KINGSWAY CHRISTIAN COLLEGE

GOD IS TRUTH

YEAR 12   ATAR
CHEMISTRY UNIT 3

SEMESTER 1 2017 - PRACTICE

Name: *ANSWERS*

Question/Answer booklet

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	/50	/25
Section Two: Short answer	9	9	60	/69	/34.5
Section Three: Extended answer	5	5	70	/81	/40.5
					/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 questions 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.
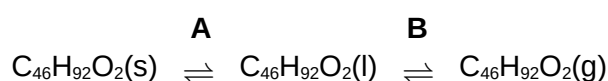
2.	When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

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%   (50 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.

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1.   When a candle burns, there are many different chemical processes occurring. Firstly the solid candle wax ($C_{46}H_{92}O_2$) is melted by the heat of the flame. This liquid wax is then drawn up the wick, where the heat of the flame vaporises it. The wax vapour then burns in air to produce the heat and light seen. The equation below represents the physical changes taking place in the candle wax **before** combustion occurs.

$$\overset{\textbf{A}}{}\qquad\qquad\overset{\textbf{B}}{}$$
$$C_{46}H_{92}O_2(s) \rightleftharpoons C_{46}H_{92}O_2(l) \rightleftharpoons C_{46}H_{92}O_2(g)$$

Classify the processes labelled A and B as endothermic or exothermic.

	A	**B**
(a)	endothermic	endothermic
(b)	endothermic	exothermic
(c)	exothermic	exothermic
(d)	exothermic	endothermic

2.   Consider the information in the table below regarding three different monoprotic acids.

Acid	**K_a**
Formic acid	1.82×10^{-4}
Hydrofluoric acid	6.76×10^{-4}
Propionic acid	1.35×10^{-5}

If separate 0.5 mol L^{-1} solutions of these three acids were tested with a pH meter, at the same temperature, which would have the highest pH?

(a)   Formic acid.
(b)   Hydrofluoric acid.
(c)   Propionic acid.
(d)   More information is required.

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

(a) $NaC\ell$
(b) $HOC\ell$
(c) $C\ell_2O_7$
(d) $C\ell F$

Questions 4 and 5 refer to the information below.

The Haber process is the final step in the production of ammonia. It involves the reaction of nitrogen and hydrogen gases in the presence of an iron/iron oxide catalyst. This process is carried out at 350-550 °C and 15-35 MPa. The reaction can be represented by the equation below.

$$N_2(g) + 3 H_2(g) \rightleftharpoons 2 NH_3(g)$$
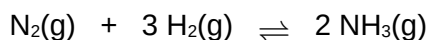
4. Which statement is **not** correct regarding the action of a catalyst?

   (a) A catalyst increases the rate of reaction.
   (b) A catalyst increases the average kinetic energy of the reactant particles.
   (c) A catalyst allows a greater proportion of particles to react.
   (d) A catalyst provides an alternate reaction pathway.

5. The iron/iron oxide catalyst is added to this system **before** it establishes equilibrium. What is the resulting effect?

   (a) Both forward and reverse reactions would be favoured equally.
   (b) The forward reaction rate would be increased more than the reverse reaction rate.
   (c) The system would establish equilibrium faster.
   (d) The yield of NH_3 would be increased.

6. A student had five different 0.2 mol L^{-1} solutions on her lab bench. They were;

   - nitric acid, $HNO_3(aq)$
   - zinc chloride, $ZnCl_2(aq)$
   - lithium hydrogencarbonate, $LiHCO_3(aq)$
   - potassium hydroxide, $KOH(aq)$
   - ammonium chloride, $NH_4Cl(aq)$

   Rank these solutions in order of **increasing** pH (i.e. lowest to highest).

(a)	HNO_3	<	NH_4Cl	<	$ZnCl_2$	<	$LiHCO_3$	<	KOH
(b)	KOH	<	NH_4Cl	<	$ZnCl_2$	<	$LiHCO_3$	<	HNO_3
(c)	HNO_3	<	$LiHCO_3$	<	NH_4Cl	<	$ZnCl_2$	<	KOH
(d)	KOH	<	$ZnCl_2$	<	$LiHCO_3$	<	NH_4Cl	<	HNO_3

7. Consider the following reaction between cobalt metal and hydrochloric acid.

   $$Co(s) + 2 H^+(aq) \rightarrow Co^{2+}(aq) + H_2(g)$$
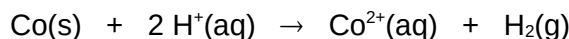
   Which of the following statements is **correct**?

   (a) Electrons are transferred from $Co(s)$ to $H^+(aq)$.
   (b) Electrons are transferred from $H^+(aq)$ to $Co(s)$.
   (c) Both $Co(s)$ and $H^+(aq)$ will each gain and lose some electrons.
   (d) Electrons are not transferred, as this is not a redox reaction.

Questions 8, 9 and 10 refer to the following information.

Consider the following equilibrium system, which is formed when solid white phosphorus reacts with fluorine gas to form phosphorus trifluoride vapour.

$$P_4(s) \ + \ 6\,F_2(g) \ \rightleftharpoons \ 4\,PF_3(g)$$
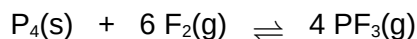
8.   What is the correct equilibrium constant (K) expression for the following reaction?

   (a) $K \ = \ \dfrac{[P_4][F_2]^6}{[PF_3]^4}$

   (b) $K \ = \ \dfrac{4[PF_3]}{6[F_2]}$

   (c) $K \ = \ \dfrac{[PF_3]^4}{[F_2]^6}$

   (d) $K \ = \ \dfrac{[PF_3]^4}{[P_4][F_2]^6}$

9.   If the total volume of the system was increased, which of the following effects would **not** occur while equilibrium is being re-established?

   (a)   The forward reaction rate would decrease.
   (b)   The reverse reaction rate would be higher than the forward reaction rate.
   (c)   The reverse reaction rate would increase.
   (d)   The forward reaction rate would have the greater change in rate.

10.   Once the system has re-established equilibrium (after the increase in total volume), which of the following statements would **not** be correct?

   (a)   The mass of $P_4(s)$ would not have changed.
   (b)   The concentration of $F_2(g)$ would have decreased.
   (c)   The number of moles of $PF_3(g)$ present would have decreased.
   (d)   The number of moles of $F_2(g)$ present would have increased.

