BOARD OF STUDIES
NEW SOUTH WALES

2009

HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet and a Periodic Table are provided at the back of this paper
- Write your Centre Number and Student Number at the top of pages 9, 11, 13, 15 and 17

Total marks – 100

Section I Pages 2–20

75 marks

This section has two parts, Part A and Part B

Part A – 15 marks

- Attempt Questions 1–15
- Allow about 30 minutes for this part

Part B – 60 marks

- Attempt Questions 16–26
- Allow about 1 hour and 45 minutes for this part

Section II Pages 21–33

25 marks

- Attempt ONE question from Questions 27–31
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 15 marks
Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet for Questions 1–15.

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1 Which of the following is an important factor in predicting the nuclear stability of an isotope?

(A) Atomic radius

(B) Nuclear radius

(C) The ratio of neutrons to protons

(D) The ratio of electrons to protons

2 Unpolluted rain water in New South Wales is slightly acidic.

Which substance is the major contributor to this acidity?

(A) Ozone

(B) Sulfur dioxide

(C) Carbon dioxide

(D) Nitrogen dioxide

3 Which of the following groups contains ONLY acidic substances?

(A) Antacid tablets, baking soda, laundry detergents

(B) Blood, oven cleaner, seawater

(C) Milk, tea, drain cleaner

(D) Vinegar, wine, aspirin

4 What flame colour is produced by barium ions in a flame test?

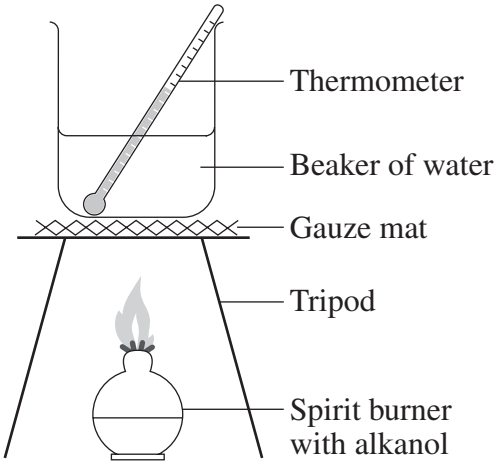
(A) Red

(B) Blue

(C) Green

(D) Orange

5 The apparatus shown is used in a first-hand investigation to determine and compare the heat of combustion of three different liquid alkanols.



Which is the independent variable?

(A) Type of alkanol used

(B) Amount of water used

(C) Amount of alkanol used

(D) Temperature change in the water

6 Bromine, Br_2, dissolves in unsaturated hydrocarbons and reacts immediately.

Which of the following is the best description of this process?

(A) Bromine is polar and reacts by adding bromine atoms across the double bond.

(B) Bromine is polar and reacts by substituting hydrogen atoms with bromine atoms.

(C) Bromine is non-polar and reacts by substituting hydrogen atoms with bromine atoms.

(D) Bromine is non-polar and reacts by adding bromine atoms across the double bond.

7 What is the conjugate base of HSO_4^-?

(A) SO_3^{2-}

(B) SO_4^{2-}

(C) H_2SO_4

(D) HSO_3^-

8 Three separate colourless solutions each contain one cation, Na^+, Pb^{2+} or Ca^{2+}.

Which of the following would be an appropriate reagent to unambiguously identify the solution containing Pb^{2+}?

(A) KI

(B) K_2CO_3

(C) K_3PO_4

(D) $AgNO_3$

9 One test used for random breath testing in NSW involved crystals of potassium dichromate reacting with ethanol. In this reaction the orange dichromate ion, $Cr_2O_7^{2-}$, changes to the green chromium ion, Cr^{3+}.

Which statement is true for this reaction?

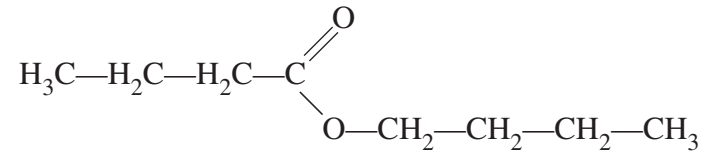
(A) Chromium has lost electrons and reached a lower oxidation state.

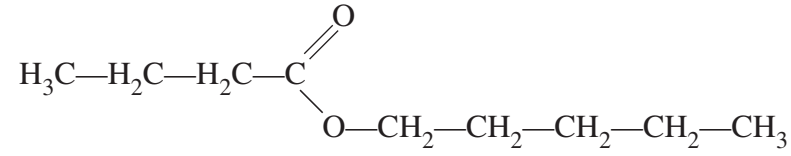
(B) Chromium has lost electrons and reached a higher oxidation state.

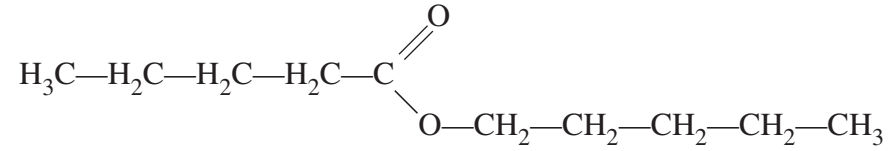
(C) Chromium has gained electrons and reached a lower oxidation state.

