[0500/518] 1992

CERTIFICATE OF SIXTH YEAR STUDIES

CHEMISTRY (REVISED)

PAPER

Wednesday, 20th May—1.30 p.m. to 3.10 p.m.

Dalziel High School
Chemistry Department

1992 CSYS

UCP 0500/518 6/3/3/4376

1. The electron configuration of an atom X is

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^3$

The chemistry of X is likely to be similar to that of

A zinc

B nitrogen

C boron

D chlorine.

2. Which one of these species has all its bond angles equal to 90°?

A $SiCl_4$

B NH_4^+

C SF_6

D BeF_4^{2-}

3. The numerical value of enthalpy changes is **not** affected by

A the addition of a catalyst

B the concentrations of solutions involved

C the pressure of gaseous reactants and products

D the physical state of reactants and products.

4. Solid ammonium dichromate decomposes to produce chromium(III) oxide, nitrogen and water. The complete decomposition of one mole of ammonium dichromate would give

A a total of one mole of all the products

B 3·0 moles of water

C 2·0 moles of chromium(III) oxide

D 1·0 mole of nitrogen.

5. Which of the following is likely to have the lowest standard molar entropy value?

A $H_2O(\ell)$

B $Br_2(\ell)$

C $H_2O(g)$

D $Br_2(g)$

6. The gas phase reaction $H_2 + I_2 \rightarrow 2HI$ is first order with respect to both reactants. If the concentrations of both H_2 and I_2 are doubled, the reaction rate will be changed by a factor of

A 0·5

B 2

C 3

D 4.

7. Cobalt has an atomic number of 27.

The number of unpaired electrons in a gaseous Co^{3+} ion is

A 0

B 3

C 4

D 5.

8. The bond angle in a molecule of ammonia is

A 90°

B 107·3°

C 109·5°

D 120°.

9. How many moles of iodine molecules are produced when excess potassium iodide is oxidised by 1 mole of potassium permanganate in acidic solution?

(You may find the Data Booklet helpful.)

A 0·5

B 1

C 2·5

D 5

10. $A + 2B \rightleftharpoons C + D$

ΔG° for the forward reaction $= -10\,kJ$

Which of the following can be deduced from the above data?

A The formation of C and D is exothermic.

B The equilibrium constant, K, will be greater than 1.

C The activation energy for the forward reaction is low.

D The rate constant, k, will be greater than 1.

11. The radioactive decay series which ends with $^{204}_{82}Pb$ after 7 alpha and 6 beta emissions must have commenced with

A $^{232}_{90}Th$

B $^{236}_{92}U$

C $^{238}_{92}U$

D $^{240}_{94}Pu$

12. In each of the following compounds, the bonding shown is between carbon and one other element. In which compound is the bond polarised such that carbon has a partial **negative** charge?

A $H_3C—Br$

B $CH_3\overset{\overset{O}{\|}}{C}H$

C $H_3Si—CH_3$

D $CH_3C{\equiv}N$

13. The following set of data was obtained for the kinetics of a reaction $A + B \rightarrow C$.

$[A]/mol\,l^{-1}$	$[B]/mol\,l^{-1}$	INITIAL RATE OF FORMATION OF C $/mol\,l^{-1}\,min^{-1}$
1·0	1·0	1·5
2·0	1·0	3·0
2·0	0·5	0·75

Which one of the following expresses the rate law for the reaction? The rate of formation of C is equal to

A $k[A][B]$

B $k[A][B]^2$

C $k[A]^2[B]$

D $k[A]^2[B]^2$

14. The use of an indicator is **not** appropriate in titrations involving

A hydrochloric acid solution and methylamine solution

B nitric acid solution and potassium hydroxide solution

C methanoic acid solution and ammonia solution

D propanoic acid solution and sodium hydroxide solution.

