National Qualifications 2022

X813/77/02

Chemistry
Section 1 — Questions

FRIDAY, 29 APRIL

9:00 AM – 12:00 NOON

Instructions for the completion of Section 1 are given on *page 02* of your question and answer booklet X813/77/01.

Record your answers on the answer grid on *page 03* of your question and answer booklet.

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.

Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

SECTION 1 — 25 marks
Attempt ALL questions

1. Which of the following statements about atomic emission spectroscopy is **not** correct?

   A   Each element has a characteristic spectrum.

   B   Visible light is used to promote electrons to higher energy levels.

   C   The lines arise from electron transitions between one energy level and another.

   D   The quantity of the element can be determined from the intensity of the radiation emitted.

2. How many electrons are there in the highest energy subshell of a Cr^+ ion, in its ground state?

   A   1

   B   2

   C   4

   D   5

3. The formula of an octahedral complex ion containing a metal ion, M^{2+}, and the bidentate ligand, L^-, is:

   A $[ML_2]^-$

   B $[ML_2]^{2+}$

   C $[ML_3]^{2+}$

   D $[ML_3]^-$

4. Which of the following statements about heterogeneous catalysts is **not** correct?

   A   They are found in the same state as their reactants.

   B   They adsorb reactive molecules onto their active sites.

   C   They provide reaction pathways with lower activation energies.

   D   They have unpaired d electrons that allow activated complexes to form.

5. A disproportionation reaction is a redox reaction in which an element in a single substance is both oxidised and reduced.

   In which of the following does a halogen undergo disproportionation?

   A $Cl_2 + 2KI \rightarrow 2KCl + I_2$

   B $IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$

   C $I_2 + 6H_2O + 5Cl_2 \rightarrow 2HIO_3 + 10HCl$

   D $Cl_2 + 2NaOH \rightarrow NaCl + NaClO + H_2O$

6. Which of the following is true for a neutral solution at 325 K?

   A $pH = 7.00$

   B $K_w = 1.01 \times 10^{-14}$

   C $[H_3O^+] = [OH^-]$

   D $[H_3O^+] = 1.00 \times 10^{-7}$

7. $$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

   Which line in the table is correct for the concentration of $SO_3(g)$ at equilibrium and the equilibrium constant, K, when the pressure of the equilibrium mixture is increased at constant temperature?

	$[SO_3(g)]$ at equilibrium	Equilibrium constant, K
A	increase	no change
B	increase	increase
C	no change	increase
D	no change	no change

8. The standard enthalpy of formation of sodium chloride is represented by:

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

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

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

   D $Na(s) + \frac{1}{2}Cl_2(g) \rightarrow Na^+Cl^-(s)$

[Turn over

9. The rate equation for a reaction is

$$\text{rate} = k[A]^2[B]$$

Which of the following statements is correct for this reaction?

A   Doubling the concentration of A will double the reaction rate.

B   Doubling the concentration of B will double the reaction rate.

C   Doubling the concentration of B will have no effect on the reaction rate.

D   Doubling the concentration of A and B will have no effect on the reaction rate.

10. The order of a reaction:

A   depends on the stoichiometry of the overall reaction

B   is the sequence of steps in the mechanism

C   controls the speed of the overall reaction

D   can only be obtained by experiment.

11. Which of the following graphs shows the variation in entropy, S, as a substance is heated from below its melting point to above its boiling point?

A

B

C

D
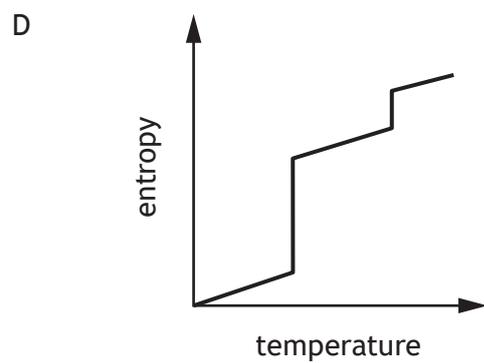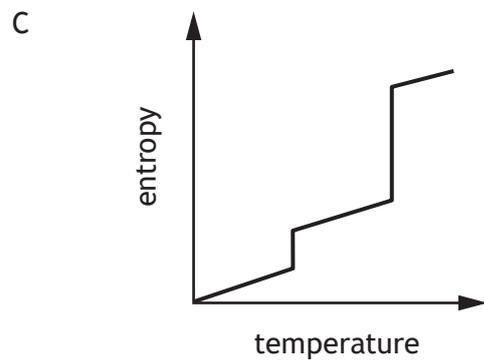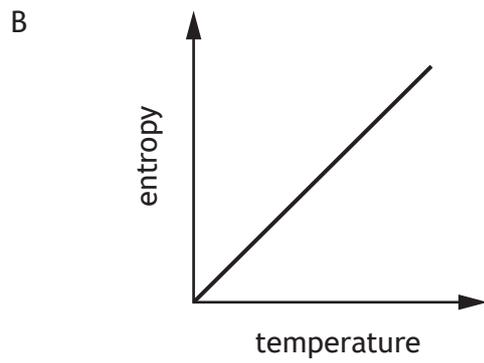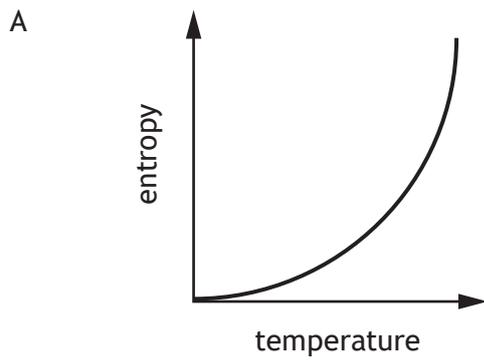
[Turn over

