



3410UB0-1

FRIDAY, 17 MAY 2024 – MORNING

**CHEMISTRY – Unit 2:
Chemical Bonding, Application of Chemical
Reactions and Organic Chemistry**

HIGHER TIER

**1 hour 45 minutes plus your additional
time allowance**

Surname _____

First name(s) _____

Centre Number _____

Candidate Number 0 _____

ADDITIONAL MATERIALS

In addition to this examination paper you will need a calculator and a ruler.

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

A separate Data Booklet.

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball-point pen or your usual method.

Write your name, centre number and candidate number in the spaces provided on the front cover.

Answer ALL questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional pages at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

Question 9(a) is a quality of extended response (QER) question where your writing skills will be assessed.

The Periodic Table and the formulae for some common ions are printed in the separate Data Booklet.

(Turn over)

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1.	7	
2.	7	
3.	6	
4.	8	
5.	9	
6.	9	
7.	13	
8.	9	
9.	8	
10.	4	
Total	80	

Answer ALL questions.

- 1 The list below shows part of the reactivity series.**

magnesium

zinc

iron

nickel

A student investigated the temperature rise when four different metal powders were added to excess copper(II) sulfate solution.

The same mass of each metal was added to 50 cm³ samples of copper(II) sulfate solution.

question continues

(Turn over)

Question 1 continued

Look at DIAGRAM 1.1 in the separate diagram booklet. The maximum temperature for each reaction was measured. The temperature rise was calculated in each case and used to find the energy given out.

The results are shown in TABLE 1.2 in the separate diagram booklet.

- (a) In one of the reactions, the initial temperature was 19.7°C and the maximum temperature was 52.7°C .**

State which one of the four metals was used in this reaction. [1 mark]

(Turn over)

1 (b) Tick (✓) the box next to the conclusion the student can draw from the results. [1 mark]

The higher the metal in the reactivity series, the greater the energy given out

The lower the metal in the reactivity series, the greater the energy given out

The energy given out is not related to the metal's position in the reactivity series

(Turn over)

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iron + nickel(II) sulfate → iron(II) sulfate + nickel

1 (c) The word equation on the opposite page represents the reaction between iron and nickel(II) sulfate solution.

Iron(II) sulfate contains Fe^{2+} and SO_4^{2-} ions.

Complete the symbol equation for the reaction. [2 marks]



(Turn over)

1 (d) The experiment shows that a more reactive metal will replace a less reactive metal in its compounds.

Give the term used to describe this type of reaction. [1 mark]

(Turn over)

1 (e) When the experiment was repeated using TITANIUM, the temperature rise recorded was 35.4 °C.

Calculate the energy given out during the reaction between TITANIUM and 50 cm³ of copper(II) sulfate solution. Give your answer to the nearest 100 J. [2 marks]

$$\text{energy given out (J)} = \text{volume of solution} \times 4.2 \times \text{temperature rise}$$

Energy given out = _____ J

7

(Turn over)

2 (a) DIAGRAM 2.1 in the separate diagram booklet shows the apparatus used by a student to investigate the electrolysis of water.

(i) The student collected a sample of the oxygen formed in a test tube.

Give the test the student would carry out to show the presence of oxygen in the test tube. Include the observation the student would expect. [1 mark]

(Turn over)

2 (a)(ii)

Use the formula of water, H₂O.

Give the volume of hydrogen that would form in the same time as 10 cm³ of oxygen. [1 mark]

_____ cm³

(Turn over)

2 (b) TABLE 2.2 in the separate diagram booklet shows information about the electrolysis of three different electrolytes. The table is incomplete.

(i) Complete TABLE 2.2 by adding the SYMBOLS of the missing IONS.
[2 marks]

(ii) Name substances A, B and C.
[3 marks]

Metal A _____

Gas B _____

Compound C _____

7

(Turn over)

3 **DIAGRAM 3.1** in the separate diagram booklet shows the structure of diamond and graphite.

(a) Name the atom being represented by a • in both diagrams. [1 mark]

(b) Name the type of **BONDING** found in both diamond and graphite. [1 mark]

(Turn over)

3 (c) TABLE 3.2 in the separate diagram booklet shows some properties of graphite.

USE ONLY PROPERTIES FROM TABLE 3.2 TO ANSWER THIS QUESTION.

Give TWO properties of graphite that are DIFFERENT from those of diamond. Give a use relating to each property. [4 marks]

Property 1 _____

Use _____

continue answer on next page

(Turn over)

Property 2 _____

Use _____

6

(Turn over)

4 (a) Sodium reacts with oxygen to form the ionic compound sodium oxide.

In DIAGRAM 4.1 in the separate diagram booklet, dots and crosses represent electrons in sodium and oxygen atoms.

(i) Complete DIAGRAM 4.2 in the separate diagram booklet.

- Complete the electronic structures of the sodium ions and the oxide ion formed.**
- Give the charges on the sodium and oxide ions. [3 marks]**

(ii) Complete and balance the symbol equation for the reaction. [2 marks]



(Turn over)

4 (b)(i)

TABLE 4.3 in the separate diagram booklet shows the electronic structure of the elements present in oxygen difluoride, F_2O .

DIAGRAM 4.4 in the separate diagram booklet is a dot and cross diagram. Complete the diagram to show the bonding in a molecule of oxygen difluoride. [2 marks]

(Turn over)

4 (b)(ii)

Tick (✓) the box next to the statement that explains why oxygen difluoride has low melting and boiling points. [1 mark]

bonds within the molecules are strong

bonds within the molecules are weak

bonds between the molecules are strong

bonds between the molecules are weak

8

(Turn over)

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5 (a) The symbol equations on the opposite page show three reactions that produce salts.

(i) Complete the symbol equation for each reaction. [3 marks]

(ii) Give the LETTER, A, B or C, of the reaction that forms a precipitate. [1 mark]

(Turn over)

5 (b)(i)

The equation below shows the reaction between dilute hydrochloric acid and sodium hydroxide solution.



**Give the term used to describe the reaction between an acid and an alkali to form a salt and water.
[1 mark]**

(Turn over)

5 (b)(ii)

Eleanor carried out an investigation to find how the pH changes when dilute hydrochloric acid is added to sodium hydroxide solution.

She gradually added dilute hydrochloric acid to 25.0 cm³ of sodium hydroxide solution.

GRAPH 5.1 in the separate diagram booklet shows how the pH of the reaction mixture changed AS THE ACID WAS ADDED.

Use GRAPH 5.1 to answer parts I–III.

- I. Sodium hydroxide is an alkali. Give the pH of the sodium hydroxide solution before any acid was added. [1 mark]**

(Turn over)

5 (b)(ii) continued

II. Give the volume of acid needed to completely react with the sodium hydroxide solution. [1 mark]

_____ **cm³**

(Turn over)

5 (b)(ii) continued

III. Tick (✓) the box next to the statement that correctly describes the concentrations of the acid and the alkali used in this investigation. [1 mark]

the acid and the alkali have the same concentration

the acid has a lower concentration than the alkali

the concentration of the acid is half of the concentration of the alkali

the acid has a higher concentration than the alkali

(Turn over)

5 (b)(iii)

Eleanor measured the pH using a pH sensor. Freddie did a similar experiment but used universal indicator solution to measure the pH.

TABLE 5.2 in the separate diagram booklet shows the colours of universal indicator at different pH values.

Suggest why the data Eleanor collected could be more useful than Freddie's data. [1 mark]

9

(Turn over)

6 The main stages in the manufacture of sulfuric acid are given below.



STAGE 3 production of sulfuric acid
from sulfur trioxide

(a) State the meaning of the symbol \rightleftharpoons used in the **STAGE 2** equation.
[1 mark]

(Turn over)

6 (b) The temperature used in STAGE 2 is 450 °C. This results in a good yield but a low rate.

Name the COMPOUND used as a catalyst to increase the rate. [1 mark]

(Turn over)

6 (c) Dissolving sulfur trioxide in water to form sulfuric acid is too exothermic to be carried out safely in one step.

Give the TWO steps carried out in STAGE 3 to convert sulfur trioxide safely into sulfuric acid. [2 marks]

Step 1

continue answer on next page

(Turn over)

Step 2

(Turn over)

6 (d) The catalyst used in STAGE 2 will NOT work below 400 °C and BREAKS DOWN above 620 °C.

TABLE 6.1 in the separate diagram booklet shows the yield of sulfur trioxide at different temperatures.

Plot the data from TABLE 6.1 on the grid in GRAPH 6.2 in the separate diagram booklet and draw a suitable line. [3 marks]

(e) State what happens to the percentage yield of sulfur trioxide when the temperature is increased. [1 mark]

(Turn over)

6 (f) Use your graph to give the temperature range that produces a yield of 90–99% of sulfur trioxide. [1 mark]

_____ to _____ °C

9

(Turn over)

7 The first three members of the alkene family are shown below.



(a)(i) Give the GENERAL formula of the alkene family. [1 mark]

(Turn over)

7 (a)(ii)

- I. On DIAGRAM 7.1 in the separate diagram booklet, complete the equation for the polymerisation of ethene by drawing the structure of the repeating unit. [1 mark]**

 - II. On DIAGRAM 7.2 in the separate diagram booklet, complete the equation by drawing the structure of the product formed when ethene reacts with bromine. [1 mark]**

 - III. Name the type of reaction that occurs in parts I and II above. [1 mark]**
-

(Turn over)

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7 (a)(iii)

Ethene burns in air forming carbon dioxide and water.

Complete and balance the equation for this reaction on the opposite page. [2 marks]

(Turn over)

7 (b) Ethene reacts with hydrogen, forming ethane.

DIAGRAM 7.3 in the separate diagram booklet shows the bonds that are broken and the bonds that are formed in the production of ethane.

The relevant bond energies are shown in **TABLE 7.4** in the separate diagram booklet.

(i) Use the information in TABLE 7.4 to show that the TOTAL energy needed to break all the bonds in the REACTANTS is 2696 kJ. [2 marks]

(Turn over)

7 (b)(ii)

The **TOTAL** energy released when the bonds in the **PRODUCTS** are formed is 2820 kJ.

Calculate the energy released when forming a C–C bond. [2 marks]

Energy = _____ kJ

(Turn over)

7 (b)(iii)

Use the total energy values given in parts (i) and (ii) to answer this question.

**On DIAGRAM 7.5 in the separate diagram booklet, tick (✓) the box next to the energy profile diagram that shows the reaction taking place.
[1 mark]**

(Turn over)

7 (c) Isomers A, B and C all have the molecular formula C_4H_8 . These are shown in DIAGRAM 7.6 in the separate diagram booklet.

**Give the LETTER of the structure fitting each of the following names.
[2 marks]**

but-1-ene _____

but-2-ene _____

2-methylpropene _____

13

(Turn over)

8 (a) FUELLING THE FUTURE

The main fuel used as a petrol substitute for cars is bioethanol. Bioethanol fuel is mainly produced by the fermentation of sugar.

The main sources of the sugar required to produce bioethanol are corn, maize and wheat. These crops absorb carbon dioxide from the atmosphere.

The use of pure bioethanol in car engines is only possible if the engines are designed for that purpose. For this reason, bioethanol-petrol mixtures called 'blends' are used.

Bioethanol-petrol mixtures have "E" numbers that describe the percentage of bioethanol in the mixture by volume. See **DIAGRAM 8.1 in the separate diagram booklet.**

question continues

(Turn over)

Question 8 (a) continued

Pure bioethanol is hard to vaporise. This makes it difficult to start a car when the weather is cold, which is why the fuels are almost always a bioethanol-petrol mixture.

