

[0500/293] 1988

CERTIFICATE OF SIXTH YEAR STUDIES

CHEMISTRY

PAPER

Friday, 6th May—9.30 a.m. to 12.00 noon



Dalziel High School
Chemistry Department



1988 CSYS

1. Which of the following electron configurations represents that of an atom in an excited state?

- A $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$
- B $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$
- C $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
- D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$

2. One mole of oxygen molecules is required for the complete combustion of 0.5 mole of a gas.

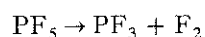
Which of the following could be that gas?

- A Carbon monoxide
- B Ethyne
- C Hydrogen
- D Methane

3. The oxidation of ethanedioate ions ($C_2O_4^{2-}$) in aqueous solution can be represented by the half reaction $C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$. What volume, in cm^3 , of acidified 0.10 M potassium permanganate solution is required to oxidise completely a solution containing 0.01 mole of ethanedioate ions?

- A 25
- B 40
- C 80
- D 100

4. What is the change in the three-dimensional arrangement of the bonds round the P atom in the following reaction?



- A Trigonal bipyramidal to trigonal planar
- B Tetrahedral to pyramidal
- C Square planar to pyramidal
- D Trigonal bipyramidal to pyramidal

5. $Ag^+(aq) + Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + Ag(s)$

The above reaction is thermodynamically feasible at 298 K.

The most likely combination of signs for the ΔS° and ΔH° values in this reaction is

- | | ΔS° | ΔH° |
|---|------------------|------------------|
| A | - | - |
| B | + | + |
| C | - | + |
| D | + | - |

6. $2P + Q \rightleftharpoons R + S$

$$\Delta G^\circ = +40 \text{ kJ mol}^{-1}$$

Which of the following **cannot** be deduced from the above information?

- A The feasibility of the reaction
- B The order of the reaction
- C The stoichiometry of the reaction
- D The position of equilibrium

7. What volume of 0.5 M sodium carbonate is required to make, by dilution with water, one litre of a solution with a $Na^+(aq)$ concentration of 0.2 M?

- A 100
- B 200
- C 300
- D 400

8. The bond dissociation energy of HBr is 364 kJ mol^{-1} . In which of the following are 364 kJ **released**, assuming molar quantities as shown?

- A $\frac{1}{2}H_2(g) + \frac{1}{2}Br_2(g) \rightarrow HBr(g)$
- B $H'(g) + Br'(g) \rightarrow HBr(g)$
- C $HBr(g) \rightarrow \frac{1}{2}H_2(g) + \frac{1}{2}Br_2(g)$
- D $HBr(g) \rightarrow H'(g) + Br'(g)$

9. Which of the following analytical techniques depends on the vibrations within molecules?
- A Colorimetry
 B Atomic emission spectroscopy
 C Infra-red absorption spectroscopy
 D Mass spectroscopy

10. For which of the following reactions will the values of ΔH° and ΔG° be most similar?
- A $\text{Mg(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Cu(s)}$
 B $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO(s)} + \text{CO}_2(\text{g})$
 C $\text{Zn(s)} + 2\text{H}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
 D $\text{C(s)} + \text{H}_2\text{O(g)} \rightarrow \text{CO(g)} + \text{H}_2(\text{g})$

11. Two colourless substances P and Q react to give a coloured substance R. The times (t) taken for various initial concentrations of P and Q to produce a certain colour intensity are as follows.

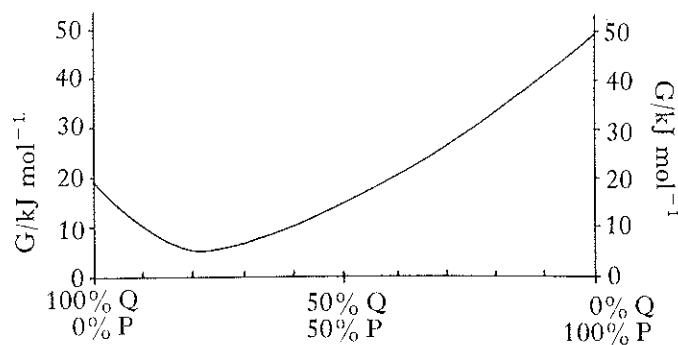
Experiment	Initial concentration of P/mol l ⁻¹	Initial concentration of Q/mol l ⁻¹	t/s
1	0.05	0.05	46
2	0.05	0.10	23
3	0.10	0.05	46