12. Which of the following diagrams represents the hybridisation of orbitals in a carbon atom of ethyne?

A

energy ↑

2s □

2p □□□ → □□□□

B

energy ↑

2s □

2p □□□ → □□□ □

C

energy ↑

2s □

2p □□□ → □□ □□

D

energy ↑

2s □

2p □□□ → □ □□□
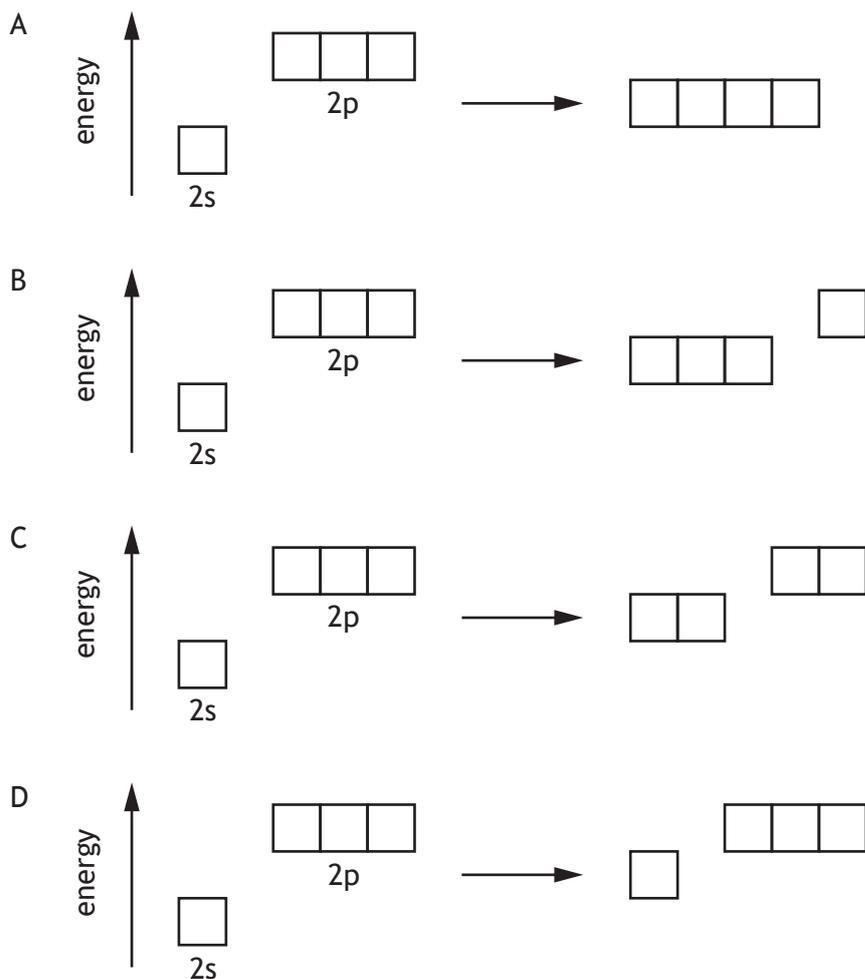
13. Which of the following molecules contains only sigma bonds?

A C_2H_4

B H_2O

C O_2

D N_2

14. The addition reaction of propene and hydrogen bromide is a two-step process.

Which of the following shows the first step in this mechanism?

A

B

C

D
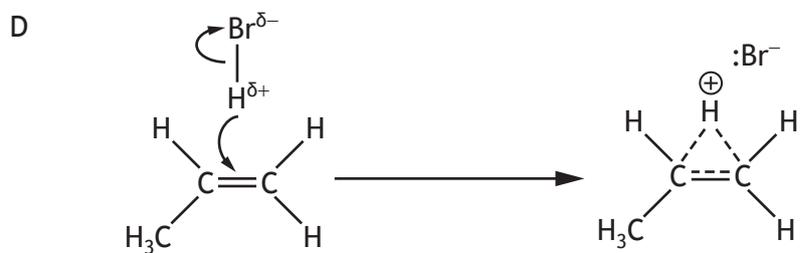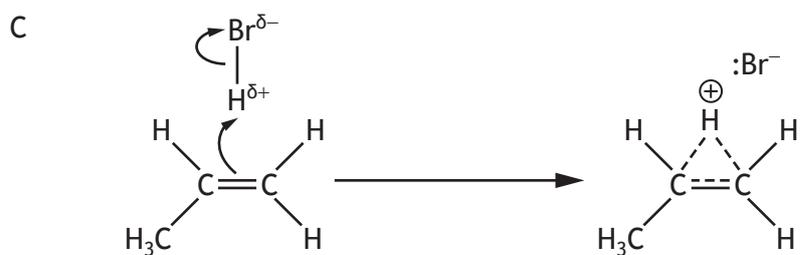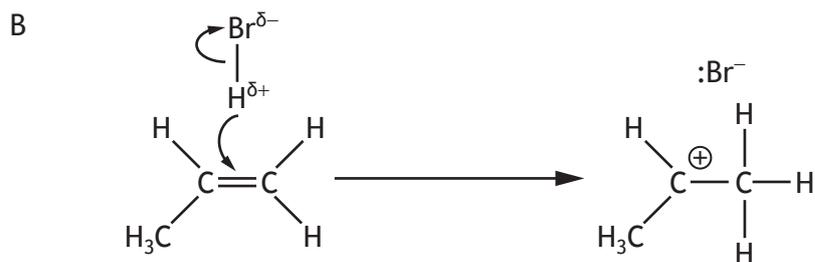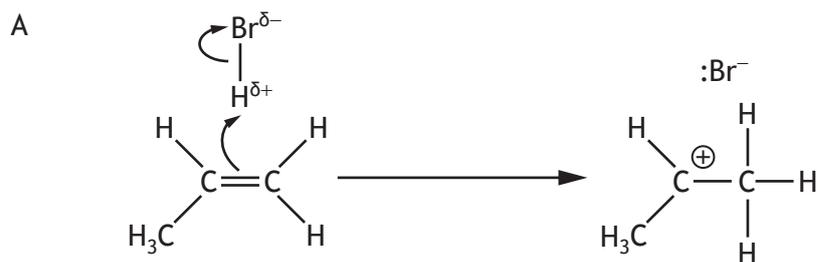
15. Which of the following compounds contains a phenyl group?

A
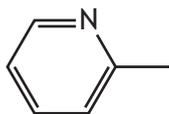
B

C
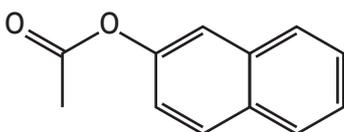
D
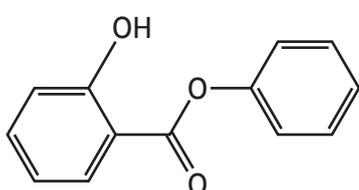
16. Consider the following reaction sequence.

$$\text{2-chlorobutane} \xrightarrow{\text{CN}^-} \text{X} \xrightarrow{\text{H}^+/\text{H}_2\text{O}} \text{Y}$$

Compound **Y** is likely to be:

A   2-methylpropanoic acid

B   butanoic acid

C   2-methylbutanoic acid

D   pentanoic acid.

