NSW GOVERNMENT

NSW Education Standards Authority

2022 HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2–12)

- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 13–36)

- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1–20.

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1 What term is used to define the repeating unit of a polymer?

A. Dimer

B. Isomer

C. Monomer

D. Primer

2 When a solution of a primary standard is prepared for titration, which of the following is required?

A. A burette

B. A balance

C. An indicator

D. A condenser

3 Which of the following features is NOT a characteristic of a state of equilibrium?

A. Equilibrium is achieved in a closed system.

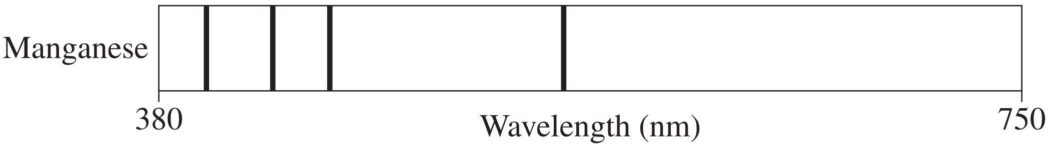
B. Equilibrium position depends on temperature.

C. Equilibrium can be reached from either direction.

D. Equilibrium concentrations of reactants and products are equal.

4 An analytical chemist was using atomic absorption spectroscopy (AAS) to determine the manganese concentration in a sample.

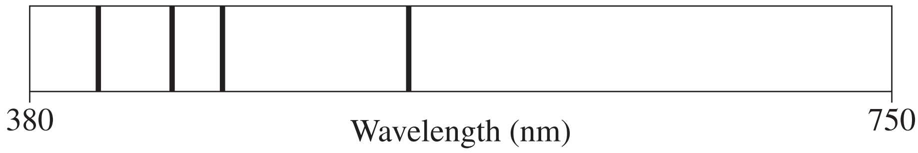
The following diagram shows the absorbance lines of manganese.



The diagrams below show the emission spectra of four AAS lamps.

Which lamp should be used to determine the manganese concentration in the sample?

A.



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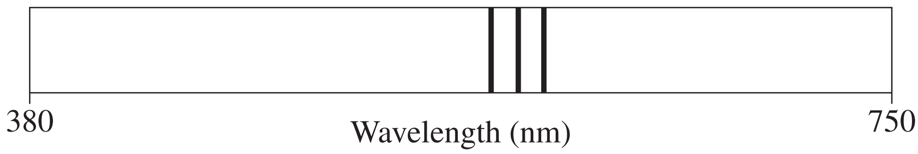

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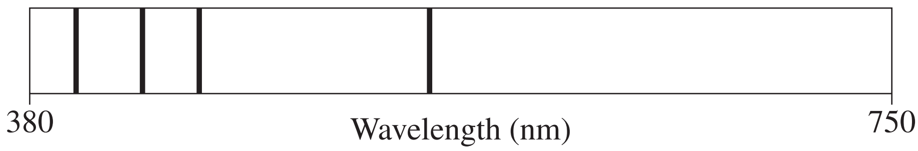

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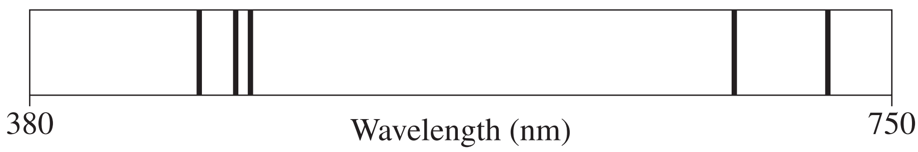


5 Which pair of ions can be distinguished using a flame test in the school laboratory?

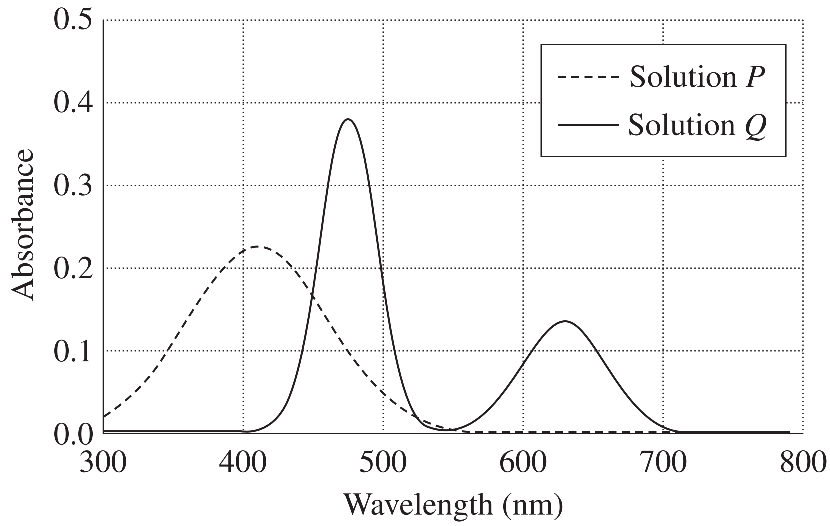
A. Ag^{+} and Mg^{2+}

B. Ba^{2+} and Ca^{2+}

C. Br^{-} and Cl^{-}

D. Fe^{2+} and Fe^{3+}

6 A UV-visible spectrometer was used to obtain the spectra of solutions of substances *P* and *Q*. The absorbance spectra are shown.



Which wavelength would be appropriate to determine the concentration of *Q* in a mixture of the two solutions?

A. 410 nm

B. 475 nm

C. 550 nm

D. 630 nm

7 The name 2-ethyl-3-chlorohexane does not follow IUPAC conventions.

What is the systematic name of this organic compound?

