1. Sodium vapour street lamps emit yellow light because

   A sodium vapour is burning and giving out a yellow glow

   B sodium vapour filters out all the light from the filament except yellow

   C energy corresponding to yellow light is given out as electrons in sodium move to higher energies

   D energy corresponding to yellow light is given out as electrons in sodium move to lower energies.

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

$$BF_4^- \rightarrow BF_3 + F^-$$

   A Square planar to trigonal planar

   B Tetrahedral to trigonal planar

   C Tetrahedral to pyramidal

   D Square planar to pyramidal

3. Which of the following oxides is amphoteric?

   A Aluminium oxide

   B Calcium oxide

   C Copper(II) oxide

   D Sulphur dioxide

4. The electrical conductivity of semiconductors

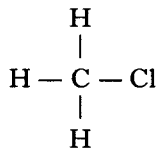
   A decreases with increasing temperature

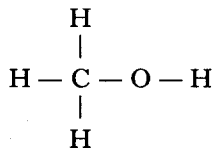
   B increases with increasing temperature

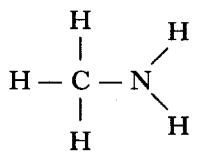
   C decreases on exposure to light

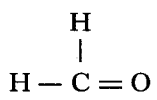
   D increases with the removal of dopant atoms.

5. Which of the following molecules has the greatest number of non-bonding electron pairs (lone pairs)?

A 

B 

C 

D 

6. A white solid gives a lilac flame colour. It reacts with water releasing hydrogen gas and forming a strongly alkaline solution.

   The solid could be

   A calcium oxide

   B potassium oxide

   C calcium hydride

   D potassium hydride.

7. Hund's rule states that

   A it is impossible to define both the position and momentum of an electron simultaneously

   B electrons occupy orbitals in order of increasing energy

   C electrons occupy degenerate orbitals singly with parallel spins before spin pairing occurs

   D the energy of an electron in an atom is quantised.

[Turn over

Questions 8 and 9 refer to the analysis of a salt whose formula is $Pt(NH_3)_xCl_y$.

8. 0·02 moles of this salt required 40·0 cm^3 of 2·0 mol l^{-1} nitric acid for exact neutralisation.

The number of moles of NH_3 per mole of salt is

A 2

B 4

C 6

D 8.

9. 0·02 moles of the salt were dissolved in nitric acid and excess silver(I) nitrate solution was added. The precipitate formed was filtered, washed and dried. It weighed 5·74 g.

The number of moles of chloride ions per mole of the salt is

A 1

B 2

C 3

D 4.

10. One mole of barium chloride ($BaCl_2$) contains

A 1 mole of positive ions

B 1 mole of molecules

C 2 moles of atoms

D 2 moles of ions.

11. Which change in reaction conditions will shift the position of equilibrium to the right in this reaction?

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H° = -197\,kJ\,mol^{-1}$

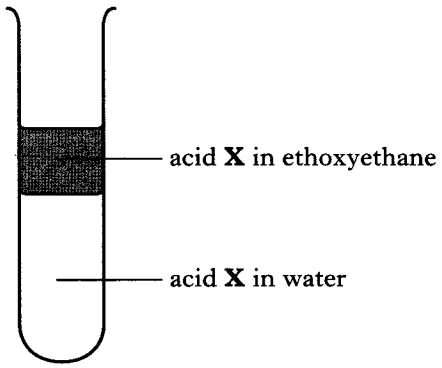
A Increasing the temperature

B Removal of some oxygen gas

C Increasing the pressure

D Adding a catalyst

12. An organic acid, **X**, was dissolved in water and then shaken with ethoxyethane until equilibrium was established.



The value of the partition coefficient for this system will be altered by changing the

A temperature

B volume of water

C original concentration of acid **X**

D original mass of acid **X**.

13. The pH of a buffer prepared by mixing equal volumes of 0·1 mol l^{-1} ethanoic acid and 0·2 mol l^{-1} sodium ethanoate is

A 2·1

B 2·7

C 4·5

D 5·1.

14. Ethanoic acid is a weak acid and hydrochloric acid is a strong acid.

Which of the following is **not** correct?

A The pH of 0·1 mol l^{-1} hydrochloric acid is 1.

B 20·0 cm^3 of 0·1 mol l^{-1} sodium hydroxide is exactly neutralised by 20·0 cm^3 of 0·1 mol l^{-1} ethanoic acid.

C The pH of 0·1 mol l^{-1} hydrochloric acid is lower than that of 0·1 mol l^{-1} ethanoic acid.

D The K_a value of ethanoic acid is greater than that of hydrochloric acid.

15. 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.