17. What is the systematic name of the molecule shown below?
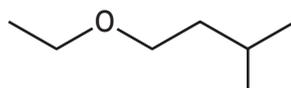
A   1-ethoxy-2-methylpropane

B   1-ethoxy-3-methylbutane

C   2-ethoxy-2-methylpropane

D   2-ethoxy-3-methylbutane

18. When propanone dissolves in water the following equilibrium is established.

$$H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3 \quad \rightleftharpoons \quad H_3C-\overset{\overset{\displaystyle OH}{|}}{C}=CH_2$$

propanone	propenol
(a ketone)	(an enol)
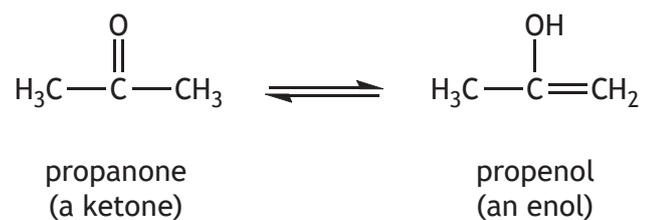
The ketone and enol are isomers and are called tautomers.

Which of the following ketones does not have an enol tautomer?

A

$$(H_3C)_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$$

B

$$(H_3C)_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2CH_3$$

C

$$(H_3C)_2HC-\overset{\overset{\displaystyle O}{\|}}{C}-C(CH_3)_3$$

D

$$(H_3C)_3C-\overset{\overset{\displaystyle O}{\|}}{C}-C(CH_3)_3$$
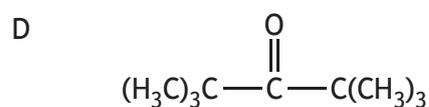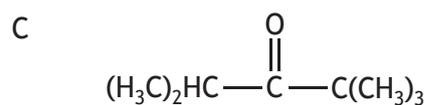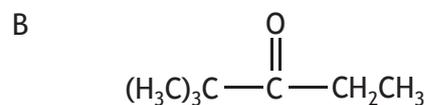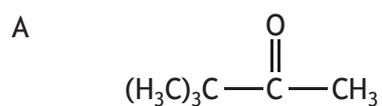
19. Which of the following compounds has non-superimposable mirror images?

A

$$H-N-C-C$$

with H, H, O, OH substituents (glycine structure)

B

$$H-N-C-C$$

with H, CH$_3$, O, OH substituents (alanine structure)

C

$$H-C-C-C-C-H$$

with substituents H, OH, H, H (top) and H, CH$_3$, H, H (bottom)

D

$$H-C-C-C-C-C-H$$

with substituents H, H, OH, H, H (top) and H, H, CH$_3$, H, H (bottom)
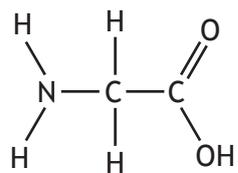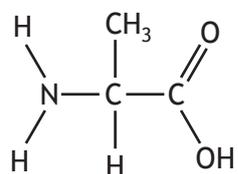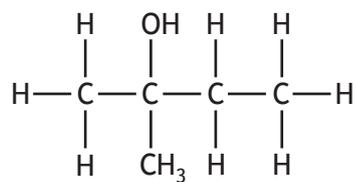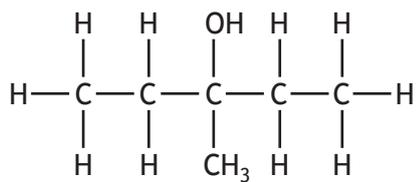
20. Compound **X** underwent elemental microanalysis and was found to contain 0.12 g of carbon and 0.02 g of hydrogen.

Compound **X** could be:

A

$$\begin{array}{c} H \qquad\qquad H \\ \diagdown \qquad\qquad \diagup \\ C - C \\ \| \qquad \| \\ C - C \\ \diagup \qquad\qquad \diagdown \\ H \qquad\qquad H \end{array}$$

B

$$\begin{array}{c} H \qquad\quad H \\ \diagdown \qquad\quad | \\ C - C - H \\ \| \qquad\quad | \\ C - C - H \\ \diagup \qquad\quad | \\ H \qquad\quad H \end{array}$$

C

$$H - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} = \overset{\displaystyle H}{C} - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} - H$$

D

$$H - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} - H$$
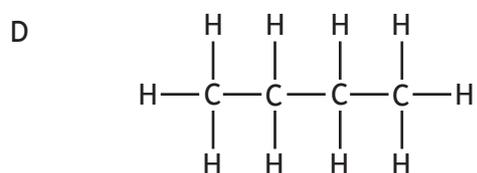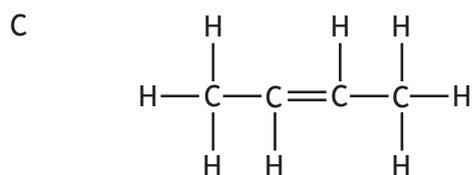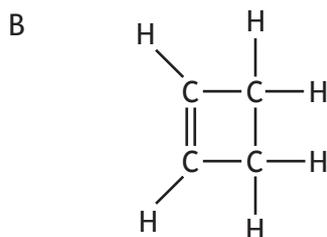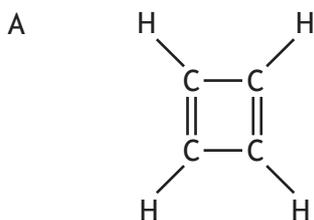
21. The mass spectrum of an organic compound had a molecular ion peak at m/z 74. There were also peaks at 15, 31 and 43.

The organic compound that produced this mass spectrum is:

A CH_3CH_2COOH

B CH_3COOCH_3

C $CH_3COCH_2CH_3$

D $CH_3CH_2CH_2CHO$

22. The structural formula of malic acid is shown below.
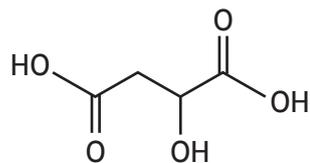
How many moles of sodium carbonate, Na_2CO_3, would be required to neutralise 6.7 g of malic acid (GFM = 134 g)?

A 0.050

B 0.075

C 0.10

D 0.15

23. A student carried out a gravimetric analysis by heating a 2.52 g sample of hydrated calcium chloride, $CaCl_2 \cdot 2H_2O$, until it reached constant mass.

What was the mass of the calcium chloride sample after heating to constant mass?

