrect as calcium chloride forms. **D** is incorrect as the calcium carbonate decomposes to form calcium oxide.

17 **B.** These molecules are alkanals and alkanones, which have different functional groups. **A** is incorrect as these molecules are chain isomers. **C** is incorrect as these are position isomers. **D** is incorrect as these molecules are not isomers because they have different molecular formulas.

18 **D.** The positive head group is present in cationic surfactants and these are used in hair conditioners. **A** is incorrect as the surfactant is cationic. **B** is incorrect are mainly produced from the petroleum by-products. **C** is incorrect as these cationic surfactants are strongly lathering.

19 **B.** The oxygen atoms in water are converted to oxygen gas. **A** is incorrect as chlorophyll absorbs red and violet light. **C** is incorrect as the Gibbs free energy change is positive and the reaction is not spontaneous. **D** is incorrect as oxygen is produced by water oxidation.

20 **A.** Sodium carbonate requires salt and limestone, which are closest at site Y. Sodium hydroxide production requires salt and large amounts of electricity, which are close to site W. Sulfuric acid uses sulfur dioxide as a feedstock and so site X is best as a sulfide mine is nearby. The sulfide can be roasted to generate the sulfur dioxide. Therefore **B**, **C** and **D** are incorrect.

Section II

21 **EM** Students need to recall the format of the equilibrium constant. In the calculation the student should show the substitution of values into the formula.

a $2HI(g) \rightleftarrows H_2(g) + I_2(g)$ ✓

b $K_{eq} = [H_2][I_2]/[HI]^2$ ✓

c $K_{eq} = \dfrac{(2.60 \times 10^{-3})(2.60 \times 10^{-3})}{(1.76 \times 10^{-2})^2}$

$= 0.0218$ ✓

The equilibrium lies to the left (reactants). ✓

d The equilibrium constant decreased as the temperature decreased. Therefore the reaction is endothermic in the forward direction. ✓

22 **EM** This question requires graphical interpretation as well as a deep understanding of titrations and mole calculations. Students need to recall the colours of indicators at different pH levels.

a $H_2SO_4(aq) + 2NH_3(aq) \rightarrow (NH_4)_2SO_4(aq)$ ✓

b ammonia solution ✓

c pH = 5.5 ✓

d $V = 10.0$ mL ✓

e $n(H_2SO_4) = cV = (0.00245)(0.0250) = 6.125 \times 10^{-5}$ mol ✓

Reaction stoichiometry = 1 : 2

$n(NH_3) = 2(6.125 \times 10^{-5}) = 1.225 \times 10^{-4}$ mol

$c(NH_3) = n/V = \left(\dfrac{1.225 \times 10^{-4}}{0.0100}\right) = 0.0123$ mol/L ✓

f methyl orange ✓

23 **EM** Students need to recall characteristic reactions of cation and anions and then write appropriate equations for the observed reactions.

The gas is acidic as the indicator turned pink. The gas is probably carbon dioxide because it forms carbonic acid when dissolved in water. Therefore X is a carbonate. ✓

Carbon dioxide reacts with barium hydroxide solution to form barium carbonate precipitate:

$Ba(OH)_2(aq) + CO_2(g) \rightarrow BaCO_3(s) + H_2O(l)$ ✓

The cation in the solution is lead (II) ions. Lead (II) ions form a yellow precipitate of PbI_2 when sodium iodide solution is added:

$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$ ✓

Lead (II) ions form a white precipitate of $PbSO_4$ when sulfuric acid is added:

$Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$ ✓

Lead (II) ions form a faint white precipitate of $PbCl_2$ when sodium chloride is added. $PbCl_2$ dissolves when the mixture is heated:

$Pb^{2+}(aq) + 2Cl^-(aq) \rightarrow PbCl_2(s)$ ✓

24 **EM** Students must demonstrate high level understanding of AAS and how dilution standards are prepared. Students need to demonstrate graphical skills to achieve full marks.

a The following steps are taken to prepare these standards:

1 Prepare a stock solution of higher concentration and dilute this stock solution systematically. ✓

2 A stock solution containing 2000 ppm (= 2000 mg Hg^{2+}/L = 2.000 g/L) of mercury (II) ions is prepared by weighing out 3.236 g of mercury (II) nitrate and dissolving it in distilled water. The solution made up to 1.00 L in a volumetric flask.

