

CHEMISTRY

UNIT 3

2018

MARKING GUIDE

Section One: Multiple-choice

(50 marks)

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(2 marks per
question)

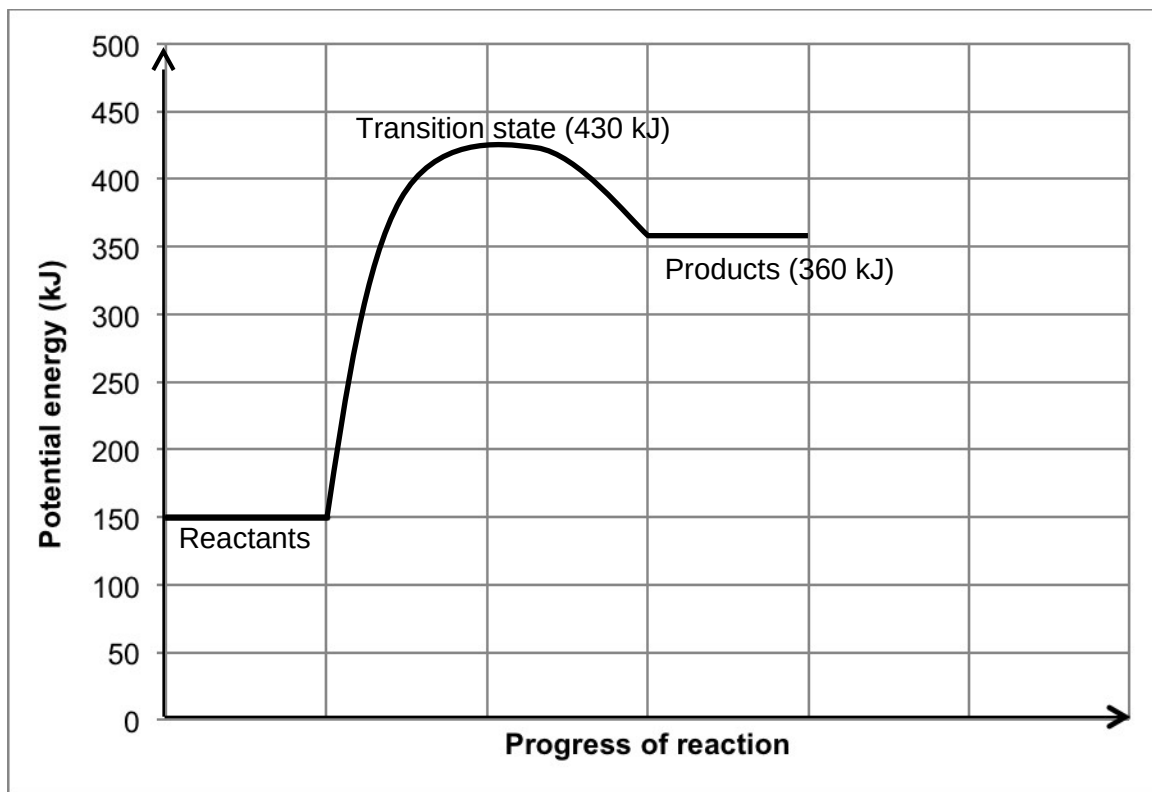
Section Two: Short answer

35% (70 marks)

Question 26

(10 marks)

The first part of an energy profile diagram has been sketched on the axes below.



If the activation energy of the **reverse** reaction is 70 kJ and the heat of reaction (enthalpy change) of the **forward** reaction is 210 kJ mol^{-1} ;

- (a) Complete the energy profile diagram above. Label the products and the transition state (activated complex). (3 marks)

- transition state labelled
- transition state at 430 kJ
products at 360 kJ

If a catalyst was added at the start of the reaction;

- (b) Which of the following is the **most likely** new value of the activation energy for the **forward** reaction? (circle your answer) (1 mark)

180 kJ

230 kJ

290 kJ

If the temperature of this system was decreased;

- (c) Explain, in terms of the collision theory, the effect this would have on the rate of reaction. (3 marks)

- decreased average kinetic energy of particles
- proportion of particles with $E_k > E_a$ is decreased (and less frequent collisions occur)
- reaction rate therefore decreased