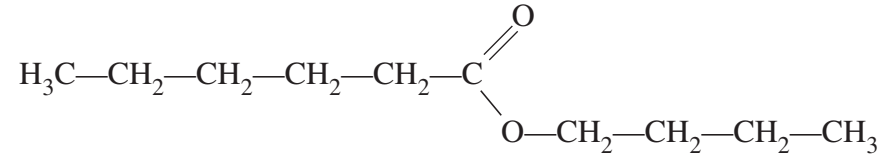
(D) Chromium has gained electrons and reached a higher oxidation state.

10 Which of the following is the main organic product resulting from the reaction of butanoic acid and pentanol?

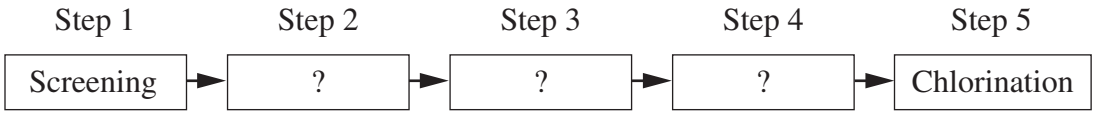
(A) 

(B) 

(C) 

(D) 

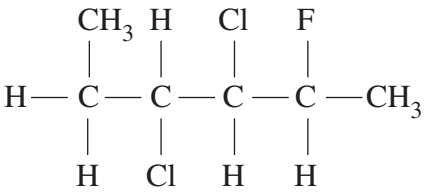
11 The following process is used to purify water for drinking.



Which sequence represents the correct order of Steps 2, 3 and 4?

	Step 2	*Step 3*	*Step 4*
(A)	Flocculation	pH adjustment	Settling
(B)	pH adjustment	Flocculation	Settling
(C)	pH adjustment	Settling	Flocculation
(D)	Flocculation	Settling	pH adjustment

12 What is the IUPAC name of the following compound?



(A) 3,4–dichloro–2–fluorohexane

(B) 3,4–dichloro–5–fluorohexane

(C) 2–fluoro–3,4–dichlorohexane

(D) 5–fluoro–3,4–dichlorohexane

13 In a fermentation experiment 6.50 g of glucose was completely converted to ethanol and carbon dioxide.

What is the mass of carbon dioxide produced?

(A) 1.59 g

(B) 3.18 g

(C) 9.53 g

(D) 13.0 g

14 Citric acid, the predominant acid in lemon juice, is a triprotic acid. A student titrated 25.0 mL samples of lemon juice with 0.550 mol L^{-1} NaOH. The mean titration volume was 29.50 mL. The molar mass of citric acid is 192.12 g mol^{-1}.

What was the concentration of citric acid in the lemon juice?

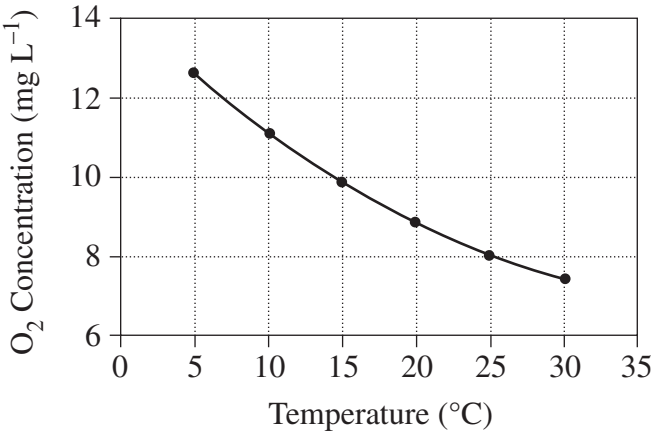
(A) 1.04 g L^{-1}

(B) 41.6 g L^{-1}

(C) 125 g L^{-1}

(D) 374 g L^{-1}

15 The graph shows the maximum dissolved oxygen concentration in water as a function of temperature at normal atmospheric pressure.



What is the volume of O_2 that can dissolve in 10.0 L of water at 25°C and normal atmospheric pressure?

(A) 62.0 mL

(B) 63.5 mL

(C) 80.0 mL

(D) 124 mL

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Chemistry

Centre Number

Student Number

Section I (continued)

Part B – 60 marks
Attempt Questions 16–26
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 16 (3 marks)

Describe how to prepare an ester in the school laboratory. Include a specific safety precaution in your answer. **3**

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Question 17 (4 marks)

Water and ethanol are both used as solvents. **4**

Explain the differences and similarities in their solvent behaviour in terms of their molecular structures. Include a diagram in your answer.

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Centre Number

Student Number

Section I – Part B (continued)

Question 18 (5 marks)

There has been an increase in the concentration of the oxides of nitrogen in the atmosphere as a result of combustion. **5**

Assess both the evidence to support this statement and the need to monitor these oxides.

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Question 19 (6 marks)

Outline the chemical and physical processes involved in the production of ONE of the following from a natural raw material: **6**

- a polyethylene bottle
- a polyvinyl chloride pipe
- a polystyrene cup.

Include relevant chemical equations in your answer.

Question 20 (4 marks)

(a) Calculate the mass of ethanol that must be burnt to increase the temperature of 210 g of water by 65°C, if exactly half of the heat released by this combustion is lost to the surroundings. **3**

The heat of combustion of ethanol is 1367 kJ mol^{-1}.