A 1.70 g

B 1.90 g

C 2.11 g

D 2.21 g

24. Which of the following techniques can be used to both purify and identify a compound?

A Distillation

B Recrystallisation

C Solvent extraction

D Melting point determination

25. The progress of a reaction was followed by periodically sampling the reaction mixture and analysing it using thin-layer chromatography. The chromatogram for the analysis of one sample is shown.
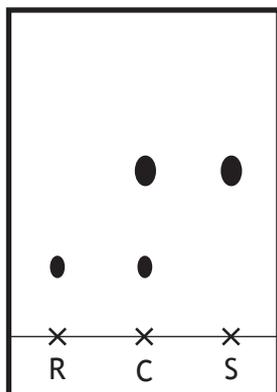
R is a spot of pure reactant

C is a co-spot of pure reactant and the reaction mixture sample

S is a spot of the reaction mixture sample

Which of the following conclusions **must** be correct for this thin-layer chromatogram?

A   The reaction mixture does not contain impurities.

B   All of the reactant has been used up.

C   Only the desired product is present.

D   The reaction is complete.

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET.]

AH

National Qualifications 2022

Mark

X813/77/01

**Chemistry
Section 1 — Answer grid
and Section 2**

FRIDAY, 29 APRIL

9:00 AM – 12:00 NOON

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day   Month   Year   Scottish candidate number

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.

Total marks — 110

SECTION 1 — 25 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *page 02*.

SECTION 2 — 85 marks

Attempt ALL questions.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

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SECTION 2 — 85 marks

Attempt ALL questions

1. Oxygen is found in the p-block of the periodic table.

    (a) The electronic configuration of an oxygen atom is $1s^2 2s^2 2p^4$.

        (i) Draw the shape of a p orbital.

        1

        (ii) For a 2p electron in oxygen, complete the table to show one possible set of values for the quantum numbers.

        1

Quantum number	Value
n	2
l	
m_l	
m_s	

[Turn over

1. (continued)

(b) The graph shows the trend in first ionisation energy from lithium to neon.
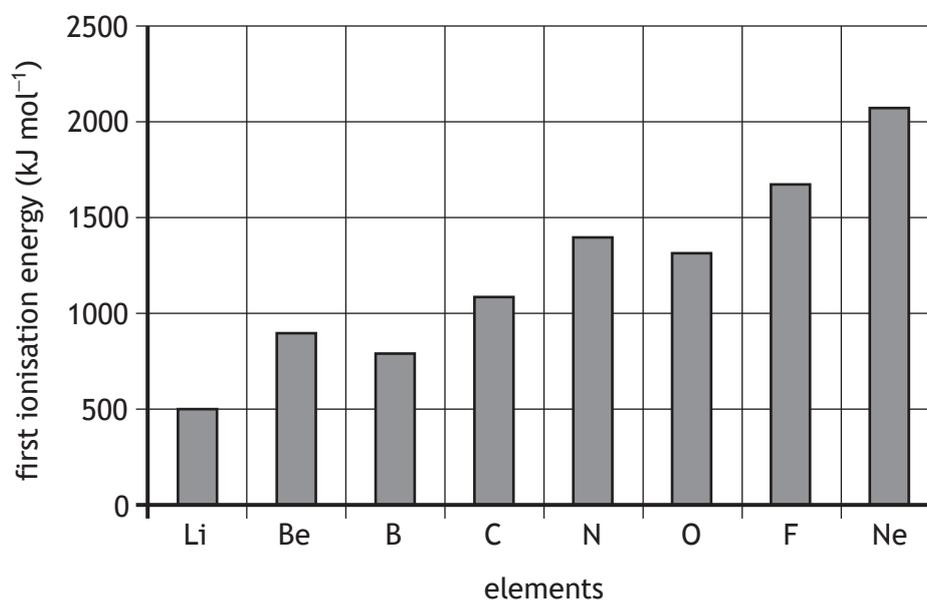
Explain, in terms of electronic structure, why the first ionisation energy of oxygen is less than the first ionisation energy of nitrogen. **1**

1. (continued)

(c) The remains of a star were found to be rich in oxygen. Some of the oxygen atoms had been ionised to single electron ions, O^{7+}. The emission spectrum of O^{7+} has a characteristic spectral line.

The energy, E, of this spectral line is given by the equation

$$E = R Z^2 \left(1 - \frac{1}{n^2}\right)$$

where: E is the energy, in J

Z is the atomic number

n is the principal quantum number of the second energy level

R is the Rydberg energy, with a value of 2.18×10^{-18} J.

Calculate the energy, in J, of this O^{7+} spectral line.   **1**

[Turn over

2. Nitrogen monoxide, NO, is an important oxide of nitrogen.

(a) Photochemical smog is a type of air pollution. It is formed through a sequence of atmospheric reactions involving nitrogen monoxide. One of the reactions is

$$\tfrac{1}{2}N_2(g) + \tfrac{1}{2}O_2(g) \rightarrow NO(g)$$
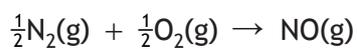
Substance	$\Delta H_f°$ (kJ mol^{-1})	$S°$ (J K^{-1} mol^{-1})
N$_2$(g)	0	192
O$_2$(g)	0	205
NO(g)	90.3	211

Use the data in the table to determine if the reaction is feasible at 298 K. **3**

(*Clearly show your working for the calculation.*)

2. (continued)

(b) The UK workplace exposure limit for nitrogen monoxide is 2 ppm.

A worker inhales 5 litres of air per minute containing 2 ppm of nitrogen monoxide.

Calculate the mass of nitrogen monoxide inhaled in one hour by the worker.   **2**

(c) Nitrogen monoxide can react with nitrogen dioxide to form dinitrogen trioxide.

$$NO(g) \ + \ NO_2(\ell) \ \rightarrow \ N_2O_3(s)$$
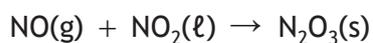
Complete the table to show the oxidation number of nitrogen in each oxide.   **1**

Oxide	Oxidation number of nitrogen
NO	+2
NO$_2$	
N$_2$O$_3$	

[Turn over

2. (continued)

(d) At high temperatures, nitrogen monoxide can also react with hydrogen.

A proposed reaction mechanism is

Step 1 $2NO(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g)$ (slow)

Step 2 $N_2O(g) + H_2(g) \rightarrow N_2(g) + H_2O(g)$ (fast)

(i) (A) Write a rate equation for this reaction. **1**

(B) The experimental rate constant is $2.7 \times 10^3\ l^2\,mol^{-2}\,s^{-1}$.