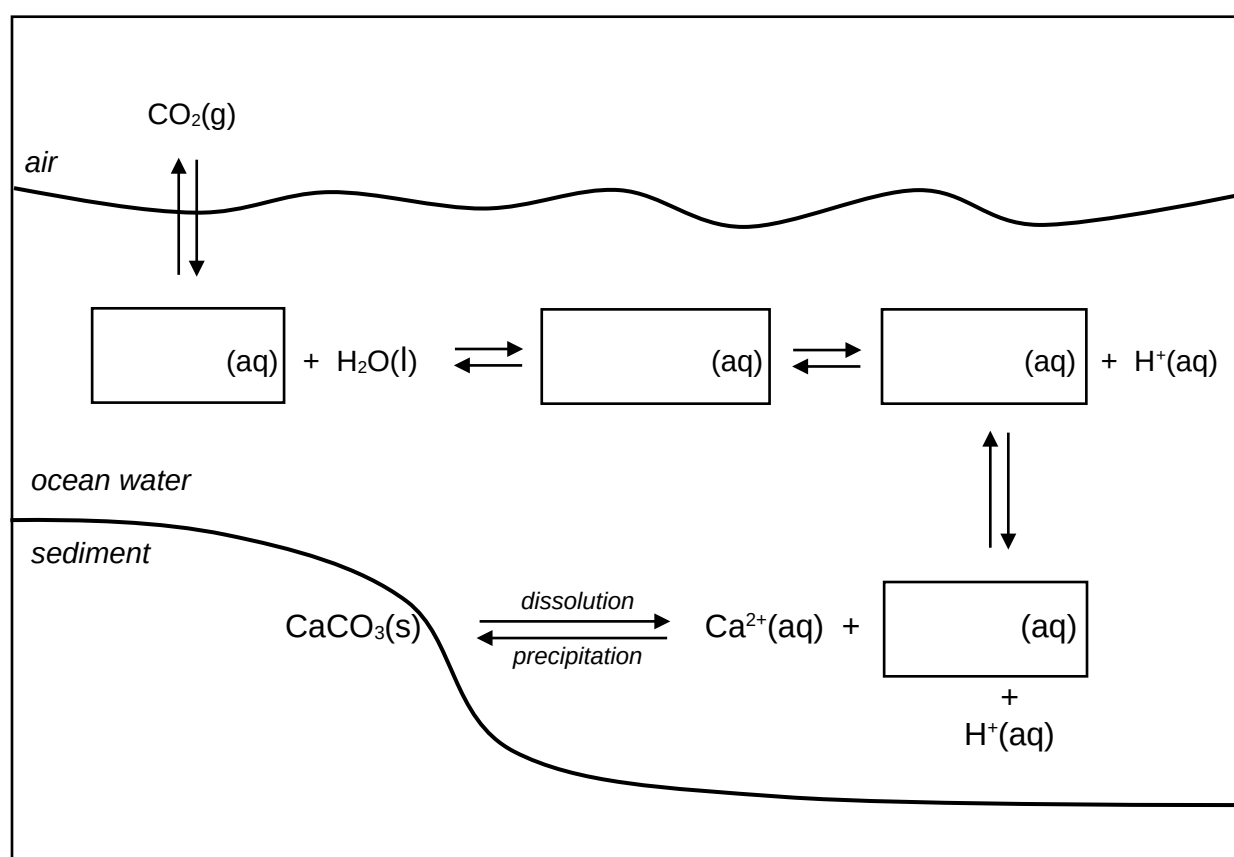
- (d) Assuming this is a reversible reaction, what effect would this temperature decrease have on the value of the equilibrium constant, K? Justify your answer. (3 marks)

- decrease in temp would favour exothermic i.e. reverse reaction
- this would increase reactant concentration/decrease product concentration
- (no mark for more / less // reactant / product)
- this would lower the value of K

Question 27

(8 marks)

Examine the diagram below, which shows some of the relevant equations involved in ocean equilibria, specifically the role of carbon-containing species.



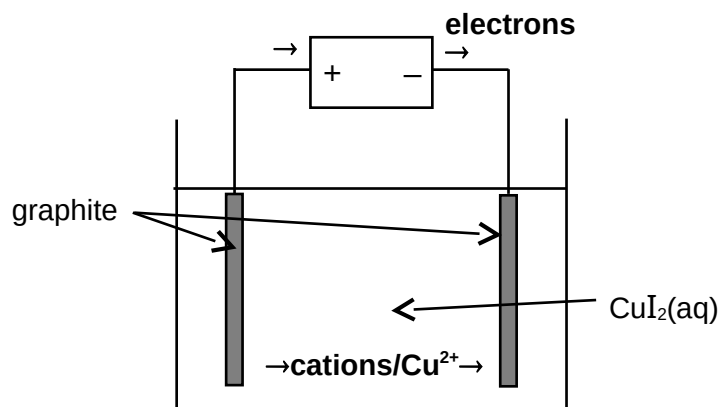
- (a) Complete the equilibrium equations on the diagram above, by writing the chemical formula of the four (4) missing carbon-containing species in the boxes. (4 marks)
- (b) Explain how higher atmospheric carbon dioxide levels cause a decrease in ocean pH, whereas the calcium carbonate present in sediment can counteract this to increase ocean pH. (4 marks)

- an increase in atmospheric CO_2 will increase the concentration of dissolved CO_2 , carbonic acid and H^+ in ocean water (as shown in diagram)
- this lowers the pH, since $\text{pH} = -\log [\text{H}^+]$
- the CaCO_3 present in sediment can dissolve in water, increasing the concentration of CO_3^{2-} (as shown in the diagram)
- this CO_3^{2-} can react with the H^+ in the ocean water, (forming HCO_3^-) and thereby increasing pH

Question 28

(8 marks)

An electrolytic cell is set up as shown below. The electrolyte is aqueous copper(II) iodide and both electrodes are made from graphite. As the cell runs, copper metal and iodine are produced.



- (a) Indicate the direction of electron flow and cation flow on the diagram above. (2 marks)
- (b) Write half-equations to illustrate the reactions occurring at each electrode. (2 marks)

cathode	$\text{Cu}^{2+}_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Cu}_{(\text{s})}$
anode	$2\text{I}^{-}_{(\text{aq})} \rightarrow \text{I}_{2(\text{aq})} + 2\text{e}^-$

- (c) Tick **all** of the **observations** that are **correct** for this cell as it continues to run. (2 marks)

- ☐ copper metal forms at the cathode
- ☐ a silver metal forms at the negative electrode
- ☐ a salmon pink metal forms at the anode
- ☒ the electrolyte becomes paler blue
- ☒ a brown solution forms around the positive electrode

(-1) per mistake

("copper metal" is not an observation)

- (d) When aqueous copper(II) **chloride** is electrolysed, oxygen gas forms instead of chlorine gas. Explain why this occurs. (2 marks)

-	water is oxidised to O_2 (instead of Cl^- to Cl_2)
-	since water has a higher oxidation potential/requires less energy input

Question 29**(10 marks)**

The 'etching' of silicon is performed in the production of semiconductor materials, which are used in all forms of modern technology, such as mobile phones and computers. This etching can be achieved using the reversible chemical reaction below.