16. In the presence of bright light, hydrogen and chlorine react explosively. One step in the reaction is shown below.

$$H_2(g) + Cl(g) \rightarrow HCl(g) + H(g)$$

Using information from the Data Booklet, the enthalpy change, in kJ mol^{-1}, for this step is calculated as

A −189

B −4

C +4

D +189.

17. For which of the following reactions does the $\Delta H°$ value correspond to **both** the enthalpy of combustion of an element and the enthalpy of formation of a compound?

A $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$

B $H_2(g) + O_2(g) \rightarrow H_2O_2(\ell)$

C $2Na(s) + \frac{1}{2}O_2(g) \rightarrow Na_2O(s)$

D $Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$

18. In which of the following reactions would the energy change represent the lattice enthalpy of sodium chloride?

A $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$

B $Na(g) + Cl(g) \rightarrow NaCl(s)$

C $Na(s) + \frac{1}{2}Cl_2(g) \rightarrow NaCl(s)$

D $Na(s) + Cl(g) \rightarrow NaCl(s)$

19. A Born-Haber cycle can be used to calculate the lattice enthalpy of sodium chloride. Which of the following is **not** required in the calculation?

A The bond enthalpy of chlorine

B The first ionisation energy of chlorine

C The first ionisation energy of sodium

D The enthalpy of formation of sodium chloride

20. Which of the following reactions results in a **decrease** in entropy?

A $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

B $N_2O_4(g) \rightarrow 2NO_2(g)$

C $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

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

21. The equilibrium constant for a particular hydrolysis reaction has the value 3×10^4 at 25 °C. From this we can conclude that, at 25 °C, this hydrolysis reaction is

A fast

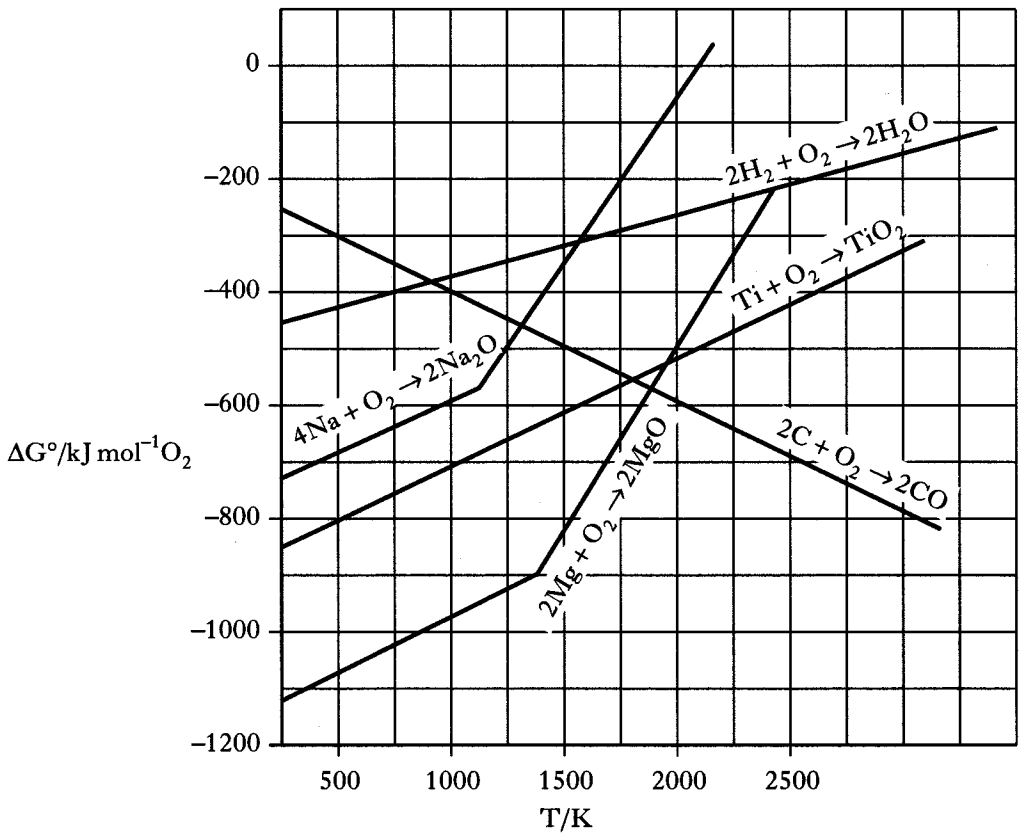
B feasible

C exothermic

D endothermic.

[Turn over

22.



