Junior Chemistry Challenge
2025

Time allowed: 45 minutes

Instructions:

- Answer all the questions.
- The marks for each question are shown in brackets.
- Calculators are permitted.
- Do not start until you are instructed to do so.
- A periodic table is provided on the first page.

To administer the Junior Chemistry Challenge, your name, academic year, school, and score will be securely recorded in a database. After certificates and prizes are awarded, all entries will be anonymised. By taking part in the Junior Chemistry Challenge you consent to your data being handled in this manner.

Name: _____ Year: _____

Question:	1	2	3	Total
Max:	10	15	15	40
Mark:				

1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.94	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.085	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078		21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.97	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62		39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium [97]	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 ln Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	53 Te Tellurium 127.60	53 I Iodine 126.904	54 Xe Xenon 131.293
55 Cs Cesium 132.905	56 Ba Barium 137.327	* 57 - 70	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	78 lr Iridium 192.217	79 Pt Platinum 195.084	80 Au Gold 196.997	81 Hg Mercury 200.592	81 TI Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	** 89 - 102	103 Lr Lawrencium [262]	104 Rf Rutherfordium [267]	105 Db Dubnium [270]	106 Sg Seaborgium [269]	107 Bh Bohrium [270]	108 Hs Hassium [270]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [281]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [293]	118 Og Oganesson [294]

*Lanthanide series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.045
**Actinide series	89 Ac Actinium [227]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	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]

1. Please circle the correct answer. There is **only one** correct answer to each question.

   (a) The general formula of an alcohol is $C_nH_{2n+1}OH$, where n is a positive whole-number. When an alcohol undergoes complete combustion it produces carbon dioxide and water. What is the minimum number of oxygen molecules needed for one molecule of a generic alcohol to undergo complete combustion? [1]

   A. $3n + 1$
   B. $\frac{3}{2}n$
   C. $n + \frac{1}{2}$
   D. $3n$
   E. $\frac{3}{2}n + \frac{1}{2}$

   (b) Copper chromate is an ionic compound with the formula $CuCrO_4$. What ions are present in copper chromate? [1]

   A. Cu^{2+} and CrO_4^{2-}
   B. Cr^{2+} and CuO_4^{2-}
   C. $CuCr^{2+}$ and O^{2-}
   D. Cu^{2+}, Cr^{6+}, and O^{2-}
   E. CrO_4^{2+} and Cu^{2-}

   (c) An element has the following properties:

   - Its oxide has a melting point of 1710 °C
   - Its chloride does not conduct electricity when liquid.

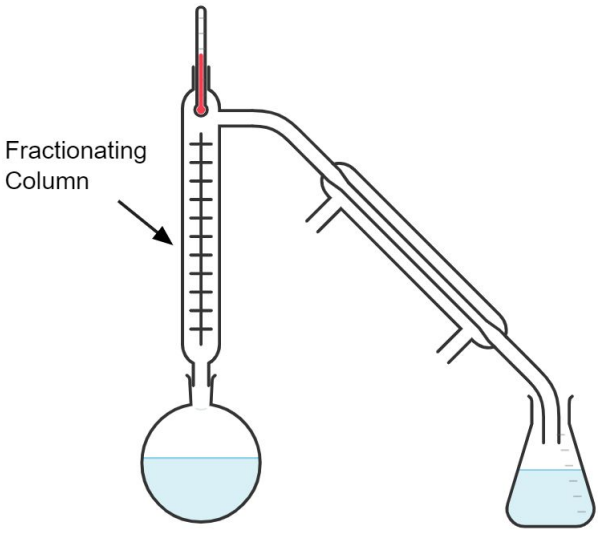
   What is this element? [1]

   A. C
   B. Na
   C. S
   D. Fe
   E. Si

   (d) Which of the following is the smallest? [1]

   A. O^{2-}
   B. F^-
   C. Ne
   D. Na^+
   E. Mg^{2+}

(e) Fractional distillation is used to separate liquids with similar boiling points. The equipment for a fractional distillation is shown below with the fractionating column labelled. Which of the following statements best describes how a fractionating column works? [1]



A. The fractionating column uses a series of filters to separate liquids based on their molecular size, allowing smaller molecules to pass through while larger ones condense at lower levels.

