PART 1 (60 marks = 30% of paper)

Answer ALL questions in Part 1 on the separate Multiple Choice Answer Sheet provided. Each question in this part is worth 2 marks.

---

1. Which of the following species have the same electron configuration?

   I Ar

   II Sc^{3+}

   III $^{35}Cl^-$

   IV $^{37}Cl^-$

   A. None of them.

   B. All of them.

   C. I and II only.

   D. III and IV only.

2. Which list of elements is arranged in order of increasing atomic radius?

   A. potassium, aluminium, chlorine, fluorine.

   B. fluorine, aluminium, chlorine, potassium

   C. fluorine, chlorine, aluminium, potassium.

   D. potassium, chlorine, aluminium, fluorine.

3. Which of the pairs of elements, described in terms of their electron configurations, will combine with each other to form **ionic bonds**?

I	$1s^2\ 2s^2\ 2p^3$	$1s^2\ 2s^2\ 2p^4$
II	$1s^2\ 2s^2\ 2p^5$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
III	$1s^2\ 2s^2\ 2p^2$	$1s^2\ 2s^2\ 2p^4$
IV	$1s^2\ 2s^2\ 2p^6\ 3s^1$	$1s^2\ 2s^2\ 2p^5$
V	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

   A. I and II only.

   B. IV only.

   C. I, II and III.

   D. IV and V.

4. Which of the following represents the correct shapes of each of the molecules PBr_3, HCCH, Cl_2S and Cl_2CO respectively as shown?

	PBr_3	HCCH	Cl_2S	Cl_2CO
A.	pyramidal	bent	bent	pyramidal
B.	trigonal planar	bent	linear	pyramidal
C.	pyramidal	linear	bent	trigonal planar
D.	trigonal planar	linear	linear	trigonal planar

Questions 5 and 6 refer to the ionisation energies of two elements X and Y.

5. Consider the following successive ionisation energies of an element X.

Ionisation	1st	2nd	3rd	4th	5th	6th	7th	8th
Ionisation Energy ($kJ\ mol^{-1}$)	1,310	3,390	5,320	7,450	11,000	13,300	71,000	91,600

The group this element belongs to, and the charge on its most common and stable ion, would be:

A. group V and 3–

B. group V and 5+

C. group VI and 2-

D. group I and 1+

6. The successive ionisation energies of an element Y are:

Ionisation	1st	2nd	3rd	4th	5th	6th	7th	8th
Ionisation Energy ($kJ\ mol^{-1}$)	577	1,820	2,740	11,600	14,800	18,400	23,400	27,500

The compound formed between X and Y would most likely be:

A. A covalent compound of formula Y_3X_2

B An ionic compound of formula Y_3X_2

C A covalent compound of formula Y_2X_3

D. An ionic compound of formula Y_2X_3

7. Which of the following lists the four substances in order of increasing melting points?

A. SiO_2, CO_2, O_2, He

B. He, O_2, SiO_2, CO_2

C. He, CO_2, O_2, SiO_2

D. He, O_2, CO_2, SiO_2

8. Which of the following compounds can form hydrogen bonds?

I H_2O
II H_2O_2
III CH_3COCH_3
IV C_2H_5OH

A. I,II and IV.

B. II and III.

C. I, III and IV.

D. all of them.

9. The values of *a* and *b* in the following redox equation are:

$$a VO_2^+ + b Al + c H^+ \rightarrow d VO^{2+} + e Al^{3+} + 3H_2O$$

A. *a* = 3 , *b* = 1

B. *a* = 3 , *b* = 2

C. *a* = 2 , *b* = 3

D. *a* = 1 , *b* = 3

10. Which of the following are endothermic reactions?

I $6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)} + 6O_{2(g)}$
II $C_2H_5OH_{(g)} \rightarrow C_2H_5OH_{(l)}$
III $2Al_2O_{3(s)} \rightarrow 4Al_{(s)} + 3O_{2(g)}$
IV $H^+_{(g)} + H^-_{(g)} \rightarrow H_{2(g)}$

A. I and II.

B. I, II and III.

C. I and III.

D. II and III.

Questions 11 to 14 refer to the equilibrium reaction:

$$Co(H_2O)_6^{2+}{}_{(aq)} + 4Cl^-_{(aq)} \rightleftharpoons CoCl_4^{2-}{}_{(aq)} + 6H_2O_{(l)} \quad \Delta H=+ve$$

$Co(H_2O)_6^{2+}{}_{(aq)}$ is pink whilst $CoCl_4^{2-}{}_{(aq)}$ is blue. A solution contains equal concentrations of both of these ions.

