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.

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1. Calcium sulfate is more soluble in cold water than hot water. This means that the value of the equilibrium constant for the reaction:

$$CaSO_{4(s)} \rightleftarrows Ca^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$$

A. increases with rise in temperature
B. does not change with rise in temperature
C. decreases with rise in temperature
D. may increase or decrease with rise in temperature depending on the initial ionic concentrations.

2. Solid ammonium hydrogensulfide is in equilibrium with ammonia and hydrogen sulfide in a closed flask. The equation is:

$$NH_4HS_{(s)} \rightleftarrows NH_{3(g)} + H_2S_{(g)}$$

If a little more gaseous ammonia is added to the flask, the mass of ammonium hydrogensulfide will:

A. remain the same
B. increase
C. decrease
D. increase or decrease depending on whether the reaction is endothermic or exothermic

3. Nitrous acid (HNO_2) is a weak acid which ionises as shown in the following reaction

$$HNO_{2(aq)} + H_2O_{(l)} \rightleftarrows NO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

If 50ml of water is added to 100ml of a 0.100 mol L^{-1} HNO_2 solution
Which of the following occurs?

A. The value of equilibrium constant increases
B. The pH of the solution increases
C. The mass of HNO_2 present increases
D. $[H_3O^+]$ increases

4. The steam reforming of methane depends on the following reaction:

$$CH_{4(g)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + 3\ H_{2(g)} \quad \Delta H = +\ 206\ kJ$$

Lowering the temperature of the system will

I Slow down the forward reaction.

II Slow down the backward reaction.

III Decrease the yield of CO and H_2.

A. I and II only.
B. I and III only.
C. II and III only.
D. I, II and III.

5. When bore water from limestone is boiled in an electric kettle a deposit of white boiler scale is usually observed on the inside of the kettle. The boiler scale is a deposit of both calcium carbonate and magnesium carbonate. The chemical reactions involved are:

$$Ca^{2+}_{(aq)} + 2\,HCO_3^-{}_{(aq)} + \text{heat} \rightleftarrows CaCO_{3(s)} + CO_{2(aq)} + H_2O_{(l)}$$

$$Mg^{2+}_{(aq)} + 2\,HCO_3^-{}_{(aq)} + \text{heat} \rightleftarrows MgCO_{3(s)} + CO_{2(aq)} + H_2O_{(l)}$$

Using these equations predict which of the following sets of conditions is most favourable to the formation of "boiler scale".

	Concentration of $CO_{2(aq)}$	Temperature
A.	low	high
B.	high	high
C.	low	low
D.	high	low

6. A solution contains a mixture of 0.200 mol of sodium chloride and 0.200 mol of another metal chloride. The solution contains 0.600 mol of chloride ions in total. The other metal chloride in the solution could be:

A. potassium chloride
B. magnesium chloride
C. aluminium chloride
D. lead(IV) chloride

7. A 10L sample of air at 25^{o}C weighing 11.80 g was collected from a busy city intersection and was found to contain 0.230 mg of lead. The concentration of lead in the air is which of the following?

A. 0.0230 ppm
B. 1.18 ppm
C. 19.5 ppm
D. 51.3 ppm

8. Which species is the same shape as the NO_3^- ion?

A. SO_3^{2-}
B. SO_3
C. ClO_3^-
D. NF_3

9. For magnesium the ionisation energies that are significantly higher than the ones that precede them, due to removing an electron from a principal energy level, are the:

A. 1st and 2nd
B. 2nd and 3rd
C. 3rd and 10th
D. 3rd and 11th

10. A substance contains polar molecules, has intramolecular covalent bonding and exhibits intermolecular hydrogen bonds. Of the following it could only be:

A. $CHF_{3(g)}$
B. $H_{2(g)}$
C. $NH_{3(l)}$
D. $KOH_{(s)}$

11. How many pairs of outer-shell electrons are not used in the bonding in a single molecule of OCl_2?

A. 2
B. 4
C. 8
D. 16

12. Which of the following does NOT occur as we move from left to right across the third row of elements in the periodic table?

A. Electronegativity of the elements across the row increases.
B. The atomic radius increases.
C. Melting and boiling points increase up to Group IV, then decrease.
D. The number of outer energy level electrons increases.

