**CHEMISTRY 12**

**Task 15 - Semester 2 Examination**

**2021**

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MARKING KEY FOR SEMESTER EXAM

Teachers: O McClements & A Hua

# 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 (blue/black preferred), pencils (including coloured), sharpener,

eraser, correction tape/fluid, ruler, highlighters

Special items: up to three non-programmable calculators approved for use in the WACE examinations

# 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 | 10 | 10 | 60 | / 81 | / 35 |
| Section Three:  Extended answer | 5 | 5 | 70 | / 91 | / 40 |
|  | | | | | / 100 |

**Instructions to candidates**

1. Answer the questions according to the following instructions.

Section One: 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.

Sections Two and Three: Write your answers in this Question/Answer Booklet.

2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

* + Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
  + Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

5. The Chemistry Data Book is **not** handed in with your Question/Answer Booklet.

**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 a chemical reaction with the following characteristics.

1. The reaction is exothermic.
2. The reaction occurs spontaneously at room temperature.
3. The reaction is very difficult to reverse.

Which energy profile diagram most accurately represents this reaction? Assume the scale on each set of axes is identical.

1. (b)

Reaction progress

Enthalpy

Reaction progress

Enthalpy

1. **(d)**

Reaction progress

Enthalpy

Reaction progress

Enthalpy

2. Which of the following ranks the compounds in order of increasing oxidation state for chlorine?

1. **NH4Cl HClO3 Cl2O7**
2. HClO3 Cl2O7 NH4Cl
3. Cl2O7 HClO3 NH4Cl
4. NH4Cl Cl2O7 HClO3

3. Consider the following organic compound.



The correct IUPAC name for this substance is

1. 1-amino-4-chloro-3-ethylhexanal.
2. **4-chloro-3-ethylhexanamide.**
3. 3-ethyl-4-chlorohexanamide.
4. 1-amino-3-ethyl-4-chlorohexanal.

**Questions 4 and 5 refer to the following equilibrium system.**

A sample of liquid dinitrogen trioxide, N2O3, is placed in a sealed glass tube where the temperature of the system is maintained at -15 °C. The N2O3 begins to decompose and eventually establishes equilibrium, as shown in the chemical equation below.

N2O3(l) ⇌ NO(g) + NO2(g)

The following rate graph illustrates the establishment of equilibrium in this system at Time E1.

reaction rate

forward

reverse

l

E1 Time

4. Which of the following statements is **not** correct?

(a) Before Time E1, the forward reaction rate is decreasing.

(b) Before Time E1, the forward reaction rate is faster than the reverse reaction rate.

**(c) At Time E1, the forward and reverse reaction rates both become zero.**

(d) At Time E1, the forward and reverse reaction rates become equal.

5. At Time E1, the NO(g) and NO2(g) present in the system would **not** have the same

1. number of moles.
2. **mass.**
3. partial pressure.
4. concentration.

6. Three separate test tubes contain three different 0.5 mol L-1 aqueous salts. Several drops of universal indicator were added to each test tube; one turned pink, one turned green and one turned blue.

Which of the following lists three solutions that would produce these observations?

**pink green blue**

1. KNO3 Na2SO4 CaCO3
2. **NaHSO4 KCl LiF**
3. NH4Cl Mg(NO3)2 NaH2PO4
4. LiHCO3 CaF2 BaCl2

7. A piece of silver-coloured metal was placed into a beaker containing nickel chloride solution. Over time, the green colour of the solution faded. The identity of the metal is

1. silver.
2. chromium.
3. tin.
4. **zinc.**

8. Consider the segment of polypeptide shown below.



Bonds contributing to the secondary structure of this protein could form between sites

1. A and C.
2. B and F.
3. A and E.
4. **D and F.**

**Questions 9 and 10 refer to the following equilibrium system.**

Consider the following chemical reaction that has been allowed to establish equilibrium in a closed system.

Cl2(g) + F2(g) ⇌ 2 ClF(g) + 113 kJ

Two different changes were imposed on the system at Time T1 and T2. In each case the system was allowed to re-establish equilibrium. The graph below illustrates the changes that occurred in the system.

Partial pressure (kPa)

l l l l

T1 E1 T2 E2 Time

ClF(g)

F2(g)

Cl2(g)

9. Identify the changes imposed on the system at Times T1 and T2.

**T1 T2**

1. increased volume increased temperature
2. increased volume decreased temperature
3. **decreased volume increased temperature**
4. decreased volume decreased temperature

10. Compare the rate of forward reaction and the value of the equilibrium constant at Time E1 and Time E2. Which of the following correctly describes these characteristics at Time E2?

**Rate of forward reaction Value of Kc**

1. higher than E1 higher than E1
2. **higher than E1 lower than E1**
3. lower than E1 higher than E1
4. lower than E1 lower than E1

11. Which of the following are weak, monoprotic acids?

1. CH3COOH(aq)
2. HF(aq)
3. H2C2O4(aq)
4. HCl(aq)
5. NH3(aq)
6. **(i) and (ii) only.**
7. (ii) and (iv) only.
8. (i) and (v) only.
9. (iii) and (iv) only.

12. Consider the reaction represented by the chemical equation below.

2 Cu(CN)32-(aq) + 6 H+(aq) + S2-(aq) ⇌ Cu2S(s) + 6 HCN(aq)

The equilibrium constant expression for this reaction is

[Cu(CN)32-]2 [H+]6 [S2-]

[HCN]6

[Cu2S] [HCN]6

[Cu(CN)32-]2 [H+]6 [S2-]

[HCN]6

[Cu(CN)3]2- [H]+ [S]2-

[HCN]6

[Cu(CN)32-]2 [H+]6 [S2-]

K =

K =

K =

K =



13. Consider the industrial conditions used in the Haber process during the manufacture of ammonia. Which of the following reaction conditions presents a conflict between the rate of reaction and the equilibrium yield of ammonia?

1. high concentration of reactants
2. high pressure
3. **high temperature**
4. addition of an Fe3O4 catalyst

14. Identify the strongest reducing agent.

(a) F2(g)

(b) F-(aq)

(c) K+(aq)

**(d) K(s)**

15. The following chemical equation represents the autoionisation of water.

2 H2O(l) + heat ⇌ H3O+(aq) + OH-(aq)

As a sample of pure water is cooled from 25 °C to 4 °C, the

1. concentration of H3O+(aq) increases.
2. concentration of OH-(aq) increases.
3. **pH increases.**

(d) value of Kw increases.

