Chemistry of Materials (SPECIMEN)

1 (a) (i) $Si + O_2 \rightarrow SiO_2$ [1 mark]

$SiO_2 + CaO \rightarrow CaSiO_3$ [1 mark]

[2 marks]

(ii) Otherwise it would be removed as an oxide **[1 mark]**

(b) (i) +3 **[1 mark]**

(ii) Octahedral shape indicated (must be three-dimensional) [1 mark]

NH_3 ligand labelled and bonded via N atom to metal ion [1 mark]

[2 marks]

(c) *Five marks for five of the following points:*

Select a suitable filter

Use a blank/reference cell

Make up solutions of known concentration

Measure the absorptions of the solutions

Plot a calibration curve

Measure absorption of the green solution of unknown concentration

Read off its concentration from calibration curve **[5 marks]**

(d) (i) Amount of MnO_4^- used in the titration $= \frac{0.0200 \times 24.2}{1000}$ [1 mark]

$(= 4.84 \times 10^{-4}$ moles)

Mass of iron in steel sample $= 5 \times 4.84 \times 10^{-4}$ [1 mark]

$\times 10 \times 56.0 = 1.36$ g [1 mark]

[3 marks]

(ii) Percentage by mass of iron in steel $= \frac{1.36 \times 100}{1.40} = 96.8\%$ [1 mark]

allow 2 or 3 significant figures

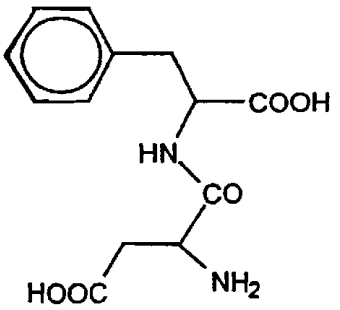
Total 15 marks

2 (a) Two amino acids [1 mark]

Joined together by a peptide/amide/ –CONH– link [1 mark]

[2 marks]

(b) *The structure below is one possible answer:*



Formula drawn omitting skeletal C atoms and C–H bonds and C–C bonds represented by lines with bends at bond junctions [1 mark]

Accuracy [1 mark]

[2 marks]

(c) (i) Heat under reflux [1 mark]

with moderately concentrated acid [1 mark]

(e.g. 4 mol dm^{-3} HCl)

[2 marks]

(ii) **Products of hydrolysis:** aspartic acid and phenylalanine [1 mark]

and methanol [1 mark]

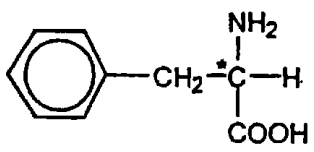
Further information needed:

which way round the two amino acids are linked [1 mark]

and which acid group is esterified [1 mark]

[4 marks]

(d) (i) *The α C atom of the amino acid should be starred:*

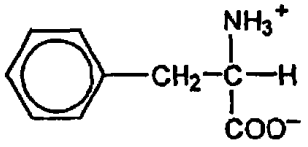


[1 mark]

(ii) The two diagrams should be **mirror images**. They should be clear and use the wedge and dashed-bond convention

(1 mark where this convention is not used but there is an attempt to show the correct stereochemistry) **[2 marks]**

(e) *The zwitterion structure is the most likely:*



NH_3^+ or COO^- [1 mark]

Or for

complete structure [2 marks]

[2 marks]

(f) The peptide linkage is being hydrolysed **[1 mark]**

Total 16 marks

3 (a) High resistance voltmeter (*or* potentiometer) [1 mark]

Salt bridge [1 mark]

Hydrogen half-cell (*or* other reference cell; allow copper ions/copper) [1 mark]

Vanadium ions half-cell (or general ion/ion half-cell) [1 mark]

Standard conditions [1 mark]

[5 marks]

(b) (i) Stable oxidation state would be expected to be +5 **[1 mark]**

(ii) Electrons flow from more negative to more positive helf-cell [1 mark]

Both vanadium half-cells are more negative than oxygen half-cell [1 mark]

or V(+4) to V(+5) is still sufficiently negative to supply electrons to oxygen half-cell)

[2 marks]

(c) Electrode potential values depend on the ligands present in a complex **[1 mark]**