The table shows experimental rate data for the reaction.

[NO] (mol l^{-1})	[H$_2$] (mol l^{-1})	Initial reaction rate (mol $l^{-1}\,s^{-1}$)
	0.015	0.0040

Complete the table to show the concentration of nitrogen monoxide. **1**

(ii) Write a balanced equation for the overall reaction. **1**

3. Hydrofluoric acid, HF, is a weak acid.

$$HF(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + F^-(aq)$$
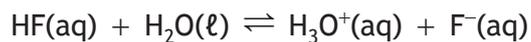
(a) State what is meant by a weak acid. **1**

(b) $3.75\ mol\,l^{-1}$ hydrofluoric acid solution can be used to engrave glass.

   (i) Calculate the pH of this hydrofluoric acid solution. **2**

   (ii) The concentration of commercially available hydrofluoric acid solution is expressed in terms of percentage by mass.

     Calculate the percentage by mass of a $3.75\ mol\,l^{-1}$ hydrofluoric acid solution. **2**

   (iii) Hydrofluoric acid solution reacts with the silicon dioxide in glass to produce silicon fluoride, SiF_4.

   State the shape of SiF_4 molecules. **1**

4. Hippuric acid is found in urine.
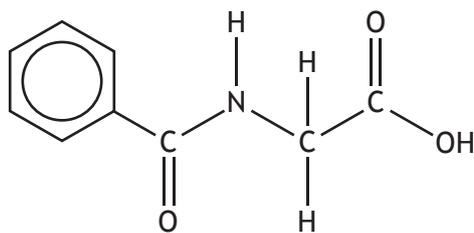
hippuric acid

(a) Hippuric acid can be made in the laboratory.

   (i) The first step of the procedure involves heating a mixture of glycine and benzoyl chloride with excess dilute sodium hydroxide solution.

      The diagram shows the apparatus used to heat the mixture.

water out

water in

glycine + benzoyl chloride in NaOH (aq)

heating mantle
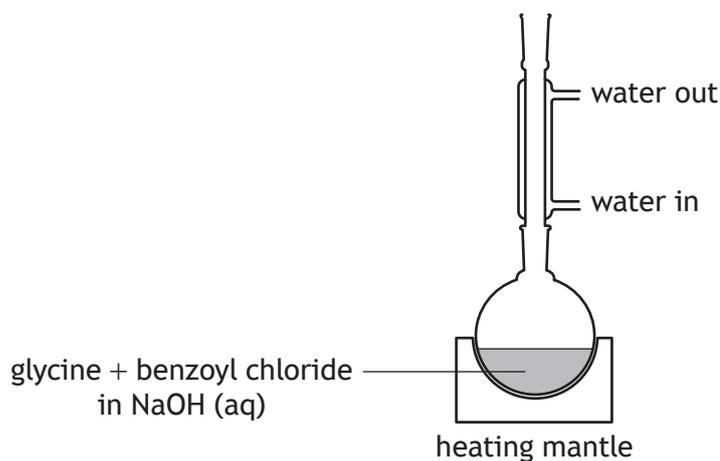
    (A) Name the technique shown in the diagram.   **1**

    (B) State what else should be added to the round-bottomed flask before heating the mixture.   **1**

4. (a) (continued)

(ii) The sodium salt of hippuric acid formed in the reaction mixture during the first step is then treated with dilute hydrochloric acid. A white precipitate of hippuric acid is formed.

Explain why adding hydrogen ions to the salt of a weak acid results in the formation of undissociated weak acid molecules.

1

(iii) The reaction mixture was filtered and the hippuric acid was recrystallised from hot water.

(A) Describe how the filtration should have been carried out to ensure that the hippuric acid was separated quickly from the reaction mixture.

1

(B) State why the hippuric acid was recrystallised.

1

[Turn over

4. **(continued)**

(b) An infrared spectrum for hippuric acid is shown below.
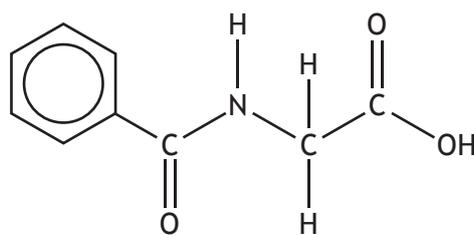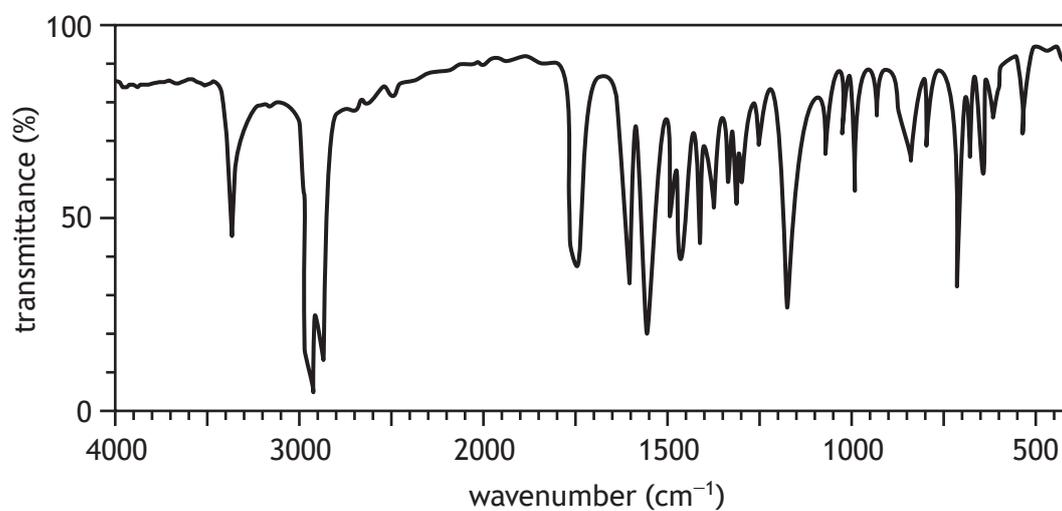
hippuric acid

(i) State a reason why different bonds absorb different wavenumbers of infrared radiation.

1

(ii) State the wavenumber, in cm^{-1}, of the peak in this infrared spectrum caused by the N–H bond.