DIAGRAM 8.2 in the separate diagram booklet shows three properties of some fuels.

Some people claim that bioethanol is 'carbon neutral' because the plants that are the source of the bioethanol absorb carbon dioxide as they grow. This compensates for the carbon dioxide released when bioethanol is burned.

However, carbon dioxide is also emitted during the construction of the fermentation factory, during fermentation and when bioethanol is transported around the world.

question continues

(Turn over)

Question 8 (a) continued

In some parts of the world, large areas of forest have been cleared and burned to develop the bioethanol industry. Deforestation to make space for crops has a devastating effect on the environment because it drastically reduces the number of trees that can capture carbon dioxide emissions. The amount of land needed to grow the biomass material is considered the main drawback of bioethanol as a fuel.

(Turn over)

8 (a)(i)

Tick (✓) the box next to the ratio of bioethanol : petrol in the E20 fuel blend. [1 mark]

80% bioethanol : 20% petrol

20% bioethanol : 20% petrol

20% bioethanol : 80% petrol

(Turn over)

8 (a)(ii)

Tick (✓) the box next to the statement that describes the effect of increasing the percentage of bioethanol in a fuel blend. [1 mark]

the energy value decreases

the density decreases

the flash point decreases

(Turn over)

8 (a)(iii)

Give ONE reason that undermines the claim that burning bioethanol is 'carbon neutral'. [1 mark]

(Turn over)

8 (b) The molecular formula for ethanol is C_2H_5OH .

**(i) Draw the structure of ethanol.
[1 mark]**

(Turn over)

8 (b)(ii)

When ethanol is exposed to air it slowly forms ethanoic acid.

When ethanoic acid reacts with magnesium carbonate, a salt is formed.

I. Give the name of the salt. [1 mark]

II. The negative ion in the salt has the formula CH_3COO^- .

UNDERLINE the correct formula of the salt. [1 mark]



(Turn over)

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UNKNOWN COMPOUND

CHEMICAL NAME

A

copper(II) chloride

iron(II) chloride

ammonium sulfate

B

iron(III) chloride

copper(II) carbonate

C

ammonium carbonate

iron(II) sulfate

8 (c) A student carries out a series of chemical tests on solutions of three unknown compounds, A, B and C.

Her results are recorded in TABLE 8.3 in the separate diagram booklet.

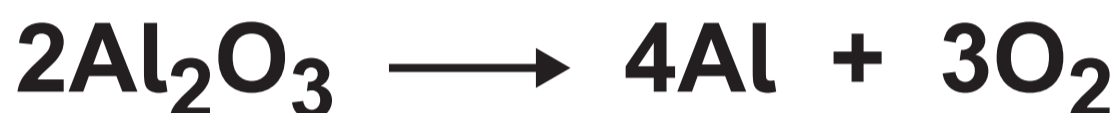
On the opposite page, draw a line from the unknown compound to its correct chemical name. [3 marks]

9

(Turn over)

9 (a) DIAGRAM 9.1 in the separate diagram booklet shows a model of the cell used in the extraction of aluminium from molten aluminium oxide.

The overall equation for the reaction is shown below.



Aluminium oxide contains Al^{3+} and O^{2-} ions.

Explain, in terms of these ions, the formation of both products. Include electrode equations to support your answer. [6 marks QER]

continue answer on next page (Turn over)

(Turn over)

9 (b) Apart from a workforce and local transport infrastructure, explain ONE other important factor when choosing a site for an aluminium extraction plant in the UK. [2 marks]

8

10 A technician prepared 250 cm^3 of a 0.50 mol/dm^3 solution of citric acid, $\text{C}_6\text{H}_8\text{O}_7$.

(a) Calculate the number of moles of citric acid in the solution. [2 marks]

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{number of moles}}{\text{volume (dm}^3\text{)}}$$

$$1 \text{ dm}^3 = 1000 \text{ cm}^3$$

Number of moles = _____ mol
(Turn over)

10 (b)

Calculate the mass of citric acid in the solution. [2 marks]

$$A_r(\text{H}) = 1 \quad A_r(\text{C}) = 12 \quad A_r(\text{O}) = 16$$

$$\text{number of moles} = \frac{\text{mass (g)}}{M_r}$$

Mass = _____ g

4

END OF PAPER

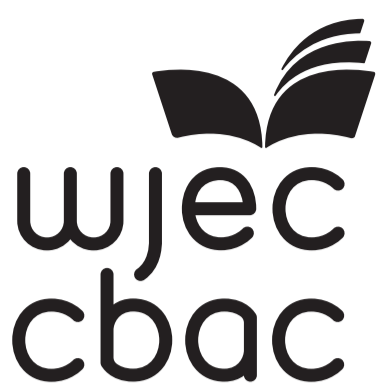
Question number	Additional page, if required. Write the question numbers in the left-hand margin.

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GCSE

3410UB0-1

FRIDAY, 17 MAY 2024 – MORNING

**CHEMISTRY – Unit 2:
Chemical Bonding, Application of Chemical
Reactions and Organic Chemistry
HIGHER TIER**

**1 hour 45 minutes plus your additional
time allowance**

DIAGRAM BOOKLET

**This Diagram Booklet MUST be handed in
to the invigilators and sent for marking.**

Surname _____

First name(s) _____

Centre Number _____

Candidate Number 0 _____

DIAGRAM 1.1

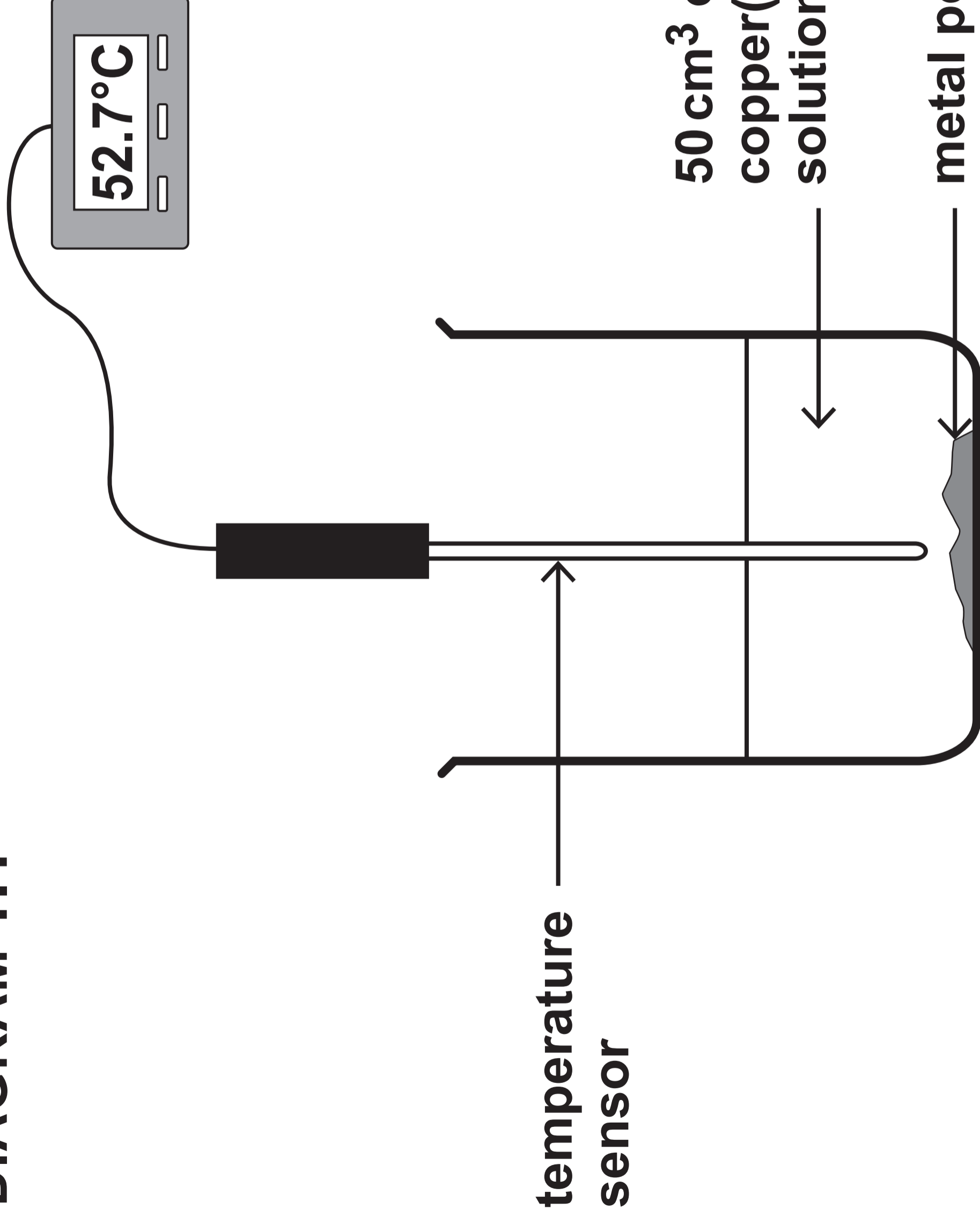
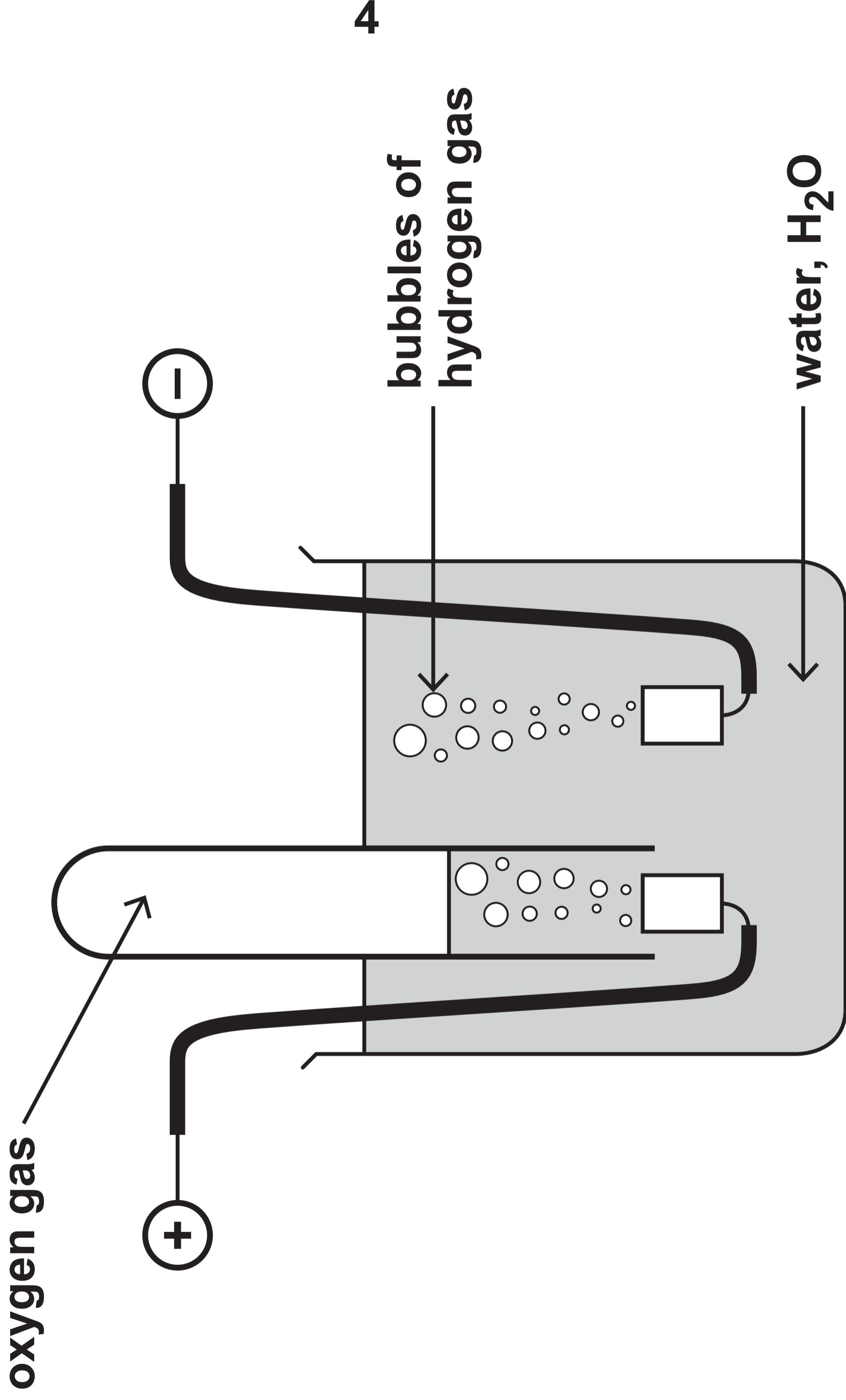


