Tertiary Entrance Examination, 2001

Question/Answer Booklet

CHEMISTRY

Please place your student identification label in this box

Student Number: In figures

In words

Time allowed for this paper
Reading time before commencing work: Ten minutes
Working time for paper: Three hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Separate Multiple Choice Answer Sheet
Chemistry Data Sheet (inside front cover of this Question/Answer Booklet)

To be provided by the candidate
Standard items: Pens, pencils, eraser or correction fluid, ruler
Special items: A 2B, B or HB pencil for the separate Multiple Choice Answer Sheet and calculators satisfying the conditions set by the Curriculum Council for this subject.

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

Part	Number of questions available	Number of questions to be attempted	Suggested working time	Marks available
1 Multiple choice	30	All	55	60 (30%)
2 Short answers	10	All	60	70 (35%)
3 Calculations	5	All	45	50 (25%)
4 Extended answers	2	1	20	20 (10%)
			Total marks	200 (100%)

Instructions to candidates

1. The rules for the conduct of Tertiary Entrance Examinations are detailed in the booklet *TEE Handbook*. Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions:
    Part 1   Answer **all** questions, using a 2B, B or HB pencil, on the separate Multiple Choice Answer Sheet. Do **not** use a ball point or ink pen.

    If you consider that two or more of the alternative responses are correct, choose the one you think is best. If you think you know an answer, mark it even if you are not certain you are correct. Marks will not be deducted for incorrect answers.

    Feel free to write or do working on the question paper; many students who score high marks in the Multiple Choice Section do this.

    Parts 2, 3 and 4   Write your answers in the spaces provided in this Question/Answer Booklet. A blue or black ball point or ink pen should be used.
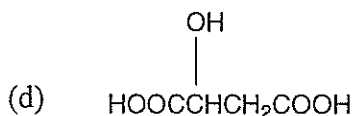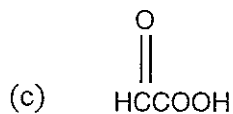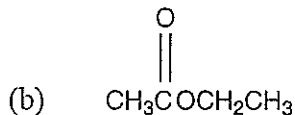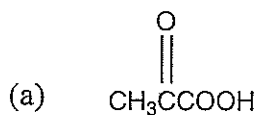
    Questions containing specific instructions to show working should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at; correct answers which do not show working will not be awarded full marks.

3. The examiners recommend that you spend your reading time mainly reading the Instructions to Candidates and Parts 2, 3 and 4.

4. **Chemical equations**
    For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be **ions** [for example $Ag^+(aq)$], **molecules** [for example $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(l)$, $CH_3COOH(aq)$] or **solids** [for example $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

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**PART 1**   **(60 marks = 30% of paper)**

Answer ALL questions in Part 1 on the separate Multiple Choice Answer Sheet provided, using a 2B, B or HB pencil. Each question in this part is worth 2 marks.

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1.   Which formula represents a compound which is both a ketone and a carboxylic acid?

(a) CH_3CCOOH (with O double-bonded to the C)

(b) $CH_3COCH_2CH_3$ (with O double-bonded to the C)

(c) $HCCOOH$ (with O double-bonded to the C)

(d) $HOOCCHCH_2COOH$ (with OH on the CH)

2.   Which formula represents two substances which are geometric (*cis/trans*) isomers?

(a) C_3H_6

(b) C_3H_8

(c) $H_2CC(CH_3)_2$

(d) $CH_3CHCHCH_3$
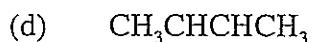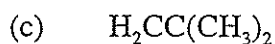
3.   Which one of the following **cannot** be a product of oxidation of $CH_3CH_2CH_2CH_2OH$?

(a) $CH_3CH_2CH_2CHO$

(b) $CH_3CH_2CH_2COOH$

(c) $CH_3COCH_2CH_3$

(d) CO_2
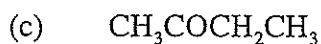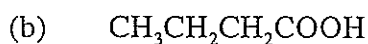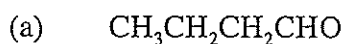
4.   Which one of the following statements about the transition state (also called the activated complex) in a chemical reaction is **false**?

(a)   It has higher energy than the reactants.

(b)   It has lower energy than the products of the reaction.

(c)   It is unstable and has a very short lifetime.

(d)   Transition state formation involves bond making.

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5. Which one of the following processes is exothermic?