The rate equation for this reaction is

- A Rate = $k[\text{P}]$
 B Rate = $k[\text{Q}]$
 C Rate = $k[\text{Q}]^2$
 D Rate = $k[\text{P}][\text{Q}]$

12. Which of the following correctly represents the second ionisation energy of calcium?
- A $\text{Ca(s)} \rightarrow \text{Ca}^{2+}(\text{s}) + 2\text{e}^-$
 B $\text{Ca}^+(\text{s}) \rightarrow \text{Ca}^{2+}(\text{g}) + \text{e}^-$
 C $\text{Ca}^+(\text{g}) \rightarrow \text{Ca}^{2+}(\text{g}) + \text{e}^-$
 D $\text{Ca(g)} \rightarrow \text{Ca}^{2+}(\text{g}) + 2\text{e}^-$

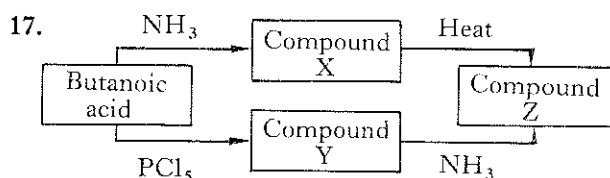
The diagram below refers to questions 13 and 14.



13. Assuming that P and Q are in their standard states when 100% of either is present, what is the value of ΔG° , in kJ mol^{-1} , for the reaction represented by the stoichiometric equation $\text{Q} \rightarrow \text{P}$?
- A -30
 B +30
 C -65
 D +65
14. The equilibrium constant for the reaction in question 13 above is
- A 0.25
 B 0.40
 C 2.50
 D 4.00.
15. Which of the following formulae could only represent an aldehyde?
- A CH_2O
 B $\text{C}_2\text{H}_4\text{O}$
 C $\text{C}_2\text{H}_6\text{O}$
 D $\text{C}_3\text{H}_6\text{O}$

[Turn over

16. Which pair of compounds would **not** react together to form an ester?
- A Propanoic acid and methanol
 - B Ethanoyl chloride and ethanol
 - C Ethanoic anhydride and propan-1-ol
 - D Sodium propanoate and ethanol



The formula for Z will be

- A $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$
- B $\text{CH}_3\text{CH}_2\text{CH}_2\text{COONH}_4$
- C $\text{CH}_3\text{CH}_2\text{CH}_2\text{CONH}_2$
- D $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

Questions 18 and 19 refer to the following.

An organic compound is sometimes identified by the preparation of a crystalline derivative.

18. To help in identification, a derivative **must**
- A decompose at its melting point
 - B have a low relative molecular mass
 - C have a sharp boiling point
 - D have a sharp melting point.
19. Which of the following can be distinguished by making 2,4-dinitrophenylhydrazone derivatives?
- A Propan-1-ol and propan-2-ol
 - B Ethanoic acid and benzenecarboxylic acid (benzoic acid)
 - C Methoxyethane and ethoxyethane
 - D Ethanal and propanal

20. Which is a correct statement about a catalyst? For a chemical reaction it
- A does not alter the value of the activation energy
 - B alters the value of the equilibrium constant
 - C does not affect the mechanism
 - D alters the value of the rate constant.

21. Which change would have a negative ΔH value?
- A $\text{Na(g)} \rightarrow \text{Na}^+(\text{g}) + \text{e}^-$
 - B $\text{Na}^+\text{Cl}^-(\text{s}) \rightarrow \text{Na}^+(\text{g}) + \text{Cl}^-(\text{g})$
 - C $\text{Cl}_2(\text{g}) \rightarrow 2\text{Cl}(\text{g})$
 - D $\text{Cl}(\text{g}) + \text{e}^- \rightarrow \text{Cl}^-(\text{g})$

22. Which of the following compounds has the highest degree of ionic character?
- A NaCl
 - B MgCl_2
 - C AlCl_3
 - D SiCl_4

23. A substance X reacts with phosphorus pentachloride, liberating fumes of hydrogen chloride.

X is readily oxidised by acidified potassium dichromate solution to give a product which does **not** react with sodium carbonate, **nor** with silver(I) nitrate in dilute ammonia solution.

Which of the following could represent the structure of X?

- A $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- B $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
- C CH_3CCH_3
 $\begin{array}{c} \parallel \\ \text{O} \end{array}$
- D $\text{CH}_3\text{CH}_2\text{C} \begin{array}{l} \nearrow \text{O} \\ \searrow \text{OH} \end{array}$

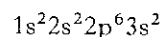
24.