16. Consider the incomplete series of equations below, representing the chemical reactions occurring in the Contact process.

S(l) + O2(g) → **X**(g)

**X**(g) + O2(g) ⇌ **Y**(g)

**Y**(g) + H2SO4(l) → **Z**(l)

**Z**(l) + H2O(l) → 2 H2SO4(aq)

Identify the substances represented by X, Y and Z.

**X Y Z**

1. **SO2 SO3 H2S2O7**
2. SO3 S7O2 H2SO4
3. SO2 SO3 H2SO4
4. SO3 S7O2 H2S2O7

**Questions 17 and 18 refer to atmospheric carbon dioxide levels.**

An increased level of atmospheric CO2(g) is resulting in various negative environmental consequences.

17. Which of the following environmental impacts is **not** caused by an increase in atmospheric CO2(g)?

1. **deforestation**
2. global warming
3. ocean acidification
4. rising sea levels

Due to the Covid-19 pandemic, the level of global CO2(g) emissions was reduced by 6% in 2020.

18. Which of the following sources is **least** likely to have contributed to this fall in CO2(g) emissions?

1. the aviation industry
2. cars, trucks, and other vehicles
3. commercial electricity
4. **residential electricity**

19. The diagram below represents the molecular structure of a segment of the polymer named poly-3-hydroxyvalerate (PHV).

****

Identify the PHV monomer(s).





20. The chemical equation below shows the combustion of butane in a limited oxygen supply.

C4H10(l) + 4 O2(g) → 3 CO(g) + C(s) + 5 H2O(g)

Identify the correct statement.

1. **Carbon atoms are oxidised.**
2. Carbon atoms are reduced.
3. Some carbon atoms are oxidised whilst others are reduced.
4. Oxygen atoms are oxidised.

**Questions 21 and 22 refer to the galvanic cell below.**

The following cell was set up under standard conditions.

V

Cu(NO3)2(aq)

Cu

Pb

Pb(NO3)2(aq)

**X**

**Y**

21. Correctly identify X and Y, as labelled in the diagram above.

**X Y**

1. anode anion movement
2. **anode cation movement**
3. cathode anion movement
4. cathode cation movement

22. Which of the following changes to the cell above, would result in a greater EMF being produced? Assume all changes maintain standard conditions.

(a) Change the Pb/Pb2+ half-cell to Ag/Ag+.

(b) Change the Cu/Cu2+ half-cell to Fe/Fe2+.

**(c) Change the Cu/Cu2+ half-cell to Cr/Cr3+.**

(d) Change the Cu/Cu2+ half-cell to Co/Co2+.

23. When compared to high density polyethene, low density polyethene has

1. a higher melting point.
2. **lower tensile strength.**
3. stronger dispersion forces.
4. lower transparency.

24. Identify the conjugate base of glutamic acid. **(c)**





25. Which of the amino acids below would have the highest melting point?

(a) Alanine

(b) Glycine

**(c) Leucine**

(d) Valine.

**End of Section One**

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**CHEMISTRY**

**UNIT 3 + 4**

**2021**

**MARKING GUIDE**

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | a □ b □ c □ d ■ |  | 11 | a ■ b □ c □ d □ |  | 21 | a □ b ■ c □ d □ |
| 2 | a ■ b □ c □ d □ |  | 12 | a □ b □ c □ d ■ |  | 22 | a □ b □ c ■ d □ |
| 3 | a □ b ■ c □ d □ |  | 13 | a □ b □ c ■ d □ |  | 23 | a □ b ■ c □ d □ |
| 4 | a □ b □ c ■ d □ |  | 14 | a □ b □ c □ d ■ |  | 24 | a □ b □ c ■ d □ |
| 5 | a □ b ■ c □ d □ |  | 15 | a □ b □ c ■ d □ |  | 25 | a □ b □ c ■ d □ |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 6 | a □ b ■ c □ d □ |  | 16 | a ■ b □ c □ d □ |  |  |  |
| 7 | a □ b □ c □ d ■ |  | 17 | a ■ b □ c □ d □ |  |  |  |
| 8 | a □ b □ c □ d ■ |  | 18 | a □ b □ c □ d ■ |  |  | (1 mark per question) |
| 9 | a □ b □ c ■ d □ |  | 19 | a □ b □ c □ d ■ |  |  |  |
| 10 | a □ b ■ c □ d □ |  | 20 | a ■ b □ c □ d □ |  |  |  |

**Section Two: Short answer 35% (81 marks)**

**Question 26 (12 marks)**

A 0.7707 g sample of purified amino acid, containing only the elements carbon, hydrogen, oxygen and nitrogen, was analysed to determine its composition. When completely combusted, the water vapour collected at 122 kPa and 197 °C occupied a volume of 822.3 mL. The sample was also found to contain 0.2641 g of carbon. The percent by mass of nitrogen in the amino acid was known to be 13.33%.

(a) Determine the empirical formula of the amino acid. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Calculating moles of H** | **1** |
| **Calculating mass of H** | **1** |
| **Calculating mass of N** | **1** |
| **Calculating mass of O** | **1** |
| **Calculating moles of C/N/O** | **1** |
| **Determining simplest ratio by dividing all by moles of N** | **1** |
| **Writing empirical formula as C3H7NO3** | **1** |
| **Total** | **7** |
| **Example of a seven-mark response**  **n(H) = 2 x n(H2O) = (122 x 0.8223) / (8.314 x 470.15) = 0.05133 mol**  **m(H) = 0.05133 x 1.008 = 0.05174 g**   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **C** | **H** | **N** | **O** | | **mass (g)** | **0.2641** | **0.05174** | **(13.33/100) x 0.7707**  **= 0.10273** | **0.7707 – (0.2641 + 0.05174 + 0.10273)**  **= 0.35213** | | **moles (mol)** | **0.2641 / 12.01**  **= 0.02199** | **0.05133** | **0.10273 / 14.01**  **= 0.00733** | **0.35213 / 16.00**  **= 0.02201** | | **ratio** | **0.02199 / 0.00733 = 2.999** | **0.05133 / 0.00733 = 7.000** | **0.00733 / 0.00733 =**  **1** | **0.02201 / 0.00733 = 3.002** | | **3** | **7** | **1** | **3** |   **Empirical formula is C3H7NO3** | |

(b) If the molecular mass of the amino acid is 105.1 g mol-1, determine its identity. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **M(EF) = 105.096 g mol-1, therefore MF = EF** | **1** |
| **Serine** | **1** |
| **Total** | **2** |

(c) When the amino acid is dissolved in water, ion-dipole forces form. Draw a diagram illustrating the arrangement of these forces. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Serine (or other amino acid) drawn in zwitterion form** | **1** |
| **Correct orientation of water around positive charge** | **1** |
| **Correct orientation of water around negative charge** | **1** |
| **Total** | **3** |
| **Example of a three-mark response**  ion-dipole forces | |
| **Note:**  **Award mark for correct zwitterionic structure of any amino acid.** | |

**Question 27 (9 marks)**

Write balanced ionic equations for any reactions occurring between the following substances and describe the observation(s).