11.   Which of the following statements explain(s) why sodium carbonate decahydrate ($Na_2CO_3.10H_2O$) 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
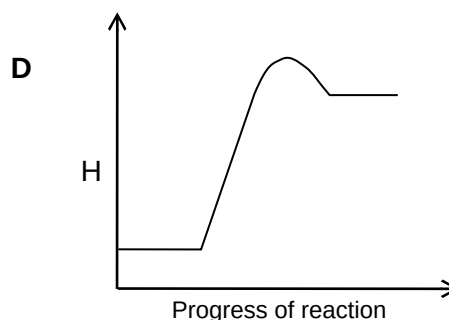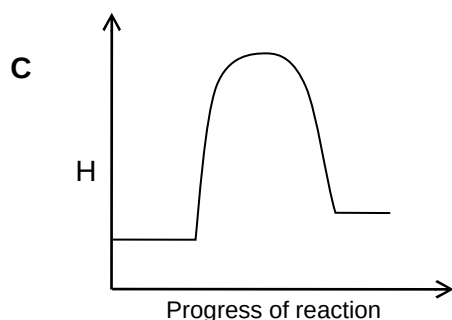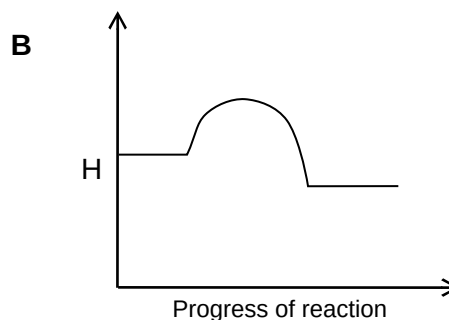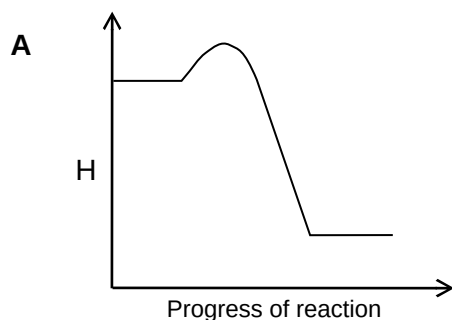   (b)   II and IV only
   (c)   II, III and IV only
   (d)   I, II, III and IV

12. Calculate the pH of a solution formed by mixing 10.0 mL of 0.125 mol L^{-1} nitric acid, HNO_3(aq), with 90.0 mL of water.

(a)   2.90
(b)   1.86
(c)   0.90
(d)   1.90

13. Examine the following energy profile diagrams which represent four different chemical processes. You may assume the scale on the y-axis is the same for each diagram.

A

Progress of reaction

B

Progress of reaction

C

Progress of reaction

D

Progress of reaction

Considering the forward and reverse activation energies of these reactions, which is **most likely** to be a reversible reaction (i.e. the reaction that is most likely to proceed in both the forward and reverse directions)?

(a)   A
(b)   B
(c)   C
(d)   D

14. The value of K_w for pure water at 30°C is 1.471 x 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

Questions 15 and 16 refer to the information below.

An acid-base titration was conducted by a chemistry professor, with the pH being monitored throughout the experiment. From the data collected, the following titration curve was produced.


Addition of burette reagent
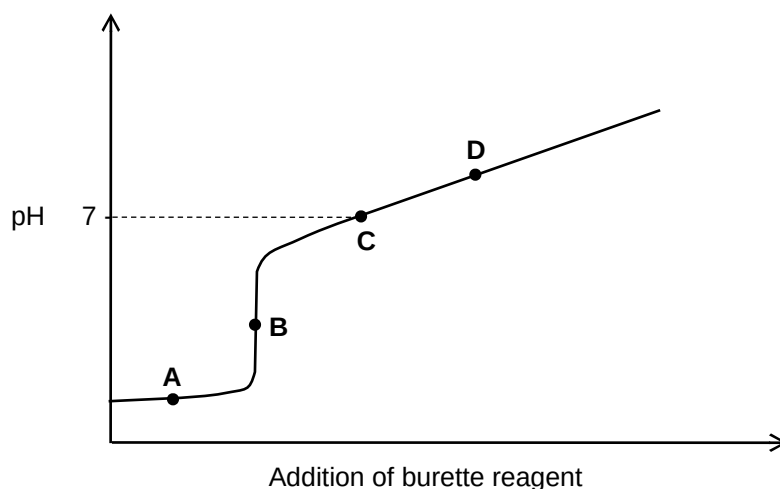
15.   Which of the following arrangements could have produced this titration curve?

	Burette reagent	**Conical flask reagent**
(a)	HNO_3(aq)	KOH(aq)
(b)	NH_3(aq)	HCl(aq)
(c)	NaOH(aq)	CH_3COOH(aq)
(d)	HCl(aq)	Na_2CO_3(aq)

16.   Which letter represents the equivalence point of the titration?

(a)   A
(b)   B
(c)   C
(d)   D

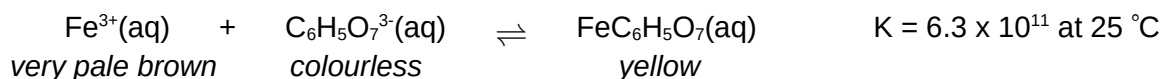17.   The endothermic auto-ionisation of water can be represented by the equation below.

$$H_2O(l) \ + \ H_2O(l) \ + \ heat \ \rightleftharpoons \ H_3O^+(aq) \ + \ OH^-(aq) \qquad K_w = 1.0 \times 10^{-14} \text{ at } 25\ ^\circ C$$
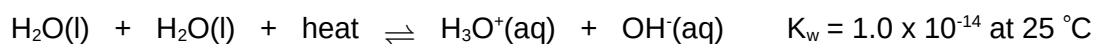
If the temperature of pure water was raised to 50 °C, which of the following statements are **correct**?

(i)   The concentration of H_3O^+(aq) would be greater than 1.0×10^{-7} mol L^{-1}.
(ii)   The concentration of OH^-(aq) would be lower than 1.0×10^{-7} mol L^{-1}.
(iii)   The value of K_w would increase.
(iv)   The pH of the water would increase.
(v)   The acidity of the water would increase.

(a)   (i) and (ii) only
(b)   (iii) and (iv) only
(c)   (i), (iii) and (v) only
(d)   (i) and (iii) only

Questions 18 and 19 refer to the following information.

Consider the following equilibrium which is formed between iron(III) ions and citrate ions, when 50 mL of iron(III) nitrate, $Fe(NO_3)_3$(aq), is mixed with 50 mL of sodium citrate, $Na_3C_6H_5O_7$(aq).

$$Fe^{3+}(aq) \quad + \quad C_6H_5O_7^{3-}(aq) \quad \rightleftharpoons \quad FeC_6H_5O_7(aq) \qquad K = 6.3 \times 10^{11} \text{ at } 25\,^{\circ}C$$
very pale brown   *colourless*   *yellow*

18. If this system was allowed to establish equilibrium at 25 $^{\circ}C$, which of the following would be the **best prediction** of the appearance of the system?

    (a) The solution would appear yellow.
    (b) The solution would appear brown-yellow.
    (c) The solution would appear very pale brown.
    (d) The colour of the solution cannot be predicted.

19. If a few drops of citric acid ($C_6H_8O_7$) were added to this equilibrium system, which of the following gives the expected result?

	Favoured direction	New concentration of Fe^{3+}(aq)
(a)	forward	increased
(b)	forward	decreased
(c)	reverse	increased
(d)	reverse	decreased

Questions 20 and 21 refer to the following information.

The equation for the complete combustion of butanol is shown below.

$$C_4H_{10}O(l) \quad + \quad 6\,O_2(g) \quad \rightarrow \quad 4\,CO_2(g) \quad + \quad 5\,H_2O(l)$$
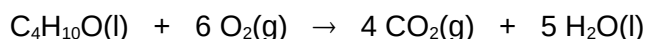
20. How does the oxidation number of the element carbon (C) change during this reaction?