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

$$K = \frac{[\text{SiF}_4][\text{H}_2]^2}{[\text{HF}]^4}$$

- (b) Complete the following table, for each of the imposed changes stated. In each case, state the effect on the forward reaction rate and the equilibrium position. (6 marks)


	Forward reaction rate (increase, decrease, no change)	Equilibrium position (left, right, no change)
Increase in total volume of the system	Decrease	Left
Removal of some H ₂ (g) from system	Decrease Also accept "no change"	Right
Increase in temperature of the system	Increase	Left

- (c) Rather than blocks or cubes of silicon (Si), the silicon used in etching is in the form of extremely thin pieces called 'wafers'. Explain, in terms of the collision theory, what effect this has on both the forward reaction rate and yield of the reaction. (3 marks)

- forward reaction rate would be increased
- increase in surface area will result in a higher rate of reactant collisions
- yield will be unaffected by this change as the equilibrium position is not altered

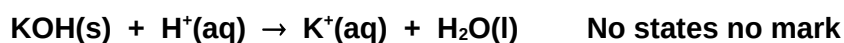
Question 30**(7 marks)**

Six reactions (A-F) were carried out, as shown in the table below.

A	$\text{Zn(s)} + \text{Ni(NO}_3)_2\text{(aq)}$
B	$\text{Br}_2\text{(aq)} + \text{KI (aq)}$
C	$\text{HCl(aq)} + \text{KOH(s)}$
D	$\text{Br}_2\text{(aq)} + $  (l)
E	$\text{Fe(s)} + \text{H}_2\text{O(l)}$
F	$\text{Ni(s)} + \text{HCl(aq)}$

(a) Name the reaction that would occur in E. **rusting / corrosion / oxidation** (1 mark)(b) In which reaction would halogen displacement occur? **B** (1 mark)

(c) Write the ionic equation for the reaction occurring in C. (1 mark)



(d) Give full observations for the reaction occurring in A. (2 marks)

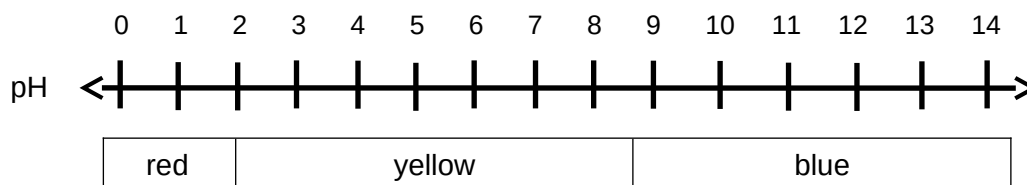
- new silver/grey solid forms as original solid dissolves
- green solution fades in colour

(e) Write two half-equations for the reaction occurring in B. (2 marks)

oxidation	$2 \text{I}^-_{\text{(aq)}} \rightarrow \text{I}_{2\text{(aq)}} + 2 \text{e}^-$
reduction	$\text{Br}_{2\text{(aq)}} + 2 \text{e}^- \rightarrow 2 \text{Br}^-_{\text{(aq)}}$

Question 31**(10 marks)**

Thymol blue is an indicator that has two distinct colour changes and displays three different colours over the pH range 0 to 14, as shown in the diagram below.



A few drops of thymol blue were added to the following 0.2 mol L⁻¹ solutions;

- HNO₃(aq)
- Mg(NO₃)₂(aq)
- NH₄NO₃(aq)
- KHCO₃(aq)

- (a) Which of these substances is most likely to turn blue? Use an equation to support your answer. (2 marks)

- KHCO ₃ has basic pH (due to hydrolysis with water forming OH ⁻ ions)
- $\text{HCO}_3^- (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{H}_2\text{CO}_3 (\text{aq}) + \text{OH}^- (\text{aq})$
- Minus ½ no states; no equilibrium arrows 0

- (b) State two (2) solutions that **could not** be distinguished by adding thymol blue. Justify your answer using appropriate chemical equations. (4 marks)

- NH ₄ NO ₃ and Mg(NO ₃) ₂
- NH ₄ NO ₃ is acidic, $\text{NH}_4^+ (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{NH}_3 (\text{aq}) + \text{H}_3\text{O}^+ (\text{aq})$
- Minus ½ no states; no equilibrium arrows 0 marks
- Mg(NO ₃) ₂ is neutral
- Therefore they would both produce a yellow solution in this indicator

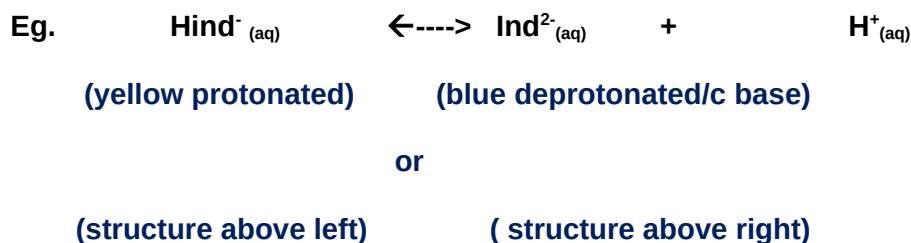
- (c) Two forms of thymol blue, at different pH, are shown in the table below. Complete the table, by writing which structure is blue in colour and which is yellow. (1 mark)

Thymol blue structure		
Colour (blue or yellow)	yellow	blue

- (d) Justify your answer to (c). Include a brief description of how indicators function (i.e. how they are able to change colour). (3 marks)