A. 3-chloro-2-ethylhexane

B. 4-chloro-3-methylheptane

C. 4-chloro-5-ethylhexane

D. 5-methyl-4-chloroheptane

8 A system is described as follows.

$$2NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

What is the equilibrium expression for this system?

A. $K_{eq} = [CO_2]$

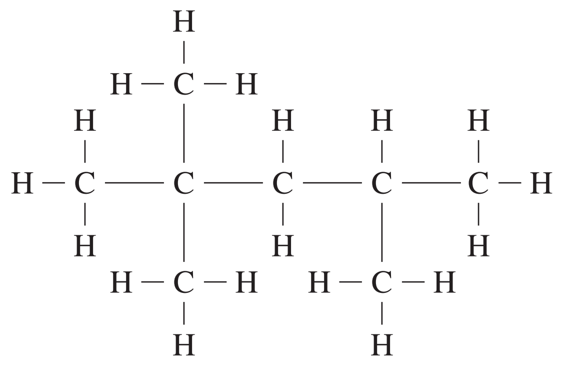
B. $K_{eq} = [CO_2][H_2O]$

C. $K_{eq} = \dfrac{1}{[CO_2][H_2O]}$

D. $K_{eq} = \dfrac{[Na_2CO_3][CO_2][H_2O]}{[NaHCO_3]^2}$

9 What is the structure of $CH_3C(CH_3)_2CH_2CH(CH_3)_2$?

A.



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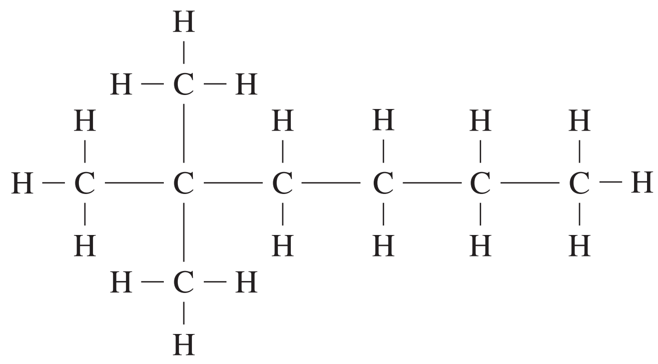
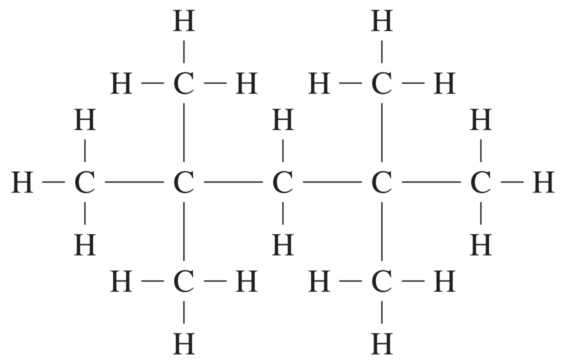
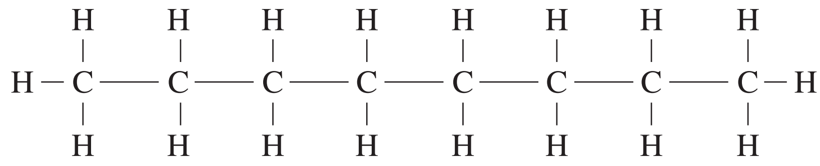


C.



D.



10 Which equation shows the hydrogen carbonate ion acting as a Brønsted–Lowry acid?

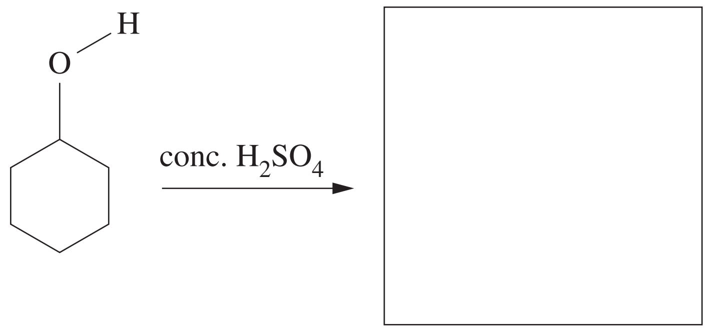
A. $HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq)$

B. $HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$

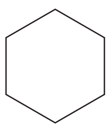
C. $HCO_3^-(aq) + NH_3(aq) \rightleftharpoons CO_3^{2-}(aq) + NH_4^+(aq)$

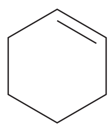
D. $HCO_3^-(aq) + HCOOH(aq) \rightleftharpoons HCOO^-(aq) + H_2CO_3(aq)$

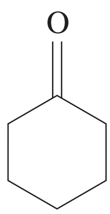
11 Cyclohexanol is an alcohol and undergoes a dehydration reaction with sulfuric acid as shown.

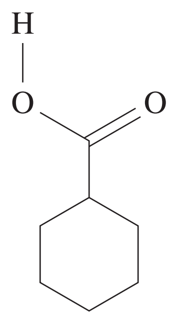


What is the major organic product of this reaction?

A. 

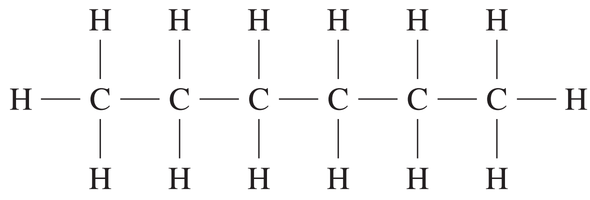
B. 

C. 

D. 

12 Which isomer of C_6H_{14} would have the fewest signals in ^{13}C NMR?

A.



