Government of **Western Australia**
**School Curriculum and Standards Authority**

# CHEMISTRY

# ATAR course examination 2017

# Marking Key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

**Section One: Multiple-choice** **25% (25 Marks)**

| Question No. | Answer |
|---|---|
| 1 | D |
| 2 | B |
| 3 | B |
| 4 | C |
| 5 | A |
| 6 | A |
| 7 | D |
| 8 | D |
| 9 | C |
| 10 | A |
| 11 | D |
| 12 | B |
| 13 | C |
| 14 | C |
| 15 | B |
| 16 | B |
| 17 | A |
| 18 | B |
| 19 | A |
| 20 | D |
| 21 | C |
| 22 | D |
| 23 | C |
| 24 | A |
| 25 | D |

**Section Two: Short answer** **35% (85 Marks)**

**General Notes:**

- Answers provided in brackets are desired but not essential for the relevant mark to be allocated.
- Clear and unambiguous demonstration of the candidate's understanding in their response is required rather than the exact wording in the marking key.
- Notes provided within the marking key will indicate which elements of the model answers are required for the allocated mark.

**Question 26** **(13 marks)**

(a) (i) List **three** changes that would be observed. (3 marks)

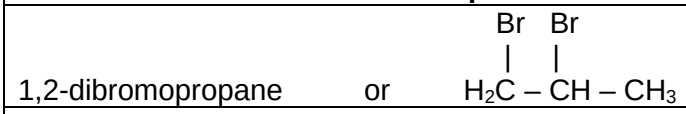
| Description | Marks |
|---|---|
| Up to three observations for one mark each | |
| Answers could include:<br>• sodium/silver solid floats to the top of the water and moves vigorously across its surface or violent/vigorous reaction<br>• sodium/silvery metal (completely) reacts<br>• bubbling, fizzing, or effervescence (evidence of a (colourless, odourless) gas evolved)<br>• pink colouration appears in the liquid<br>• reaction vessel becomes warmer or heat evolved.<br>• (orange) flame produced. | 1–3 |
| **Total** | **3** |

(ii) Write the ionic equation for any reaction involving both sodium and water. Include **all** state symbols. (3 marks)

| Description | Marks |
|---|---|
| $2\ Na(s) + 2\ H_2O(\ell) \rightarrow 2\ Na^+(aq) + 2\ OH^-(aq) + H_2(g)$ | 2 |
| Equation with one minor error | 1 |
| | |
| All state symbols provided and correct | 1 |
| **Total** | **3** |
| Note: If not ionic - maximum two marks.<br>Not simplest whole number ratio - maximum two marks.<br>If equation has some merit and correct state symbols for equation, zero for equation, one mark for state symbols. | |

**Question 26** (continued)

(b) (i) Identify, by name or formula, any new substance/s produced. (1 mark)

| Description | Marks |
|---|---|
| 1,2-dibromopropane or  | 1 |
| **Total** | **1** |

(ii) Write descriptions of the substances **before** and **after** mixing. (2 marks)

| Description | Marks |
|---|---|
| Before: Colourless gas and orange liquid (need both for the mark) | 1 |
| After: Colourless liquid/solution (two layers) | 1 |
| **Total** | **2** |
| Note: The colourless gas **completely** decolourises the orange liquid.<br>Also accept correct descriptions of the molecular structures and bonding of the substances. E.g. Hydrocarbon with a double bond, diatomic molecule dissolved in colourless liquid; alkene and halogen solution to give alkyl halide – need both before and after for two marks. | |

(c) (i) Identify, by name or formula, any new substance/s produced. (1 mark)

| Description | Marks |
|---|---|
| iron(II) ions or $Fe^{2+}(aq)$ **and** lead (II) ions or $Pb^{2+}(aq)$ | 1 |
| **Total** | **1** |

(ii) List **all** observations that would be made for any reaction, describing clearly the substances before and on completion of any reaction. (3 marks)

| Description | Marks |
|---|---|
| Before: pale brown liquid/solution **and** grey metal/solid | 1 |
| Indication that solid has lost mass e.g. reacts, becomes thinner | 1 |
| Solution turns pale green | 1 |
| **Total** | **3** |
| Note:<br>From the description it should be assumed that the lead is in excess and all of the $Fe^{3+}$ ions are converted to $Fe^{2+}$ so there is full colour change. | |

**Question 27** **(6 marks)**

Balance the following redox equation by determining and then combining the oxidation and reduction half-equations. State symbols are **not** required.

$$SCN^- + IO_3^- + C\ell^- \rightarrow SO_4^{2-} + HCN + IC\ell$$

| Description | Marks |
|---|---|
| Oxidation half-equation<br><br>$SCN^- + 4\ H_2O \rightarrow SO_4^{2-} + HCN + 7\ H^+ + 6\ e^-$<br><br>(One error eg incorrect balancing, incorrect formula) | 2<br><br>(1) |
| Reduction half-equation<br><br>$4\ e^- + IO_3^- + 6\ H^+ + C\ell^- \rightarrow IC\ell + 3\ H_2O$<br><br>(One error eg incorrect balancing, incorrect formula) | 2<br><br>(1) |
| Overall equation<br>*Working – not required*<br>*$(SCN^- + 4\ H_2O \rightarrow SO_4^{2-} + HCN + 7\ H^+ + 6\ e^-)$ x 2*<br>*$(4\ e^- + IO_3^- + 6\ H^+ + C\ell^- \rightarrow IC\ell + 3\ H_2O)$ x 3*<br><br>$2\ SCN^- + 3\ IO_3^- + 4H^+ + 3\ C\ell^- \rightarrow 2\ SO_4^{2-} + 2\ HCN + 3\ IC\ell + H_2O$<br><br>(One error eg incorrect balancing, incorrect formula, not simplest whole number ratio)<br><br>If half equations are both incorrect and have some merit, but half equations multiplied correctly for number of electrons present – maximum one mark. | 2<br><br>(1) |
| **Total** | **6** |
| Note: Oxidation and reduction half equations in wrong boxes – maximum of five marks | |

**Question 28** **(10 marks)**

(a) Predict how
- the forward reaction rate and
- the pH

will differ from their original values after the following changes are imposed on the system and equilibrium has been re-established. Use the terms **increase**, **decrease**, **no change**. (6 marks)

| **Description** | | | **Marks** |
|---|---|---|---|
| **Change imposed by the addition of** | **Effect on forward reaction rate when equilibrium is re-established** | **Effect on pH when equilibrium is re-established** | |
| a few drops of concentrated hydrochloric acid | Increase | Decrease | 1–2 |
| a few drops of concentrated lead(II) nitrate solution | Decrease | Decrease | 1–2 |
| distilled water | Decrease | Increase | 1–2 |
| | | **Total** | **6** |
| Note:<br>No marks awarded for up, down or horizontal lines or arrows. | | | |