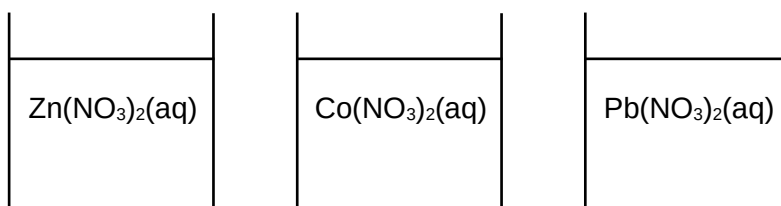
- indicators are substances (often weak acids or bases) where the conjugate acid/base species (protonated/deprotonated forms) display a different colour
-
- the structure with the -OH group is the acidic form, having accepted a proton (from the acidic solution, neutral or slightly alkaline solution it is in)
- this would occur at a medium to low pH, when $[H^+]$ is higher, or not very low and is therefore the yellow form
OR
- the structure with the $-O^-$ group is the basic form, having donated a proton (to the basic solution it is in)
- this would occur at a higher pH, when $[H^+]$ is low, (and the indicator is acting as a proton donor) and is therefore the blue form

To obtain full marks, the example used to illustrate the conjugate acid/base nature of indicators should relate their own general formula to the structure above.



Question 32**(10 marks)**

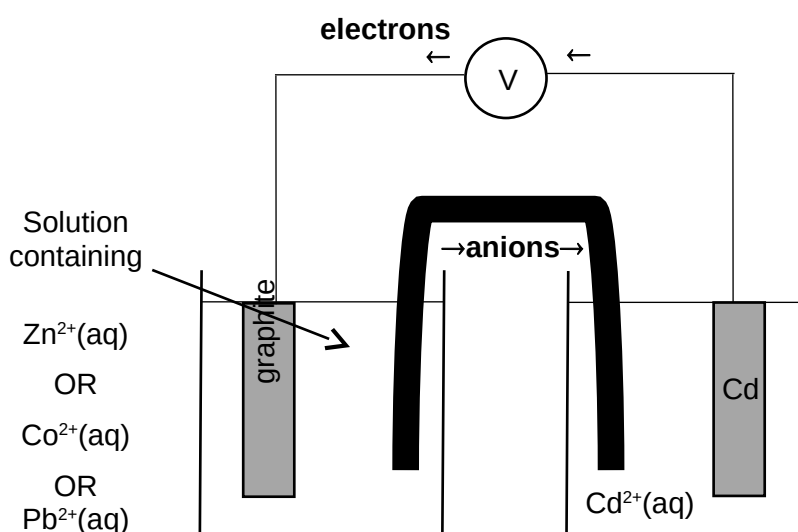
Three beakers were prepared as shown below, each containing a 1.0 mol L^{-1} solution of a different aqueous metallic salt.



(a) Which of these is the strongest oxidising agent (oxidant)? Justify your answer. (2 marks)

- Pb^{2+} (Accept $\text{Pb}(\text{NO}_3)_2$)
- Has the highest reduction potential of -0.13 V (compared to -0.28 V for Co^{2+} and -0.76 V for Zn^{2+})

A graphite rod was placed in each of the beakers shown above. One by one, they were connected to a $\text{Cd}(\text{s})/\text{Cd}^{2+}(\text{aq})$ half-cell and the voltage of each combination was measured. The following diagram represents the experimental set up. Assume standard conditions for all half-cells.



One of the half-cells would **not** produce a voltage when connected to the $\text{Cd}(\text{s})/\text{Cd}^{2+}(\text{aq})$ half-cell.

(b) Name this half-cell and explain why no voltage is produced. (2 marks)

- Zn^{2+} half-cell
- Zn^{2+} can't react / be reduced as Cd^{2+} has a higher reduction potential, therefore no tendency for a reaction to occur / no EMF to drive the reaction (this is because there is no Zn electrode present to act as the anode)

The remaining half-cells **would** produce a voltage when connected to the $\text{Cd(s)}/\text{Cd}^{2+}(\text{aq})$ half-cell. For these examples;

(c) Indicate the direction of electron flow and anion flow on the diagram above. (2 marks)

(d) Is the Cd(s) the anode or the cathode? (1 mark)

- **anode**

(e) Which combination of half-cells would produce the highest voltage? Calculate the EMF produced by this combination. (2 marks)

-	$\text{Cd}/\text{Cd}^{2+} // \text{Pb}^{2+}/\text{graphite}$ (Accept Cd and Pb^{2+})
-	+0.27 V

(f) What is the function of the graphite electrode in the half-cells? (1 mark)

- **surface for electron transfer**

Question 33**(7 marks)**

The Arrhenius theory of acids and bases introduced the relationship between acid behaviour and $\text{H}^+(\text{aq})$ ions. Ethanoic acid (CH_3COOH) is a common organic acid found in vinegar. It is a weak, monoprotic acid.

- (a) Write an Arrhenius equation for the ionisation of ethanoic acid. (1 mark)

$\text{CH}_3\text{COOH}_{(\text{aq})} \rightleftharpoons \text{CH}_3\text{COO}^-_{(\text{aq})} + \text{H}^+_{(\text{aq})}$ Minus $\frac{1}{2}$ no states; no equilibrium 0
(no marks for Bronstead Lowry equation)

- (b) Define the term 'monoprotic' and explain why ethanoic acid is monoprotic, despite having four (4) hydrogen atoms per molecule. (2 marks)

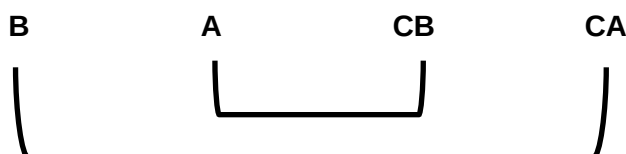
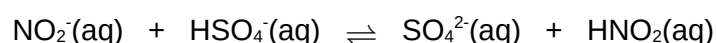
- | |
|---|
| - one ionisable/acidic hydrogen atom per molecule |
| - only the H attached to the O is ionised/acidic (also award mark if molecule is drawn with acidic H circled/labelled etc) |

The Bronsted-Lowry theory of acids and bases introduced the concept of the hydronium ion, $\text{H}_3\text{O}^+(\text{aq})$, as well as conjugate acid-base pairs.

