

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:

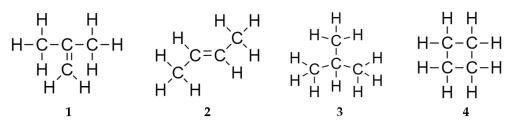
Section A: Multiple Choice

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]

[1]

[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?
 - A. $Sn(NO_3)_4$
 - B. Sn_4N_3
 - C. $Sn(NO_3)_2$
 - D. Sn_3N_4
 - E. $Sn_3(NO_3)_4$
- 3. The colours of three indicators are shown.

T., J: 4	Colou	ır at	II - f l l		
Indicator	low pH	high pH	pH of colour change		
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?

- 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]

[1]

[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 Cl₂ molecules which contain two atoms of 35 Cl?
 - 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?

$$Cd(s) + PbCl_2(aq) \longrightarrow CdCl_2(aq) + Pb(s)$$

$$Cd\left(s\right) + NiCl_{2}\left(aq\right) \, \longrightarrow \, CdCl_{2}\left(aq\right) + Ni\left(s\right)$$

$$\mathrm{Ni}\left(s\right) + \mathrm{PbCl}_{2}(\mathrm{aq}) \, \longrightarrow \, \mathrm{NiCl}_{2}(\mathrm{aq}) + \mathrm{Pb}\left(s\right)$$

$$\operatorname{Cd}\left(s\right)+\operatorname{ZnCl}_{2}\left(aq\right)$$
 \twoheadrightarrow no reaction

- A. Zn > Cd > Ni > Pb
- $B. \ Zn > Cd > Pb > Ni$
- C. Pb > Ni > Cd > Zn
- D. Cd > Zn > Ni > Pb
- E. Pb > Ni > Zn > 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	
	\bullet 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.	
	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]

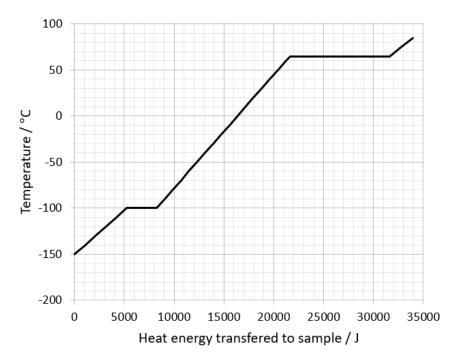
- A. K_2FeO_2
- B. KFe_2O_3
- C. $K_2Fe_2O_3$
- D. KFe_2O_4
- E. K_2FeO_4

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]

ature 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 fix walls so the gas has a constant volume and cannot expand. The other container (B) has piston at the top so the gas can expand and have a constant pressure.	
I I	
(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 high	er
heat capacity? Explain your answer.	[3]
	••
	••
T-4-1 f O4	 ion 1. 10
Total for Quest	10H T: 10

The heat capacity of a substance is defined as the heat energy needed to raise the temper-

\sim	. •	_
(J)	uestion	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]
trea	en magnesium silicide (prepared by heating a mixture of magnesium and silicon) is ted with dilute hydrochloric acid, a very reactive substance called silane is produced. s has the formula SiH_4 and a boiling point of $-112^{\circ}C$.	
(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]
~		
	up 4 of the Periodic Table contains the elements carbon, silicon, germanium, tin, lead order of increasing atomic number). The melting and boiling points of the oxides of	

these elements are in the table below.

Oxide	Melting Point/°C	Boiling Point ^o 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 be?	would	you	expect	the	melting	and	boiling	points	of ger	maniu	m (IV) ox	ide 1	to	[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]
	he next step, sulphur dioxide reacts with V_2O_5 to produce \mathbf{X} , another oxide of sulphur, VO_2 . The VO_2 then reacts with oxygen to regenerate the V_2O_5 .	
(b)	Give the formula of X .	[1]
(c)	$\rm V_2O_5$ speeds up the reaction. What other property of $\rm V_2O_5$ makes it a catalyst in this reaction?	[1]
(d)	State whether if the following substances are oxidised or reduced in this step: i. $\rm V_2O_5$	[1]
	ii. VO_2	[1]
	iii. Oxygen	[1]
	apound X is reacted with sulphuric acid to give Y , a compound called oleum. Y then ets with water to produce two molecules of sulphuric acid.	
	Give the formula of \mathbf{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]
	10
Total for Question 3: Total for Section B: 30	10

End of Paper

0	4 He	2	20 N	neon 10	40	argon	2 8	첫	krypton 36	131	Xe	xenon 54	[222]	Kn g	86	heen		
7			19 F	fluorine 9	35.5	chlorine	80	B	bromine 35	127	_	iodine 53	[210]	At	85	16 have	ated	
9			16	oxygen 8	32	sulfur 16	62	Se	selenium 34	128	<u>е</u>	tellurium 52	[209]	Po mind	84	112 – 1	uthentic	
2			14 N	nitrogen 7	33	P phosphorus	75	As	arsenic 33	122	Sp	antimony 51	209	n	83	Flements with atomic numbers 112 – 116 have been	reported but not fully authenticated	,
4			12 C	carbon 6	28	Silicon	73	Ge	germanium 32	119	Sn	tin 20	207	a P	82	atomic	ted but n	
က			## ##	boron 5	27	aluminium	202	Ga	gallium 31	115	<u>_</u>	indium 49	204	_ Hoff	81	nts with	report	.
		·					65	Zn	zinc 30	112	ဦ	cadmium 48	201	Hg	80	Fleme		
							63.5	Cu	copper 29	108	Ag	silver 47	197	Au	79	[272]	roentgenium	111
							59	Ż	nickel 28	106	Pa	palladium 46	195	1	78	[271]	darmstadtium	110
							59	ပိ	cobalt 27	103	Rh	modium 45	192	-	77	[268]	IVI (109
	- T	1 1					56	Fe	iron 26	101	Ru	ruthenium 44	190	SO	92	[277]		
					1		55	Mn	manganese 25	[86]			186	Ke	75	[264]	bohrium	107
			c mass	atomic (proton) number			52	ပ်	chromium 24	96	Mo	molybdenum 42	184	V	74	[566]	seaborgium	106
		Key	relative atomic mass	name (proton)			51	>	vanadium 23	93		niobium 41	181	la tartalim	73	[262]		105
			relativ	atomic			48	F	titanium 22	91	Zr	zirconium 40	178	H H	72	[261]	ntherfordium	104
							45	Sc	scandium 21	89	-	yttrium 39	139	La	57	[227]		89
2			9	beryllium 4	24	Mg magnesium	40	Ca	calcium 20	88	ั้ว	strontium 38	137	Pari in	56	[226]	radium	88
_			7 I i	lithium 3	23	Na sodium		¥	potassium 19	85	S S	nubidium 37	133	S i	52	[223]	francium	87

 * The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.