15. An organic compound can be purified by recrystallisation. This involves the use of a solvent which

A dissolves both the compound and impurities at room temperature only

B dissolves the compound above room temperature only but dissolves impurities both at and above room temperature

C dissolves the compound at room temperature only but dissolves impurities above room temperature only

D dissolves both the compound and impurities at above room temperature only.

16.

$$OH^- + CO_2 \rightarrow HCO_3^-$$

$$C_2H_4 + Br_2 \rightarrow C_2H_4Br^+ + Br^-$$

In the above two reactions, which two substances are acting as electrophiles?

A OH^- and Br_2

B OH^- and C_2H_4

C CO_2 and Br_2

D CO_2 and C_2H_4

17. 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.

18. When one mole of phosphorus pentachloride was heated to 523 K in a closed vessel, 50% of the pentachloride dissociated as shown.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

How many moles of gas were present in the equilibrium mixture?

A 1·0

B 1·5

C 2·0

D 2·5

19. The purification of one of the following ores (prior to the extraction of the metal) depends on the amphoteric nature of the metal oxide.

Which is the ore concerned?

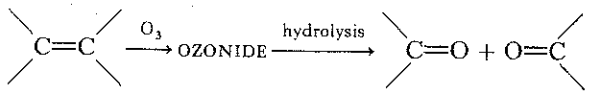
A Haematite (iron ore)

B Rutile (titanium ore)

C Malachite (copper ore)

D Bauxite (aluminium ore)

20. Alkenes react with ozone (O_3) to form ozonides which can be hydrolysed to give carbonyl compounds.



Which of the following alkenes will produce a mixture of propanone and ethanal when acted upon in this way?

A $CH_3CH{=}CHCH_2CH_3$

B $CH_3CH{=}CHCH_3$

C $CH_3C(CH_3){=}CH_2$

D $CH_3CH{=}CCH_3$ with CH_3 branch

21. Which of the following could **not** exist in isomeric forms?

A C_3H_6

B C_3H_7Br

C $C_2H_4Cl_2$

D C_2F_4

22. $C_2H_5Br + C_2H_5O^-Na^+ \rightarrow C_2H_5OC_2H_5 + Na^+Br^-$

This reaction is an example of

A a condensation reaction to form an ether

B a condensation reaction to form an ester

C a nucleophilic substitution to form an ether

D an electrophilic substitution to form an ether.

23. What would be the products formed when $CH_3COOCH_2CH_2OOCCH_3$ is warmed with aqueous sodium hydroxide solution?

A $CH_3COONa + C_2H_4(OH)_2$

B $CH_3COOH + C_2H_4(ONa)_2$

C $CH_3COOH + C_2H_5COOCH_3$

D $CH_3COOCH_3 + H_2O$

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

The above reaction is thermodynamically feasible at 298 K. The most likely combination of signs for the ΔH° and ΔS° values in this reaction are

	ΔH°	ΔS°
A	−	+
B	+	−
C	−	−
D	+	+

25. Which of the following represents a compound with a linear molecule?

A C_2H_2

B C_2H_6

C C_2H_4

D CH_4

26. The standard enthalpy of formation of solid calcium nitrate at 298 K is $-937\,kJ\,mol^{-1}$. Which one of the equations below correctly represents this formation process?

A $Ca^{2+}(aq) + 2NO_3^-(aq) \rightarrow Ca(NO_3)_2(s)$

B $Ca(g) + N_2(g) + 3O_2(g) \rightarrow Ca(NO_3)_2(s)$

C $Ca(s) + N_2(g) + 3O_2(g) \rightarrow Ca(NO_3)_2(s)$

D $Ca(s) + 2NO_3^-(aq) \rightarrow Ca(NO_3)_2(s)$

27. For a solution of ammonia in water, the dissociation constant is given by

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

If solid ammonium chloride is added

A the dissociation constant remains unchanged

B the pH increases

C the dissociation constant and pH decrease

D neither dissociation constant nor pH will alter.

28. Which of the following statements about an ethanoic acid/sodium ethanoate buffer solution is correct?

A The total molar concentration of ethanoate ions is much higher than the molar concentration of sodium ethanoate.