The reduction of TiO_2 to Ti is thermodynamically feasible at 1500 K using

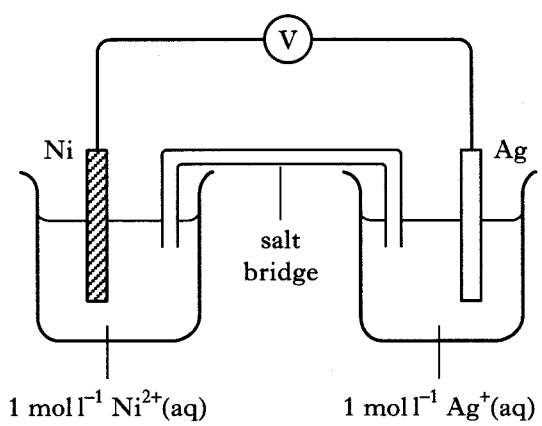
A hydrogen

B magnesium

C carbon

D sodium.

23.



In the cell, which of the following is reduced?

(Assume standard conditions.)

A Ni(s)

B $Ni^{2+}(aq)$

C Ag(s)

D $Ag^{+}(aq)$

24. For the reaction

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

the suggested mechanism is

$$NO(g) + Cl_2(g) \xrightarrow{\text{slow}} NOCl_2(g)$$

$$NOCl_2(g) + NO(g) \xrightarrow{\text{fast}} 2NOCl(g)$$

The rate equation is

A rate = $k[NO][Cl_2]$

B rate = $k[NO]^2[Cl_2]$

C rate = $k[NOCl_2][NO]$

D rate = $k[NO_2]^2[NOCl_2][Cl_2]$.

25. In a series of experiments, P and Q reacted to form R. The times taken to produce a fixed concentration of R were recorded.

Experiment	Initial [P] /mol l^{-1}	Initial [Q] /mol l^{-1}	Time/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

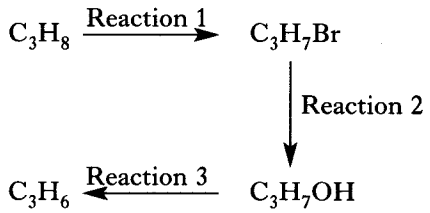
A rate = k[P]

B rate = k[Q]

C rate = $k[Q]^2$

D rate = k[P][Q].

26. Which line in the table correctly describes the types of reaction in the following sequence?



	Reaction 1	Reaction 2	Reaction 3
A	addition	substitution	dehydration
B	addition	addition	condensation
C	substitution	substitution	dehydration
D	substitution	addition	condensation

27. When ethene reacts with bromine in the presence of potassium chloride, CH_2BrCH_2Cl and CH_2BrCH_2Br are both formed. The first of these two compounds is produced because chloride ions

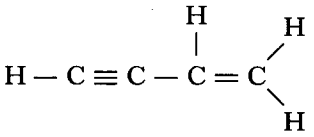
A compete with ethene to form an ionic intermediate

B compete with bromide ions in attacking a cyclic ion intermediate

C attack the CH_2BrCH_2Br which had originally formed, displacing the less reactive bromide ions

D react with bromine to give chlorine which then attacks the ethene.

28. Which line in the table has the correct number and type of bonds in



	Number of σ-bonds	Number of π-bonds
A	7	3
B	7	2
C	5	2
D	5	5

29. Which of the following best describes the bonding in alkanes?

A sp^2 hybridisation of the carbon atoms giving sigma bonds only

B sp^2 hybridisation of the carbon atoms giving sigma and pi bonds

C sp^3 hybridisation of the carbon atoms giving sigma bonds only

D sp^3 hybridisation of the carbon atoms giving sigma and pi bonds

30. Which of the following represents a termination step in a chain reaction?

A $Cl\bullet + Cl\bullet \rightarrow Cl_2$

B $Cl\bullet + CH_4 \rightarrow CH_3\bullet + HCl$

C $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

D $Cl_2 \rightarrow Cl\bullet + Cl\bullet$

31. Which one of the following statements about ethoxyethane is **not** correct?

A It burns readily in air.

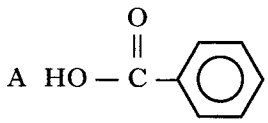
B It is isomeric with butan-1-ol.

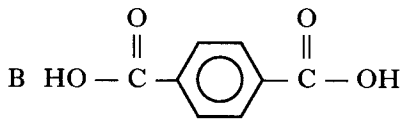
C It has a higher boiling point than butan-1-ol.

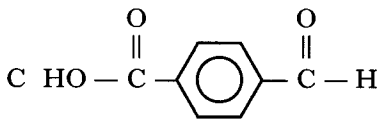
D It may be prepared from sodium ethoxide and bromoethane.