   (a) $I_2(g) \rightarrow 2\, I(g)$

   (b) $I_2(s) \rightarrow I_2(g)$

   (c) $Na(g) \rightarrow Na^+(g) + e^-$

   (d) $Na^+(g) + I^-(g) \rightarrow NaI(s)$

6. What is the equilibrium constant expression for the dissolving of lead(II) chloride according to the following equation?

$$PbC\ell_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\, C\ell^-(aq)$$

   (a) $K = [Pb^{2+}]\,[C\ell^-]^2$

   (b) $K = [Pb^{2+}]\,[2\, C\ell^-]$

   (c) $K = \dfrac{[Pb^{2+}]\,[C\ell^-]^2}{[PbC\ell_2]}$
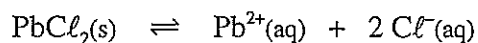
   (d) $K = \dfrac{[PbC\ell_2]}{[Pb^{2+}]\,[C\ell^-]^2}$

7. Consider the following reaction at equilibrium.

$$2\, NO(g) + O_2(g) \rightleftharpoons 2\, NO_2(g) \qquad \Delta H = -114\ kJ$$
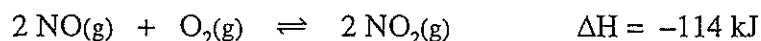
   Which one of the following changes will increase the concentration of $NO_2(g)$ in the mixture when equilibrium is re-established?

   (a) decreasing the concentration of NO at constant temperature and pressure

   (b) decreasing the concentration of O_2 at constant temperature and pressure

   (c) decreasing the pressure

   (d) decreasing the temperature

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8.   Which one of the following reagents, when mixed with ammonium sulfate and heated, produces ammonia?

   (a)   a solution containing potassium permanganate and dilute sulfuric acid

   (b)   dilute hydrochloric acid

   (c)   limewater (saturated calcium hydroxide solution)

   (d)   water

9.   Group I and II metal hydrides react with water according to the following equation:

$$H^- + H_2O(\ell) \rightarrow OH^-(aq) + H_2(g)$$
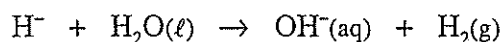
   In a particular experiment, 1.00 g of each of the following metal hydrides is treated with an excess of water. Which metal hydride will produce the greatest volume of hydrogen?

   (a)   NaH

   (b)   KH

   (c) MgH_2

   (d) CaH_2

10.   Species 'X' has the valence electron configuration of s^2, and 'Z' has the valence electron configuration of s^2p^5. Which of the following is the most likely formula of a compound formed between 'X' and 'Z'?

   (a)   XZ

   (b) XZ_2

   (c) X_2Z_5

   (d) X_2Z_7

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11.   An element has the first five successive ionisation energies as shown on the graph below.
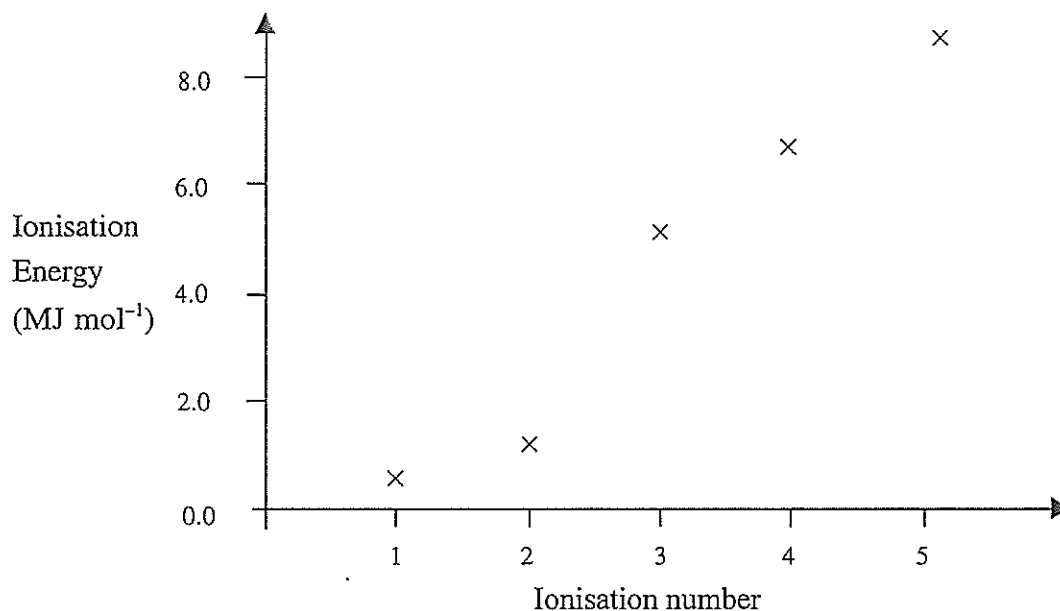
Which one of the following is it?