- (c) Explain what the ' $\text{H}_3\text{O}^+(\text{aq})$ ' notation is referring to and why it is often used in preference to the ' $\text{H}^+(\text{aq})$ ' notation. (2 marks)

- | |
|---|
| - refers to the donation of a proton to a water molecule |
| - more accurate representation of what occurs in aqueous solution / displays the conjugate nature and reversibility of acid/base reactions |

- (d) Label and link the conjugate acid-base pairs in the equation below. (2 marks)



Section Three: Extended answer

40% (80 marks)

Question 34

(15 marks)

Iodic acid (HIO_3) is found as a white solid at room temperature. It readily dissolves in water to produce an acidic solution, with a solubility of 2.69 kg L^{-1} at 20°C . Iodic acid can be used in analytical chemistry to standardise alkaline solutions.

Iodic acid also acts as a strong oxidising agent under acidic conditions. When behaving as an oxidant, it can be reduced to either elemental iodine (I_2), iodide ions (I^-) or, under the right conditions, to the iodine trichloride dimer (I_2Cl_6) which is golden yellow in solution.

A solution of acidified iodic acid has some toxic carbon monoxide gas bubbled through it. A brown solution is observed to form, as the carbon monoxide is converted to the less harmful carbon dioxide gas.

- (a) Write the oxidation and reduction half-equations and the overall redox equation for this reaction. (3 marks)

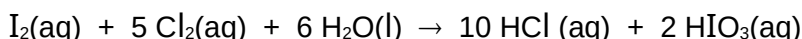
Oxidation half-equation	$\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 2 \text{H}^+ + 2 \text{e}^-$
Reduction half-equation	$2 \text{HIO}_3 + 10 \text{H}^+ + 10 \text{e}^- \rightarrow \text{I}_2 + 6 \text{H}_2\text{O}$ OR $2 \text{IO}_3^- + 12 \text{H}^+ + 10 \text{e}^- \rightarrow \text{I}_2 + 6 \text{H}_2\text{O}$
Overall redox equation	$5 \text{CO} + 2 \text{HIO}_3 \rightarrow 5 \text{CO}_2 + \text{I}_2 + \text{H}_2\text{O}$ OR $5 \text{CO} + 2 \text{H}^+ + 2 \text{IO}_3^- \rightarrow 5 \text{CO}_2 + \text{I}_2 + \text{H}_2\text{O}$ No follow through marks if either the above are incorrect

A chemistry student is experimenting with iodic acid, to investigate some of its physical and chemical properties. She wants to determine the strength of the acid, but cannot find any information about the acidity constant (K_a) of iodic acid in her research.

- (b) Write an acidity constant expression for iodic acid and explain what information a K_a value would provide regarding the acid. (2 marks)

- $K_a = \frac{[\text{H}_3\text{O}^+/\text{H}^+][\text{IO}_3^-]}{[\text{HIO}_3]}$
- Value indicates extent to which acid ionises (i.e. strength of acid)

One method used to prepare iodic acid is by reacting aqueous iodine with aqueous chlorine. This produces a mixture of iodic and hydrochloric acids, as shown in the equation below;



- (c) Identify the oxidising agent (oxidant) and reducing agent (reductant) in this reaction. Use oxidation numbers to support your answer. (4 marks)

- **I₂ is reducing agent**
- **O.N. from 0 to +5 (oxidation)**
- **Cl₂ is oxidising agent**
- **O.N. from 0 to -1 (reduction)**

The chemistry student decided to prepare a sample of iodic acid according to the reaction above. She mixed 750 mL of $2.15 \times 10^{-3} \text{ mol L}^{-1}$ aqueous iodine (I₂) with 830 mL of chlorine water (Cl₂) in a large beaker. Once the reaction had finished, a mixture of iodic and hydrochloric acids was present. She used a digital pH meter to measure the resulting pH of the solution and determined it to be 1.96.

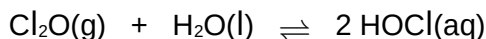
- (d) Determine and justify whether iodic acid is a strong or weak acid. Use appropriate calculations to support your answer. (You may assume that the chlorine water was in excess and that the reaction went to completion, consuming all of the iodine.) (6 marks)

n(I₂)	=	cV
	=	$2.15 \times 10^{-3} \times 0.75$
	=	$1.6125 \times 10^{-3} \text{ mol}$
if both acids are strong, then		
n(H⁺ total produced)	=	$12 \times n(\text{I}_2)$
	=	0.01935 mol
c(H⁺ total)	=	n/V
	=	$0.01935 / 1.580$
	=	$0.012247 \text{ mol L}^{-1}$
pH	=	$-\log[\text{H}^+]$
	=	$-\log 0.012247$
	=	1.912
pH of 1.96 is > than 1.912 i.e. pH is less acidic than maximum possible		
therefore iodic acid is weak (also accept moderate / moderately strong – just not ‘strong’!)		
OR		
If pH is 1.96;	[H⁺] =	$1.09648 \times 10^{-2} \text{ mol L}^{-1}$ (1)
then	n(H⁺ total) = cV =	$1.09648 \times 10^{-2} \times 1.580 = 0.017324 \text{ mol}$ (1)
compare this to	n(H⁺ total produced if both acids strong) =	0.01935 mol (2, see above)
Then can deduce that total moles actually present is less than theoretical moles if both acids are strong. Since HCl is a strong acid, iodic acid can’t be. (2)		