1

4. (continued)

(c) The structure of hippuric acid can be investigated using ^{1}H NMR spectroscopy.
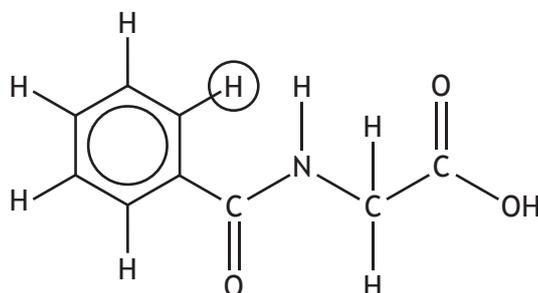
hippuric acid

(i) State the number of ^{1}H environments in hippuric acid. **1**

(ii) Predict the splitting pattern in a high resolution ^{1}H NMR spectrum that would be observed for the hydrogen atom circled in the structure above. **1**

(iii) The absorption of radiation in the radiofrequency region causes ^{1}H nuclei to adopt a high energy state aligned against a strong magnetic field.

Explain how this leads to peaks in an NMR spectrum corresponding to different ^{1}H environments. **2**

4. **(continued)**

(d) Human urine is mostly water (91% to 96%) with organic solutes including urea, creatinine and uric acid, with trace amounts of other substances such as carboxylic acids, enzymes, carbohydrates, pigments and salts. The pH of human urine can vary throughout the day.
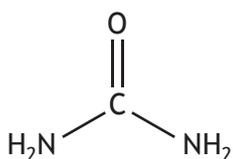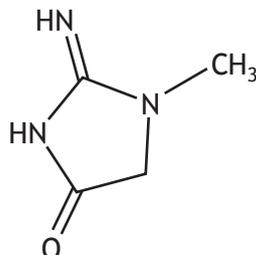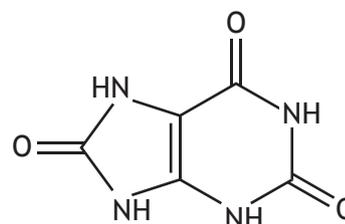
urea   creatinine   uric acid

Using your knowledge of chemistry, comment on the likely pH range of human urine.

3

5. Cobalt can bind to different ligands to form octahedral complexes where the d orbitals are split into higher and lower energies.

   (a) State what causes the d orbital splitting in octahedral complexes.　**1**

   (b) In some complex ions, the electrons in the d orbitals exist in a 'low spin state' and in other complex ions, the electrons exist in a 'high spin state'. The low spin state and high spin state electron arrangements of a complex ion with five d electrons are shown below.

   　　　　low spin state　　　　high spin state
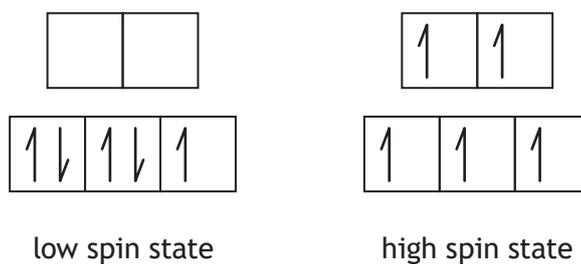
   　(i) The filling of orbitals obeys the aufbau principle.

   　　State the aufbau principle.　**1**

5. (b) (continued)

(ii) Information about some complex ions of cobalt is shown in the table.

Complex ion	P (kJ mol^{-1})	Δ (kJ mol^{-1})	Spin state
$[Co(OH_2)_6]^{2+}$	250	111	high
$[CoF_6]^{3-}$	283	156	high
$[Co(OH_2)_6]^{3+}$	283	323	low
$[Co(CN)_6]^{3-}$	283	416	low

where: P is the energy required to pair two electrons with opposite spin

Δ is the difference in energy between subsets of d orbitals.

(A) From the information in the table, give two conclusions.   **2**

(B) Write the name of the complex ion $[CoF_6]^{3-}$.   **1**

(C) Complete the diagram to show the arrangement of the d electrons in $[CoF_6]^{3-}$.   **1**

(An additional diagram, if required, can be found on *page 34*.)
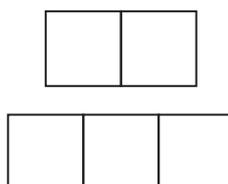
6. Jaundice is a condition caused by a yellow compound in the body called bilirubin.

The structure of bilirubin has two chromophores.

(a)   (i)   Circle one of the chromophores in the structure of bilirubin below.   **1**

(An additional diagram, if required, can be found on *page 34*.)
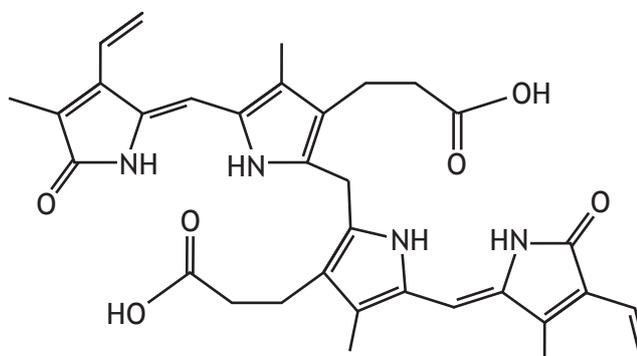
(ii)   Bilirubin is coloured due to the presence of bonding molecular orbitals and antibonding molecular orbitals.

State one difference between a bonding molecular orbital and an antibonding molecular orbital.   **1**

(b)   Bilirubin can have cis or trans isomerism.

(i)   Explain fully why cis and trans isomerism can exist in some compounds with carbon–carbon double bonds.   **2**

6. (b) (continued)

(ii) One isomer of bilirubin is insoluble in water due to the presence of internal hydrogen bonding.

On the diagram below draw a dotted line to show one internal hydrogen bond.

(An additional diagram, if required, can be found on *page 34*.)

1
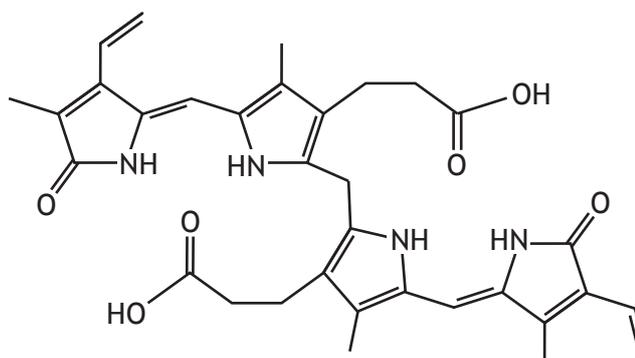
(c) One treatment for jaundice in new-born babies is to expose them to blue light. This causes the yellow bilirubin to change into compounds that can be excreted by the body.