B It has a pH higher than 7·0.

C It is effective because ethanoic acid and sodium ethanoate are both strong electrolytes.

D When hydrogen ions are added, more ethanoic acid is produced.

29. In which of the following compounds of nickel is the metal in the highest oxidation state?

A NiO

B K_2NiF_6

C $K_4[Ni_2(CN)_6]$

D $[Ni(NH_3)_6][BF_4]_2$

30. In a reaction between AB and C^- (present in similar concentrations) the overall process is found to be represented by

$$AB + C^- \rightarrow AC + B^-$$

and the reaction rate is given by

$$\text{Rate} = k[AB]$$

Which one of the following mechanisms is most plausible?

A Single-stage reaction

$$AB + C^- \rightarrow AC + B^-$$

B Two-stage mechanism

$$AB \rightarrow A^+ + B^- \quad \text{(slow)}$$
$$A^+ + C^- \rightarrow AC \quad \text{(fast)}$$

C Two-stage mechanism

$$AB \rightarrow A^+ + B^- \quad \text{(fast)}$$
$$A^+ + C^- \rightarrow AC \quad \text{(slow)}$$

D Two-stage mechanism

$$AB + C^- \rightarrow (ABC)^- \quad \text{(slow)}$$
$$(ABC)^- \rightarrow AC + B^- \quad \text{(fast)}$$

31. A solution of a chemical absorbs energy only from the green region of the spectrum. Which of the following is the most likely colour of the solution?

A Yellow

B Red

C Blue

D Purple

32. A monoprotic acid has a dissociation constant $K_a = 3 \times 10^{-5}\,\text{mol}\,l^{-1}$. The approximate pH of a solution of this acid of concentration $0{\cdot}1\,\text{mol}\,l^{-1}$ will be

A 1·76

B 2·76

C 3·52

D 5·52.

33. What would be the volume of water required to dilute $25\,cm^3$ of $CaCl_2$ solution ($0{\cdot}2\,\text{mol}\,l^{-1}$) to produce a solution with a $Cl^-(aq)$ concentration of $0{\cdot}1\,\text{mol}\,l^{-1}$?

A $25\,cm^3$

B $50\,cm^3$

C $75\,cm^3$

D $100\,cm^3$

34. Which of the following is **not** involved in determining the lattice enthalpy of an ionic halide, MX, using a Born–Haber cycle?

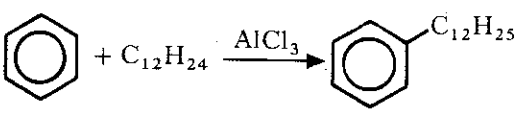
A The ionization energy of the halogen

B The enthalpy of formation of the compound

C The ionization energy of the metal

D The bond dissociation enthalpy of X_2

35.



This important industrial reaction is used in the manufacture of

A soaps

B soapless detergents

C polymers

D explosives.

36. $5{\cdot}0\,cm^3$ of a solution of hydrochloric acid was diluted to exactly $250\,cm^3$ with water. The pH of this diluted solution is 2·0. The concentration of the original undiluted solution is

A $0{\cdot}02\,mol\,l^{-1}$

B $0{\cdot}04\,mol\,l^{-1}$

C $0{\cdot}40\,mol\,l^{-1}$

D $0{\cdot}50\,mol\,l^{-1}$

37. Given the standard reduction potential

$MnO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow MnO_2(s) + 2H_2O(\ell) \quad E^\circ = +2{\cdot}26\,V$

What is the cell potential for the reaction of $MnO_4^{2-}(aq)$ with $SO_3^{2-}(aq)$ under standard conditions?

A $-2{\cdot}06\,V$

B $-2{\cdot}46\,V$

C $+2{\cdot}06\,V$

D $+2{\cdot}46\,V$

38. Which of the following are the main products when an aqueous solution of copper(II) sulphate ($1{\cdot}0\,mol\,l^{-1}$) is electrolysed using platinum electrodes?

