

Junior Chemistry Challenge
2023

Time allowed: 45 minutes

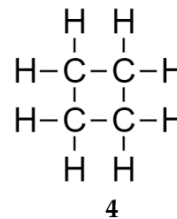
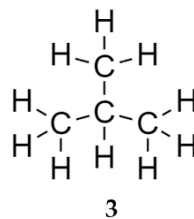
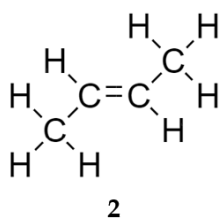
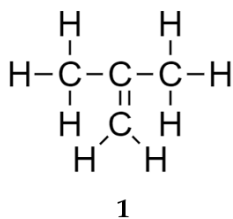
Instructions:

- There are two Sections A & B, answer all questions in each section.
- Answer in blue or black ink.
- Diagrams and graphs should be drawn in pencil.
- 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 at the back of the paper.

Name: _____ Form: _____

Section A: Multiple Choice

1. Isomers are molecules with the same molecular formula but with different structures. Which of the following molecules (1–4) are isomers of butene? [1]



- A. 1 and 2 only
 B. 1, 2, and 3 only
 C. 1, 2, and 4 only
 D. 2, 3, and 4 only
 E. 1, 2, 3, and 4
2. Which of these is the formula of Tin Nitride? [1]

- A. $\text{Sn}(\text{NO}_3)_4$
 B. Sn_4N_3
 C. $\text{Sn}(\text{NO}_3)_2$
 D. Sn_3N_4
 E. $\text{Sn}_3(\text{NO}_3)_4$

3. The colours of three indicators are shown.

Indicator	Colour at		pH of colour change
	low pH	high pH	
Methyl orange	Red	Yellow	4.0
Bromothymol blue	Yellow	Blue	6.5
Phenolphthalein	Colourless	Pink	9.0

Equal volumes of these three indicators were mixed and added to water. What colour would be seen? [1]

- A. Blue
 B. Green
 C. Orange
 D. Red
 E. Yellow

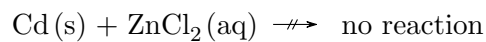
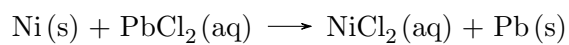
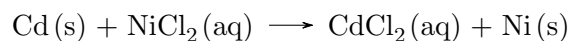
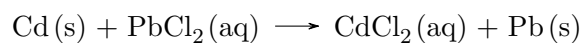
4. Red lead has the formula Pb_3O_4 . All the oxide ions in the compound have the formula O^{2-} , what is the charge on the Pb ions? [1]

- A. 1+ and 2+
- B. 1+ and 3+
- C. 2+ and 3+
- D. 3+ and 4+
- E. $\frac{8}{3}+$

5. Chlorine comes in two isotopes: ^{35}Cl – 75% abundance, and ^{37}Cl – 25% abundance. What is the percentage abundance of Cl_2 molecules which contain two atoms of ^{35}Cl ? [1]

- A. 6.25%
- B. 18.75%
- C. 37.5%
- D. 56.25%
- E. 75%

6. Based on the following reactions, what is the order of these metals from most reactive to least reactive? [1]



- A. $\text{Zn} > \text{Cd} > \text{Ni} > \text{Pb}$
- B. $\text{Zn} > \text{Cd} > \text{Pb} > \text{Ni}$
- C. $\text{Pb} > \text{Ni} > \text{Cd} > \text{Zn}$
- D. $\text{Cd} > \text{Zn} > \text{Ni} > \text{Pb}$
- E. $\text{Pb} > \text{Ni} > \text{Zn} > \text{Cd}$

7. An atom has a mass number of 32 and an atomic number of 16. Which of the following statements are correct? [1]

1. The atom contains 32 neutrons.
2. The atom is of a non-metallic element.
3. The atom forms negative ions.
4. The atom is in group 2 of the Periodic Table.

