* Copyright for test papers and marking guides remains with *West Australian Test Papers*.
* The papers may only be reproduced within the purchasing school according to the advertised conditions of sale.
* Test papers must be withdrawn after use and stored securely in the school until 13th October 2021.



**CHEMISTRY**

**UNITS 3 & 4**

**2022**

**MARKING GUIDE**

***TIME ALLOWED FOR THIS PAPER***

Reading time before commencing work: Ten minutes

Working time for the paper: Three hours

***MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER***

**To be provided by the supervisor:**

This Question/Answer Booklet

Multiple-choice Answer Sheet

Chemistry Data Book

**To be provided by the candidate:**

Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: calculators satisfying the conditions set by the SCSA for this subject.

***IMPORTANT NOTE TO CANDIDATES***

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of questions available | Number of questions to be answered | Suggested working time  (minutes) | Marks available | Percentage of exam |
| Section One  Multiple-choice | 25 | 25 | 50 | 25 | 25 |
| Section Two  Short answer | 9 | 9 | 60 | 83 | 35 |
| Section Three  Extended answer | 5 | 5 | 70 | 94 | 40 |
|  |  |  |  | **Total** | 100 |

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | a □ b ■ c □ d □ |  | 6 | a □ b □ c □ d ■ |  | 11 | a ■ b □ c □ d □ |
| 2 | a ■ b □ c □ d □ |  | 7 | a □ b □ c ■ d □ |  | 12 | a ■ b □ c □ d □ |
| 3 | a □ b □ c □ d ■ |  | 8 | a □ b □ c □ d ■ |  | 13 | a □ b □ c ■ d □ |
| 4 | a □ b □ c □ d ■ |  | 9 | a ■ b □ c □ d □ |  | 14 | a □ b ■ c □ d □ |
| 5 | a □ b □ c ■ d□■ |  | 10 | a □ b □ c □ d ■ |  | 15 | a □ b □ c ■ d □ |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 16 | a □ b □ c ■ d □ |  | 21 | a □ b □ c □ d ■ |  |  |  |
| 17 | a □ b □ c □ d ■ |  | 22 | a □ b □ c ■ d □ |  |  |  |
| 18 | a □ b ■ c □ d □ |  | 23 | a □ b ■ c □ d □ |  |  |  |
| 19 | a □ b □ c □ d ■ |  | 24 | a □ b ■ c □ d □ |  |  |  |
| 20 | a ■ b □ c □ d □ |  | 25 | a □ b ■ c □ d □ |  |  |  |

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

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

1. Consider the equilibrium between dichromate and chromate ions.

Cr2O72-(aq) + H2O(l) ⇌ 2 CrO42-(aq) + 2 H+(aq)

A change was imposed upon the system, the result of which can be represented by the following rate graph.

Reaction rate

for

rev

Time

What was the imposed change?

1. Addition of Na2Cr2O7(aq).
2. **Addition of H2O(l).**
3. Addition of Na2CrO4(aq).
4. Addition of HCl(aq).

2. Which of the **bolded** elements has a different oxidation number to the others?

1. **K2S2O3**
2. Na3**P**O4
3. H**N**O3
4. **V**2O5

3. Excess chlorine water was added to a test tube containing potassium bromide solution. The mixture was shaken and allowed to sit until all reactions were complete. The final mixture in the test tube would contain

1. Cl2(aq), Cl-(aq) and Br2(aq) only.
2. K+(aq), Br2(aq) and Cl2(aq) only.
3. Br -(aq), Cl-(aq), Cl2(aq) and Br2(aq) only.

**(d) K+(aq), Cl2(aq), Cl-(aq) and Br2(aq) only.**

4. Consider the organic compound shown below.



When this compound was **completely** oxidised with excess acidified sodium dichromate solution, which of the following would be the major organic product formed?



5. Ocean acidification has severe consequences for many calcifying species. The following equation shows the interaction between solid calcium carbonate and hydronium ions in the ocean.

CaCO3(s) + H3O+(aq) ⇌ Ca2+(aq) + HCO3-(aq) + H2O(l)

An increase in the concentration of H3O+(aq), as caused by ocean acidification, would **not** result in

1. the equilibrium position shifting to the right.
2. an increase in HCO3-(aq) concentration.
3. **an increase in the K value.**
4. a decrease in the mass of CaCO3(s) present.

6. Consider the partially drawn diagram of a hydrogen-oxygen fuel cell.

← gas

V

→ waste gas

**gas X** →

waste gas ←

← H+

← H+ **Y**

← H+

Which of the following correctly identifies reactant gas X and the polarity of electrode Y?

**Gas X Polarity of Electrode Y**

1. H2(g) positive
2. H2(g) negative
3. O2(g) positive
4. **O2(g) negative**

**Question 7 and 8 refer to the information below.**

Consider the following five (5) pairs of substances.

(i) H2SO4 and NaHSO4

(ii) HCl and NaCl

(iii) H2SO3 and NaHSO3

(iv) HNO3 and CH3COOH

(v) NaHSO4 and Na2SO4

7. Which pairs contain one strong acid and one weak acid?

1. (i) and (ii) only.
2. (i) and (iii) only.
3. **(i) and (iv) only.**
4. (ii) and (iv) only.

8. Which pairs could be mixed in aqueous solution to form a buffer?

1. (i) and (v) only.
2. (ii), (iii) and (v) only.
3. (ii) and (iv) only.
4. **(iii) and (v) only.**

**Questions 9 and 10 refer to the -amino acids alanine, glycine, leucine and valine.**

A section of protein contained four (4) -amino acids as shown in the diagram below.



9. What is the primary sequence of this section of protein?

1. **Leu – Gly – Val – Ala**
2. Val – Gly – Leu – Ala
3. Leu – Ala – Val – Gly
4. Val – Ala – Leu – Gly

10. Which of these -amino acids has the IUPAC name 2-amino-3-methylbutanoic acid?

1. Alanine
2. Glycine
3. Leucine
4. **Valine**

11. A particular reaction has a forward activation energy of 393 kJ and a reverse activation energy of 321 kJ. The forward reaction is therefore

1. **endothermic with H = +72 kJ.**
2. endothermic with H = -72 kJ.
3. exothermic with H = +72 kJ.
4. exothermic with H = -72 kJ.

12. A sample of waste vegetable oil was divided in half and then each half was converted to biodiesel. One half of the vegetable oil was converted to biodiesel using a sodium hydroxide catalyst, whilst the other half was converted using a lipase catalyst.

Which of the following would remain the same, regardless of the choice of catalyst?

1. **The chemical structure of the biodiesel.**
2. The rate of production of the biodiesel.
3. The purity of the biodiesel.
4. The cost of the biodiesel production.

**Questions 13 and 14 refer to the equilibrium system below.**

The following system is at equilibrium.

2 N2(g) + O2(g) + heat ⇌ 2 N2O(g)

Consider the effect of imposing the following changes on this equilibrium. The effect of each of these changes should be considered in isolation.