(d) $4s^2 3d^3$ (or $3d^3 4s^2$) (1 mark for each sub-shell correctly stated)

[2 marks]

(e) $V^{2+}(g) \rightarrow V^{3+}(g) + e^-$ *(1 mark for change from +2 to +3)*

(1 mark for gaseous state)

[2 marks]

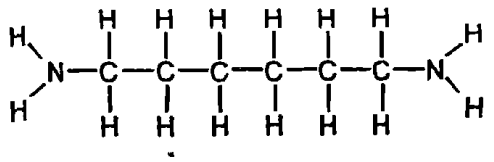
(f) Comment to the effect that: after the loss of 2 electrons from calcium, further ionisation requires a large energy input [1 mark]

Comment to the effect that: vanadium can lose a greater number of electrons before a large energy input is required [1 mark]

[2 marks]

Total 15 marks

4 (a)



six carbon atoms in a chain [1 mark]

$-NH_2$ groups at both ends and fully correct [1 mark]

[2 marks]

(b) $H_2N-(CH_2)_6-NH_2 + 2HCl \rightarrow Cl^- {}^+H_3N-(CH_2)_6-NH_3^+ Cl^-$

At least one $-NH_2$ group converted to $-NH_3^+$ group [1 mark]

Completely correct [1 mark]

[2 marks]

(c) (i) There are 6 carbon atoms in each monomer **[1 mark]**

or in each of the two reagents

(ii) *Six marks for six of the following points:*

Nylon has hydrogen bonding

between the C=O and –NH– groups

This is relatively strong intermolecular bonding

and prevents polymer chains sliding over one another

As temperature is raised, molecules have more energy

Can overcome the intermolecular forces

and chains can slide over one another

Link movement of chains to strength of polymer [6 marks]

Quality of written communication:

a minimum of 2 linked sentences, presenting a logical argument which distinguishes between covalent bonds within the molecules and hydrogen bonds with correct use of scientific terms such as, molecule, polymer chain, temperature, energy in this context [1 mark]

[7 marks]

(d) (i) Genes that code for the particular enzyme [1 mark]

are inserted [1 mark]

into the DNA of the bacterium [1 mark]

[3 marks]

(ii) Chemical shifts at:

6.1 (CH=CH) [1 mark]

11.0 (COOH) [1 mark]

[2 marks]

Total 17 marks

5 (a) Water ligands around the copper ions [1 mark]

are replaced by new ligands (L) [1 mark]

[2 marks]

(b) (i) Awareness of Le Chatelier's Principle or reversibility of process [1 mark]

Correct discussion of effect of [H+] on position of equilibrium [1 mark]

[2 marks]

(ii) Small volume of extracting solvent used **[1 mark]**

(c) (i) $K_c = \dfrac{[CuL_2(org)][H^+(aq)]^2}{[Cu^{2+}(aq)][LH(org)]^2}$

Top correct [1 mark]

Bottom correct [1 mark]

[2 marks]

(ii) Ratio is 22.5 : 1 [1 mark]

Hence percentage extracted $= \dfrac{22.5 \times 100}{23.5}$ [1 mark]

$= 96\%$ [1 mark]

[3 marks]

(iii) Correct insertion of data into equilibrium constant expression [1 mark]

$K_c = 0.23$ (*or* 0.223) [1 mark]

candidates who omit the $[H^+]^2$ term in (c)(i) and who give the answer as 2250 $dm^6\ mol^{-2}$ gain both marks **[2 marks]**

Total 12 marks

6 (a) (i) Reactions are exothermic *or* heat/energy given out by reactions **[1 mark]**

(ii) Oxygen *(not just gas)* (*or* steam) is produced (as well) [1 mark]
so pressure builds up in gland (*or* forced out) [1 mark]
[2 marks]

(b) (i) Phenol (*or* hydroxyl) **[1 mark]**

(ii) Ketone (*or* carbonyl) **[1 mark]**

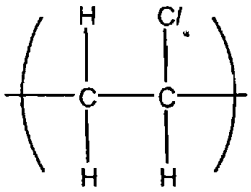
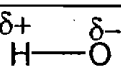
(c) (i) Flask or tube containing labelled reaction mixture connected to next stage without leaks [1 mark]
Some indication of how reaction started [1 mark]
(allow 'add catalase quickly and restopper' or funnel method)
Collection of gas in syringe or over water [1 mark]
(reasonable sized ; no leaks)
Calibration shown or labelled [1 mark]
(extra pieces of apparatus (e.g. reflux condensers) lose 1 mark if 3 otherwise scored) **[4marks]**