(a) A few drops of bromine water were added to a test tube containing sodium iodide solution, and the mixture was briefly shaken. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Equation**  **Br2(aq) + 2 I-(aq) → I2(aq) + 2 Br - (aq)** |  |
| **Correct species** | **1** |
| **Correct balancing** | **1** |
| **Observations**  **Orange and colourless solutions mix to form a brown solution.** | **1** |
| **Total** | **3** |
| **Note:**  **State symbols are not required for full marks.**  **Also accept formation of ‘purple solid’ as observation.** | |

(b) Excess nitric acid was poured over zinc carbonate powder. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Equation**  **ZnCO3(s) + 2 H+(aq) → Zn2+(aq) + CO2(g) + H2O(l)** |  |
| **Correct species** | **1** |
| **Correct balancing** | **1** |
| **Observations**  **White solid dissolves (to form a colourless solution) and a colourless (odourless) gas is produced / effervescence is observed.** | **1** |
| **Total** | **3** |
| **Note:**  **State symbols are not required for full marks.** | |

(c) A few drops of acidified sodium dichromate solution were added to a sample of propan-2-ol, and the mixture was gently warmed. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Equation**  **3 CH3CHOHCH3(l) + Cr2O72-(aq) + 8 H+(aq) → 3 CH3COCH3(aq) + 2 Cr3+(aq) + 7 H2O(l)** | |
| **Correct species** | **1** |
| **Correct balancing** | **1** |
| **Observations**  **Orange and colourless solutions mix to form a deep green solution.** | **1** |
| **Total** | **3** |
| **Note:**  **State symbols are not required for full marks.**  **Award one mark if a correctly balanced oxidation half-equation is given.** | |

**Question 28 (6 marks)**

A sealed glass vial contained the following gaseous equilibrium at room temperature. The appearance of the mixture was pale brown.

SO2(g) + NO2(g) ⇌ SO3(g) + NO(g)

*colourless brown colourless colourless*

Describe how you could experimentally determine whether this reaction, as written, is endothermic or exothermic. Include the observations that would allow you to reach this conclusion, and justify your answer using Le Chatelier’s principle.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Increase the temperature of the glass vial.** | **1** |
| **An increase in temperature will favour the endothermic direction in order to use up the heat / decrease the temperature.** | **1** |
| **If the mixture becomes darker brown then the reverse reaction is favoured.** | **1** |
| **Thus the equation is exothermic as written.** | **1** |
| **If the mixture becomes paler brown, then the forward reaction is favoured.** | **1** |
| **Thus the equation is endothermic as written.** | **1** |
| **Total** | **6** |
| **Alternate response:**   * **Decrease the temperature of the glass vial.** * **A decrease in temperature will favour the exothermic direction in order to produce more heat / increase the temperature.** * **If the mixture becomes darker brown, then the reverse reaction is favoured.** * **Thus the equation is endothermic as written.** * **If the mixture becomes paler brown, then the forward reaction is favoured.** * **Thus the equation is exothermic as written.** | |

**Question 29 (9 marks)**

Consider the information in the table below, regarding ethanoic acid and several of its derivatives.

|  |  |  |
| --- | --- | --- |
| Name | Formula | Ka at 25 °C |
| ethanoic acid | CH3COOH | 1.74 x 10-5 |
| chloroethanoic acid | CH2ClCOOH | 1.38 x 10-3 |
| dichloroethanoic acid | CHCl2COOH | 0.0513 |
| trichloroethanoic acid | CCl3COOH | 0.224 |

(a) Identify the strongest acid. Justify your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **CCl3COOH** | **1** |
| **It has the highest Ka value, indicating the ionisation of the acid occurs to the greatest extent.**  **or**  **It has the highest Ka value, indicating the highest ratio of product to reactant concentration.** | **1** |
| **Total** | **2** |
| **Note:**  **Do not accept ‘has the highest Ka value’ as only justification.** | |

Consider now, the potassium salts of each of these acids.

CH3COOK(aq) CH2ClCOOK(aq) CHCl2COOK(aq) CCl3COOK(aq)

Separate 0.1 mol L-1 aqueous samples of these salts each had three drops of cresol red indicator added to them. The endpoint of cresol red is pH 7.2 – 8.8 and the associated colour changes are shown in the diagram below.

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

pH

|  |  |
| --- | --- |
| yellow | purple |

Three of the salt solutions turned purple, whilst one turned yellow.

(b) Which salt solution is likely to have turned yellow? Justify your answer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **CCl3COOK** | **1** |
| **The stronger the acid, the weaker the conjugate base.**  **or**  **Anions derived from strong acids have little tendency to hydrolyse.** | **1** |
| **Therefore the pH is likely to be (the closest to) 7 and thus yellow.** | **1** |
| **Total** | **3** |

(c) Explain why the CH2ClCOOK(aq) solution turned purple. Use a relevant chemical equation to support your answer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The CH2ClCOO-(aq) ion hydrolyses with water to produce OH-(aq).** | **1** |
| **Therefore [OH-] > [H3O+] and solution will be basic / turn purple.** | **1** |
| **CH2ClCOO-(aq) + H2O(l) ⇌ CH2ClCOOH(aq) + OH-(aq)** | **1** |
| **Total** | **3** |
| **Note:**  **State symbols are not required for full marks.** | |

Cresol red indicator can exist as either of the two structures shown below.

Structure A Structure B



(d) When cresol red was added to the CH2ClCOOK(aq) solution, which of these would have been the predominant indicator structure present? (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Structure A (circled)** | **1** |
| **Total** | **1** |

**Question 30 (6 marks)**

The following equation represents the overall chemical process involved in the corrosion of iron.