(a)   aluminium

(b)   calcium

(c)   carbon

(d)   neon

12.   Which one of the following best describes, for the elements across the third row of the periodic table: the trends in the first ionisation energy and acidity of the oxides?

(a)   Going from left to right: the first ionisation energy decreases; and the acidity of the oxides decreases while their basicity increases.

(b)   Going from left to right: the first ionisation energy decreases; and the acidity of the oxides increases while their basicity decreases.

(c)   Going from left to right: the first ionisation energy increases; and the acidity of the oxides decreases while their basicity increases.

(d)   Going from left to right: the first ionisation energy increases; and the acidity of the oxides increases while their basicity decreases.

Questions 13 and 14 are both about the following experiment.

An electric current is passed through a solution containing:
1 mol L^{-1} each of $CuSO_4$, NaBr and KCl using two platinum electrodes.

13.   Which one of the following species is produced at the anode?

    (a) Br_2(aq)

    (b) Cl_2(g)

    (c)   Cu(s)

    (d) O_2(g)

14.   Which one of the following species is produced at the cathode?

    (a)   Cu(s)

    (b) H_2(g)

    (c)   K(s)

    (d) O_2(g)

15.   Which underlined element has the highest oxidation state?

    (a) $KMnO_4$

    (b) Mn^{2+}

    (c) Na_2SO_3

    (d) PCl_3

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16. One solution contains $AuC\ell_3$ and a second solution contains $AgNO_3$. A quantity of electricity is passed through the two solutions as shown in the diagram below.
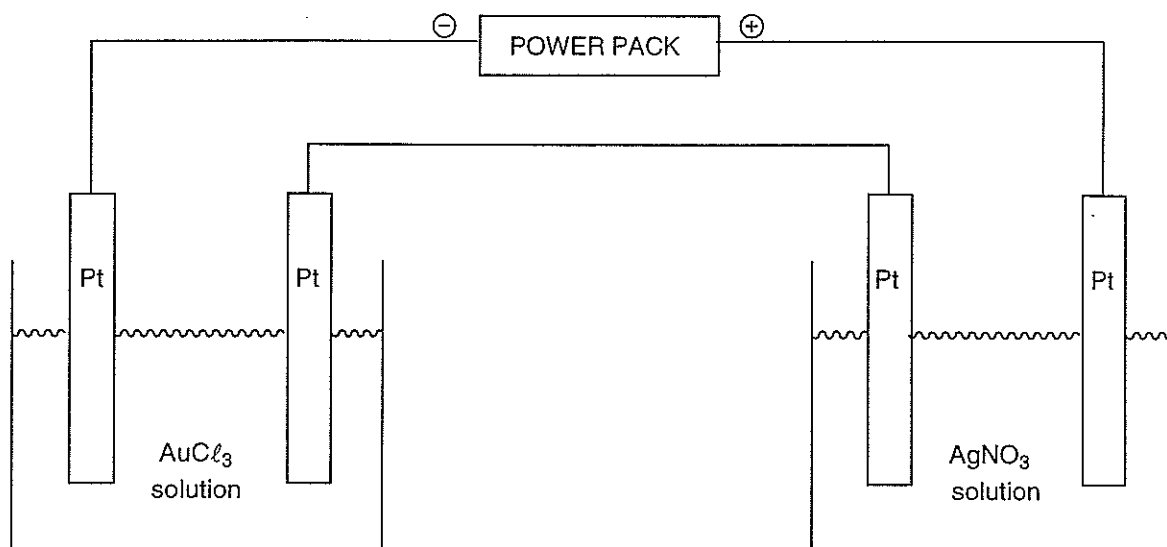
What is the ratio of the number of moles of gold deposited to the number of moles of silver deposited? {that is, n(Au):n(Ag)}.

(a) 1:1

(b) 1:3

(c) 2:1

(d) 3:1

17. Potassium permanganate solution is standardised using the following procedure: sulfuric acid is added to 25.00 mL of a standard solution of oxalic acid (ethanedioic acid), and the mixture warmed and titrated with the potassium permanganate solution. Which one of the following will cause an error?