TABLE 1.2

Metal	Temperature rise (°C)	Energy given out (J)
magnesium	40.5	8500
zinc	33.0	6900
iron	23.2	4900
nickel	19.0	4000

DIAGRAM 2.1



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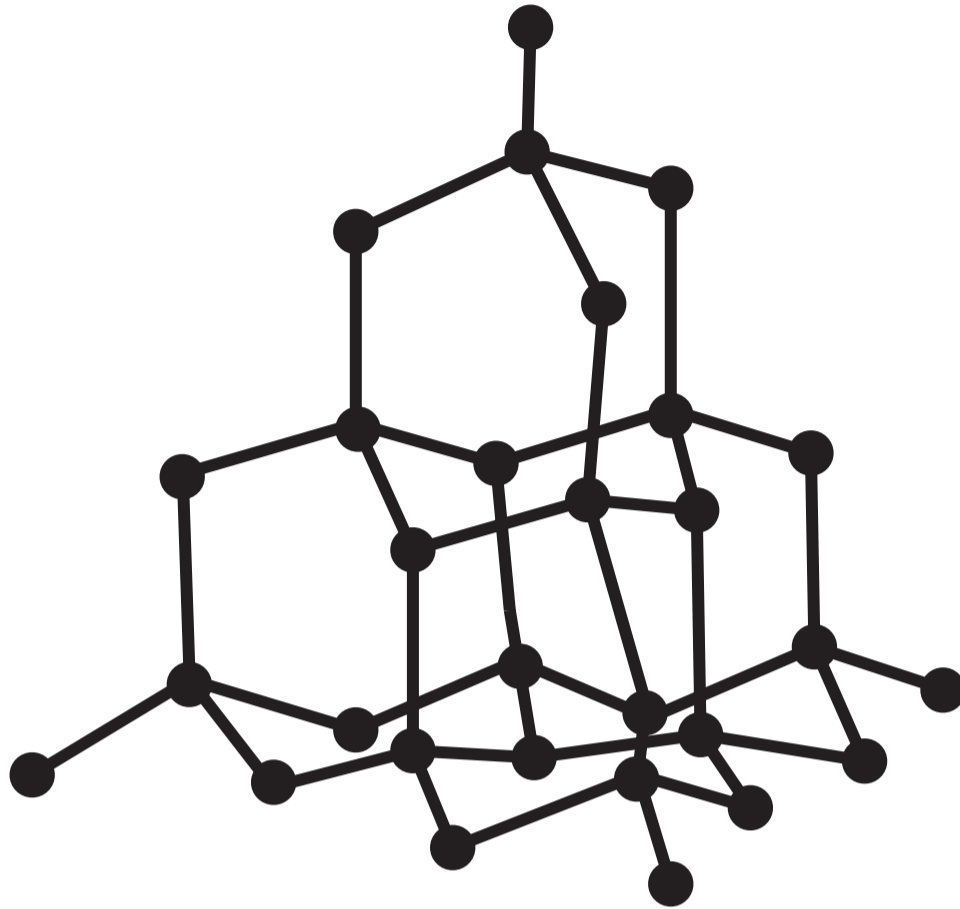
TABLE 2.2

Ions present in the electrolyte	
Electrolyte	Negative ion(s)
molten lead(II) bromide	Positive ion(s) Pb²⁺ _____
aqueous copper(II) chloride	Cl⁻ and OH⁻ _____ and H ⁺
aqueous compound C	I⁻ and OH⁻ Zn²⁺ and H⁺

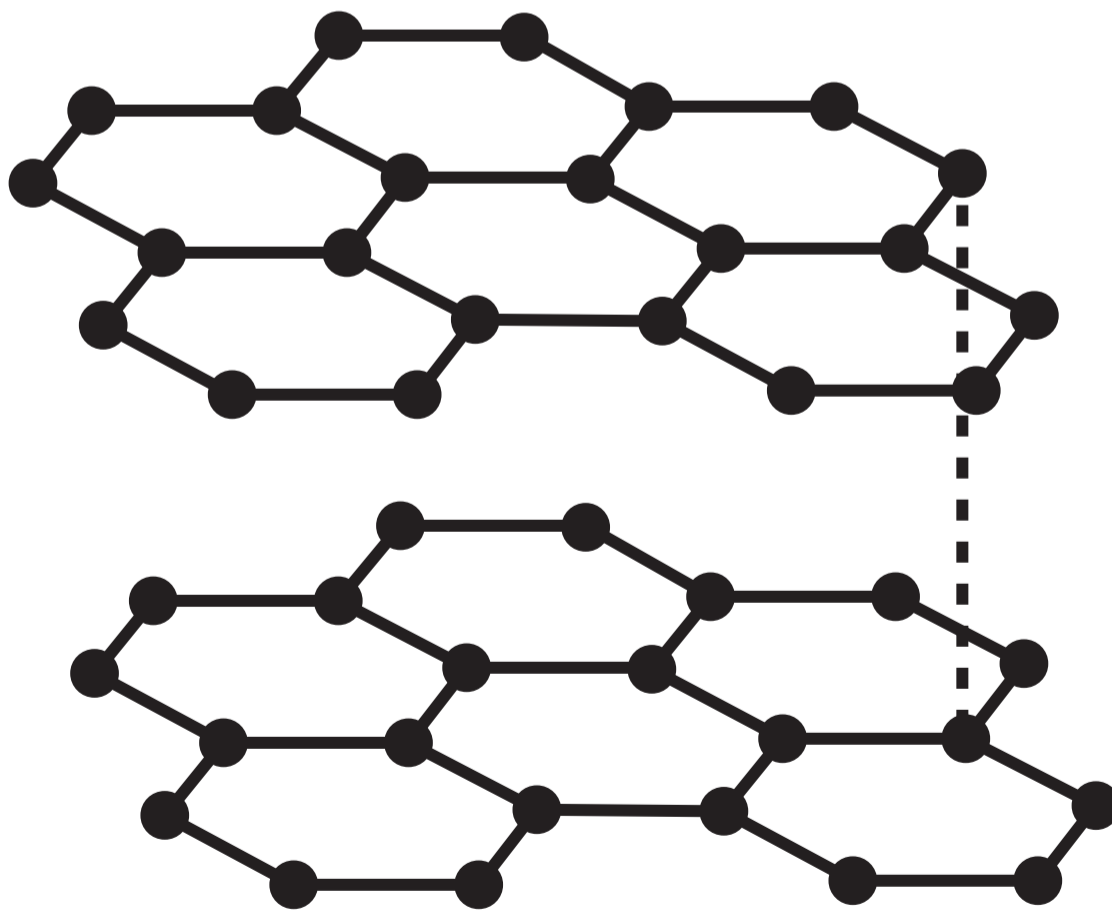
TABLE 2.2 continued

Electrolyte	Observations	
	At the negative (-) electrode	At the positive (+) electrode
molten lead(II) bromide	grey metal A formed	orange gas formed
aqueous copper(II) chloride	brown metal formed	green-yellow gas B formed
aqueous compound C	grey metal formed	brown solution formed

DIAGRAM 3.1



diamond



graphite

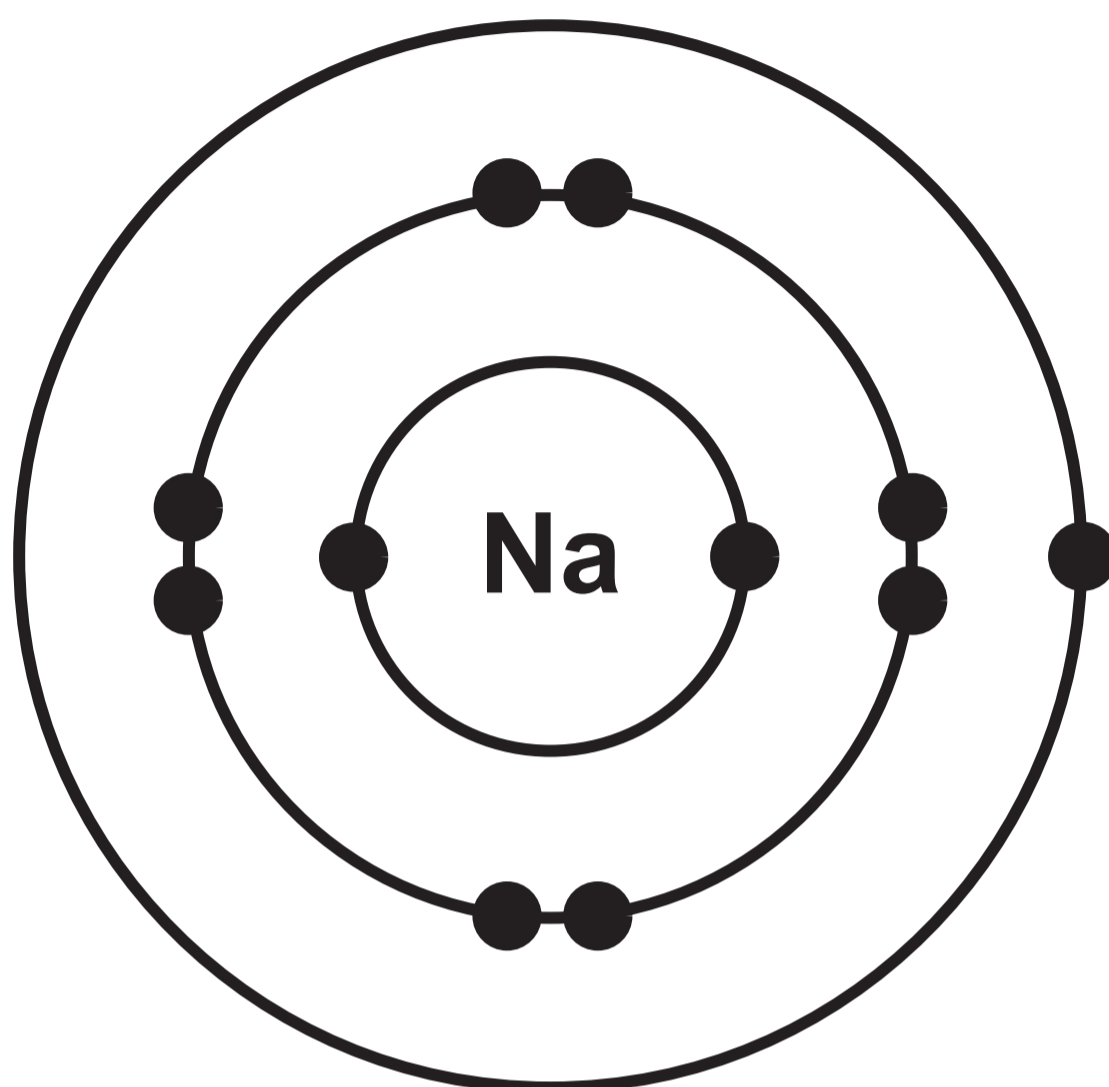
TABLE 3.2

Properties of graphite
soft
high melting point
insoluble in water
conducts electricity