13. The complexed metal ion in the compound $Ba_2Fe(CN)_6$ is:

A. Ba^{+}
B. Ba^{2+}
C. Fe^{2+}
D. Fe^{3+}

14. Which of the following compounds does not exist in two or more structural forms?

A. C_4H_{10}
B. $C_2H_4Cl_2$
C. C_2H_3Cl
D. $C_2H_2Cl_2$

15. Which of the following is likely to have the greatest solubility in ethanol?

A. $CH_3CH_2CH_2CH_3$
B. $CH_3CH_2CH_2COOH$
C. $CH_3CH_2COCH_3$
D. $CH_3CH_2COOCH_3$

16. The repeating section of a condensation polymer is represented below:

$$-O(CH_2)_3OCOCOO-$$

Which of the following pairs of monomers is most likely to produce the above section of polymer?

A. $CH_3(CH_2)_2COOH$ and CH_3CH_2OH
B. $HO(CH_2)_3OH$ and $HOOCCOOH$
C. $HO(CH_2)_3OH$ and $HOOC(CH_2)_2COOH$
D. CH_3COCH_3 and $CH_3(CH_2)_3CO(CH_2)_2CH_3$

17. Which of the following contains only one carbon-carbon double bond?

A. $CH_3CHCHOH$
B. CH_3CH_2CCH
C. CH_3CH_2COOH
D. $CH_2CCHCH_2CH_3$

18. The following substances can all be oxidised. Which one could react (under appropriate conditions) with one of its own oxidation products to form 1-propyl propanoate?

A. Propanal
B. Propan-1-ol
C. Propan-2-ol
D. Propene

19. Which of the following 0.100 mol L^{-1} aqueous solutions has the highest pH?

A. Glucose
B. Ammonium sulfate
C. Sodium chloride
D. Potassium hydrogencarbonate

20. The pH of 0.100 mol L^{-1} hydrochloric acid (HCl) is about 1.0 and the pH of 0.100 mol L^{-1} phosphoric acid (H_3PO_4) is about 1.6. The pH of the phosphoric acid solution is higher because:

A. HCl ionises more fully than H_3PO_4
B. H_3PO_4 has more hydrogen atoms
C. HCl is a weaker acid than H_3PO_4
D. H_3PO_4 is amphoteric in water.

21. A student titrated an approximately 2 mol L^{-1} solution of propanoic acid into a 25.0 mL sample of 2 mol L^{-1} KOH. The indicator used, bromothymol blue, changes colour at a pH of 7.0. The equivalence point of the titration will occur:

A. after the end point is reached.
B. before the end point is reached.
C. at exactly the same titre as the end point.
D. either before or after the end point, additional information is necessary to decide this.

22. Sodium cyanide is a white solid which is soluble in water. The pH of a 0.100 mol L^{-1} solution is 9.5. The ion present in the highest concentration is:

A. hydroxide ions
B. hydrogen ions
C. sodium ions
D. cyanide ions

23. Iodine reacts with hydroxide ions to give the following equilibrium mixture:

$$3\ I_{2(aq)} + 6\ OH^-_{(aq)} \rightleftarrows IO_3^-{}_{(aq)} + 5\ I^-_{(aq)} + 3\ H_2O_{(l)}$$

Which two species are acting as oxidizing agents (oxidants)?

A. I_2 and IO_3^-

B. IO_3^- and OH^-

C. OH^- and I^-

D. I^- and I_2

24. Four hypothetical metallic elements *A*, *B*, *C* and *D* form soluble nitrates having formulae ANO_3, $B(NO_3)_2$, CNO_3 and $D(NO_3)_3$.

Strips of the four metals were immersed into 0.100 mol L^{-1} aqueous solutions of the other metal nitrates and it was observed that:

Metal *B* underwent reaction in all solutions

Metal *A* only reacted with CNO_3

In order of increasing strength as reducing agents, the metals are:

A. *A D C B*

B. *B C D A*

C. *B D A C*

D. *C A D B*

25. A dilute solution of sulfuric acid in water is electrolysed using platinum electrodes. The substances collected at the electrodes are:

A. Sulfur dioxide and hydrogen gas

B. Hydrogen gas and oxygen gas

C. Hydrogen gas and sulfur

D. Sulfur dioxide gas and oxygen gas

26. 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

27. As the lead accumulator battery is charging, the pH of the electrolyte solution in the battery:

A. initially increases, then remain constant
B. remains constant
C. decrease steadily
D. increase steadily.

28. The emf of an electrochemical cell constructed using the standard Ni^{2+}/Ni and Sn^{4+}/Sn^{2+} half-cells would be

A. 0.41 V with the Ni electrode positive.
B. 0.41 V with the Pt electrode positive.
C. 0.11 V with the Ni electrode positive.
D. 0.11 V with the Pt electrode positive.