1. Adding N2(g)
2. Removing O2(g)
3. Increasing the volume of the system
4. Increasing the temperature of the system
5. Adding a catalyst to the system

13. Which of these changes would **instantaneously** increase the rate of the reverse reaction?

(a) (i) and (iv) only.

(b) (ii) and (iii) only.

**(c) (iv) and (v) only.**

(d) (v) only.

14. Which of these changes would result in the reverse reaction being favoured?

(a) (i), (iv) and (v) only.

**(b) (ii) and (iii) only.**

(c) (ii), (iii) and (v) only.

(d) (iv) and (v) only.

15. Consider a micelle formed from soap particles, as shown below. The two (2) distinct regions of the soap particle are labelled as X and Y.

X

Y

Which statement is **not** correct?

1. X would form ion-dipole interactions with water.
2. X is the hydrophilic part of the soap.
3. **Y would interact through hydrogen bonding.**
4. Y would dissolve in oil or grease.

16. Which of the following polymers would be formed from the polymerisation of

trans-2,3-dichlorobut-2-ene?





17. Which of the following metals could **not** be used as a sacrificial anode, to reduce the rate of corrosion of iron?

1. Zinc
2. Magnesium
3. Chromium
4. **Tin**

18. A student incorrectly named an organic substance 1,1,2-tribromo-3-methylhexan-4-one. What is the correct IUPAC name for this organic substance?

1. 1,1,2-tribromo-3-methylhexan-2-one
2. **5,6,6-tribromo-4-methylhexan-3-one**
3. 1,1,2-tribromo-3-methylhexan-3-one
4. 5,6,6-tribromo-4-methylhexan-4-one

19. Consider the following equilibrium system.

Cl2(g) + F2(g) ⇌ 2 ClF(g)

If the volume of this equilibrium system was increased,

(a) the forward reaction rate would increase more than the reverse reaction rate.

(b) the forward reaction rate would decrease less than the reverse reaction rate.

(c) both forward and reverse reaction rates would increase equally.

**(d) both forward and reverse reaction rates would decrease equally.**

**Questions 20 and 21 refer to the indicator o-cresolphthalein.**

o-Cresolphthalein indicator displays two (2) different colours and has an end point of approximately pH 9.6, as shown in the diagram below.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

pH

|  |  |
| --- | --- |
| colourless | red |

o-Cresolphthalein indicator can also be represented by the following chemical equilibrium system.

H*Ind*(aq) + H2O(l) ⇌ *Ind* -(aq) + H3O+(aq)

colourless red

A dilute solution of Na2HPO4(aq) was known to have a pH of 8.2. A few drops of o-cresolphthalein indicator were added to this solution and it remained colourless.

20. Which of the following correctly shows the relative concentrations of the o-cresolphthalein indicator species, when in the dilute Na2HPO4 solution?

**(a) [ H*Ind* ] > [ *Ind* - ]**

(b) [ *Ind* -] > [ H*Ind* ]

(c) [ H*Ind* ] = [ *Ind* -]

(d) More information is required.

21. Which of the following equations best demonstrates why the pH of Na2HPO4(aq) is 8.2?

1. Na2HPO4(aq) → 2 Na+(aq) + HPO42-(aq)
2. HPO42-(aq) + H2O(l) ⇌ PO43-(aq) + H3O+(aq)
3. Na+(aq) + 2 H2O(l) ⇌ NaOH(aq) + H3O+(aq)
4. **HPO42-(aq) + H2O(l) ⇌ H2PO4-(aq) + OH-(aq)**

22. The chemical equation below represents the process occurring in a lead-acid accumulator whilst it is being recharged.

2 PbSO4(s) + 2 H2O(l) → Pb(s) + PbO2(s) + 4 H+(aq) + 2 SO42-(aq)

Which of the following statements is **correct** regarding this recharging process?

1. The redox reaction occurring would be spontaneous.
2. The cathode would be assigned a positive polarity.
3. **The pH of the electrolyte would decrease.**
4. Lead would be formed at the anode.

23. Consider a sample of the electrolyte solution taken from a cell carrying out the electrolytic refining of copper metal. The ion **least** likely to be present in this solution is

1. Cu2+(aq).
2. **Au3+(aq).**
3. Ni2+(aq).
4. SO42-(aq).

24. The Haber process is used to produce ammonia gas, NH3(g), and can be represented by the equation below. Assume the following species had established equilibrium.

N2(g) + 3 H2(g) ⇌ 2 NH3(g) + 92 kJ

If the temperature of the reaction system was increased, this would

1. increase the frequency of collisions
2. increase the proportion of successful collisions
3. increase the rate of the forward reaction
4. increase the yield
5. increase the value of K
6. (ii) and (iii) only.
7. **(i), (ii) and (iii) only.**
8. (iii) and (iv) only.
9. (iv) and (v) only.

25. The following diagram shows one type of cathodic protection that can be used to prevent corrosion.

DC power supply

steel structure

protective electrode

sea water

Assuming a suitable EMF was applied,

1. oxidation would occur at the steel structure.
2. **oxidation would occur at the protective electrode.**
3. oxidation would occur at various locations in the sea water.
4. oxidation would not occur.

**End of Section One**

**Section Two: Short answer 35% (83 marks)**

This section has **9** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

**Question 26 (11 marks)**

A group of chemistry students were given samples of three (3) colourless organic substances;

* butan-1-ol
* butanone, and
* butanoic acid.

Their teacher asked them to design a series of chemical tests to distinguish and identify each of these substances.

The students devised the following flow chart.

butan-1-ol, butanone, butanoic acid

X

final colour of solution is pale pink

final colour of solution is purple

to a sample of each organic substance, add a few drops of acidified potassium permanganate solution

to a fresh sample of the remaining organic substances, add a small amount of sodium carbonate powder

Y

colourless, odourless gas produced

Z

no reaction observed

**Question 26 (11 marks)**

(a) Complete the flow chart, by writing the name of each organic substance in the boxes labelled X, Y and Z. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **X is butan-1-ol** | **1** |
| **Y is butanoic acid** | **1** |
| **Z is butanone** | **1** |
| **Total** | **3** |

(b) Write a balanced ionic equation for the reaction that produced the colourless, odourless gas. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Correct reactants and products** | **1** |
| **Balanced** | **1** |
| **Total** | **2** |
| **Examples of a two mark response:**  **2CH3CH2CH2COOH(aq) + Na2CO3(s) → 2CH3CH2CH2COO-(aq) + 2Na+(aq) + CO2(g) + H2O(l)**  **2 C3H7COOH(aq) + Na2CO3­­­(s) → 2 C3H7COO-(aq)+ 2 Na+(aq) + CO2(g) + H2O(l)** | |
| **Note:**  **one mark may be allocated for the correctly balanced molecular equation** | |

(c) Rank the 3 original organic substances in order of boiling point, and explain your answer by referring to the intermolecular forces present in each substance. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Butanoic acid > butan-1-ol > butanone** | **1** |
| **The greater the sum of intermolecular forces, the higher the boiling point.** | **1** |
| **Substances have similar M, therefore similar strength dispersion forces.** | **1** |
| **Butanone has only dipole-dipole forces (in addition to dispersion) and therefore has the lowest boiling point.** | **1** |
| **Butan-1-ol and butanoic acid have hydrogen bonding (in addition to dipole-dipole and dispersion forces) which elevate their boiling point.** | **1** |
| **The hydrogen bonding in butanoic acid is the strongest because the -COOH group is more polar than the -OH group.**  **or**  **Butanoic acid molecules form dimers, with stronger hydrogen bonds (than those in butan-1-ol).**  **or**  **The boiling point of butanoic acid is the highest because it has more potential hydrogen bonding sites (than butan-1-ol).** | **1** |
| **Total** | **6** |

**Question 27 (8 marks)**

The following equations demonstrate how the -amino acid ‘aspartic acid’ ionises in solution.