A Copper and sulphur dioxide

B Hydrogen and oxygen

C Copper and oxygen

D Hydrogen and sulphur dioxide

39. Use the data below to determine the standard enthalpy of formation of HCl(g).

BOND	BOND ENTHALPY/kJ mol^{-1}
H—H	436
Cl—Cl	242
H—Cl	431

A $-92\,kJ\,mol^{-1}$

B $-247\,kJ\,mol^{-1}$

C $+247\,kJ\,mol^{-1}$

D $+770\,kJ\,mol^{-1}$

40. The table below gives certain properties of four compounds, A, B, C and D. Which of these compounds is ethan-1,2-diol? (Note: The boiling point of ethanol is 352 K.)

	BOILING POINT/K	ACTION WITH SODIUM	ACTION WITH ACIDIFIED POTASSIUM DICHROMATE SOLUTION
A	over 352	compound formed	readily oxidised
B	over 352	compound formed	no reaction
C	below 352	compound formed	readily oxidised
D	below 352	no reaction	readily oxidised

[Turn over

41. The boxes in the grid below show steps in the chain reaction between methane and chlorine.

A $Cl^{\cdot} + Cl^{\cdot} \rightarrow Cl_2$	B $Cl{-}Cl \rightarrow Cl^{\cdot} + Cl^{\cdot}$	C $^{\cdot}CH_3 + Cl_2 \rightarrow CH_3Cl + Cl^{\cdot}$
D $Cl^{\cdot} + CH_4 \rightarrow {}^{\cdot}CH_3 + HCl$	E $^{\cdot}CH_3 + {}^{\cdot}CH_3 \rightarrow C_2H_6$	F $Cl^{\cdot} + {}^{\cdot}CH_3 \rightarrow CH_3Cl$

(*a*) Identify **two** propagation steps.

(*b*) Identify **three** termination steps.

42. The boxes in the grid below show certain chemical species.

A H_2O	B CN^-	C EDTA
D $CH_3NH_3^+$	E $H_2NCH_2CH_2NH_2$	F NH_4^+
G Cl^-	H $\begin{matrix} COO^- \\ \vert \\ COO^- \end{matrix}$	I NH_3

(*a*) Identify the species which is (are) **unlikely** to be a ligand (or ligands).

(*b*) An invisible ink can be made from $CoCl_2(aq)$. When the writing is heated, it appears as blue. If this is left in the air, the blue fades. Identify the different ligands associated with this colour change.

(*c*) Identify the ligand, one mole of which will form an octahedral complex with one mole of Ni^{2+} ions.

43. * The boxes in the grid below contain symbols for, or electron configurations of, atoms and ions. The symbol [Ar] indicates complete filling of electron shells up to and including argon.

A [Ar] $3d^5$	B Cr	C [Ar] $3d^5 4s^1$
D Fe	E [Ar] $3d^4$	F Fe^{3+}
G [Ar] $3d^6$	H Mn^{2+}	I [Ar] $3d^5 4s^2$

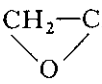
(*a*) Identify the electron configuration of Fe^{2+}.

(*b*) Identify the symbols (**not** configurations) of **two** species which are isoelectronic.

(*c*) ~~Only~~ Select one species which has **both** its symbol **and** electron configuration shown on the grid.

[END OF QUESTION PAPER]

Marks

1. Epoxyethane,  , is also known as ethylene oxide.

It is made by reacting ethene (obtained by cracking naphtha) and oxygen at a moderate temperature, using a catalyst. A highly exothermic secondary reaction also occurs, producing carbon dioxide and steam.

Epoxyethane has various uses. For example it reacts with:
water, to form ethane-1,2-diol (used in antifreeze);
alcohols, to produce polyether-polyols (used in polyurethane foams);
ammonia, to produce ethanolamines (used to make detergents).