(b) The reaction in part (a) is endothermic in the forward direction as written. Predict what will happen to the pH when the temperature is increased. Justify this prediction. (4 marks)

| **Description** | **Marks** |
|---|---|
| Prediction : Decrease in pH | 1 |
| Justification: According to Le Chatelier's Principle,<br>• an increase in temperature will favour the endothermic direction.<br>• the forward reaction is the endothermic reaction, therefore there will be an increase in products, $HSO_4^-(aq)$ and $H_3O^+(aq)$<br>• (as the relationship between $[H_3O^+](aq)$and pH is inverse), the increase in $[H_3O^+]$ will result in decrease in pH. | <br>1<br>1<br>1 |
| **Total** | **4** |
| Note: Reference to concentration required **or** maximum three marks<br>Justification: Rates<br>(Recognition that there is an increase in the proportion of successful collisions due to more particles have the activation energy)<br>Recognition that both forward and reverse reaction rates increase, (1)<br>but forward increases more (1)<br>Therefore, the increase in $[H_3O^+]$ will result in decrease in pH (1) | |

**Question 29** **(10 marks)**

(a) Identify the limiting reagent in this reaction. Show **all** workings. (5 marks)

| Description | Marks |
|---|---|
| $n(H^+)$ = 2 x 0.012 x 0.0334<br>= $8.016 \times 10^{-4}$ mol | 1 |
| $n(OH^-)$ = 0.03250 x 0.0288<br>= $9.36 \times 10^{-4}$ mol | 1 |
| $H^+ + OH^- \rightarrow H_2O$ or $H_3O^+ + OH^- \rightarrow 2H_2O$<br>Or some evidence of the stoichiometric ratio | 1 |
| As the stoichiometric ratio between $H^+(aq) + OH^-(aq)$ is 1:1, the species with the smaller number of moles will be the limiting reagent.<br>**Some justifying statement is required** | 1 |
| Therefore, $H^+$ or $H_2SO_4$ is LR | 1 |
| **Total** | **5** |

Note: Accept KOH is in excess

| Description | Marks |
|---|---|
| $n(H_2SO_4)$ = 0.012 x 0.0334 = $4.008 \times 10^{-4}$ mol | 1 |
| n(KOH) = 0.03250 x 0.0288 = $9.36 \times 10^{-4}$ mol | 1 |
| $n(H_2SO_4)$ = 2 x n NaOH (aq) | 1 |
| $4.008 \times 10^{-4}$ mol $H_2SO_4$ requires 2 x $4.008 \times 10^{-4}$ = $8.016 \times 10^{-4}$ mol KOH<br>There is more KOH than required ($9.36 \times 10^{-4}$ mol); KOH is in excess | 1 |
| Therefore, $H^+$ or $H_2SO_4$ is LR | 1 |
| **Total** | **5** |

(b) Calculate the final concentration of the excess reagent. Show **all** workings. (3 marks)

| Description | Marks |
|---|---|
| $n(OH^-$ remaining) = $n(OH^-$ initial) – $n(OH^-$ reacted)<br>= $9.36 \times 10^{-4} - 8.016 \times 10^{-4}$<br>= $1.344 \times 10^{-4}$ mol | 1 |
| Total volume = 0.012 + 0.0325<br>= 0.0445 L | 1 |
| $[OH^-]$ = $1.344 \times 10^{-4}$ /(0.0445)<br>= $3.02 \times 10^{-3}$ mol $L^{-1}$ | 1 |
| **Total** | **3** |

(c) Calculate the pH of the final solution. Show **all** workings. (2 marks)

| Description | Marks |
|---|---|
| $[H^+]$ = $1 \times 10^{-14}/3.02 \times 10^{-3}$<br>= $3.31 \times 10^{-12}$ | 1 |
| pH = - log $3.31 \times 10^{-12}$<br>= 11.480 | 1 |
| **Total** | **2** |
| Note:<br>Also accept pH = 14 – pOH<br>= 14 – 2.520 | |

**Question 30** **(8 marks)**

(a) For this industrial process state the conditions that would optimise the: (2 marks)
rate of reaction
yield

| Description | Marks |
|---|---|
| Rate: high temperature, high pressure, catalyst<br>Note: At least two conditions must be given | 1 |
| Yield: low temperature, high pressure/maintain high concentration of reactants; removal of products<br>Note: At least two conditions must be given | 1 |
| **Total** | **2** |
| Note: If one incorrect condition - no marks. | |

(b) State **one** compromise in conditions that might be required to produce carbonyl chloride, $COC\ell_2$, in an industrial process. Explain the effect of this condition on the rate and yield and justify why this compromise is required. (6 marks)

| Description | Marks |
|---|---|
| One condition requiring a compromise is the temperature at which the process occurs. | 1 |
| A high temperature is required to maximise the rate of reaction because a greater proportion of particles will:<br>• be moving faster and so collide more frequently and<br>• have sufficient energy (greater than the activation energy, Ea) resulting in a greater proportion of successful collisions. | 1–2 |
| A low temperature is required (to maximise the yield of $COC\ell_2$) because:<br>• the reaction is exothermic in the forward direction, lowering the temperature favours the forward reaction<br>• products are formed at a higher rate than reactants are formed. | 1–2 |
| Higher temperatures favour a higher rate but with a reduced yield while lower temperatures favour a higher yield but at a reduced rate. (A compromise of a moderate temperature is required to produce reasonable yield at a reasonable rate.) | 1 |
| **Total** | **6** |

**Question 31** **(8 marks)**

(a) Write an equation for the self-ionisation of water. (2 marks)

| Description | Marks |
|---|---|
| $2\ H_2O(\ell) \leftrightharpoons H_3O^+(aq) + OH^-(aq)$ **or** $H_2O(\ell) \leftrightharpoons H^+(aq) + OH^-(aq)$<br>Correct equation with double arrow | 1–2 |
| $2\ H_2O(\ell) \rightarrow H_3O^+(aq) + OH^-(aq)$ **or** $H_2O(\ell) \rightarrow H^+(aq) + OH^-(aq)$<br>Correct equation with single arrow | (1) |
| **Total** | **2** |

(b) Write the equilibrium constant expression for the self-ionisation of water. (1 mark)

| Description | Marks |
|---|---|
| $K = [H_3O^+][OH^-]$ **or** $K = [H^+][OH^-]$ | 1 |
| **Total** | **1** |