**Step 1.** CH2 – COOH CH2 – COOH

l l

H2N – CH – COOH + H2O ⇌ H2N – CH – COO - + H3O+

**Step 2.** CH2 – COOH CH2 – COO -

l l

H2N – CH – COO - + H2O ⇌ H2N – CH – COO - + H3O+

(a) Describe how the equations above demonstrate an understanding of the following terms. Your answer may refer to one or both equations, as required. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Bronsted-Lowry theory:** |  |
| * **one species (the aspartic acid) is acting as a proton (H+) donor** * **whilst the other species (water) is acting as a proton (H+) acceptor** | **2** |
| **Diprotic:** |  |
| * **aspartic acid contains two ionisable / acidic hydrogens per molecule** * **illustrated by use of two successive ionisation equations** | **2** |
| **Weak acid:** |  |
| * **partial ionisation of aspartic acid occurs** * **illustrated by use of reversible / double arrows in both equations** | **2** |
| **Total** | **6** |

(b) Which of the ionisation steps would have a higher Ka value? (circle your choice) (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Step 1 (circled)** | **1** |
| **Total** | **1** |

(c) Draw a structural diagram for the conjugate acid of ‘aspartic acid’. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Correct structural diagram (accept full or semi structural)** | **1** |
| **Total** | **1** |
| **Example of a correct structure:**  CH2 – COOH  l  H3N – CH – COOH  ⊕ | |

**Question 28 (8 marks)**

A student was given four (4) unlabelled jars, each containing several pieces of a different silver-coloured metal; cobalt (Co), zinc (Zn), silver (Ag) and tin (Sn). The student was asked to distinguish and identify these four metals. A bottle of 1 mol L-1 HCl(aq) was provided, but no other chemicals were available.

The student began by placing a small amount of the HCl(aq) into 4 different test tubes. The student then added a different metal to each test tube, adding several pieces each time, to ensure the metal would be in excess. The test tubes were allowed to sit until all reactions had stopped.

(a) State an observation that would allow silver and cobalt to be identified. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Silver:** |  |
| **no visible change** | **1** |
| **Cobalt:** |  |
| **pink solution formed** | **1** |
| **Total** | **2** |

When tin and zinc were reacted with HCl(aq), both produced similar observations, and therefore they were unable to be distinguished by this test.

(b) Write a balanced ionic equation, illustrating the reaction that took place between HCl(aq) and these two metals, **using the symbol X** to represent both Sn and Zn. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Correct reactants and products** | **1** |
| **Balanced** | **1** |
| **Total** | **2** |
| **Example of a two mark response: X(s) + 2 H+(aq) → X2+(aq) + H2(g)** | |

The final tin and zinc reaction mixtures remaining in the test tubes were filtered to remove any excess pieces of metal. The filtrates were collected in separate test tubes. The student then added a single piece of the previously identified cobalt metal to each.

(c) Describe how this would allow these solutions to be distinguished. Include any relevant chemical equations and observations in your answer. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Zinc solution:** |  |
| **No reaction / no visible change when cobalt added to zinc solution** | **1** |
| **Tin solution:** |  |
| **A (metal displacement) reaction occurs when cobalt added to tin solution** | **1** |
| **Any two of;**   * **silver metal dissolves** * **pink solution forms** * **new silver-grey solid forms** | **1** |
| **Equation:** |  |
| **Example of correct equation: Co(s) + Sn2+(aq) → Sn(s) + Co2+(aq)** | **1** |
| **Total** | **4** |

**Question 29 (10 marks)**

The following diagram shows part of the label on a bottle of shampoo.

INGREDIENTS: Water, Sodium Coco-Sulfate, Cocamide MIPA, Cocamidopropyl Betaine, Caprylyl Glucoside, **Glyceryl Oleate**, Coco-Glucoside, **Propanediol**, PEG-12 Dimethicone, Hydrogenated Ethylhexyl Olivate, Hydrogenated Olive Oil Unsaponifiables, Panthenol, *Hydrolysed Wheat Protein*, Persea Gratissima Oil, Aloe Barbadensis Leaf Juice, Chamomilla Recutita Flower Extract, Citrus Aurantium Amara Flower Extract, Panax Ginseng Root Extract, Polyquarternium-10, Tetrasodium Glutamate Diacetate, Polyquarternium-7, Phenoxyethanol, Fragrance, **Citric Acid**, Sodium Benzoate, Potassium Sorbate.

The structure of three (3) ingredients, shown above in **bold**, are given below.

(a) Using your knowledge of IUPAC nomenclature, match each of these 3 ingredients to their corresponding molecular structure. (3 marks)



|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Molecule 1: propanediol** | **1** |
| **Molecule 2: citric acid** | **1** |
| **Molecule 3: glyceryl oleate** | **1** |
| **Total** | **3** |

Another ingredient listed on the shampoo label is ‘Hydrolysed Wheat Protein’ (shown in *italics*). This refers to protein extracted from wheat, that has been treated in order to hydrolyse or ‘cut’ the protein into much shorter polypeptides. This process destroys most of the secondary and tertiary structures of the protein.

(b) Describe a ‘polypeptide’. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Any two of the following:** |  |
| * **condensation polymer** * **a naturally occurring polyamide** * **a long chain of amino acids** * **joined together by peptide / amide bonds / links** | **2** |
| **Total** | **2** |

(c) State the key difference between the secondary and tertiary structure of a protein. Give at least one example of each type of structure. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Secondary structure:** |  |
| **Interactions / hydrogen bonds that form between C=O and N-H groups of amino acids / within a protein chain.**  **or**  **Regular structures that form due to interactions / hydrogen bonding that occur between amino acids / within a protein chain.** | **1** |
| **and either of the following examples:** |  |
| * **-helix** * **-pleated sheet** | **1** |
| **Tertiary structure:** |  |
| **Various interactions which occur between the amino acid side chains.** | **1** |
| **and any one of the following examples:** |  |
| * **dispersion forces** * **dipole-dipole forces** * **hydrogen bonds** * **ionic bonds** * **disulfide bridge** | **1** |
| **Total** | **4** |

The shampoo label also states that the bottle is made entirely from recycled PET (RPET).