    (a) +2 to +4
    (b) -2 to +2
    (c) -2 to +4
    (d) +2 to 0

21. Which of the following statements regarding combustion is **not** correct?

    (a) Combustion requires oxygen.
    (b) Combustion is exothermic.
    (c) Oxygen (O_2) is the oxidant/oxidising agent.
    (d) Combustion is spontaneous.

22. Consider the buffer solution shown below.

$$HF(aq) \ + \ H_2O(l) \ \rightleftharpoons \ F^-(aq) \ + \ H_3O^+(aq)$$
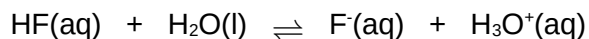
Which of the following would be **true** after the addition of a small amount of $H_3O^+(aq)$ to the buffer solution?

(a)   The forward reaction rate would decrease.
(b)   The amount of HF present in the system would increase.
(c)   The pH of the system would increase.
(d)   The forward reaction would be favoured.

23. Corrosion occurs when metals are oxidised by coming into contact with oxygen. This process is increased in the presence of water or acidic and basic conditions. When iron is corroded it often forms rust.

.   Which of the following is **correct** in relation to the rusting of iron metal?

(a)   Oxygen gas is the reducing agent / reductant
(b)   Liquid water is the reducing agent / reductant
(c)   The oxidation number of iron would decrease
(d)   The presence of salt water would increase the rate of rusting

24. 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.

25. Consider the diagram below, which shows the various colours of the indicator 'cresol red' under different pH conditions.

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

pH →

| cresol red | red | yellow | red |
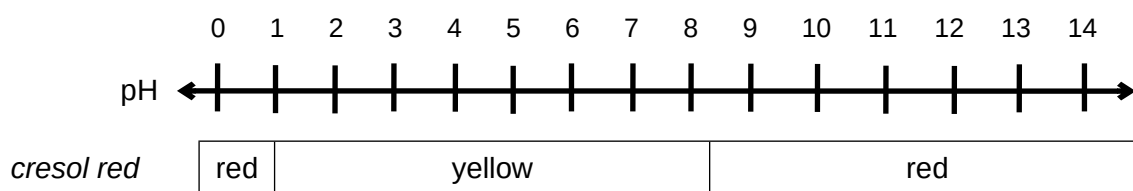
Which of the following pairs of solutions would **most easily** be distinguished by adding a few drops of cresol red indicator to each?

(a)   0.5 mol L^{-1} NaH_2PO_4 and   0.5 mol L^{-1} NaCl
(b)   2.0 mol L^{-1} H_2SO_4 and   2.0 mol L^{-1} NaOH
(c)   0.25 mol L^{-1} NH_3 and   water
(d)   0.7 mol L^{-1} H_2CO_3 and   0.7 mol L^{-1} NH_4NO_3

End of Section One

Section Two: Short answer   **34.5%   (69 marks)**

This section has **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(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26   **(9 marks)**

(a)   Give the oxidation number of the **bold** element in each of the following: (3 marks)

   (i)   **S**$_8$ **0**

   (ii) H$_2$**S**   **-2**

   (iii) Aℓ(**N**O$_3$)$_3$ **+5**
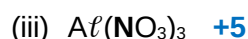
(b)   Arsenic acid (H$_3$AsO$_4$) can be produced by reacting solid arsenic trioxide (As$_2$O$_3$) with nitric acid. This produces arsenic acid, as well as the gaseous by-product dinitrogen trioxide.

Write the oxidation and reduction half-equations and the overall redox equation for this reaction, assuming acidic conditions.

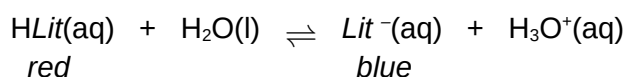|	
Oxidation half-equation	As$_2$O$_3$ + 5 H$_2$O → 2 H$_3$AsO$_4$ + 4 H$^+$ + 4 e$^-$ (2)
Reduction half-equation	2 NO$_3^-$ + 6 H$^+$ + 4 e$^-$ → N$_2$O$_3$ + 3 H$_2$O (2) OR 2 HNO$_3$ + 4 H$^+$ + 4 e$^-$ → N$_2$O$_3$ + 3 H$_2$O (1)
Overall redox equation	As$_2$O$_3$ + 2 H$_2$O + 2 NO$_3^-$ + 2 H$^+$ → 2 H$_3$AsO$_4$ + N$_2$O$_3$ (2) OR As$_2$O$_3$ + 2 H$_2$O + 2 HNO$_3$ → 2 H$_3$AsO$_4$ + N$_2$O$_3$ (2)

Question 27 **(4 marks)**

Litmus is a very common acid-base indicator which is extracted from lichens. It turns red in solutions that have a pH below 7 and blue when the pH is above 7. The substance responsible for the colour of litmus indicator is called 7-hydroxyphenoxazone. The structure of this molecule is shown below in its 'red form'.
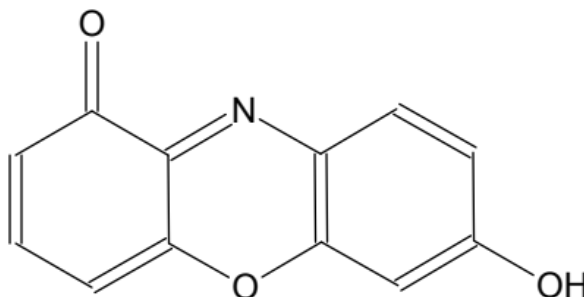

A simplified way to express this molecule is H*Lit*. This simplified notation is used in the equation below to demonstrate the reaction that litmus undergoes to change colour.

$$\text{H}Lit\text{(aq)} \; + \; \text{H}_2\text{O(l)} \; \rightleftharpoons \; Lit^-\text{(aq)} \; + \; \text{H}_3\text{O}^+\text{(aq)}$$
$$\text{red} \qquad\qquad\qquad\qquad \text{blue}$$

(a) Explain how litmus indicator works. Include details of the colour change observed in acidic and basic solution. (3 marks)

- **litmus works because the acidic / protonated form is a different colour (red) than the basic / deprotonated form (blue)**
- **In acidic solution the reverse reaction is favoured due to presence of protons/hydrogen ions/hydronium ions and protonated ie. red form of litmus dominates**
- **In basic solution the equilibrium shifts to the right due to the presence of hydroxide ions and the blue form dominates**
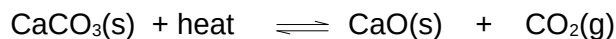
(b) Draw the 'blue form' of 7-hydroxyphenoxazone. (1 mark)
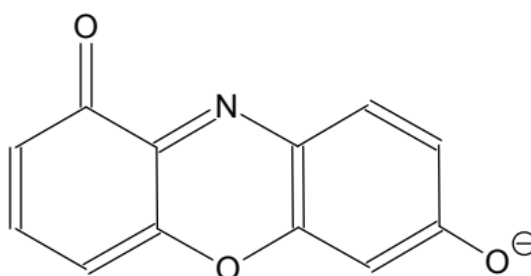
Question 28 **(10 marks)**

Consider the reversible reaction below which is used in the production of quick lime (calcium oxide).

$$CaCO_3(s) + heat \rightleftharpoons CaO(s) + CO_2(g)$$

(a) Write the equilibrium constant expression for this reaction.   (1 mark)

Description	Marks
K = [CO₂]	1
Total	1

(b) For each of the following changes made to the system at equilibrium, predict the changes to the yield of the reaction once equilibrium is re-established, using the terms increase, decrease or no change. Provide a reason for your prediction in each case.