Show all of the above information in the form of a flow chart. **(4)**

2. Before 1947, "silver" coins were made from an alloy of silver, copper and nickel. To determine the metal composition, a coin weighing 10·00 g was dissolved in nitric acid and the resulting solution diluted to 1000 cm^3 in a standard flask. A 100 cm^3 portion was treated in the following way. Hydrochloric acid (0·20 mol l^{-1}) was added to this solution until precipitation of silver(I) chloride was complete. The precipitate was recovered by filtration. It was washed and dried and found to weigh 0·60 g.

(*a*) (i) Calculate the percentage by mass of silver in the coin. **3**

(ii) How could you tell when precipitation was complete? **1**

The filtrate was treated to reduce the copper(II) ions to copper(I) ions. Ammonium thiocyanate solution was added to precipitate the copper as copper(I) thiocyanate.

$$Cu^+(aq) + CNS^-(aq) \rightarrow CuCNS(s)$$

After filtration, drying and weighing, the precipitate was found to weigh 0·31 g.

(*b*) Calculate the percentage by mass of copper in the coin. **3**

(7)

Marks

3. Rate studies on the bromination of propanone in the presence of alkali give the rate equation:

$$\text{Rate} = k[Br_2]^0[CH_3COCH_3]^1[OH^-]^1.$$

(*a*) A mechanism proposed for this reaction is

STEP (1) $CH_3-\overset{\overset{O}{\|}}{C}-CH_3 + OH^- \rightleftharpoons CH_3-\overset{\overset{O}{\|}}{C}-\bar{C}H_2 + H_2O$

STEP (2) $CH_3-\overset{\overset{O}{\|}}{C}-\bar{C}H_2 + Br_2 \rightleftharpoons CH_3-\overset{\overset{O}{\|}}{C}-CH_2Br + Br^-$

Which of the two steps is likely to be the rate determining step?
Explain your answer. 2

(*b*) Estimation of the bromine concentration was achieved by titration with sodium thiosulphate solution. The latter reacts with bromine, the colour of which gradually fades until it is pale yellow. At this point, a few drops of potassium iodide solution and starch are added. The titration is then completed.

(i) What would you observe on the addition of the potassium iodide and the starch?
Explain your answer. 2

(ii) How would you know when the end point of the titration was reached? 1

(5)

4. Water gas is prepared by passing steam over white hot coke. The equation for the reaction is

$$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$$

The products of the reaction may be used to prepare methanol industrially, using chromium(III) oxide as a catalyst, a temperature of 300 °C and a pressure of 300 atmospheres.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(\ell)$$

(*a*) The enthalpy change for the reaction to produce water gas is $130\,kJ\,mol^{-1}$. Use this value, with information on page 11 of the Data Booklet, to calculate the bond enthalpy for the carbon/oxygen bond in carbon monoxide. 3

(*b*) The mean bond enthalpy for C—O is $331\,kJ\,mol^{-1}$ and for C=O is $724\,kJ\,mol^{-1}$. Use this information and your answer to (*a*) to make a prediction about the nature of the bond in carbon monoxide. 1

(*c*) State **two** possible hazards associated with the industrial production of methanol. 2

(6)

[Turn over

Marks

***5.** The table below shows how the standard free energy change varies with temperature for the following reactions.

REACTION A $2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$

REACTION B $2C(s) + O_2(g) \rightarrow 2CO(g)$

TEMPERATURE /K	ΔG°, REACTION A /kJ mol^{-1}	ΔG°, REACTION B /kJ mol^{-1}
400	−615	−300
600	−595	−335
800	−555	−370
1000	−495	−405
1200	−425	−440
1400	−340	−475
1600	−260	−505
1800	−165	−540

(*a*) For each reaction, plot the graph of the standard free energy change against temperature. **3**