11. What will be the effect of increasing the temperature on the colour and the value of the equilibrium constant K?

A. K increases and the mixture becomes more pink.

B. K decreases and the solution becomes more pink.

C. K increases and the solution becomes more blue.

D. K decreases and the solution becomes more blue.

12. What change could make the solution become more pink in colour, without changing the value of K?

A. Add some water.

B. Heat it to evaporate some water.

C. Increase the pressure.

D. Add some solid NaCl.

13. Adding some concentrated $AgNO_{3(aq)}$ will have which of the following effects?

	Rate of forwards reaction	Rate of backwards reaction
A.	does not change	does not change
B.	decreases	decreases
C.	increases	decreases
D.	decreases	increases

14. If a suitable solid catalyst can be found for the reaction and is added to the reaction mixture, what will be the effects on the following?

	Value of K	Rate of forwards reaction	Rate of backwards reaction
A.	does not change	does not change	does not change
B.	increased	does not change	does not change
C.	does not change	increased	increased
D.	increased	increased	increased

15. The ionisation of water is an endothermic process. The ionisation constant (K_w) for this reaction is 1.00×10^{-14} at 25°C. Which of the following best describes a sample of pure water at 50°C?

A. An acidic solution with a pH of less than 7.

B. A neutral solution with a pH of 7.

C. A neutral solution with a pH of greater than 7.

D. A neutral solution with a pH of less than 7.

Questions 16 to 18 refer the following

Oxalic acid, HOOCCOOH, is a diprotic weak acid. 20.0 mL of oxalic acid solution is accurately titrated with 0.100 mol L^{-1} NaOH and the end point is reached after the addition of 21.75 mL of the NaOH. The end point occurred exactly at the equivalence point.

16. What is the concentration of the oxalic acid solution?

A. 0.0544 mol L^{-1}

B. 0.109 mol L^{-1}

C. 0.2175 mol L^{-1}

D. 0.0109 mol L^{-1}

17. What would be the most likely pH of the reaction mixture at the end point?

A. 13

B. 5

C. 7

D. 9

18. Pure oxalic acid is a white solid with a melting point of 187°C. Which of the following best describes the bonding within the solid?

	Intramolecular Forces	Intermolecular Forces	Polarity of molecule
A.	covalent bonds	van der Waals'	polar
B.	covalent bonds	hydrogen bonds	polar
C.	hydrogen bonds	covalent bonds	non-polar
D.	covalent bonds	hydrogen bonds	non-polar

19. How many isomers are there of C_3H_5Cl?

A. 3

B. 4

C. 5

D. 6

20. Which of the following display geometrical isomerism?

I 1,2-dibromohexane
II 2,3-dimethylpentane
III 1-hexene
IV 2-hexene

A. I, II and IV.

B. II and IV.

C. IV only.

D. all four of them.

21. Which of the following pairs of substances could be used to prepare a sample of $CH_3CH_2CH(OH)COOCH(CH_3)_2$?

A. 2-methylpropanoic acid and 2-butanol.

B. 3-hydroxybutanoic acid and 1-propanol.

C. 2-hydroxypropanoic acid and 2-butanol.

D. 2-hydroxybutanoic acid and 2-propanol.

22. Which monomers could be used to prepare a condensation polymer?

A. C_2H_5OH and CH_3COOH

B. CH_2CH_2 and CH_2CHCH_3

C. $HOCH_2CH_2OH$ and HOOCCOOH

D. HOOCCOOH and HCOCHO

23. Which of the following could be oxidised to a ketone using acidified potassium dichromate?

A. cyclohexanol

B. 2-methyl-2-propanol

C. methanol

D. ethanol

24. Consider the electrochemical cell set up between the Cu/Cu^{2+} and Zn/Zn^{2+} half cells, under standard conditions with a potassium nitrate solution salt bridge. Which of the following statements is true?