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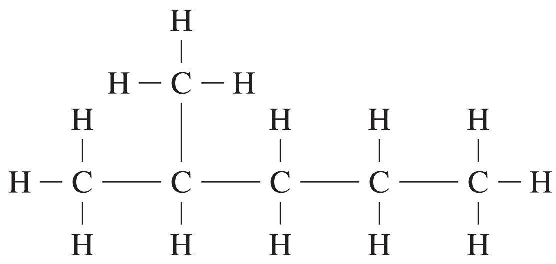

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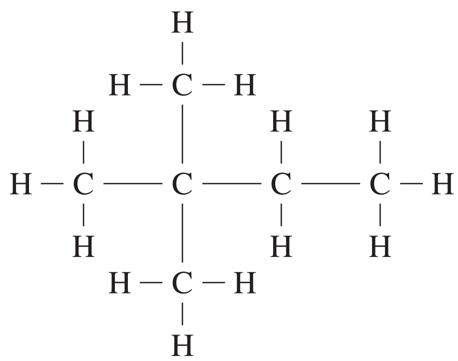
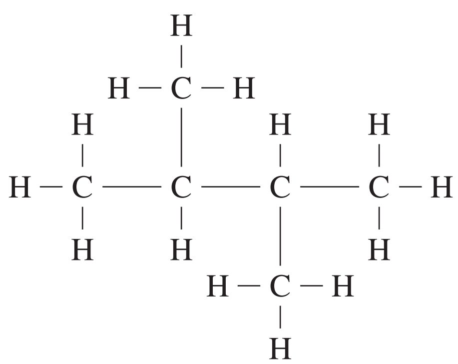


D.



13 Nitrosyl bromide decomposes according to the following equation.

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$$

A 0.64 mol sample of NOBr is placed in an evacuated 1.00 L flask. After the system comes to equilibrium, the flask contains 0.46 mol NOBr.

What are the concentrations of NO and Br_2 in the flask at equilibrium?

	$[NO]$ (mol L^{-1})	$[Br_2]$ (mol L^{-1})
A.	0.18	0.09
B.	0.18	0.18
C.	0.36	0.18
D.	0.92	0.46

14 Nitrogen dioxide can react with itself to produce dinitrogen tetroxide.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad K_{eq} = 0.010$$

In an experiment, 100.0 cm^3 of NO_2 is placed in a syringe. The plunger is then pushed in until the volume is 50.0 cm^3, while maintaining a constant temperature. The system is allowed to return to equilibrium.

Which statement is true for the system at equilibrium?

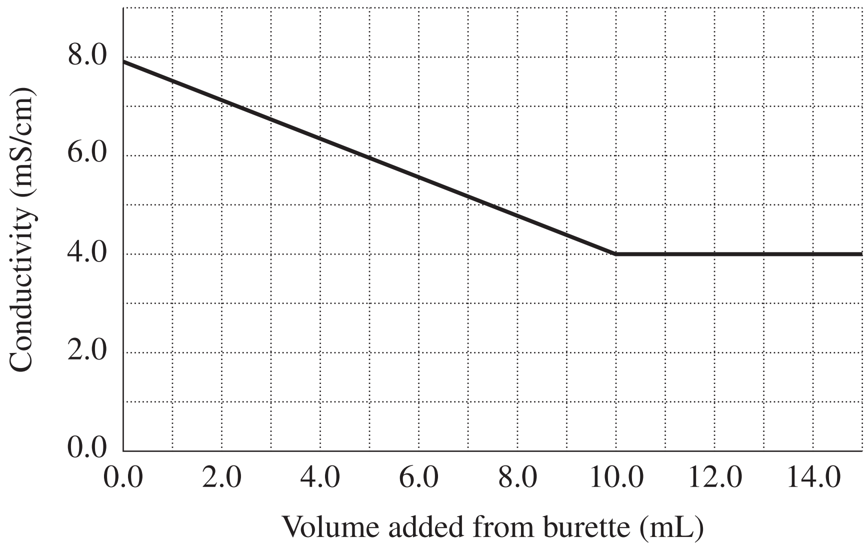
A. The value of K_{eq} has increased.

B. The ratio $\frac{[NO_2]}{[N_2O_4]}$ has decreased.

C. The concentration of N_2O_4 has decreased.

D. The concentrations of NO_2 and N_2O_4 have doubled.

15 A 25.00 mL sample of 0.1131 mol L^{-1} HCl(*aq*) was titrated with an aqueous ammonia solution. The conductivity of the solution was measured throughout the titration and the results graphed.



What was the concentration of the ammonia solution?

A. 0.0452 mol L^{-1}

B. 0.189 mol L^{-1}

C. 0.283 mol L^{-1}

D. 0.690 mol L^{-1}

16 A blue solution of copper(II) sulfate was investigated using colourimetry. Orange light (λ = 630 nm) was used and the pathlength was 1.00 cm.

Which change would result in a higher absorbance value?

A. Diluting the solution

B. Using a higher intensity lamp

C. Using blue light (λ = 450 nm)

D. Setting the pathlength to 2.00 cm

17 A 2.0 g sample of silver carbonate ($MM = 275.81\ \text{g mol}^{-1}$) was added to 100.0 mL of water in a beaker. The solubility of silver carbonate at this temperature is $1.2 \times 10^{-4}\ \text{mol L}^{-1}$. It was then diluted by adding another 100.0 mL of water.

What is the ratio of the concentration of silver ions in solution before and after dilution?

