

Semester One Examination, 2016

Question/Answer Booklet

CHEMISTRY

Unit 3

Student Number: In figures

--	--	--	--	--	--	--	--

In words

Time allowed for this paper

Reading time before commencing work:

ten minutes

Working time for paper:

three hours

Material required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet

Multiple-choice Answer sheet

Chemistry Data sheet

Number of additional
answer booklets used
(if applicable):

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener,
correction fluid/tape, eraser, 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	9	9	60	70	35
Section Three: Extended answer	5	5	70	80	40
Total					100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2016*. Sitting this examination implies that you agree to abide by these rules.
2. 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.

3. 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.
4. 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.
5. 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 question that you are continuing to answer at the top of the page.
6. The Chemistry Data Sheet is **not** handed in with your Question/Answer Booklet.

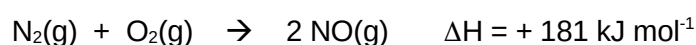
Section One: Multiple-choice

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.

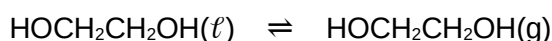
1. Nitrogen and oxygen react in a sealed container to produce nitrogen monoxide. The following equation represents the reaction.



Which of the following statements about the reaction is/are true?

- I. The reactants have a higher enthalpy than the products.
- II. The production of 30.0 g of nitrogen monoxide from oxygen and nitrogen would release approximately 90.5 kJ of energy.
- III. Adding more nitrogen to the reaction mixture would increase the rate of reaction by increasing the proportion of collisions reaching the activation energy.
- IV. The decomposition of nitrogen monoxide into nitrogen and oxygen would have a lower activation energy than the reaction above.

- (a) I and III only
 - (b) II and III only
 - (c) II and IV only
 - (d) IV only
2. Consider the following equation, showing the evaporation of ethane-1,2-diol, a commonly used antifreeze agent with a boiling point of 198°C:

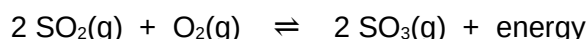


10 mL of ethane-1,2-diol was placed into a stoppered flask and allowed to reach equilibrium. The temperature of the flask was lowered from 20°C to 10°C. Which of the following statements is correct once equilibrium has been re-established?

- (a) The value of the equilibrium constant would have decreased compared with that at 20°C.
- (b) The rate of evaporation is lower than the rate of condensation.
- (c) The concentration of $\text{CH}_2(\text{OH})\text{CH}_2\text{OH}(\ell)$ would increase.
- (d) Removal of the stopper would result in the formation of more $\text{CH}_2(\text{OH})\text{CH}_2\text{OH}(\ell)$.

3. Which of the following statements about the action of a catalyst is **false**?
- (a) A catalyst provides an alternative pathway by which a reaction can take place.
 - (b) A catalyst remains chemically unchanged at the end of a reaction.
 - (c) A catalyst will increase the percentage of particles that meet or exceed the activation energy.
 - (d) A catalyst makes it more likely that particles will collide.
4. In which of the following systems at equilibrium would an increase in the overall pressure lead to a **decrease** in the mass of the species in bold when equilibrium is re-established?
- (a) $\text{CH}_4(\text{g}) + 2 \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + 4 \text{H}_2(\text{g})$
 - (b) $\text{N}_2\text{O}_5(\text{g}) + \text{NO}(\text{g}) \rightleftharpoons 3 \text{NO}_2(\text{g})$
 - (c) $\text{MgCO}_3(\text{s}) \rightleftharpoons \text{MgO}(\text{s}) + \text{CO}_2(\text{g})$
 - (d) $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2 \text{HI}(\text{g})$

Questions 5 and 6 refer to the reaction in the Contact Process between oxygen and sulfur dioxide to produce sulfur trioxide, as represented by the equation:

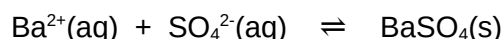


5. Which of the following statements correctly describes the effect of the addition of a vanadium pentoxide catalyst to a gaseous mixture of sulfur dioxide and oxygen?
- (a) The catalyst causes an increase in rate of the backward reaction but does not affect the yield of sulfur trioxide or the temperature.
 - (b) The catalyst causes a decrease in the rate of the backward reaction and causes the yield of sulfur trioxide and the temperature to fall.
 - (c) The catalyst causes an increase in the rate of the forward reaction and causes the temperature and the yield of sulfur trioxide to rise.
 - (d) The catalyst has no effect on the rate of the forward reaction, the yield of sulfur trioxide, or the temperature.
6. 2 moles of sulfur trioxide were placed in an empty 1.00 L vessel and the vessel sealed. When the system had reached equilibrium, it was found that the vessel contained 0.6 moles of oxygen. What would be the number of moles of sulfur dioxide and sulfur trioxide present in the equilibrium mixture?