$(m = 2.000 \times \left(\dfrac{100}{61.80}\right) = 3.236$ g) ✓

3 To prepare the 20 ppm solution, use a 10 mL pipette to transfer 10.00 mL of the stock solution to a 1 L volumetric flask and add distilled water to the mark and mix. ✓

b The AAS needs to be calibrated so that absorbance measurements can be related to known mercury ion concentrations. Usually dilution levels are selected so that there is a linear relationship between absorbance and concentration. ✓

c i Figure AE2.1 shows the absorbance versus concentration graph for mercury ions.

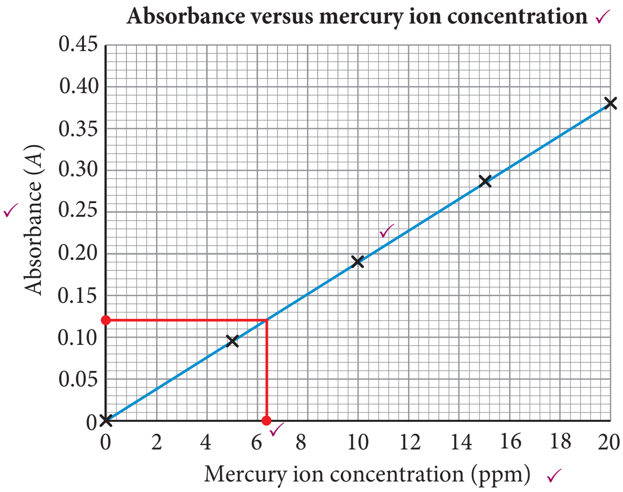

Figure AE2.1 Absorbance graph

ii $A = 0.120$

From the graph, $c(Hg^{2+}) = 6.2$ ppm

Original concentration of mercury $= 6.2 \times \left(\dfrac{10}{1}\right) = 62$ ppm ✓

25 **EM** Students need to use the calorimetry formula and show correct substitution and ensuring the correct units are used. The relationship between heat absorbed and the molar enthalpy change should be shown in the equation.

$q = mc\Delta T = (1.500)(4.18 \times 10^3)(23.68) = 148\,474$ J $= 148.474$ kJ ✓

$M(C_2H_5OH) = 2 \times 12.01 + 6 \times 1.008 + 16.00 = 46.068$ g/mol

$n(C_2H_5OH) = m/M = \dfrac{5.00}{46.068} = 0.1085$ mol ✓

$\Delta H = -q/n = \dfrac{-148.474}{0.1085} = -1368$ kJ/mol ✓

26 EM Students need to recall the K_a formula for a weak acid and relate p*Ka* to pH. Substitution of data should be shown into the equations to obtain full marks.

a $[H_3O^+] = 10^{-pH}$
$= 10^{-1.54} = 0.0288$ mol/L ✓
$= [SO_4^{2-}]$ ✓
$K_a = [H_3O^+][SO_4^{2-}]/[HSO_4^-]$
$= \frac{(0.0288)(0.0288)}{(0.100 - 0.0288)}$
$= 1.16 \times 10^{-2}$ ✓

b $NaHSO_4(aq) + KOH(aq) \rightarrow KNaSO_4(aq) + H_2O(l)$ ✓
$HSO_4^-(aq) + OH^-(aq) \rightarrow SO_4^{2-}(aq) + H_2O(l)$ ✓

27 EM Students need to determine the initial concentrations, change in concentrations and equilibrium concentrations prior to substitution into the equilibrium constant expression.

a $CO(g) + Cl_2(g) \leftrightarrows COCl_2(g)$ ✓

b The equilibrium will shift to the left to counteract the addition of heat. More CO and Cl_2 will form. ✓

c **i** $K_{eq} = [COCl_2]/[CO]\cdot[Cl_2]$ ✓

ii

Concentration	CO	Cl_2	$COCl_2$	
I: initial concentration (mol/L)	$\frac{1}{2} = 0.5$	$\frac{1}{2} = 0.5$	0	
C: change (mol/L)	−0.15	−0.15	$\frac{+30}{2} = 0.15$	✓
E: equilibrium concentration (mol/L)	0.35	0.35	0.15	✓