A. 1 : 1

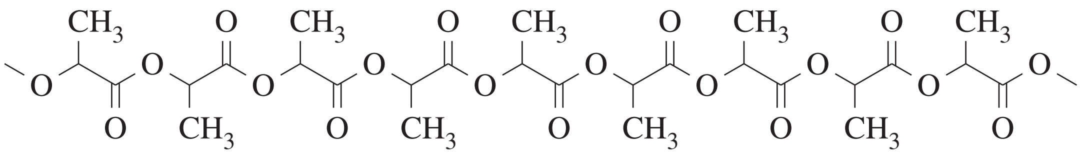
B. 1 : 2

C. 2 : 1

D. 4 : 1

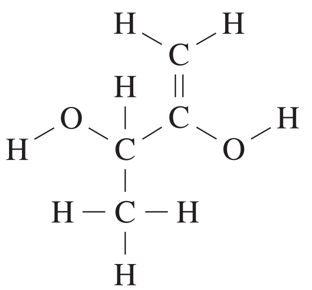
18 A low molecular weight biopolymer is being investigated for its suitability for medical use. In one trial a molecular weight of $2900 \pm 100\ \text{g mol}^{-1}$ proved to be optimum.

A section of this biopolymer is shown.



Which will produce the suitable biopolymer?

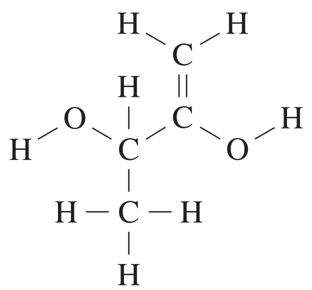
A.



Molar mass: $88.01\ \text{g mol}^{-1}$

Number of units: 42

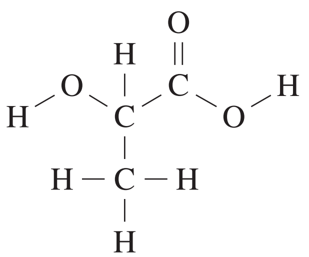
B.



Molar mass: $88.01\ \text{g mol}^{-1}$

Number of units: 33

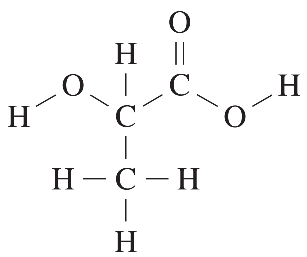
C.



Molar mass: $90.078\ \text{g mol}^{-1}$

Number of units: 32

D.



Molar mass: $90.078\ \text{g mol}^{-1}$

Number of units: 40

19 What is the molar solubility of iron(II) hydroxide?

A. 2.3×10^{-6} mol L^{-1}

B. 2.9×10^{-6} mol L^{-1}

C. 3.7×10^{-6} mol L^{-1}

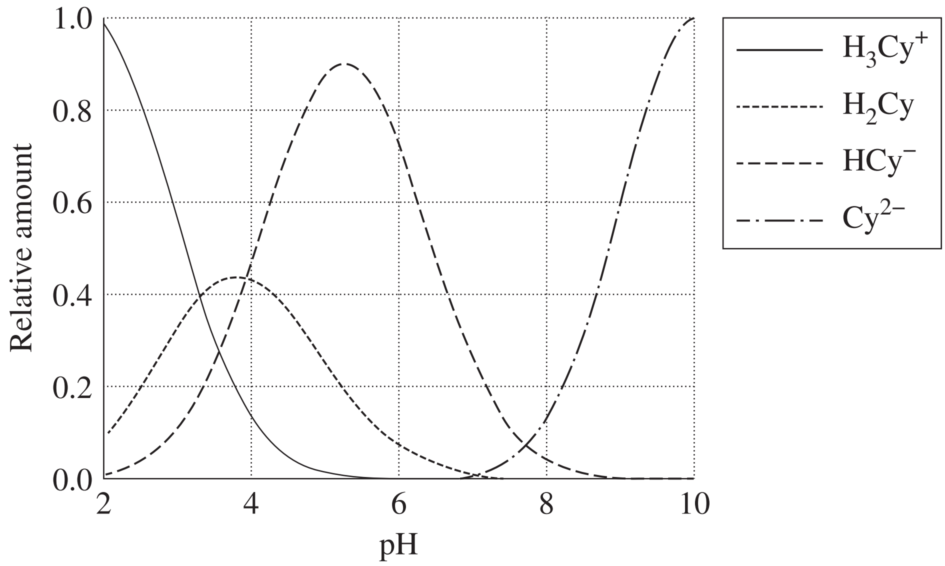
D. 4.9×10^{-9} mol L^{-1}

20 Cyanidin is a plant pigment that may be used as a pH indicator. It has four levels of protonation, each with a different colour, represented by these equilibria:

$$H_3Cy^+ \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} H_2Cy \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} HCy^- \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} Cy^{2-}$$

Red   Colourless   Purple   Blue

The following graph shows the relative amount of each species present at different pH values.



What colour would the indicator be if added to a 0.75 mol L^{-1} solution of hypoiodous acid, HIO ($pK_a = 10.64$)?

A. Red

B. Colourless

C. Purple

D. Blue

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2022 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–36
Allow about 2 hours and 25 minutes for this section

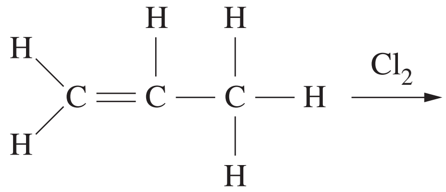
Instructions

- Write your Centre Number and Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (2 marks)

Prop-1-ene reacts with Cl_2 in an addition reaction. In the box given, draw the structural formula of the product of this reaction. **2**



Question 22 (2 marks)

The following equation describes an equilibrium reaction. **2**

$$HF(aq) + PO_4^{3-}(aq) \rightleftharpoons HPO_4^{2-}(aq) + F^-(aq)$$

Identify ONE base and its conjugate acid in the above equation.