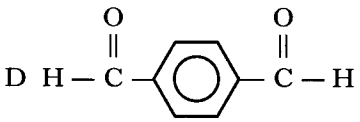
[Turn over

32. Which of the following, when reacted with ethane-1,2-diol, would form a polyester?

A 

B 

C 

D 

33. Which of the following can be oxidised by Tollens' reagent?

A CH_3COCH_3

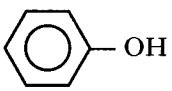
B CH_3CHO

C CH_3OH

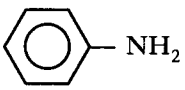
D $(CH_3)_2CHOH$

34. Which of the following is the strongest base?

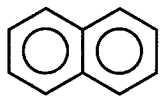
A CH_3CH_2OH

B 

C $CH_3CH_2NH_2$

D 

35. Naphthalene, $C_{10}H_8$, has the following structure.



The number of moles of hydrogen gas required for the complete hydrogenation of 12·8 g naphthalene will be

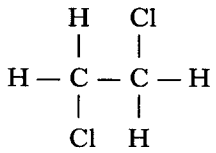
A 0·1

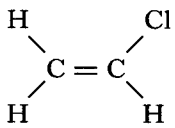
B 0·4

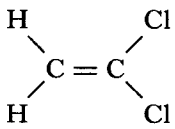
C 0·5

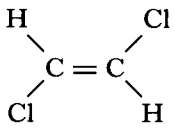
D 0·8.

36. Which of the following compounds has a geometric isomer?

A 

B 

C 

D 

37. An analysis of an organic compound found in meteorite rocks shows the following percentage composition by mass.

C = 37·5% H = 12·5% O = 50%

The empirical (simplest) formula for the compound is

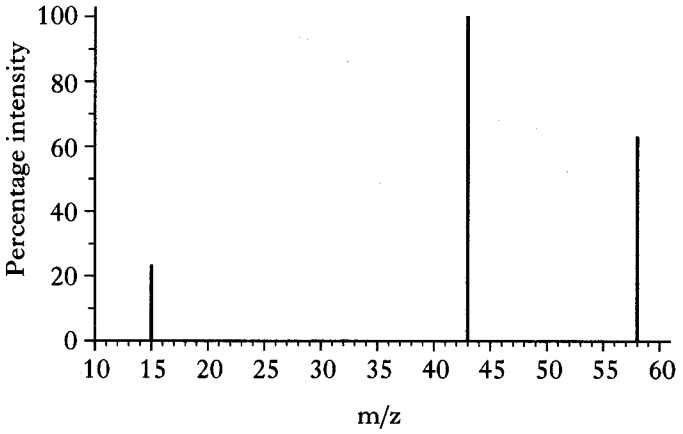
A CH_4O

B C_3HO_4

C $C_3H_{12}O_3$

D CH_2O_2.

38. A simplified mass spectrum of an organic compound is shown.



Which of the following compounds gave this spectrum?

A Propane

B Propan-1-ol

C Propan-2-ol

D Propanone

39. 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

40. Salbutamol is used to treat asthma. It behaves like the body's natural active compound by binding to receptors on the muscles of the air passages. This relaxes the muscles and gives relief from breathing difficulties. Salbutamol is

A an agonist

B an antagonist

C a pharmacaphore

D a receptor.

[END OF SECTION A]

Candidates are reminded that the answer sheet for Section A MUST be placed INSIDE the front cover of your answer book.

[Turn over

SECTION B

All answers must be written clearly and legibly in ink.

Marks

1. Molten iron, made in a blast furnace, often contains sulphur and phosphorus impurities which must be removed.

Bubbling carbon dioxide gas through molten iron removes the sulphur.

The carbon dioxide gas is produced by the decomposition of calcium carbonate.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

(*a*)

Substance	Standard enthalpy of formation, $\Delta H°/kJ\ mol^{-1}$	Standard entropy, $S°/J\ K^{-1}\ mol^{-1}$
CO_2	−393·5	213·8
$CaCO_3$	−1206·9	92·9
CaO	−635·1	38·1

For the decomposition of calcium carbonate, use the data in the table to calculate:

(i) the standard enthalpy change, $\Delta H°$, in $kJ\ mol^{-1}$; **1**

(ii) the standard entropy change, $\Delta S°$, in $J\ K^{-1}\ mol^{-1}$; **1**

(iii) the theoretical temperature at which the reaction just becomes feasible. **2**

(*b*) The phosphorus impurity is removed by first converting it into the oxide, P_4O_{10}. This oxide then reacts with calcium oxide to produce a useful fertiliser.

(i) Calculate the oxidation number of phosphorus in P_4O_{10}. **1**

(ii) Name the fertiliser formed. **1**

(6)

2. 25·0 cm^3 of an acidified solution of potassium oxalate, $K_2C_2O_4$, was heated to 80 °C and titrated with a standard solution of 0·020 $mol\ l^{-1}$ potassium permanganate, $KMnO_4$.

