Surname:	**First Name:**

Current School:

Shrewsbury School

SHREWSBURY SCHOOL

SIXTH FORM ENTRANCE EXAMINATION 2024 ENTRY

CHEMISTRY

(1 Hour)

Instructions to candidates:

- Answer **ALL THIRTY** questions from **SECTION A** on the grid provided **and**
- Answer **TWO** of the **THREE** questions from **SECTION B** in the spaces provided

Section A is worth **30 marks** and **Section B 20 marks**. 50 marks in total.

You may use a calculator.

You are provided with a **copy of the Periodic table**

The Periodic Table of the Elements

Group																
I	II										III	IV	V	VI	VII	0
							1 H Hydrogen 1									4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4										11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12										27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulphur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La Lanthanum 57 *	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	Po Polonium 84	At Astatine 85	Rn Radon 86
Fr Francium 87	226 Ra Radium 88	227 Ac Actinium 89														

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	Pa Protactinium 91	238 U Uranium 92	Np Neptunium 93	Pu Plutonium 94	Am Americium 95	Cm Curium 96	Bk Berkelium 97	Cf Californium 98	Es Einsteinium 99	Fm Fermium 100	Md Mendelevium 101	No Nobelium 102	Lr Lawrencium 103

*58-71 Lanthanoid series
90-103 Actinoid series

Key

a
X
b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

Answer **ALL** questions from **SECTION A** on the grid provided**.**

SECTION A

Answer all questions – circle the correct letter for each question below.

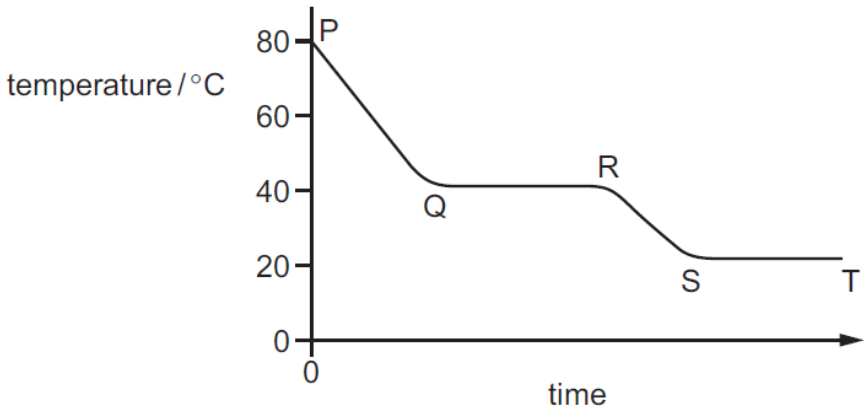
1	A	B	C	D
2	A	B	C	D
3	A	B	C	D
4	A	B	C	D
5	A	B	C	D
6	A	B	C	D
7	A	B	C	D
8	A	B	C	D
9	A	B	C	D
10	A	B	C	D
11	A	B	C	D
12	A	B	C	D
13	A	B	C	D
14	A	B	C	D
15	A	B	C	D
16	A	B	C	D
17	A	B	C	D
18	A	B	C	D
19	A	B	C	D
20	A	B	C	D
21	A	B	C	D
22	A	B	C	D
23	A	B	C	D
24	A	B	C	D
25	A	B	C	D
26	A	B	C	D
27	A	B	C	D
28	A	B	C	D
29	A	B	C	D
30	A	B	C	D

Question 1

Substance M is a solid at 30 °C.

The substance is heated to 80 °C and its temperature measured as it cools down to room temperature.

The cooling curve is shown.



Between which times is substance M freezing?

A P to Q **B** Q to R **C** R to S **D** S to T

Question 2

Which gas has the fastest rate of diffusion?

A Ar **B** C_2H_6 **C** HCl **D** H_2S

Question 3

Elements X and Y react to form a compound.

Element X loses two electrons and element Y gains one electron.

What is the charge on the ions of elements X and Y and what is the formula of the compound?

	charge on X	charge on Y	formula of compound
A	2+	–	X_2Y
B	2+	–	XY_2
C	2–	+	X_2Y
D	2–	+	XY_2

Question 4

When powdered sodium carbonate and aqueous ethanoic acid are mixed, the temperature of the mixture falls.