B. The fractionating column directly separates liquids by breaking the intermolecular bonds of the higher boiling point component, forcing it to condense.

C. The fractionating column provides a series of condensation and re-evaporation steps, creating a temperature gradient where components with lower boiling points rise further up the column.

D. The fractionating column uses a catalyst to speed up the evaporation of certain components, ensuring they rise faster and separate from the mixture.

E. The fractionating column removes impurities from liquids by trapping heavier molecules at the base of the column while lighter molecules evaporate quickly.

(f) In the following equation a, b, c and d are smallest whole numbers when the equation is balanced.

$$I_2 + a\ Cl_2 + b\ H_2O \longrightarrow c\ HIO_3 + d\ HCl$$

What is the value of a? [1]

A. 2

B. 4

C. 5

D. 6

E. 10

(g) Hydrochloric acid is reacted with excess calcium carbonate in the following reaction and the time for the reaction to produce the CO_2 was measured:

$$CaCO_3\,(s) + 2\,HCl\,(aq) \longrightarrow CaCl_2\,(aq) + H_2O\,(l) + CO_2\,(g)$$

Which of the following would happen if the reaction were repeated with excess $CaCO_3$ and the same volume of $HCl\,(aq)$ but with twice the concentration? [1]

[Concentration is a measure of the number of particles in a given volume.]

A. Same amount of $CO_2\,(g)$ produced in same amount of time.

B. Same amount of $CO_2\,(g)$ produced in half the amount of time.

C. Same amount of $CO_2\,(g)$ produced in twice the amount of time.

D. Twice the amount of $CO_2\,(g)$ produced in same amount of time.

E. Twice the amount of $CO_2\,(g)$ produced in half the amount of time.

(h) A sample of an element has two isotopes with the following properties:

- The isotopes have equal abundance.
- The lighter isotope has a mass number twice its atomic number.
- The difference in mass numbers of the isotopes is 2.
- The relative atomic mass of the sample is 25.

What is the element? [1]

A. B

B. C

C. Mg

D. Al

E. Mn

(i) Which of the following substances is **NOT** a molecule? [1]

A. NH_3

B. N_2

C. HNO_3

D. NH_4NO_3

E. NO_2

(j) When a positive and a negative electrode is placed in an aqueous solution of sodium chloride, NaCl(aq), and a current is passed through it, the following observations are made:

- A gas is given off at the positive electrode which bleaches damp litmus paper.
- A gas is given off at the negative electrode which makes a lit splint go 'pop'.
- The pH of the solution increases.

What are the products of this reaction? [1]

	Positive Electrode	**Negative Electrode**	**Solution**
A.	Cl_2	H_2	HCl
B.	H_2	Cl_2	NaOH
C.	Cl_2	O_2	H_2O
D.	Cl_2	H_2	NaOH
E.	H_2	O_2	HCl

Total for Question 1: 10

2. Mass spectrometry is a technique used to determine the masses and relative abundance of isotopes of an element.

   A sample, M, is placed into the mass spectrometer and it is turned into a gas and ionised:

$$\mathrm{M(s)} \xrightarrow{\text{vapourisation}} \mathrm{M(g)} \xrightarrow{\text{ionisation}} \mathrm{M^+(g)}$$

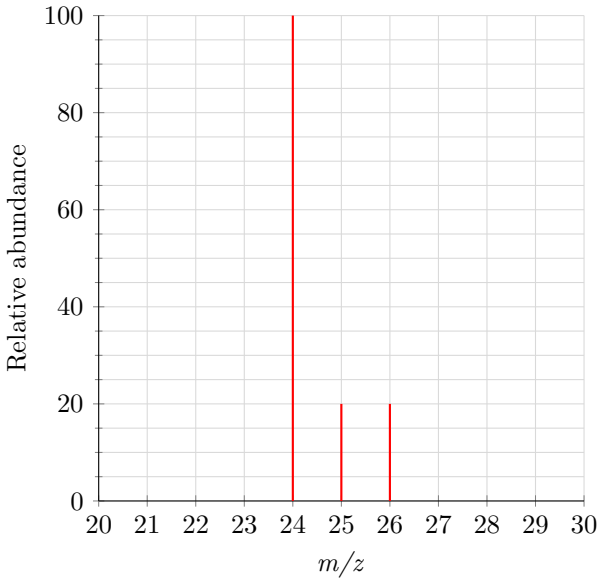
   The ionisation step forms 1+ ions, but a small number 2+ ions can be formed.