4 Fe(s) + 3 O2(g) + 2 H2O(l) → 2 Fe2O3.H2O(s)

(a) Identify the oxidant and reductant in this process, using oxidation numbers to support your answer. (2 marks)

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | | | **Marks** |
| **Oxidant** | **O2(g)** | **(0) to (-2)** | **1** |
| **Reductant** | **Fe(s)** | **(0) to (+3)** | **1** |
| **Total** | | | **2** |
| **Note:**  **Award one mark if species and oxidation numbers are correct but answers have been given the wrong way around i.e. do not correspond to ‘oxidant’ and ‘reductant’.** | | | |

(b) Complete the following table, by giving a brief description of how each method results in a reduced rate of iron corrosion. (4 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| **Appling a coat of paint to a steel structure such as the Eiffel Tower.** | **Prevents oxygen and water from coming into contact with the iron.** | **1** |
| **Connecting the negative terminal of a DC power supply to an underground gas pipeline, and the positive terminal to a protective electrode.** | **Any two of the following;**   * **This method is called cathodic protection.** * **The pipeline is held at a negative potential which prevents oxidation.** * **The protective electrode is oxidised preferentially / oxidation occurs at the protective electrode.** | **2** |
| **Mixing small amounts of chromium with molten iron to produce ‘stainless steel’.** | **Alloying with other metals can change the properties of the iron (resulting in improved corrosion resistance).** | **1** |
| **Total** | | **4** |

**Question 31 (10 marks)**

Complete the table below, by drawing the structural formulae for the organic compounds that match each of the descriptions.

|  |  |  |
| --- | --- | --- |
|  | **Description** | **Marks** |
| The *cis* isomer of  4,5-difluoropent-2-ene. |  | **2** |
| The tertiary alcohol with molecular formula C5H12O. |  | **2** |
| The compound with IUPAC name ‘hexane-1,6-diamine’. |  | **2** |
| The organic compound produced from the oxidation of 2-methylpropanal by acidified permanganate solution. |  | **2** |
| The organic compound formed from the catalysed reaction between butan-1-ol and methanoic acid. |  | **2** |
|  | **Total** | **10** |
|  | **Note:**  **In each case, one mark may be awarded if structure includes minor error.**  **Accept either full or semi-structural formulae.** | |

**Question 32 (9 marks)**

Consider the following chemical reaction, which has been allowed to establish equilibrium in a closed system.

NH4OCONH2(s) + heat ⇌ 2 NH3(g) + CO2(g) Kc = 2.9 x 10-3 at 25 °C

(a) State how the following changes would affect the rate of the forward reaction, once equilibrium had been re-established. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| **Increasing the volume of the system.** | **decreased** | **1** |
| **Decreasing the temperature of the system.** | **decreased** | **1** |
| **Increasing the partial pressure of NH3(g).** | **increased** | **1** |
| **Total** | | **3** |

(b) State how the following changes would affect the position of equilibrium. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| **Increasing the state of subdivision of NH4OCONH2(s).** | **no change** | **1** |
| **Injecting CO2(g) into the system.** | **shift left** | **1** |
| **Increasing the volume of the system.** | **shift right** | **1** |
| **Total** | | **3** |

(c) State how the following changes would affect the value of Kc. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| **Increasing the partial pressure of NH3(g).** | **no change** | **1** |
| **Decreasing the temperature of the system.** | **decreased** | **1** |
| **Decreasing the volume of the system.** | **no change** | **1** |
| **Total** | | **3** |

**Question 33 (6 marks)**

Many brands of shampoo contain both citric acid (C6H8O7) and sodium citrate (NaC6H7O7). These ingredients produce a buffer with a pH of between 5.6 and 6.2, depending on the concentrations used. In shampoo, the purpose of this buffer is to counteract the basicity of the detergent ingredients present.

(a) Write an equation for the buffer that would be formed when a small amount of shampoo is mixed with water. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **C6H8O7(aq) + H2O(l) ⇌ C6H­7O7-(aq) + H3O+(aq)**  **or**  **C6H8O7(aq) + OH-(aq) ⇌ C6H­7O7-(aq) + H2O(l) \*** |  |
| **Correct species** | **1** |
| **Double arrow** | **1** |
| **Total** | **2** |
| **Note:**  **Do not award mark for ‘double arrow’ if equation is incorrect.**  **State symbols are not required for full marks.** | |

(b) Explain how this buffer maintains its mildly acidic pH, despite the presence of a small concentration of OH-(aq) being produced by the detergents in the shampoo. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The OH-(aq) neutralises and thereby decreases the [H3O+].** | **1** |
| **Both forward and reverse reaction rates decrease (due to a decreased frequency of collisions), but the forward rate does not decrease by as much.**  **or**  **The reverse reaction rate is decreased, relative to the forward reaction rate.** | **1** |
| **This results in the equilibrium position shifting to the right.**  **or**  **This results in the forward reaction being favoured.** | **1** |
| **The [H3O+] is thus increased, maintaining pH.** | **1** |
| **Total** | **4** |
| **Alternate response (if students have given buffer equation with OH-(aq) in part (a)\*):**   * **The increased concentration of OH-(aq) increases the frequency of collisions between the reactants.** * **The forward rate is increased, relative to the reverse reaction rate.** * **This results in the equilibrium position shifting to the right.** * **The [OH-] is thus decreased, maintaining pH.**   **Alternate response:**   * **The OH-(aq) will react with the conjugate acid buffer component (C6H8O7).** * **C6H8O7(aq) + OH-(aq) ⇌ C6H­7O7-(aq) + H2O(l)** * **The additional OH-(aq) is therefore neutralised, forming water.** * **Since the [H3O+] is restored to a similar level, the pH is maintained by the buffer.** | |

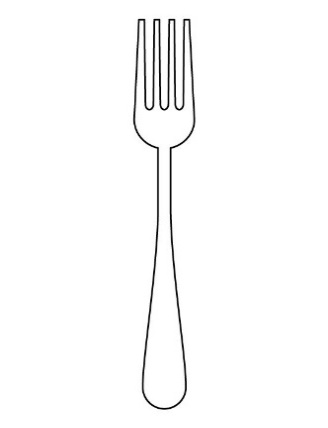
**Question 34 (8 marks)**

Hypophosphorus acid (H3PO2) is a weak, monoprotic acid. When it is mixed with silver nitrate solution, phosphonic acid (H3PO3) is formed, in addition to solid silver metal.