Question 35

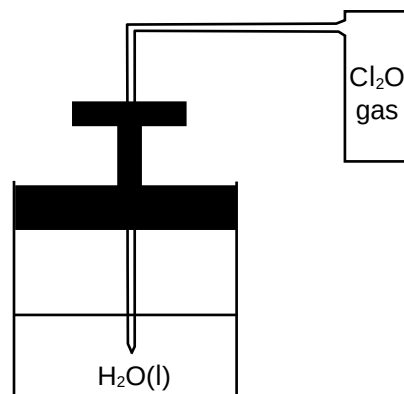
(15 marks)

Dichlorine monoxide (Cl_2O) is a brownish-yellow gas at room temperature. It is very soluble in water and when dissolved, it reacts with water to produce weak hypochlorous acid, according to the reversible reaction below;



The solution of hypochlorous acid appears colourless. At room temperature (298 K) this reaction has a K_c value of 0.090.

A sample of $\text{Cl}_2\text{O}(\text{g})$ was injected into a glass cylinder containing water, as shown in the diagram to the right, and allowed to establish equilibrium according to the equation above.

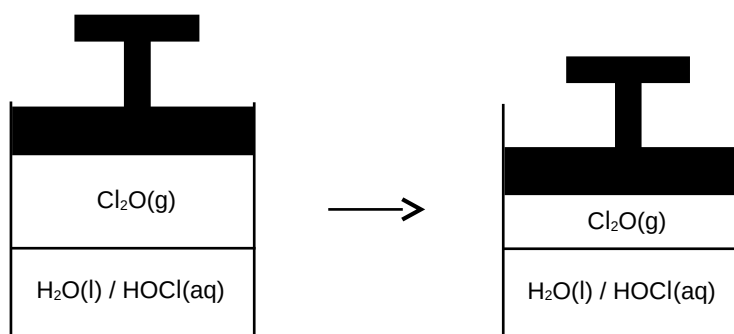


Several graphs have been sketched below, in an attempt to show the changes in concentration of $\text{Cl}_2\text{O}(\text{g})$ and $\text{HOCl}(\text{aq})$ from Time 0, when the gas was injected into the system, until equilibrium was first established at Time E1. You may assume the scales on both axes of each graph are identical.

- (a) Which of these graphs (A, B or C) is **most likely** to illustrate the concentration changes that would occur, from the time the $\text{Cl}_2\text{O}(\text{g})$ is injected into the system until the time that equilibrium is established at E1? Explain your choice below. (3 marks)

- graph C
- the final $[\text{HOCl}] > [\text{Cl}_2\text{O}]$, this reflects the K value being lower than 1
- the gradient of HOCl is twice that of Cl_2O, this reflects the 2:1 stoich ratio

At Time X, the pressure on the system was then increased, as shown in the diagram below.



- (b) State the effect this would have on the equilibrium position and describe any corresponding observations that would be made as a result of this imposed change. (3 marks)

- favour forwards reaction / favour products
- brownish yellow gas colour above solution will initially darken as pressure increased
- then gas colour will lighten as equilibrium is re-established

- (c) Explain what would happen to both the forward and reverse reaction rates, from the time the pressure was increased until the system re-establishes equilibrium (at E2). (3 marks)

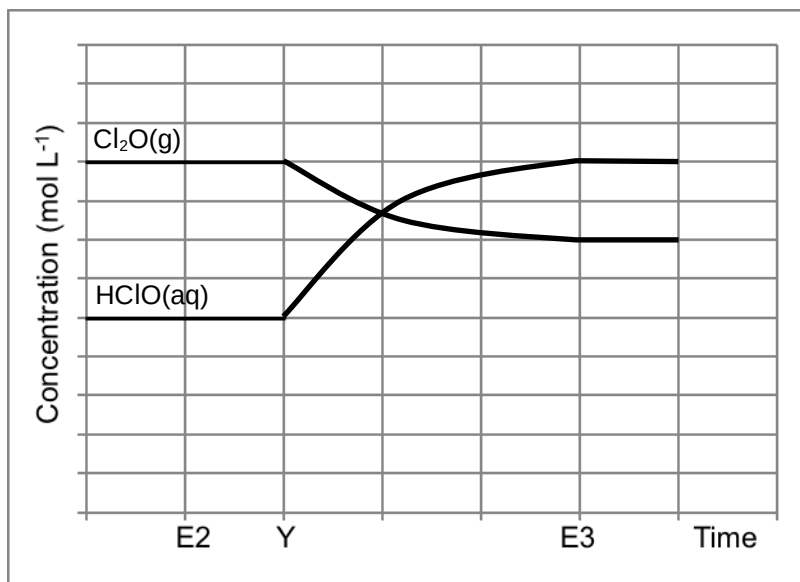
- Initially - Increase in pressure will increase the forward rate only. No change to the reverse rate){Only the gas conc is increased by compression}
- During equilibrium shift - Forward rate then starts to decrease as Cl_2O is consumed faster than produced. Reverse rate will then begin to increase as HOCl is produced faster than it's being consumed.
- at E2 the reaction rates eventually become equal, but higher, than original value.

When the temperature of this equilibrium system is increased to 400 K, the value of K_c is 1.98.