The end-point was reached when 22·5 cm^3 of $KMnO_4$ solution had been added.

The ion-electron equations for the reactions involved are:

$$C_2O_4^{2-}(aq) \longrightarrow 2CO_2(g) + 2e^-$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(\ell)$$

(*a*) How would the end-point of the titration be determined? **1**

(*b*) Write the redox equation for the reaction. **1**

(*c*) Calculate the concentration of the potassium oxalate solution used in this titration. **3**

(5)

Marks

3. The table shows two quantum numbers for the 10 electrons in a neon atom.

Electron	First Quantum Number (n)	Second Quantum Number (ℓ)
1	1	0
2	1	0
3	2	0
4	2	0
5	2	1
6	2	1
7	2	1
8	2	1
9	2	1
10	2	1

(*a*) Write the electronic configuration for a neon atom in terms of s and p orbitals. **1**

(*b*) Electrons 5 to 10 can be described as degenerate.
What is meant by the term "degenerate"? **1**

(*c*) The second quantum number, ℓ, is related to the shape of the orbitals.
Draw the shape of an orbital when $\ell = 1$. **1**

(*d*) What are the first and second quantum numbers for the outer electron in a sodium atom? **1**

(4)

[Turn over

Marks

4. In the stratosphere, oxygen molecules absorb ultraviolet radiation and break up to form oxygen atoms.

$$O=O \longrightarrow O + O$$

(*a*) The bond enthalpy of $O=O$ is $497\,kJ\,mol^{-1}$. Calculate the wavelength, in nm, of the ultraviolet radiation required to break up 1 mole of oxygen molecules into oxygen atoms. **3**

(*b*) Some of the oxygen atoms react with oxygen molecules to produce ozone, O_3.

Reaction 1 $O + O_2 \longrightarrow O_3 \qquad \Delta H° = -106\,kJ\,mol^{-1}$

Other oxygen atoms react to produce oxygen molecules.

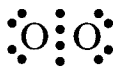
Reaction 2 $O + O \longrightarrow O_2 \qquad \Delta H° = -497\,kJ\,mol^{-1}$

Oxygen atoms can also react with ozone to produce oxygen molecules.

Reaction 3 $O + O_3 \longrightarrow O_2 + O_2$

(i) Use Hess's law to calculate the standard enthalpy change, in $kJ\,mol^{-1}$, for **Reaction 3**. **1**

(ii) A Lewis dot diagram for an oxygen molecule is



Draw a similar diagram for an ozone molecule. **1**

(5)

5. Solutions of NaH_2PO_4 are acidic because the $H_2PO_4^-$ ion partially dissociates.

$$H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq) \quad pK_a = 7{\cdot}2$$

(*a*) Write the expression for the acid dissociation constant, K_a. **1**

(*b*) Calculate the pH of $0{\cdot}1\ mol\,l^{-1}$ NaH_2PO_4 solution. **2**

(*c*) NaH_2PO_4 is used with $NaHCO_3$ in baking powders, to produce carbon dioxide.

$$H_2PO_4^-(aq) + HCO_3^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H_2O(\ell) + CO_2(g)$$

Explain how HCO_3^- acts as a base in this reaction. **1**

(4)

Marks

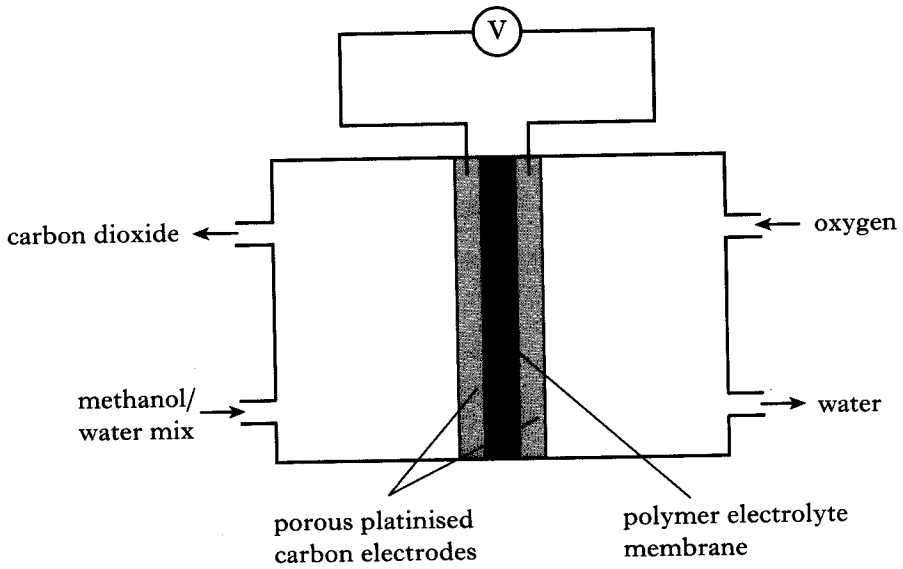
6. Most cars are powered by the combustion of petrol which consists mainly of octane isomers. Currently research is being carried out on replacing petrol with hydrogen as a fuel.