- A. 1 and 2 only
- B. 1 and 3 only
- C. 2 and 3 only
- D. 2 and 4 only
- E. 3 and 4 only

8. An element, X, has the following properties:

- It does not react with acids
- One of its chlorides has the formula XCl_2 and forms blue-green crystals
- It has a high melting point

What is element X? [1]

- A. Magnesium
- B. Sulphur
- C. Silver
- D. Zinc
- E. Copper

9. Fluorine is one of the most reactive elements in the Periodic Table. The great reactivity of fluorine is largely due to the weak F–F bond. [1]

Which statement best accounts for the weak F–F bond? [1]

- A. The F–F bond is weak because of repulsion between the non-bonding electrons.
- B. The F–F bond is weak because of the short length of the bond.
- C. The F–F bond is weak because of the small nuclear charge of the fluorine atom.
- D. The F–F bond is weak because of the small size of the fluorine atom.
- E. The F–F bond is weak because the atoms only share one electron rather than a pair of electrons.

10. Four molecules of potassium ferrate react exactly with four molecules of water to give three molecules of oxygen, two molecules of iron (III) oxide, and eight molecules of potassium hydroxide.

What is the formula of potassium ferrate?

[1]

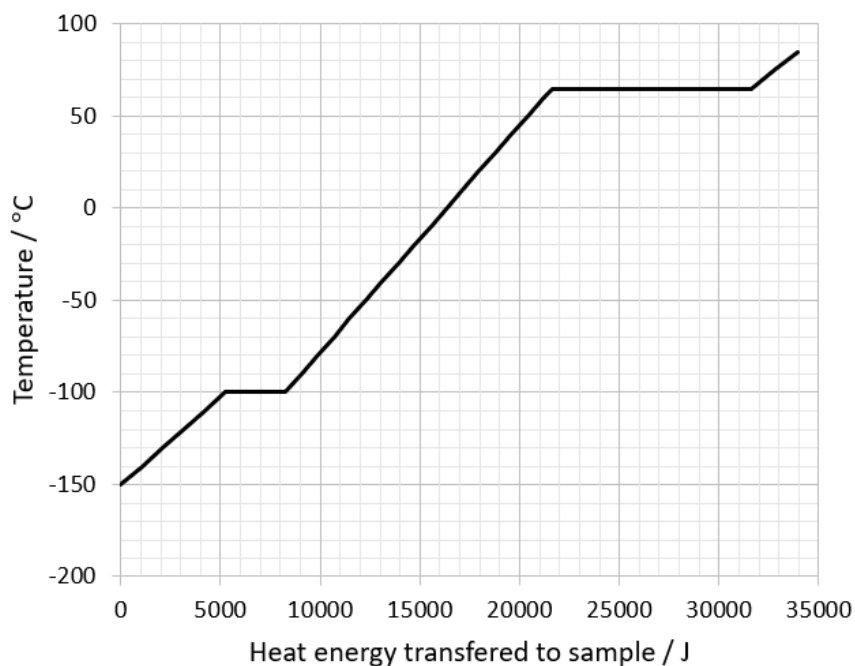
- A. K_2FeO_2
- B. KFe_2O_3
- C. $\text{K}_2\text{Fe}_2\text{O}_3$
- D. KFe_2O_4
- E. K_2FeO_4

Total for Section A: 10

Section B: Written Responses

Question 1

The graph below shows the temperature of a sample of solid methanol as it is heated.



(a) State the melting and boiling point of methanol.

[2]

.....

(b) Explain, with reference to the methanol molecules and the interactions between them, why the graph is flat in two places.

[2]

.....
.....
.....
.....
.....

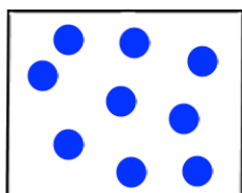
The heat capacity of a substance is defined as the heat energy needed to raise the temperature of a substance by 1 °C. Its units are J/°C

(c) Using the graph, or otherwise, work out the heat capacity of solid methanol. [2]

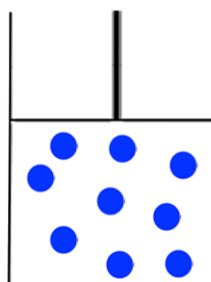
(d) State the heat capacity of methanol when it is changing state. [1]

.....