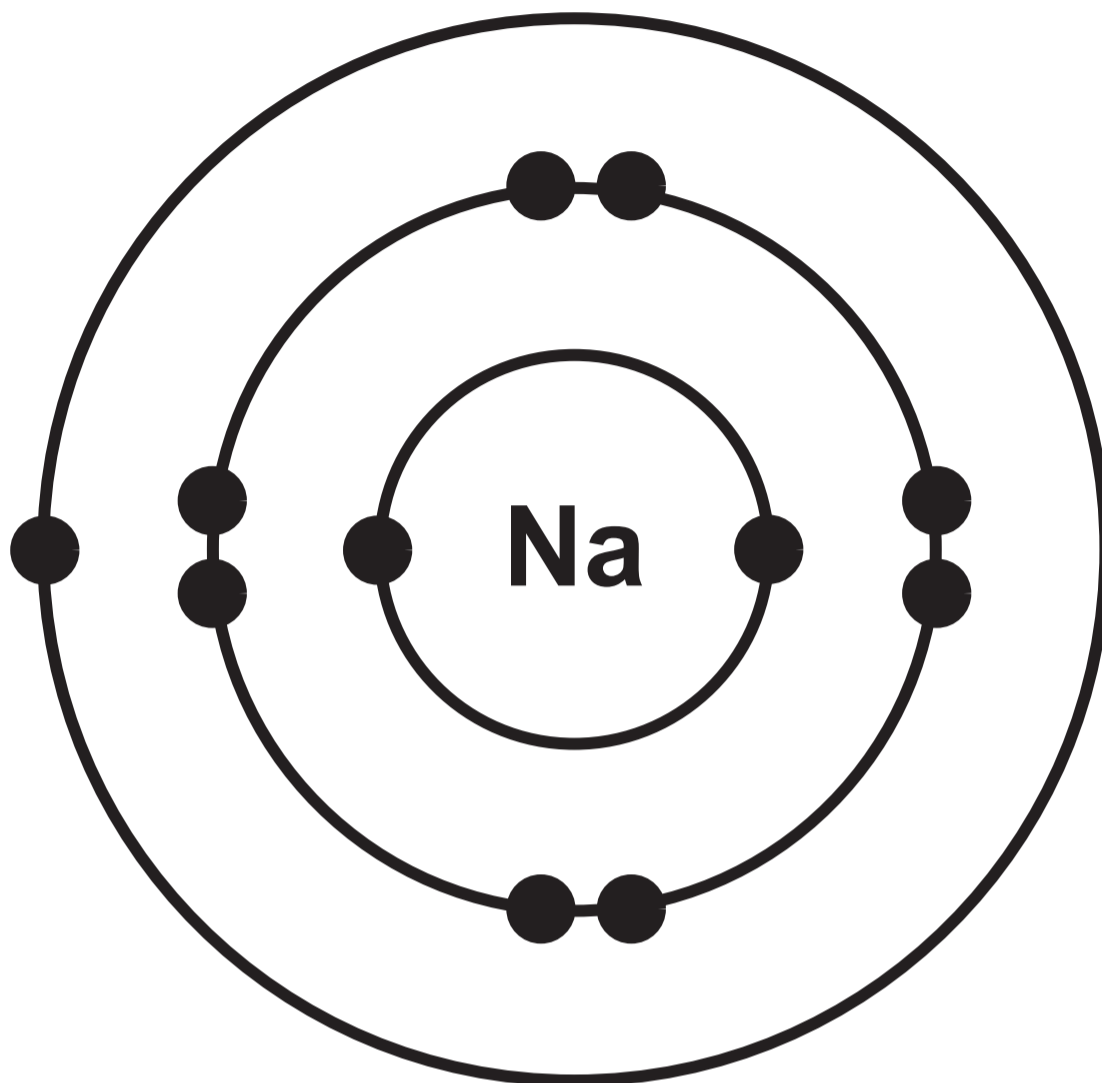
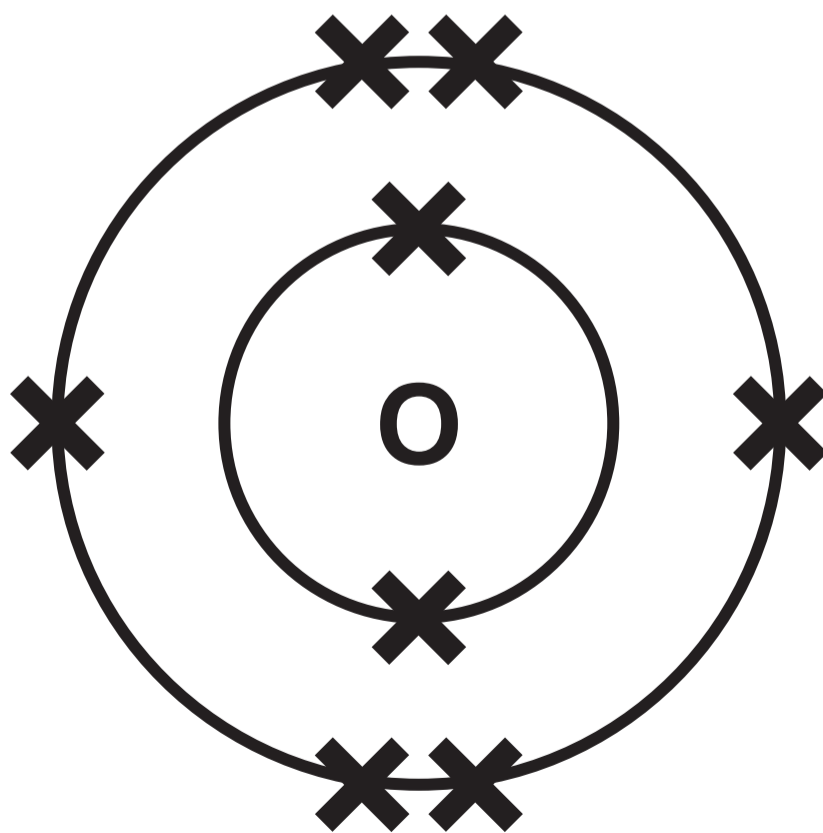
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DIAGRAM 4.1



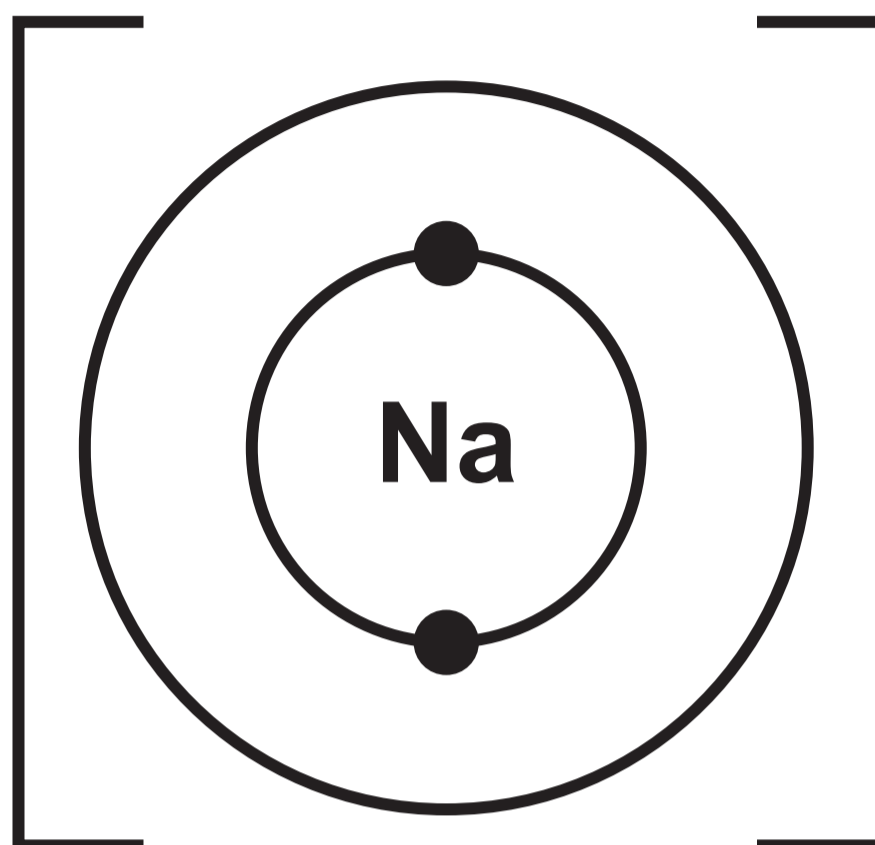
sodium atom

DIAGRAM 4.1 continued**sodium atom****oxygen atom**

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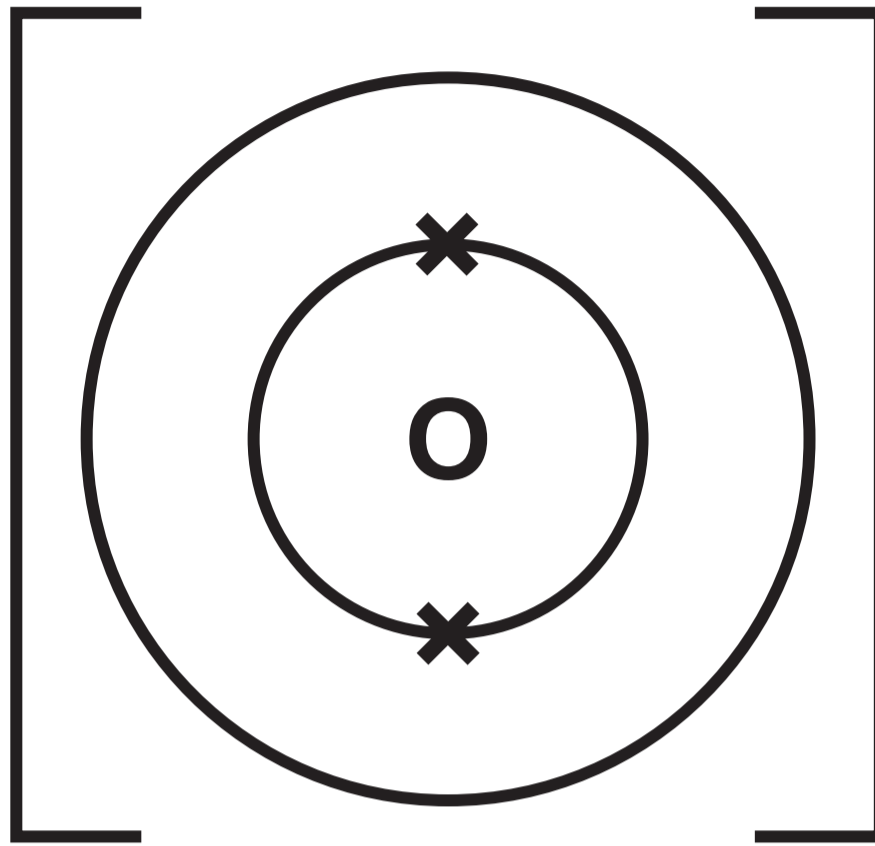
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DIAGRAM 4.2