$K_{eq} = [COCl_2]/[CO][Cl_2] = \frac{(0.15)}{(0.35)(0.35)} = 1.2$ ✓

28 EM Students use the supplied information to explain an industrial synthesis reaction. Students need to demonstrate an understanding of rates of reaction in relation to surface areas as well as conditions that promote product formation.

a The serrated plates increase the surface area of contact between the gas and the solution. This surface area increase causes the rate of the reaction to increase. ✓

b $NH_3(g) + H_2O(l) + NaCl(aq) + CO_2(aq) \rightarrow NH_4Cl(aq) + NaHCO_3(s)$ ✓

c The low temperatures ✓ and high sodium ion concentration promote crystallisation of the sodium hydrogen carbonate. ✓

29 EM Students are required to use the graphical information and reaction stoichiometry to determine the moles of nitric acid and its concentration.

From graph: Volume (KOH) = 18.0 mL at equivalence point
$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$ ✓
$n(KOH) = cV = (0.100)(0.0180) = 0.001\ 80$ mol
Stoichiometry = 1 : 1
$n(HNO_3) = 0.001\ 80$ mol ✓
$c(HNO_3) = n/V = \frac{(0.001\ 80)}{(0.025\ 00)} = 0.0720$ mol/L ✓

30 EM Students must be able to relate the observations in each test to conclusions that can be made about the possible ions that would give a positive test. A final conclusion should be stated.

Copper (II) ions are present as test 4 gives a green flame characteristic of copper (II) ions. This observation is supported by test 7, which results in a pale-blue precipitate consistent with copper (II) hydroxide.
Chloride ions are present as test 3 produces a white precipitate of silver chloride. ✓
There are no carbonate ions as test 1 was negative.
There are no sulfate ions as test 2 is negative.
There are no silver or lead (II) ions as test 5 is negative. ✓
Calcium and/or barium ions are present as test 6 produces a white precipitate.
Test 8 is negative and this eliminates calcium ions. Therefore barium ions are present. ✓
Therefore copper (II) ions, barium ions and chloride ions are present. ✓

31 EM Students need to recall the general structure of an alkanoic acid and then use the molar mass data to determine the molecular formula. The physical properties of fatty acids and their neutralisation by a strong base need to be demonstrated.

a Alkanoic acid = $CH_3(CH_2)_nCOOH$. (n = integer)
Molar mass = $(n + 2)(12.01) + (2n + 4)(1.008) + 2(16.00) = 200$ ✓
Solve for n.
$n = 10$
Condensed structural formula = $CH_3(CH_2)_{10}COOH$ ✓

b The long hydrocarbon tail is non-polar and has little affinity with the polar water solvent. The polar carboxyl head's interaction with water is insufficient to assist dissolution of the solid in water. ✓

c $CH_3(CH_2)_{10}COOH(s) + KOH(aq) \rightarrow KCH_3(CH_2)_{10}COO(aq) + H_2O(l)$ ✓

32 EM Students need to show they understand that sea water is not just a solution of sodium chloride. They need to show that they can convert concentrations in mol/L units to ppm units.

a The assumption is invalid. ✓ Seawater contains other anions such as bromide and sulfate ions that can be precipitated by silver ions. ✓

b $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
$m(AgCl) = 7.56$ g
$n(AgCl) = m/M = \frac{7.56}{(107.9 + 35.45)} = 0.0527$ mol ✓
$n(Cl^-) = 0.0527$ mol
$m(Cl^-) = n.M = (0.0527)(35.45) = 1.87$ g = 1870 mg
$c(Cl^-) = 1870$ mg/0.100 L = 18700 ppm ✓

33 EM Students should demonstrate that they can draw structural formula given the name of a molecule. They also need to demonstrate knowledge of condensation polymerisation in order to draw the repeating structure of a polymer.

a Figure AE2.2 shows the structural formula of 6-aminohexanoic acid.