(d) What does ‘PET’ stand for? (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **polyethylene terephthalate** | **1** |
| **Total** | **1** |

**Question 30 (5 marks)**

Magnesium hydrogencarbonate (MgHCO3) is not found in solid form. When CO2(g) dissolves into a saturated solution containing magnesium carbonate (MgCO3), a small amount of the magnesium carbonate dissolves to form aqueous, colourless magnesium hydrogencarbonate.

The equilibrium system described above, was established in a closed vessel that was stoppered with a plunger, as shown in the diagram below. The chemical equation for the equilibrium system is also given.

MgCO3(s) + CO2(g) + H2O(l) ⇌ Mg2+(aq) + 2 HCO3-(aq)

CO2(g)

Mg2+(aq), HCO3-(aq), H2O(l)

MgCO3(s)

(a) Write the equilibrium constant (K) expression for this system. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Products over reactants** | **1** |
| **Correct indices** | **1** |
| **Total** | **2** |
| **Example of a two mark response:**  **K = [Mg2+] [HCO3- ]2**  **[CO2]** | |

(b) Consider the effect of imposing the following changes on this system. Complete the table below by stating in which direction, if any, an equilibrium shift would occur. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| **A small amount of MgCO3(s) is added.** | **no change** | **1** |
| **A few drops of 2 mol L-1 MgCl2(aq) is added.** | **left** | **1** |
| **The volume of the system is decreased.** | **right** | **1** |
| **Total** | | **3** |

**Question 31 (11 marks)**

There are two (2) industrial methods of ethanol (CH3CH2OH) manufacture. The ‘fermentation method’ has many advantages, including the use of the enzyme *zymase*, which is used to speed up the rate of reaction.

(a) What is an enzyme? (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **A biological catalyst**  **or**  **A protein which acts as a catalyst** | **1** |
| **Total** | **1** |

(b) List four (4) additional advantages, relating to the principles of green chemistry, of the fermentation method of producing ethanol. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Any four of the following:** |  |
| * **use of a lower pressure** * **use of a lower temperature** * **no unwanted side reactions (due to use of catalyst)** * **no use of corrosive acid catalyst** * **use of renewable feedstock** * **less hazardous** * **(closer to) carbon neutral fuel** | **4** |
| **Total** | **4** |

The following reaction sequence shows the alternate method of ethanol manufacture (Step 1). The ethanol can then undergo further reactions (Step 2 and 3), to form the compound ethyl ethanoate.

(c) Complete the reaction sequence below, by filling in the boxes. (3 marks)

**H2O**

H3PO4

**Step 1:** CH2=CH2 + ⇌ CH3CH2OH

**4 Cr3+**

**Step 2:** 3 CH3CH2OH + 2 Cr2O72- + 16 H+ → 3 CH3COOH + + 11 H2O

**CH3CH2OH**

H+

**Step 3:** CH3COOH + ⇌ CH3COOCH2CH3 + H2O

**1 mark for each**

(d) Name the type of reaction occurring in each step of the sequence. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Step 1: addition / hydration** | **1** |
| **Step 2: oxidation / redox** | **1** |
| **Step 3: esterification / condensation** | **1** |
| **Total** | **3** |

**Question 32 (11 marks)**

Consider the galvanic cell shown in the diagram below. The cell is composed of Ni(s)/Ni2+(aq) and Ag(s)/Ag+(aq) half-cells. The mass, concentration and volumes of the various chemicals used to design this cell are also shown, in addition to the overall cell equation.

V

500 mL of

1.00 mol L-1 AgNO3(aq)

electrolyte

10.0 g Ag(s) electrode

10.0 g Ni(s) electrode

500 mL of

1.00 mol L-1 Ni(NO3)2(aq) electrolyte

Cell reaction: Ni(s) + 2 Ag+(aq) → Ni2+(aq) + 2 Ag(s)

(a) On the diagram above, label the (3 marks)

* anode and cathode
* direction of electron flow
* direction of anion flow through the salt bridge.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Cathode and anode labels** | **1** |
| **Direction of electron flow label** | **1** |
| **Direction of anion flow label** | **1** |
| **Total** | **3** |
| **Example of a three mark response:**  electrons  anions  V  anode cathode |  |

(b) Calculate the EMF of the cell under standard conditions. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **EMF = + 0.80 + 0.24 = + 1.04 V** | **1** |
| **Total** | **1** |

As shown in the cell diagram, each of the electrodes had a starting mass of 10.0 g, and both electrolytes were 1.00 mol L-1 solutions with a volume of 500 mL.

Once the cell begins to operate, it will continue to run until either the oxidant or the reductant has reacted entirely. At this point, the cell is said to be ‘flat’, and will no longer produce a voltage.

If this cell was allowed to run until it went flat;

(c) Calculate the final mass of the silver electrode. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(Ni) = 10 / 58.69**  **= 0.170387 mol** | **1** |
| **n(Ag+) = 1 x 0.5**  **= 0.5 mol** | **1** |
| **Appropriate working to demonstrate limiting reagent** |  |
| **actual ratio Ag+ / Ni = 2**  **stoichiometric ratio Ag+ / Ni = 2.9345**  **or**  **n(Ni required) = 0.25 mol**  **n(Ag+ required) = 0.34077 mol** | **1** |
| **Ni is limiting reagent (with appropriate justification)** | **1** |
| **n(Ag formed) = 2 x n(Ni)**  **= 0.34077 mol** | **1** |
| **m(Ag formed) = 0.34077 x 107.9**  **= 36.7695 g** | **1** |
| **m(Ag electrode) = 10 + 36.7695**  **= 46.8 g** | **1** |
| **Total** | **7** |

**Question 33 (11 marks)**

There are many factors that affect the ability of soils to act as a buffer. One of these factors is the weatherable mineral content. The chemical equation below shows one of the buffering systems in soil, that is established by the breakdown of anorthite, which is found in igneous rock.

SiO44-(aq) + H2O(l) ⇌ HSiO43-(aq) + OH-(aq)

Rain water generally has a slightly acidic pH of approximately 5.6.

(a) Explain, in terms of reaction rates, how this buffer would respond to the addition of H3O+(aq) as caused by rainfall. Include a relevant chemical equation in your answer. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **An increase in H3O+ would neutralise / remove OH- ions from the system.** | **1** |
| **Both forward and reverse reaction rates would decrease,** | **1** |
| **however the forward reaction rate decreases less than the reverse rate.** | **1** |
| **This results in the position of equilibrium shifting right,** | **1** |
| **resulting in production of more OH- ions and therefore the pH is maintained.** | **1** |
| **Equation showing H3O+ reaction with conjugate base species** | **1** |
| **Example of correct equation:**  **H3O+(aq) + SiO44-(aq) → H2O(l) + HSiO43-(aq)** |  |
| **Total** | **6** |

(b) State the two (2) factors that would affect the buffering capacity of this system. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Ratio of the concentrations of acid (HSiO43-) and base (SiO44-)** | **1** |
| **Actual / absolute concentrations of acid (HSiO43-) and base (SiO44-)** | **1** |
| **Total** | **2** |

The chemical processes that cause rain to be acidic are similar to those involved in the acidification of our oceans. These processes can be represented by the equations below.