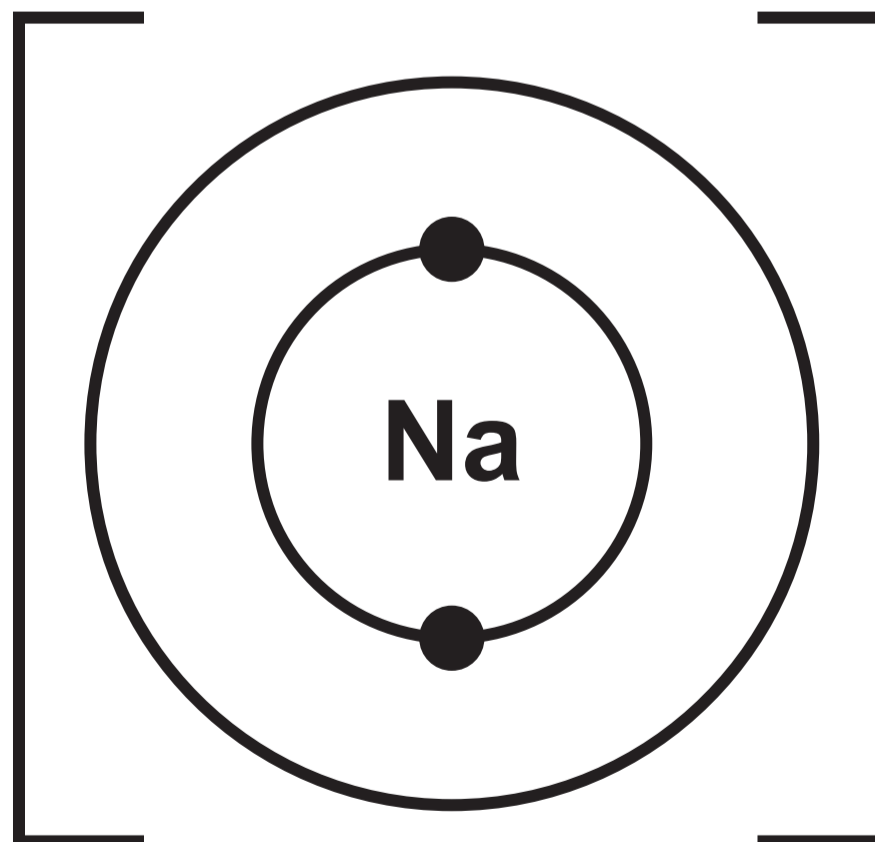


sodium ion

DIAGRAM 4.2 continued



oxide ion

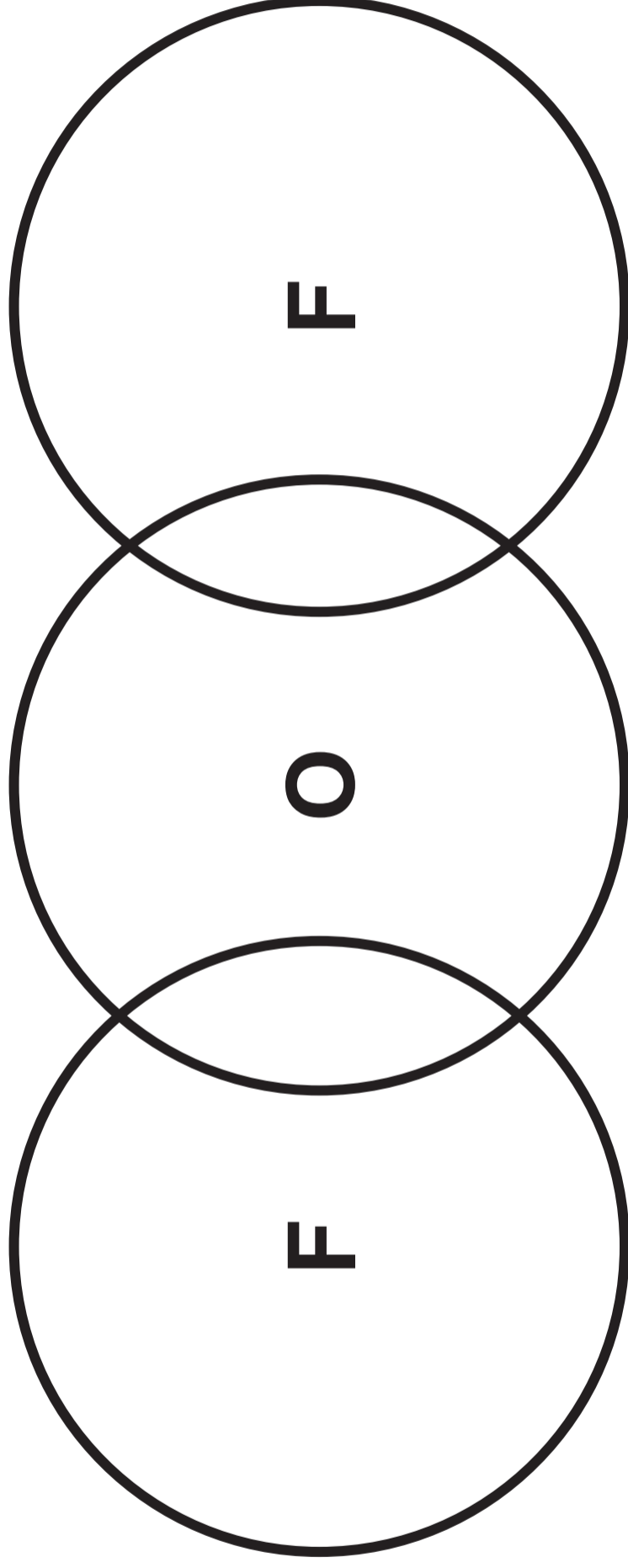


sodium ion

TABLE 4.3

Element	Electronic structure
fluorine	2,7
oxygen	2,6

DIAGRAM 4.4



GRAPH 5.1

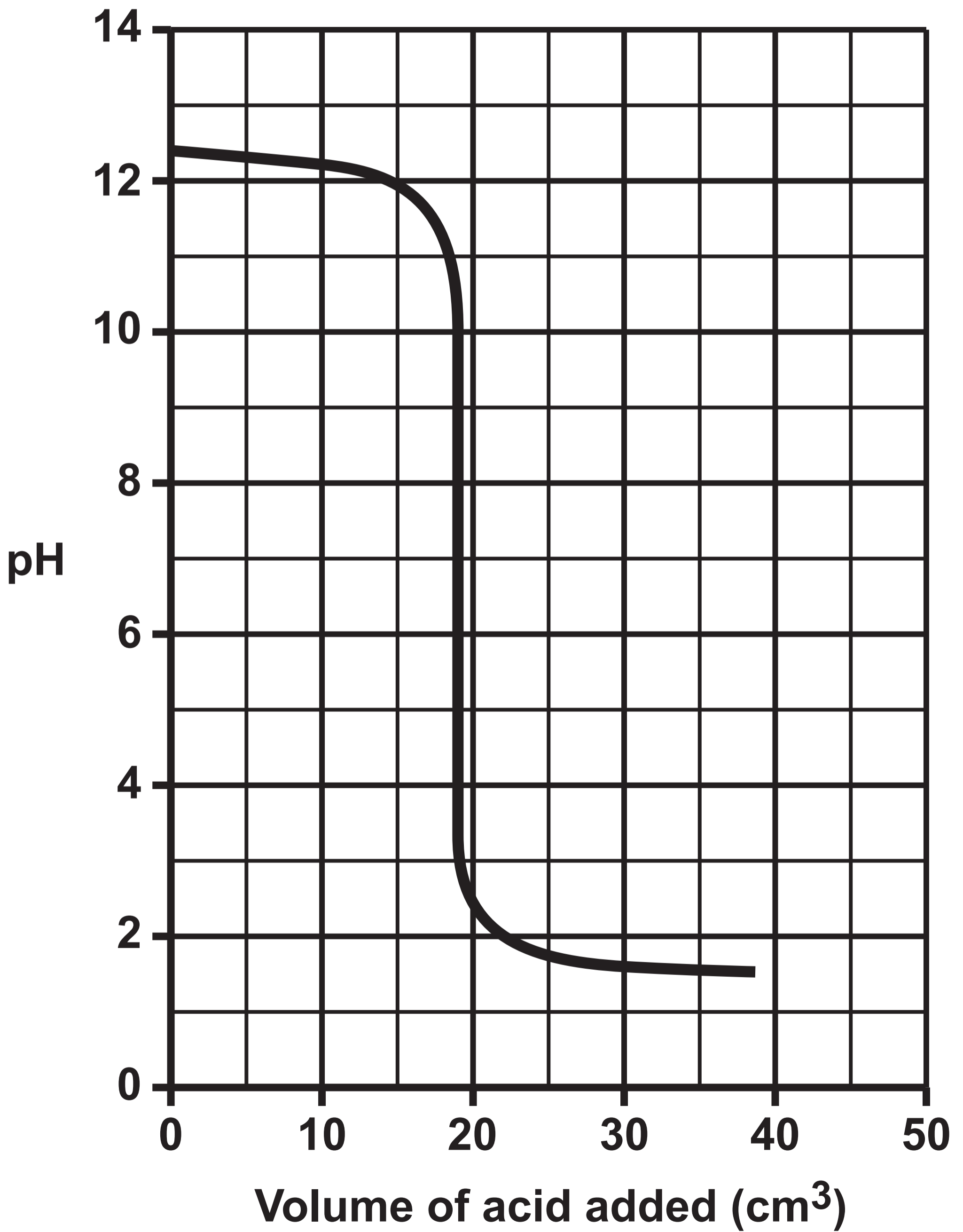


TABLE 5.2

Colour	red	orange	yellow	green	blue	navy blue	purple
pH	0–2	3–4	5–6	7	8–9	10–12	13–14

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TURN OVER

TABLE 6.1

Temperature (°C)	400	450	500	550	600
Percentage yield of sulfur trioxide (%)	99.0	96.5	92.5	86.0	76.5