(a) leaving the conical flask (titration vessel) wet after rinsing with distilled water

(b) rinsing the burette with distilled water, then with a little of the permanganate solution, and then filling it with the permanganate solution

(c) rinsing the pipette with distilled water, then using it to dispense the oxalic acid (ethanedioic acid) solution

(d) washing down the sides of the conical flask with distilled water from time to time during the titration

18. What is the maximum number of **unpaired** electrons possible in 3d orbitals?

(a) 3

(b) 5

(c) 6

(d) 10

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19.   Which one of the following is the formula of the complex ion formed between one silver ion and two cyanide ions?

(a) $[Ag(CN)_2]^{2-}$

(b) $[Ag(CN)_2]^-$

(c) $[Ag(CN)_2]^+$

(d) $[Ag(CN)_2]^{2+}$

20.   Which one of the following statements about the first row of transition metals is **false**?

(a)   Many form coloured compounds.

(b)   Many form compounds where the element has an incompletely filled d subshell.

(c)   The element can have a range of possible oxidation states in its compounds.

(d)   They are all oxidising agents.

21.   In which one of the following is the solid state maintained only by covalent bonding?

(a) $CO_2(s)$

(b) $H_2O(s)$

(c) $NH_4C\ell(s)$

(d) $SiO_2(s)$

22.   In which one of the following substances is hydrogen bonding the main intermolecular force at room temperature?

(a)   ethanol

(b)   hydrogen bromide

(c)   hydrogen sulfide

(d)   methane

23.   A chemist wishes to make a fertiliser solution containing ions that will act as a source of nitrogen, phosphorus and potassium. Which one of the following mixtures of solids will completely dissolve to give such a solution?

(a) K_3PO_4 $Ca(NO_3)_2$ $KC\ell$

(b) K_2CO_3 K_3PO_4 $Ba(NO_3)_2$

(c) NH_4NO_3 Na_3PO_4 $KC\ell$

(d) $NH_4C\ell$ K_3PO_4 $CaC\ell_2$

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24. Which one of the following statements about the trends down Group IV in the Periodic Table is **false**?

    (a) Metallic character increases.

    (b) The electronegativity increases.

    (c) The first ionisation energy decreases.

    (d) The oxides become more basic.

25. Gold is produced by the CIP (carbon in pulp) process and not in a blast furnace. Which of the following best accounts for this?

    (a) Gold cannot form alloys (as iron forms steel in the blast furnace).

    (b) Gold is found naturally in the elemental state.

    (c) Gold oxide cannot be reduced by carbon (coke).

    (d) Gold will not melt at the temperature of a blast furnace.

26. Aluminium is produced by electrolytic reduction of alumina and not in a blast furnace. Which of the following best accounts for this?

    (a) Aluminium is a highly reactive element.

    (b) Cryolite could not be used in a blast furnace.

    (c) Electricity is a cheap option.

    (d) The reaction of bauxite with coke in a blast furnace is too vigorous.

27. Which one of the following species **cannot** act as both a Brønsted-Lowry acid and base?

    (a) CH_4

    (b) HCO_3^-

    (c) HSO_4^-

    (d) NH_3

28. Pure water undergoes self-ionisation according to the equation:

$$2 H_2O(\ell) \rightarrow H_3O^+(aq) + OH^-(aq)$$
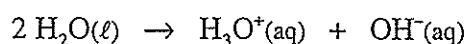
The equilibrium constant for the reaction is:
1.0×10^{-14} at 25°C   and 5.5×10^{-13} at 100°C.

Which one of the following statements is correct?

(a)   At 100°C the pH of pure water is less than 7.0 , but the water is still neutral.

(b)   At 100°C the pH of pure water is less than 7.0 , and therefore the water is acidic.

(c)   At 100°C the pH of pure water is greater than 7.0 , and therefore the water is basic.

(d)   At 100°C the pure water is obviously still neutral and the pH must be 7.0.

29. Which one of the following statements about 1.00×10^{-8} mol L^{-1} HCℓ is correct?

(a)   The pH is 6.

(b)   The pH is a little less than 7.

(c)   The pH is 8.

(d)   Such a solution cannot exist.

30. A chemist measures the pH of four 1.0×10^{-2} mol L^{-1} acid solutions, and obtains the following results.

Experiment	Solution	pH
1	1.0×10^{-2} M CH_3COOH	3.4
2	1.0×10^{-2} M H_3PO_4	2.2
3	1.0×10^{-2} M HNO_3	2.0
4	1.0×10^{-2} M H_2SO_4	1.4

Which experimental result must be **incorrect**?

(a)   experiment 1

(b)   experiment 2

(c)   experiment 3

(d)   experiment 4

END OF PART 1

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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)
                • gases evolved (give the colour or describe as colourless).