(9 marks)

Imposed Change		Effect on Yield	Explanation
Increase temperature		**increases**	**Forward endothermic reaction favoured to oppose the increase in temperature**

Description	Marks
increases yield	*1*
forward reaction is endothermic	*1*
mention of opposing/counteracting the increase in temperature	*1*
Total	*3*

Increase pressure		**reduces**	**Equilibrium shifts to the left / reverse reaction favoured to oppose the increase of pressure because there are less gaseous moles/molecules on the left hand side / as reactants**

Description	Marks
reduces yield	*1*
mention of opposing/counteracting the increase in pressure	*1*
less gaseous moles/molecules on the left hand side / as reactants	*1*
Total	*3*

Remove calcium oxide as it is produced	**No change**	**Calcium oxide is a solid so no effect on position of equilibrium / concentration of components in system**

Description	Marks
no change on yield	*1*
mention of calcium oxide is a solid	*1*
solid doesn't affect concentration / not present in equilibrium constant expression	*1*
Total	*3*

Question 29 (9 marks)

Consider the following closed equilibrium system, which has been allowed to establish equilibrium at a temperature of 600 °C. The value of K for this reaction at 600 °C is 7.94×10^{-7}.

$$2 \ Cu_2O(s) \ \rightleftharpoons \ 4 \ Cu(s) \ + \ O_2(g)$$

(a) Write an equilibrium constant (K) expression for this reaction. (1 mark)

$K = [O_2]$

Some additional $O_2(g)$ is injected into this equilibrium system at 600 °C. The system was then allowed to re-establish equilibrium.

(b) How has the mass of Cu(s) present changed in this new equilibrium? (circle) (1 mark)

increased (decreased) no change

(c) At this new equilibrium, state the concentration of $O_2(g)$, in mol L^{-1}. Explain your answer. (2 marks)

- **concentration of O_2 is 7.94×10^{-7} mol L^{-1}**
- **since temperature has not changed, the value of K has not changed; value of K only depends on concentration of O_2, therefore concentration of O_2 must have readjusted back to original level**

(d) A small amount of $Cu_2O(s)$ was then added to this equilibrium system. Explain how this would effect the equilibrium position. (2 marks)

- **no effect**
- **solids have no measurable 'concentration' so addition or removal of a solid has no impact on equilibrium**

(e) At 800 °C, the value of K for this reaction is 3.16×10^{-5}. What does this tell you about the enthalpy change (ΔH) for this reaction? Explain your answer. (3 marks)

- **the value of K has increased which indicates more products are present**
- **this means the forward reaction must be favoured with the addition of heat**
- **therefore the forward reaction is endothermic, ie ΔH is positive**

Question 30 **(9 marks)**

Oxalic acid ($H_2C_2O_4$) is an organic acid, found in high levels in foods such as almonds, banana, rhubarb and spinach. It is a weak, diprotic acid which has many uses in the laboratory, such as in volumetric analysis where it can be used as a primary standard.

(a)   Explain what is meant when oxalic acid is referred to as a 'weak, diprotic acid'. Use relevant chemical equations to support your answer.   (4 marks)

- **'weak' indicates ionisation of oxalic acid does not go to completion**
- **'diprotic' indicates each molecule of oxalic acid contains 2 ionisable/acidic hydrogen atoms**
- $H_2C_2O_4 + H_2O \rightleftharpoons HC_2O_4^- + H_3O^+$ **OR** $H_2C_2O_4 \rightleftharpoons HC_2O_4^- + H^+$
- $HC_2O_4^- + H_2O \rightleftharpoons C_2O_4^{2-} + H_3O^+$ **OR** $HC_2O_4^- \rightleftharpoons C_2O_4^{2-} + H^+$

Some oxalic acid dihydrate crystals were used to produce a primary standard for use in a titration. 4.434 g of $H_2C_2O_4.2H_2O(s)$ was dissolved in water and made up to 250.0 mL in a volumetric flask.

(b)   Calculate the concentration of the oxalic acid primary standard.   (2 marks)

$n(H_2C_2O_4.2H_2O)$ =   m/M
=   4.434 / 126.068
=   0.0351715 mol

$c(H_2C_2O_4)$ =   n/V
=   0.0351715 / 0.2500
=   0.140686 mol L^{-1}
=   0.1407 mol L^{-1} (4SF)

The oxalic acid solution was then used to standardise some aqueous potassium hydroxide. A 20.00 mL sample of KOH(aq) required 17.85 mL of oxalic acid to reach equivalence. The relevant chemical equation for the titration is shown below.

$$2\ KOH(aq)\ +\ H_2C_2O_4(aq)\ \rightarrow\ 2\ H_2O(l)\ +\ K_2C_2O_4(aq)$$
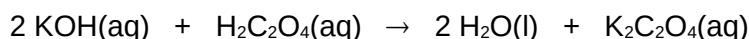
(c)   Calculate the concentration of KOH(aq).   (3 marks)

$n(H_2C_2O_4)$ =   cV
=   0.140686 x 0.01785
=   0.0025112 mol

$n(KOH)$ =   2 x $n(H_2C_2O_4)$
=   0.0050225 mol

$c(KOH)$ =   n/V
=   0.0050225 / 0.02000
=   0.251124 mol L^{-1}
=   0.2511 mol L^{-1} (4SF)

Question 31 (6 marks)

Conjugate base	Species X	Conjugate acid
NH_2^-	**NH_3 or ammonia**	**NH_4^+ or ammonium**
SO_3^{2-} or sulfite	**HSO_3^- Hydrogensulfite**	Sulfurous acid
HPO_4^- or hydrogenphospahate	Dihydrogenphosphate ion	**H_3PO_4 or phosphoric acid**

Question 32 (8 marks)

In the following equilibrium system, nitrogen, oxygen and chlorine gases combine to produce nitrosyl chloride vapour. This equilibrium system can form at temperatures of around 400 °C.

$$N_2(g) + O_2(g) + Cl_2(g) \rightleftharpoons 2\ NOCl(g)$$
colourless   colourless   greenish-yellow   yellow
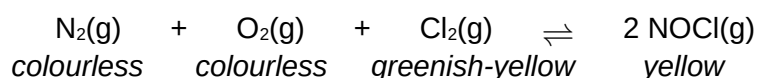
If an equal number of moles of $N_2(g)$, $O_2(g)$ and $Cl_2(g)$ were injected into a sealed flask at 400 °C;

(a)   Explain what would happen to the forward and reverse reaction rates as the system moved to establish equilibrium. (3 marks)

   - **the forward reaction rate would initially be high, as the molecules collide to produce NOCl, and would slowly decrease as the reactants form products**
   - **the reverse reaction rate would initially be zero, but as NOCl is produced it would begin to increase**
   - **at equilibrium the rate of forward and reverse reactions becomes equal**

(b)   Explain what would happen to the concentration of all gases as the system moved to establish equilibrium. (3 marks)

   - **the concentration of N_2, O_2, and Cl_2 would all decrease**
   - **the concentration of NOCl would increase from an initial concentration of zero**
   - **the concentration of NOCl would increase by double the amount that N_2/O_2/Cl_2 decrease, in proportion with the stoic ratio 1:1:1:2**

(c)   Explain what you would observe as the system moved to establish equilibrium.   (2 marks)

-     **the greenish-yellow colour of the original mixture would become more yellow**
-     **at equilibrium the colour of the system would be unchanging**

Question 33   **(8 marks)**

Phosphate buffered saline (PBS) is a solution which is commonly used in biological research. It was specifically designed so that the ion concentrations of the buffer solution match those found in the human body. The table below gives a standard 'recipe' for making PBS. The four salts are dissolved in water to produce the concentrations indicated.