	moles of $\text{SO}_2(\text{g})$	moles of $\text{SO}_3(\text{g})$
(a)	1.2	1.2
(b)	1.2	0.8
(c)	0.3	1.4
(d)	0.3	1.7

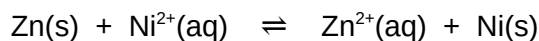
7. A state of dynamic equilibrium is established when a reversible reaction takes place in a closed system. Which of the following statements best describes a closed system?
- (a) A system that can exchange matter, but not energy, with its surroundings
 - (b) A system that can exchange energy, but not matter, with its surroundings
 - (c) A system that can exchange neither matter nor energy with its surroundings
 - (d) A system that can exchange both matter and energy with its surroundings

8. When sulfuric acid and barium chloride are mixed, a precipitation reaction occurs that can be represented by the following equilibrium.



Which of the following statements about the conductivity of the solution as the system approaches equilibrium is correct?

- (a) The conductivity increases at a decreasing rate.
 - (b) The conductivity decreases at a decreasing rate.
 - (c) The conductivity decreases at a constant rate.
 - (d) The conductivity increases at an increasing rate.
9. Consider the following equilibrium system in aqueous solution:

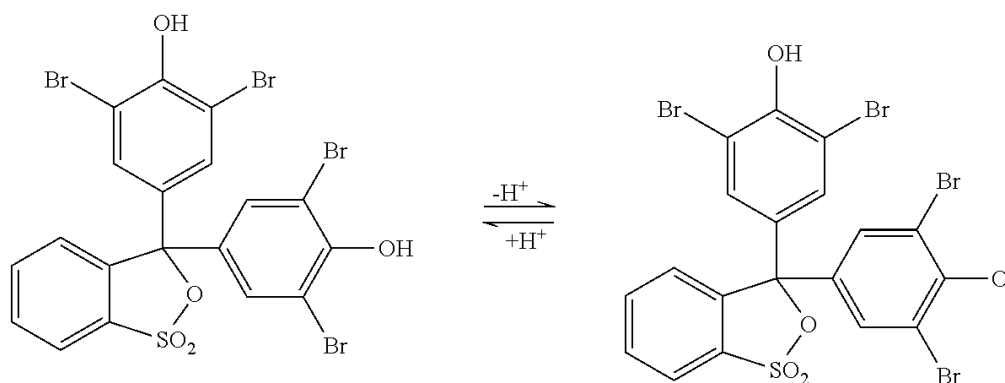


Which of the following would occur if a small quantity of water was evaporated from the system?

- (a) The value of the equilibrium constant, K , would increase.
 - (b) The concentration of Zn^{2+} would increase.
 - (c) The solution would appear less green.
 - (d) The mass of both solid zinc and solid nickel would increase.
10. Which of the following statements explain(s) why sodium carbonate decahydrate ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$) makes a good primary standard in acid-base titrations?
- I. It has a relatively high molar mass, allowing a reduction of systematic error in weighing.
 - II. It is chemically stable, allowing it to be obtained in a pure form.
 - III. It is readily soluble in water.
 - IV. It is not hygroscopic.
- (a) I and III only
 - (b) II and IV only
 - (c) II, III and IV only
 - (d) I, II, III and IV

11. The pH of a solution was measured using a pH probe, and was observed to change from 4 to 2. Which of the following statements about the hydroxide ion concentration in the solution is correct?
- (a) It doubled
 - (b) It decreased by half
 - (c) It increased by a factor of 100
 - (d) It decreased by a factor of 100

Questions 12 and 13 refer to the indicator bromophenol blue, which changes colour from yellow in acidic solutions to blue in basic solutions. Its end point is in the pH range 3 – 4.6. The two forms of bromophenol blue are represented in the equation:



12. Which of the following statements about bromophenol blue is **false**?
- (a) The conjugate base of bromophenol blue is blue.
 - (b) The blue form is a weak acid.
 - (c) The protonated form is yellow.
 - (d) The end point will depend on the temperature of the solution.
13. An experiment was carried out using bromophenol blue, in which 0.904 mol L^{-1} sodium hydroxide was titrated against 20 mL aliquots of an ethanoic acid solution of unknown concentration.

Which of the following statements about this titration is correct?

- (a) The indicator would change colour after the equivalence point was reached, leading to an artificially high value for the concentration of the ethanoic acid solution.
- (b) The indicator would change colour before the equivalence point was reached, leading to an artificially high value for the concentration of the ethanoic acid solution.
- (c) The indicator would change colour after the equivalence point was reached, leading to an artificially low value for the concentration of the ethanoic acid solution.
- (d) The indicator would change colour before the equivalence point was reached, leading to an artificially low value for the concentration of the ethanoic acid solution.