(*a*)

Fuel	Combustion Reaction	$\Delta H°/kJ\ mol^{-1}$
Hydrogen	$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$	−286
Petrol	$C_8H_{18} + 12\frac{1}{2}O_2 \longrightarrow 8CO_2 + 9H_2O$	−5100

Calculate the energy produced per gram of each fuel. **1**

(*b*) Research is also being carried out on replacing engines with fuel cells such as the direct methanol fuel cell shown.



The overall cell reaction is

$$CH_3OH + 1\frac{1}{2}O_2 \longrightarrow CO_2 + 2H_2O$$

The ion-electron equation for the oxidation of methanol is

$$CH_3OH + H_2O \longrightarrow CO_2 + 6H^+ + 6e^-$$

The standard reduction potential for oxygen is 1·23 V.

(i) Write the ion-electron equation for the reduction of oxygen. **1**

(ii) The emf of the cell measured under standard conditions is 1·20 V.
Calculate the standard **reduction** potential for the ion-electron reaction involving the methanol. **1**

(iii) Calculate the standard free energy change, $\Delta G°$, in kJ per mole of methanol, for the cell reaction. **3**

(6)

[Turn over

Marks

7. In a **PPA**, the kinetics of the acid-catalysed propanone/iodine reaction were studied.

$$CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+(aq)} CH_3COCH_2I(aq) + HI(aq)$$

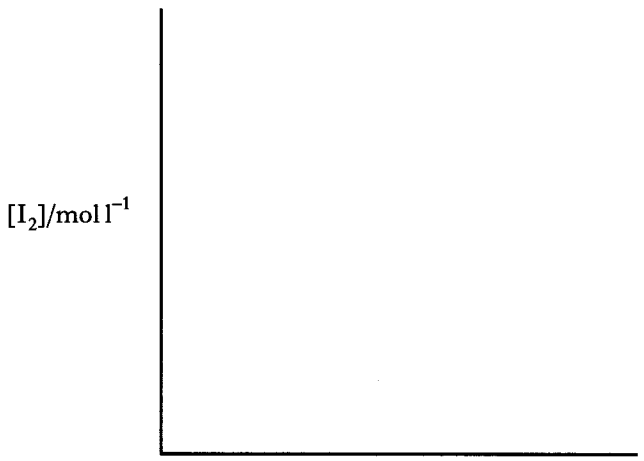
The reaction is first order with respect to propanone and first order with respect to the hydrogen ions which catalyse the reaction. The order with respect to iodine is unknown. The rate equation is

$$\text{Rate} = k[I_2]^{\mathbf{x}}[CH_3COCH_3][H^+]$$

The aim of the experiment was to determine **x**.

(*a*) How did the initial concentrations of the propanone and acid compare with that of the iodine to allow the value of **x** to be determined? **1**

(*b*) The experiment proved that the order of the reaction with respect to iodine was zero. Copy the axes shown and sketch the graph which would be obtained.



1

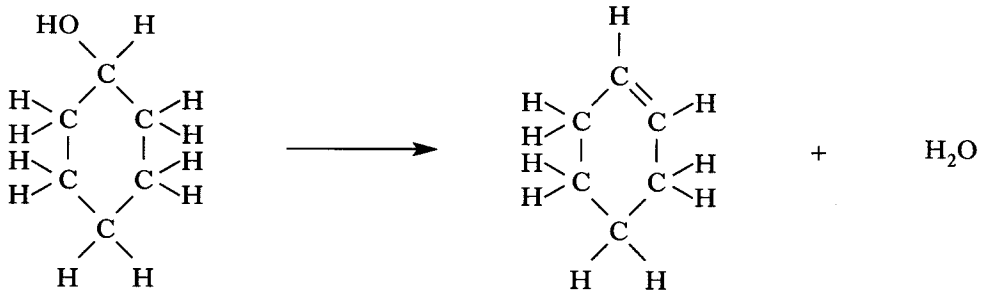
(*c*) What is the overall order of the reaction? **1**

(*d*) What are the units for the rate constant, k? **1**

(4)