(a) Write balanced oxidation and reduction half-equations, as well as an overall equation for this chemical reaction. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Oxidation**  **H3PO2(aq) + H2O(l) → H3PO3(aq) + 2 H+(aq) + 2 e-** |  |
| **Correct species** | **1** |
| **Correct balancing** | **1** |
| **Reduction**  **Ag+(aq) + 1 e- → Ag(s)** |  |
| **Correct species and balancing** | **1** |
| **Overall**  **H3PO2(aq) + H2O(l) + 2 Ag+(aq) → H3PO3(aq) + 2 H+(aq) + 2 Ag(s)** |  |
| **Correct species** | **1** |
| **Correct balancing** | **1** |
| **Total** | **5** |
| **Note:**  **State symbols are not required for full marks.** | |

The silver produced by this reaction was collected and melted to form a solid silver electrode, which was then used as part of an electrolytic cell. The cell was used to silver-plate a fork, as shown in the diagram below.



fork

Ag+(aq)

silver

power source

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

* the direction of electron flow through the wire,
* the cathode and the anode, and
* the polarity (sign) of the electrodes.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Electron flow (right to left) labelled** | **1** |
| **Cathode (left) and anode (right) correctly labelled** | **1** |
| **Negative (left) and positive (right) correctly labelled** | **1** |
| **Total** | **3** |
| **Example of a three-mark response**  Cathode  ( – )  Anode  ( + )  ← electrons ←  power source | |
| **Note:**  **Award mark for labelling polarity either on electrodes or on power source.** | |

**Question 35 (6 marks)**

Sodium dodecyl sulfate (SDS) is an anionic detergent used in many cleaning products such as liquid hand wash. SDS can be represented by the formula CH3–(CH2)11–SO4- Na+.

One of the simple, yet effective ways that people can prevent transmission of the Covid-19 virus, is by frequently washing their hands. This process enables detergents such as SDS to destroy the virus particles, as illustrated in the diagram below.

SDS surfactant

spike protein

virus DNA

oily lipid molecules make up the cell membrane

surrounding aqueous environment

(a) Explain, in terms of intermolecular forces, how SDS is able to break apart and destroy these coronavirus particles. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **SDS has both a hydrophilic / polar head and a hydrophobic / non-polar tail.** | **1** |
| **Both the non-polar tail and the cell membrane interact (primarily) through dispersion forces.** | **1** |
| **The polar head is able to interact with the surrounding aqueous environment through ion-dipole forces.** | **1** |
| **This allows the SDS to embed in the cell membrane and disrupt / break apart the virus particles.** | **1** |
| **Total** | **4** |

(b) Explain why liquid hand wash containing SDS is equally effective in both hard and soft water. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **SDS will not precipitate / form a scum in hard water (as it is a detergent).** | **1** |
| **Therefore the surfactant ions will still be able to perform their cleaning function (equally well in both soft and hard water).** | **1** |
| **Total** | **2** |

**Section Three: Extended answer 40% (91 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 36 (20 marks)**

Polyethylene vinyl acetate (PEVA) is a copolymer made from the monomers ethylene and vinyl acetate. There are several different types of PEVA, and these differ in the relative amount of each monomer used in the polymerisation process. Some of the most common uses of PEVA are listed in the table below.

|  |
| --- |
| Uses of polyethylene vinyl acetate (PEVA) |
| * foam art and craft stickers * toys * shower curtains * soles of flip flops/thongs, slippers and other shoes * hockey pads * foam floor mats * mattress protectors * gloves |

(a) Considering the uses above, suggest three (3) physical properties that PEVA is likely to have. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Any three of the following:**   * **light weight** * **flexible** * **soft / squishy** * **durable** * **able to be coloured** * **moldable / easily shaped** * **waterproof / water repellant** | **3** |
| **Total** | **3** |

PEVA is produced by polymerising two monomers; ethylene and vinyl acetate. The table below provides information regarding the composition of the most common form of PEVA.

|  |  |  |
| --- | --- | --- |
|  | Monomer 1 | Monomer 2 |
| Name | Ethylene / Ethene | Vinyl acetate / Ethenyl ethanoate |
| Structure |  |  |
| Proportion of reaction mix | 28 – 33% | 67 – 72% |

(b) State whether PEVA is made by addition or condensation polymerisation. Justify your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Addition polymerisation.** | **1** |
| **Both monomers contain double carbon-carbon bonds / an alkene group.** | **1** |
| **Total** | **2** |

(c) Draw a segment of PEVA comprised of four (4) monomer units. Your diagram should take into account the percentage composition of the monomers. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  |  |
| **Polymer segment shows at least one unit of ethylene (monomer 1) drawn correctly** | **1** |
| **Polymer segment shows at least one unit of vinyl acetate (monomer 2) drawn correctly** | **1** |
| **Segment shows 4 units with a 1:3 ratio of ethylene:vinyl acetate** | **1** |
| **Total** | **3** |
| **Note:**  **Accept the four monomers joined and oriented in any order.**  **Marks not deducted for terminating ends or inclusion of brackets at ends.** | |

PEVA is a ‘thermoplastic’ polymer. This means it will soften when heated, and then harden again once cooled. However, the properties of PEVA can be greatly altered by crosslinking. Crosslinked-PEVA is classified as a ‘thermosetting’ polymer, which means it has been irreversibly hardened and will not melt, even at high temperatures.

(d) Describe why thermoplastic polymers are generally much easier to recycle than thermosetting polymers. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **When heated, the polymer will melt and can therefore be reshaped.** | **1** |
| **When cooled, the polymer hardens and can therefore been transformed into a new object.** | **1** |
| **Total** | **2** |

Crosslinked-PEVA is proving to be of great use in the manufacture of solar cells, due to its increased mechanical and thermal stability, as well as its optical transparency. It is stable, long lasting and prevents cracking and overstressing of the solar cells, as well as providing electrical insulation.

(e) Explain, in terms of structure and bonding, why crosslinked-PEVA is stronger and has a higher melting point, than regular PEVA . (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Crosslinking increases the size / length of the polymer chains.** | **1** |
| **This decreases the mobility of the polymer chains / ability of polymer chains to slide past one another (thus making the polymer stronger).** | **1** |
| **The increased M increases the strength of the dispersion forces.** | **1** |
| **Therefore a greater amount of heat is required to disrupt the bonding (resulting in a higher melting point).** | **1** |
| **Total** | **4** |

To keep up with the demand for PEVA, a plentiful supply of the monomers is required. Vinyl acetate is prepared industrially by the vapour phase reaction of ethene, ethanoic acid and oxygen, in the presence of a palladium catalyst.