(*b*) Use your graph to

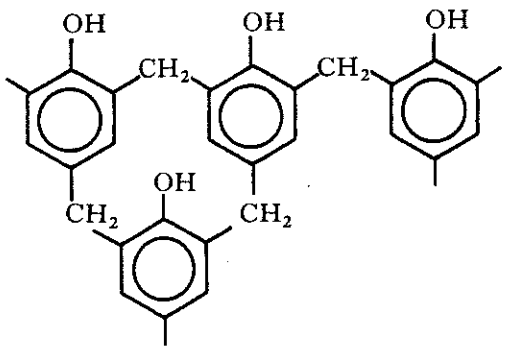
(i) determine the minimum temperature at which carbon can reduce zinc oxide, and **1**

(ii) calculate the standard free energy change for this reaction at 1500 K. **2**

(*c*) Give one advantage and one disadvantage of using carbon for this reduction on an industrial scale. **2**

(8)

6. This diagram shows part of the structure of a thermosetting polymer.



(*a*) Explain the term thermosetting and discuss why this polymer is thermosetting and not thermoplastic. **2**

(*b*) Draw the structural formulae of the two monomers which are used to prepare the above polymer. Name the monomers. **2**

(4)

Marks

7. Magnesium is produced by electrolysing molten magnesium chloride in electrolytic cells operating at 250 000 A.

(*a*) Calculate, in tonnes, how much magnesium is produced in 24 hours. **3**

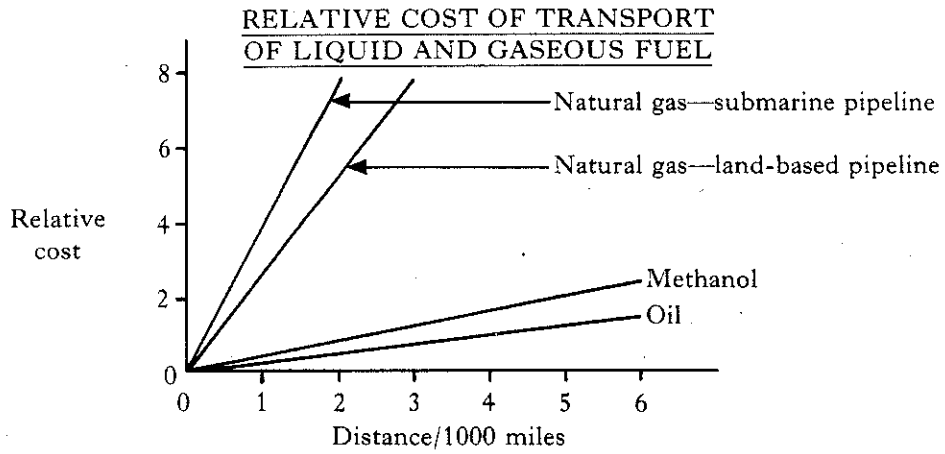
(*b*) Magnesium cost £1,410 per tonne and iron cost £130 per tonne in 1987.
Suggest a major reason for this difference in cost. **1**

(*c*) 4 tonnes of magnesium chloride also produces 2·8 tonnes of chlorine. What is the percentage yield of chlorine? **2**

(6)

8. The following passage has been adapted from "*Chemistry in Britain*", September 1990.

Natural gas is a very large resource. The proven reserves will last for around 60 years at the current rate of world consumption. Many of the major gas sources are associated with petroleum production and are large distances from where they would be most useful. Much of the gas is flared.



Apart from combustion, methane is relatively stable and unreactive. If we can convert methane to methanol (an oxidation), the methanol will be more reactive than the original methane and will tend to oxidise further to the undesirable end-products carbon monoxide and carbon dioxide.