(c) The equilibrium constant for the self-ionisation of water $K_w$ is $1.00 \times 10^{-14}$ at 25 °C. What does this value indicate about this reaction? (1 mark)

| Description | Marks |
|---|---|
| Answers could include:<br>• only a very small proportion of products are present at equilibrium<br>• the system is found predominantly in the form of molecular water.<br><br>Accept other relevant answers | 1 |
| **Total** | **1** |

(d) Calculate the pH of water at 50 °C. (2 marks)

| Description | Marks |
|---|---|
| K @ 50 °C = $5.48 \times 10^{-14}$<br>In pure water $[H^+] = [OH^-]$<br>Therefore $[H^+] = \downarrow 5.48 \times 10^{-14}$<br>$= 2.34 \times 10^{-7}$ | 1 |
| pH $= -\log 2.34 \times 10^{-7}$<br>$= 6.63$ | 1 |
| **Total** | **2** |

(e) Is water acidic, basic or neutral at 50 °C? State a reason for your answer. (2 marks)

| Description | Marks |
|---|---|
| Water is neutral at 50 °C | 1 |
| Regardless of the temperature in pure water $[H^+] = [OH^-]$,<br>(Therefore there is no excess of either $H^+$ or $OH^-$) | 1 |
| **Total** | **2** |

**Question 32** **(9 marks)**

(a) By referring to any intermolecular forces present, describe the dissolving process as ethanol is added to water. (3 marks)

| Description | Marks |
|---|---|
| H bonds,(dipole-dipole) and dispersion forces between water molecules are disrupted | 1 |
| H bonds, dipole-dipole and dispersion forces between ethanol are disrupted | 1 |
| New H bonds, dipole-dipole and dispersion forces are formed between ethanol and water molecules<br>Note: any discussion including energy or strength of bonds acceptable but not required for full marks | 1 |
| **Total** | **3** |
| Note: For full marks evidence of disruption of existing forces and formation of new forces must be demonstrated.<br><br>Alternative response<br>Disruption of pre-existing hydrogen bonds between water molecules and between ethanol molecules and formation of new hydrogen bonds between water and ethanol molecules – one mark<br>Similar statement for dipole-dipole forces – one mark<br>Similar statement for dispersion forces – one mark | |

(b) Explain what happens to the solubility of alcohols in water as the hydrocarbon chain length increases. (3 marks)

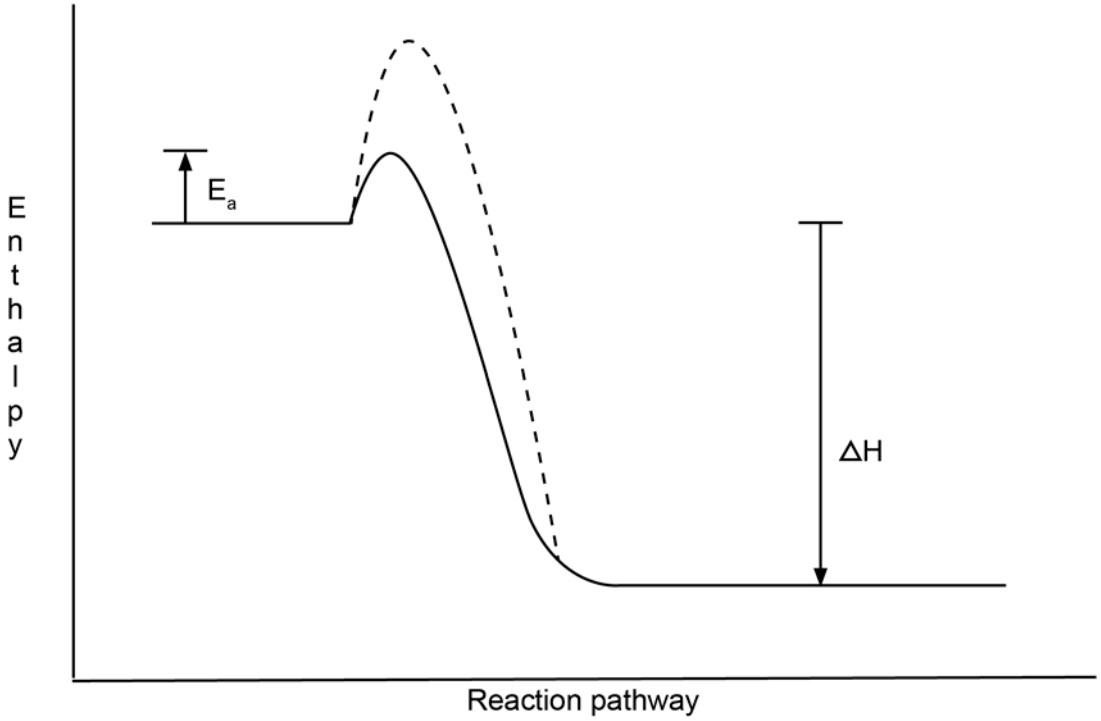
| Description | Marks |
|---|---|
| The solubility of alcohol in water decreases as the hydrocarbon chain length increases | 1 |
| The longer the chain length of an alcohol, the greater the strength of the dispersion forces between the molecules | 1 |
| The difference between the energy released in the formation of new forces of attraction and the energy required to overcome the existing forces of attraction increases | 1 |
| **Total** | **3** |

(c) For each of the following substances, list **all** attractive force/s formed between the solute and solvent when each substance dissolves in water. (3 marks)

| Description | | Marks |
|---|---|---|
| Propanal | H Bonding, dispersion forces, dipole-dipole forces | 1 |
| Methanoic acid | H Bonding, , dipole-dipole, dispersion forces, (ion-dipole) | 1 |
| Sodium chloride | ion-dipole forces, dispersion forces | 1 |
| | **Total** | **3** |
| Note:<br>All forces of attraction must be stated for the mark to be awarded. | | |

**Question 33** **(9 marks)**

(a) An explosion is a 'very fast and very exothermic reaction'. Use a solid line (——) to draw, and then label, an energy profile diagram reflecting an explosive reaction. (3 marks)




| Description | Marks |
|---|---|
| Enthalpy (H) of product lower than that of reactant | 1 |
| Large difference in enthalpy of reactants and products | 1 |
| Small activation energy<br>Note:<br>$E_a$ should be significantly smaller than the difference in Heat of Reaction.<br>Labels are not required for full marks. | 1 |
| **Total** | **3** |