2 CH2=CH2(g) + 2 CH3COOH(g) + O2(g) 2 CH3COOCH=CH2(g) + 2 H2O(g)

*ethene + ethanoic acid + oxygen* → *vinyl acetate + water*

388 kg of ethene and 471 kg of ethanoic acid were placed in a reactor, in the presence of excess oxygen gas and a palladium catalyst.

(f) Calculate the maximum volume of gaseous vinyl acetate, measured at 195 °C and 855 kPa, that could be produced. State your final answer to the appropriate number of significant figures. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(CH2CH2) = (388 x 103) / 28.052**  **= 13831.46 mol** | **1** |
| **n(CH3COOH) = (471 x 103) / 60.052**  **= 7843.20 mol** | **1** |
| **CH3COOH is limiting reagent, since n(CH3COOH) < n(CH2CH2)** | **1** |
| **n(vinyl acetate) = 7843.20 mol** | **1** |
| **V(vinyl acetate) = (7843.20 x 8.314 x 468.15) / 855**  **= 35704 L** | **1** |
| **= 35.7 kL or 3.57 x 104 L (3 SF)** | **1** |
| **Total** | **6** |

**Question 37 (19 marks)**

Cow’s milk is composed primarily of water and protein, as well as fats, minerals and lactose (a type of sugar found only in milk).

Fresh cow’s milk has a relatively short shelf life and must be kept refrigerated. This is due to the presence of bacteria which ferment the lactose in milk, forming lactic acid. This increased acidity causes milk to sour and eventually curdle. This curdling causes the lumpy texture of ‘off’ milk.

Some information on lactic acid is given in the following table.

|  |  |  |
| --- | --- | --- |
| Formula | Structure | Molar mass |
| CH3CHOHCOOH |  | 90.078 g mol-1 |

Fresh cow’s milk usually has a pH of 6.6 and a very low concentration of lactic acid. As milk ferments, the concentration of lactic acid increases and the pH will fall. Once the pH reaches 4.6, the milk curdles.

The table below provides a comparison between fresh and sour milk.

(Note: You may assume lactic acid is the only acidic substance present in the milk.)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Concentration of lactic acid | pH | Appearance |
| Fresh milk | 1.8 g L-1 | 6.6 | opaque, white liquid with  a low viscosity |
| Sour milk | 8.1 g L-1 | 4.6 | liquid becomes more viscous and contains clumps of white solid |

A sample of **fresh** milk was analysed by titration, to assess its quality and determine its lactic acid content. A 25.00 mL aliquot of the fresh milk was placed in a conical flask, and a few drops of phenolphthalein were added.

The chemist performing the titration had three (3) bottles of standardised sodium hydroxide solution, NaOH(aq), available for use. They were labelled as follows.

0.01012 mol L-1 0.02073 mol L-1 0.03141 mol L-1

NaOH(aq) NaOH(aq) NaOH(aq)

The equation for the titration reaction is given below.

CH3CHOHCOOH(aq) + NaOH(aq) → CH3CHOHCOONa(aq) + H2O(l)

“In this titration, NaOH(aq) is used as the standard solution, however it is not a primary standard.”

(a) Explain this statement, including two (2) reasons that sodium hydroxide is **not** an appropriate primary standard. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The sodium hydroxide is a standard solution because it has an accurately known concentration.** | **1** |
| **Sodium hydroxide is not a primary standard because the solid cannot be accurately weighed and dissolved in water to produce a standard solution.** | **1** |
| **Any two of the following:**   * **Sodium hydroxide is deliquescent** * **Sodium hydroxide is hygroscopic** * **The molar mass of sodium hydroxide is too low** * **Sodium hydroxide reacts with CO2(g) in the air** * **Sodium hydroxide is difficult to obtain in pure form / with known purity** | **2** |
| **Total** | **4** |

(b) Determine which of the standard NaOH(aq) solutions would be most appropriate for use in this titration. Show all workings. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **c(lactic acid in fresh milk) = 1.8 g L-1**  **Therefore c (lactic acid) = 1.8 / 28.052**  **= 0.01998 mol L-1** | **1** |
| **Since the acid and base are reacting in a 1:1 stoichiometric ratio, it is desirable that they have similar concentrations.** | **1** |
| **The chemist should use 0.02073 mol L-1 NaOH(aq) (circled)** | **1** |
| **Total** | **3** |

An open bottle of milk, that had been sitting in a refrigerator for five days, was then analysed. A 50.00 mL sample of the milk was placed in a 100.0 mL volumetric flask and diluted with water. 25.00 mL aliquots of the dilute milk were titrated against the 0.03141 mol L-1 NaOH(aq) solution. An average titre of 22.13 mL was required to reach the phenolphthalein end point.

The titration equation is shown again below.

CH3CHOHCOOH(aq) + NaOH(aq) → CH3CHOHCOONa(aq) + H2O(l)

(c) Calculate the concentration of lactic acid in the open milk sample, in grams per litre, and thus determine whether the milk would be classified as ‘sour’ or not. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(NaOH) = 0.03141 x 0.02213**  **= 0.0006951 mol** | **1** |
| **n(lactic acid in 25 mL) = 0.0006951 mol** | **1** |
| **n(lactic acid in 100 mL) = 0.0006951 x (100/25)**  **= 0.0027804 mol** | **1** |
| **= n(lactic acid in 50 mL milk)** | **1** |
| **m(lactic acid in 50 mL milk) = 0.0027804 x 90.078**  **= 0.25045 g** | **1** |
| **c(lactic acid in 50 mL milk) = 0.25045 / 0.050**  **= 5.009 g L-1 (i.e. less than 8.1 g L-1)** | **1** |
| **No, the milk is not sour (circled)** | **1** |
| **Total** | **7** |

Milk is an excellent source of protein as it contains all nine essential amino acids. Approximately 82% of the proteins in cow’s milk are ‘casein’ proteins.

The curdling observed in sour milk is due to the denaturation of these proteins. This occurs because the decrease in pH disrupts the tertiary structures in the casein proteins, resulting in them clumping together.

(d) Define the ‘tertiary structure’ of a protein. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The folding of the polypeptide chain to produce the overall protein shape.** | **1** |
| **Created by the bonds and interactions between the amino acid side chains.** | **1** |
| **Total** | **2** |

Consider the effect of pH on the tertiary structures that the amino acids aspartic acid and lysine are able to form.