Which statement about this reaction is correct?

A The reaction is endothermic and ΔH is negative.

B The reaction is endothermic and ΔH is positive.

C The reaction is exothermic and ΔH is negative.

D The reaction is exothermic and ΔH is positive.

Question 5

Magnesium powder reacts with an excess of dilute hydrochloric acid to produce hydrogen gas.

Which statements about this reaction are correct?

1 The smaller the particles of magnesium powder, the more slowly the hydrogen is produced.

2 The higher the temperature, the faster the magnesium powder disappears.

3 The lower the concentration of dilute hydrochloric acid, the faster the rate of reaction.

4 The faster the magnesium powder disappears, the faster the rate of reaction.

A 1 and 2 **B** 2 and 3 **C** 2 and 4 **D** 3 and 4

Question 6

Copper(II) sulfate is prepared by adding excess copper(II) carbonate to sulfuric acid.

Why is an **excess** of copper(II) carbonate added?

A to ensure all the copper(II) carbonate has reacted

B to ensure all the sulfuric acid has reacted

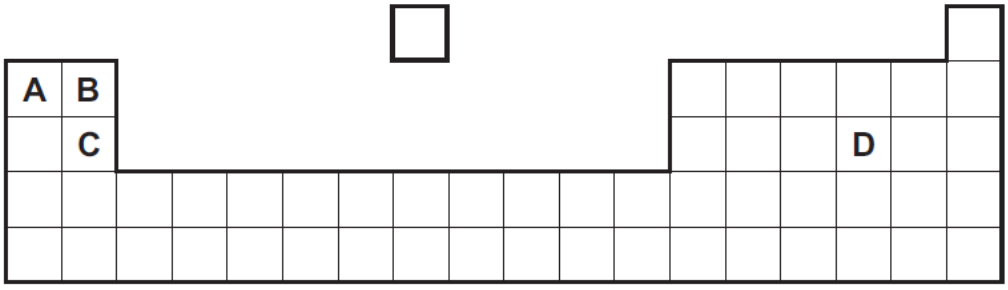
C to increase the rate of reaction

D to increase the amount of copper(II) sulfate produced

Question 7

Part of the Periodic Table is shown.

Which element has two electrons in its outer shell and three electron shells?



Question 8

Elements in Group I and Group II show the same trends in their reactions with water and in their density.

Which row shows how the properties of barium compare with calcium?

	reaction with water	density
A	faster	higher
B	faster	lower
C	slower	higher
D	slower	lower

Question 9

Which substances react to form hydrogen gas?

1 calcium and water

2 silver and dilute hydrochloric acid

3 magnesium and steam

4 zinc and dilute hydrochloric acid

A 1, 3 and 4 **B** 1 and 3 only **C** 2 and 4 **D** 4 only

Question 10

Some combustion reactions produce pollutant gases.

Which reactions produce a pollutant gas that is **not** present in clean air?

1 $2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$

2 $2H_2 + O_2 \rightarrow 2H_2O$

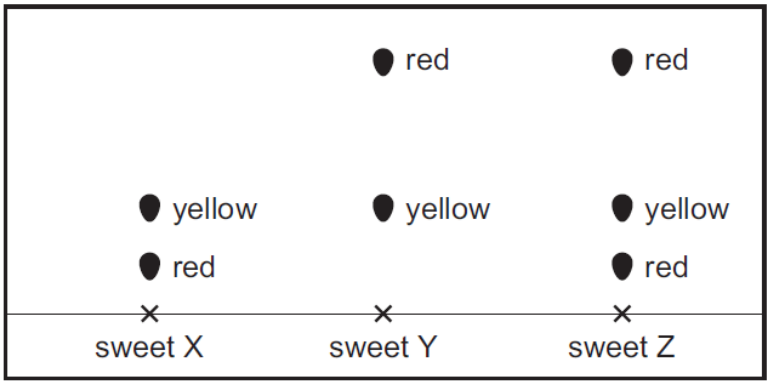
3 $C + O_2 \rightarrow CO_2$

4 $N_2 + O_2 \rightarrow 2NO$

A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 3 and 4

Question 11

The diagram shows a chromatogram obtained from the colours of three different sweets, X, Y and Z.