29. When two metals are in direct contact in the presence of a suitable electrolytic solution, such as salt water, an electrochemical reaction may occur. Which one of the following materials should not be used to fasten two sheets of zinc together in a wet, salty environment if it essential that the zinc sheets do not corrode electrolytically?

A. Magnesium
B. Zinc
C. Aluminium
D. Tin

30. During the industrial extraction of gold, air is bubbled through the finely divided ore in the presence of sodium cyanide solution. Which of the following best describes the role of air in this process?

A. It reduces the oxidation potential of gold
B. It increases the equilibrium yield of products by mixing reagents
C. It provides the oxidising agent
D. It provides the reducing agent

End of Part 1

PART 2 (70 marks = 35% of paper)

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

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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 nitric acid is added to magnesium carbonate.

Equation _____

Observation _____

_____

[3 marks]

b) An excess of 2 mol L^{-1} potassium hydroxide solution is gradually added to a zinc chloride solution.

Equation _____

Observation _____

_____

[3 marks]

c) A piece of sodium is added to 2-butanol.

Equation _____

Observation _____

_____

[3 marks]

d) Hydrochloric acid is added to potassium permanganate solution.

Equation _____

Observation _____

_____

[3 marks]

2. 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 of each species by either a sketch or a name

Species	*Structural Formula*	*Shape*
SO_2Cl_2		
ClO_3^-		

[2 x 3 = 6 marks]

3. a) On the following set of axes, sketch a graph that depicts the trend in first ionisation energy of the alkali metals.

[1 mark]

   b) Briefly account for the trend depicted in a).

_____

_____

_____

_____

_____

[3 marks]

4. a) Complete the following table by matching the boiling points with the following compounds: butanal, pentane, 2,2-dimethylpropane and propanoic acid.

Name of compound	*Boiling point (ºC)*
	9.5
	36.1
	74.8
	140.8

[2 marks]

b) Explain your choices in a).

[4 marks]

5. Hydrogen gas for use in the Haber Process can be produced by the reaction of methane and water, according to the following equation:

$$CH_{4(g)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + 3\ H_{2(g)} \qquad \Delta H = -ve$$

The usual conditions for this reaction are a temperature of 750°C in the presence of a nickel catalyst.

Consider an equilibrium mixture of these gases. State, using the terms *increase*, *decrease* and *no change*, how each of the changes described in the table below will affect:
- the **initial** rate of the forward reaction; and
- the yield of hydrogen gas.

Change	*Effect on **initial** rate of forward reaction*	*Effect on yield of hydrogen gas*
Increase in volume		
Increase in temperature		
Increase in pressure via the addition of argon gas		
Removal of $CO_{(g)}$		
Removal of the nickel catalyst		

[10 marks]

6. a) Write an equation for the ionisation of water.

_____

[1 mark]

b) The pH of pure water decreases with increasing temperature. Using Le Chatelier's Principle, explain whether the ionisation of water is an endothermic or exothermic process.

_____

_____

_____

_____

_____

_____

_____

[3 marks]

7. Lactic acid ($CH_3CH(OH)COOH$) is a weak monoprotic acid. The pH of a 0.100 mol L^{-1} solution of lactic acid is 2.43.

a) Write an equation representing the ionisation of lactic acid in aqueous solution.

_____

[2 marks]

b) Determine the $[H^+]$ in the 0.100 mol L^{-1} lactic acid solution.

[1 mark]

c) What percentage of lactic acid molecules have ionised in solution?

[1 mark]

d) Compare the electrical conductivity of a 0.100 mol L^{-1} lactic acid solution with pH 2.43 and a 0.100 mol L^{-1} hypochlorous acid (HOCl) solution with pH 4.23. Explain your answer.

_____

_____

_____

_____

_____

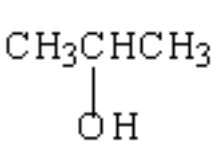
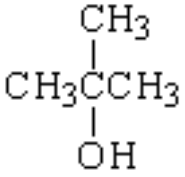
_____

_____

_____

[3 marks]

8. Describe a chemical test could be performed to distinguish between the following two compounds. State your expected observations for each compound.