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(b) What are TWO ways to limit heat loss from the apparatus when performing a first-hand investigation to determine and compare heat of combustion of different liquid alkanols? **1**

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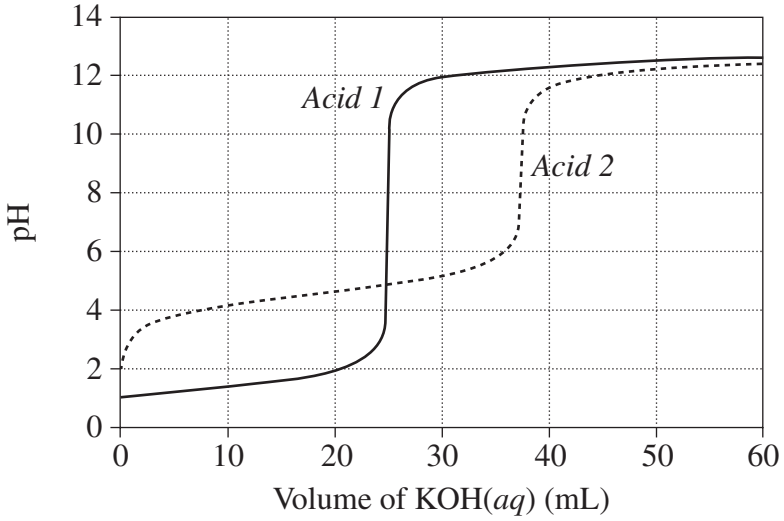
Question 21 (6 marks)

The graph shows changes in pH for the titrations of equal volumes of solutions of two monoprotic acids, *Acid 1* and *Acid 2*.



(a) Explain the differences between *Acid 1* and *Acid 2* in terms of their relative strengths and concentrations. **3**

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(b) Name the salt produced by the reaction of an acid of the same type as *Acid 2* with KOH*(aq)*. **1**

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(c) Calculate the concentration of hydrogen ions when 20 mL of KOH(*aq*) has been added to *Acid 1*. **1**

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(d) Why would phenolphthalein be a suitable indicator for both titrations? **1**

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Question 22 (7 marks)

The nitrogen content of bread was determined using the following procedure:

- A sample of bread weighing 2.80 g was analysed.
- The nitrogen in the sample was converted into ammonia.
- The ammonia was collected in 50.0 mL of 0.125 mol L^{-1} hydrochloric acid. All of the ammonia was neutralised, leaving an excess of hydrochloric acid.
- The excess hydrochloric acid was titrated with 23.30 mL of 0.116 mol L^{-1} sodium hydroxide solution.

(a) Write balanced equations for the TWO reactions involving hydrochloric acid. **2**

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(b) Calculate the moles of excess hydrochloric acid. **1**

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(c) Calculate the moles of ammonia. **2**

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(d) Calculate the percentage by mass of nitrogen in the bread. **2**

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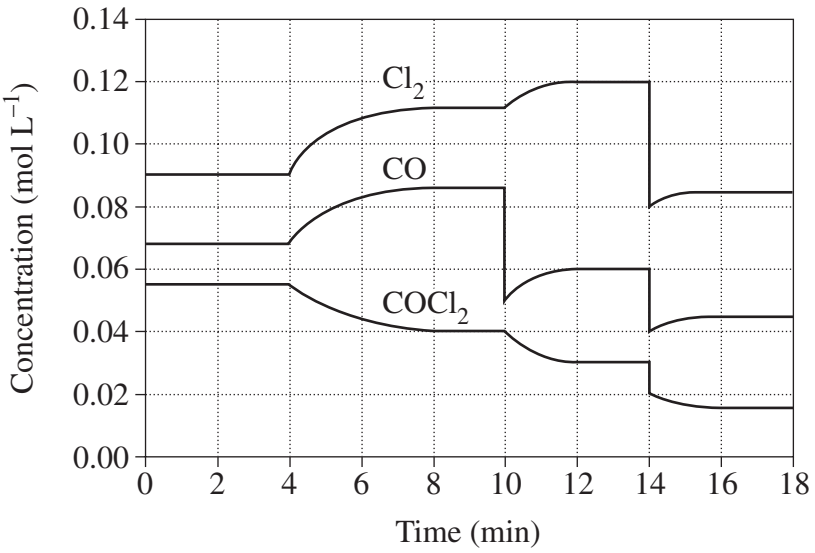
Question 23 (6 marks)

The graph shows the variation in concentration of reactant and products as a function of time for the following system. **6**

$$COCl_2(g) \rightleftharpoons Cl_2(g) + CO(g) \quad \Delta H = +108 \text{ kJ}$$



Identify and explain each of the changes in conditions that have shaped the curves during the time the system was observed.

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Centre Number

Student Number

Section I – Part B (continued)

Question 24 (5 marks)

Describe the principle of atomic absorption spectroscopy and its application in environmental monitoring. Include a diagram in your answer. **5**