Compound	Lattice Enthalpy (Energy) /kJ mol ⁻¹	Hydration Enthalpy /kJ mol ⁻¹
Lithium bromide	800	-854
Potassium bromide	670	-557

Which of the following statements is correct?

- A The enthalpy of solution of LiBr is +54 kJ mol⁻¹.
- B The enthalpy of solution of KBr is -113 kJ mol⁻¹.
- C The temperature rises as LiBr is dissolved in water.
- D The temperature rises as KBr is dissolved in water.

25. An atom has the electron configuration



What is the charge on the most probable ion formed by this element?

- A +1
- B -1
- C +2
- D -2
26. The rate of a chemical reaction may **not** be expressed in terms of the
- A equilibrium constant for the observed reaction
- B rate at which the product concentration increases
- C rate constant for the observed reaction
- D rate at which the reactant concentration decreases.

27.

Acid	K _a /mol l ⁻¹
X	1.0 × 10 ⁻²
Y	1.6 × 10 ⁻¹
Z	4.5 × 10 ⁻⁴

X, Y and Z are monoprotic acids.

When pH values of equimolar solutions of these acids are compared

- A Z will be the lowest and X the highest
- B X will be the lowest and Z the highest
- C Z will be the lowest and Y the highest
- D Y will be the lowest and Z the highest.

28. 10 cm³ of 0.1 M NaOH is added to 20 cm³ of 0.1 M HCl.

In the resulting solution

- A [Na⁺] = [Cl⁻]
- B [H⁺] = [OH⁻]
- C [Na⁺] = [H⁺]
- D [Cl⁻] = [H⁺]

29. Which of the following aqueous solutions is **not** a buffer?

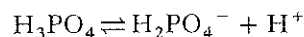
- A Sodium ethanoate and ethanoic acid
- B Ammonium chloride and ammonia
- C Potassium chloride and hydrochloric acid
- D Sodium sulphite and sulphurous acid

30. Some indicators and their pH ranges are shown below. Which is the most suitable indicator to use in a titration of hydrochloric acid solution with ammonia solution?

- A Methyl orange (4.2-6.3)
- B Bromothymol blue (6.0-7.6)
- C Phenol red (6.8-8.4)
- D Phenolphthalein (8.3-10.0)

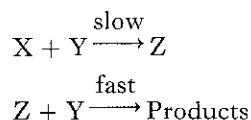
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31. Phosphoric acid undergoes partial dissociation according to the equation



Once equilibrium had been reached, this dissociation could be increased by the addition of

- A sodium hydroxide
 B sulphuric acid
 C a catalyst
 D sodium dihydrogen phosphate.
32. In the reaction $\text{X} + 2\text{Y} \rightarrow \text{Products}$, the reaction occurs in two stages:



Which one of the following statements is correct?

- A The rate of the reaction = $k[\text{X}][\text{Y}]^2$.
 B The overall order of reaction is 3.
 C The order with respect to Y is 2.
 D The reaction is first order for both X and Y.
33. The metal undergoes oxidation in
- A $\text{VO}^{2+} \rightarrow \text{VO}_2^+$
 B $\text{MnO}_4^{2-} \rightarrow \text{MnO}_2$
 C $\text{Co}(\text{NH}_3)_6^{3+} \rightarrow \text{Co}(\text{NH}_3)_6^{2+}$
 D $\text{Fe}(\text{CN})_6^{3-} \rightarrow \text{Fe}(\text{CN})_6^{4-}$

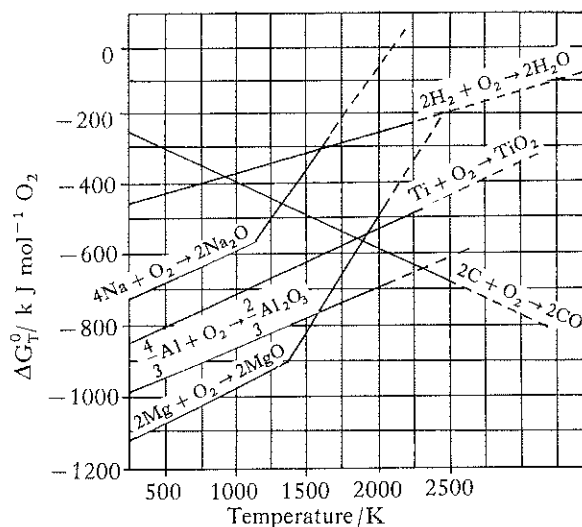
34. Each of the following compounds contains a complex ion.

Equimolar amounts of each, in aqueous solution, are allowed to react with excess silver(I) nitrate solution.