14. Which of the following lists of 1 mol L⁻¹ aqueous solutions is written in order of increasing pH (starting with the lowest)?

- (a) NH₄NO₃(aq), H₃PO₄(aq), NH₃(aq), NaCl(aq)
- (b) HNO₃(aq), NH₄Cl(aq), KNO₃(aq), Ca(OH)₂(aq)
- (c) CH₃COOH(aq), HCl(aq), NaHSO₄(aq), NaCH₃COO(aq)
- (d) NH₃(aq), K₂SO₄(aq), CaCl₂(aq), CH₃COOH(aq)

15. A 1 mol L⁻¹ aqueous solution is found to have the following properties.

- It is a good conductor of electricity
- Its pH rises when it is diluted with distilled water
- It gives a white precipitate when added to an aqueous solution of silver nitrate

Which of the following is the most likely identity of the solution?

- (a) NH₄NO₃(aq)
- (b) NaCl(aq)
- (c) HBr(aq)
- (d) K₃PO₄(aq)

16. The value of K_w for pure water at 30°C is 1.471 × 10⁻¹⁴. Which of the following statements best describes water at this temperature?

- (a) A neutral substance with a pH of 7
- (b) An acidic substance with a pH of 7
- (c) A neutral substance with a pH of 6.9
- (d) An acidic substance with a pH of 6.9

17. Benzoic acid, chlorous acid and butanoic acid are weak monoprotic acids. The K_a values for these acids are shown in the table below.

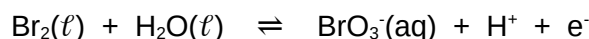
Acid	K _a
Benzoic acid	6.31 × 10 ⁻⁵
Chlorous acid	1.12 × 10 ⁻²
Butanoic acid	1.51 × 10 ⁻⁵

Which of the following statements is **false**?

- (a) Of these three acids, chlorous acid has the highest degree of ionisation in aqueous solution.
- (b) A solution of benzoic acid will always have a lower pH than an equimolar solution of butanoic acid.
- (c) Butanoic acid is weaker than chlorous acid.
- (d) Solutions of benzoic acid will always be less acidic than solutions of chlorous acid.

18. Which of the following could **best** be described as a dilute solution of a strong monoprotic acid?
- (a) Hydrochloric acid with a pH of 1.1
 - (b) Ethanoic acid with a pH of 3.8
 - (c) Sulfuric acid with a pH of 6.6
 - (d) Nitric acid with a pH of 0.9

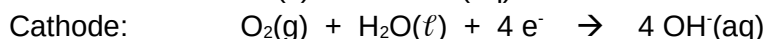
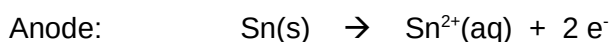
19. How many moles of electrons are required when the following half-equation is balanced using the smallest possible integers?



- (a) 2
 - (b) 5
 - (c) 10
 - (d) 12
20. Consider the following combinations of substances:
- I. A magnesium rod dipped in a 1.0 mol L^{-1} solution of copper sulfate
 - II. A zinc rod dipped in a 1.0 mol L^{-1} solution of nitric acid
 - III. A silver rod dipped in a 1.0 mol L^{-1} solution of hydrochloric acid
 - IV. 1.0 mol L^{-1} solutions of calcium hydroxide and sulfuric acid mixed together

In which of the mixtures would a redox reaction take place?

- (a) I and II only
 - (b) I, and III only
 - (c) II and IV only
 - (d) I, III and IV only
21. The anode and cathode processes involved in the corrosion of tin can be represented using the following half equations.



Which of the following statements about the corrosion of tin is correct?

- (a) The process involves the reduction of oxygen.
- (b) Tin ions act as a reducing agent in the process.
- (c) The cell potential for the reaction would be +1.37 V.
- (d) The reaction cannot occur unless tin is placed in direct contact with water and oxygen.

22. Which of the following correctly represents the process taking place at the anode during the electrolysis of a molten sodium chloride using inert electrodes?