1. CO2(g) ⇌ CO2(aq)
2. CO2(aq) + H2O(l) ⇌ H2CO3(aq)
3. H2CO3(aq) + H2O(l) ⇌ H3O+(aq) + HCO3-(aq)

(c) Use Le Chatelier’s principle, to justify how an increase in the concentration of atmospheric CO2(g) can lower the ocean pH. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **An increase in CO2 concentration favours the forward reaction / shifts the position of equilibrium to the right in equations 1, 2 and 3.** | **1** |
| **This counteracts the imposed change by decreasing the CO2, but results in increased [H3O+ ].** | **1** |
| **As [H3O+ ] increases, pH is lowered (since pH = -log[H3O+]).** | **1** |
| **Total** | **3** |

**Question 34 (8 marks)**

Consider the polymer fragment drawn below.



(a) What type of condensation polymer is shown? (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **A polyester** | **1** |
| **Total** | **1** |

(b) Draw structural diagrams of the monomers used to produce this polymer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Diacid:** | **1** |
| **Diol:** | **1** |
| **Total** | **2** |

If **one** of the monomers used to form the polymer above is changed, this allows for the possibility of crosslinks to form between polymer strands, as shown in the diagram below.



(c) Define ‘crosslinking’. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The formation of (usually) covalent bonds between polymer chains.** | **1** |
| **Total** | **1** |

The crosslinked polymer shown above has different physical properties when compared to the original polymer. Namely, it has;

* a much higher melting point, and
* a higher physical strength.

(d) Choose one (1) of these altered properties, and describe how crosslinking can result in this change to the polymer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Higher melting point:** |  |
| **The crosslinked polymer chains have a much greater molecular mass (M) / The crosslinks result in formation of a polymer network.** | **1** |
| **This increases the strength of intermolecular forces (resulting in an increased melting point) / This results in a greater amount of heat required to melt the polymer (which may in fact char before melting).** | **1** |
| **Total** | **2** |

**or**

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Higher physical strength:** |  |
| **The crosslinked polymer chains have a decreased ability to slide past each other / The crosslinks result in a polymer network.** | **1** |
| **This enables the polymer to withstand a greater application of force (resulting in an increased physical strength) / This results in a more rigid and strong polymer structure.** | **1** |
| **Total** | **2** |

(e) Draw a structural diagram and give the name for the **new** monomer that has been used to form this crosslinking polymer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Structure:** | **1** |
| **Name: glycerol / propane-1,2,3-triol** | **1** |
| **Total** | **2** |

**Section Three: Extended answer 40% (94 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

**Question 35 (24 marks)**

The two major uses of chromium metal are in the production of stainless steel and electroplating. Many objects such as tools, musical instruments, car parts and kitchen utensils are commonly plated in chromium metal. Chrome plating can be done for decorative reasons, or to improve the surface hardness or corrosion resistance of the object.

The following series of equations shows how chromium(III) oxide can be extracted from chromite ore, and then dissolved in an acidic solution to ready it for use in chrome plating.

**Step 1:** Chromite (FeCr2O4) is first roasted in the presence of oxygen gas and excess sodium carbonate, to form sodium chromate (Na2CrO4).

4 FeCr2O4(s) + 8 Na2CO3(s) + 7 O2(g) → 8 Na2CrO4(s) + 2 Fe2O3(s) + 8 CO2(g)

**Step 2:** The sodium chromate is then converted to sodium dichromate (Na2Cr2O7). This is the most important chromium-containing species, from which many other chromium compounds can be synthesised.

2 Na2CrO4(s) + H2SO4(aq) → Na2Cr2O7(aq) + Na2SO4(aq) + H2O(l)

**Step 3:** The sodium dichromate solution is concentrated by evaporation, and then heated in the presence of charcoal to produce chromium(III) oxide.

Na2Cr2O7(s) + 2 C(s) → Cr2O3(s) + Na2CO3(s) + CO(g)

**Step 4:** Chromium(III) oxide is dissolved in sulfuric acid to produce a solution containing chromium(III) ions. This solution is then used for chrome plating.

Cr2O3(s) + 6 H+(aq) → 2 Cr3+(aq) + 3 H2O(l)

A 3.21 tonne sample of FeCr2O4 was processed and placed into a 1500 kL reaction chamber. An excess of solid Na2CO3 was added, and the temperature of the chamber was maintained at 1100 °C. Oxygen gas was then pumped into the reaction chamber. The pressure was measured to determine when enough O2(g) had been added.

(a) Calculate the minimum pressure that would need to be exerted by the O2(g) in the reaction chamber, to ensure sufficient O2(g) was present for all the chromite to react. State your answer to the appropriate number of significant figures. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(FeCr2O4) = 3.21 x 106 / 223.85**  **= 14 339.96 mol** | **1** |
| **n(O2) = 7/4 x n(FeCr2O4)**  **= 25 094.93 mol** | **1** |
| **P(O2) = (25 094.93 x 8.314 x 1373.15) / (1500 x 103)**  **= 190.995 kPa** | **1** |
| **= 191 kPa (correct to 3 significant figures)** | **1** |
| **Correct conversions, t → g, kL → L, °C → K** | **1** |
| **Total** | **5** |

If the combined yield of Step 1 and Step 2 is 68.9%;

(b) Calculate the mass of Na2Cr2O7(s) produced. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Correct theoretical stoichiometric ratio of n(Na2Cr2O7) = n(FeCr2O4)** | **1** |
| **n(Na2Cr2O7) = n(FeCr2O4) x 68.9/100** | **1** |
| **= 14 339.96 x 68.9/100**  **= 9 880.23 mol** | **1** |
| **m(Na2Cr2O7) = 9 880.23 x 261.98**  **= 2 588 423 g (2.59 x 106 g or 2.59 t)** | **1** |
| **Total** | **4** |

If 1.28 tonnes of Cr2O3(s) was produced;

(c) Calculate the percentage yield of Step 3. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(Cr2O3 theor.) = n(Na2Cr2O7)**  **= 9 880.23 mol** | **1** |
| **m(Cr2O3 theor.) = 9 880.23 x 152**  **= 1 501 795 g (1.502 x 106 g or 1.502 t)** | **1** |
| **% yield = 1.28 / 1.502 x 100**  **= 85.2 %** | **1** |
| **Total** | **3** |
| **Alternate method:**  **n(Cr2O3 actual) = 1.28 x 106 / 152**  **= 8 421.053 mol**  **% yield = 8 421.053 / 9 880.23 x 100**  **= 85.2 %** |  |

The entire 1.28 tonnes of Cr2O3(s) was then dissolved in concentrated excess H2SO4(aq), as shown in Step 4. The final volume of this solution was 3500 L.