Which compound will yield the greatest mass of silver(I) chloride?

- A $\text{K}_2[\text{PtCl}_6]$
 B $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$
 C $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
 D $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$

Questions 35 and 36 refer to the Ellingham diagram below.



35. The reduction of TiO_2 to Ti is thermodynamically feasible at 2000 K using

- A carbon
 B magnesium
 C hydrogen
 D sodium.

36. Aluminium is not produced commercially by simple reduction of its oxide with carbon because

- A this is never thermodynamically feasible
 B the temperature for thermodynamic feasibility is too high
 C the carbon is oxidised to poisonous carbon monoxide
 D the kinetics are never favourable.

37. Which of the following solids would you expect to yield a colourless solution in water?

- A NaMnO_4
 B $\text{K}_2\text{Cr}_2\text{O}_7$
 C K_2SeO_4
 D CrCl_3

To answer **questions 38 to 40**, use the following code.

If all the responses 1, 2 and 3 are correct, select A.

If only 1 and 2 are correct, select B.

If only 3 is correct, select C.

Otherwise select D.

38. Which of the following has/have the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$?

- 1 Mn
- 2 Co^{2+}
- 3 Fe^{3+}

39. Which of the following reactions are examples of nucleophilic substitution?

- 1 $C_2H_5Br + NaOH \xrightarrow{\text{water}} C_2H_5OH + NaBr$
- 2 $C_3H_7Br + KCN \xrightarrow{\text{ethanol}} C_3H_7CN + KBr$
- 3 $C_3H_7Br + KOH \xrightarrow{\text{ethanol}} C_3H_6 + KBr + H_2O$

40. The atomic emission spectrum of hydrogen

- 1 provides information about the radiation emitted by excited electrons when they lose energy
- 2 provides information for measuring the ionisation of hydrogen
- 3 consists of several series of lines, each series converging to a limit at the low frequency end.

[END OF QUESTION PAPER]

1. (a) Boron forms a molecular compound with fluorine. Draw the structure of this molecule. What name is given to its shape? 2
- (b) Boron also forms a negatively charged ion with fluorine. Write the formula of this ion. What name is used to describe its shape? 2
- (4)**

2. Answer **EITHER A OR B.**

- A. Gunmetal is an alloy of, mainly, copper and tin. The copper content is sufficiently high to be worth recovering from gunmetal scrap. In order to determine the approximate percentage of copper in a sample, the following estimation was carried out.

0.500 g of the gunmetal sample was weighed into a beaker and 50% nitric acid solution was added in a fume cupboard. When the metal had dissolved, the solution was cooled and diluted. At this stage an insoluble tin compound was formed and this was filtered off.

Sodium carbonate was added to the filtrate until effervescence stopped. The thick, green, gelatinous precipitate was filtered, washed and dried. The green precipitate was heated strongly in a crucible until decomposition was complete and a black powder obtained.

Results: Mass of crucible + black powder = 26.658 g

Mass of crucible = 26.101 g

- (a) What gas is given off as the gunmetal dissolves in the nitric acid? 1
- (b) Give one way, other than effervescence, to determine when enough sodium carbonate had been added. 1
- (c) Write an equation for the decomposition of the green precipitate to the black powder. 1
- (d) Calculate the percentage of copper in the gunmetal alloy. 4
- (7)**