A. the overall cell voltage is 0.43V.

B. the copper electrode is the anode.

C. electrons in the wire flow from the Cu electrode to the Zn electrode.

D. potassium ions in the salt bridge flow from the Zn/Zn^{2+} half cell to the Cu/Cu^{2+} half cell.

25. Which of the following are disproportionation reactions?

I $BrO_3^- + 5Br^- \rightarrow 3Br_2 + 3H_2O$
II $2H_2O_2 \rightarrow 2H_2O + O_2$
III $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$
IV $2Cu^+ \rightarrow Cu^{2+} + Cu$

A. All of them.

B. II, III and IV.

C. I, II and IV.

D. II and III.

26. Which of the following contains species listed in order of increasing oxidation state of sulfur?

A. $S_2O_3^{2-}$, $S_4O_6^{2-}$, SO_4^{2-}, SO_3^{2-}

B. SO_4^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, $S_4O_6^{2-}$

C. $S_2O_3^{2-}$, $S_4O_6^{2-}$, SO_3^{2-}, SO_4^{2-}

D. $S_4O_6^{2-}$, $S_2O_3^{2-}$, SO_3^{2-}, SO_4^{2-}

27. Which of the following can convert iron(II) ions in water to iron(III) ions?

I Bromine dissolved in water
II Potassium chloride solution
III Zinc metal
IV A solution containing both potassium dichromate and sulfuric acid

A. I and II only.

B. I and IV only.

C. II and III only.

D. III and IV only.

28. Mercury oxide-zinc batteries are used in many low power applications such as watches and calculators. The cell reaction is:

$HgO(s) + Zn(s) + H_2O(l) \rightarrow Hg(l) + Zn(OH)_2(s)$

The half-cell reaction at the positive electrode of the battery is:

A. $HgO(s) + H_2O(l) + 2e^- \rightarrow Hg(l) + 2OH^-(aq)$

B. $Hg(l) + 2OH^-(aq) \rightarrow HgO(s) + H_2O(l) + 2e^-$

C. $Zn(OH)_2(s) + 2e^- \rightarrow Zn(s) + 2OH^-(aq)$

D. $Zn(s) + 2OH^-(aq) \rightarrow Zn(OH)_2(s) + 2e^-$

29. What will be the products at each electrode during the electrolysis of 1.0 mol L^{-1} aqueous potassium iodide?

	Cathode product	Anode product
A.	iodine	hydrogen
B.	hydrogen	oxygen
C.	hydrogen	iodine
D.	potassium	iodine

30. When Freddie Flintoff celebrates England's Ashes victory at Sydney in January, he will choose a bottle of champagne containing 14% ethanol by mass. Assuming the champagne has a density of 1.00 kg L^{-1}, what is the concentration of ethanol (in mol L^{-1}) in the champagne?

A. 1.40×10^{1} mol L^{-1}

B. 0.330 mol L^{-1}

C. 3.00 mol L^{-1}

D. 1.40 mol L^{-1}

End of Part 1

PART 2 (70 marks = 35% of paper)

Answer ALL questions in Part 2 in the spaces provided below.

---

1. 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) and gases evolved (give the colour or describe as colourless). If no change is observed you should state this.

   a) Dilute hydrochloric acid is added to sodium hydrogencarbonate crystals.

   Equation _____

   Observation _____

   _____

   b) Pieces of chromium are added to 6 mol L^{-1} sodium hydroxide solution.

   Equation _____

   Observation _____

   _____

   c) Excess ammonia solution is added to zinc nitrate solution.

   Equation _____

   Observation _____

   _____

   d) Ethanol and methanoic acid are heated together with a small amount of sulfuric acid.