GRAPH 6.2

**Percentage yield of
sulfur trioxide (%)**

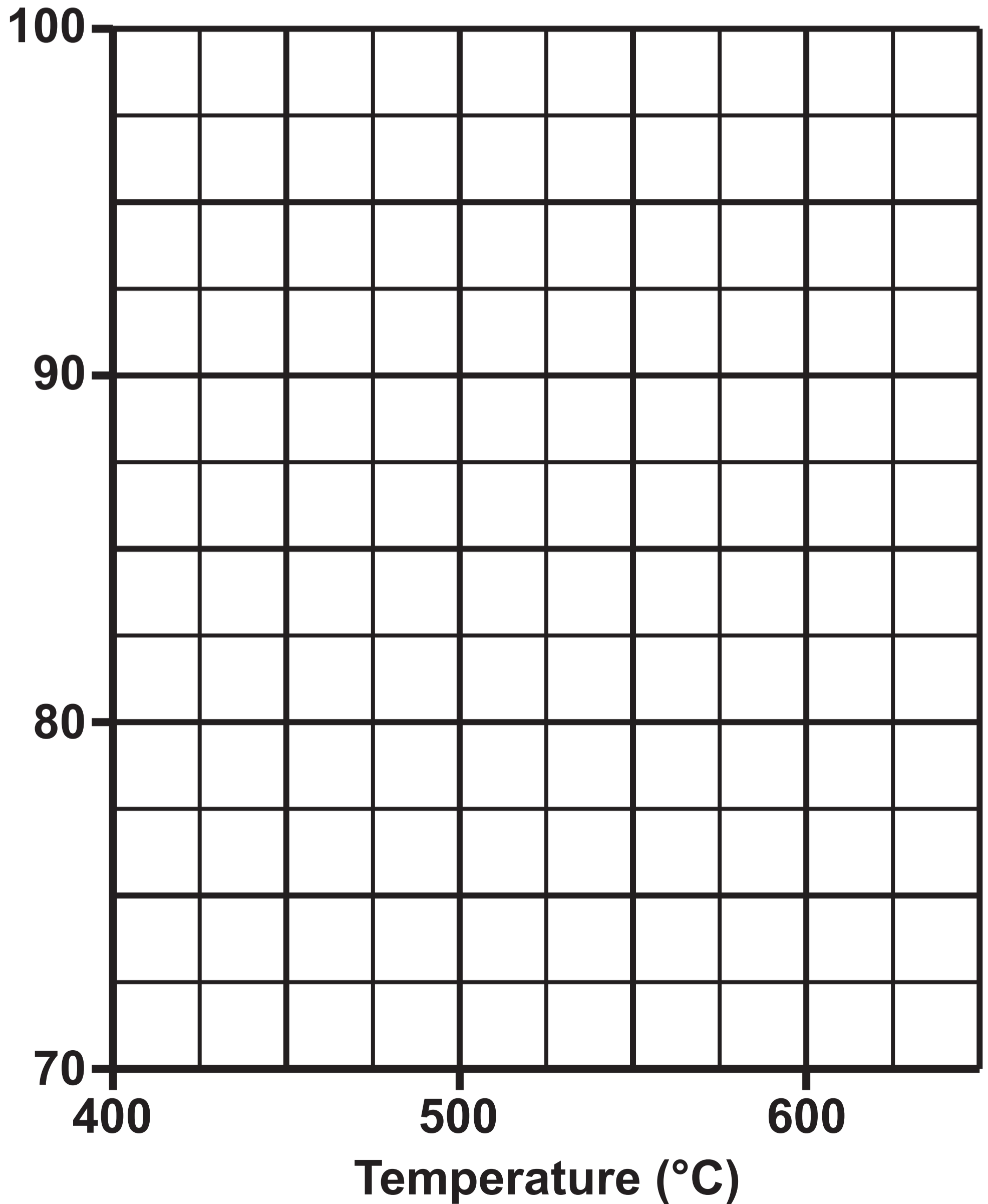


DIAGRAM 7.1

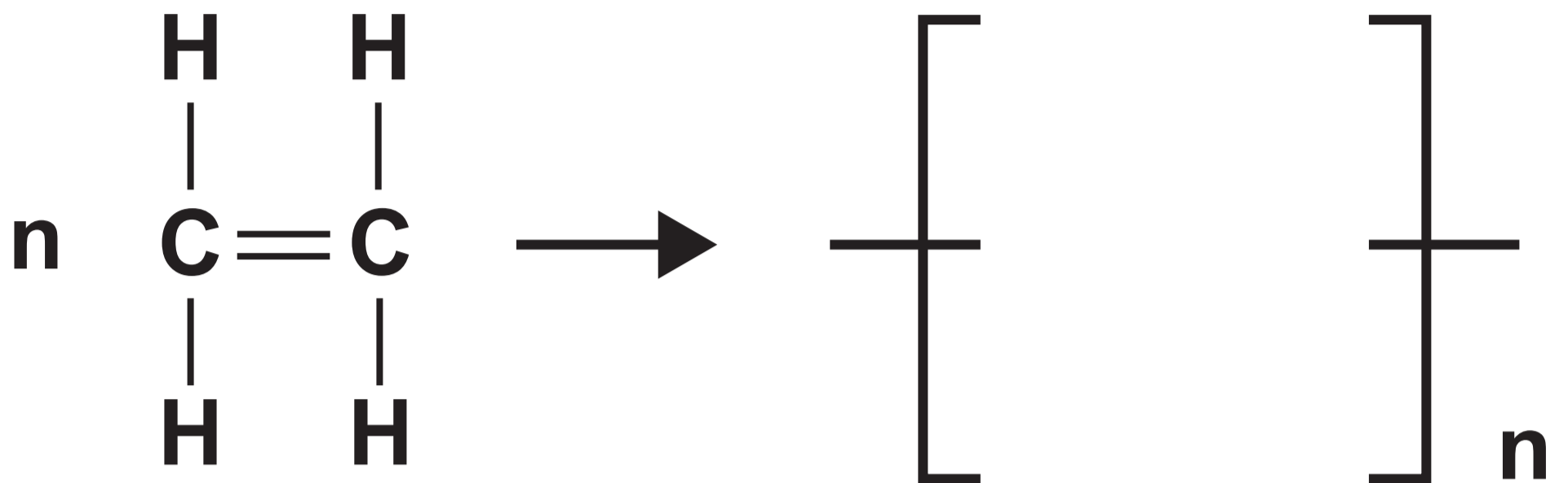


DIAGRAM 7.2

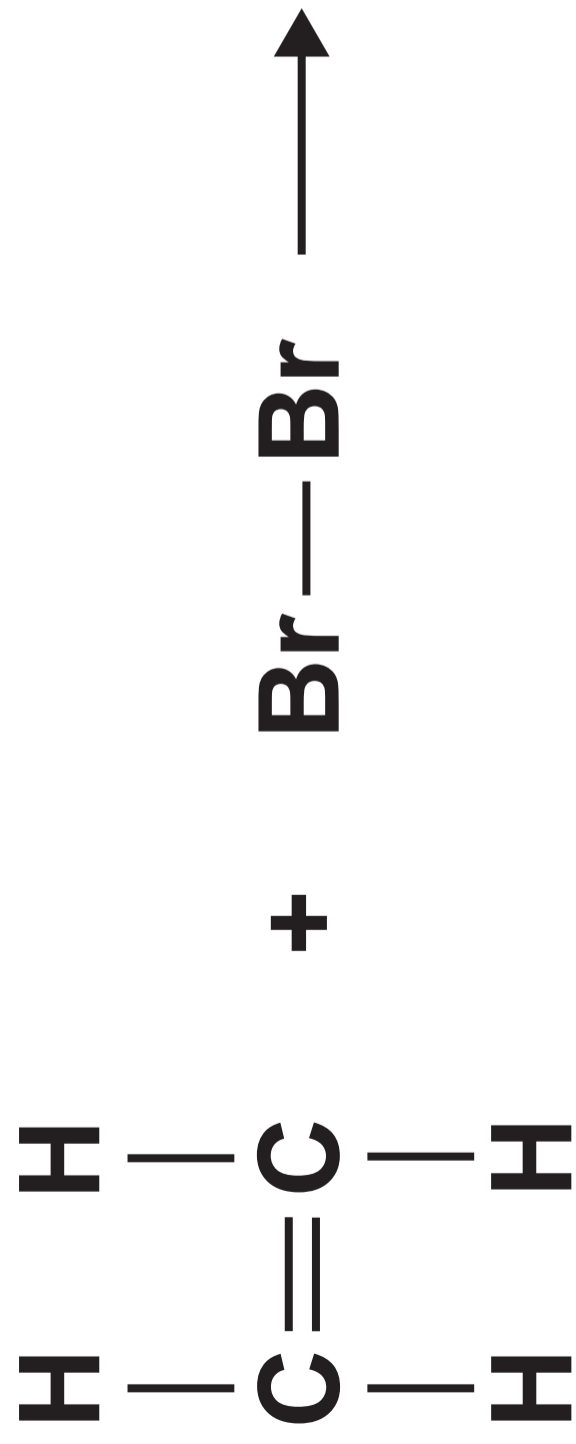


DIAGRAM 7.3

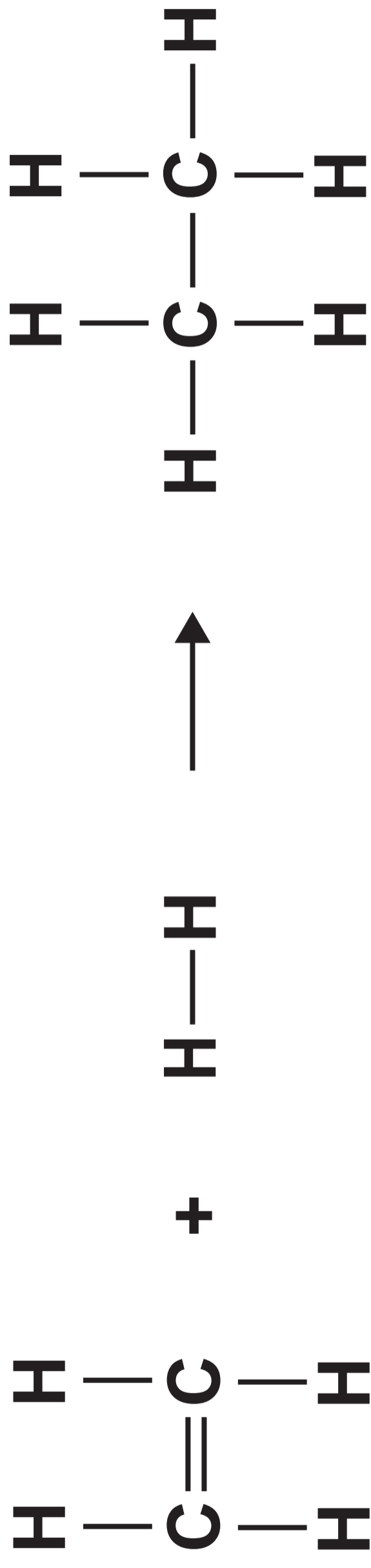


TABLE 7.4

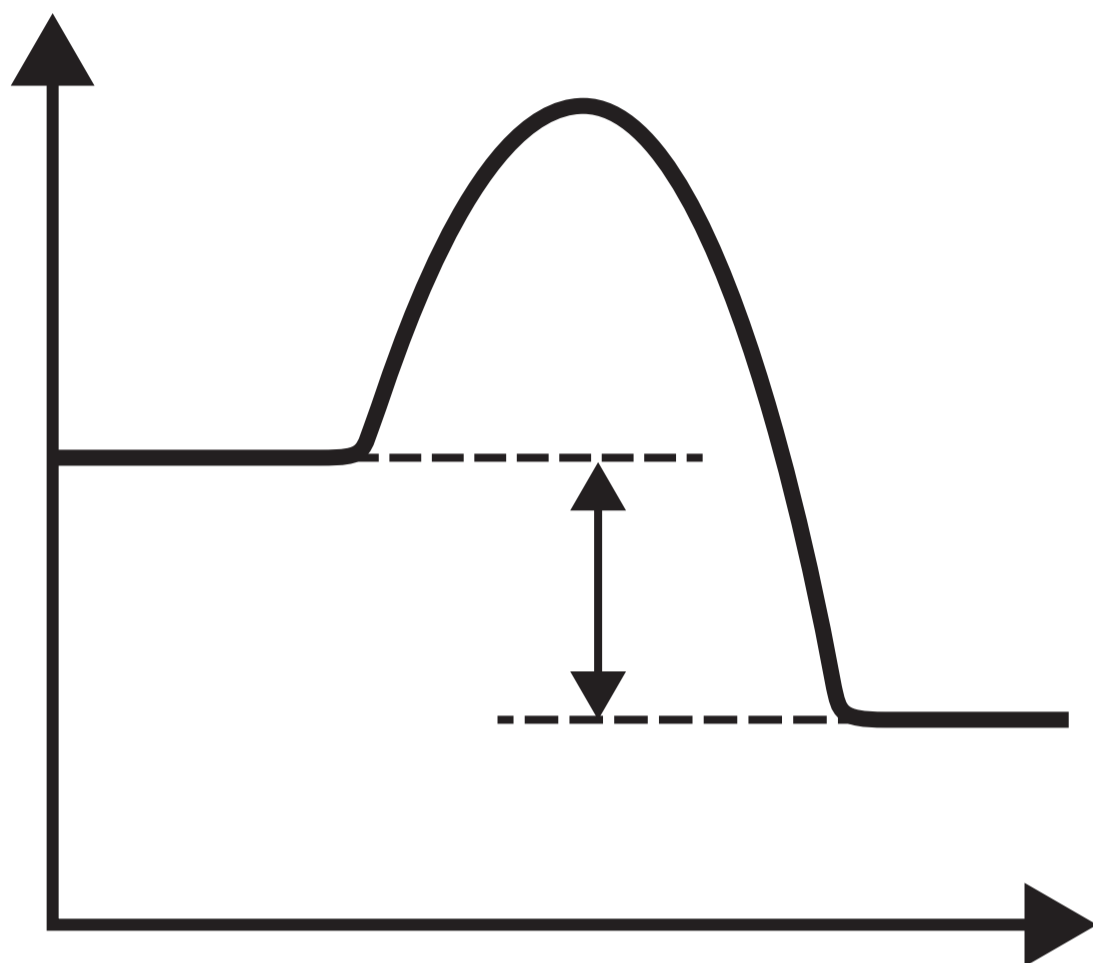
Bond	Bond energy (kJ)
C—H	412
H—H	436
C=C	612