- (a) $\text{Na(s)} \rightarrow \text{Na}^+(\text{aq}) + \text{e}^-$
- (b) $\text{Na}^+(\text{aq}) + \text{e}^- \rightarrow \text{Na(s)}$
- (c) $2 \text{Cl}^-(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2 \text{e}^-$
- (d) $\text{Cl}_2(\text{g}) + 2 \text{e}^- \rightarrow 2 \text{Cl}^-(\text{aq})$

23. Which of the following compounds contains chlorine with the **lowest** oxidation number?

- (a) NaCl
- (b) HOCl
- (c) Cl_2O_7
- (d) ClF

24. Consider the following standard reduction potentials:

Half reaction	$E^\circ(\text{volts})$
$\text{Be}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Be(s)}$	- 1.97
$\text{Ga}^{3+}(\text{aq}) + 3 \text{e}^- \rightleftharpoons \text{Ga(s)}$	- 0.55
$\text{Hg}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Hg(l)}$	+ 0.85
$\text{Pd}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Pd(s)}$	+ 0.92

From these data it can be deduced that:

- (a) Ga is a stronger oxidising agent than Be.
 - (b) Ga^{3+} is a stronger oxidising agent than Hg^{2+} .
 - (c) Be is a stronger reducing agent than Hg.
 - (d) Pd^{2+} is a stronger reducing agent than Ga^{3+} .
25. An experiment is set up to electroplate a brass key with silver. Which of the following statements describes how the experiment should be set up?
- (a) The cathode is made of silver and the key is the anode.
 - (b) The key is the anode and the electrolyte is a solution of copper sulfate.
 - (c) The key is the cathode and the electrolyte is a solution of silver nitrate.
 - (d) The cathode is made of silver and the electrolyte is a solution of silver nitrate.

End of section one

See next page

Section Two: Short answer

35% (70 Marks)

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

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.

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 that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26

(9 marks)

Write equations for any reactions that occur in the following procedures. If no reaction occurs, write 'no reaction'.

In each case describe in full what you would observe, including any: colours; odours; precipitates (give the colour).

(a) Solid chromium(III) hydroxide is added to ethanoic acid. (3 marks)

Equation _____

Observation _____

(b) 1 mol L⁻¹ aqueous solutions of lead(II) nitrate and hydrochloric acid are mixed. (3 marks)

Equation _____

Observation _____

(c) A strip of zinc is dipped in a 1 mol L⁻¹ solution of sulfuric acid. (3 marks)

Equation _____

Observation _____

See next page

Question 27

(5 marks)

Tetrafluoroethene (C_2F_4) is an important feedstock in the manufacture of polymers. Its production takes place via a series of reactions, the last of which is represented by the equation:



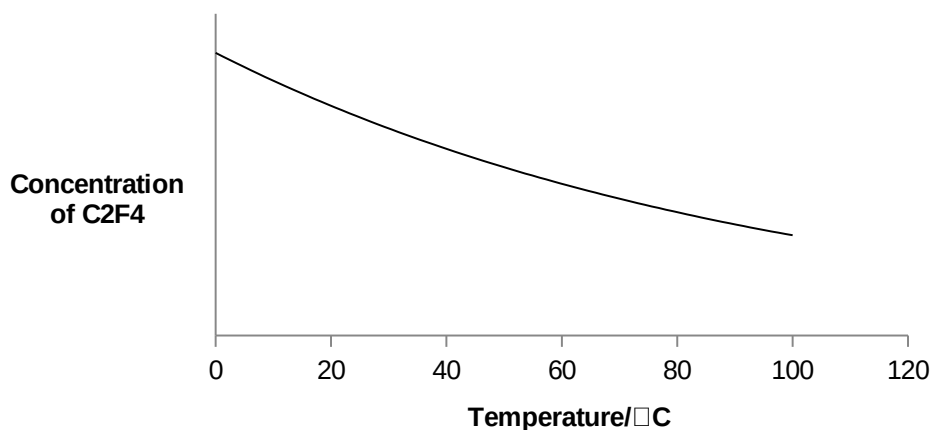
Some of the physical properties of the species shown in the equation are given in the table below:

Species	$\text{CHClF}_2(\text{g})$	C_2F_4	HCl
Melting Point/ $^{\circ}\text{C}$	-146	-142	-114
Boiling Point/ $^{\circ}\text{C}$	-41	-76	-85

(a) Write an expression for the equilibrium constant, K , at the following temperatures: (2 marks)

Temperature	Equilibrium constant expression
25°C	
-50°C	

The graph below shows the variation in the concentration of C_2F_4 present at equilibrium as the temperature of the system is changed.

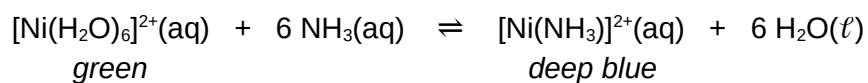


(b) Explain what conclusion about the enthalpy change for the formation of tetrafluoroethene can be drawn from the graph. (3 marks)

Question 28

(8 marks)

When ammonia solution is added to an aqueous solution of nickel(II) chloride, the following reversible reaction takes place:



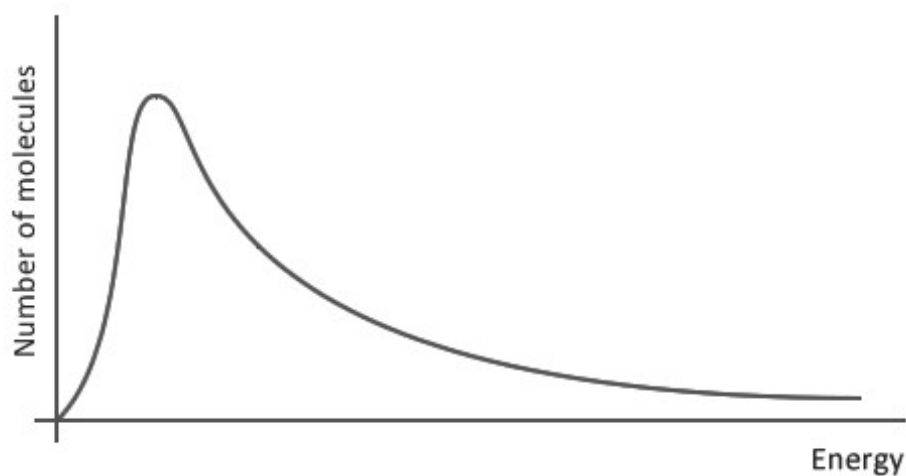
Two test tubes were set up, each containing some of this equilibrium mixture. A different change was imposed upon each test tube. Complete the following table, stating and **explaining** the observations that would be made. No equations are required.

Imposed change	Expected observation	Explanation
A small amount of distilled water is added		
A small amount of ammonia gas is bubbled through the solutions		

Question 29

(5 marks)

The graph below shows how the kinetic energy of the particles in a sample of gas is distributed at a particular temperature.



Use the graph, and your understanding of collision theory, to explain why increasing temperature by a relatively small amount will have a dramatic effect upon the rate of a chemical reaction.

(5 marks)

Question 30

(12 marks)

A student carrying out an investigation into some common laboratory reagents placed 1 mol L⁻¹ solutions of ethanoic acid, hydrochloric acid, and sulfuric acid into three separate beakers. She later realised that she had failed to label the beakers.

The values of the acid dissociation constants, K_a , for the three acids are shown in the table (N/A denotes that the respective K_a value is not applicable):

Acid	K_a (1 st ionisation)	K_a (2 nd ionisation)
Hydrochloric acid	N/A	N/A
Ethanoic acid	1.74×10^{-5}	N/A
Sulfuric acid	N/A	0.0102

- (a) Using appropriate chemical equations, explain how the student could have used a pH probe and the data in the table to determine the identity of the acid in each beaker. (6 marks)

- (b) Explain why there is no K_a value quoted for hydrochloric acid. (2 marks)

- (c) Write an expression for the dissociation constant, K_a , of ethanoic acid. (1 mark)

- (d) Use the value of K_a for ethanoic acid to calculate the percentage of ethanoic acid molecules that are dissociated in a 1 mol L^{-1} solution (to make the calculation simpler, you may use the approximation that the concentration of undissociated molecules is equal to 1 mol L^{-1}). (3 marks)

Question 31**(6 marks)**

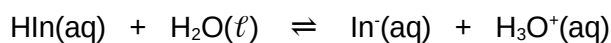
Complete the table by writing the name or formula for the conjugate base, species X, or conjugate acid in each blank space as appropriate. Species X is the species that is able to form both the respective conjugate acid and conjugate base.

Conjugate base	Species X	Conjugate acid
NH_2^-		
		Sulfurous acid
	Dihydrogenphosphate ion	

Question 32

(7 marks)

Acid-base indicators are usually able to exist as conjugate pairs, the two of which can be represented as “HIn” and “In⁻”, and will have different colours from one another. The two forms will exist in equilibrium in aqueous solution, as shown in the equation:



Like other weak acids, the degree to which an indicator dissociates in solution can be expressed using the indicator's dissociation constant, K_a .

- (a) Use appropriate chemical equations, and your understanding of equilibrium principles, to explain how the addition of limewater (an aqueous solution of calcium hydroxide) to a solution containing an indicator can lead to a change in the colour of the solution. (4 marks)

The pH at which an indicator changes colour is known as its *end point*. A solution with this pH will have equal concentrations of the two forms, HIn and In⁻.

- (b) The indicator methyl yellow has a K_a value of 7.94×10^{-4} . Use the information above to calculate the pH at the end point for this indicator. (3 marks)

Question 33

(7 marks)

(a) Give the oxidation number of the **bold** element in each of the following:

(3 marks)

(i) **S**₈ _____(ii) H₂**S** _____(iii) Al(**N**O₃)₃ _____

The reaction in acidic solution between hydrogen sulfide, H₂S, and nitrate ions, NO₃⁻, produces sulfur, S₈, and nitrogen monoxide, NO.

(b) Complete the table to show the reduction and oxidation half-equations, and the overall balanced redox equation for the reaction that takes place.