Marks

8. In a **PPA**, cyclohexene was prepared from cyclohexanol by dehydration.



(*a*) Which reagent was used to convert cyclohexanol to cyclohexene? **1**

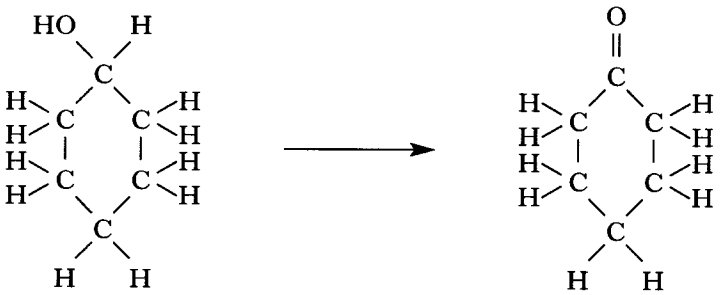
(*b*) Distillation was used to separate the cyclohexene product from the reaction mixture because cyclohexanol has a higher boiling point than cyclohexene.

Explain why cyclohexanol has the much higher boiling point. **1**

(*c*) To purify the cyclohexene distillate, a saturated sodium chloride solution was added to it in a separating funnel.

Why was sodium chloride solution used instead of water? **1**

(*d*) Cyclohexanol can also be oxidised to the cycloketone, cyclohexanone.



Ketones can be identified using 2,4-dinitrophenylhydrazine solution (Brady's reagent).

How would this be used to identify the ketone as cyclohexanone? **2**

(5)

[Turn over

Marks

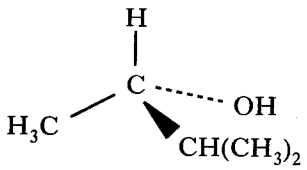
9. Mixtures of the isomers of the alcohol, $C_5H_{11}OH$, are used as solvents for resins and oily materials.

The shortened structural formulae for four of these isomers are shown in the table.

Isomer	Shortened structural formula
A	$(CH_3)(C_2H_5)CHCH_2OH$
B	$(CH_3)_3CCH_2OH$
C	$(CH_3)_2(C_2H_5)COH$
D	$(C_2H_5)_2CHOH$

(*a*) Which isomer is the tertiary alcohol? **1**

(*b*) Another isomer of $C_5H_{11}OH$ displays optical isomerism.
One of its optical isomers is shown below.



Draw a diagram representing the other optical isomer. **1**

(*c*) One of the four isomers, A to D, in the table above, is also optically active.
Draw a similar diagram to that shown in part (*b*) to represent one of its optical isomers. **1**

(3)

10. Fusel alcohols are components of fusel oil which is obtained during the process of brewing beer. They contribute to the flavour of the beer and are also the major cause of hangovers. The most important fusel alcohols are

3-methylbutan-1-ol
2-methylbutan-1-ol
propan-1-ol.

(*a*) Give a reason why propan-1-ol is the most soluble of these alcohols in water. **1**

(*b*) Other flavours found in beer are caused by esters.
Esters can be formed by reacting alcohols with carboxylic acids.

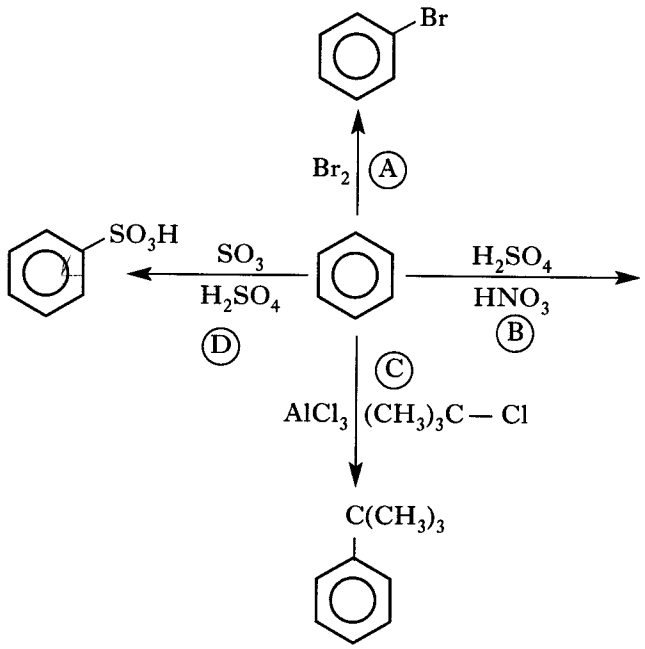
(i) What can be used in place of carboxylic acids to form esters? **1**

(ii) What advantage is there in using this type of reagent? **1**

(3)

Marks

11. Benzene is one of the most important aromatic feedstocks in the chemical industry. Four electrophilic substitution reactions which benzene undergoes are shown.