(e) Complete the polypeptide segments in the following table, to show how the tertiary structures formed by these amino acids may be disrupted by pH changes. (2 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| **Aspartic acid – low pH** | **Aspartic acid – high pH** | **1** |
| **Lysine – low pH** | **Lysine – high pH** | **1** |
| **Total** | | **2** |

(f) Identify the type of tertiary structure that is predominantly affected by changes in surrounding pH. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Ionic bonding** | **1** |
| **Total** | **1** |

**Question 38 (19 marks)**

Diesel fuels can generally be classified as either ‘petrodiesel’ or ‘biodiesel’. Petrodiesel is a non-renewable diesel made from fossil fuels. Biodiesel is a renewable form of diesel fuel made from animal fats or plant oils (triglycerides). Over 80% of the biodiesel produced in the US is made from soybean oil, and is often referred to as ‘soy biodiesel’.

The production and use of biodiesel is continually advancing and increasing, in efforts to reduce our reliance on petrodiesel. A major advantage of biodiesel is that it can be used in place of petrodiesel, without the need for modifying existing vehicle engines and other infrastructure.

(a) Explain why combustion of biodiesel results in overall lower carbon emissions than petrodiesel. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The carbon in biodiesel comes from renewable sources / plant material.** | **1** |
| **Plants have taken CO2 out of the atmosphere, therefore less overall carbon emissions than diesel from non-renewable fossil fuels.** | **1** |
| **Total** | **2** |

An important factor when assessing the quality and usefulness of diesel fuels is their ‘cloud point’. The cloud point is the temperature where the fuel begins to freeze, and small wax crystals start to form throughout the liquid. This causes the fuel to appear cloudy.

A low cloud point generally corresponds to a lower boiling point and a more desirable fuel. One of the disadvantages of biodiesel, is that it usually has a higher cloud point than petrodiesel.

Consider the information provided in the tables below.

|  |  |
| --- | --- |
| Petrodiesel | |
| Major component: dodecane, C12H26 | Cloud point -9 °C |
|  | |

|  |  |
| --- | --- |
| Soy biodiesel | |
| Major component: methyl linoleate, C19H­34O2 | Cloud point 1 °C |
|  | |

(b) Explain, in terms of intermolecular forces, why the cloud point of soy biodiesel is higher than that of petrodiesel. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Petrodiesel only exhibits dispersion forces.** | **1** |
| **Biodiesel exhibits dispersion forces of greater strength due to its larger M.** | **1** |
| **Biodiesel also has a polar ester group and therefore exhibits some dipole-dipole forces.** | **1** |
| **Therefore the sum of intermolecular forces in biodiesel is greater than petrodiesel (resulting in a higher cloud point).**  **or**  **Therefore a greater amount of energy would be required to overcome the intermolecular forces in biodiesel (resulting in a higher cloud point).** | **1** |
| **Total** | **4** |

The cloud point of biodiesel will depend on the triglycerides from which it is made. For example, palm oil biodiesel has a cloud point of 17 °C, resulting in a much narrower range of applications.

To a large extent, the cloud point is determined by the percentage of saturated and unsaturated fatty acids comprising the triglycerides used to manufacture the biodiesel. The tables below compare the fatty acid composition of the triglycerides found in soybean oil and palm oil.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Soybean oil fatty acid content | % of oil | Type of fatty acid |  | Palm oil fatty acid content | % of oil | Type of fatty acid |
| linoleic acid | 55 | polyunsaturated |  | palmitic acid | 44 | saturated |
| oleic acid | 18 | monounsaturated |  | oleic acid | 41 | monounsaturated |
| linolenic acid | 13 | polyunsaturated |  | linoleic acid | 10 | polyunsaturated |
| palmitic acid | 10 | saturated |  | stearic acid | 5 | saturated |
| stearic acid | 4 | saturated |  |  |  |  |

(c) State the relationship between the percentage of unsaturated fatty acid present in the component triglycerides, and the cloud point of a biodiesel. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The higher the percentage of unsaturated fatty acids, the lower the cloud point of the biodiesel.** | **1** |
| **Total** | **1** |

(d) Explain the relationship stated in part (c), in terms of intermolecular forces. Your answer should include a definition of ‘unsaturated fatty acids’. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Unsaturated fatty acids have one or more double carbon-carbon bonds.** | **1** |
| **These double bonds (usually in cis conformation) cause the fatty acid chains to be bent rather than linear.** | **1** |
| **This makes it harder for the molecules to pack together / reduces the surface area in contact between the molecules / reduces interactions between the molecules.** | **1** |
| **Therefore resulting in weaker dispersion forces (and thus a lower cloud point).** | **1** |
| **Total** | **4** |

Biodiesel is made by a transesterification reaction between triglycerides and methanol, in the presence of a sodium hydroxide catalyst. The equation below represents a simplified version of the production of soy biodiesel.



A particular batch of soybean oil was treated, and this resulted in the production of 7545 L of soy biodiesel. The density of the soy biodiesel was measured to be 0.882 kg L-1.

(e) If the yield of this process was 92.1%, calculate the mass of soybean oil that reacted. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **m(soy biodiesel) = 0.882 x 7545**  **= 6654.69 kg** | **1** |
| **= 6654690 g** | **1** |
| **n(soy biodiesel) = 6654690 / 294.462**  **= 22599.5 mol** | **1** |
| **n(soybean oil) = 22599.5 / 3**  **= 7533.16 mol** | **1** |
| **n(soybean oil inc. yield) = 7533.16 x (100/92.1)**  **= 8179.33 mol** | **1** |
| **m(soybean oil) = 8179.33 x 879.354**  **= 7192526 g**  **(7.19 t or 7.19 x 106 g)** | **1** |
| **Total** | **6** |

The reaction above can also be carried out using lipase enzymes in place of sodium hydroxide.

(f) Identify two (2) reasons why ‘the use of enzymes’ is one of the twelve principles of green chemistry. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Any two of the following:**   * **Allows use of lower temperature and/or pressure** * **Aligns with less harmful synthesis / use of milder conditions** * **Can be reused / minimises waste** * **Purer product formed / less refining required** * **Results in a lower energy input** | **2** |
| **Total** | **2** |

**Question 39 (19 marks)**

The lead-acid battery was invented by Gaston Planté in 1859 and was the first rechargeable battery to be developed. Well over a century later, lead-acid batteries are still used as the starter battery in most vehicles, due to their relatively low cost and ability to produce high currents.

The lead-acid battery consists of six (6) individual cells which are connected in series to increase the overall voltage. Each cell contains a lead(IV) oxide cathode and a lead anode, submerged in a sulfuric acid electrolyte.

A diagram of a typical lead-acid battery is shown below.