(i) Suggest why blue light is used in this treatment.

1

(ii) Calculate the energy, in $kJ\,mol^{-1}$, associated with blue light with a wavelength of 465 nm.

2

7. Fertilisers and other garden chemicals may contain small quantities of different metals.

(a) The concentration of manganese(II) ions, Mn^{2+}, in a fertiliser can be determined by colorimetry.

5.66 g of fertiliser was weighed by difference, dissolved in deionised water and heated with a strong oxidising agent. The Mn^{2+} ions were oxidised to purple permanganate ions, MnO_4^-.

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

The resulting permanganate solution was transferred to a 100 cm^3 standard flask and made up to the mark with deionised water.

The absorbance of this solution was measured using a colorimeter. The concentration of the solution was then determined from a calibration graph.

(i) Describe fully the procedure of weighing by difference.　　　　**2**

7. (a) (continued)

(ii) The calibration graph obtained is shown below.

concentration of permanganate solution (mol l^{-1})
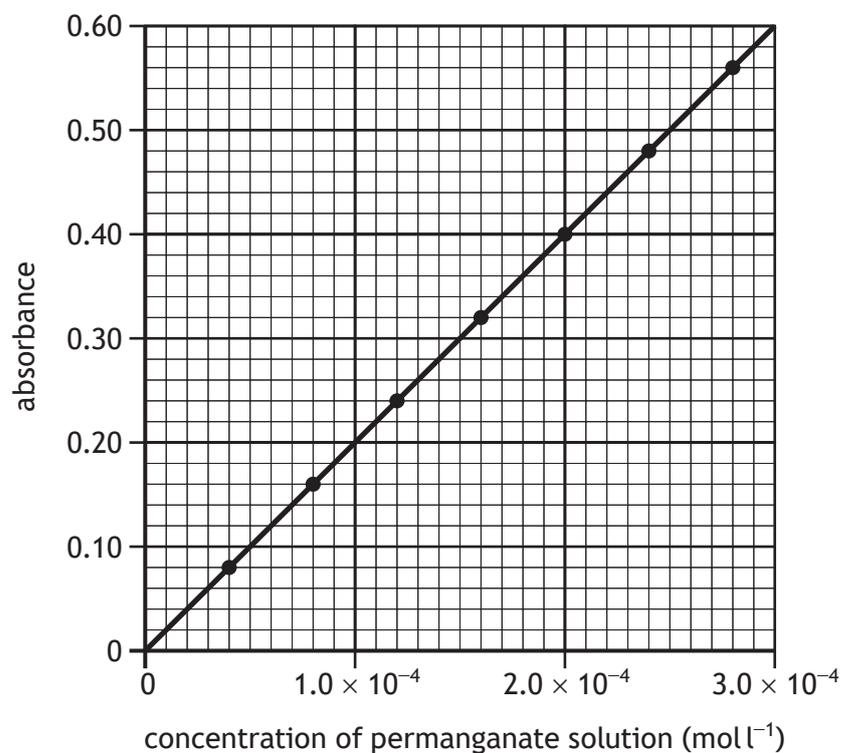
The absorbance of the permanganate solution was 0.42.

Use this information and the calibration graph to calculate the percentage by mass of manganese(II) ions in the fertiliser. **2**

7. (continued)

(b) Lawn sand, which is used to kill moss in lawns, contains iron(II) ions, Fe^{2+}.

The percentage of iron(II) ions in lawn sand can be determined by redox titration with standard acidified potassium dichromate solution, $K_2Cr_2O_7(aq)$.

(i) State one characteristic of potassium dichromate that makes it suitable for use as a primary standard.

1

(ii) A sample of lawn sand was mixed with dilute sulfuric acid. The solution was filtered into a 250 cm^3 standard flask with rinsing and made up to the mark with deionised water.

25.0 cm^3 samples of the iron(II) solution were titrated with 0.0050 mol l^{-1} acidified potassium dichromate solution and the average titre was found to be 21.4 cm^3.

$$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(\ell)$$
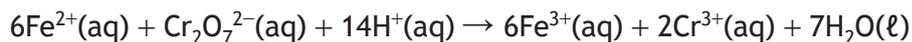
Calculate the mass, in g, of iron(II) ions in the lawn sand sample.

3

7. (b) (continued)

(iii) The titration can be carried out using diphenylbenzidine indicator. Diphenylbenzidine is oxidised to a violet compound at the end-point.

The oxidised form of this indicator contains a conjugated system.
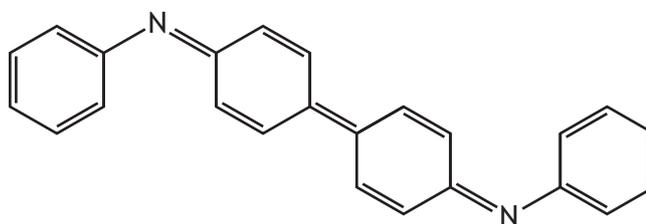
oxidised form of diphenylbenzidine

Explain fully how the violet colour arises in the oxidised form of diphenylbenzidine.

2

[Turn over

8. Acid chlorides are useful reagents in organic synthesis.

(a) Ethanoyl chloride is an acid chloride that can be prepared by the reaction between ethanoic acid and phosphorus trichloride.

$$3CH_3COOH + PCl_3 \rightarrow 3CH_3COCl + X$$
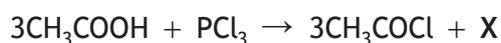
Write a formula for **X**.

1

(b) Propanoyl chloride reacts with 3-methylpentan-2-ol to form an ester. The first step in this reaction involves nucleophilic attack.

(i) State what is meant by the term nucleophile.

1

(ii) Add a curly arrow between the structures below to show the nucleophilic attack step.