(*a*) (i) Which catalyst is required to carry out reaction (A)? **1**

(ii) What is the organic product in reaction (B)? **1**

(iii) The specific name for reaction (C) is alkylation.
What is the specific name for reaction (D)? **1**

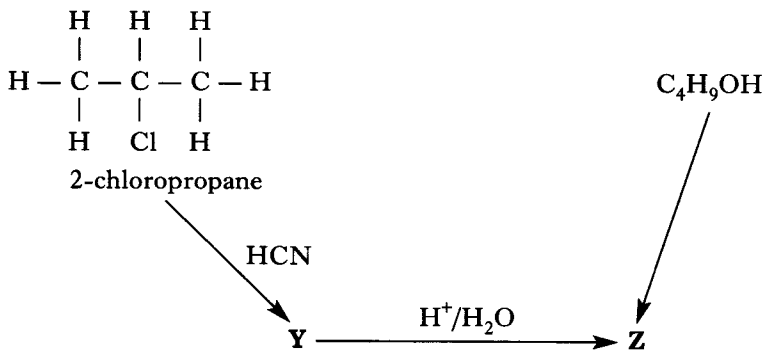
(*b*) Both benzene and graphite have delocalised electrons.
Suggest why benzene does not conduct electricity. **1**

(4)

[Turn over

Marks

12. The diagram illustrates two methods of preparing compound **Z**.



(*a*) Draw a structural formula for compound **Y**. **1**

(*b*) Compound **Z** has the molecular formula $C_4H_8O_2$.
Name **and** draw a structural formula for compound **Z**. **2**

(*c*) (i) Name the alcohol, C_4H_9OH, used to prepare compound **Z**. **1**

(ii) Which reagent could be used to convert C_4H_9OH to compound **Z**? **1**

(*d*) The conversion of 2-chloropropane into compound **Y** proceeds by an S_N2 mechanism.

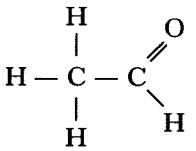
(i) Explain what is meant by the abbreviation S_N2. **2**

(ii) Draw a structural formula for the transition state in this reaction. **1**

(8)

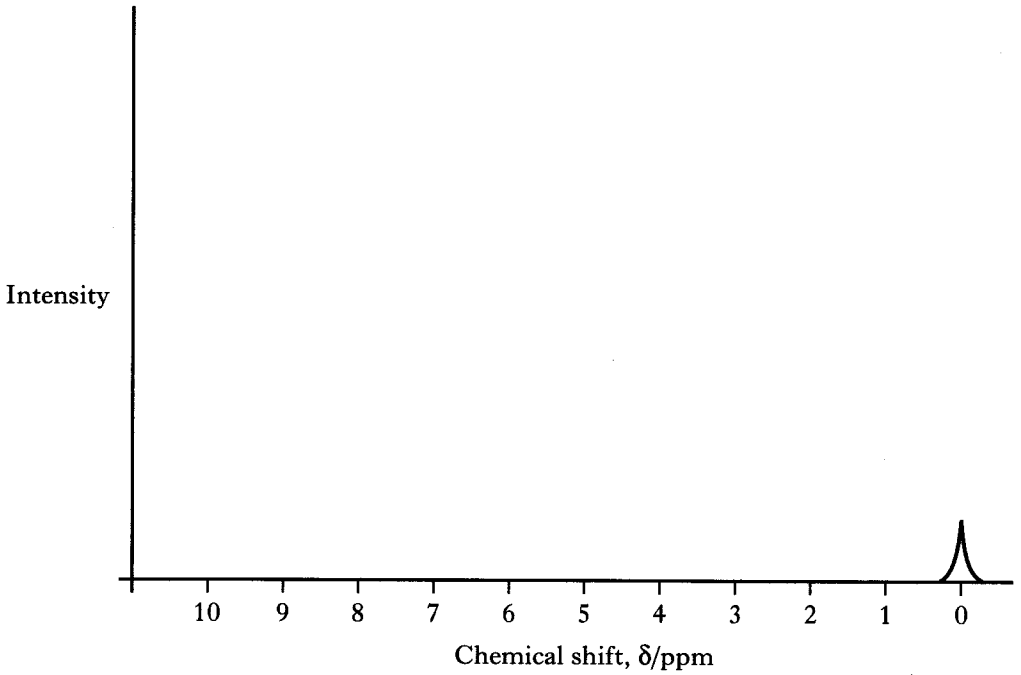
Marks

13. A proton nmr spectrum was produced for ethanal.



ethanal

(*a*) Copy and complete the following diagram to show the approximate positions and relative heights of the two peaks in the proton nmr spectrum of ethanal.



2

(*b*) Which reference substance is used in proton nmr spectroscopy and causes the peak at $\delta = 0$ ppm?

1

(3)

[END OF QUESTION PAPER]