(b) An inhibitor is a substance that decreases the rate of, or prevents, a chemical reaction. On the diagram in part (a) above, indicate by way of a dashed line ( - - - ) any change/s that would be evident if an inhibitor were to be introduced. (2 marks)

| Description | Marks |
|---|---|
| Higher activation energy | 1 |
| No change in enthalpy of reactants and products | 1 |
| **Total** | **2** |

**Question 33** (continued)

(c) The energy density of dynamite is 5.0 MJ $kg^{-1}$ and the energy density of TNT is 4.0 MJ $kg^{-1}$. Show by calculation and by reasoning which of these two explosives produces more energy per mole of the **active** ingredient. (4 marks)

| Description | Marks |
|---|---|
| M $C_3H_5N_3O_9$ (in Dynamite) = 227.10 g $mol^{-1}$<br>M $C_6H_2(NO_2)_3CH_3$ (TNT) = 227.14 g $mol^{-1}$<br>The molar masses of both are essentially identical.<br>The ratio of energy density of dynamite to TNT = 5.0/4.0 = 1.25 the energy density of TNT | |
| Reasoning to include:<br>• As dynamite is at most 50% nitroglycerine, $C_3H_5N_3O_9$, the energy output of the active ingredient in dynamite (nitroglyerine) ≥ twice 5.0 MJ $kg^{-1}$<br>• As TNT is essentially 100% trinitrotoluene, the energy output of the active ingredient in TNT = 4.0 MJ $kg^{-1}$.<br>• The ratio of energy density of the active ingredients dynamite to TNT ≥ 10.0/4.0 = 2.5 the energy density of TNT | 1<br>1<br>1 |
| Nitroglycerine, $C_3H_5N_3O_9$ in dynamite produces more energy per mol than the energy produced per mol of trinitrotoluene, $C_6H_2(NO_2)_3CH_3$ | 1 |
| **Total** | **4** |
| Note:<br>Dynamite given with no working – no marks.<br>If 50% not considered explicitly in response, then maximum of three marks. | |

Alternative answer

| | |
|---|---|
| Dynamite<br>50% active, therefore 500 g/kg is active<br>Therefore: n(active ingredient) = 500/227.10<br>= 2.2015 mol<br>So energy released per mol = 5.0 / 2.2015<br>= 2.3 MJ $mol^{-1}$ | 1–2 |
| TNT<br>100% active ingredient, therefore 1000 g/kg active<br>Therefore n(active ingredient) = 1000/227.14<br>= 4.4.026<br>Energy released per mol = 4/4.4026<br>= 0.91 MJ $mol^{-1}$ | 1 |
| Nitroglycerine, $C_3H_5N_3O_9$ in dynamite produces more energy per mol than the energy produced per mol of trinitrotoluene, $C_6H_2(NO_2)_3CH_3$ | 1 |
| Total | **4** |

**Question 34** **(7 marks)**

(a) Write a chemical equation to show the reaction at the anode of the cell. (1 mark)

| Description | Marks |
|---|---|
| $M \rightarrow M^{2+} + 2e^-$ | 1 |
| **Total** | **1** |

(b) List **two** observations that would be expected in the $Cu/Cu^{2+}$ cell. (2 marks)

| Description | Marks |
|---|---|
| The copper electrode will grow in size/have (salmon pink) solid form on it and | 1 |
| the solution will decolourise/fade to a less intense blue. **(must give colour of solution)** | 1 |
| **Total** | **2** |

(c) (i) To the appropriate degree of accuracy, what is the reading on the voltmeter? (1 mark)

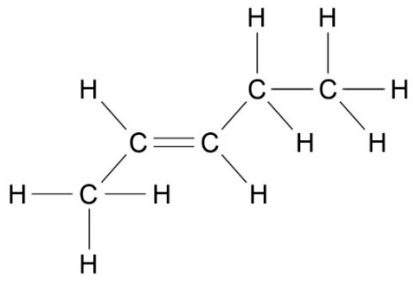
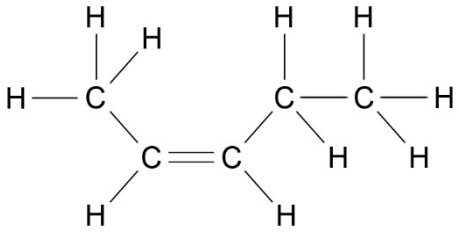
| Description | Marks |
|---|---|
| The voltmeter reads approximately 1.09 V.<br>(accept 1.08 – 1.10 V)<br>Must be to 2 decimal places. | 1 |
| **Total** | **1** |

(ii) Using the voltmeter reading and other relevant information, predict the identity of the unknown metal. Clear reasoning, including a calculation, **must** be provided. (3 marks)

| Description | Marks |
|---|---|
| As copper is +0.34 V<br>The emf for the other metal must be<br>1.10, 1.09 or 1.08 – 0.34 = 0.76 V or 0.75 V or 0.74 V. | 1 |
| Provide additional reasoning to support choice<br>E.g.<br>Looking at the standard reduction potentials table, (allowing for experimental error) the possible metal choices are<br>$Cr \rightarrow Cr^{3+} + 3e^-$ at 0.74V<br>$Zn \rightarrow Zn^{2+} + 2e^-$ at 0.76 V<br>**or**<br>Unknown metal produces a colourless and/or +2 ion. | 1 |
| Therefore Zn is the unknown metal | 1 |
| **Total** | **3** |

**Question 35** **(5 marks)**

(a) Draw **one** isomer for $C_5H_{10}$ that satisfies each of the following types. For each isomer, show **all** atoms and **all** bonds. (2 marks)

| Description | Diagram | Marks |
|---|---|---|
| Trans isomer |  | 1 |
| Cis isomer |  | 1 |
| | **Total** | **2** |
| Note:<br>Must show all bonds around the double bond, some condensed $CH_3$ etc acceptable.<br>If a minor error is made with structure formula (eg omission of a H atom) but answer clearly differentiates between cis and trans isomer – one mark. | | |

(b) In the table below suggest a distinguishing test by stating the reagent/s used and the observations expected for any reaction with each isomer. (3 marks)

| Description | Marks |
|---|---|
| Reagent:<br>Addition of bromine water, $Br_2(aq)$ **or** other reasonable test | 1 |
| Observations:<br>• cis/trans chain isomer – orange solution fades to colourless (rapidly)<br>• cyclic isomer – orange solution remains orange (accept colour fades very slowly).<br>Note: Also accept orange colour turns more red and moves into organic layer. | 1<br>1 |
| **Total** | **3** |
| Note: If test has merit and observations correct, maximum two marks. | |

**Section Three: Extended answer** **40% (100 Marks)**

For all calculations, there may be other valid methods for obtaining the correct answer. Accept all methods that have clear and logical reasoning.