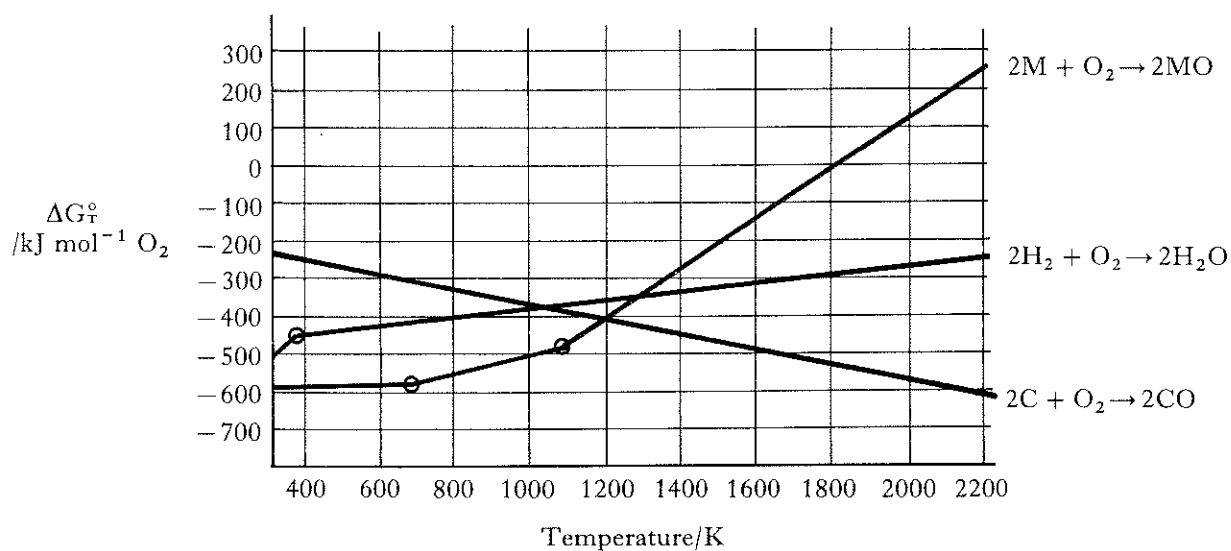
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- B. Compound fertilisers are mixtures of chemicals which provide elements essential for plant growth. A certain fertiliser contains ammonium phosphates as the only source of nitrogen and phosphorus. In an experiment to estimate the percentage of nitrogen present in a sample of the fertiliser, the following estimation was carried out.

1.40 g of the fertiliser was weighed and then heated with excess sodium hydroxide solution. The gas given off was absorbed in 50 cm³ of 0.5 M hydrochloric acid solution. When the reaction was finished, unreacted hydrochloric acid was titrated with 0.1 M sodium hydroxide solution. 50 cm³ of the alkali was needed for neutralisation.

- (a) Name the gas given off when the fertiliser is heated with sodium hydroxide solution. 1
- (b) Write the equation for the reaction of the gas referred to in (a) with hydrochloric acid solution. 1
- (c) Calculate the number of moles of hydrochloric acid which reacted with the gas. 3
- (d) Calculate the percentage of nitrogen in the fertiliser. 2
- (7)**

3. Examine this Ellingham diagram showing data for a metal, M.



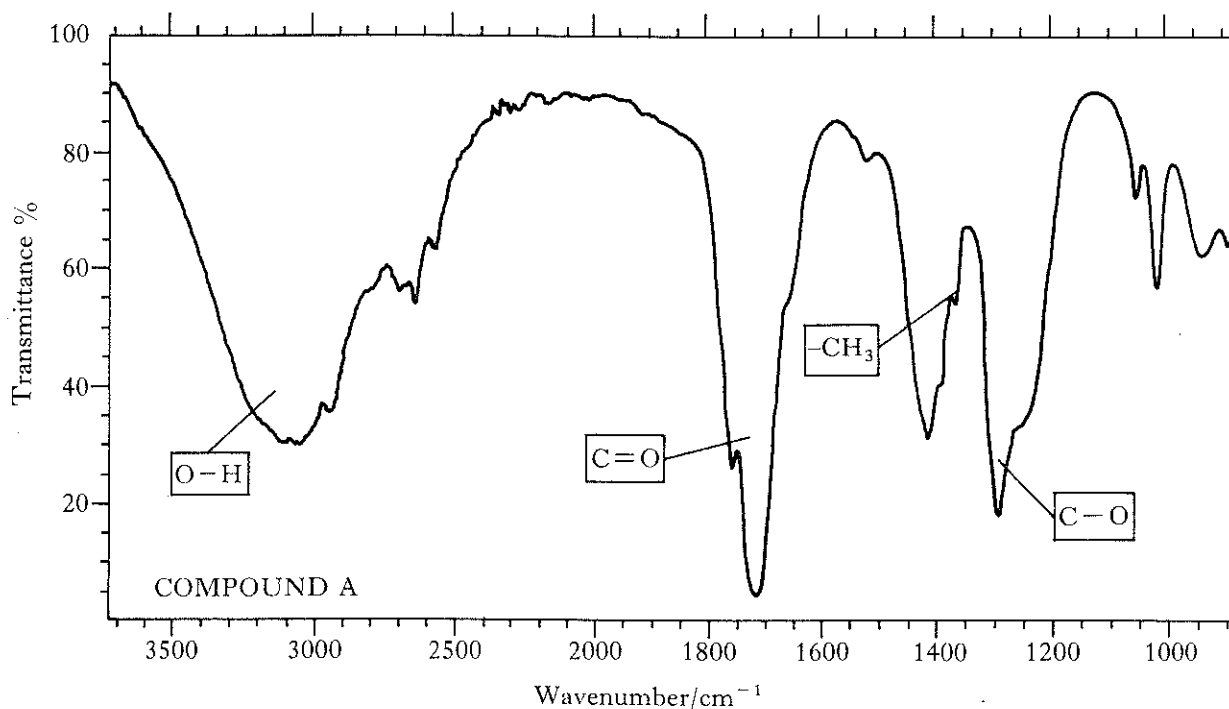
- (a) What is the minimum temperature at which the metal oxide, MO, can be reduced by
- hydrogen
 - carbon?
- (b) Using thermodynamic, kinetic and other factors, comment on the relative merits of carbon and hydrogen as reducing agents for producing the metal M from the oxide MO.
- (c) What state would the metal be in at the reduction temperature?
4. 25 cm³ of 0.4 M sulphuric acid and 75 cm³ of 0.4 M sodium hydroxide solution were mixed. Calculate the pH of the resulting solution.