   (a) Is the ionisation step an oxidation or reduction? [1]

   .....

   A magnetic field separates the ions based on their **mass-to-charge ratio** (m/z). A detector calculates the relative abundance of particles at each m/z and plots a graph called the mass spectrum.

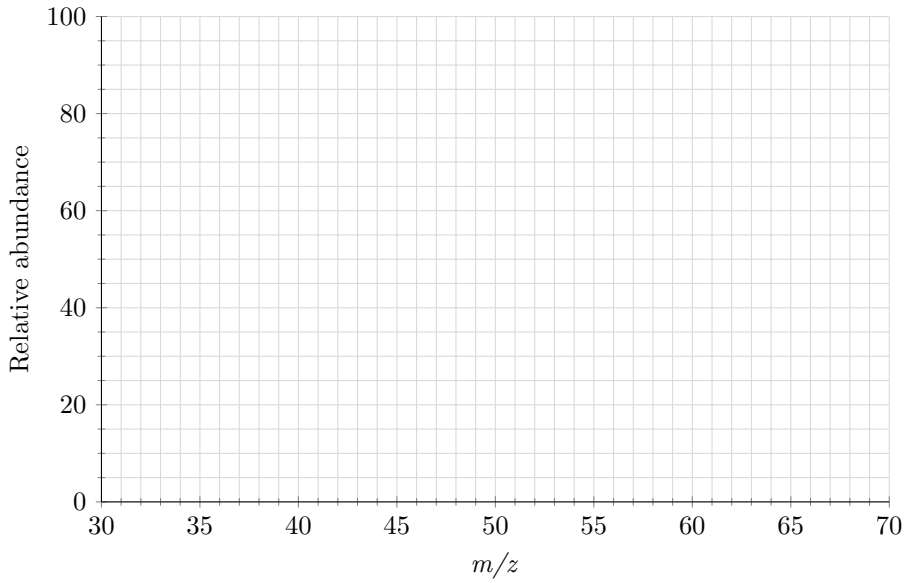
   (b) The mass spectrum for a sample of magnesium is shown below. Use it to calculate the relative atomic mass of magnesium in this sample. [3]



   Relative Atomic Mass:.....

(c) Copper is found as two isotopes: ^{63}Cu with a 70% abundance and ^{65}Cu with a 30% abundance.

i. On the graph below predict the mass spectrum of copper. [2]



ii. The mass spectrum of copper also has peaks with an m/z of 31.5 and 32.5. What ions are responsible for these peaks? [2]

.....

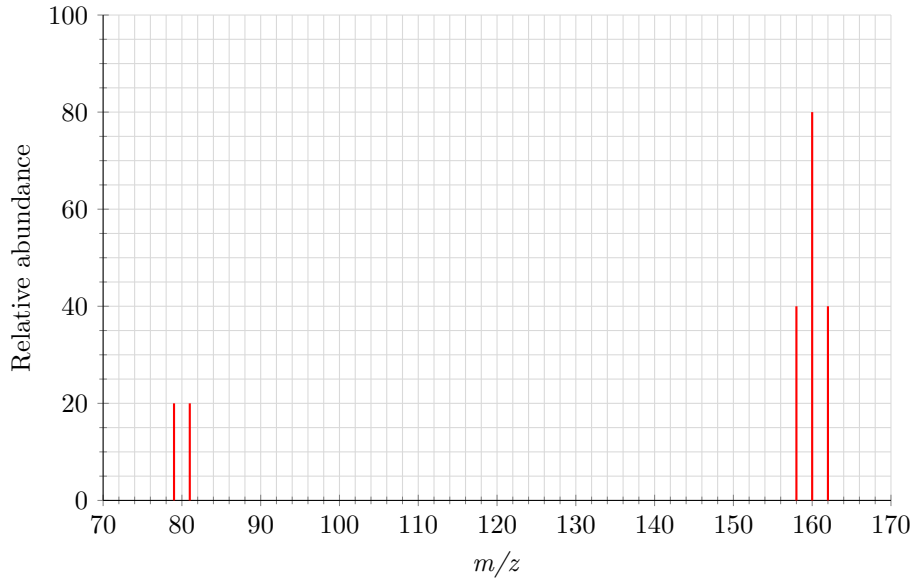
.....