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DIAGRAM 7.5

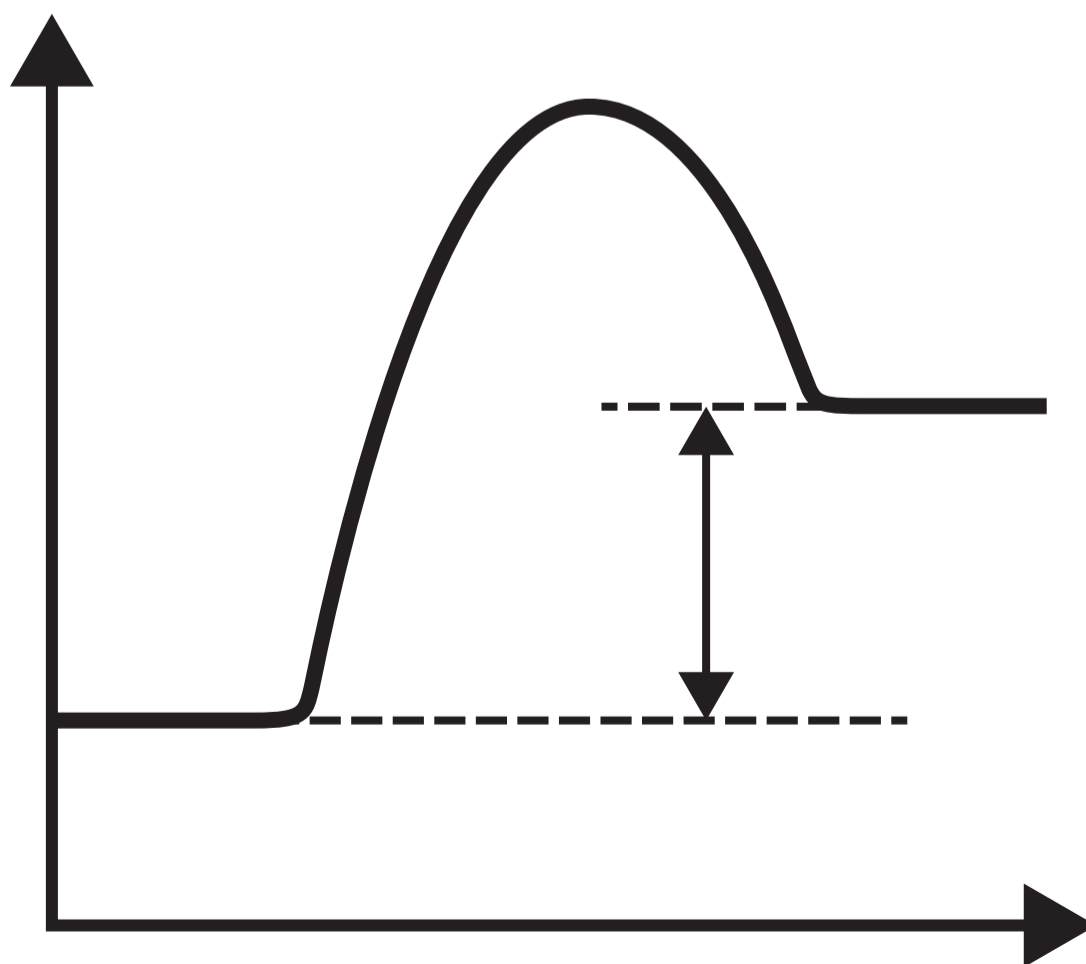
Energy



Reaction pathway

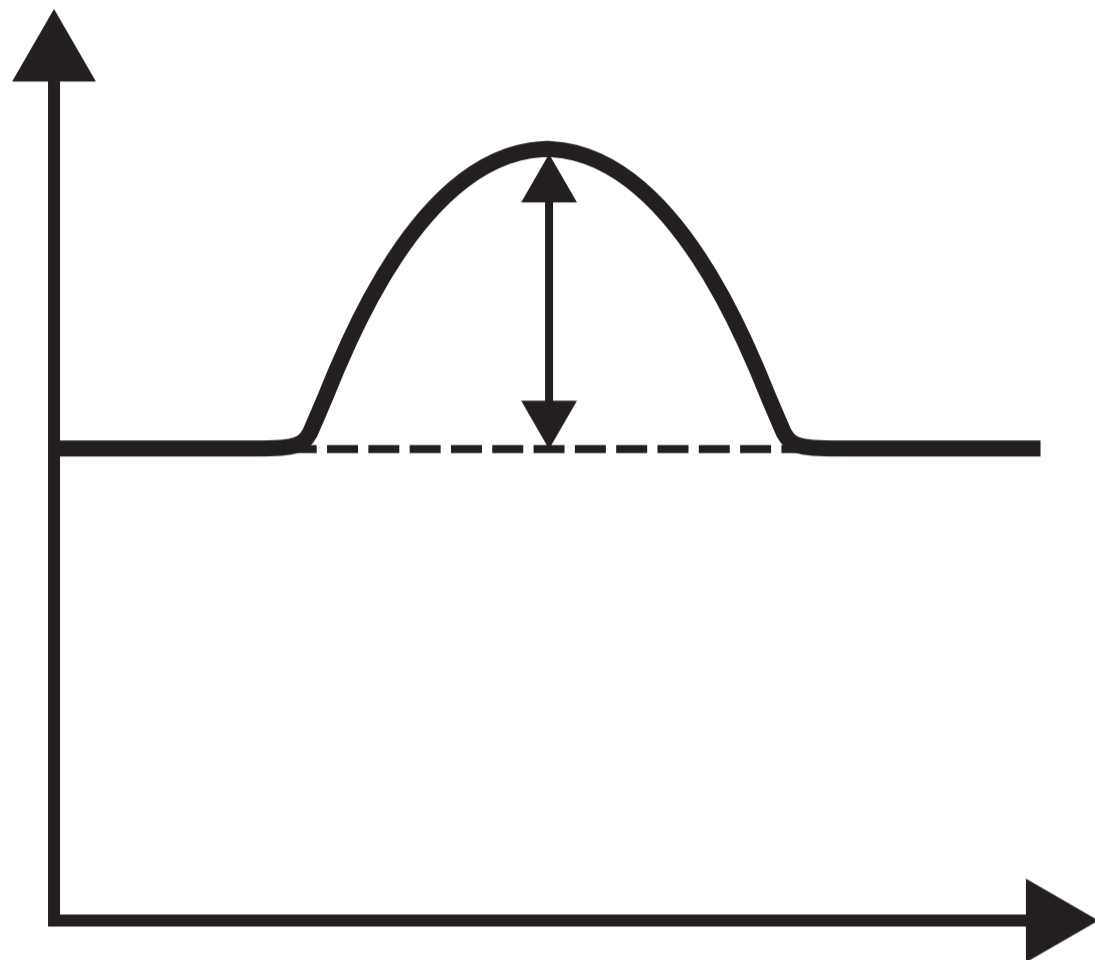


Energy



Reaction pathway



DIAGRAM 7.5 continued**Energy****Reaction pathway**

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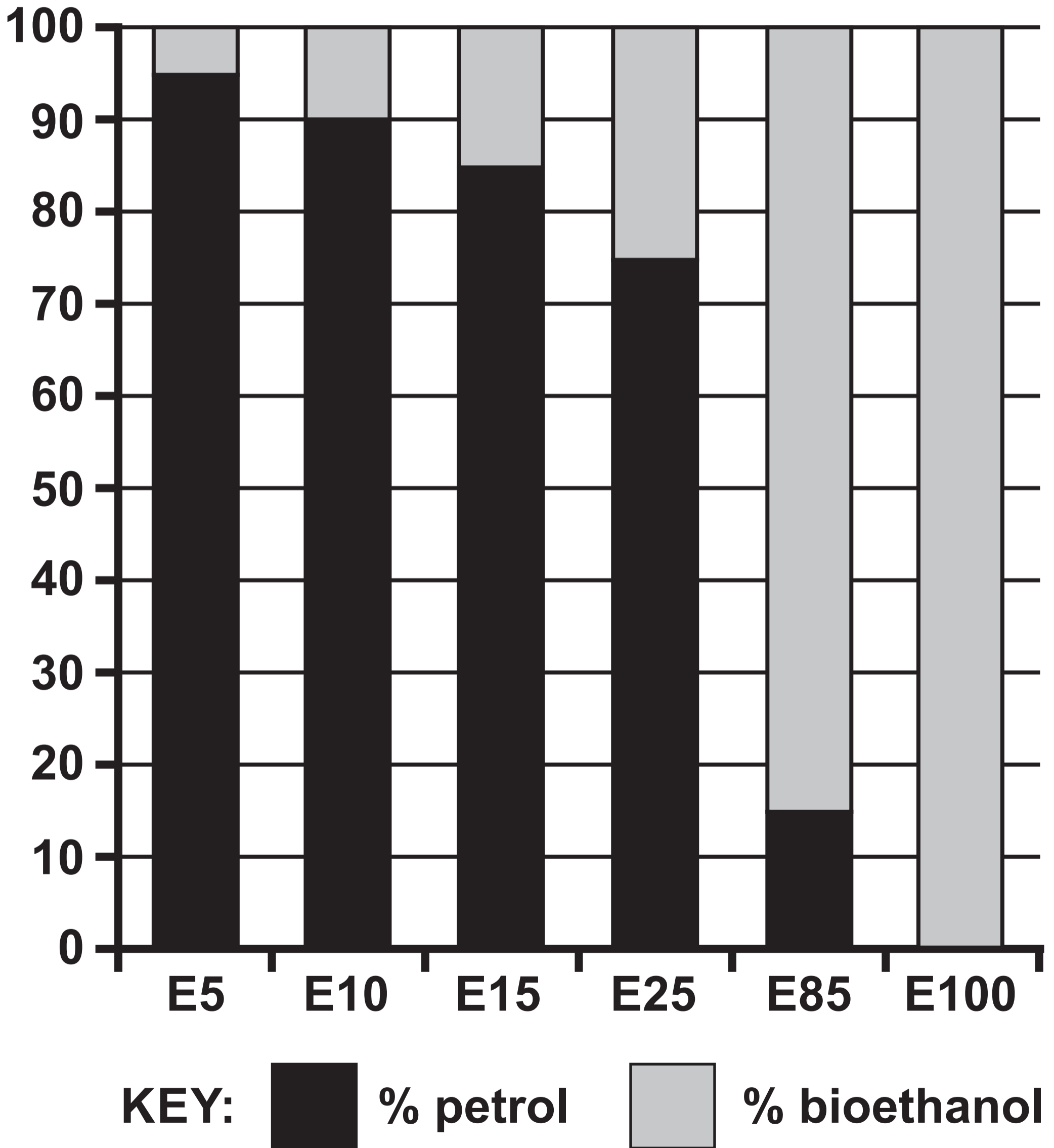
DIAGRAM 8.1**% composition
by volume**

DIAGRAM 8.2

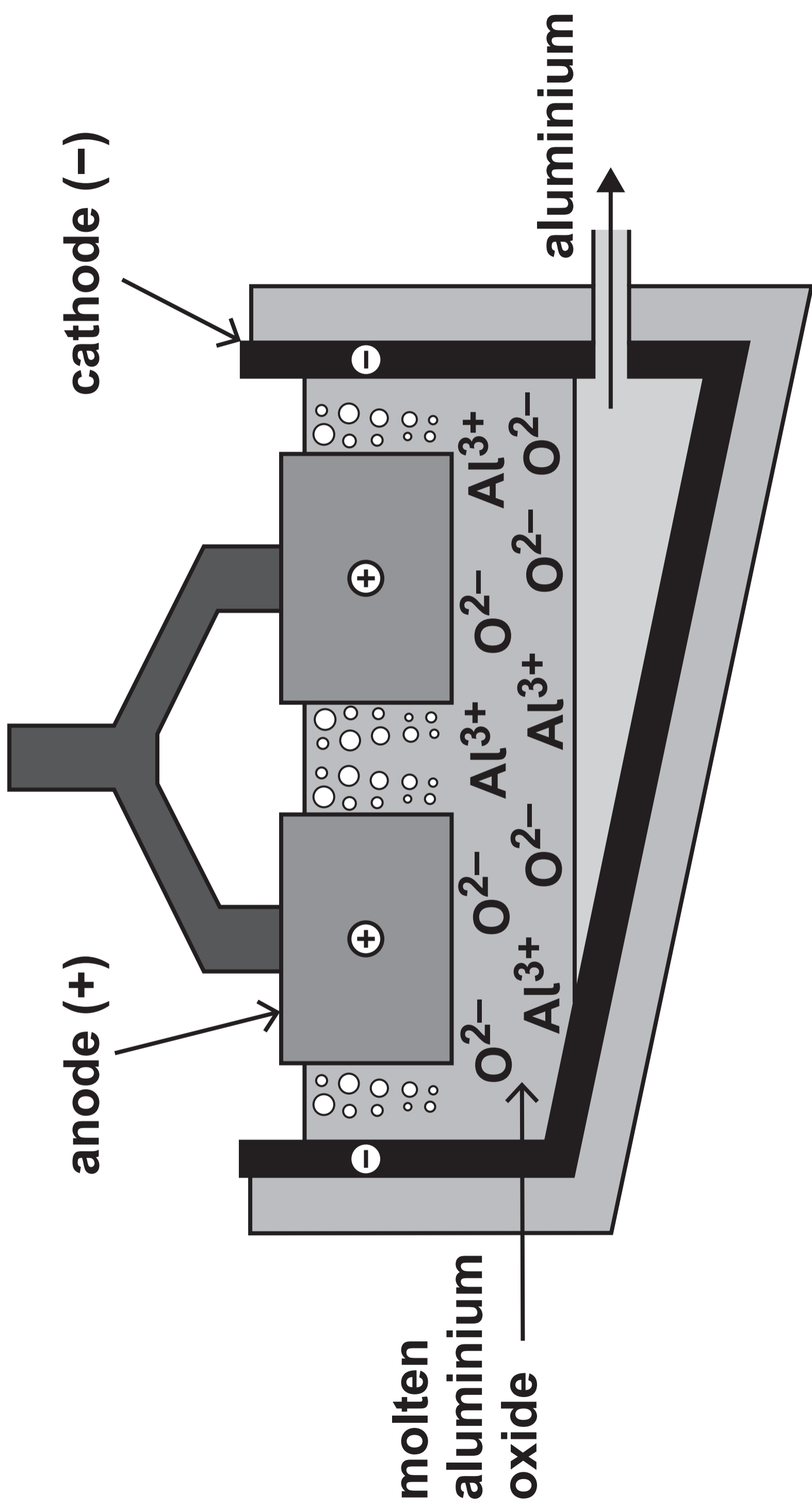
Property	Petrol	E10	E20	E30	E40	E60	Bioethanol
Density (kg/m³)	747.4	750.8	760.5	778.2	779.2	781.2	789.0
Flash point (°C)	-65	-40	-20	-15	-13.5	-1.0	12.5
Energy value (MJ/kg)	44.40	44.22	42.08	40.48	38.50	35.84	29.78

**Flash point:
The flash point is the lowest temperature at which the fuel ignites.**

TABLE 8.3

	Add dilute HCl	Add BaCl₂(aq)	Add NaOH(aq)	Add AgNO₃(aq)
A	gas given off turns limewater milky		pungent smelling gas given off that turns damp red litmus paper blue	
B	no reaction	white precipitate forms	green precipitate forms	no reaction
C	no reaction	no reaction	blue precipitate forms	white precipitate forms

DIAGRAM 9.1





3410UB0-1

FRIDAY, 17 MAY 2024 – MORNING

CHEMISTRY – Unit 2:

**Chemical Bonding, Application of Chemical
Reactions and Organic Chemistry**

HIGHER TIER

Data Booklet

FORMULAE FOR SOME COMMON IONS

POSITIVE IONS	
Name	Formula
aluminium	Al³⁺
ammonium	NH₄⁺
barium	Ba²⁺
calcium	Ca²⁺
copper(II)	Cu²⁺
hydrogen	H⁺
iron(II)	Fe²⁺
iron(III)	Fe³⁺
lithium	Li⁺
magnesium	Mg²⁺
nickel	Ni²⁺
potassium	K⁺
silver	Ag⁺
sodium	Na⁺
zinc	Zn²⁺

NEGATIVE IONS

Name	Formula
bromide	Br^-
carbonate	CO_3^{2-}
chloride	Cl^-
fluoride	F^-
hydroxide	OH^-
iodide	I^-
nitrate	NO_3^-
oxide	O^{2-}
sulfate	SO_4^{2-}

THE PERIODIC TABLE

1 2 GROUP

1 H 1

7 Li 3	9 Be 4
23 Na 11	24 Mg 12

KEY	
A_r	relative atomic mass
Sym	symbol
Z	atomic number