        If no change is observed, you should state this.

(a)   Copper(II) nitrate solution is added to sodium carbonate solution.

Equation _____

Observation _____

_____

                                                                [3 marks]

(b)   An excess of warm dilute hydrochloric acid is added to solid sodium sulfite.

Equation _____

Observation _____

_____

                                                                [3 marks]

(c)   Dilute hydrochloric acid is added to solid silver.

Equation _____

Observation _____

_____

                                                                [3 marks]

(d)   A little concentrated sulfuric acid is added to a mixture of ethanol and acetic acid (ethanoic acid) and the mixture heated.

Equation _____

Observation _____

_____

                                                                [3 marks]

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2.   For each species listed in the table below

(a)   draw the structural formula,
      including **all** valence shell electron pairs and representing each either as **:** or as —

      [for example, water   H : Ö : H   or   H — Ö — H   or   H — Ö — H   and so on]

(b)   indicate the shape of each species by either a sketch or a name

(c)   indicate the polarity of each species. Write 'non-polar' or 'polar'.

In each of the three species, sulfur is the central atom.

Species	Structural formula (showing all valence shell electrons)	Shape (sketch or name)	Polarity ('non-polar' or 'polar')
Sulfur dioxide, SO_2			
Sulfur trioxide, SO_3			
Sulfite ion, SO_3^{2-}			

[12 marks]

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3.   Identify by name or formula an example of each of the following.

Description	Name or Formula
a species with delocalised electrons	
a salt that dissolves in water to give a neutral solution	
a molecule containing three carbon atoms and two nitrogen atoms	
a compound used in fertilisers	
an element that exhibits in its compounds oxidation states including +2 and +7	
a monomer used to prepare an addition polymer	
a functional group in an organic molecule, where the organic compound reacts with $NaHCO_3$ solution	

[7 marks]

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4.   (a)   Write a chemical equation which is consistent with the observation in the following experiment.

What is done	Observation	Equation
A colourless odourless liquid is added to a white solid.	The white solid dissolves, and a colourless, odourless gas bubbles off, leaving a colourless solution.	

[2 marks]

(b)   Give a test which would confirm the identity of the gas produced in the reaction in (a).

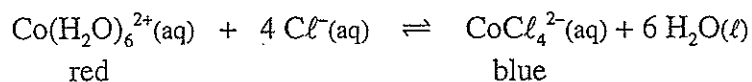|	
What is done	
What is observed	
Equation	

[4 marks]

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5. (a) A 0.1 mol L^{-1} water-solution of Na_2HPO_4 has a pH of about 10. Explain this, using an equation or equations.

[3 marks]

(b) A 0.1 mol L^{-1} water-solution of $NH_4CH_3CO_2$ (ammonium acetate, also known as ammonium ethanoate) has a pH of approximately 7. Explain this, using at least two equations.

[4 marks]

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6. Consider the equilibrium

$$Co(H_2O)_6^{2+}(aq) + 4\,Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6\,H_2O(\ell)$$

    red   blue

An equilibrium mixture is set up by dissolving cobalt chloride in water to make a concentrated solution, and then adding concentrated hydrochloric acid until the mixture is purple. The solution is divided into three parts, and each part is treated as described in the table. Explain the observations. [A statement such as 'nc', '→', or '←' is not sufficient as an explanation.]

Experiment and Observation	Explanation
A little concentrated hydrochloric acid is added and the mixture turns more blue and less red.	
A little silver nitrate solution is added. There is a precipitate and the mixture turns more red and less blue.	
The solution is warmed and the mixture turns more blue and less red.	

[6 marks]

7. Write the equilibrium constant expression for each of the following:

Equation	$2\,H_2O(\ell) + 4\,Au(s) + O_2(g) + 8\,CN^-(aq) \rightleftharpoons 4\,Au(CN)_2^-(aq) + 4\,OH^-(aq)$
Equilibrium constant expression	

Equation	$H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$
Equilibrium constant expression	

[4 marks]

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8.   A small piece of rubidium metal (Rb) is added to water.

      (a)   Write the equation for the reaction.

      _____

                                                                [2 marks]

      (b)   Would you expect this reaction to be slow or rapid? Explain.

      _____

                                                                [3 marks]

9.   1,2-Ethanediol (ethylene glycol) is water-soluble, and is often used as an additive in car radiators to raise the boiling point of the water. Its structural formula is:

$$HO-CH_2-CH_2-OH$$
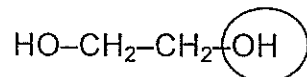
      (a)   State whether the circled hydroxyl group is primary, secondary or tertiary.