   Equation _____

   Observation _____

   _____

   [4 x 3 = 12 marks]

2. The electron configuration of a lithium atom is $1s^2 2s^1$. Using the same notation, give the electron configuration of:

   a) a halogen atom in period 3 _____

   b) an excited sodium ion _____

[2 marks]

3. A colourless solution with pH = 1.0 is added to a colourless solution with pH =11 producing a white precipitate. Write an equation for this reaction.

[2 marks]

4. For each of the species listed in the table below:
   a) draw the structural formula, representing all valence shell electron pairs as either : or –
   b) indicate the shape and polarity of each species by either a sketch or a name

Species	Structural Formula	Shape	Molecular polarity
OF_2			
BF_3			

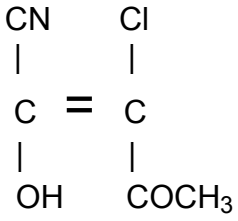
[2 x 4 = 8 marks]

5. For each of the following pairs of chemicals describe fully a chemical test that could be used to distinguish between the two substances. Provide observations for each substance.

Substances	Full description	Observations
calcium carbonate and zinc carbonate solids		calcium carbonate
		zinc carbonate
methyl butanoate and butanoic acid		methyl butanoate
		butanoic acid

[4 + 3 = 7 marks]

6. Draw a piece of the polymer that would be produced from the monomer below. Show at least 3 monomers in your answer:



[2 marks]

7. For each of the following reactions draw the full structural formula of the main organic products.

a) 2-propyl ethanoate is boiled with sodium hydroxide

b) Iodine water is added to 3-methyl-2-pentene.

[3 x 1 = 3 marks]

7. c) Draw the structural formula of two (2) aromatic isomers of C_8H_{10}.

_____ _____

d) Name the following molecules:

i) $CHCCH_2CH_3$

_____

ii) $(CH_3)_2CHCH_2COCH_3$

_____

[4 x 1 = 4 marks]

8. Using equations in your answer, explain why a solution of $NH_4CH_3COO(aq)$ has a pH = 6.28.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

[5 marks]

9. a) Consider the construction of an electrochemical cell using $Ni(s)/Ni^{2+}(aq)$ and $Br^{-}(aq)/Br_2(aq)$. Sketch a diagram of such an electrochemical cell, labeling the cathode and anode and showing the electrolytes used, electrodes used, polarity of electrodes and flow of electrons.

b) What is the EMF of this cell under standard conditions?

_____

c) Write the anode reaction.

_____

d) State your expected observation at the cathode.

_____

e) Why would $Na_2CO_3(aq)$ be unsuitable for use in the salt bridge?

_____

_____

_____

_____

_____

[4+1+1+1+1 = 8 marks]

10. Consider the following chemical equilibrium system:

$$4\ HCl(g) + O_2(g) \rightleftharpoons 2\ H_2O(g) + 2\ Cl_2(g) + 113\ kJ$$

Three vessels containing an equilibrium mixture of these gases were each subjected to one of the changes in conditions described below.

For each, state whether the rate of reaction and the equilibrium yield of $Cl_2(g)$ will be increased, decreased or unchanged at the newly established equilibrium compared to the initial equilibrium.

a) The volume of the container is halved at constant temperature:

i) rate of reaction _____

ii) equilibrium yield _____

b) The temperature of the mixture is raised:

i) rate of reaction _____

ii) equilibrium yield _____

c) Additional HCl(g) is added:

i) rate of reaction _____

ii) equilibrium yield _____

[6 x 1 = 6 marks]

d) In (a) above, explain the effect that halving the volume will have on the $[O_2]$ and the mass of O_2.

i) $[O_2]$ _____

_____

_____

_____

ii) Mass of O_2 _____

_____

_____

_____

[2 x 2 = 4 marks]

11. a) Rank the following in order of decreasing boiling point. In the table write "1" for the compound with the highest boiling point, down to "4" for the compound with the lowest boiling point.

