



South Australian
Certificate of Education

Chemistry 2025

Question booklet 1

- Questions 1 to 3 (59 marks)
- Answer **all** questions
- Write your answers in this question booklet
- You may write on page 12 if you need more space
- Allow approximately 65 minutes

Examination information

Materials

- Question booklet 1
- Question booklet 2
- Periodic table and data sheet
- SACE registration number label

Instructions

- Use black or blue pen
- You may use a sharp dark pencil for diagrams and other representations
- Approved calculators may be used

Total time: 130 minutes

Total marks: 120

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The SACE Board of South Australia acknowledges that this examination was created on Kaurna Land. We acknowledge First Nations Elders, parents, families, and communities as the first educators of their children, and we recognise and value the cultures and strengths that First Nations students bring to the classroom. We respect the unique connection and relationship that First Nations peoples have to Country, and their ever-enduring cultural heritage.

Attach your SACE registration number label here



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1. Gluten in bread is a mixture of proteins. It helps to make the bread dough elastic so that it maintains its shape before baking. It also helps trap gas to make the bread dough rise.

(a) The gas is a result of the fermentation of glucose.

Write an equation for this fermentation reaction.

(2 marks)

(b) Gluten is a mixture of two proteins, gliadin and glutenin.

(i) Explain how protein chains can form unique three-dimensional shapes.

(3 marks)

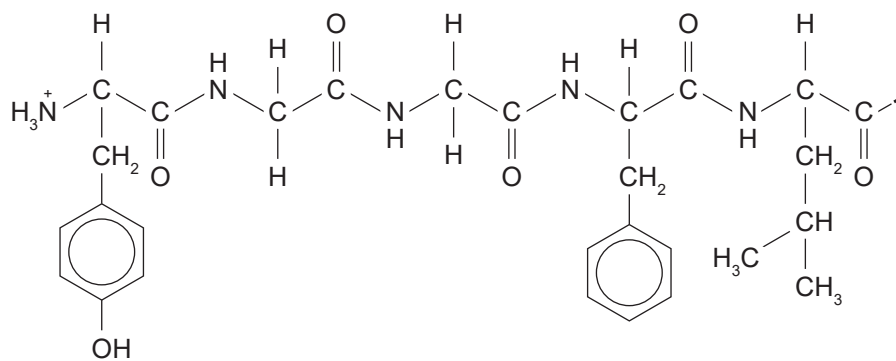
(ii) Covalent disulfide bonds in gluten are formed between the proteins gliadin and glutenin.

Explain how the covalent disulfide bonds between these protein chains give the bread dough elastic properties.

(2 marks)

- (c) During the digestion of bread, enzymes catalyse the hydrolysis of the protein chains into amino acids.

The structural formula of a section of a protein chain is shown below.



Draw the structural formula of *one* of the amino acids that will be produced from the hydrolysis of the protein chain section shown above.

(2 marks)

Question 1 continues on page 4.

- (d) Some people are allergic to the proteins in bread. Samples from food preparation surfaces can be analysed to detect the presence of these proteins using thin layer chromatography (TLC).

TLC was performed on one sample using a polar stationary phase and a less polar mobile phase. Table 1 below shows the resulting R_F values of different proteins in bread.

Table 1

<i>Protein</i>	<i>R_F value</i>
albumin	0.10
casein	0.15
gliadin	0.85
glutenin	0.90

- (i) With reference to the R_E values, explain which of the proteins in Table 1 is most polar.

(3 marks)

- (ii) Calculate the distance, in cm, that **gliadin** moved up the TLC plate if the solvent front travelled 8.0 cm from the sample spot origin.

(1 mark)

- (iii) (1) Identify *one* pair of proteins from Table 1 that would be difficult to distinguish based on their R_F values.

(1 mark)

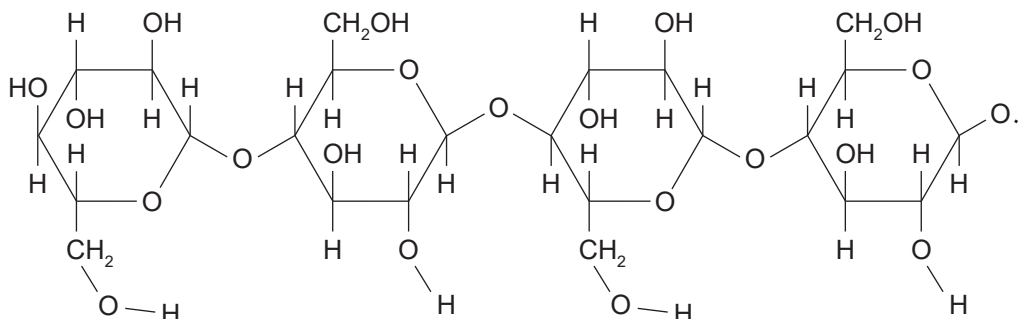
- (2) Describe how the pair of proteins that you identified in part (iii)(1) could be better separated using a subsequent TLC procedure.