      _____

                                                                [1 mark]

      (b)   Explain why 1,2-ethanediol is soluble in water. Include a diagram in your answer. [Note that "like dissolves like" is a statement and not an explanation.]

      _____

                                                                [3 marks]

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10.   Use the following condensed structural formulas (some of the isomers of $C_5H_{12}O$) to answer the following questions.

OH
|
$CH_3CH_2CH_2CH_2CH_2OH$ $CH_3CHCH_2CH_2CH_3$

               A   B

OH
|
$CH_3CCH_2CH_3$
|
CH_3

               C

CH_3   CH_3
| |
$CH_3CH\ CHCH_3$ CH_3CCH_2OH
| |
OH   CH_3

               D   E

(a)   Choose **one** compound (A, B, C, D or E) which will give each of the following reactions.
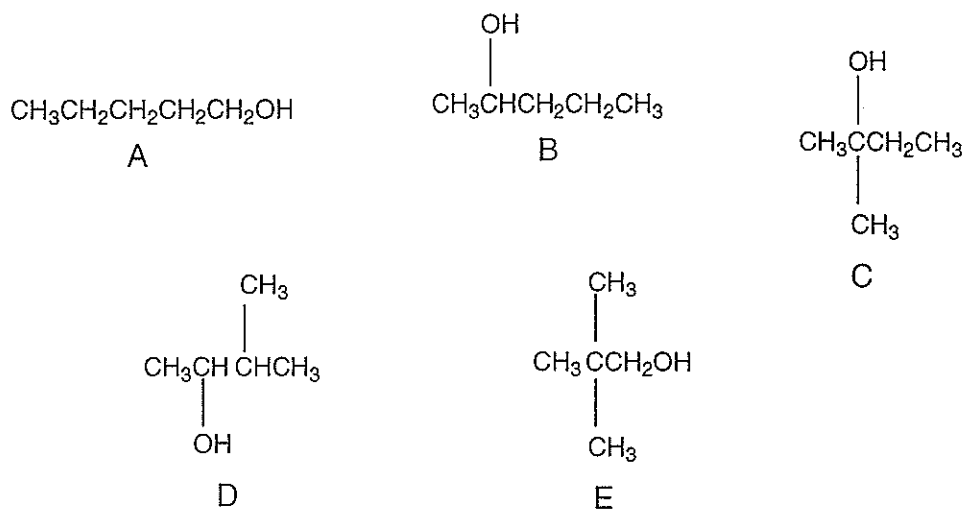
Description of reaction	Identity of compound (Use A, B, C, D or E)
A compound that reacts with a warm solution containing sulfuric acid and potassium dichromate to produce a carboxylic acid.	
A compound that reacts with a warm solution containing sulfuric acid and potassium dichromate to produce a ketone.	

[2 marks]

(b)   Write an equation for the reaction of sodium metal with any of the above alcohols?

[2 marks]

(c)   Primary, secondary and tertiary alcohols react with sodium metal at different rates. Classify (using the letters A, B, C, D and E), **all five** alcohols according to their rates of reaction with Na.

| slowest reaction	intermediate rate of reaction	fastest reaction

[3 marks]

END OF PART 2
SEE NEXT PAGE

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.   Ferrovanadium is an alloy of Fe and V.

When 0.8765 g of the alloy was placed in hot, moderately concentrated sulfuric acid the alloy dissolved:

- the iron was converted into iron(III) ion, and

- the vanadium was converted into vanadate ion (VO_3^-)

$$2\,V \;+\; 8\,H^+ \;+\; 5\,SO_4^{2-} \;\rightarrow\; 2\,VO_3^- \;+\; 5\,SO_2 \;+\; 4\,H_2O \;.$$
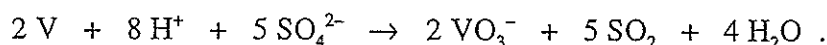
The solution was cooled and diluted to 250.0 mL with water. A 50.00 mL sample was made basic with NaOH solution to precipitate the Fe^{3+} as $Fe(OH)_3$. This was filtered out, and the vanadium-containing solution re-acidified with sulfuric acid.