(d) Calculate the concentration of Cr3+(aq) ions, in **grams per litre**, in the final solution.

(4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(Cr2O3 actual) = 1.28 x 106 / 152**  **= 8 421.053 mol** | **1** |
| **n(Cr3+) = 2 x n(Cr2O3)**  **= 16 842.105 mol** | **1** |
| **c(Cr3+) = 16 842.105 / 3500**  **= 4.812 mol L-1** | **1** |
| **c(Cr3+) = 4.812 x 52**  **= 250.2 g L-1** | **1** |
| **Total** | **4** |
| **Alternate method for final two steps:**  **m(Cr3+) = 16 842.105 x 52**  **= 875 789 g**  **c(Cr3+) = 875 789 / 3500**  **= 250.2 g L-1** |  |

This solution containing Cr3+(aq) was then prepared for use as an electrolyte in a cell set up for chrome plating. The electrolytic cell had been designed to electroplate car parts, such as door handles, alloy wheels and bumper bars, with chromium metal.

(e) What is an electrolytic cell? (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **One of the following:** |  |
| * **cell that uses an external power source that** * **cell which converts electrical energy to chemical energy and** | **1** |
| **with either of:** |  |
| * **drives a non-spontaneous redox reaction** * **causes a redox reaction with a negative EMF to occur** | **1** |
| **Total** | **2** |

The electroplating cell consisted of a tank with a 850 L capacity. A sample of the hot (approximately 50 °C) solution containing Cr3+(aq) ions was obtained for use as the electrolyte.

The cell was to be set up **under standard conditions** so that the data on the standard reduction potential table would be relevant.

(f) Describe how the electrolyte solution for this cell could be prepared to standard conditions, using the Cr3+(aq) solution. Your answer should include appropriate calculations. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(Cr3+ required) = 1 x 850**  **= 850 mol** | **1** |
| **V(Cr3+ required) = 850 / 4.812**  **= 176.64 L** | **1** |
| **Add 177 L of Cr3+ solution to tank, fill to 850 L with water** | **1** |
| **Cool solution to final temperature of 25 °C** | **1** |
| **Total** | **4** |
| **Alternate calculation method for two marks:**  **V1 = c2V2 / c1**  **= 1 x 850 / 4.812**  **= 176.64 L**  **Note: award follow through marks for correct working based on incorrect initial Cr3+(aq) concentration from part (d).** |  |

A partially completed sketch representing the electrolytic cell that was used for the chrome plating is shown below. Assume the cell was going to be used to apply a layer of chromium to a car door handle.

– +

(g) Add to this diagram by labelling; (2 marks)

* where you would connect the inert graphite electrode,
* where you would connect the car door handle, and
* the direction of electron flow.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Door handle on left (-)**  **Graphite on right (+)** | **1** |
| **Direction of electron flow label** | **1** |
| **Total** | **2** |
| **Example of a three mark response:**  – +  electrons  door handle  graphite electrode |  |

**Question 36 (16 marks)**

Gumbi-gumbi (scientific name: *Pittosprum angustifolium*) is a small tree native to Australia. It is traditionally used in Aboriginal medicine to treat coughs, colds and eczema. Gumbi-gumbi leaves can be used, either fresh or dried, to make a tea drink. In addition to their antibacterial, antifungal, antiviral and antioxidant properties, gumbi-gumbi leaves are known to have very high levels of ascorbic acid.

Ascorbic acid is also known by the common name ‘Vitamin C’. It is a weak, monoprotic acid with molecular formula C6H8O6.

A 30.0 g sample of dried gumbi-gumbi leaves was ground into a fine powder and then soaked for 2 hours in hot water, to ensure all the Vitamin C had dissolved.

Once the gumbi-gumbi solution had cooled it was filtered, made up to 25.00 mL, and transferred to a conical flask. The sample was then titrated against 0.01118 mol L-1 NaOH(aq) and required 18.28 mL to reach equivalence. The titration reaction can be represented by the chemical equation below.

C6H8O6(aq) + NaOH(aq) → NaC6H7O6(aq) + H2O(l)

(a) Select an appropriate indicator from the table below for use in this titration. Justify your indicator choice, including a relevant chemical equation in your answer. (3 marks)

|  |  |
| --- | --- |
| **Indicator** | **End point pH range** |
| chlorophenol red | 4.8 - 6.4 |
| thymol blue | 8.0 - 9.6 |
| brilliant yellow | 6.6 - 7.8 |
| bromophenol blue | 3.0 - 4.6 |

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Thymol blue** | **1** |
| **Basic solution at equivalence due to hydrolysis of C6H7O6- (ascorbate ions)** | **1** |
| **Balanced equation** | **1** |
| **Total** | **3** |
| **Example of correct equation:**  **C6H7O6-(aq) + H2O(l) ⇌ C6H8O6(aq) + OH-(aq)** | |

(b) Calculate the concentration of Vitamin C in the dried gumbi-gumbi leaves, expressing your final answer as ‘**mg of Vitamin C per 100 g gumbi-gumbi leaves**’.

(You may assume the ascorbic acid was the only acidic substance present in the leaves.) (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(NaOH) = 0.01118 x 0.01828**  **= 0.00020437 mol** | **1** |
| **n(C6H8O6) = n(NaOH)**  **= 0.00020437 mol** | **1** |
| **m(C6H8O6) = 0.00020437 x 176.124**  **= 0.0359945 g** | **1** |
| **= 35.9945 mg (in 25 mL / in 30 g)** | **1** |
| **m(C6H8O6 in 100 g) = 35.9945 x 100/30**  **= 119.98 mg**  **= 120 mg** | **1** |
| **Total** | **5** |

**The concentration is: 120 mg of Vitamin C per 100 g gumbi-gumbi leaves**

In addition to its acidic properties, ascorbic acid (Vitamin C) also has hydroxyl (–OH) groups, allowing it to react as an alcohol to form an ester. For example, it can react with palmitic acid to form the ester ‘ascorbyl palmitate’, which is shown below.



(c) Draw structural formulas for both ascorbic and palmitic acid. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Ascorbic acid:** | **1** |
| **Palmitic acid:**    **or**  **CH3(CH2)14COOH** | **1** |
| **Total** | **2** |

Ascorbic acid (Vitamin C) is highly soluble in water. However, ascorbyl palmitate is referred to as a ‘fat-soluble form of Vitamin C’, and is often used as an antioxidant food additive.