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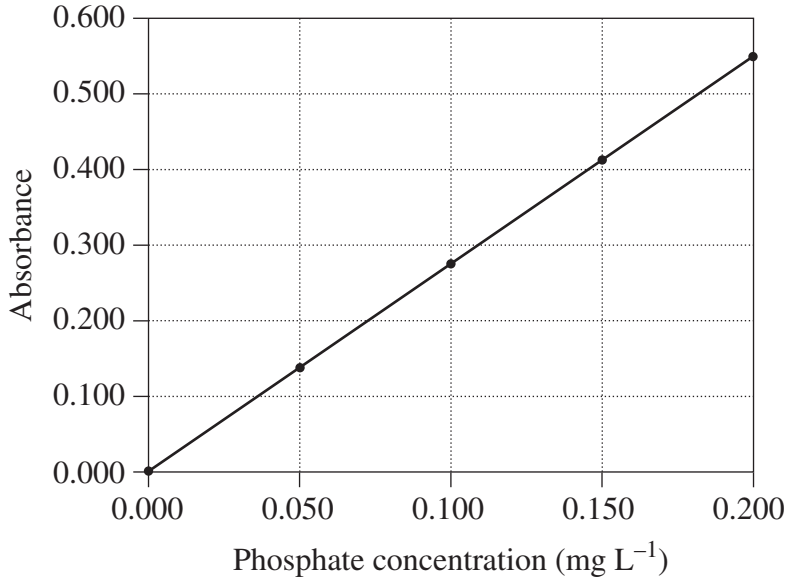
Question 25 (7 marks)

An analytical chemist determined the phosphate concentration of water samples from three local streams.

(a) Using the absorbance values in the table and graph, determine the mean absorbance and mean phosphate concentration for each stream and complete the table. **2**

Stream	*Absorbances measured*	*Mean absorbance*	*Mean phosphate concentration* (mg L^{-1})
1	0.090, 0.092, 0.088		
2	0.513, 0.511, 0.514		
3	0.234, 0.237, 0.234		



Question 25 continues on page 19

Question 25 (continued)

(b) The recommended maximum level of phosphate in streams is 0.100 mg L^{-1}.

With reference to the recommended maximum level of phosphate for stream water, explain why there are differences between the three streams. **3**

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(c) Why is phosphate concentration a water quality issue? **2**

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End of Question 25

Question 26 (7 marks)

An electrochemical cell is constructed using two half cells. One half cell consists of an inert platinum electrode and a solution of Fe^{2+} and Fe^{3+}. The other half cell consists of a lead electrode and a solution of Pb^{2+}.

Current will flow from one electrode to the other electrode when the cell is completed using a voltmeter and a salt bridge.

(a) Write relevant half equations and a balanced net ionic equation for the overall cell reaction. **2**

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(b) Calculate the standard cell potential ($E^{\ominus}$). **1**

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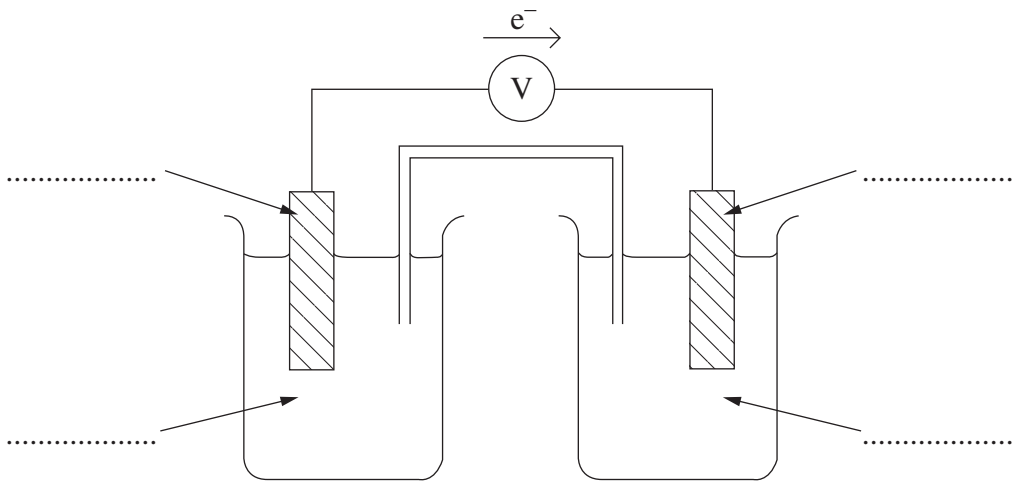
(c) Identify the anode, cathode, metals and ions by labelling the following diagram. **3**



(d) Identify an appropriate electrolyte to use in the salt bridge. **1**

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Chemistry

Section II

25 marks
Attempt ONE question from Questions 27–31
Allow about 45 minutes for this section

Answer the question in a writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

		Pages
Question 27	Industrial Chemistry	22–23
Question 28	Shipwrecks, Corrosion and Conservation	24–25
Question 29	The Biochemistry of Movement	26–27
Question 30	The Chemistry of Art	28–30
Question 31	Forensic Chemistry	31–33

Question 27 — Industrial Chemistry (25 marks)

(a) Sulfuric acid is one of the world's most significant industrial chemicals because of the variety and importance of its uses.

(i) Identify the major use of sulfuric acid. **1**

(ii) Outline the industrial process for the manufacture of sulfuric acid from its raw materials. **3**

(iii) Account for the safety precautions associated with the industrial transport of sulfuric acid. **2**

(b) At a particular temperature, iodine trichloride dissociates into iodine gas and chlorine gas according to the following equation:

$$2ICl_3(g) \qquad I_2(g) + 3Cl_2(g) \qquad \Delta H = 240 \text{ kJ}$$

Initially 0.35 mol of $ICl_3(g)$ was introduced into a 1.0 L container and allowed to come to equilibrium. At equilibrium there was 0.45 mol L^{-1} of $Cl_2(g)$.