	Final concentration when dissolved in distilled water	
Salt	**Conc. (g L^{-1})**	**Conc. (mmol L^{-1})**
NaCl	8.0	137
KCl	0.2	2.7
Na_2HPO_4	1.42	10
KH_2PO_4	0.24	1.8

(a)   Which components would produce the buffering effect observed in PBS? Explain your
        answer.   (2 marks)

-     **Na_2HPO_4 and KH_2PO_4**
-     **The HPO_4^{2-} / $H_2PO_4^-$ are a weak conjugate acid-base pair**

(b)   Write an equation showing the buffering system that would form.   (1 mark)

-     **$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$ (B1)**
      OR
-     **$H_2PO_4^- + OH^- \rightleftharpoons HPO_4^{2-} + H_2O$ (B2)**

(c)   Explain how this buffer is able to resist a change in pH when a small amount of NaOH(aq)
        is added.   (2 marks)

-     **The addition of NaOH neutralises the H_3O^+ (B1) / increases the concentration of
      OH^- (B2)**
-     **The system then favours the forward reaction to produce more H_3O^+ (B1) / reduce
      the amount of OH^- (B2), thereby maintaining a constant pH**

PBS is specially designed for use in molecular biology and microbiology labs, so it is made to particular specifications.

(d)   Define 'buffering capacity' and describe how you could increase the buffering capacity of PBS if you did not have to take into account its biological uses.   (3 marks)

-    **buffering capacity is the extent to which a buffer can maintain a constant pH when additional H_3O^+ or OH^- is being added**
-    **the buffering capacity of PBS could be increased by combining the HPO_4^{2-} / $H_2PO_4^-$ in equimolar amounts, and**
-    **by increasing the concentration of both HPO_4^{2-} / $H_2PO_4^-$**

Question 34   **(6 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   **$Cr(OH)_3 + 3 CH_3COOH \rightarrow Cr^{3+} + 3 CH_3COO^- + 3 H_2O$**
             Correct species (1)   Correctly balanced (1) Must have correct species for balancing mark. Award 1 mark for correctly balanced non-ionic equation
Observation **Green solid dissolves in c/less solution to form c/less solution**

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

Equation   **$Pb^{2+} + 2 C\ell^- \rightarrow PbC\ell_2$**
             Correct species (1)   Correctly balanced ✓ Must have correct species for balancing mark. Award 1 mark for correctly balanced non-ionic equation
Observation **Two c/less solutions form white ppt in c/less solution(1)**

End of Section Two

Section Three: Extended answer 40.5% (81 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.

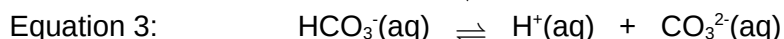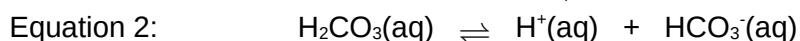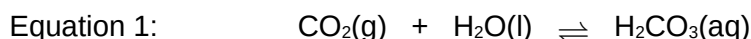Final answers to calculations should be expressed to the appropriate number of significant figures.

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.

Suggested working time: 70 minutes.

Question 35 **(12 marks)**

For the last few decades, the climate change debate has been taking place between the scientists, governments, companies and citizens of our planet. Rising carbon dioxide levels are thought to have contributed significantly to this climate change, including the phenomenon known as 'ocean acidification'. Some of the chemistry behind carbon dioxide and its link to ocean acidification is represented in the equations below.

Equation 1: $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

Equation 2: $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

Equation 3: $HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)$

One of the many negative consequences of ocean acidification is thought to be the disruption of the chemistry of ocean water, leading to things such as a decreased rate of calcification amongst many marine organisms. For example, one of the main compounds from which coral build their structure is calcium carbonate. Ocean acidification decreases the amount of calcium carbonate available to these organisms and thereby severely impacts their survival. This has already been observed in the Great Barrier Reef and many countries are already committed to reducing their nation's carbon dioxide emissions in an effort to combat the climate change we are witnessing.

(a) Explain how an increase in atmospheric carbon dioxide, $CO_2(g)$, levels can cause a change in the pH of our oceans. (3 marks)

- **Some atmospheric carbon dioxide dissolves in ocean water to produce the weak carbonic acid (equation 1)**
- **The carbonic acid then ionises to produce H_3O^+ (equation 2 and 3)**
- **Since pH = -log[H_3O^+], the presence of additional H_3O^+ in our oceans lowers the pH and causes acidification**

A chemistry teacher was attempting to demonstrate the process of ocean acidification to her class using the apparatus shown in the diagram below. A sample of ocean water was placed in a glass fish tank and a canister of carbon dioxide was attached by a tube. When the canister was opened, additional carbon dioxide gas was introduced into the air in the fish tank. A small vent ensured the overall air pressure in the fish tank remained constant.
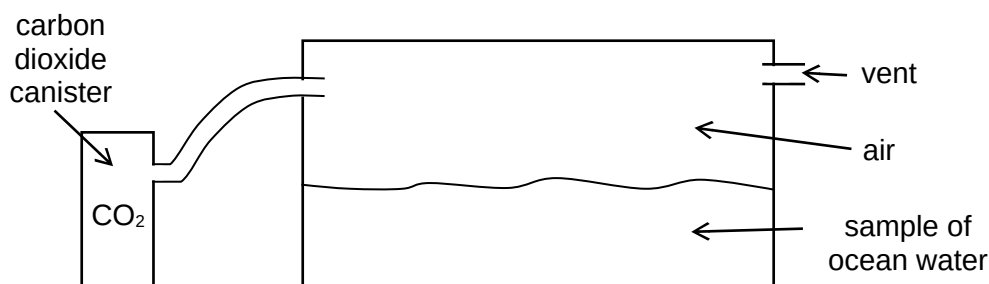
(b)   Explain, in terms of the collision theory and with reference to Equation 1, the effect on both the forward and reverse reaction rates, when the partial pressure of CO_2(g) present in the tank was increased.   (3 marks)

- **as the partial pressure of CO_2 is increased, this increases the rate of collision between CO_2 and H_2O (Equation 1), increasing the forward reaction rate significantly**
- **the production of more H_2CO_3 molecules then also causes the reverse reaction rate to increase**
- **as the system moves to establish equilibrium, the forward reaction rate will decrease and the reverse reaction rate will increase, until they are again equal; however at the new equilibrium, both reaction rates will be higher than original**

(c)   Does the teacher's demonstration represent an open or closed equilibrium system? Explain.   (2 marks)

- **open**
- **matter (i.e. CO_2) is being added into the system (and air is able to leave)**

(d)   State two (2) negative consequences associated with a decreased calcification rate amongst marine organisms such as coral.   (2 marks)

- **any 2 consequences… species may become threatened / populations of calcifying organisms may decline or die out / coral reefs become damaged / marine organisms which shelter in coral reefs may be at risk / sources of food may be removed from ecosystems / coastlines become less protected without the coral reefs etc**

(e)   Australia recently committed to reducing its carbon dioxide emissions 26% by the year 2030. Other than reducing the effects of ocean acidification, state and explain one other benefit this might produce for our climate.   (2 marks)

- **may prevent further increase in global surface temperatures**
- **carbon dioxide is a greenhouse gas which traps heat and is thought to contribute to global warming**

Question 36 **(17 marks)**

In the process of cheese making a bacterial culture is added to milk, which causes the milk to separate into the curds (solid cheese) and whey (remaining liquid). During this process the bacteria convert the lactose present in milk, into lactic acid, $CH_3CHOHCOOH$. Lactic acid is a weak, monoprotic, organic acid. Cheese makers use the concentration of lactic acid in the whey to determine when the reaction has proceeded to the extent that the cheese (curds) are ready for consumption or storage.