(ii) *Labelled axes* [1 mark]
correctly plotted data and straight line [1 mark]
[2 marks]

(iii) Initial rate of reaction is proportional to starting concentration of H_2O_2 [1 mark]
so reaction is first order with respect to hydrogen peroxide [1 mark]
[2 marks]

(iv) It is the constant in the rate equation that relates rate [1 mark]
to concentrations [1 mark]
or by writing the rate equation:
rate of reaction $= k [H_2O_2] [\text{catalase}]^n$ and identifying k **[2 marks]**

Total 15 marks

Question	Expected answers	Marks
7 (a) (i)	chloroethene (1). *Ignore numbers if 1 or 2.*	1
7 (a) (ii)	Softens / changes shape / remoulded (1); when heated/*allow* when it is melted / no cross-links (1).	2
7 (a) (iii)	 *allow* –CH_2-CHCl– (1).	1
7 (b)	 *(uses numbers to identify) correct bond (1); partial charges correct (1).*	2
7 (c) (i)	Acidified/sulphuric acid (1) *allow any mineral acid/H^+* ; (potassium) dichromate/$Cr_2O_7^{2-}$ (1).	2
7 (c) (ii)	condensing vapours (1); returning liquid to flask /vapours not allowed to escape (1).	2
7 (c) (iii)	1700-1725 cm^{-1} (1); C=O (1).	2

Total [12]

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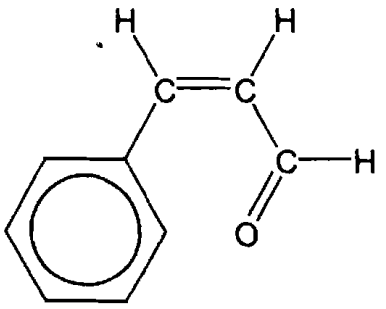
Question	Expected answers	Marks
8(a)	-CHO group correct (1)	1
8(b) (i)	*Two marks for everything correct, 1 mark only if* cis *but not all detail of molecule correct*  *accept* C_6H_5– *instead of ring*	2
8(b) (ii)	2 different groups on each C atom (of the C=C bond) (1); C=C bond cannot rotate *or* groups can be arranged differently in space *or* double bond has to be broken for groups to rotate (1)	2
8(c) (i)	Molecule fragments/ breaks down, *or* isotope peaks (1)	1
8(c) (ii)	132 = $[C_6H_5CH=CHCHO]^+$ (1); *allow* $C_9H_8O^+$ 131 = $[C_6H_5CH=CHC=O]^+$ (1); *allow* $C_9H_7O^+$ 77 = $C_6H_5^+$ (1) *Accept molecular or structural formulae containing* ***the correct number of atoms.*** *The fourth mark is for all structures having a positive charge, if not then only 3 marks.*	4
8(d) (i)	Orange/red/brown/yellow colour (1); decolourised only by cinnamic acid (1)	2
8(e)(i)	Oxygen, *or* air (1)	1
8(e)(ii)	Cinnamic acid formed because an -OH group is present, *allow* C-O bond is present Label on O-H peak or allow label on C-O peak *accept reference to correct* frequencies instead of label *i.e.* O-H 3200-3600 cm^{-1}/ 2500 - 3200 cm^{-1} C-O 1050-1300 cm^{-1} (1) (should be clarified with a statement re cinnamic acid)	2
8(f)	*Any 4 points:* Aldehyde has (permanent) dipole-(permanent) dipole forces (1); acid has hydrogen bonding (1); hydrogen bonding is the strongest force, *may imply this using the word* 'strong' (1) *(comparison should be implied);* acid has greater intermolecular forces (1); more energy needed to separate molecules in cinnamic acid/ overcome the intermolecular forces (1) 1 mark for two sentences / 2 bullet points including correct use of **two** of the following phrases: *intermolecular forces, (permanent) dipole-(permanent) dipole forces, hydrogen bonding, instantaneous dipole-induced dipole forces*	5
	Total mark	20