Base	*Conjugate acid*

Please turn over

Question 23 (6 marks)

Consider the following system which is at equilibrium in a rigid, sealed container.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -950 \text{ kJ mol}^{-1}$$

(a) Identify what would happen to the amount of $NO(g)$ if the temperature was increased. **1**

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(b) Explain why a catalyst does not affect the equilibrium position of this system. **2**

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(c) Using collision theory, explain what would happen to the concentration of $NO(g)$ if $H_2O(g)$ was removed from the system. **3**

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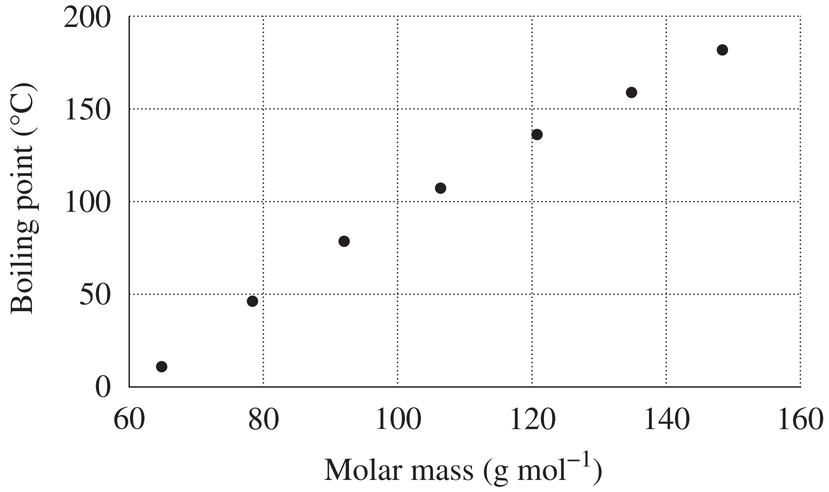
Question 24 (3 marks)

The following graph shows the boiling points of some 1-chloroalkanes. **3**



Explain the trend shown in the graph.

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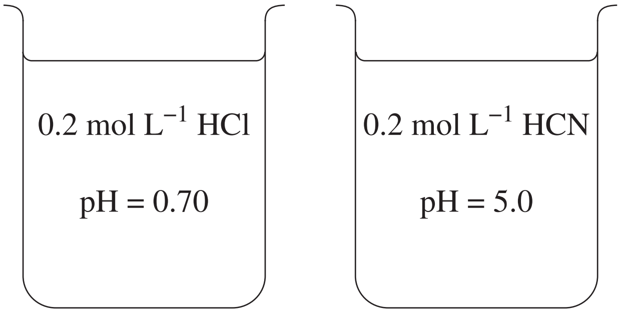
Question 25 (3 marks)

The pH of two aqueous solutions was compared. **3**



Explain why the HCN(*aq*) solution has a higher pH than the HCl(*aq*) solution. Include a relevant chemical equation for the HCN(*aq*) solution.

Do NOT write in this area.

Question 26 (4 marks)

Students conducted an experiment to determine ΔH for the reaction between sodium hydroxide and hydrochloric acid.

The data from one student are shown in the table below.

Mass of 100.0 mL of 0.50 mol L^{-1} HCl	100.7 g
Mass of 100.0 mL of 0.50 mol L^{-1} NaOH	102.0 g
Initial temperature of HCl solution	21.0°C
Initial temperature of NaOH solution	21.2°C
Final temperature of mixture	24.4°C

Assume that all the solutions have the same specific heat capacity as water.

(a) Calculate the heat energy released in this experiment. **2**

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(b) A second student using the same procedure obtained 2.6×10^3 J for the heat energy released in their experiment. **2**

Use this value to determine the enthalpy of neutralisation, ΔH, in kJ mol^{-1}, for the reaction shown.

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

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Question 27 (7 marks)

A bottle labelled 'propanol' contains one of two isomers of propanol.

(a) Draw the TWO isomers of propanol. **2**

(b) Describe how ^{13}C NMR spectroscopy might be used to identify which isomer is in the bottle. **2**

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(c) Each isomer produces a different product when oxidised. **3**

Write equations to represent the oxidation reactions of the two isomers. Include reaction conditions.

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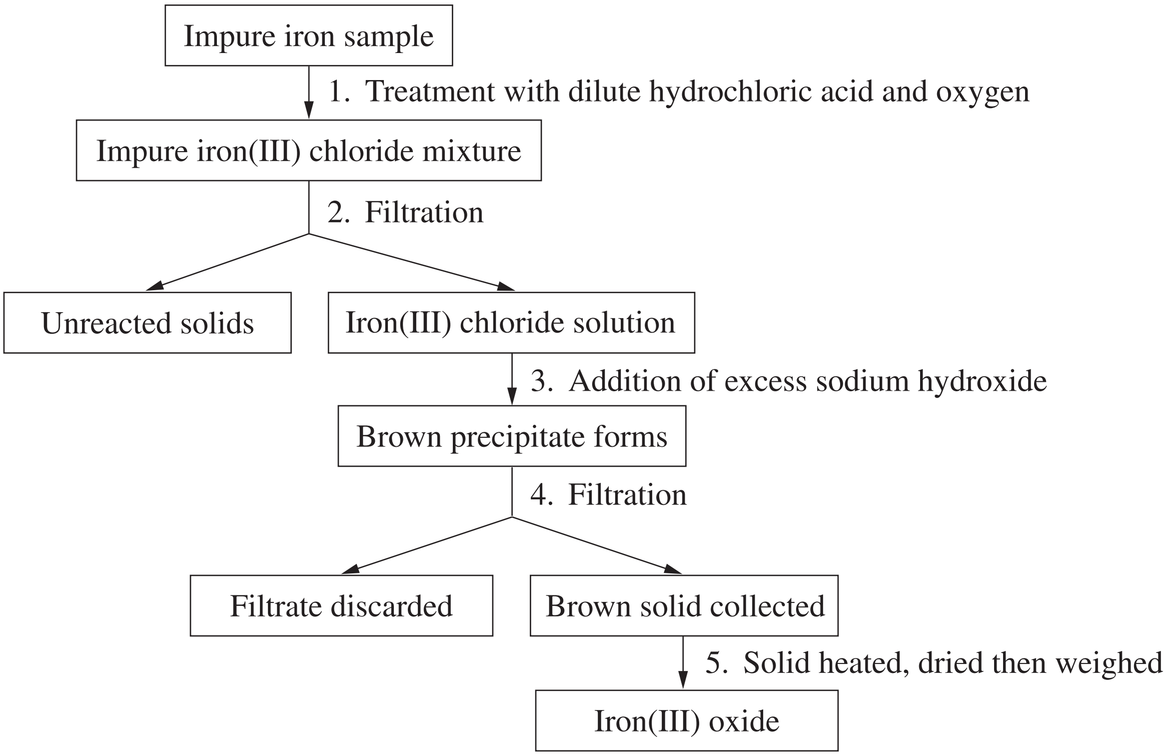
Question 28 (5 marks)