[Turn over

5. Answer EITHER A OR B.

A. Examine this infra-red spectrum of a pure sample of an organic compound, A, whose relative molecular mass is 60.

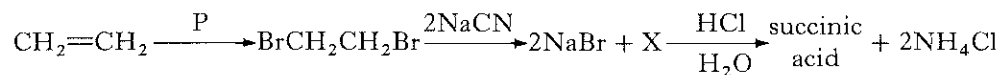
A can be reduced to form an alcohol, B, whose relative molecular mass is 46. A and B can react in the presence of an acid catalyst to form a compound C and water.



- (a) Give the full structural formula of A. 1
- (b) Why is the O—H peak broader than most peaks? (This broadening is typical of this type of compound.) 1
- (c) Which peak in the spectrum of A would not be present in that of B? 1
- (d) Name compound C. 1
- (e) Will there be a peak at around 1300 cm^{-1} in the spectrum of C? 1
Explain your answer. (5)

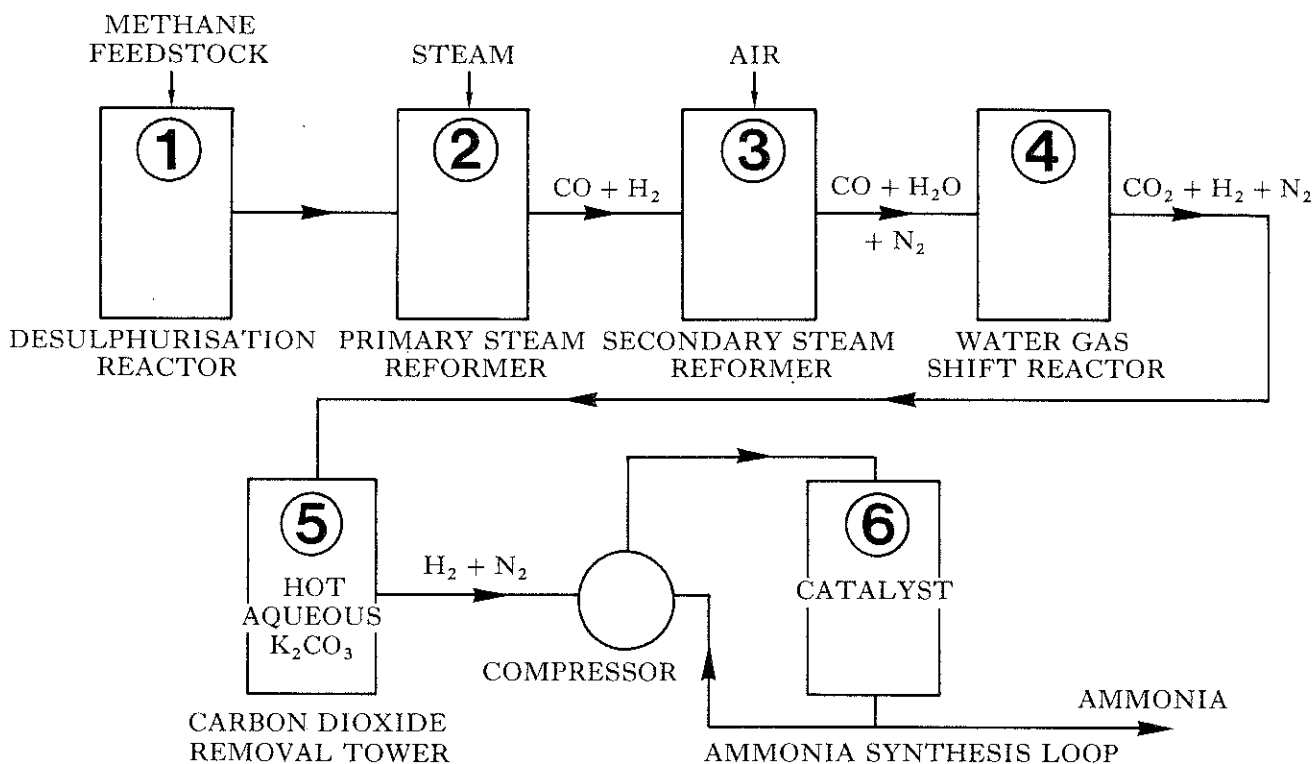
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B. Examine this reaction sequence.