(i) Write the equilibrium constant expression for this reaction. **1**

(ii) Calculate the value of K at this temperature. **3**

(iii) What are TWO consequences of increasing the temperature of the mixture at equilibrium? **2**

Question 27 continues on page 23

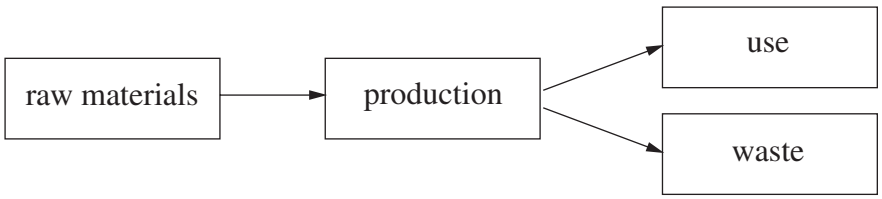
Question 27 (continued)

(c) Account for a use of an emulsion in terms of its properties. **2**

(d) (i) Explain the cleaning action of soap in terms of its molecular structure. **2**

(ii) Soap is one product of saponification. Name the other product and draw its structural formula. **2**

(e) The flowchart summarises the fundamental criteria that must be considered in order to find a suitable location for an industrial plant. **7**

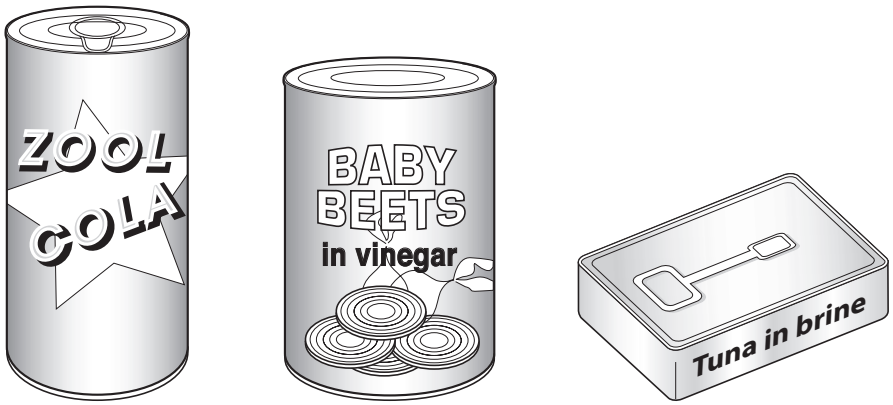


With reference to the flowchart, explain the significance of each criterion to determine a suitable location for an industrial plant to manufacture sodium carbonate.

End of Question 27

Question 28 — Shipwrecks, Corrosion and Conservation (25 marks)

(a) Tins and cans are used to store a range of foods, beverages and general household chemicals.



(i) Identify the passivating metal used in drink cans in Australia. **1**

(ii) Compare the use and effectiveness in preventing corrosion of different protective coatings on containers, such as those shown. **3**

(b) Galvanising is used outside the home on water tanks and fencing. Explain the protection provided to iron by galvanising. **2**

(c) The roof guttering on a garage has rusted through.

(i) Explain, using chemical equations, the cause of this problem. **2**

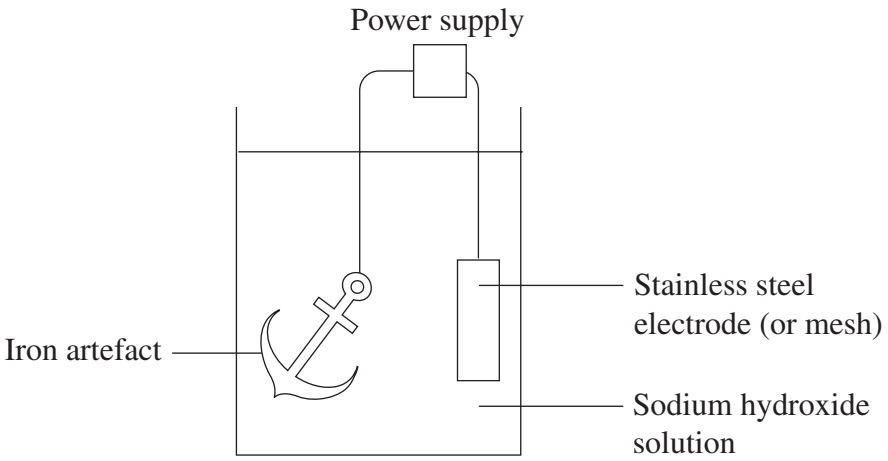
(ii) The owners have decided to replace the guttering. They have steel screws and a choice of aluminium or copper guttering. **4**

Justify the course of action the owners should take, based on chemical principles.

Question 28 continues on page 25

Question 28 (continued)

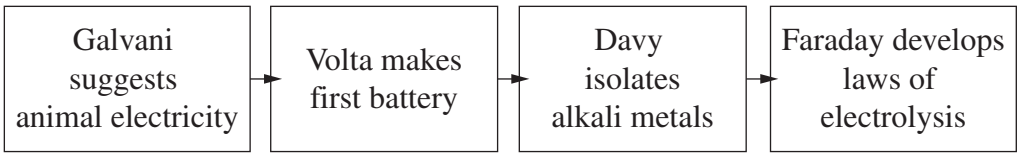
(d) (i) The diagram shows an electrolytic cell used to conserve an iron artefact recovered from the wreck of a ship that sank in the early 1800s. **3**



Explain how this process is used to conserve this iron artefact.