Compound	Boiling points in order (1 = highest, 4 = lowest)
$CH_3CH_2CH_2CH_2CHO$	
$CH_3(CH_2)_4OH$	
$CH_3(CH_2)_4CH_3$	
$CH_3(CH_2)_2CH(CH_3)_2$	

[2 marks]

b) Explain your ranking using appropriate chemical theory.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

[5 marks]

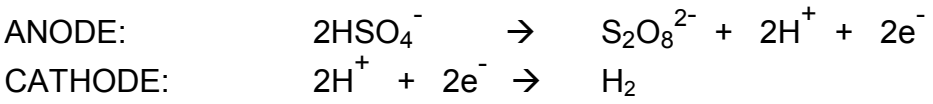
End of Part 2

PART 3 (50 marks = 25% of paper)

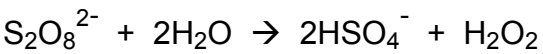
Answer ALL questions in Part 3. The calculations are to be set out in detail in this Question/Answer booklet. Marks will be allocated for correct equations and clear setting out, even if you cannot complete the problem. When questions are divided into sections, clearly distinguish each section using (a), (b), and so on. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information which may be necessary for solving the problems is located on the separate Chemistry Data Sheet. Show clear reasoning: if you don't, you will lose marks.

---

1. One industrial preparation of hydrogen peroxide involves the electrolysis of cold ammonium sulfate in sulfuric acid. The electrode reactions are:



In this process the peroxydisulfate ion formed at the anode is hydrolysed to give hydrogen peroxide:



a) If a current of 300 amperes is passed through the electrolyte for one and a half hours, what mass of hydrogen peroxide would be formed if the electrolysis is 100% efficient and the conversion of peroxydisulfate ion to hydrogen peroxide is 50% efficient?

[5 marks]

b) Calculate the volume of hydrogen produced at the cathode at 95^{o}C and 105 kPa.

[3 marks]

1. cont.

2. A textile company uses a solution of calcium hypochlorite to bleach sheets. An industrial chemist is asked to investigate the change in concentration of the bleaching solution after sheets have been soaked in this solution for a time of 2 hours. The original solution is known to contain 30.0 g L^{-1} of calcium hypochlorite. During bleaching the hypochlorite ions are reduced to chloride ions.

   The chemist takes 20.0 mL samples of the bleaching solution after 2 hours of soaking and titrates these samples with 0.250 mol L^{-1} sodium thiosulfate solution, using a starch-iodine indicator.
   The samples require 31.2 mL of thiosulfate solution for complete reaction. The titration reaction may be represented as follows:

$$OCl^-(aq) + 2S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S_4O_6^{2-}(aq) + Cl^-(aq) + H_2O(aq)$$

   a) Calculate the original hypochlorite ion concentration in mol L^{-1}
   [3 marks]

   b) Calculate the hypochlorite ion concentration after soaking in mol L^{-1}
   [3 marks]

   c) What mass of calcium hypochlorite would need to be added to 100 L of the solution after 2 hours of bleaching to restore the original hypochlorite ion concentration?
   [5 marks]

2. cont.

3. An ester underwent hydrolysis to produce a monoprotic carboxylic acid X and a secondary alcohol Y.

A 17.5 g sample of pure X, when combusted, produced 44.15 g of carbon dioxide and 7.750 g of water as the only products.

Y was oxidised with potassium dichromate according to the following equation:

$$3Y + Cr_2O_7^{2-} + 8H^+ \rightarrow 3Z + 2Cr^{3+} + 7H_2O$$

44.88 mL of 0.500 mol L^{-1} of potassium dichromate solution was required to oxidise 4.99 g of Y.

a) Calculate the empirical formula of X

[5 marks]

b) Calculate the molar mass of Y

[3 marks]

c) Draw possible structures of X and Y

[2 marks]

d) Name the original ester.

[1 marks]

3. cont.

4. A hydrochloric acid solution contains 15% hydrogen chloride by mass. 10.20 g sample of this solution was diluted to 100.0 mL in a volumetric flask. A 25.0 mL sample of this diluted acid solution was then added to 48.0 mL of 0.118 mol L^{-1} NaOH solution. Calculate the pH of the final solution.