The acid solution was passed through a column of Zn wire reducing the VO_3^- to V^{2+}

$$2\,VO_3^- \;+\; 12\,H^+ \;+\; 3\,Zn \;\rightarrow\; 2\,V^{2+} \;+\; 3\,Zn^{2+} \;+\; 6\,H_2O \;.$$
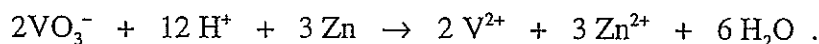
The solution was then treated with excess iron(III) sulfate solution

$$V^{2+} \;+\; 2\,Fe^{3+} \;+\; H_2O \;\rightarrow\; VO^{2+} \;+\; 2\,H^+ \;+\; 2\,Fe^{2+}$$
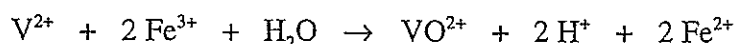
and the resulting iron(II) ion titrated with 0.03004 mol L^{-1} $KMnO_4$

$$5\,Fe^{2+} \;+\; MnO_4^- \;+\; 8\,H^+ \;\rightarrow\; 5\,Fe^{3+} \;+\; Mn^{2+} \;+\; 4\,H_2O$$
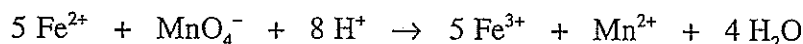
and 24.60 mL of the $KMnO_4$ was required.

(a)   Use the above equations to work out how many moles of permanganate ion will be required to react with the iron(II) ion produced from 1 mole of vanadium originally.

[3 marks]

(b)   Calculate the percentage by mass of vanadium metal in the alloy.

[5 marks]

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2.   Sulfur dioxide is an important preservative in food and wine processing. Winemakers add solid potassium metabisulfite $K_2S_2O_5$, which in mildly acidic wine, is a source of SO_2.

(a)   Write the equation for the reaction between solid $K_2S_2O_5$ and H^+ ion producing SO_2, water and potassium ions.

[2 marks]

(b)   How many grams of $K_2S_2O_5$ should the winemaker add to a 12 000 L vat of wine to achieve 45 ppm of SO_2? [45 ppm means 45 mg SO_2 in 1.00 kg]. Since wine is mostly water, its density is close to 1.00 g mL^{-1}.

[4 marks]

The SO_2 level in the wine is tested by a procedure which involves liberating the SO_2, then oxidising it with H_2O_2 to produce sulfuric acid, which is titrated against 0.0092 mol L^{-1} NaOH solution.

(c)   Write the equation for the reaction of SO_2 with H_2O_2.

[2 marks]

(d)   A 40 mL sample of wine was analysed. The average titre was 6.51 mL. Calculate the concentration of SO_2 in the wine in ppm.

[4 marks]

SEE NEXT PAGE

3. Compound X, a brownish solid, was once considered as an additive in place of lead in petrol. The compound contains carbon, hydrogen, oxygen and iron.

1.3270 g of X is burned in dry oxygen to give 3.037 g of CO_2, 0.615 g of H_2O and 0.392 g of Fe_2O_3.

(a) Calculate the empirical formula of X.

[8 marks]

(b) When 0.375 g of X was decomposed the gas product occupied 71 mL at 30°C and 98 kPa. When this decomposition occurs 1 mole of X is known to produce 2 moles of gas. Calculate the molecular weight of X.

[3 marks]

(c) What is the molecular formula of X?

[1 mark]

4. The following equation describes the reaction between sulfur tetrafluoride and diiodine pentaoxide:

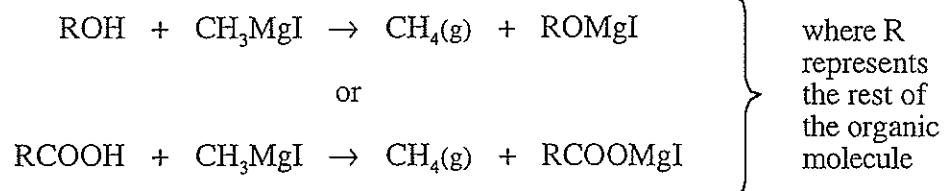$$5\ SF_4(g)\ +\ 2\ I_2O_5(s)\ \rightarrow\ 4\ IF_5(\ell)\ +\ 5\ SO_2(g)$$
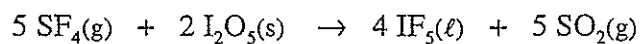
32.07 g of I_2O_5 is shaken with 6.02 L of SF_4 at 76°C and 120 kPa, and the reaction allowed to go to completion.

(a) What volume of sulfur dioxide is produced at 76°C and 120 kPa?

[5 marks]

(b) What mass of **each** of the substances (reactants and products) is present at the completion of the reaction?

[6 marks]

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5. Replaceable H atoms of alcohol and carboxylic acid groups are sometimes described as "active H". In the Zerewitinoff "active H" determination of 1907, every "active H" atom in a compound displaces MgI from CH_3MgI, giving CH_4.