A 4g sample of helium is placed in two different containers. One container (A) has fixed walls so the gas has a constant volume and cannot expand. The other container (B) has a piston at the top so the gas can expand and have a constant pressure.



(A) Container with fixed volume



(B) Container with movable piston on top

(e) Do you expect helium with the constant volume or constant pressure to have the higher heat capacity? Explain your answer. [3]

.....
.....
.....
.....
.....

Total for Question 1: 10

Question 2

Silicon and carbon are in Group 4 of the Periodic Table and can be reacted together to form silicon carbide. This substance, which is commonly known as carborundum, has a very high melting point and is extremely hard, often used in cutting tools.

- (a) Suggest the structure of silicon carbide. [2]

.....
.....
.....
.....

When magnesium silicide (prepared by heating a mixture of magnesium and silicon) is treated with dilute hydrochloric acid, a very reactive substance called silane is produced. This has the formula SiH_4 and a boiling point of -112°C .

- (b) What conclusions can you make about the structure of silane? [1]

.....

- (c) Silane reacts violently with the oxygen in the air. The reaction produces an explosive gas which is ignited by the heat given off by the reaction. The other product is an unreactive solid. Write a balanced chemical equation for the reaction between silane and oxygen. [2]

.....

Group 4 of the Periodic Table contains the elements carbon, silicon, germanium, tin, lead (in order of increasing atomic number). The melting and boiling points of the oxides of these elements are in the table below.

Oxide	Melting Point/ $^\circ\text{C}$	Boiling Point/ $^\circ\text{C}$
Carbon dioxide	-	-78 (sublimes)
Silicon (IV) oxide	1610	2230
Germanium (IV) oxide	?	?
Tin (IV) oxide	1127	1800
Lead (IV) oxide	300 (decomposes)	-

- (d) What would you expect the melting and boiling points of germanium (IV) oxide to be? [1]

.....

(e) The elements of Group 4 become increasingly metallic as relative atomic mass increases. In view of this, how would you expect the electrical conductivity of the Group 4 oxides to change down the group when:

i. they are in the solid state

[1]

.....

ii. they are in the liquid state

[1]

.....

(f) Why are boiling points of silicon (IV) oxide and carbon dioxide so different?

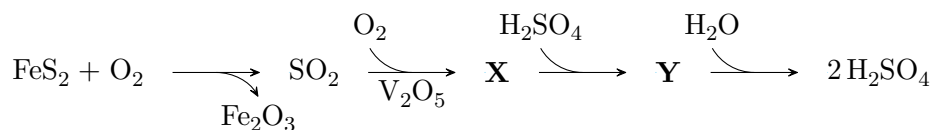
[2]

.....
.....
.....
.....
.....

Total for Question 2: 10

Question 3

Sulphuric acid is produced commercially in a process called the Contact Process. The steps of the process are set out in the scheme below.



The first step involves reacting the mineral pyrite, FeS₂, with oxygen to produce sulphur dioxide and iron (III) oxide.

- (a) Write a balanced chemical equation for this reaction. [2]

.....

In the next step, sulphur dioxide reacts with V₂O₅ to produce **X**, another oxide of sulphur, and VO₂. The VO₂ then reacts with oxygen to regenerate the V₂O₅.

- (b) Give the formula of **X**. [1]

.....

- (c) V₂O₅ speeds up the reaction. What other property of V₂O₅ makes it a catalyst in this reaction? [1]

.....

- (d) State whether if the following substances are oxidised or reduced in this step:
i. V₂O₅ [1]

.....

- ii. VO₂ [1]

.....

- iii. Oxygen [1]

.....

Compound **X** is reacted with sulphuric acid to give **Y**, a compound called oleum. **Y** then reacts with water to produce two molecules of sulphuric acid.

- (e) Give the formula of **Y**. [1]

.....

Sulphuric acid is rarely transported in bulk by road, rail, or ship. Instead oleum, compound **Y**, is transported to the desired location where water is then added to give sulphuric acid.

(f) What might be the advantage of transporting oleum rather than sulphuric acid? [2]

.....

.....

.....

.....

Total for Question 3: 10

Total for Section B: 30

End of Paper