- (a) Name reagent P. 1
- (b) Give the structural formulae of X and of succinic acid. 2
- (c) Succinic acid forms a cyclic anhydride. Draw the full structural formula of this anhydride. 1
- (d) $\text{BrCH}_2\text{CH}_2\text{Br}$ can also react with aqueous sodium hydroxide solution. Give a use for the organic compound formed. 1
(5)

6. Consider this flow diagram for the manufacture of ammonia.



- (a) Why is step ① essential? 1
- (b) In the above diagram, hydrogen is obtained from methane and steam. What other method could be used to obtain hydrogen from water? 2
- Why is the above method preferred? 2
- (c) What is the function of hydrogen in step ③? 1
- (d) Give **two** reasons for converting carbon monoxide to carbon dioxide in step ④. 2
- (e) Potassium hydrogen carbonate is the product at step ⑤. Write an equation for the reaction which produces it. 1
- (f) Only a 15% yield of ammonia can be obtained in the ammonia synthesis chamber ⑥ without recycling. 1

What does this suggest about

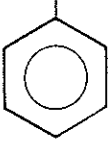
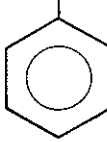
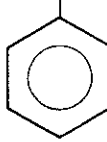
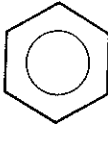
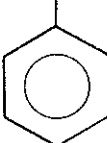
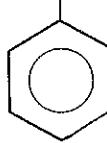
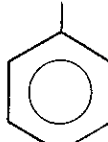
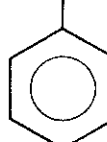
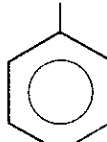
- (i) ΔG° for the forward reaction, and
- (ii) the value of K for the reaction



(9)

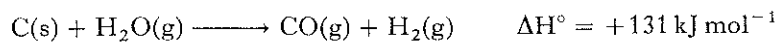
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7. The formulae for certain compounds are shown below. All the questions are about the compounds shown. The answer to each question will be a letter (or group of letters) corresponding to the box(es) in the grid. A box may be used more than once in different answers. Correct boxes, and no more, are required to obtain each mark.

Cl  A	CH ₃  B	OH  C
 D	NO ₂  E	SO ₃ H  F
NH ₂  G	COOH  H	CH ₂ OH  I

- (a) Which compound(s), when dissolved in water, will give a solution whose pH value is less than 7? 1
- (b) Which compound is produced when the substance in box D reacts with a mixture of concentrated sulphuric and nitric acids? 1
- (c) If compound I is oxidised, which compound is formed? 1
- (d) Which compound is produced when the substance in box D reacts with a mixture of aluminium chloride and chloromethane? 1
- (e) Which compound will form an ester with the compound in box H? 1
- (f) Which compound will form a salt when it reacts with hydrochloric acid? 1
- (6)**

8. The reaction of carbon with steam is endothermic.



The reaction proceeds successfully at 1500 K when $\Delta G^\circ = -71.5 \text{ kJ mol}^{-1}$.

- (a) Calculate the entropy change for the above reaction at 1500 K. 3
- (b) Is the above reaction thermodynamically feasible at 25°C? 3
- Show your calculation. 3
- (6)**

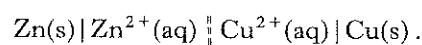
9. Answer EITHER A OR B.

- A. The dissolution of ammonium nitrate crystals in water is an endothermic process.
- (a) From your understanding of the concept of entropy, comment on any entropy changes, during the dissolution, in the
- (i) ammonium nitrate crystals,
 - (ii) water,
 - (iii) surrounding air.
- (b) Would the overall entropy change be positive or negative?