**Question 36** **(19 marks)**

(a) What mass of ore would be required to produce 6.00 tonnes of antimony, assuming the ore contains 25.6% by mass of antimony(III) sulfide and the reactions go to completion?(6 marks)

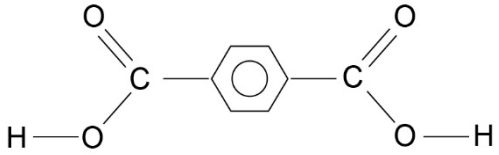
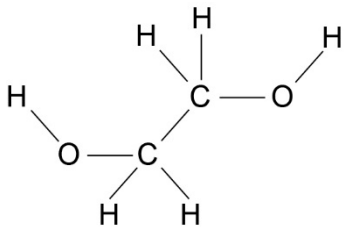
| Description | Marks |
|---|---|
| $M(Sb_2S_3)$ = 339.81 g $mol^{-1}$ | 1 |
| n(Sb) = $6.00 \times 10^6/121.8$<br>= $4.93 \times 10^4$ mol | 1 |
| $n(Sb_2S_3)$ = ½ n(Sb)<br>= $2.46 \times 10^4$ mol | 1 |
| $m(Sb_2S_3)$ = $2.46 \times 10^4$ (339.81)<br>= $8.37 \times 10^6$ g | 1 |
| m(ore) = $100/25.6 \times 8.37 \times 10^6$ | 1 |
| = $3.27 \times 10^7$ g (or 32.7 tonne) | 1 |
| **Total** | **6** |

(b) Calculate the maximum volume of sulfur dioxide that could be produced in Reaction one at 525.0 $^oC$ and 105 kPa. Give the answer to the correct number of significant figures. (4 marks)

| Description | Marks |
|---|---|
| $n(SO_2)$ = 3/2 n(Sb)<br>= 3/2 ($4.93 \times 10^4$)<br>= $7.39 \times 10^4$ mol | 1 |
| $V(SO_2)$ = nRT/P<br>= $7.39 \times 10^4(8.314)(273.15+525)/105$ | 1 |
| = 4672634.1 L | 1 |
| = $4.67 \times 10^6$ L (mark for 3 sig figs) | 1 |
| **Total** | **4** |

**Question 36** (continued)

(c) Draw the monomers required to produce this polymer. (4 marks)

| Description | Marks |
|---|---|
| 1,4-benzenedioic acid (benzene-1,4-dicarboxylic acid or terephthalic acid) | |
|  <br>Name not required | 2 |
| Clearly indicates that it is di-carboxylic acid but the structure contains a minor error | 1 |
| | |
| 1,2-ethandiol (ethane-1,2-diol, (ethylene glycol)) | |
|  <br>Name not required | 2 |
| Clearly indicates that it is a di-ol but the structure contains a minor error | 1 |
| **Total** | **4** |

Note:
- Condensed structures are acceptable as long as the functional groups are clearly and unambiguously indicated.
- For this course, being an ester, PET it is considered to be made from an acid, 1,4-benzenedioic acid and an alcohol,1,2-ethandiol.

(d) State **one** common use for PET and state **two** properties that enable it to be used for this purpose. (3 marks)

| Description | Marks |
|---|---|
| One mark for use | |
| Answers could include:<br>• capacitators, graphics, film base and recording tapes<br>• fibres for a very wide range of textile fibres<br>• bottles (water bottles)<br>• food packaging<br>• electrical components<br>• magnetic tape<br>• backing for adhesive tape<br>• sail cloth.<br><br>Accept other relevant answers | 1 |
| **One mark for each property relevant to the use** | |
| Answers could include:<br>• can be produced with varying degrees to crystallisation providing a range of rigidity absorbs very little water<br>• good gas barrier<br>• excellent moisture barrier<br>• chemically resistant to acids, oils, alcohol (but not to alkalis)<br>• highly transparent and colourless<br>• high mechanical strength<br>• low density<br>• impact resistant.<br><br>Accept other relevant answers | 1–2 |
| **Total** | **3** |

(e) Distinguish between the types of monomers used for each type of polymerisation. (2 marks)

| Description | Marks |
|---|---|
| Monomer/s of condensation polymers contain two reactive functional groups (that link with each other) | 1 |
| Monomer/s of addition polymers contain a carbon-carbon double bond/alkene (which can 'open' to allow the bonding to another atom) | 1 |
| **Total** | **2** |

**Question 37** **(24 marks)**

(a) Write an equation for the reaction between carbon dioxide gas and lithium hydroxide to form lithium carbonate and water. (2 marks)

| Description | Marks |
|---|---|
| $2\ LiOH(s) + CO_2(g) \rightarrow Li_2CO_3(s) + H_2O(g)$ | 2 |
| Equation with one minor error | 1 |
| **Total** | **2** |

(b) A typical lithium hydroxide canister contains 750.0 g of lithium hydroxide. What mass of carbon dioxide would be required to react completely with the lithium hydroxide in each canister? (3 marks)

| Description | Marks |
|---|---|
| $n(LiOH) = 750.0/23.976$<br>$= 31.28$ mol | 1 |
| $n(CO_2) = 0.5 \times n(LiOH)$<br>$= 15.64$ mol | 1 |
| $m(CO_2) = 44.01 \times 15.64$<br>$= 6.883 \times 10^2$ g | 1 |
| **Total** | **3** |

The following results were obtained from the titrations.

| **Volume (mL)** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **Final Volume** | 18.55 | 34.90 | 18.50 | 34.85 |
| **Initial Volume** | 1.50 | 18.55 | 2.20 | 18.50 |
| **Titre** | 17.05 | 16.35 | 16.30 | 16.35 |

(c) Complete the results table above and calculate the percentage of lithium hydroxide remaining in the canister (6 marks)

| Description | Marks |
|---|---|
| Correctly completing the table above | 1 |
| Average $= (16.35 + 16.30 + 16.35) / 3$<br>$= 16.33$ mL | 1 |
| $n(HCl) = 0.01633 \times 0.116$<br>$= 1.89 \times 10^{-3}$ mol<br>= n(LiOH) in 20.00 mL | 1 |
| n(LiOH) in 500.0 mL $= 1.89 \times 10^{-3}(500.0/20.00)$<br>$= 4.74 \times 10^{-2}$ mol | 1 |
| $m(LiOH) = 4.74 \times 10^{-2}\ (23.976)$<br>$= 1.136$ g | 1 |
| % LiOH $= 1.136/12.33 \times 100$<br>$= 9.21$ % | 1 |
| **Total** | **6** |