(d) Explain, in terms of intermolecular forces, why ascorbic acid is a water-soluble vitamin but ascorbyl palmitate is a fat-soluble vitamin. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Water and ascorbic acid both exhibit hydrogen bonding as their predominant intermolecular interaction.** | **1** |
| **Thus new hydrogen bonds (as well as dipole-dipole and dispersion forces) are able to form between water and ascorbic acid.** | **1** |
| **These new hydrogen bonds (and dipole-dipole and dispersion forces) are sufficient in strength to disrupt / release sufficient energy to overcome the existing intermolecular forces within both water and ascorbic acid (and therefore they are soluble).** | **1** |
| **The large non-polar region (and greater size) of ascorbyl palmitate, means it interacts predominantly through dispersion forces.** | **1** |
| **Fats are also non-polar / interact largely through dispersion forces, and** | **1** |
| **therefore the new dispersion forces formed between fat and ascorbyl palmitate are sufficient in strength to disrupt / release sufficient energy to overcome the existing intermolecular forces within both fat and ascorbyl palmitate (and therefore they are soluble).** | **1** |
| **Total** | **6** |

**Question 37 (17 marks)**

The Contact Process is used to manufacture sulfuric acid. There are several steps involved in this process, but the key equilibrium reaction involves the conversion of sulfur dioxide to sulfur trioxide, as shown in the reversible reaction below.

2 SO2(g) + O2(g) ⇌ 2 SO3(g) + heat

This reaction takes place in the presence of an appropriate catalyst. The reaction chamber is maintained at a temperature of around 450 °C and a pressure of between 1 - 2 atm.

The graph below shows the results of a small-scale simulation of this equilibrium process.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

O2

SO2

SO3

l l l l l l

0 E1 T1 E2 T2 E3

Time

Partial pressure (kPa)

Consider the processes occurring between Time 0, when the reactants are introduced, and Time E1, when equilibrium is established for the first time.

(a) Describe what is happening to both the forward and reverse reaction rates from Time 0 to Time E1. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Decrease in forward reaction rate.** | **1** |
| **Increase in reverse reaction rate.** | **1** |
| **At time E1 the forward and reverse reaction rates become equal.** | **1** |
| **Total** | **3** |

(b) Complete the table below, by stating how the pressure and temperature of the system are different at Time E1, compared to Time 0. Justify each of your choices. (4 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| **Pressure** | |  |
| **Conditions** | **decreased (circled)** | **1** |
| **Justification** | **3 : 2 molar ratio of gaseous reactants : products** | **1** |
| **Temperature** | |  |
| **Conditions** | **increased (circled)** | **1** |
| **Justification** | **forward reaction is exothermic** | **1** |
| **Total** | | **4** |

At Time T1, the temperature of the system was decreased from 450 °C to 300 °C. This results in an increased yield of sulfur trioxide.

(c) Explain, in terms of the collision theory, why the actual temperature used in the Contact Process is not lowered to 300 °C. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **A lower temperature would:** |  |
| **Decrease the frequency of collisions, and** | **1** |
| **decrease the average kinetic energy of the reacting particles.** | **1** |
| **This would result in a lower proportion of particles able to react / overcome the activation energy barrier,** | **1** |
| **therefore the reaction rate would decrease to non-viable levels.** | **1** |
| **Total** | **4** |

Consider the change imposed on the system at Time T2.

(d) State the change that was imposed, and justify why the system would temporarily be classified as an ‘open system’. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Removal of SO3(g).** | **1** |
| **Matter being removed from the system (therefore classified as open).** | **1** |
| **Total** | **2** |

Consider the various changes made throughout this simulation, and any effect they would have had on the value of the equilibrium constant (Kc).

(e) State when (i.e. at Time E1, E2 or E3) the value of Kc would have been highest and when it would have been lowest. Justify your answers. (4 marks)

(Note: calculations of Kc values are not required.)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Equal highest at E2 and E3.** | **1** |
| **Lowest at E1.** | **1** |
| **After E1, the temperature is decreased, which favours the forward reaction / increases the yield, and increases the value of K.** | **1** |
| **After E2, there are no imposed changes that would affect the value of K.** | **1** |
| **Total** | **4** |

**Question 38 (17 marks)**

A chemist was preparing a solution of sodium hydroxide for use in a saponification reaction. They began by dissolving 160.0 g of NaOH(s) into 500.0 mL of water. The chemist then decided to titrate the NaOH(aq) to determine the standardised concentration of the solution.

A standard solution of 0.2074 mol L-1 oxalic acid, H2C2O4(aq), was available for use. Oxalic acid is a weak, diprotic acid. The chemist placed a 20.00 mL aliquot of the H2C2O4(aq) into a conical flask.

The equation for the titration reaction is;

2 NaOH(aq) + H2C2O4(aq) → Na2C2O4(aq) + 2 H2O(l)

Before pouring the NaOH(aq) into the burette, the chemist needed to first dilute this solution. The glassware available to perform this dilution was;

* a 25.00 mL pipette
* a 250.0 mL volumetric flask
* a 500.0 mL volumetric flask
* a 1000 mL volumetric flask

(a) State which two (2) pieces of glassware the chemist should use to perform the NaOH(aq) dilution. Justify your answer using appropriate calculations. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Approximate concentration of base** |  |
| **n(NaOH) = 160 / 39.998**  **= 4.0002 mol** | **1** |
| **c(NaOH) = 4.0002 / 0.5**  **= 8.0004 mol L-1** | **1** |
| **Moles of acid present in 20 mL** |  |
| **n(H2C2O4) = 0.2074 x 0.020**  **= 0.004148 mol** | **1** |
| **Approximate requirements for an equivalent titre volume (~20 mL)** |  |
| **n(NaOH required) = 2 x n(H2C2O4)**  **= 0.008296 mol** | **1** |
| **c(NaOH required) = 0.008296 / 0.020**  **= 0.4148 mol L-1** | **1** |
| **Dilution factor required = 8.0004 / 0.4148 ≈ 20 fold** | **1** |
| **Use 25 mL pipette and 500 mL volumetric flask** | **1** |
| **Total** | **7** |
| **Note:**  **Award equivalent marks for alternate working, including partly ‘worded’ justifications such as “conical flask aliquot and average titre should be approximately the same volumes, therefore the concentration of base would need to be approximately double the concentration of acid” etc** | |

Upon completion of the titration, the chemist was able to determine that the original **undiluted** NaOH(aq) solution had a concentration of 7.86 mol L-1.

The chemist then used the sodium hydroxide solution and some jojoba oil in a saponification reaction, to make a small batch of soap.

First, they adjusted the pH of the sodium hydroxide solution slightly, by mixing 380 mL of the 7.86 mol L-1 NaOH(aq) with 110 mL of distilled water.

(b) Calculate the resulting pH of the sodium hydroxide solution. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(NaOH) = 7.86 x 0.380**  **= 2.9868 mol** | **1** |
| **c(NaOH final) = 2.9868 / 0.490**  **= 6.09551 mol L-1** | **1** |
| **[H+] = (1.0 x 10-14) / 6.09551**  **= 1.64055 x 10-15 mol L-1** | **1** |
| **pH = - log (1.64055 x 10-15)**  **= 14.785 (14.8)** | **1** |
| **Total** | **4** |

The resultant NaOH(aq) was then mixed with jojoba oil and heated. The structure of the soap produced in the saponification reaction is shown below.