3
1
(4)

OR

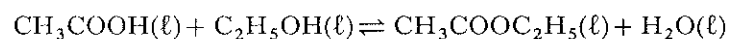
- B. Zinc metal reacts with copper(II) sulphate solution to give copper metal and zinc(II) sulphate solution. The reaction may be made to do work in an electrochemical cell,



With the help of the Data Booklet, calculate the e.m.f. of the above cell and hence calculate the maximum amount of work (in kJ mol^{-1}) which can be obtained from it under standard conditions.

(4)

10. Ethanol reacts with ethanoic acid as follows:



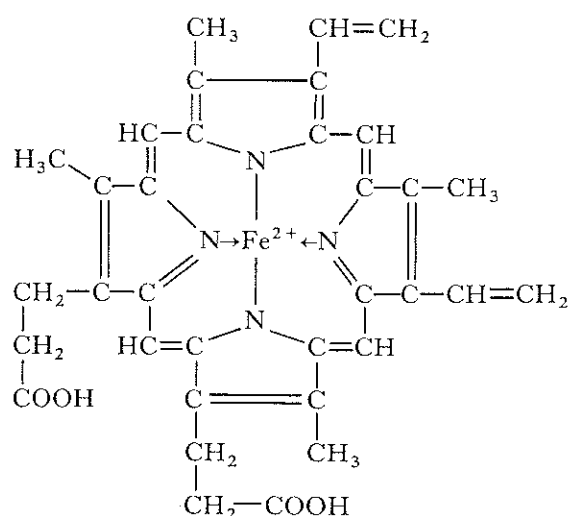
1 mole of ethanoic acid was mixed with 2 moles of ethanol. At equilibrium, 0.858 moles of ethyl ethanoate were present.

Calculate the value of the equilibrium constant, K_c .

(4)

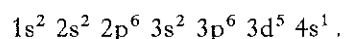
[Turn over

11. The diagram shows part of the structure of haemoglobin, the pigment in blood.



- (a) (i) Draw the structure of one of the 5-membered rings which are the basis of haemoglobin. Do not include side-chains. 1
- (ii) Why can this ring act as a ligand? 1
- (b) The delocalisation of electrons along the chain represented by alternating double and single bonds stabilises the structure and allows absorption of energy from the visible spectrum.
- (i) What colour is haemoglobin? 1
- (ii) In which part of the visible spectrum is haemoglobin likely to absorb? 1
- (iii) Name another organic substance stabilised by delocalised electrons. 1
- (5)**

12. (a) The electron configuration of a neutral chromium atom is



Write down the electron configuration of chromium in the yellow chromate ion, CrO_4^{2-} . Show how you arrived at your answer. 2

- (b) What is the name of the theory which explains the origin of colour in ions like chromate? 1
- (c) Chromate ions which are yellow change into orange dichromate ions, $\text{Cr}_2\text{O}_7^{2-}$, on the addition of acid.
- Is this a redox reaction? Explain your answer. 2
- (5)**

13. Photochemical reactions can be initiated by visible or ultra-violet light.

Calculate the frequency of radiation which would, in theory, start a reaction involving chlorine. (Refer to the Data Booklet, page 7.) (4)

14. Dinitrogen pentoxide, dissolved in tetrachloromethane, decomposes to nitrogen dioxide and oxygen. The change in the rate of reaction with concentration of dinitrogen pentoxide is shown in the table. The rate is the decrease in dinitrogen pentoxide concentration per second.

Concentration of dinitrogen pentoxide / mol l ⁻¹	Rate of reaction / mol l ⁻¹ s ⁻¹
2.20	2.25 × 10 ⁻⁵
2.00	2.10 × 10 ⁻⁵
1.79	1.93 × 10 ⁻⁵
1.52	1.58 × 10 ⁻⁵
1.24	1.21 × 10 ⁻⁵
0.93	0.96 × 10 ⁻⁵

- (a) Write the equation for the decomposition of dinitrogen pentoxide. 1
- (b) Draw the graph of the rate of reaction against the concentration of dinitrogen pentoxide. 1
- (c) Use the graph produced in (b) to answer the following questions.
- (i) What is the rate expression for this reaction? 1
- (ii) What is the order of the reaction with respect to dinitrogen pentoxide? 1
- (iii) Find the value of the rate constant. 1
- (5)**
15. Answer **A OR B OR C**.
- A. Write a concise account of the extraction of aluminium from crude bauxite ore. (4)
- OR**
- B. Compare the structures, properties and reactions of ethanol and ethoxyethane. (4)
- OR**
- C. There is considerable debate about the use of coal or nuclear fuel for generating electricity. Discuss this issue—producing arguments on both sides. (4)

[END OF QUESTION PAPER]