- (d) Explain what information this provides about the heat of reaction (ΔH). (3 marks)

- an increased K value means an increase in product concentration, decrease in the reactant concentration, (since $K = \frac{[\text{Products}]}{[\text{Reactants}]}$)
- this means the forward reaction must have been favoured
- this means the forward reaction is endothermic i.e. ΔH positive (a temp increase always favours the endo direction{ forward reaction will absorb some of the added heat})

- (e) Continue the graph below, showing the effect of a temperature increase on the system (imposed at Time Y) until equilibrium is re-established at E3. (You may assume water is still in the liquid state, as a result of the previous pressure increase.) (3 marks)



graphs must cross over (1)
HClO must increase 2x the units that Cl_2O decreases (1)
lines must become horizontal at E3 (1)

Question 36**(19 marks)**

Powdered baby formula (milk powder) must be manufactured according to very strict specifications, to ensure it contains the correct nutritional balance to sustain the healthy growth of a baby. By law, whole milk powder for babies must contain a minimum of **26.44 g of protein per 100 g of milk powder**.

A sample of powdered baby formula was analysed for quality control purposes to determine the protein content. 3.75 grams of dairy milk powder was dissolved in 50.00 mL of sulfuric acid. The ammonium sulfate formed was distilled and the liberated ammonia gas was then captured and absorbed into 75.00 mL of a 0.200 mol L⁻¹ boric acid solution.

Three 20.00 mL aliquots of the captured boric acid solution were then titrated against a standard 0.0650 mol L⁻¹ sodium carbonate solution. The results of the titration are shown in the table below.

	1	2	3
Initial reading (mL)	48.30	33.15	17.95
Final reading (mL)	33.15	17.95	2.75
Titre (mL)	15.15	15.2	15.2

- (a) Use the titration results to calculate the number of moles of excess B(OH)₃ remaining in the 75.00 mL sample **after** the capture of NH₃. (4 marks)

average titre =	15.1833 mL
n(Na₂CO₃) =	cV
=	0.0650 x 0.015833
=	9.8692 x 10⁻⁴ mol
n(B(OH)₃ in 20 mL aliquot) =	n(Na₂CO₃)
n(B(OH)₃ in 75 mL) =	9.8692 x 10⁻⁴ x (75 / 20)
=	3.7009 x 10⁻³ mol
=	3.70 x 10⁻³ mol (3SF)

- (b) Use your answer from (a), as well as the **original** concentration of B(OH)₃, to calculate the number of moles of NH₃ that was captured in the boric acid solution. (3 marks)

n(B(OH)₃ originally) =	cV
=	0.200 x 0.07500
=	0.015 mol
n(B(OH)₃ used to capture NH₃) =	n(original B(OH)₃) - n(remaining B(OH)₃)
=	0.015 - 3.7009 x 10⁻³
=	0.0112991 mol
n(NH₃ captured) =	n(B(OH)₃) = 0.0113 mol (3SF)

- (c) Calculate the percent composition (by mass) of nitrogen in the sample of powdered baby formula. Express your answer to the correct number of significant figures. (4 marks)

n(N)	=	n(NH₃)
m(N)	=	nM
	=	0.0112991 x 14.01
	=	0.1583 g
% N in powder	=	0.1583 / 3.75 x 100
	=	4.2213%
	=	4.22 % (3 SF)
(1m has been included here for stating answers to correct SF, only lose 1 mark in <u>total</u> for incorrect SF, not 1m per Q)		

- (d) Use the appropriate conversion factor to calculate the protein content in the baby formula, and comment on whether this batch of milk powder meets the minimum requirement for protein content. (2 marks)

protein content	=	m(N) x dairy conversion factor
	=	0.1583 x 6.38
	=	1.009954 g
i.e.	1.009954 g of protein in the 3.75 g sample of milk powder used	
therefore	1.009954 x (100/3.75)	
	=	26.93 g per 100 g of milk powder
OR		
protein content	=	%N (already in g per 100 g) x dairy conversion factor
	=	4.22 x 6.38
	=	26.93 g protein in 100 g milk powder
Yes, this meets the requirements of 26.44 g per 100 g milk powder		

As outlined previously, the back titration in the Kjeldahl method is performed using a sodium carbonate primary standard as well as the indicator methyl orange.

- (e) Define the term 'standard solution' and state two (2) characteristics of Na₂CO₃ that allow it to be used as a primary standard. (3 marks)

-	standard solution is one that has known concentration
-	high molecular weight, high purity, soluble in water, reacts according to known equations, not deliquescent etc (any 2 relevant characteristics, 1m each)

If the burette had been rinsed with distilled water at the start of the experiment;

- (f) What effect would this error have on the value of the titre volumes obtained (i.e. higher volumes, lower volumes or unaffected)? (1 mark)

- **higher volumes**

- (g) Is this a random or systematic error? Explain your answer. (2 marks)

-	systematic error
-	this is an incorrect technique, so error can be minimised by using correct scientific technique (systematic errors always give consistently high/low results)

Question 37**(16 marks)**

Consider the two cells below, both of which use a silver metal electrode as well as a silver nitrate solution.

- (a) Complete the following table with regards to the two cells illustrated on the previous page. Your answer should;

- Classify each cell as either a galvanic or electrolytic cell.
- Give a brief description (one sentence) of the purpose of each cell.
- Complete the cathode and anode reactions for each cell.