The iron content of an impure sample (4.32 g) was determined by the process shown in the flow chart.



(a) Identify the brown precipitate formed at the end of step 3. **1**

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(b) Calculate the percentage of iron in the original impure sample if 4.21 g of iron(III) oxide (Fe_2O_3) was collected. Assume that all the iron was converted to iron(III) oxide. **4**

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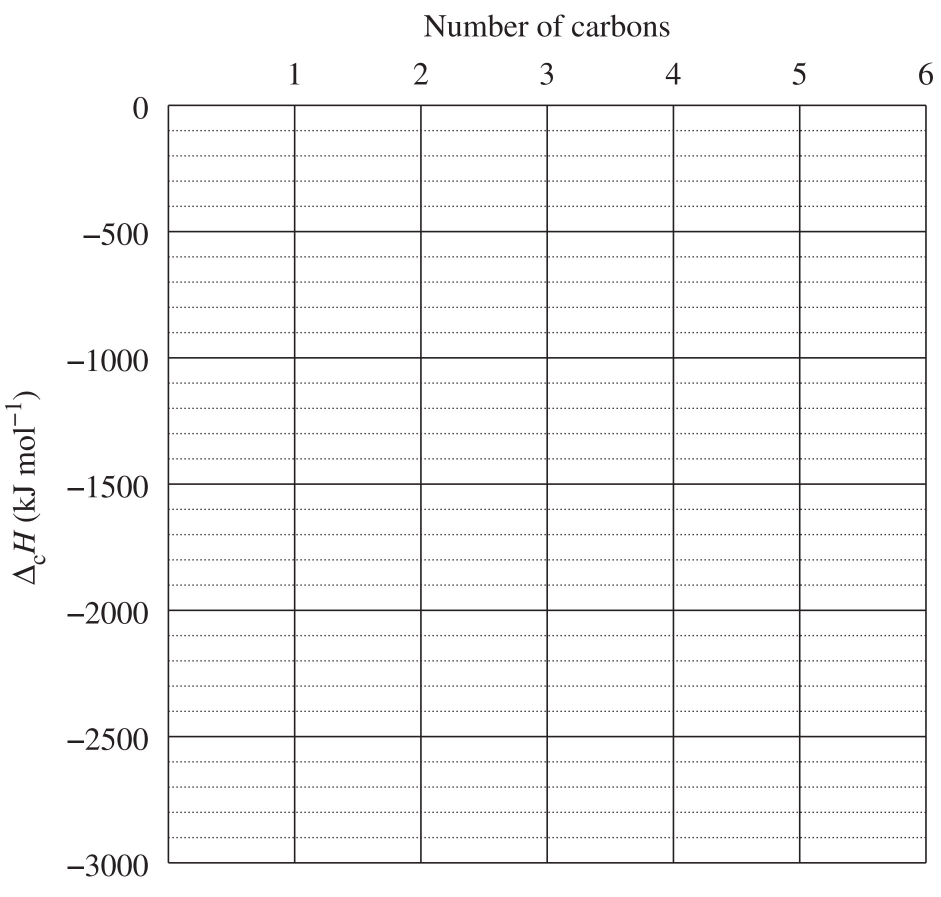
Question 29 (5 marks)

The enthalpies of combustion of four alcohols were determined in a school laboratory.

The results are shown in the table.

Alcohol	$\Delta_c H$ (kJ mol^{-1})
Methanol	–596
Ethanol	–978
Propan-1-ol	–1507
Pentan-1-ol	–2910

(a) Plot the results, including a curved line of best fit, to estimate the enthalpy of combustion of butan-1-ol. **3**



Enthalpy of combustion of butan-1-ol

Question 29 continues on page 23

Question 29 (continued)

(b) The published value for the enthalpy of combustion of pentan-1-ol is closer to -3331 kJ mol^{-1}. **2**

Justify ONE possible reason for the difference between the school's results and published values.