1

(An additional diagram, if required, can be found on *page 35*.)
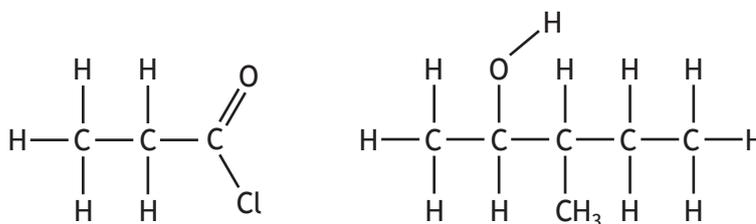
8. (b) (continued)

    (iii) Draw a structural formula for the ester formed in this reaction.   **1**

    (iv) Name the other product of this reaction.   **1**

    (v) State why acid chlorides are preferred to carboxylic acids for the preparation of esters.   **1**

(c) Acid chlorides react with some amines.
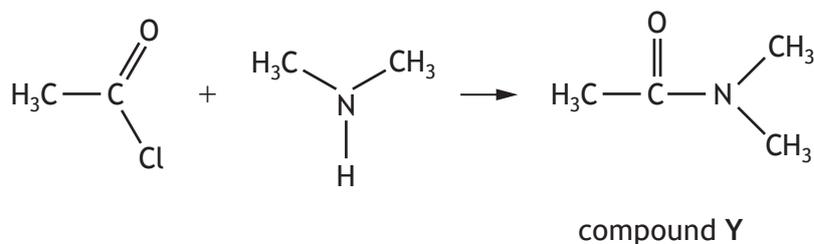
compound **Y**

    (i) State the type of amine used in this reaction.   **1**

    (ii) State the class of compound to which compound **Y** belongs.   **1**

8. (continued)

(d) Benzophenone is used as a fragrance enhancer in some cosmetic products. It can be produced by reacting benzoyl chloride with benzene in the presence of aluminium chloride.

benzoyl chloride   benzophenone
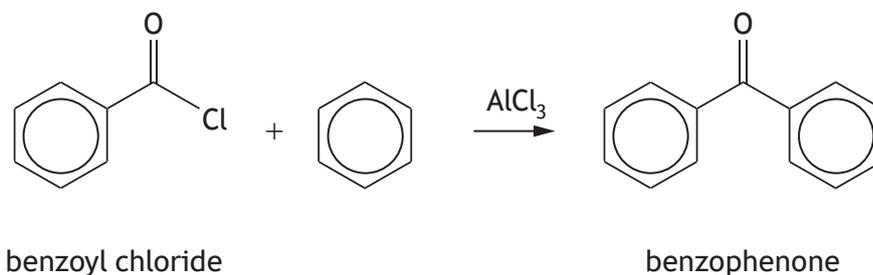
(i) Suggest a name for the type of reaction taking place. **1**

(ii) 21.8 g of benzoyl chloride ($GFM = 140.5$ g) was reacted with excess benzene, producing 18.4 g of benzophenone ($GFM = 182$ g).

Calculate the percentage yield. **2**

9. Haloalkanes can react with sodium hydroxide in elimination reactions and nucleophilic substitution reactions.

A student reacted 2-bromopentane with sodium hydroxide in ethanol. Analysis of the reaction mixture showed a complex mixture of products.

Using your knowledge of chemistry, suggest how these products might form and how they could be identified.

3

10. Eucalyptol is a natural antagonist that is used as an anti-inflammatory drug.
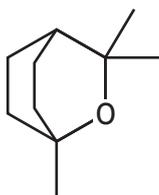
eucalyptol

(a) State what is meant by the term antagonist. **1**

(b) Homeopathy is an alternative therapy based on the use of highly diluted substances.

500 cm^3 of a stock solution was prepared by diluting eucalyptol with water by a factor of one in one hundred.

(i) State the volume, in cm^3, of eucalyptol required to prepare this stock solution. **1**

(ii) Eucalyptol (GFM = 154 g) has a density of 0.921 g cm^{-3}.

Calculate the concentration, in mol l^{-1}, of the stock solution. **2**

(iii) A homeopathic solution of eucalyptol was prepared by further dilution giving a concentration of 9.97×10^{-24} mol l^{-1}.

The number of molecules in 1 mole of eucalyptol is 6.02×10^{23}.

Calculate the number of molecules in 1 litre of the homeopathic solution. **1**

11. Caffeine is found in many soft drinks. It acts as an adenosine receptor antagonist. Adenosine is a chemical that binds to receptors in the brain and promotes sleep.

The structures of caffeine and adenosine are shown.
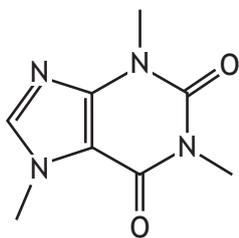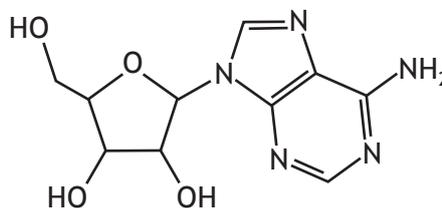
caffeine   adenosine

(a)   (i)   Write the molecular formula for caffeine.   **1**

    (ii) Suggest why caffeine and adenosine can bind to the same receptors.   **1**

[Turn over

11. **(continued)**

(b) 100 cm^3 of a soft drink contained 32 mg of caffeine. The caffeine was separated by solvent extraction using dichloromethane.

The following equilibrium was established.

caffeine (aq) $\rightleftharpoons$ caffeine (dichloromethane)

(i) To determine the equilibrium constant, a single extraction of caffeine was carried out using 100 cm^3 of the soft drink and 60 cm^3 of dichloromethane. The mass of caffeine in the dichloromethane was found to be 23.5 mg.

(A) Outline the steps that would have been carried out to extract the caffeine.

2

(B) Calculate the equilibrium constant, K, for this extraction.

3

(ii) Suggest an improvement to the procedure that would maximise the mass of caffeine extracted from 100 cm^3 of the soft drink using 60 cm^3 of dichloromethane.

1

11. (continued)

(c) A zwitterion is a molecule with positive and negative charges on different atoms. Overall, the zwitterion molecule is electrically neutral.

Caffeine can form a zwitterion due to the movement of electrons within the molecule as shown.
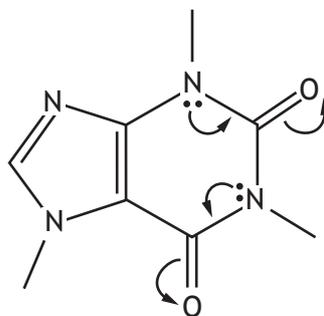
Complete the diagram below to show all the charges on the caffeine zwitterion resulting from the movement of electrons.   **1**

(An additional diagram, if required, can be found on *page 35*.)

[END OF QUESTION PAPER]