(ii) Describe, with the aid of a diagram, how a nickel spoon could be silver-plated using equipment available in a school laboratory. **3**

(e) The flowchart summarises the historical development of the understanding of electron transfer reactions. **7**



With reference to the flowchart, describe how the work of the scientists led to a better understanding of electron transfer reactions.

End of Question 28

Question 29 — The Biochemistry of Movement (25 marks)

(a) (i) Identify a factor that will cause denaturation of a protein molecule. **1**

(ii) Explain denaturation of a protein in terms of its structure and bonding. **2**

(b) All enzymes are proteins. Polyphenoloxidase (PPO) is an enzyme that catalyses the browning of fruit and vegetables. This catalytic action can be studied in the laboratory by monitoring the oxidation of a phenol to a quinone, a red compound. The intensity of the red colour indicates the extent of the reaction. A student studied the enzyme activity of PPO in relation to a number of biological factors, using quinone as the measure of activity. **3**

The following table summarises the results of one set of these experiments.

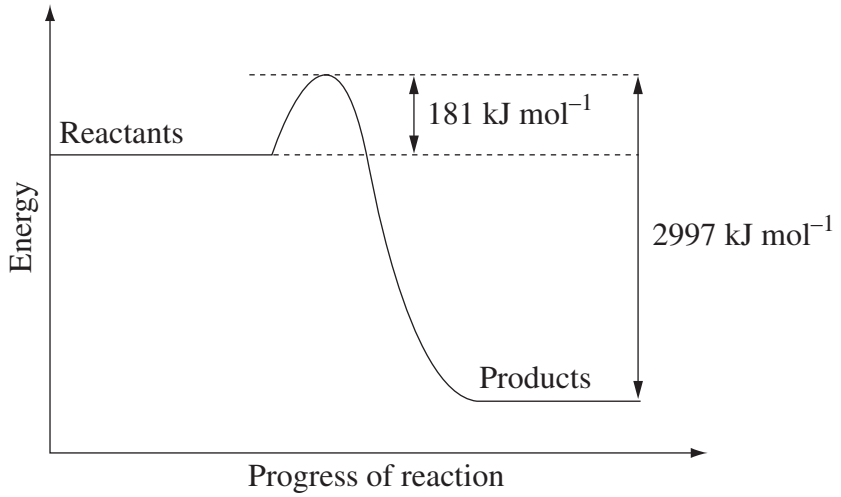
pH at 37°C	3.0	4.0	5.0	6.0	7.0	8.0
Colour	colourless	light red	medium red	dark red	dark red	colourless

Account for this set of experimental results in terms of the characteristics of reactions involving enzymes.

Question 29 continues on page 27

Question 29 (continued)

(c) The following energy diagram shows the energy change associated with the combustion of glucose in kJ mol^{-1} during cellular respiration.



(i) Write a balanced chemical equation for the combustion of glucose. Include the energy released per mole of glucose. **2**

(ii) Calculate the energy released per gram of glucose. **2**

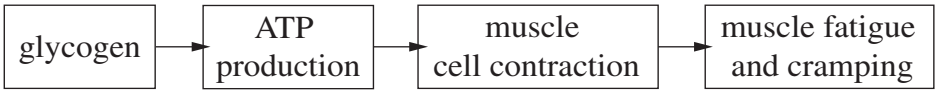
(iii) An average cyclist uses 80 kJ for every km travelled. If the glucose content of an energy bar is 36.7 g, how far can an average cyclist travel on only one energy bar? **2**

(d) Analysing the structure of the glycerol molecule helps explain many of its properties.

(i) Explain the viscosity of glycerol and its solubility in water. **3**

(ii) Explain the solubility of both fatty acids and triacylglycerols in water in terms of their molecular structures. **3**

(e) The flowchart summarises a particular biochemical pathway related to muscle cell respiration. **7**



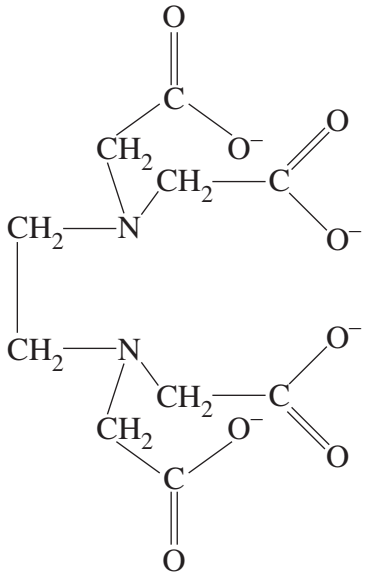
With reference to the flowchart, describe how a knowledge of the biochemical reactions involved in muscle cell respiration has led to more informed training programs. Include relevant chemical equations in your answer.

End of Question 29

Question 30 — The Chemistry of Art (25 marks)

(a) (i) Name a monodentate ligand. **1**

The ethylenediaminetetraacetate ion (EDTA) is a polydentate ligand. It is sometimes used to treat people suffering from heavy metal poisoning.