[9 marks]

4. cont.

5. A 2.00 g sample containing potassium oxalate ($K_2C_2O_4$), oxalic acid dihydrate ($H_2C_2O_4.2H_2O$) and impurities was dissolved in 100.0 mL of water and divided into two 50.0 mL portions.

One portion required 48.32 mL of 0.1010 mol L^{-1} NaOH to reach an end point using phenolphthalein as an indicator.

The other portion required 47.74 mL of 0.0255 mol L^{-1} $KMnO_4$ solution for complete reaction, according to the following equation:

$$2MnO_4^-(aq) + 16H^+(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 10CO_2(g)$$

Assuming that the impurities are inert, calculate the percentages of the potassium oxalate and oxalic acid dihydrate in the solid sample.

[11 marks]

5 cont.

End of Part 3

PART 4 (20 marks = 10% of paper)

Answer the following extended answer question. Where applicable use equations, diagrams and illustrative examples of the chemistry you are describing.

Marks are awarded for the relevant chemical content of your answer, but you will lose marks if what you write is unclear or lacks coherence.

Cyano compounds are those that contain a CN (cyano) group. These include inorganic cyanides, for example the salt sodium cyanide (NaCN), and organic cyanides which contain the cyano functional group (R-CN).

These compounds are usually extremely toxic to living organisms because the cyanide ion (CN^-) attaches to and inactivates enzymes that catalyse important biological processes. For example, hydrogen cyanide was used in gas chambers for capital punishment. The production of gaseous hydrogen cyanide was by the addition of sodium cyanide pellets into a vessel containing sulfuric acid.

An example of an organic cyanide is 1,4-dicyanobutane, NC-$(CH_2)_4$-CN. It is a clear, yellow-coloured liquid at room temperature (MP 1ºC) and has low solubility in water. It is used as a solvent for a variety of chemical processes and as a reactant for the preparation of other organic compounds. 1,4-dicyanobutane is itself prepared from cyanoethene, CH_2=CHCN, via electrolysis of an aqueous according to the following equation:

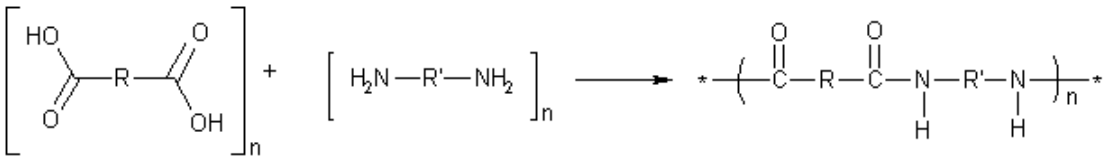
$$2CH_2=CHCN + 2H^+ + 2e^- \rightarrow NC\text{-}(CH_2)_4\text{-}CN$$

1,4-dicyanobutane can be reduced by hydrogen gas to form 1,6-hexanediamine, H_2N-$(CH_2)_6$-NH_2, which is a yellow-white crystalline solid at room temperature (MP 39ºC) and has moderate solubility in water.

1,6-hexanediamine is one of the components of the polymer nylon, the production of which was scaled up by the United Sates during the Second World War to decrease their reliance upon Asian silk for parachutes. Today, some of the uses for nylon include clothing, fishing line and toothbrush bristles, as well as some machine parts such as gears and bearings.

The other component of nylon is hexanedioic acid, $HOOC(CH_2)_4COOH$, which is a white crystalline solid at room temperature (MP 153ºC) and is soluble in solvents such as water, ethanol and acetone.

The reaction between a dicarboxylic acid and a diamine is similar to that between a dicarboxylic acid and a diol. The general reaction is:



With specific reference to this information, discuss the chemistry that you have studied this year. In your answer you may draw on your understandings of: acids and bases; bonding; electrochemistry; organic chemistry and reactions. You do not need to address all these areas, but you must include equations in your answer where relevant.

End of Examination