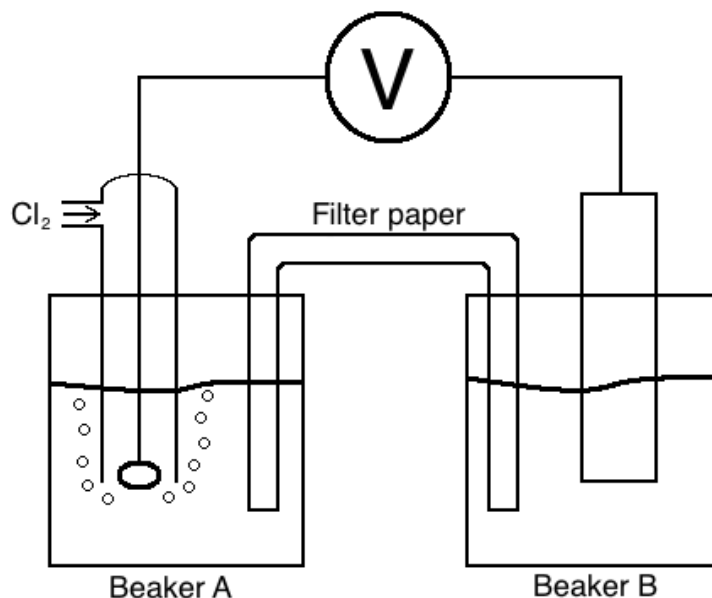
(4 marks)

Reduction half-equation	
Oxidation half-equation	
Overall equation	

Question 34

(11 marks)

The cell, $\text{Cu(s)} \mid \text{Cu}^{2+}(\text{aq}) \parallel \text{Pt} \mid \text{Cl}_2(\text{g}) \mid \text{Cl}^-(\text{aq})$, was set up as shown in the diagram below. Beaker A contained a 1.00 mol L^{-1} aqueous solution of ammonium chloride, and the filter paper shown in the diagram was soaked in an aqueous solution of potassium nitrate before being placed in the two beakers.



- (a) Give a reason why platinum was a suitable material from which to construct the electrode in beaker A. (1 mark)

- (b) Give the name or formula of a suitable electrolyte for use in beaker B. (1 mark)

- (c) Give two reasons why potassium nitrate was a suitable material for soaking the filter paper. (2 marks)

- (d) Calculate the cell potential (E°) you would expect to measure for the cell. (1 mark)

- (e) Give a reason why the measured cell potential might differ from the value calculated in part (a). (1 mark)

- (f) What changes would be observed in beaker B during the operation of the cell? (1 mark)

- (g) State and explain what how the voltmeter reading would change if a few drops of silver nitrate solution were placed in beaker A. (4 marks)

End of section two

See next page

This page has been left blank intentionally

See next page

Section Three: Extended answer**40% (80 marks)**

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

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.

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 that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 35**(19 marks)**

Rising carbon dioxide levels in the atmosphere are believed to play an important role in the life of organisms known as calcifiers, a group that includes many forms of coral and crustaceans. These organisms use a precipitation reaction between calcium ions and carbonate ions present in sea-water to form shells and skeletons.

Measurements have detected a fall of around 0.1 in the pH of the oceans since the beginning of the industrial revolution at the end of the 18th century. Scientists believe this acidification can be attributed to an increase in the partial pressure of carbon dioxide in the atmosphere over the same period.

- (a) Use appropriate chemical equations to explain why a rise in the partial pressure of carbon dioxide in the atmosphere can decrease the pH of the oceans. (3 marks)

- (b) The carbonate ions used by calcifiers exist in equilibrium with hydrogencarbonate ions in sea-water. Use appropriate chemical equations and your understanding of equilibrium to explain what effect a decrease in the pH of the ocean would have on the availability of carbonate ions. (3 marks)

A student wished to investigate the composition of prawn shells. In order to do this, he decided to carry out a back titration. The steps carried out were as follows:

- The shells of 10 prawns were ground to a fine powder using a pestle and mortar.
- The powder was dried in an oven at 80°C for three days.
- 2.17 g of the powder was placed in a beaker, and 50.0 mL of 1.20 mol L^{-1} nitric acid (an excess) was added to the beaker and the mixture heated on a Bunsen burner.
- The resulting mixture was filtered into a 250 mL volumetric flask, the beaker and filter paper rinsed thoroughly, and the rinsings added to the flask, before making up to the line with distilled water.
- 20 mL aliquots of the solution in the volumetric flask were titrated against a standard solution of sodium hydroxide with a concentration of 0.0502 mol L^{-1} . All readings were taken from the top of the meniscus.