(2 marks)

2. Fabrics can be made from naturally grown polymers, synthetic polymers, or a mixture of the two.

(a) Cotton fabric is mostly cellulose.

The structural formula of **a section of cellulose** is shown below.



(i) Cotton fabric takes a long time to dry due to the strong interactions between water molecules and cellulose.

In the space below the section of cellulose, draw the structural formula of a water molecule interacting with cellulose.

Use appropriate notation to show polarity and label the strongest intermolecular force that occurs between the water molecule and cellulose.

(3 marks)

(ii) Despite absorbing water, cellulose does not dissolve in water.

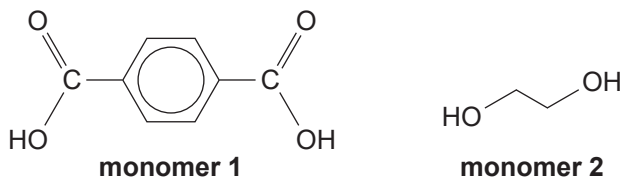
Explain why cellulose does not dissolve in water.

(2 marks)

Question 2 continues on page 6.

- (b) Polyethylene terephthalate (PET) is a common synthetic polymer used in the production of fabrics that dry quickly.

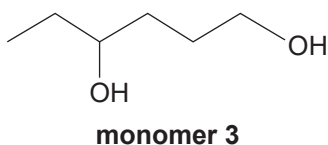
PET is made by a polymerisation reaction involving the two monomers shown below.



- (i) Draw a section of the PET polymer formed from the reaction of monomers 1 and 2.
Include *two* repeating units in your diagram.

(2 marks)

- (ii) If monomer 2 is replaced with monomer 3 in the same reaction, a new polymer with properties similar to those of PET will be formed. The structure of monomer 3 is shown below.



State the systematic name of monomer 3.

_____ (2 marks)

- (c) Fabric made of PET alone can be recycled by melting and reshaping. However, fabrics containing mixtures of PET and other polymers, such as cotton, cannot be easily recycled using melting and reshaping.

- (i) Explain why it is difficult to recycle these mixed polymer fabrics.

_____ (2 marks)

- (ii) Chemists have been investigating reactions that can turn the mixed polymer fabrics back into reusable monomers. They have found that most methods require temperatures above 200°C and corrosive acids or strong bases as both reactants and catalysts.

A group of researchers has found a new method that can be performed at lower temperatures. This process uses ethanol in place of acids or bases, and an iron compound as a catalyst. The researchers found that after the reaction they could separate the PET monomers from the cotton. These monomers could then be used to make further high-quality PET, or they could be used in other materials.

With reference to *one or more* relevant key concepts of science as a human endeavour, and information from the passage above, discuss the environmental advantages of the new method for processing mixed PET polymer fabrics.

(4 marks)

Question 3 begins on page 8.

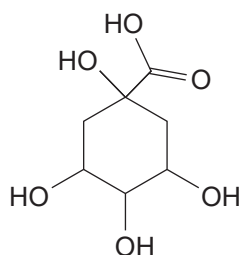
3. Iron is an important element for the human body. Haemoglobin, a protein molecule in human red blood cells, contains iron(II) ions (Fe^{2+}) which bind to oxygen (O_2) to transport it around the body.

(a) Using subshell notation, write the electron configuration of Fe^{2+} .

(2 marks)

- (b) Drinking tea or coffee during a meal inhibits the absorption of iron from the food into the body. One of the compounds believed to be responsible for this effect is quinic acid.

The structural formula of quinic acid is shown below.



quinic acid

- (i) Write the molecular formula of quinic acid.

(2 marks)

- (ii) Explain whether or not quinic acid should be classified as a carbohydrate.

(2 marks)

(iii) Quinic acid undergoes a reaction with acidified potassium dichromate solution.

(1) State the colour change observed when this reaction takes place.

_____ (2 marks)

(2) Draw the structural formula of *one* possible organic product of the reaction between quinic acid and acidified potassium dichromate solution.