The concentration of lactic acid present in the whey can be determined at any time during the cheese making process via a simple titration. This usually involves taking a 10 mL sample of whey and titrating it against some standard sodium hydroxide solution, $NaOH(aq)$, using phenolphthalein as an indicator.

(a)   Explain why phenolphthalein indicator is used. Use a chemical equation to support your
        answer.   (3 marks)

- **the equivalence point of this titration is basic**
- **due to the production of the basic salt $CH_3CHOHCOONa$**
- **$CH_3CHOHCOO^- + H_2O \rightleftharpoons CH_3CHOHCOOH + OH^-$**

A cheese maker added 4.00 L of milk to a small sample of bacterial culture. He knew that once the concentration of lactic acid reached 1.25×10^{-2} mol L^{-1} the cheese would be ready. He took a 10.00 mL sample of the whey, added several drops of phenolphthalein, and titrated the sample against a 0.111 mol L^{-1} NaOH solution. 1.15 mL of NaOH was required for equivalence. The reaction that took place in the titration is shown below.

$$CH_3CHOHCOOH(aq) \ + \ NaOH(aq) \ \rightarrow \ H_2O(l) \ + \ CH_3CHOHCOONa(aq)$$
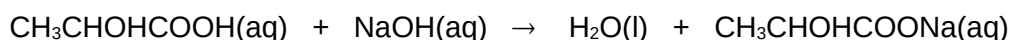
(b)   Determine the concentration of lactic acid in the whey, and comment on whether or not the
        cheese maker should allow the reaction to proceed for longer before isolating the curds.
                                                                                     (4 marks)

n(NaOH)   =   cV
=   0.111 x 0.00115
=   1.2765 x 10⁻⁴ mol

n($CH_3CHOHCOOH$)   =   n(NaOH)
=   1.2765 x 10⁻⁴ mol

c($CH_3CHOHCOOH$)   =   n/V
=   1.2765 x 10⁻⁴ / 0.01000
=   1.2765 x 10⁻² mol L⁻¹
=   1.28 x 10⁻² mol L⁻¹ (3SF)

reaction should be stopped now as concentration of lactic acid is > 1.25 x 10⁻² mol L⁻¹

(c) Determine the percent by mass of lactic acid present in the whey at this point in time, if the 10.00 mL sample was taken from a total volume of 3.10 L of whey. The density of the whey is 1.040 kg L^{-1}. (5 marks)

n($CH_3CHOHCOOH$ in 3.10 L) = cV
= 1.2765 x 10^{-2} x 3.1
= 0.0395715 mol

m($CH_3CHOHCOOH$) = nM
= 0.0395715 x 90.078
= 3.56452 g

m(whey) = V
= 1.040 x 3.10
= 3.224 kg

= 3224 g

% lactic acid in whey = 3.56452 / 3224 x 100
= 0.11056 %
= 0.111 % (3SF)

(d) The cheese maker only took one 10.00 mL sample of whey to examine, but he could have performed multiple trials of the titration if he had wished. Explain how this would improve the accuracy of his calculated lactic acid concentration. (2 marks)

- **repeat trials allow an average titre to be calculated rather than one single value**
- **averaging data reduces the effects of random errors on the results and improves reliability**

Another cheese maker mistakenly used methyl orange indicator in an identical titration.

(e) Would he have obtained a smaller or larger NaOH titre reading? Comment on whether this is a random or systematic error. Explain your answer. (3 marks)

- **his titre value would have been smaller (resulting in a lower calculated lactic acid concentration)**
- **systematic error**
- **error was in the method used by the scientist, would have given consistently low titre values, accuracy can be improved by altering the method i.e. indicator**

Question 37 **(14 marks)**

This question is about the production of sulfuric acid (H_2SO_4). This process is carried out through a number of steps:

Step 1
Liquid sulfur is reacted with dry air to produce sulfur dioxide (SO_2).

Step 2
The sulfur dioxide is oxidised to sulfur trioxide using vanadium(V) oxide as a catalyst. This step is called the Contact Process. The equation for the reaction is shown below.

$$2\ SO_2(g)\ +\ O_2(g)\ \rightleftharpoons\ 2\ SO_3(g)\qquad \Delta H = -\ 196\ kJ\ mol^{-1}$$
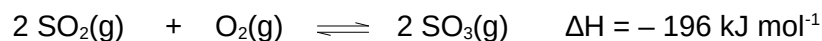
Step 3
Concentrated sulfuric acid (98.0 % by mass) is used to dissolve sulfur trioxide where it forms oleum ($H_2S_2O_7$).

Step 4
The oleum is mixed with water to obtain more sulfuric acid.

A team of chemical engineers carried out step 2 at a variety of temperatures to inform decisions about the optimum conditions for the reaction. Their results are shown on the next page.

CONTINUED ON NEXT PAGE

Table 1. Yield of sulphur trioxide for contact process reaction carried out at 150 kPa pressure, with a V_2O_5 catalyst at a range of temperatures.

Temperature of reaction vessel (°C)	Yield of SO_3 (%)
200	95
400	92
500	72
600	40
650	31
700	26
800	18
1000	12