(d) From the list of indicators given below, identify **two** that could be used in the titration between lithium hydroxide and hydrochloric acid. Explain why both indicators are appropriate choices for this titration. (4 marks)

| Indicator | Low pH colour | Transition pH range | High pH colour |
|---|---|---|---|
| Methyl violet | yellow | 0.0 – 1.6 | blue |
| Bromothymol blue | yellow | 6.0 – 7.6 | blue |
| Phenolphthalein | colourless | 8.3 – 10.0 | pink |
| Thymolphthalein | colourless | 9.4 – 10.6 | blue |

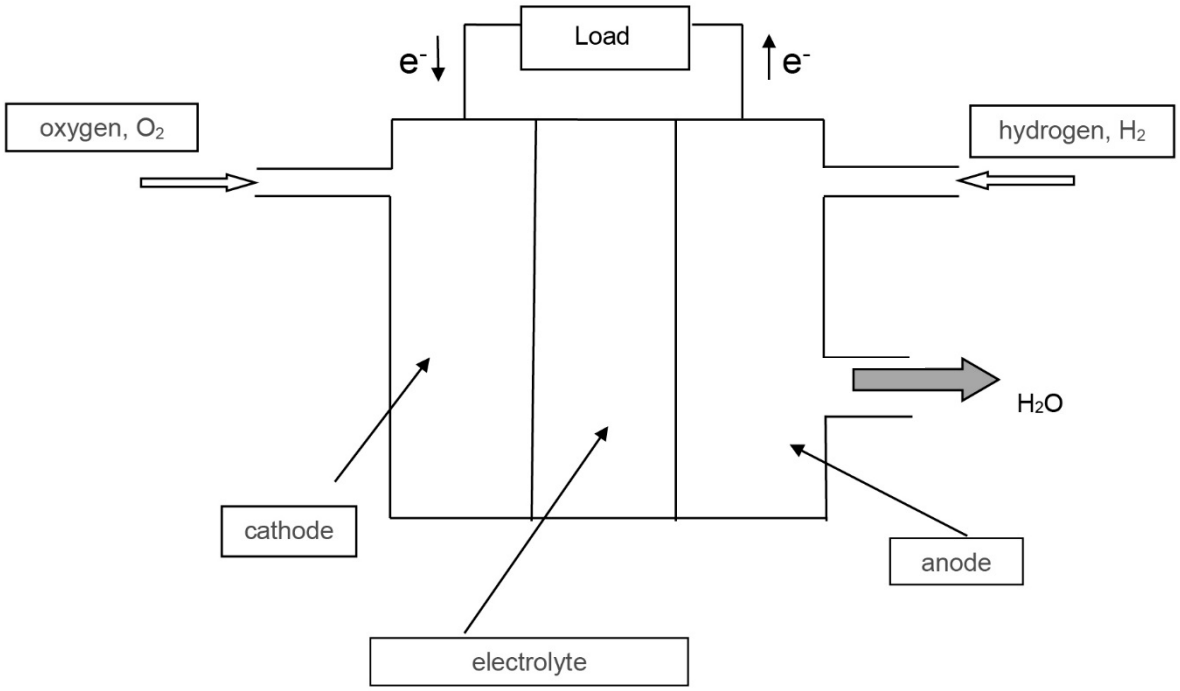
| Description | Marks |
|---|---|
| One mark for each indicator | |
| Bromothymol blue | 1 |
| Phenolphthalein | 1 |
| Two marks for explanation | |
| Equivalence point for this titration occurs at pH = 7 (strong acid + strong base produces neutral salt) | 1 |
| These indicators will change colour/end point at or near pH = 7 | 1 |
| **Total** | **4** |

(e) List **two** advantages that fuel cells have over primary and secondary cells. (2 marks)

| Description | Marks |
|---|---|
| One mark for each advantage | |
| Answers could include:<br>• constant flow of reactants means it can operate as long as fuel is available (compared to other cells that have limited operational time due to limited reactants)<br>• no memory effect (as with secondary cells)/ efficiency doesn't reduce over time<br>• the electrodes do not get depleted during the process of generating electricity<br>• higher efficiency<br>• produce energy at the same rate over a long period of time<br>• produce constant voltage.<br><br>Accept other relevant answers that have chemical merit e.g. if referring to better for the environment, must provide supporting evidence. | 1–2 |
| **Total** | **2** |

**Question 37** (continued)

(f) In the boxes provided, label the following diagram of a typical hydrogen-oxygen fuel cell. Include anode, cathode, electrolyte, hydrogen gas and oxygen gas. (3 marks)




| Description | Marks |
|---|---|
| Both $O_2$ and $H_2$ correctly labelled | 1 |
| Both the cathode and anode correctly labelled | 1 |
| Electrolyte correctly labelled | 1 |
| **Total** | **3** |

(g) Explain the function of the electrolyte. (2 marks)

| Description | Marks |
|---|---|
| The electrolyte:<br>• will allow for the movement of ions<br>• maintains electrical neutrality in the cell<br>• completes the circuit.<br>Any two for two marks | 1–2 |
| **Total** | **2** |

(h) From the table provided in the Chemistry Data booklet, calculate the EMF for the reaction between hydrogen gas and oxygen gas. (1 mark)

| Description | Marks |
|---|---|
| 1.23 + 0 = 1.23 V (acidic conditions) **or**<br>0.4 + 0.83 = 1.23 V (basic conditions) | 1 |
| **Total** | **1** |
| Note: Calculation not required for mark. | |

(i) A hydrogen-oxygen fuel cell on the Apollo spacecraft generally produced an EMF of 1.21 V per cell. State **one** reason why the theoretical (calculated) value was not the same as the actual EMF generated by the fuel cells on the spacecraft. (1 mark)

| Description | Marks |
|---|---|
| Answers could include:<br>• fuel cell is not at standard conditions (students may refer to an individual condition e.g. temperature not 25 °C, pressure etc)<br>• resistance in the wire<br>• Eddy currents being produced. | 1 |
| **Total** | **1** |