(2 marks)

(c) When a person lacks iron in their diet, iron(II) sulfate is commonly used as an iron supplement.

One manufacturer claims their iron supplement solution contains Fe^{2+} at a concentration of 10.0 ppm.

The concentration is analysed using two different methods.

(i) The first method of Fe^{2+} analysis is spectroscopy. This method relies on light absorption by iron at a wavelength of 508 nm.

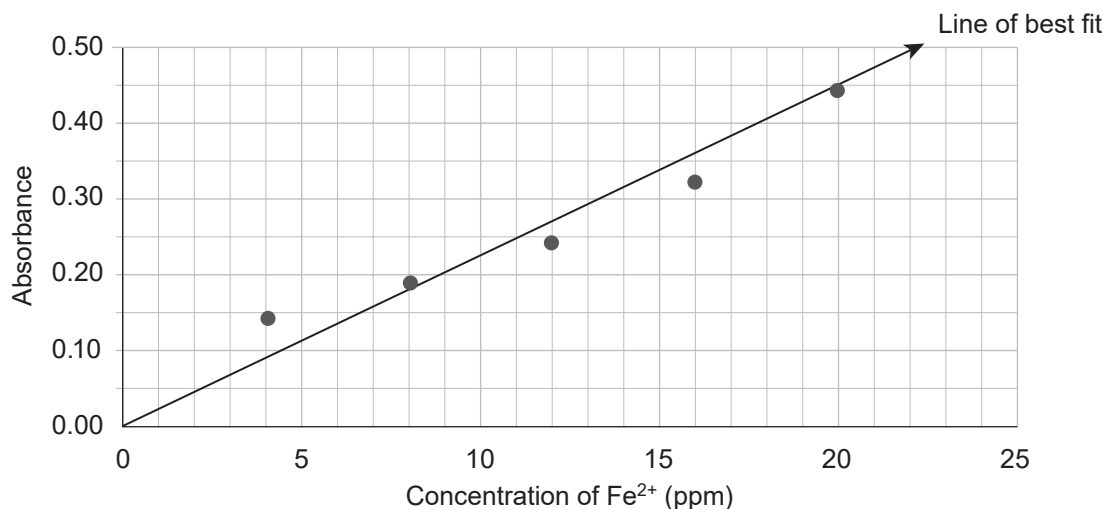
(1) Explain why iron absorbs light of a unique wavelength.

_____ (3 marks)

Question 3 continues on page 10.

- (2) A calibration graph for the analysis of Fe^{2+} concentration was constructed using standard solutions of Fe^{2+} with concentrations 4.0, 8.0, 12.0, 16.0, and 20.0 ppm.

The graph is shown below.



- (A) The absorbance of the iron supplement was measured as 0.19.

Show that the calibration graph can be used to determine the concentration of Fe^{2+} in the supplement **and** record the value, in ppm.

_____ (2 marks)

- (B) In relation to the data plotted, discuss the appropriateness of the line of best fit drawn on the calibration graph above.

 _____ (2 marks)

- (ii) The second method of Fe^{2+} analysis is by titration with an acidified potassium dichromate solution. The reaction equation is given below.



The concentration of the dichromate ions is $3.50 \times 10^{-5} \text{ mol L}^{-1}$.

The titration was performed using 20.00 mL samples of the Fe^{2+} supplement in each trial.

- (1) Name the piece of volumetric glassware used to deliver the acidified potassium dichromate solution.

_____ (1 mark)

(2) The results for all trials are shown in Table 2 below.

Table 2

<i>Titre value (mL)</i>			
Trial 1	Trial 2	Trial 3	Trial 4
17.46	16.93	17.00	16.98

(A) Calculate the appropriate average titre value in mL.

(1 mark)

(B) Showing your working, calculate the concentration, in mol L^{-1} , of Fe^{2+} in the supplement, according to this volumetric determination.

Give your final answer to the appropriate number of significant figures.

(5 marks)

(iii) An iron supplement solution given to some newborn infants contains 30 mg of Fe^{2+} in every 5.0 mL. Convert this concentration to ppm.

(2 marks)

(d) Iron(II) in haemoglobin binds more strongly to CO than to O_2 , resulting in CO having the ability to block O_2 transport by red blood cells.

Describe a source of CO in residential urban areas that could result in accidental exposure of a person to toxic levels.