39 K 19	40 Ca 20	45 Sc 21	48 Ti 22	51 V 23	52 Cr 24	55 Mn 25	56 Fe 26	59 Co 27
86 Rb 37	88 Sr 38	89 Y 39	91 Zr 40	93 Nb 41	96 Mo 42	99 Tc 43	101 Ru 44	103 Rh 45
133 Cs 55	137 Ba 56	139 La 57	179 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77
223 Fr 87	226 Ra 88	227 Ac 89						

3 4 5 6 7 0

4
He
2

11 B 5	12 C 6	14 N 7	16 O 8	19 F 9	20 Ne 10
27 Al 13	28 Si 14	31 P 15	32 S 16	35.5 Cl 17	40 Ar 18

59 Ni 28	63.5 Cu 29	65 Zn 30	70 Ga 31	73 Ge 32	75 As 33	79 Se 34	80 Br 35	84 Kr 36
106 Pd 46	108 Ag 47	112 Cd 48	115 In 49	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	210 Po 84	210 At 85	222 Rn 86

THE PERIODIC TABLE

PERIODIC TABLE – KEY

ATOMIC NUMBER – SYMBOL – NAME

1	H – Hydrogen	19	K – Potassium
2	He – Helium	20	Ca – Calcium
3	Li – Lithium	21	Sc – Scandium
4	Be – Beryllium	22	Ti – Titanium
5	B – Boron	23	V – Vanadium
6	C – Carbon	24	Cr – Chromium
7	N – Nitrogen	25	Mn – Manganese
8	O – Oxygen	26	Fe – Iron
9	F – Fluorine	27	Co – Cobalt
10	Ne – Neon	28	Ni – Nickel
11	Na – Sodium	29	Cu – Copper
12	Mg – Magnesium	30	Zn – Zinc
13	Al – Aluminium	31	Ga – Gallium
14	Si – Silicon	32	Ge – Germanium
15	P – Phosphorus	33	As – Arsenic
16	S – Sulfur	34	Se – Selenium
17	Cl – Chlorine	35	Br – Bromine
18	Ar – Argon	36	Kr – Krypton

37	Rb – Rubidium	57	La – Lanthanum
38	Sr – Strontium	72	Hf – Hafnium
39	Y – Yttrium	73	Ta – Tantalum
40	Zr – Zirconium	74	W – Tungsten
41	Nb – Niobium	75	Re – Rhenium
42	Mo – Molybdenum	76	Os – Osmium
43	Tc – Technetium	77	Ir – Iridium
44	Ru – Ruthenium	78	Pt – Platinum
45	Rh – Rhodium	79	Au – Gold
46	Pd – Palladium	80	Hg – Mercury
47	Ag – Silver	81	Tl – Thallium
48	Cd – Cadmium	82	Pb – Lead
49	In – Indium	83	Bi – Bismuth
50	Sn – Tin	84	Po – Polonium
51	Sb – Antimony	85	At – Astatine
52	Te – Tellurium	86	Rn – Radon
53	I – Iodine	87	Fr – Francium
54	Xe – Xenon	88	Ra – Radium
55	Cs – Caesium	89	Ac – Actinium
56	Ba – Barium		