The results of the titration are given in the following table:

Final	37.10	35.10	35.05	35.25	36.05	35.75
Start	0.00	0.10	0.00	1.25	0.00	0.65
Titre / mL						

- (c) Complete the results table and calculate a titre value to be used in calculations. (2 marks)

- (d) Explain why the student needed to carry out a back titration. (1 mark)

(8 marks)

[illegible]

Question 36

(12 marks)

The electrolysis of aqueous solutions plays an extremely important role in industry. These reactions can be carried out on a small scale in the laboratory using standard laboratory equipment.

An aqueous solution of copper sulfate can be electrolysed using either inert electrodes or copper electrodes. Discuss the important similarities and differences between these two methods of electrolysis.

Your answer should pay particular attention to the following areas. 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.

- How the cells can be constructed
- The processes occurring at each electrode
- Observations made at each electrode
- Appropriate chemical equations
- Role of the electrolyte
- Reasons for the industrial importance of the process

[illegible]

[illegible]

Question 37

(21 marks)

Propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, is a weak monoprotic acid that is produced by bacteria in the skin that cause acne. In an experiment to determine the concentration of an aqueous solution of propanoic acid, a student reacted a 25.0 mL aliquot of the solution with a standardised 0.976 mol L^{-1} solution of sodium hydroxide in a conical flask, using a pH probe and data logger to monitor the pH. Some of the student's results are shown in the table below.

Volume of NaOH (mL)	20.75	20.80	20.85	20.90	20.95	21.00	21.05	21.10	21.15
pH of solution	4.7	5.3	5.2	5.6	7.9	12.7	13.0	13.2	13.3

- (a) Explain why a failure to standardise the sodium hydroxide solution would have led to a systematic error, and what effect it would have on the calculated value for the concentration of the acid. (3 marks)

- (b) Plot the results from the experiment on the graph paper provided below, and use your graph to estimate the pH at the equivalence point. (5 marks)



Estimated pH at equivalence: _____

See next page

(c) Use appropriate equations to explain the pH at the equivalence point of this titration.

(3 marks)

(d) Use appropriate equations to explain why the reaction mixture in the flask was able to act as a buffer after the addition of 10 mL of sodium hydroxide.

(4 marks)

After repeating the experiment a number of times, the student found the concentration of the propanoic acid solution was 0.815 mol L^{-1} .

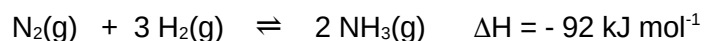
(e) Use the data provided to calculate the pH of the mixture in the flask after 30.0 mL of sodium hydroxide had been added to the 25.0 mL aliquot of propanoic acid.

(6 marks)

Question 38

(16 marks)

Ammonia is amongst the top ten most produced chemicals in the world. It is an essential feedstock in the manufacture of fertilisers, as well as playing an important role as a complexing agent in the mining industry. The manufacture of ammonia on an industrial scale is carried out using the Haber process, which relies on the reversible reaction of nitrogen and hydrogen in the presence of an iron catalyst, as shown in the equation:

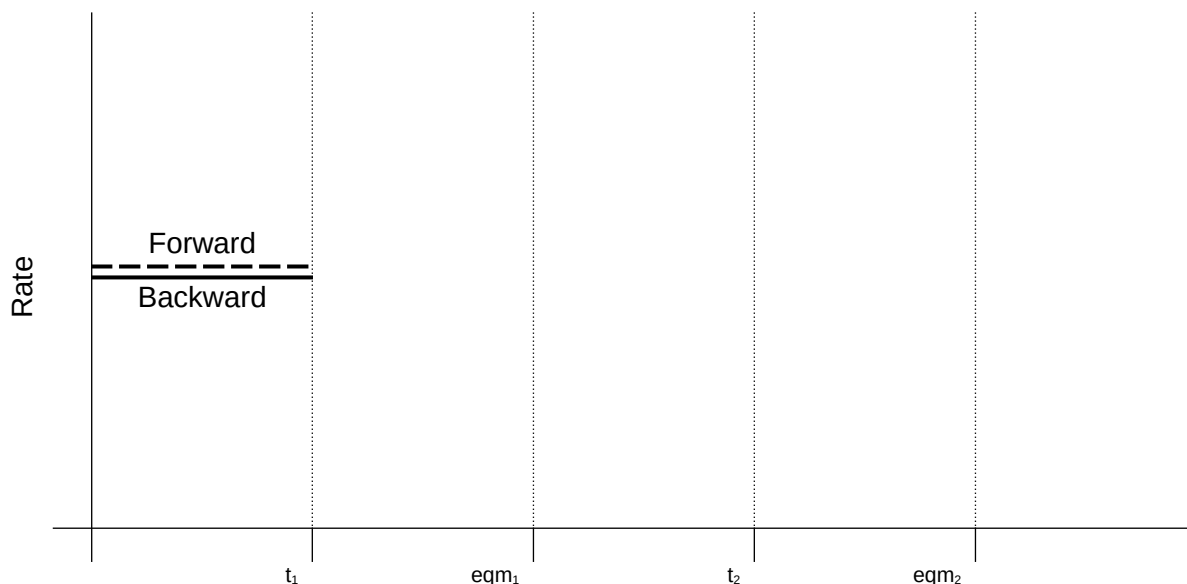


The conditions for the reaction in industry must be chosen carefully, taking into consideration not only the yield, but also the rate of the reaction. Commonly, a temperature of around 500°C is used, and the reaction operated at a pressure of around 20,000 kPa. Since ammonia has a much higher boiling point than the other gases, it can easily be removed from the equilibrium mixture by condensation.

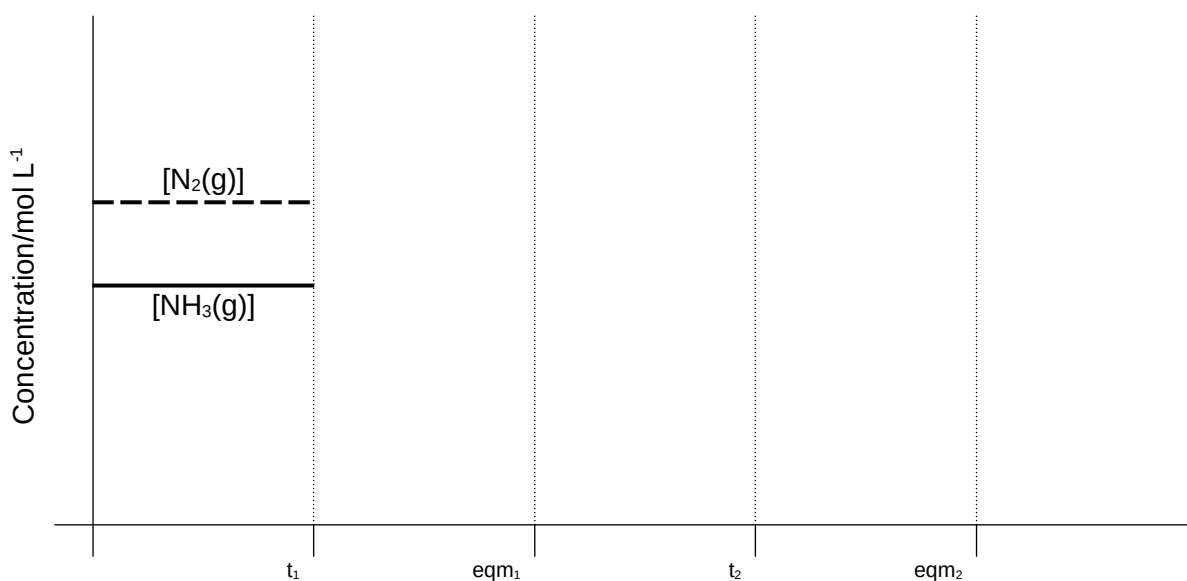
- (a) In the space provided below, draw a fully labelled enthalpy level diagram to show the reaction between nitrogen and hydrogen in the Haber process, in the presence and absence of an iron catalyst. (4 marks)

A sealed vessel containing an equilibrium mixture of nitrogen, hydrogen and ammonia was subjected to the following changes in conditions:

- At a time, t_1 , the temperature of the vessel was increased
- At a time, eqm_1 , the system had returned to equilibrium
- At a time, t_2 , all ammonia was removed from the system
- At a time, eqm_2 , the system had again returned to equilibrium



- (b) Complete the following graphs to show what happens to the rates of the forward and backward reactions, and the concentrations of nitrogen and ammonia as these changes are made. (12 marks)



Question 39

(12 marks)

Iron(II) sulfate can exist in many forms in nature, often in hydrated forms with the general formula $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

Rozenite is a mineral composed of a hydrated form of iron(II) sulfate. A student wishing to find the formula of rozenite by titration dissolved a 2.45 g sample and reacted it with a $0.0905 \text{ mol L}^{-1}$ solution of potassium permanganate. She found that 24.20 mL of the potassium permanganate solution was required for complete reaction.

- (a) State and explain what indication there would have been that the equivalence point had been reached in the student's titration. (2 marks)

- (b) Use the data provided to calculate the value of x and the formula of rozenite. (8 marks)

- (c) Identify one source of random error in the procedure and state how this error could be minimized. (2 marks)

End of questions

Spare graph paper

Question number: _____



Question number: _____

[illegible]

Question number: _____

[illegible]

Question number: _____

[illegible]

Question number: _____

[illegible]

Question number: _____

[illegible]