**Question 38** **(17 marks)**

(a) Determine the empirical formula of caffeine. (13 marks)

| **Description** | | | | | **Marks** |
|---|---|---|---|---|---|
| $n(CO_2)$ | = 4.623 / 44.01<br>= 0.10504<br>= n(C) | | | | 1 |
| m(C) | = 12.01 x 0.10504<br>= 1.2616 | | | | 1 |
| %(C) | = 1.2616 / 2.55 x 100<br>= 49.475 % | | | | 1 |
| $n(H_2O)$ | = 1.18 / 18.016<br>= 0.065497 | | | | 1 |
| n(H) | = 2 $n(H_2O)$ = 2 x 0.065497<br>= 0.13099 | | | | 1 |
| m(H) | = 1.008 x 0.13099<br>= 0.13204 | | | | 1 |
| %(H) | = (0.13204 / 2.55) x 100<br>= 5.1781 % | | | | 1 |
| $n(N) = n(NH_3)$ | = 1.17 / 17.034<br>= 0.068686 | | | | 1 |
| m(N) | = 14.01 x 0.068686<br>= 0.96229 | | | | 1 |
| %(N) | = (0.96229 / 3.33) x 100<br>= 28.898 | | | | 1 |
| %(O) | = 100 – (49.475 + 5.1781 + 28.898)<br>= 16.449 % | | | | 1 |
| | C | H | N | O | 1 |
| n | 49.475/12.01<br>= 4.119 | 5.1781/1.008<br>= 5.137 | 28.898/14.01<br>= 2.063 | 16.449/16.00<br>= 1.028 | |
| ratio | 4.12/1.03<br>= 3.999<br>~ 4 | 5.14/1.03<br>= 4.987<br>~ 5 | 2.063/1.03<br>= 2.003<br>~ 2 | 1.028/1.03<br>= 0.998<br>~ 1 | |
| Empirical Formula $C_4H_5N_2O$ | | | | | 1 |
| | | | | **Total** | **13** |

Note:
Not every step needs to be set out as above but it must be clear how the answer was obtained - all ratios, conversions and calculations are demonstrated.

(b) Calculate the molar mass of caffeine. (2 marks)

| Description | Marks |
|---|---|
| n = (0.100 x 370) / (8.314 x (550 + 273.15))<br>= $5.41303 \times 10^{-3}$ mol | 1 |
| M = 1.05 / $5.41 \times 10^{-3}$<br>= 194.073<br>= 194 g $mol^{-1}$ | 1 |
| **Total** | **2** |

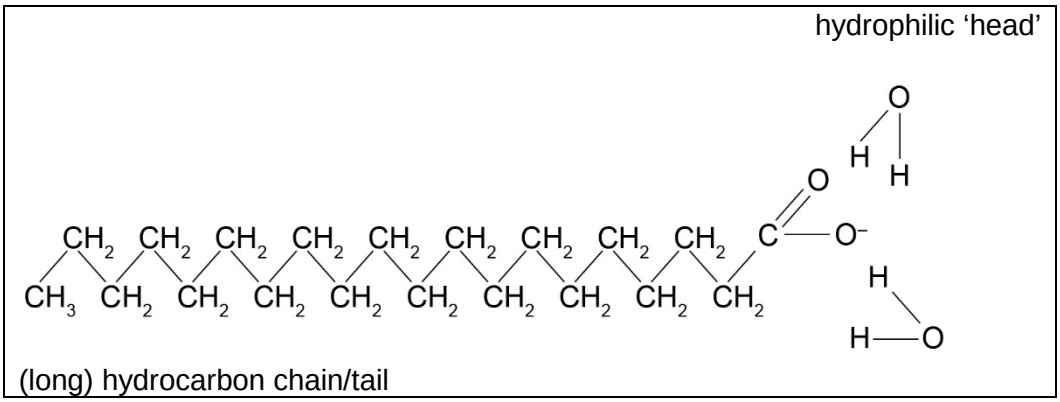
(c) From your answers to part (a) and part (b), determine the molecular formula of caffeine, showing clearly how this was determined. (2 marks)

| Description | Marks |
|---|---|
| Molecular formula = MFM / EFM x EF<br>= 194.1 / 97.1 x EF<br>= 2 x EF | 1 |
| Therefore molecular formula = 2 x $C_4H_5N_2O$<br>= $C_8H_{10}N_4O_2$ | 1 |
| **Total** | **2** |

**Question 39** **(25 marks)**

(a) (i) On the diagram below:
- complete the structure of a soap
- identify and label the key structural features of soap
- draw **two** molecules of water showing how they are orientated about soap.

(5 marks)




| Description | Marks |
|---|---|
| Addition of (more $CH_2$ units with) a terminating methyl unit $CH_3$ | 1 |
| Addition of $COO^-$ ($Na^+$, $Li^+$ or $K^+$) | 1 |
| Labelling of long chain hydrocarbon tail:<br>• (long) hydrocarbon chain/tail **or**<br>• non polar tail **or**<br>• hydrophobic chain/tail. | 1 |
| Labelling of ionic (sodium) carboxylate head:<br>• hydrophilic 'head'<br>• anionic<br>• ionic<br>• polar<br>• carboxylate<br>• charged group/head. | 1 |
| Orientation of all water molecule/s at ionic end with H atoms pointing towards the $COO^-$ group | 1 |
| **Total** | **5** |

(ii) Name and explain the origin of the predominant attractive force exhibited between the composite particles of soap and water. (3 marks)

| Description | Marks |
|---|---|
| Ion-dipole | 1 |
| The negative charge on the carboxylate ion at the end of the soap structure is mutually attracted | 1 |
| to the positive end of the hydrogen-oxygen dipole of the water molecule. | 1 |
| **Total** | **3** |

(iii) Name and explain the origin of the predominant attractive force exhibited between the composite particles of soap and oil. (3 marks)

| Description | Marks |
|---|---|
| Dispersion forces | 1 |
| The (uneven distribution of electrons produces) weak, temporary dipoles formed along the hydrocarbon chain of soap | 1 |
| are mutually attracted to the similarly formed weak temporary dipoles formed along the oil molecules | 1 |
| **Total** | **3** |

(b) Explain why soaps do **not** function very effectively in hard water. (2 marks)

| Description | Marks |
|---|---|
| The surfactant ions precipitate with calcium or magnesium ions or give equation | 1 |
| Prevents soap from interacting with water/removes the surfactant ion from the system or similar | 1 |
| **Total** | **2** |