(2 marks)

[illegible]

Chemistry

2025

Question booklet 2

- Questions 4 to 7 (61 marks)
- Answer **all** questions
- Write your answers in this question booklet
- You may write on page 12 if you need more space
- Allow approximately 65 minutes

2

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4. The production of iron from iron ore involves the burning of coal and contributes 6–9% of global carbon dioxide emissions.

Methane is also emitted at various stages in the production of iron, including the conversion of coal into 'coke', which is the form of coal used for this process.

- (a) Most iron ore contains a large percentage of the mineral *hematite*, Fe_2O_3 . In a blast furnace, the coke reacts with oxygen to form carbon monoxide.

The carbon monoxide is a reducing agent that reacts with the hematite to produce iron. Carbon dioxide is also produced in the reaction.

Write a balanced equation for the reaction that occurs between carbon monoxide and hematite.

(2 marks)

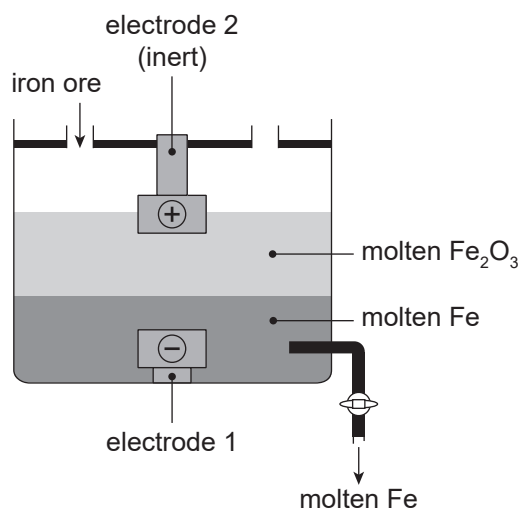
- (b) Alternative methods of iron production are being developed.

- (i) Hydrogen gas can be used as a reducing agent in place of carbon monoxide.

Describe *one* environmental advantage of this alternative method of iron production.

(2 marks)

- (ii) Electrolysis of molten Fe_2O_3 is also being investigated as a method of iron production.
The diagram for the electrolytic cell is shown below.



- (1) Write the half-equation for the production of iron in this cell.

(2 marks)

- (2) Give the reason why iron is produced at electrode 1.

(1 mark)

- (3) Identify the product formed at electrode 2.

(1 mark)

Question 4 continues on page 4.

(c) Methane emissions from coal mines are sometimes burned off rather than being released directly into the atmosphere.

(i) Write a balanced equation for the complete combustion of methane.

(2 marks)

(ii) In one year in Australia, 0.90 megatonne of methane was released during the production of coke.

Calculate the energy, in kJ, that could be generated from the complete combustion of this mass of methane.

[One tonne = 1000 kg]

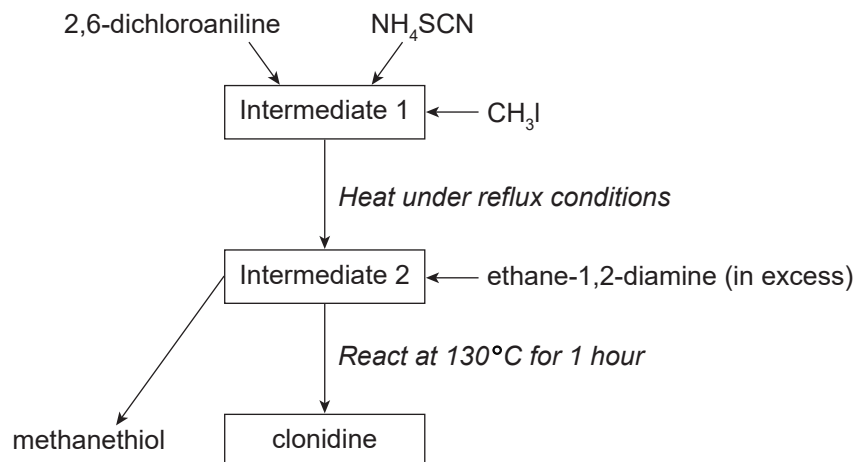
[Enthalpy of combustion of methane = -890 kJ mol^{-1}]

[Molar mass of methane = $16.042 \text{ g mol}^{-1}$]

(3 marks)

5. Clonidine is a synthetically manufactured pharmaceutical used for the treatment of high blood pressure in humans.

The manufacture of clonidine is outlined in the flow chart below.

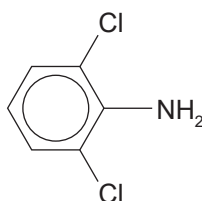


- (a) Methanethiol is used as an additive to methane gas because its strong odour makes gas leaks easily detectable.