Compound		
Test		
Observation		

[3 marks]

9. Consider the following <u>unbalanced</u> equation:

$$As_2O_{3(s)} + NO_3^-{}_{(aq)} \longrightarrow H_3AsO_{4(aq)} + NO_{(g)}$$

a) Identify the (i) oxidant _____

(ii) reductant _____

[2 marks]

b) Write the oxidation and reduction half equations.

Oxidation

_____

[2 marks]

Reduction

_____

[1 mark]

c) Write the balanced overall equation for the reaction.

_____

[2 marks]

10. a) In the space below, sketch an electrolytic cell that could be used to plate an iron spoon with nickel. Clearly identify the following:
- the materials that you would use at each electrode and as the electrolyte
- the anode and cathode
- the direction of flow of electrons

[4 marks]

b) Write equations for the reactions that would occur at each electrode

Anode _____

Cathode _____

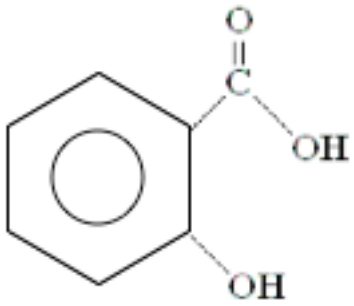
[2 marks]

c) Assuming standard conditions, what minimum voltage would be required?

_____

[1 mark]

11. The structure salicylic acid is depicted below.



Note that salicylic acid has an alcohol functional group and a carboxylic acid functional group.

Sketch the product of the reaction of salicylic acid, under appropriate conditions, with:

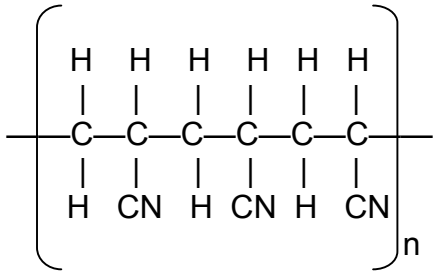
a) ethanoic acid

[1 mark]

b) methanol

[1 mark]

12. Polyacrylonitrile (PAN) is a polymer that is widely used in carpets. A section of its structure is depicted in the following diagram:



a) In the space below sketch the monomer, acrylonitrile.

[1 mark]

b) What class of polymer, addition or condensation, is polyacrylonitrile?

_____

[1 mark]

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.

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1. A common ore of manganese is hausmannite, which contains Mn_3O_4. A particular sample of hausmannite is known to contain 29.2% Mn_3O_4.

   Mn_3O_4 can be reduced to manganese metal by reduction with aluminium as follows

   $$3\ Mn_3O_4 + 8\ Al \rightarrow 9\ Mn + 4\ Al_2O_3$$

   In a particular process, 5.00 kg of the sample of hausmannite is reacted with 500.0 g of aluminium.

   a) Assuming that the reaction is 100% efficient, what mass of manganese metal can be obtained?

   (7 marks)

   b) What mass of the excess reactant will remain?

   (3 marks)

1. cont.

2. When England win the Rugby World Cup (again!), they will be presented with a trophy that is an alloy of several metals, including chromium. The chromium content of a trophy can be determined by oxidising the chromium to sodium dichromate by reacting with an excess of persulfate ($S_2O_8^{2-}$) ions, boiling to destroy any excess oxidant and then titrating the acidified solution with standardised iron (II) sulfate solution. Using this method, a 8.405 g sample of the same alloy used to make the trophy was converted into an acidified solution of sodium dichromate and diluted to 250 mL. A 25.0 mL sample was then titrated against 0.415 mol L^{-1} iron (II) sulfate and required 24.80 mL to reach the end-point.

   a) Write a balanced equation for the reaction between $Cr_2O_7^{2-}$ and Fe^{2+}

   (2 marks)

   b) Calculate the percentage by mass of chromium in the trophy.

   (6 marks)

2. cont.

3. A D.C. electric current was passed through three cells connected in series for 30.0 minutes. The first cell contained silver nitrate solution with silver electrodes, the second cell contained nickel(II) sulfate solution with nickel electrodes and the third cell contained potassium iodide solution with graphite electrodes. In the first cell, 0.6389 g of silver was deposited.

   (a) Calculate the magnitude of the electric current.