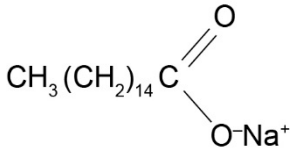
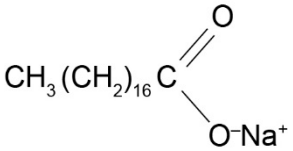
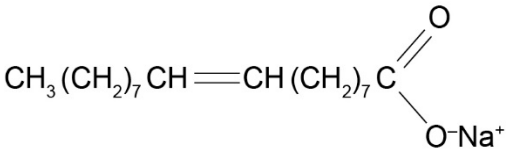
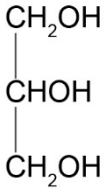
(c) (i) Name the functional group in glycerol. (1 mark)

| Description | Marks |
|---|---|
| Functional group – alcohol **or** hydroxyl group | 1 |
| **Total** | **1** |

(ii) State the **two** distinctive parts of a fatty acid used to make soap. (2 marks)

| Description | Marks |
|---|---|
| Long hydrocarbon chain ($CH_3$-$CH_2$-$CH_2$-...) | 1 |
| Carboxyl group (-COOH) **or** carboxylic acid | 1 |
| **Total** | **2** |

(d) Draw structural formula of the **four** products from this saponification process. Names are **not** required. (4 marks)

| Description | | Marks |
|---|---|---|
| One mark for each structure | | |
|  |  | 1–4 |
|  |  | |
| **Total** | | **4** |
| Note: $Na^+$ not required | | |

**Question 39** (continued)

(e) Why are soap solutions basic? (2 marks)

| Description | Marks |
|---|---|
| The $RCOO^-$ is the conjugate base of a weak acid or appropriate equation | 1 |
| therefore in the reaction with water it accepts a proton (or it hydrolyses) to produce $OH^-$ | 1 |
| **Total** | **2** |

(f) State **one** health risk caused by chemicals used in the saponification process that would require careful monitoring by NICNAS. (1 mark)

| Description | Marks |
|---|---|
| Answers could include:<br>A strong base, typically sodium hydroxide, is used in the manufacture of soap, which is very caustic and:<br>• can cause severe irritation of the nose and throat<br>• contact can cause pain, redness, burns, blistering and permanent scarring<br>• a severe exposure can cause death<br>• contact with eyes causes severe burns with redness, swelling, pain and blurred vision. Permanent damage including blindness can result<br>• if ingested can burn the lips, tongue, throat and stomach.<br><br>Accept other relevant answers | 1 |
| **Total** | **1** |

(g) Use the information in the table to write an **hypothesis** that could be used to investigate cleaning effectiveness. (2 marks)

| Description | Marks |
|---|---|
| Statement that gives relationship between independent and dependent variable | 2 |
| Statement that links independent and dependent variable without indicating the direction of the relationship between the variables | 1 |
| **Total** | **2** |
| Example of a two mark answer:<br>As the hydrocarbon length increases in a soap its cleaning effectiveness increases. | |

**Question 40** **(15 marks)**

(a) Draw a section of the polypeptide that is composed of the **three** most abundant amino acids found in keratin. (4 marks)

| Description | Marks |
|---|---|
| A structure that shows correct identification of cysteine, serine and glutamic acid in any order by drawing R groups correctly in a chain | 1-2 |
| Two peptide bonds drawn correctly between the three amino acids | 1 |
| Demonstration that it is part of polypeptide (no terminal groups) | 1 |
| For example<br><br>cysteine serine glutamic acid<br><br>$CH_2 – SH$ $CH_2 – OH$ $CH_2 – CH_2 – COOH$<br>\| \| \|<br>-(- HN – CH – C – N – CH – C – N – CH – CO -)-<br>\|\| \| \|\| \|<br>O H O H<br><br>One minor error in the drawing – one mark out of two | |
| **Total** | **4** |

(b) With reference to the structure drawn in part (a), state **three** types of attractive forces/bonding other than dispersion forces that can occur **between** neighbouring keratin polypeptide chains. (3 marks)

| Description | Marks |
|---|---|
| Hydrogen bonding | 1 |
| Dipole-dipole interactions | 1 |
| Disulfide bridges/disulfide bond | 1 |
| **Total** | **3** |

(c) Describe the $\alpha$-helix structure of keratin. (2 marks)

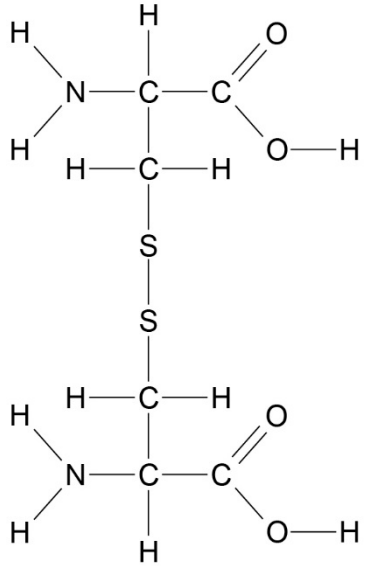
| Description | Marks |
|---|---|
| Hydrogen bonding (between amide and carbonyl functional groups) in the same (peptide) chain | 1 |
| Coiled/spiral structure | 1 |
| **Total** | **2** |

(d) State why hair can absorb water. (1 mark)

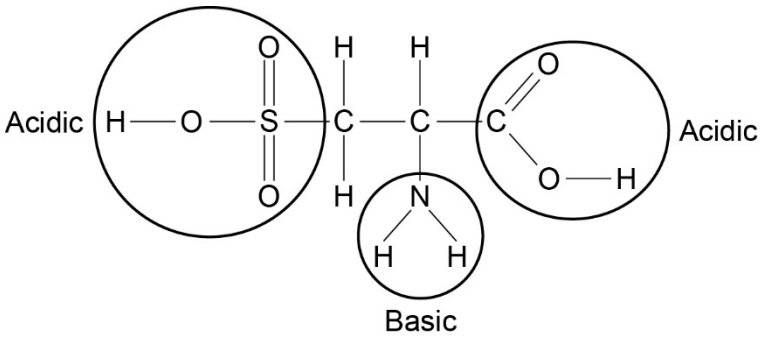
| Description | Marks |
|---|---|
| Water is attracted to the amino acids within the polypeptide that exhibit hydrogen bonding | 1 |
| **Total** | **1** |

**Question 40** (continued)

(e) Draw the structure of cystine. (2 marks)

| Description | Marks |
|---|---|
| Two cysteine molecules drawn | 1 |
| A bond drawn between the linking S atoms; a connecting disulfide bridge | 1 |
|  | |
| **Total** | **2** |

(f) On the structural formula of cysteic acid drawn below, circle and label any functional groups as acidic or basic. (3 marks)

| Description | Marks |
|---|---|
| One mark for each region correctly circled and correctly labelled. | |
|  | 1–3 |
| **Total** | **3** |

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