The reaction is of the type:

$$ROH \ + \ CH_3MgI \ \rightarrow \ CH_4(g) \ + \ ROMgI$$

or

$$RCOOH \ + \ CH_3MgI \ \rightarrow \ CH_4(g) \ + \ RCOOMgI$$

where R represents the rest of the organic molecule

A 0.1345 g sample of a compound $C_8H_8O_3$, treated with an excess of CH_3MgI (in diethyl ether as solvent), gave 43 mL of CH_4 at 25°C and 1.0 atm.

(a) How many of the eight H atoms in $C_8H_8O_3$ are "active H" atoms?

[5 marks]

(b) This substance, $C_8H_8O_3$, burns with a smoky flame and therefore is aromatic. Suggest a structural formula for it.

[2 marks]

SEE NEXT PAGE

PART 4   (20 marks = 10% of paper)

Answer ONE of the following two extended answer questions. 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, and also for coherence and clarity of expression. Your answer should be presented in about $1\frac{1}{2}$ - 2 pages. Begin your essay on page 32.

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1.   Phosphoric acid, H_3PO_4, is one of the most widely produced industrial chemicals in the world. Pure phosphoric acid is a colourless solid with a melting point of 42°C.

Phosphoric acid has a vast range of uses, the major one being in the production of fertilizers, since phosphorus is essential for plant growth. Phosphoric acid is also used in the manufacture of detergents. Phosphoric acid is added to soft drinks to give a 'tangy' flavour and an appropriate acid pH. The anhydride of H_3PO_4 (which is P_4O_{10}) has such a strong affinity for water that it is used as a drying agent.

In one method for producing phosphoric acid, $Ca_3(PO_4)_2$ from phosphate rock is heated in an electric furnace with SiO_2 and C(graphite). This produces P_4 as a hot vapour according to the following equation.

$$2\,Ca_3(PO_4)_2(s)\ +\ 6\,SiO_2(s)\ +\ 10\,C(s)\ \rightarrow\ 6\,CaSiO_3(\ell)\ +\ 10\,CO(g)\ +\ P_4(g)$$
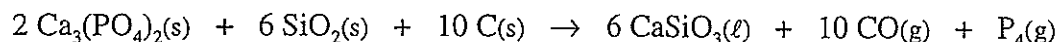
$$\Delta H = -3060 \text{ kJ per mole of } P_4$$

The reaction mixture can reach a temperature of about 2000°C. In some modern plants the heat generated is used to power steam turbines.

The P_4 is converted into P_4O_{10} by the combustion of phosphorus vapour as it is produced by the furnace ($\Delta H = -3053$ kJ per mole of P_4). [This reaction can occur spontaneously at room temperature.]
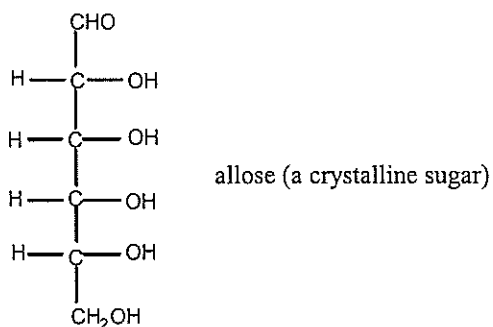
The H_3PO_4 is formed by passing the P_4O_{10} through a spray of water in a tower ($\Delta H = -377$ kJ per mole of P_4O_{10}).

Compare and contrast this information about phosphoric acid with the manufacture and uses of sulfuric acid.

OR

2.   The following table gives information about the solubility of some solutes in the solvents water and hexane. The only unusual solute is allose whose structure is:

```
          CHO
           |
    H ——— C ——— OH
           |
    H ——— C ——— OH
           |                          allose (a crystalline sugar)
    H ——— C ——— OH
           |
    H ——— C ——— OH
           |
         CH₂OH
```

Solute	Solvent	
	Water	Hexane
decane	insoluble	soluble
methanol	soluble	slightly soluble
1-pentanol	slightly soluble	soluble
allose	soluble	insoluble
sodium chloride	soluble	insoluble
silver chloride	insoluble	insoluble

Discuss the intermolecular and interionic forces involved in the above solutes and solvents, and so account for whether each solute dissolves or not.

[Note that "like dissolves like" is a statement and not an explanation.]

END OF QUESTIONS

Check that you have written your Student Number on the front cover of this booklet

SEE NEXT PAGE

Write your response to Part 4 below.