(a)   On the grid below, display this data with a line graph.   (4 marks)
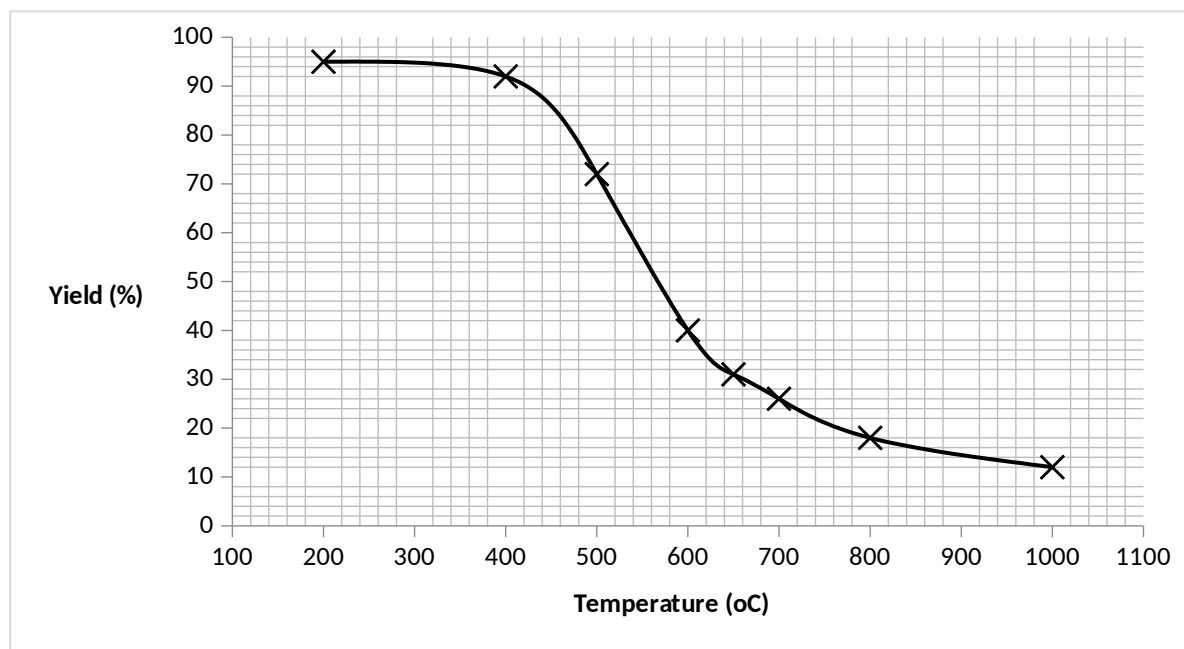
Description	Marks
correct scales (temperature on horizontal axis)	*1*
scales labelled, including units	*1*
correct plot	*1*
line drawn	*1*
Total	**4**

(b)   Use your graph to predict the yield of the reaction at 550 °C.   (1 mark)

Description	Marks
54 – 58%	*1*
Total	**1**

(c)   Describe the trend shown by these results.   (2 marks)

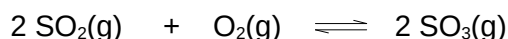| Description	Marks
the yield decreases with increasing temperature	1
Some description related to the shape, e.g. the yield changes significantly between 30 – 90 degrees / little change to yield at when changing temperature at low or high temperatures	1
Total	**3**

(d)   As a result of these findings, the chemical engineer decided to operate the sulfuric acid plant at a temperature of 200 °C. However, the amount of sulphur dioxide produced was very low. Suggest a reason for this.   (1 mark)

Description	Marks
the reaction would be too slow (at this temperature)	1
Total	**1**

(e)   After further tests, it was decided to operate the plant at 400 °C. With reference to your graph, explain why this temperature, and not a higher temperature, was chosen.
(2 marks)

Description	Marks
There is a relatively high yield (92%) at this temperature	1
The yield drops significantly at temperatures higher than 400 °C	1
Total	**2**

(f)   Assuming a yield of 92.0%, Calculate the volume of oxygen, at 400 °C and a pressure of 150 kPa, required to produce 1.00 tonne (1.00×10^6 g) of sulphur trioxide in the Contact Process: (4 marks)

$2 \text{ SO}_2(g) \quad + \quad \text{O}_2(g) \quad \rightleftharpoons \quad 2 \text{ SO}_3(g)$

Description	Marks
$n(SO_3) = m / M = 1.00 \times 10^6 / 80.07 = 1.2489 \times 10^4$ mol	1
$n(O_2)_{required} = (1/2) \times n(SO_3) \times (100/92)$ $= (1/2) \times 1.2489 \times 10^4 \times (100/92) = 6.787 \times 10^3$ mol	1
PV = nRT $V = nRT / P = (6.787 \times 10^3 \times 8.314 \times 673.15) / 150$ **$= 2.53 \times 10^5$ L**	1
units and correct significant figures (3)	1
Total	**4**

Question 38   **(19 marks)**

Silicon dioxide (SiO_2) is one of the most abundant substances in the Earth's crust. It is most commonly found in quartz and many types of sand and because of this, is often found in metal ores that are mined from the Earth's crust. One of the methods that can be used to remove silicon dioxide from an ore is illustrated in the equation below.

$$SiO_2(s) \; + \; H_2(g) \; \rightleftharpoons \; SiO(g) \; + \; H_2O(g) \qquad \Delta H = +534 \text{ kJ mol}^{-1}$$
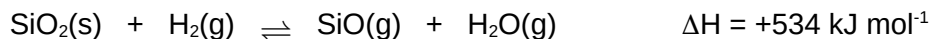
This chemical equation represents the equilibrium that forms between silicon dioxide and silicon monoxide. The activation energy for this reaction is 565 kJ mol^{-1}.

(a)   Identify the oxidising agent (oxidant) and reducing agent (reductant) in this reaction. Use oxidation numbers to support your answer. (2 marks)

-   **SiO_2 is the oxidant; O.N. of Si changes from +4 to +2**
-   **H_2 is the reductant; O.N. of H changes from 0 to +1**

(b)   Draw an energy profile diagram for this reaction. Label the activation energy and the enthalpy change. (4 marks)

Progress of reaction

Potential energy (k

Ea = +565 kJ

SiO + H$_2$O

ΔH = +534 kJ

SiO$_2$ + H$_2$
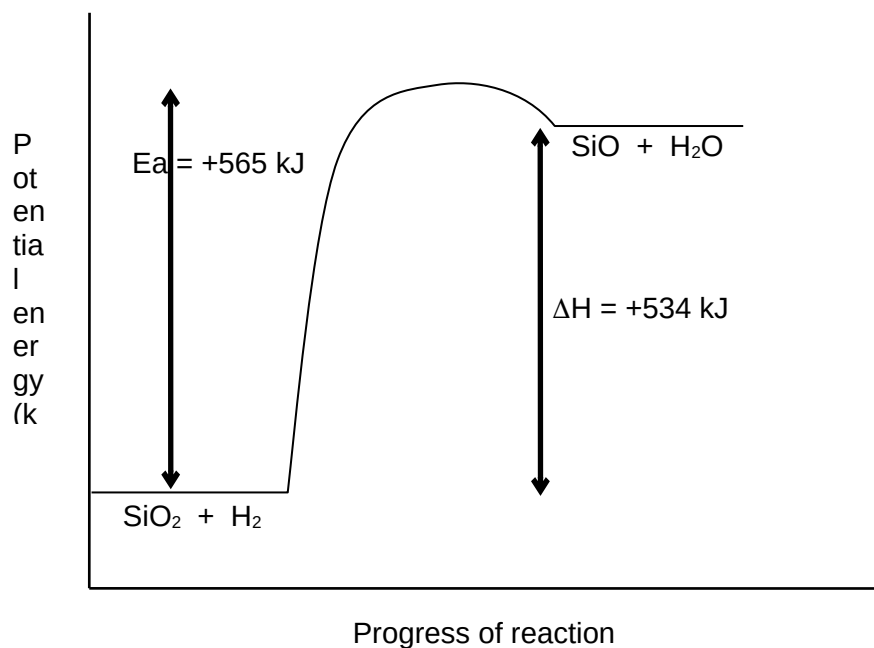
(c)   Determine the value of; (2 marks)

Ea(rev)   **31 kJ mol^{-1}**

ΔH(rev)   **-534 kJ mol^{-1}**

Quite a low pressure, around atmospheric, is used for this process. However a high temperature of 1550 °C is maintained in the reaction chamber.