EDTA

(ii) With reference to EDTA, explain what is meant by the term *polydentate ligand*. **2**

(iii) Using copper as the ion and EDTA as the ligand, explain how bonding occurs between a metal ion and a ligand. **3**

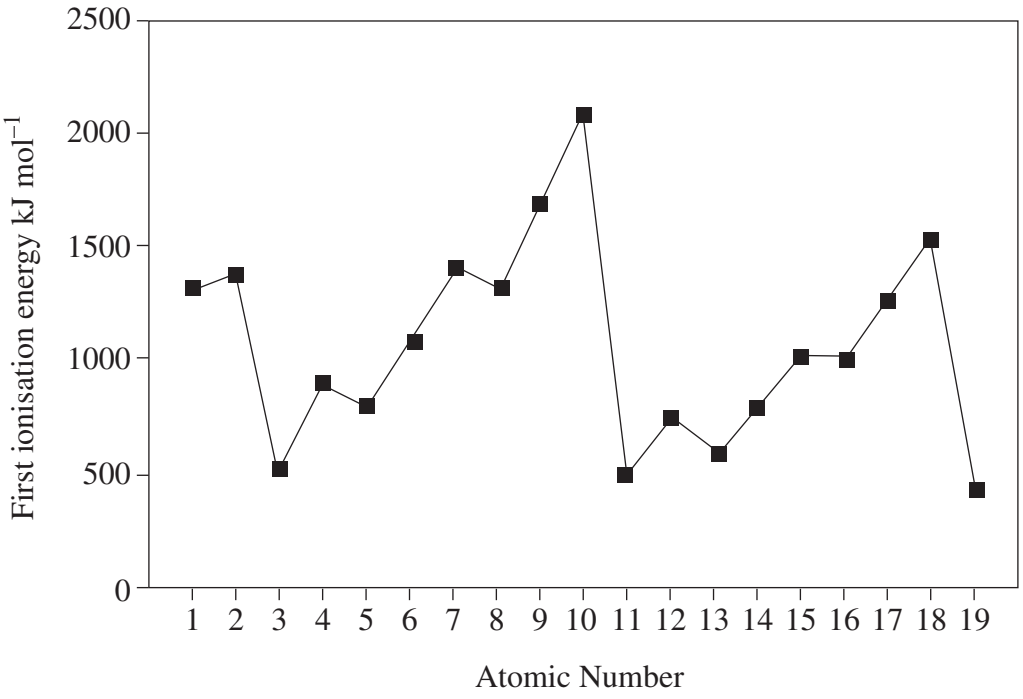
Question 30 continues on page 29

Question 30 (continued)

(b) (i) What is the maximum number of electrons that a p-orbital can hold? **1**

(ii) Write the full electron configurations for a Ca atom in the ground state, an excited Ca atom and a Ca^+ ion. **2**

(c) The graph shows the first ionisation energy of some elements. **3**



Account for the trends in the graph in terms of the electron configuration of the elements.

(d) (i) Gustav Kirchhoff formulated a law that states that 'a hot gas produces light with spectral lines at discrete wavelengths'. **3**

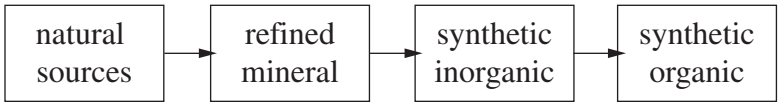
Explain the chemical principle that underpins this law.

(ii) Describe how a first-hand investigation in the school laboratory could be undertaken to determine the presence of a particular metal in a water sample using a flame test. Give a reason why this method may not work. **3**

Question 30 continues on page 30

Question 30 (continued)

(e) The flowchart summarises the development of pigments over time. **7**



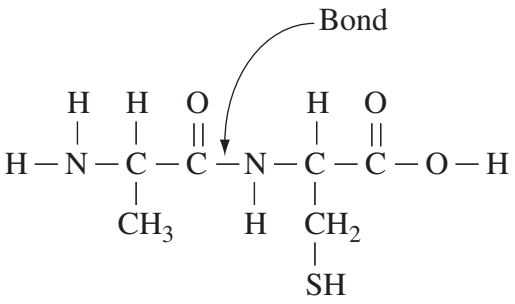
Historically many pigments have contained elements with atomic numbers in the range of 22 to 30.

With reference to the flowchart, describe the use of pigments containing these elements and the origin of pigment colour at the atomic level.

End of Question 30

Question 31 — Forensic Chemistry (25 marks)

(a) (i) This structure represents a biological molecule.



Name the specific type of covalent bond indicated. **1**

(ii) Distinguish between the primary, secondary and tertiary structures of proteins. **3**