.....

Diatomic elements like Br_2 can also be put in a mass spectrometer. When a molecule is placed into a mass spectrometer it breaks apart into fragments. Both the molecular ion and ion fragments are detected in the mass spectrum. For example with Br_2:

$$Br_2(g) \xrightarrow{\text{ionisation}} Br_2^+(g) \xrightarrow{\text{fragmentation}} Br^+(g) + Br(g)$$

This means Br_2 gives the following mass spectrum:



(d) Bromine has two isotopes: ^{79}Br and ^{81}Br. Explain how this mass spectrum shows they have equal abundance. [1]

.....

.....

(e) Identify the ions responsible for the peaks with a m/z of 158, 160, 162. [3]

.....

.....

(f) Explain why the peak at the m/z of 160 is twice the relative abundance of the peaks at 158 and 162. [3]

.....

.....

.....

Total for Question 2: 15

3. Ammonium nitrate, NH_4NO_3, is an extremely important industrial compound used mainly as a fertiliser.

Ammonium nitrate is made from nitrogen, oxygen, and hydrogen.

(a) Nitrogen and oxygen are obtained from air. Suggest how pure nitrogen and pure oxygen can be separated from gaseous air. [2]

.....

.....

.....

In the first step to make ammonium nitrate, nitrogen is reacted with hydrogen to form ammonia at 300× atmospheric pressure:

$$N_2(g) + 3\,H_2(g) \longrightarrow 2\,NH_3(g)$$

(b) Suggest why this reaction is conducted at such a high pressure? [1]

.....

.....

Then the ammonia is turned into nitric acid by the Ostwald process. The first step is the reaction of ammonia with oxygen to form nitrogen monoxide.

$$\ldots NH_3(g) + \ldots O_2(g) \longrightarrow \ldots NO(g) + \ldots H_2O(g)$$

(c) Balance the above equation. [1]

The nitrogen monoxide is then oxidised to form compound **X** which is further reacted with water to form nitric acid.

$$3\,\mathbf{X} + 2\,H_2O \longrightarrow 4\,HNO_3 + 2\,NO$$

(d) What is the formula of compound **X**? [1]

.....

Finally the nitric acid is reacted with the ammonia for form ammonium nitrate.

$$NH_3(g) + HNO_3(g) \longrightarrow NH_4NO_3(s)$$

(e) What type of reaction is this? [1]

.....

Fertilisers are ranked on now much nitrogen they contain by mass. This is calculated as the percent of relative formula mass which is from the nitrogen.

(f) Calculate the percent of nitrogen by mass in ammonium nitrate. [2]

[You may find the following A_r values helpful: H = 1, N = 14, O = 16]

Ammonium nitrate is often mixed with phosphorous (v) oxide (P_2O_5) and potassium oxide (K_2O) to also provide crops with vital phosphorous and potassium nutrients.

(g) NH_4NO_3, P_2O_5, and K_2O were mixed together in a 1:1:1 ratio. What would be the percent of nitrogen, phosphorous, and potassium by mass in this mixture? [3]

[You may find the following A_r values helpful: P = 31, K = 39]

Ammonium nitrate must be stored carefully because if it is heated it can violently decompose forming nitrogen, oxygen, and water.

(h) Write a balanced chemical equation for the decomposition of ammonium nitrate. [2]

.....

(i) In 2020, a warehouse in Beirut with 2 750 000 kg of ammonium nitrate caught fire and exploded. Ammonium nitrate releases 1673 J of energy per gram when it decomposes. Calculate the total energy released in this explosion. [2]

Total for Question 3: 15

End of Paper

Junior Chemistry Challenge 2025 © Andrew North.
Junior Chemistry Challenge is kindly supported by The Perse School, Cambridge.
Periodic Table by Dmarcus100, CC BY-SA 4.0 https://creativecommons.org/licenses/by-sa/4.0, via Wikimedia Commons
Figure of fractional distillation in Question 1(j) drawn in Chemix (https://chemix.org/)
Typeset in LaTeX