(d) Explain, in terms of the collision theory, the effect of each of the following on reaction rate.

(5 marks)

Use of high temperature	- **increases average kinetic energy of reactants and results in an increased number of collisions** - **also a greater proportion of reacting species have sufficient energy to overcome Ea barrier** - **therefore a faster reaction rate**
Use of low pressure	- **decreases number of collisions that occur between reactants due to large distances between gas particles** - **therefore a slower reaction rate**

(e) State the effect (increased, decreased or no change) of each of the following on yield.

(2 marks)

Use of high temperature	**increased**
Use of low pressure	**increased**

Since the silicon monoxide is produced in gaseous form, SiO(g), it is easily removed from the system. This in turn helps to favour the forward reaction.

(f) Continue the concentration graph below, by sketching the effect of removing a batch of SiO(g) from the reaction chamber. (4 marks)
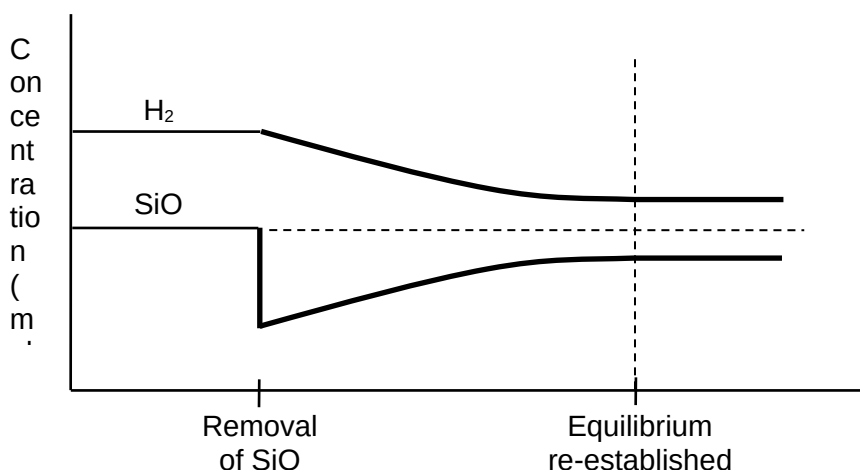
(1) steep drop in SiO
(1) lines should curve in correct direction
(1) lines should have the same shape (reduction in H_2 approx. same as increase in SiO)
(1) SiO should not return to original levels
(1) lines should be parallel at equilibrium

-1 mark for each mistake

Question 39 **(19 marks)**

Barium hydroxide, $Ba(OH)_2(s)$, also known as 'baryta' is often found in hydrated form and appears as white crystals. It is corrosive, toxic and moderately soluble in water. It can be used in titrations, for the manufacture of organic substances, as well as in the synthesis of other barium-containing compounds.

A barium hydroxide solution was made by dissolving 1.31 g of solid anhydrous $Ba(OH)_2$ crystals into 795 mL of water.

(a)   Calculate the pH of this solution.   (5 marks)

$$n(Ba(OH)_2) = m/M$$
$$= 1.31 / 171.316$$
$$= 7.64669 \times 10^{-3} \text{ mol}$$

$$c(Ba(OH)_2) = n/V$$
$$= 7.64669 \times 10^{-3} / 0.795$$
$$= 9.61848 \times 10^{-3} \text{ mol L}^{-1}$$

$$c(OH^-) = 2 \times c(Ba(OH)_2)$$
$$= 0.019237 \text{ mol L}^{-1}$$

$$[H^+] = 1.0 \times 10^{-14} / [OH^-]$$
$$= 1.0 \times 10^{-14} / 0.019237$$
$$= 5.19833 \times 10^{-13} \text{ mol L}^{-1}$$

$$pH = -\log[H^+]$$
$$= -\log(5.19833 \times 10^{-13})$$
$$= 12.2841$$
$$= 12.3 \text{ (3SF)}$$

This solution of barium hydroxide was then neutralised by the addition of hydrochloric acid, $HCl(aq)$, as shown in the equation below.

$$Ba(OH)_2(aq) + 2\,HCl(aq) \rightarrow BaCl_2(aq) + 2\,H_2O(l)$$
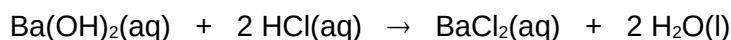
(b)   Davy was one of the first chemists to study the composition of hydrochloric acid. Briefly state the main developments he made in the field of acid-base theory.   (2 marks)

any 2 relevant points…
-     **it was previously thought that acids must contain oxygen and therefore 'oxides' were all acidic**
-     **demonstrated HCl was composed of hydrogen and chlorine**
-     **proposed that acids must contain hydrogen**
-     **(also accept 'proposed that acids contain replaceable hydrogen' as this is stated in the Unit 3 syllabus, however this was an extension of Davy's theory made by Von Leibig, not actually proposed by Davy himself)**

(c)   Using the same equation, explain how it relates to the definition of an acid and a base as proposed by Arrhenius, and why it is that these two substances are able to neutralise each other.   (3 marks)

-    **according to Arrhenius; acids are substances that contain H in their formula and produce H^+ ions in solution (i.e. HCl fits definition)**
-    **bases are substances that have OH in their formula and produce OH^- ions in solution (i.e. $Ba(OH)_2$ fits definition)**
-    **they are able to neutralise each other because $H^+ + OH^- \rightarrow H_2O$**

Hydrocyanic acid, HCN(aq), is an extremely poisonous acid with a Ka value of 6.17×10^{-10}. It is made by dissolving liquid or gaseous hydrogen cyanide in water. Small amounts of hydrogen cyanide can be extracted from the stones of some fruits such as cherries, apricots and apples, however it is generally manufactured on an industrial scale.

(d)   Write two (2) equations for the ionisation of HCN in water, one illustrating the Arrhenius theory and one the Bronsted-Lowry theory.   (2 marks)

Arrhenius	**$HCN(aq) \rightleftharpoons H^+(aq) + CN^-(aq)$**
Bronsted-Lowry	**$HCN(aq) +$ $H_3O^+(aq) +$** **$H_2O(l) \rightleftharpoons$ $CN^-(aq)$** **A B CA CB**

(e)   On the Bronsted-Lowry equation above, label the conjugate acid-base pairs.   (2 marks)

(f)   What information does the value of Ka give us about hydrocyanic acid, HCN(aq)? Explain your answer.   (2 marks)

-    **tells us that HCN is a weak acid i.e. ionisation of HCN does not occur to a large extent**
-    **since K is equivalent to P/R, very low K value indicates that there is a much higher concentration of reactants present at equilibrium i.e. unionised HCN**

The Bronsted-Lowry theory accounts for the acidic and basic properties of a much wider array of substances whose properties cannot be explained by earlier theories.

(g)   Complete the following table by stating the pH and giving a supporting equation for each of the substances.   (3 marks)

Substance	pH (acidic, basic or neutral)	Equation
MgS(aq)	basic	$S^{2-}(aq) + H_2O(l) \rightleftharpoons HS^-(aq) + OH^-(aq)$
NH$_3$(aq)	basic	$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
KHSO$_4$(aq)	acidic	$HSO_4^-(aq) + H_2O(l) \rightleftharpoons SO_4^{2-}(aq) + H_3O^+(aq)$

End of questions