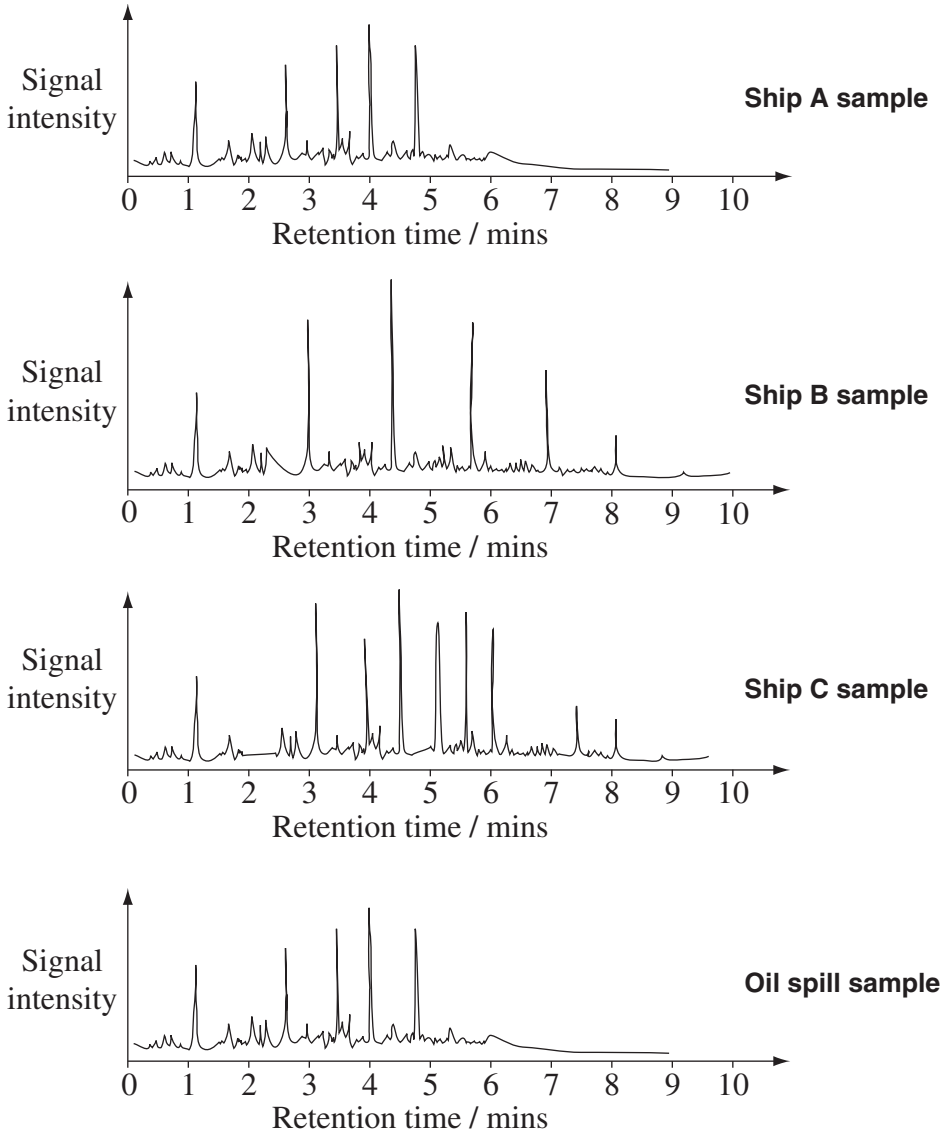
(iii) How could electrophoresis be used to identify the origins of proteins in an investigation of adulterated food? **2**

Question 31 continues on page 32

Question 31 (continued)

(b) An oil spill occurred at a shipping port. To determine which ship was responsible, a sample of the oil was collected and analysed by gas chromatography. Samples of bunker oil were collected from three ships in port at the time and analysed by gas chromatography.

The chromatograms of the samples collected are shown.



(i) By comparing the chromatograms identify whether the oil spill originated from one of these vessels. **1**

(ii) Explain what the peaks in the chromatograms represent. **2**

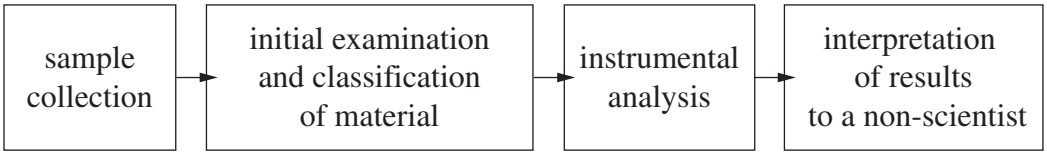
(c) Describe the features of instrumental chromatography (GLC or HPLC) that allow the analysis of small samples. **3**

Question 31 continues on page 33

(d) (i) Describe how a first-hand investigation in the school laboratory could be used to separate and identify the components of a mixed food dye. **3**

(ii) Describe the chemical tests that could be used to distinguish between alkenes, alkanols and alkanoic acids. **3**

(e) The flowchart summarises the steps involved in sample processing and presentation of results for a forensic investigation. **7**



You are the forensic chemist investigating a crime scene and collecting samples. With reference to the flowchart, describe how you would process the sample and present the results. Illustrate your answer with relevant tests and appropriate analyses.

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Chemistry

DATA SHEET

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

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}

Some useful formulae

$$\text{pH} = -\log_{10}[\text{H}^+] \qquad \Delta H = -m\,C\,\Delta T$$

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 this examination paper. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

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 65.41 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 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [97.91] 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 183.8 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 [209.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223] Francium	88 Ra [226] Radium	89–103 Actinoids	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [271] Darmstadtium	111 Rg [272] Roentgenium							

Atomic Number: 79 — Symbol of element: Au — Atomic Weight: 197.0 — Name of element: Gold

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [145] 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 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac [227] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237] Neptunium	94 Pu [244] Plutonium	95 Am [243] Americium	96 Cm [247] Curium	97 Bk [247] Berkelium	98 Cf [251] Californium	99 Es [252] Einsteinium	100 Fm [257] Fermium	101 Md [258] Mendelevium	102 No [259] Nobelium	103 Lr [262] Lawrencium

For elements that have no stable or long-lived nuclides, the mass number of the nuclide with the longest confirmed half-life is listed between square brackets.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (October 2005 version) is the principal source of data. Some data may have been modified.