CH3 – (CH2)7 – CH = CH – (CH2)9 – COO- Na+

(c) Draw a structural diagram of the triglyceride found in jojoba oil. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Glycerol backbone (accept full or semi structural)** | **1** |
| **Three identical fatty acids (accept full or semi structural)** | **1** |
| **Total** | **2** |
| **Example of a two mark response:**  CH3 – (CH2)7 – CH = CH – (CH2)9 – COOCH2  l  CH3 – (CH2)7 – CH = CH – (CH2)9 – COOCH  l  CH3 – (CH2)7 – CH = CH – (CH2)9 – COOCH2 | |
| **Note:**  **one mark may be allocated if there is only one minor error**  **e.g. one H atom missing, one subscript error in fatty acid formula, etc** | |

(d) Draw the chemical structure of the scum that would form if this soap was used in hard water. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Both ions in formula correct (accept Ca2+/ Mg2+/ Fe2+)** | **1** |
| **Correct subscript (i.e. 2) for soap anion** | **1** |
| **Total** | **2** |
| **Example of a two mark response:**  **Ca(CH3(CH2)7CH=CH(CH2)9COO)2** | |
| **Note:**  **one mark may be allocated if there is only one minor error**  **e.g. one subscript error in fatty acid formula, etc** | |

(e) Draw a structural diagram for an anionic detergent with the same number of carbon atoms as the soap. Assume the detergent is an ‘alkylbenzene sulfonate’. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Benzene ring and sulfonate group (accept full or semi structural)** | **1** |
| **Alkyl group with 14 carbons (accept full or semi structural)** | **1** |
| **Total** | **2** |
| **Example of a two mark response:** | |
| **Note:**  **one mark may be allocated if there is only one minor error**  **e.g. charge missing from sulfonate group, etc** | |

**Question 39 (20 marks)**

Benzoic acid is a colourless crystalline solid, which is often used as a food preservative. It is also found in relatively high amounts in fruit such as blueberries, cranberries and cherries.

Consider the reaction sequence below, which summarises the conversion of phenol to benzoic acid, through the intermediates of benzene and toluene.



+ Zn

+ CH3Cl

+ KMnO4

Phenol Benzene Toluene Benzoic acid

(C6H6O) (C6H6) (C7H8) (C7H­6O2)

In the first step of the reaction sequence, phenol is reacted with zinc dust, to produce benzene and zinc oxide residue, as shown in the chemical equation below.

C6H6O(l) + Zn(s) → C6H6(l) + ZnO(s)

(a) Demonstrate that this is a redox reaction, using oxidation numbers to support your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Zinc is oxidised, oxidation number changes from (0) to (+2)** | **1** |
| **Carbon is reduced, oxidation number changes from (-2/3) to (-1)** | **1** |
| **Total** | **2** |

In the second step, benzene is converted to toluene by the addition of chloromethane, CH3Cl.

(b) Predict the substance formed, in addition to toluene. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **HCl / hydrochloric acid / hydrogen chloride** | **1** |
| **Total** | **1** |

In the last step of the reaction sequence, toluene reacts with potassium permanganate solution to form benzoic acid. This reaction also produces solid manganese(IV) oxide, MnO2.

(c) Write the oxidation and reduction half-equations and overall redox reaction for this process, assuming acidic conditions. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Correctly identifying which half-equation is oxidation and which is reduction** | **1** |
| **Oxidation half-equation:** |  |
| **Correct reactants and products** | **1** |
| **Correct balancing** | **1** |
| **Example of a two mark response:**  CH3  COOH  + 2H2O(l) → + 6H+(aq) + 6e-  **or**  **C7H8(l) + 2H2O(l) → C7H6O2(aq) + 6H+(aq) + 6e-** |  |
| **Reduction half-equation:** |  |
| **Correct reactants and products** | **1** |
| **Correct balancing** | **1** |
| **Example of a two mark response:**  **MnO4-(aq) + 4H+(aq) + 3e- → MnO2(s) + 2H2O(l)** |  |
| **Overall equation:** |  |
| **Correctly written and balanced equation** | **1** |
| **Example of correct equation:**  CH3  COOH  + 2MnO4-(aq) + 2H+(aq) → + 2MnO2(s) + 2H2O(l)  **or**  **C7H8(l) + 2MnO4-(aq) + 2H+(aq) → C7H6O2(aq) + 2MnO2(s) + 2H2O(l)** |  |
| **Total** | **6** |

Combustion analysis was performed on a sample of **one** of the organic compounds in the original reaction sequence (i.e. phenol, benzene, toluene or benzoic acid).

A 0.6789 g sample of the compound was combusted and, at 168 kPa and 215 °C, produced 1.905 g of carbon dioxide gas and 522.8 mL of water vapour.

(d) Determine the empirical formula of this compound and thereby identify it. (9 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Calculating moles and mass of C** | **2** |
| **Calculating moles and mass of H** | **2** |
| **Calculating moles and mass of O** | **2** |
| **Determining simplest ratio by dividing all by smallest moles** | **1** |
| **Writing empirical formula C6H6O** | **1** |
| **Stating compound is ‘phenol’** | **1** |
| **Total** | **9** |
| **Example of a nine mark response:**   |  |  |  |  | | --- | --- | --- | --- | |  | **C** | **H** | **O** | | **mass (g)** | **(12.01 / 44.01) x 1.905**  **= 0.5199** | **0.04328 x 1.008**  **= 0.04363** | **0.6789 – (0.51986 + 0.043629)**  **= 0.1154** | | **moles (mol)** | **0.5199 / 12.01**  **= 0.04329** | **2x [(168 x 0.5228) /(8.314 x 488.15)]**  **= 0.04328** | **0.1154 / 16.00**  **= 0.007213** | | **ratio** | **0.04329 / 0.007213 = 6.001** | **0.04328 / 0.007213 = 6.000** | **0.007213 / 0.007213 = 1.000** | | **6** | **6** | **1** |   **Empirical formula is C6H6O. The identity of the compound is phenol.** |  |
| **Note:**  **If mass/moles of oxygen not determined and benzene (C6H6) is given as answer, award a maximum of 6 marks.** |  |

In the human body, benzoic acid reacts with the -amino acid glycine, to form hippuric acid. The hippuric acid is then excreted in urine.

To form the hippuric acid, benzoic acid and glycine react and are joined by an amide bond (amide link). This reaction also produces a molecule of water.

(e) Draw the chemical structure of hippuric acid. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Structure of benzoic ‘half’ without -OH group (accept full or semi structural)** | **1** |
| **Structure of glycine ‘half’ without -H group (accept full or semi structural)** | **1** |
| **Total** | **2** |
| **Example of a two mark response:** | |
| **Note:**  **one mark may be allocated if there is only one minor error** | |