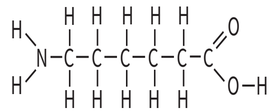
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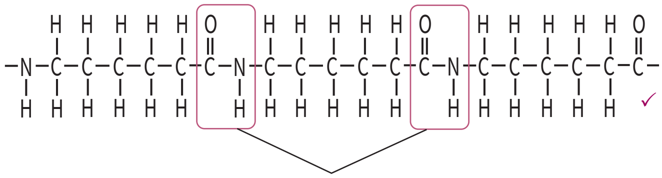
Figure AE2.2

b Figure AE2.3 shows a section of the polymer chain with monomers linked via amide functional groups.


✓

amide linkage

Figure AE2.3

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34 EM Students need to use the reaction stoichiometry to perform the mole calculation and be able to convert concentration data to ppm units. Students then need to use the tabulated data to determine the temperature of the water sample.

a $O_2(aq) + 4S_2O_3^{2-}(aq) + 4H^+(aq) \rightarrow 2H_2O(l) + 2S_4O_6^{2-}(aq)$

$O_2 : S_2O_3^{2-}$ stoichiometry = 1 : 4

$n(S_2O_3^{2-}) = cV = (0.0100)(0.01235) = 1.235 \times 10^{-4}$ mol ✓

$n(O_2) = \frac{1}{4} \times 1.235 \times 10^{-3} = 3.089 \times 10^{-5}$ mol ✓

$m(O_2) = n.M = (3.089 \times 10^{-5})(32.00) = 9.885 \times 10^{-4}$ g = 0.989 mg

$c(O_2) = m/V = \frac{0.989 \text{ mg}}{0.100 \text{ L}} = 9.89$ ppm ✓

b Temperature = 15 °C ✓

35 EM Recall of indicator colours in acidic and basic solutions is required. The student needs to relate pH to the hydrogen ion concentration.

a **i** red ✓ **ii** blue ✓

b The indicator changes from blue to green ✓then to green-yellow ✓ and then yellow ✓in the last drop of acid as neutralisation is just achieved. (Note: The indicator will stay yellow if excess acid is added.)

c Bromothymol blue is green in the pH range 6.0–7.6 ($[H^+] = 10^{-6} - 10^{-7.6}$ mol/L). Thymol blue would be yellow in this pH range. ✓

36 EM Students need to write an appropriate solubility equation and using the supplied data to determine the solubility product constant. Significant figures need to be considered.

Calculate the molar mass of lead (II) carbonate.

$M(PbCO_3) = 207.2 + 12.01 + (3 \times 16.00) = 267.21$ g/mol

$n(PbCO_3) = m/M = \frac{(7.27 \times 10^{-6})}{267.21} = 2.72 \times 10^{-8}$ mol ✓

Write the equation for the dissolution equilibrium:

$PbCO_3(s) \leftrightharpoons Pb^{2+}(aq + CO_3^{2-}(aq)$

Reaction stoichiometry: $Pb^{2+} : CO_3^{2-} = 1 : 1$

$n(Pb^{2+}) = n(CO_3^{2-}) = 2.72 \times 10^{-8}$ mol

100 g water = 100 mL = 0.100 L

Calculate the ion concentrations at equilibrium.

$[Pb^{2+}] = [CO_3^{2-}] = \frac{2.72 \times 10^{-8}}{0.100} = 2.72 \times 10^{-7}$mol/L ✓

Calculate K_{sp}.

$K_{sp} = [Pb^{2+}]\cdot[CO_3^{2-}] = (2.72 \times 10^{-7})^2 = 7.40 \times 10^{-14}$ ✓

37 EM Students need to understand the composition of a buffer and how buffering occurs when small amounts of strong acids and bases are added to the buffer solution.

a $NH_3(aq) + H_2O(l) \leftrightharpoons NH_4^+(aq) + OH^-(aq)$ ✓

b The ammonium ion is a Brønsted–Lowry acid and it reacts with hydroxide ions. The equilibrium shifts to the left ✓ and the pH decreases as the hydroxide ion concentration decreases. ✓

c The mixture contains a Brønsted–Lowry base (NH_3) and its conjugate acid (NH_4^+). ✓ As the solution is equimolar in the base and its conjugate acid, then the solution acts as a buffer because the addition of small quantities of a strong acid or a strong base leads to a very small pH change. The strong acid will be neutralised by NH_3 and the strong base will be neutralised by NH_4^+. ✓