(8 marks)

	Cell A	Cell B
Type of cell	galvanic	electrolytic
Purpose of cell	Produce electricity / convert chemical energy into electrical energy	To plate the fork with a thin layer of silver / To use electrical energy to force a non-spontaneous reaction (silver plating) to occur
Cathode reaction	$\text{Ag}^+_{(\text{aq})} + \text{e}^- \rightarrow \text{Ag}_{(\text{s})}$	$\text{Ag}^+_{(\text{aq})} + \text{e}^- \rightarrow \text{Ag}_{(\text{s})}$
Anode reaction	$\text{Zn}_{(\text{s})} \rightarrow \text{Zn}^{2+}_{(\text{aq})} + 2\text{e}^-$	$\text{Ag}_{(\text{s})} \rightarrow \text{Ag}^+_{(\text{aq})} + \text{e}^-$

Refer to the diagram of Cell A.

- (b) What is X? State the role of X and explain why Cell B does not need this. **(4 marks)**

X is the salt bridge
- Salt bridge completes circuit
- This stops charge from building up in the two half-cells / allows ion migration between cells / allows flow of ions to maintain charge balance
- B does not need this, as it does not have two half-cells / uses a single electrolyte / the electrolyte maintains neutrality

Refer to the diagram of Cell B.

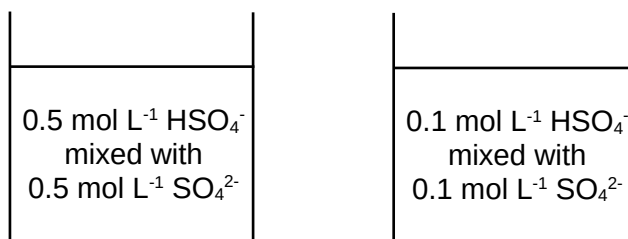
- (c) What is Y? State the role of Y and explain why Cell A does not need this. **(4 marks)**

Y is the power supply / power source
- The power pack supplies / forces the electrical current / electrons required
- This drives a non-spontaneous reaction
- A does not need this, as it is a spontaneous reaction that produces electricity

Question 38**(15 marks)**

A chemistry student was investigating what type of solutions can be mixed together to form a buffer.

Firstly, he made two different hydrogensulfate / sulfate buffers. As illustrated in the diagrams below, one beaker contained a 1 L mixture of $0.5 \text{ mol L}^{-1} \text{ NaHSO}_4(\text{aq})$ and $0.5 \text{ mol L}^{-1} \text{ Na}_2\text{SO}_4(\text{aq})$. The second beaker contained a 1 L mixture of $0.1 \text{ mol L}^{-1} \text{ NaHSO}_4(\text{aq})$ and $0.1 \text{ mol L}^{-1} \text{ Na}_2\text{SO}_4(\text{aq})$.



Unfortunately, the student forgot to label the beakers, and could not remember which was which.

- (a) Explain how the student could experimentally determine which beaker contained which buffer. Include a description of buffering capacity in your answer. Assume you have access to standard laboratory reagents and equipment. (6 marks)

- buffering capacity is a measure of the extent to which a buffer can resist changes in pH as small amounts of strong acid or base are added to it
to distinguish the solutions;
- add either strong acid or base drop wise to each beaker
- monitor pH using pH meter
- when buffer has a drastic change in pH this shows buffering capacity has been exceeded
- the beaker which has less acid/base added to cause this sudden change can be identified as the 0.1/0.1 buffer OR the beaker which has more acid/base added to cause this sudden change can be identified as the 0.5/0.5 buffer
- since 0.1/0.1 buffer has lower absolute concentrations of the conjugate acid/base species it will have the lower buffering capacity OR since 0.5/0.5 buffer has higher absolute concentrations of the conjugate acid/base species it will have the higher buffering capacity

If candidates have used indicators:

1. they could be awarded full marks for adding a strong base and using an indicator like phenolphthalein (assuming all other points are correctly given)
2. They can only be awarded a maximum of 4/6 for adding a strong acid and using methyl red or similar.

Next, the student decided to mix together solutions of sodium hydroxide, NaOH, and barium hydroxide, Ba(OH)₂.

(b) Why doesn't this solution form a buffer? (1 mark)

- **these solutions do not contain conjugate species / both are strong bases**

NaOH
mixed with
Ba(OH)₂

The original sodium hydroxide solution had a pH of 9.9 and the student measured 850 mL of this into a beaker. He then added 95.0 mL of a 0.075 mol L⁻¹ barium hydroxide solution to the same beaker.

(c) Calculate the pH of the resulting solution. (8 marks)

[H ⁺ in NaOH]	=	10 ^{-pH}
	=	10 ^{-9.9}
[OH ⁻ in NaOH]	=	(1.0 x 10 ⁻¹⁴) / 10 ^{-9.9}
	=	7.94328 x 10 ⁻⁵ mol L ⁻¹
n(OH ⁻ in NaOH)	=	cV
	=	7.94328 x 10 ⁻⁵ x 0.850
	=	6.75179 x 10 ⁻⁵ mol
n(OH ⁻ in Ba(OH) ₂)	=	2x n(Ba(OH) ₂)
	=	2 x (0.075 x 0.0950)
	=	0.01425 mol
n(OH ⁻ total)	=	6.75179 x 10 ⁻⁵ + 0.01425
	=	0.0143175 mol
c(OH ⁻ total)	=	n/V
	=	0.0143175 / 0.945
	=	0.0151508 mol L ⁻¹
[H ⁺ total]	=	(1.0 x 10 ⁻¹⁴) / 0.0151508
	=	6.6003 x 10 ⁻¹³ mol L ⁻¹
pH	=	-log 6.6003 x 10 ⁻¹³
	=	12.18
	=	12 (2 SF) mark allocated here for SF

If students have used the [H⁺] from both solutions then a maximum of 6/8 can be allocated.
(pH = 9.95 OR 10SF)

End of questions