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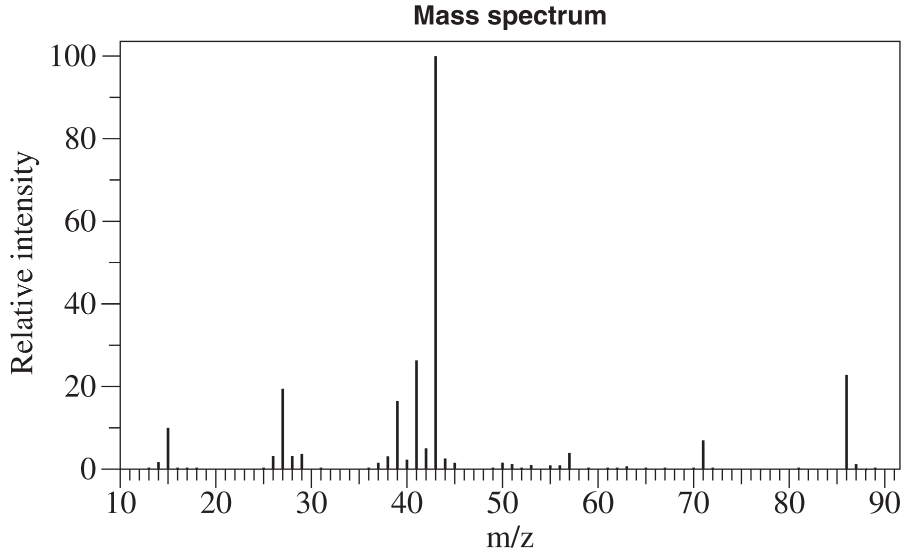
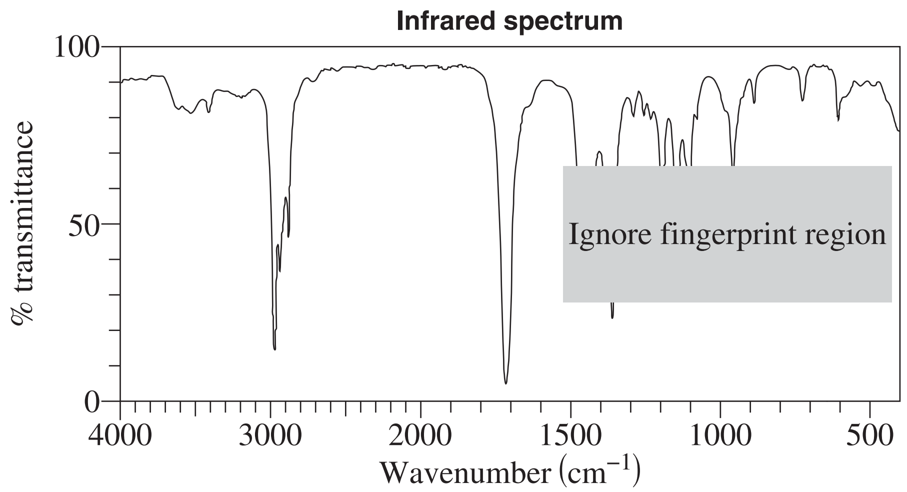
End of Question 29

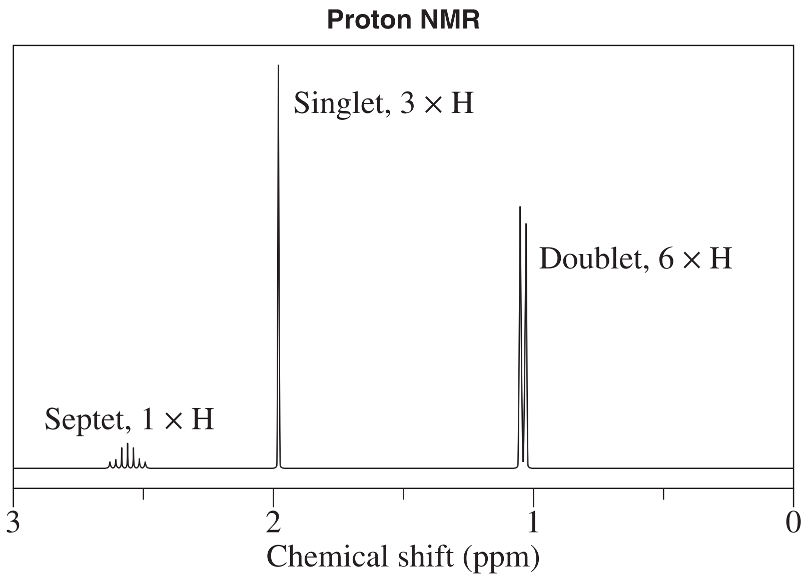
Please turn over

Question 30 (7 marks)

The following spectra were obtained for an unknown organic compound. **7**



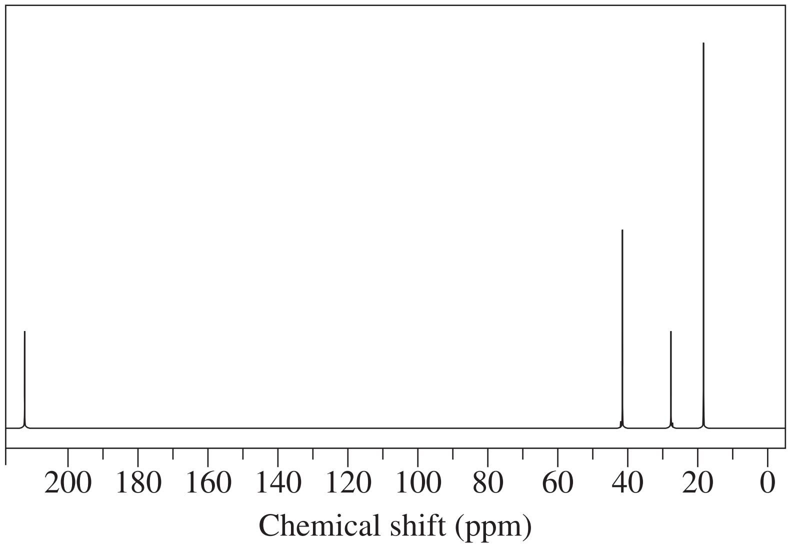




Question 30 continues on page 25

Question 30 (continued)

Carbon-13 NMR



In the space provided, draw and name the unknown compound that is consistent with all the information provided. Justify your answer with reference to the information provided.