–

+

lead

lead(IV) oxide

sulfuric acid solution

separator

When discharging, the lead-acid battery is functioning as a galvanic cell. The chemical equations for the discharge reactions occurring in the lead-acid battery are;

Cathode: PbO2(s) + SO42-(aq) + 4 H+(aq) + 2 e- → PbSO4(s) + 2 H2O(l)

Anode: Pb(s) + SO42-(aq) → PbSO4(s) + 2 e-

(a) Explain, in terms of the chemical processes occurring, how a galvanic cell is able to produce an electrical current. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Galvanic cells make use of a spontaneous redox reaction.** | **1** |
| **Oxidation occurs at the anode, where electrons are lost.** | **1** |
| **Reduction occurs at the cathode, where electrons are gained.** | **1** |
| **The electrons travel via an external pathway, generating an electric current.** | **1** |
| **Total** | **4** |

(b) Calculate the electrical potential difference produced by a **single** lead-acid cell under standard conditions. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **2.05 V** | **1** |
| **Total** | **1** |

As the lead-acid battery operates, the lead(IV) oxide cathode reacts to become lead(II) sulfate. Since this process consumes H+(aq) ions, the pH of the electrolyte solution will rise as the cell discharges.

A single lead-acid cell was tested by a mechanic. The cell contained 5.00 x 102 mL of electrolyte solution, which had an initial pH of 0.800. After several hours of use, the electrolyte pH was measured again, and found to be 3.50.

(c) Calculate the mass of PbSO4(s) that would have formed at the cathode. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **[H+ at start] = 10-0.80**  **= 0.15849 mol L-1** | **1** |
| **n(H+ at start) = 0.15849 x 0.5**  **= 0.079245 mol** | **1** |
| **[H+ at end] = 10-3.5**  **= 0.00031623 mol L-1** | **1** |
| **n(H+ at end) = 0. 00031623 x 0.5**  **= 0.00015811 mol** | **1** |
| **n(H+ used) = 0.079245 – 0.00015811**  **= 0.079097 mol** | **1** |
| **n(PbSO4 formed) = 0.079097 / 4**  **= 0.019772 mol** | **1** |
| **m(PbSO4 formed) = 019772 x 303.26**  **= 5.996 g**  **(6.0 g)** | **1** |
| **Total** | **7** |

(d) If the initial mass of the PbO2(s) cathode was 695 g, calculate its final mass. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(PbO2 used up) = n(PbSO4 formed)**  **= 0.019772 mol** | **1** |
| **m(PbO2 used up) = 0.019772 x 239.2**  **= 4.7295 g** | **1** |
| **Final cathode mass = 695 – 4.7295 + 5.9960**  **= 696.3 g** | **1** |
| **Total** | **3** |

The lead-acid battery is a secondary cell and thus is capable of being recharged. During this process it functions as an electrolytic cell.

(e) Explain, in terms of the chemical processes occurring, how a secondary cell becomes recharged. Include the overall balanced redox equation for the recharging reaction occurring in the lead-acid battery. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **A voltage / electric current is applied to the cell.** | **1** |
| **Thereby forcing a non-spontaneous redox reaction to occur.** | **1** |
| **This reverses the oxidation and reduction processes.**  **Or This converts the products of the discharge reaction back into reactants.** | **1** |
| **2 PbSO4(s) + 2 H2O(l) → PbO2(s) + Pb(s) + 2 SO42-(aq) + 4 H+(aq)** | **1** |
| **Total** | **4** |

**Question 40 (14 marks)**

Ethyl ethanoate (CH3COOCH2CH3) is a colourless liquid with a sweet smell. It is a commonly used solvent due to its low cost and low toxicity. Ethyl ethanoate is used in nail polish remover, perfume, varnishes, paints, column chromatography and the production of decaffeinated coffee and tea.

Ethyl ethanoate can be manufactured on an industrial scale using several different methods. One such method is summarised by the reaction sequence shown in the diagram below.

ethene



ethanol



ethanoic acid



ethyl ethanoate



Reaction A

Reaction B

Reaction C

(a) Complete the table below, regarding each step of this reaction sequence, by identifying;

* the name or formula of any additional reactant(s) required,
* the name or formula of any catalyst required, and
* the type of reaction occurring. (7 marks)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Description** | | | | **Marks** |
| **A** | **H2O** | **H3PO4**  **or**  **H+**  **or**  **H2SO4** | **addition**  **or**  **hydration** | **3** |
| **B** | **MnO4- / H+**  **or**  **Cr2O72- / H+** |  | **oxidation**  **or**  **redox** | **2** |
| **C** |  | **H2SO4**  **or**  **H+** | **esterification**  **or**  **condensation** | **2** |
| **Total** | | | | **7** |

The chemical process represented by Reaction C is reversible, as shown below.



All the compounds in this reaction mixture are miscible and form a single solution. This represents a homogeneous equilibrium system with the following equilibrium constant expression;

[CH3COOCH2CH3] [H2O]

K =

[CH3CH2OH] [CH3COOH]

At room temperature this reaction occurs slowly, and the value of the equilibrium constant is 3.38.

(b) State what information the value of Kc provides about this equilibrium system. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **A slightly greater concentration of products than reactants is present at equilibrium.**  **or**  **Approximately equal concentrations of products and reactants are present at equilibrium.** | **1** |
| **Total** | **1** |

The equation for Reaction C is shown again below.

CH3CH2OH + CH3COOH ⇌ CH3COOCH2CH3 + H2O

When optimising the industrial conditions used in Reaction C, it was found that the yield of ethyl ethanoate could be greatly increased by

1. incorporating additional ethanol into the reaction mixture, and
2. using a dehydrating agent to remove water as it forms.

(c) On the axes below, sketch graphs showing the effect of each of these changes on both the forward and reverse reaction rates, from the time of the imposed change until equilibrium is re-established. Consider each change in isolation. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **(i) Addition of ethanol at Time T1**  reaction rate  forward  reverse  l l  T1 E1 Time |  |
| **Shape of curves between T1 and E1** | **1** |
| **Forward and reverse correctly labelled** | **1** |
| **Curves merge and become horizontal at E1** | **1** |
| **(ii) Removal of water at Time T2**  reaction rate  forward  reverse  l l  T2 E2 Time |  |
| **Shape of curves between T2 and E2** | **1** |
| **Forward and reverse correctly labelled** | **1** |
| **Curves merge and become horizontal at E2** | **1** |
| **Total** | **6** |
| **Note: Do not award marks for ‘horizontal lines’ if curves are sketched incorrectly.** | |