Explain whether methanethiol should be classified as a *waste product* **or** as a *by-product* of the manufacture of clonidine.

_____ (2 marks)

- (b) The structural formula of 2,6-dichloroaniline is shown below.



Classify 2,6-dichloroaniline as either a primary, a secondary, or a tertiary amine.

_____ (1 mark)

- (c) Explain the purpose of *heating under reflux* (used in the production of Intermediate 2).

_____ (2 marks)

(d) Intermediate 2 is reacted with ethane-1,2-diamine to produce clonidine.

(i) Draw the structural formula of ethane-1,2-diamine.

(2 marks)

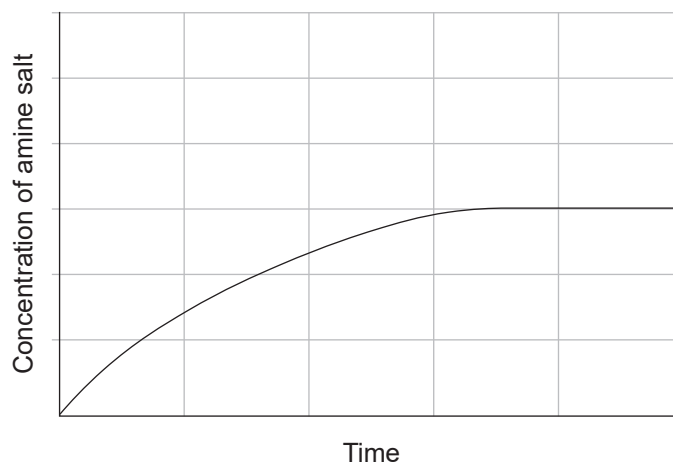
(ii) Using collision theory, explain the benefit to the manufacturer of carrying out this reaction at 130°C instead of room temperature.

(4 marks)

(e) To increase the solubility of clonidine in the aqueous environment in the body, clonidine is converted to its amine salt before being included in the medication. The protonation of clonidine is conducted in the presence of a catalyst.

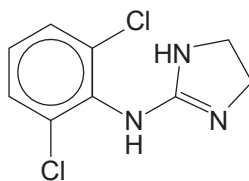
(i) The graph below shows the change in concentration of the amine salt against time **in the absence of a catalyst**.

On the graph below, sketch the curve for the same reaction when it is carried out in the presence of a catalyst.



(2 marks)

- (ii) The structural formula of the unprotonated form of clonidine is shown below.



Explain why the protonated form of clonidine has a higher solubility in water than the unprotonated form of clonidine.

(4 marks)

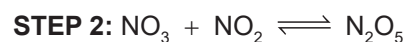
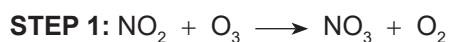
Question 6 begins on page 8.

6. Climate change has resulted in more frequent wildfires. Research shows that wildfire emissions of NO and NO₂ into the troposphere are now comparable with those from vehicles and factories.

(a) Explain how increased NO₂ emissions lead to increased tropospheric ozone pollution.

(3 marks)

(b) During the night, when air temperatures are lower than during the day, the air quality improves. This is because NO₂ concentration decreases due to the reactions shown below.



(i) When the temperature is lower, the equilibrium in STEP 2 produces an increased yield of N₂O₅.

(1) Explain whether the forward reaction in STEP 2 is an exothermic or an endothermic reaction.

(2 marks)

(2) State whether the value of K_c for the equilibrium will increase, decrease, or remain unchanged during such lower nighttime temperatures.

(1 mark)

(ii) Once formed, N₂O₅ reacts with water vapour in the air to form nitric acid.

Explain the effect of this reaction on the position of the equilibrium in STEP 2.

(3 marks)

- (i) Explain how eutrophication in water bodies can lead to a series of undesirable consequences.

[illegible]

- To prevent eutrophication, it is recommended that the *phosphorus* concentration in the water body be decreased to 0.04 mg L⁻¹.

Calculate the mass, in kg, of HT-clay that must be added to this water body to decrease the *phosphorus* concentration to 0.04 mg L^{-1} , given that 0.5 g of HT-clay is required to remove every 1 mg of *phosphorus*.

(4 marks)

Question 7 continues on page 10.

- (iii) The addition of the HT-clay to the water body also causes a temporary change in the pH of the water from 6.6 to 6.8.

Calculate the concentration of hydroxide ions in water that has a pH of 6.8.