Structure:

Name: ....

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Question 30 continues on page 26

Question 30 (continued)

End of Question 30

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Do NOT write in this area.

Question 31 (7 marks)

Silver ions form the following complex with ammonia solution.

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons \left[Ag(NH_3)_2\right]^+(aq)$$

The equilibrium constant is 1.6×10^7 at 25°C.

(a) In order to determine the free Ag^+ concentration in an aqueous ammonia solution, a student carried out a precipitation titration with NaI(*aq*) as the titrant. **3**

Evaluate the suitability of this method.

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(b) If 0.010% of the total silver ions in solution are present as $Ag^+(aq)$ at equilibrium, calculate the equilibrium concentration of aqueous ammonia in this solution. **4**

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Question 32 (8 marks)

The concentration of citric acid, a triprotic acid, in a carbonated soft drink was to be determined.

Step 1: A solution of NaOH(*aq*) was standardised by titrating it against 25.00 mL aliquots of a solution of the monoprotic acid potassium hydrogen phthalate (KHP). The KHP solution was produced by dissolving 4.989 g in enough water to make 100.0 mL of solution. The molar mass of KHP is 204.22 g mol^{-1}.

The results of the standardisation titration are given in the table.

Titration	*Volume NaOH* (mL)
1	28.60
2	27.40
3	27.20
4	27.60

Step 2: A 75.00 mL bottle of the drink was opened and the contents quantitatively transferred to a beaker. The soft drink was gently heated to remove CO_2.

Step 3: The cooled drink was quantitatively transferred to a 250.0 mL volumetric flask and distilled water was added up to the mark.

Step 4: 25.00 mL samples of the solution were titrated with the NaOH(*aq*) solution. The average volume of NaOH(*aq*) used was 13.10 mL.

Question 32 continues on page 29

(a) Calculate the concentration of the triprotic citric acid in the soft drink. **6**

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(b) Explain how your answer to part (a) would be different if the carbon dioxide was not removed from the soft drink. **2**

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End of Question 32

Question 33 (8 marks)

Analyse how a student could design a chemical synthesis process to be undertaken in the school laboratory. In your response, use a specific process relating to the synthesis of an organic compound, including a chemical equation, and refer to: **8**

- selection of reagent(s)
- reaction conditions
- any potential hazards and any safety precautions to minimise the risk
- yield and purity of the product(s).

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Question 33 continues on page 31

Question 33 (continued)

End of Question 33

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Question 34 (4 marks)

Sodium hypochlorite (NaOCl) is the active ingredient in pool chlorine. It completely dissolves in water to produce the hypochlorite ion (OCl^-), which undergoes hydrolysis according to the following equilibrium. **4**

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

The equilibrium constant for this reaction at 25°C is 3.33×10^{-7}.

For pool chlorine to be effective the pH is maintained by a different buffer at 7.5 and the hypochlorous acid (HOCl) concentration should be 1.3×10^{-4} mol L^{-1}.

Calculate the volume of 2.0 mol L^{-1} sodium hypochlorite solution that needs to be added to a 1.00×10^4 L pool to meet the required conditions.

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Question 35 (5 marks)

A precipitate of strontium hydroxide $Sr(OH)_2$, (MM = 121.63 g mol^{-1}) was produced when 80.0 mL of 1.50 mol L^{-1} strontium nitrate solution was mixed with 80.0 mL of 0.855 mol L^{-1} sodium hydroxide solution. The mass of the dried precipitate was 3.93 g. **5**

What is the K_{sp} of strontium hydroxide?

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Question 36 (4 marks)

Consider the equilibrium system shown. **4**

$$H_2O(l) \rightleftharpoons H_2O(g)$$

In a laboratory at 23°C, a 100 mL sample of water is held in a beaker and another 100 mL sample is held in a sealed bottle.

Explain the differences in evaporation for these TWO samples. In your answer, consider changes in enthalpy and entropy for this process.

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Section II extra writing space

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Chemistry

FORMULAE SHEET

$n = \frac{m}{MM}$	$c = \frac{n}{V}$	$PV = nRT$
$q = mc\Delta T$	$\Delta G° = \Delta H° - T\Delta S°$	$\text{pH} = -\log_{10}[\text{H}^+]$
$pK_a = -\log_{10}[K_a]$	$A = \varepsilon lc = \log_{10}\frac{I_o}{I}$	

Avogadro constant, N_A	6.022×10^{23} mol^{-1}
Volume of 1 mole ideal gas: at 100 kPa and at 0°C (273.15 K)	22.71 L
at 25°C (298.15 K)	24.79 L
Gas constant	8.314 J mol^{-1} K^{-1}
Ionisation constant for water at 25°C (298.15 K), K_w	1.0×10^{-14}
Specific heat capacity of water	4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

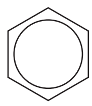
Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
Silver iodide	8.52×10^{-17}
Silver phosphate	8.89×10^{-17}
Silver sulfate	1.20×10^{-5}

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
—C—C— (with bonds above and below each C)		5–40
R—C—Cl or Br (with bonds above and below C)		10–70
R—C(=O)—C— (with bonds above and below the second C)		20–50
R—C—N< (with bonds above and below C)		25–60
—C—O— (with bonds above and below C)	alcohols, ethers or esters	50–90
>C=C<		90–150
R—C≡N		110–125
		110–160
R—C(=O)—	esters or acids	160–185
R—C(=O)—	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for the standard potentials. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.