About 7% of natural gas in the UK is converted to ammonia and methanol, using the steam reforming process to first make synthesis gas.

$$CH_4 + H_2O \rightarrow CO + 3H_2 \quad \Delta H^\circ = +206\,kJ\,mol^{-1}$$

There is also considerable research into the process called oxidative coupling, but this is not yet economically viable.

$$2CH_4 + O_2 \rightarrow C_2H_4 + H_2O$$

(*a*) Give **two** reasons why flaring is undesirable. **2**

(*b*) Use the graph to suggest why it would be advantageous to turn methane into methanol at the remote oil fields. **1**

(*c*) Why is some natural gas made into synthesis gas in the UK? **1**

(*d*) What is a major economic disadvantage of steam reforming? **1**

(*e*) Why is partial oxidation of methane to methanol difficult to achieve? **1**

(*f*) Suggest on economic grounds why research should continue into oxidative coupling. **2**

(8)

Marks

9. A technician read the following information on a bottle of concentrated ammonia:

Density = $0{\cdot}88\ g\ cm^{-3}$
Percentage of pure ammonia by mass = 28

(*a*) Calculate the concentration of the ammonia solution in $mol\ l^{-1}$. **3**

(*b*) Why is concentrated ammonia solution **not** suitable for use as a primary standard? **1**

The table below shows the pK_a values for some acid–alkali indicators.

INDICATOR	pK_a
bromocresol green	4·7
bromothymol blue	7·0
phenolphthalein	9·3

(*c*) Choose the indicator most suitable for use in the titration of hydrochloric acid against ammonia solution.

Explain the reason for your choice. **2**

(6)

10. (*a*) For the complex ion tetrachlorocuprate(II), give the formula of the ion, including its charge. **2**

(*b*) Dilution of a solution containing tetrachlorocuprate(II) ions with water results in all of the chloro ligands being displaced by water ligands. An octahedral complex ion forms.

(i) Name the octahedral complex ion.

(ii) Draw its structure. **2**

(4)

Marks

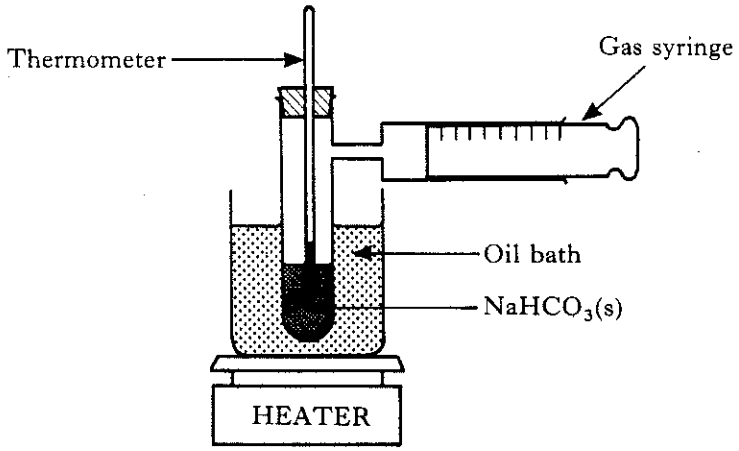
11. When sodium vapour street lights are first switched on, they glow red before turning orange-yellow. This is because they contain some neon which produces the red colour as the lamps warm up.

(*a*) Explain how the orange-yellow colour is produced by the sodium. **3**

(*b*) How would the light coming from one of these street lights be analysed to prove the presence of both sodium and neon? **2**

(5)

12. The apparatus shown in the diagram below can be used to find the decomposition temperature of sodium hydrogencarbonate.



The equation for the decomposition is

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g) \quad \Delta H^\circ = +129\,kJ\,mol^{-1}$$

SUBSTANCE	$S^\circ/JK^{-1}\,mol^{-1}$
$NaHCO_3(s)$	102·1
$Na_2CO_3(s)$	136·0
$H_2O(g)$	188·7
$CO_2(g)$	213·6

(*a*) Calculate ΔS° for the reaction. **2**

(*b*) Calculate the temperature at which the decomposition becomes thermodynamically feasible. **3**

(*c*) As the temperature of the oil bath is increased, the volume of gas in the syringe increases. Sketch the shape of the graph you would expect to obtain if the volume of gas is plotted against temperature. Graph paper is not required. Start at room temperature and mark clearly the decomposition temperature on your graph. **2**

(7)

[END OF QUESTION PAPER]