(3 marks)

- (iv) Although costly, it is possible to reclaim the phosphorus from the HT-clay after its use in the water body.

Explain *one* advantage of reclaiming the phosphorus.

(2 marks)

- (b) Hydrotalcite compounds are often used as catalysts. One use of hydrotalcite catalysts is in the reaction of steam with hydrocarbons to produce hydrogen gas for use as a fuel.

- (i) This method of hydrogen production uses hydrocarbons from fossil fuels as the starting material.

Identify *one* possible benefit of producing hydrogen gas by this method.

(1 mark)

- (ii) Hydrogen gas may be considered a 'renewable fuel' if it is produced by a method that has little or no fossil fuel involvement.

Briefly describe *one* such method of hydrogen gas production.

(2 marks)

- (iii) The complete combustion of one mole of hydrogen releases 286 kJ of energy.

Write a thermochemical equation that summarises this information.

(4 marks)

This image shows a single page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page, typical of notebook or legal stationery. There are no margins, text, or other markings on the page.

Chemistry data sheet

Metal activity

K	<i>most reactive</i>
Ca	
Na	
Mg	
Al	
Zn	
Cd	
Co	
Ni	
Bi	
Cu	
Hg	
Ag	
Au	<i>least reactive</i>

Table of SI prefixes

<i>SI prefix</i>	<i>Symbol</i>	<i>Value</i>
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Symbols of common quantities

amount of substance	n
mass	m
molar concentration	c
change in enthalpy	ΔH
molar mass	M
volume	V
heat energy	Q
specific heat capacity	c
temperature	T

Mathematical relationships

$$n = \frac{m}{M}$$

$$c = \frac{n}{V}$$

$$Q = mc\Delta T$$

$$\Delta H = \frac{Q}{n}$$

$$\text{pH} = -\log[\text{H}^+]$$

Periodic table of the elements

1 H hydrogen 1.008												2 He helium 4.003																							
3 Li lithium 6.941		4 Be beryllium 9.012																																	
11 Na sodium 22.99		12 Mg magnesium 24.31																																	
19 K potassium 39.10		20 Ca calcium 40.08		21 Sc scandium 44.96		22 Ti titanium 47.90		23 V vanadium 50.94		24 Cr chromium 52.00		25 Mn manganese 54.94		26 Fe iron 55.85		27 Co cobalt 58.93		28 Ni nickel 58.70		29 Cu copper 63.55		30 Zn zinc 65.38													
37 Rb rubidium 85.47		38 Sr strontium 87.62		39 Y yttrium 88.91		40 Zr zirconium 91.22		41 Nb niobium 92.91		42 Mo molybdenum 95.94		43 Tc technetium (97)		44 Ru ruthenium 101.1		45 Rh rhodium 102.9		46 Pd palladium 106.4		47 Ag silver 107.9		48 Cd cadmium 112.4		49 In indium 114.8		50 Sn tin 118.7		51 Sb antimony 121.8		52 Te tellurium 127.6		53 I iodine 126.9		54 Xe xenon 131.3	
55 Cs caesium 132.9		56 Ba barium 137.3		57 ¹ La lanthanum 138.9		72 Hf hafnium 178.5		73 Ta tantalum 180.9		74 W tungsten 183.8		75 Re rhenium 186.2		76 Os osmium 190.2		77 Ir iridium 192.2		78 Pt platinum 195.1		79 Au gold 197.0		80 Hg mercury 200.6		81 Tl thallium 204.4		82 Pb lead 207.2		83 Bi bismuth 209.0		84 Po polonium (209)		85 At astatine (210)		86 Rn radon (222)	
87 Fr francium (223)		88 Ra radium (226)		89 ² Ac actinium (227)		104 Rf rutherfordium (267)		105 Db dubnium (268)		106 Sg seaborgium (271)		107 Bh bohrium (272)		108 Hs hassium (270)		109 Mt meitnerium (276)		110 Ds darmstadtium (281)		111 Rg roentgenium (280)		112 Cn copernicium (285)		113 Nh nihonium (284)		114 Fl flerovium (289)		115 Mc moscovium (288)		116 Lv livermorium (293)		117 Ts tennessine (294)		118 Og oganesson (294)	

¹lanthanide series

58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium (145)	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.0	71 Lu lutetium 175.0
90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium (237)	94 Pu plutonium (244)	95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (251)	99 Es einsteinium (252)	100 Fm fermium (257)	101 Md mendelevium (258)	102 No nobelium (259)	103 Lr lawrencium (262)

²actinide series