   (4 marks)

   (b) If the nickel anode had a mass of 2.00 g before the electrolysis, what would be its mass at the end?

   (3 marks)

   (c) What volume of gas would be given off at the cathode of the third cell, measured at 103 kPa and 24.0^{o}C?

   (2 marks)

3. cont.

4. Putrescine ($C_4H_{12}N_2$) is an organic chemical that is responsible for the foul odour of decaying flesh. By determining the putrescine content of body tissue of corpses, forensic scientists can estimate how long a body has been dead. Putrescine contains two amine ($-NH_2$) groups and reacts with hydrochloric acid as follows;

$$H_2N\text{-}(CH_2)_4\text{-}NH_2(aq) + 2\ H^+(aq) \rightarrow {}^+H_3N\text{-}(CH_2)_4\text{-}NH_3{}^+(aq)$$

During a murder investigation, a 500.0 g sample of dead tissue was boiled up in 3.00 L of 0.200 mol L^{-1} hydrochloric acid to react all the putrescine.

The organic product was removed from the reaction mixture by precipitation and then 20.00 mL samples of the remaining solution were extracted and titrated against 0.200 mol L^{-1} sodium hydroxide solution with a phenolphthalein indicator. The following results were obtained.

vol NaOH added	1	2	3	4
Final (mL)	19.25	37.85	18.50	36.75
Initial (mL)	0.00	19.25	0.20	18.50
Titre (mL)				

a) Calculate the average titre of sodium hydroxide

(1 mark)

b) Calculate the percentage by mass of putrescine in the dead tissue.

(8 marks)

4. cont.

5. Desflurane is a commonly used general anaesthetic, and is known to contain carbon, hydrogen, oxygen and fluorine only. The following experiments were performed to determine the molecular formula of desflurane.

Firstly, 2.00 g of desflurane was completely combusted in excess oxygen to form 1.57 g of carbon dioxide and 0.214 g of water.

In a second experiment, the fluorine in 1.20 g of desflurane was completely converted into hydrofluoric acid, HF(aq), and made up to 250.0 mL in a volumetric flask. A 25.00 mL aliquot of this solution required 21.43 mL of 0.200 mol L^{-1} sodium hydroxide solution for neutralisation.

Finally, a 1.00 g sample of desflurane was vapourised at 250 ^{o}C and 101.3 kPa and was found to occupy a volume of 256.0 mL.

a) Calculate the empirical and molecular formula of desflurane.

(13 marks)

b) Given that it does not contain an –OH (alcohol) group, suggest a *possible* structural formula of desflurane.

(1 mark)

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.

Many metals are extracted from their ores by chemical processing. The following methods have been used commercially.

- Sodium is obtained by electrolysis of $NaCl_{(l)}$

- Magnesium is obtained by electrolysis of $MgCl_{2\ (l)}$

- Aluminium can be obtained by the reaction of sodium with $AlCl_3$:

$$AlCl_{3\ (g)} + 3\ Na_{(l)} \rightarrow Al_{(l)} + 3\ NaCl_{(l)}$$

- Silicon can be obtained by treatment of $SiCl_4$ with Zn :

$$SiCl_{4\ (g)} + 2\ Zn_{(l)} \rightarrow Si_{(s)} + 2\ ZnCl_{2\ (l)}$$

- Lead can be obtained by roasting PbS in air then heating the PbO product with C :

$$2\ PbS_{(s)} + 3\ O_{2\ (g)} \rightarrow 2\ PbO_{(s)} + 2\ SO_{2\ (g)} \quad \text{then}$$

$$2\ PbO_{(s)} + C_{(s)} \rightarrow 2\ Pb_{(l)} + CO_{2\ (g)}$$

- Copper can be obtained by roasting CuS in air and then reducing the resultant CuO with further CuS :

$$2\ CuS_{(s)} + 3\ O_{2\ (g)} \rightarrow 2\ CuO_{(s)} + 2\ SO_{2(g)}$$

$$CuS_{(s)} + 2\ CuO_{(s)} \rightarrow 3\ Cu_{(l)} + 2\ SO_{2(g)}$$

- Silver can be found in nature in the elemental state or it can be extracted from ore by a cyanide-complex method. It is also a by-product of gold production.

Discuss the chemical basis and condition of these processes comparing them with what you know about the extraction of metals such as Al, Au and Fe.

Use your E^o table as a guide to the relative ease of reduction of the metal compounds.

End of Examination