How many different **red** dyes are present in the sweets?

A 1 **B** 2 **C** 3 **D** 4

Question 12

The arrangements of particles in solids, liquids and gases are different.

Which statement about the molecules in ice, water or steam is correct?

A The H_2O molecules are on average closest together in steam.

B The H_2O molecules are on average furthest apart in water.

C The H_2O molecules in steam have the second highest average velocity.

D The H_2O molecules in ice are able to vibrate.

Question 13

The melting points and boiling points of three elements, at 1 atm pressure, are shown.

	melting point / °C	boiling point / °C
argon	–189	–186
nitrogen	–210	–196
oxygen	–218	–183

Separate samples of argon, nitrogen and oxygen are stored at –200 °C and at 1 atm pressure.

How many samples are liquids?

A 0 **B** 1 **C** 2 **D** 3

Question 14

The formula of an aluminium ion is Al^{3+}.

What is the formula of aluminium sulfate?

A Al_2SO_4 **B** $Al(SO_4)_2$ **C** $Al_2(SO_4)_3$ **D** $Al_3(SO_4)_2$

Question 15

Which molecule has only two shared pairs of electrons?

A CH_4 **B** Cl_2 **C** HCl **D** H_2O

Question 16

The properties of the element titanium, Ti, can be predicted from its position in the Periodic Table.

Which row identifies the properties of titanium?

	can be used as a catalyst	conducts electricity when solid	has low density	forms coloured compounds
A	✓	✓	✓	✗
B	✓	✓	✗	✓
C	✓	✗	✓	✓
D	✗	✓	✓	✓

Question 17

Some statements about the reactions of the metals tin, lithium and manganese are listed.

- Tin does not react with steam but does react with dilute hydrochloric acid.
- Lithium reacts with cold water.
- Manganese does not react with cold water but does react with steam.

What is the order of reactivity of the three metals?

	least reactive	→	most reactive
A	lithium	manganese	tin
B	tin	lithium	manganese
C	manganese	tin	lithium
D	tin	manganese	lithium

Question 18

Petroleum is fractionally distilled at an oil refinery.

The table shows some fractions and uses.

	fraction	use
1	gasoline	fuel for ships
2	refinery gas	lubrication
3	naphtha	making chemicals
4	kerosene	jet fuel

Which rows identify a use for the fraction listed?

A 1 and 2 **B** 1 and 3 **C** 2 and 4 **D** 3 and 4

Question 19

Which statement describes a compound?

A It contains two or more elements chemically combined.

B It contains two or more elements physically combined.

C It contains two or more elements forming an alloy.

D It contains two or more elements that can easily be separated.

Question 20

A mixture contains salt, sand and sulfur.

Salt dissolves in water but not in xylene.

Sulfur dissolves in xylene but not in water.

Sand does not dissolve in water or xylene.

What is the order of the processes used to separate the salt, the sand and the sulfur from the mixture?

A add water → filter → add xylene to the filtrate → filter

B add water → filter → add xylene to the residue → filter

C add xylene → filter → add water to the filtrate → filter

D add xylene → filter → add xylene to the residue → filter

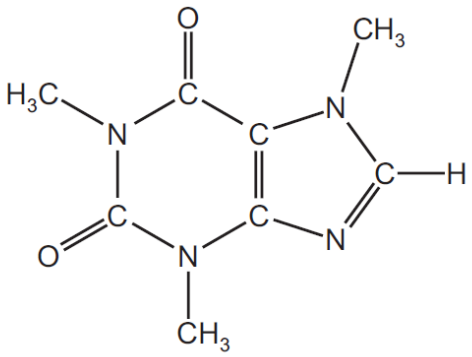
Question 21

Which row describes the bonding in graphite and a use of graphite?

	bonding in graphite	a use of graphite
A	each atom is bonded covalently to three other atoms	in cutting tools
B	each atom is bonded covalently to three other atoms	as an electrical conductor
C	each atom is bonded covalently to four other atoms	in cutting tools
D	each atom is bonded covalently to four other atoms	as an electrical conductor

Question 22

Caffeine is a stimulant found in coffee.



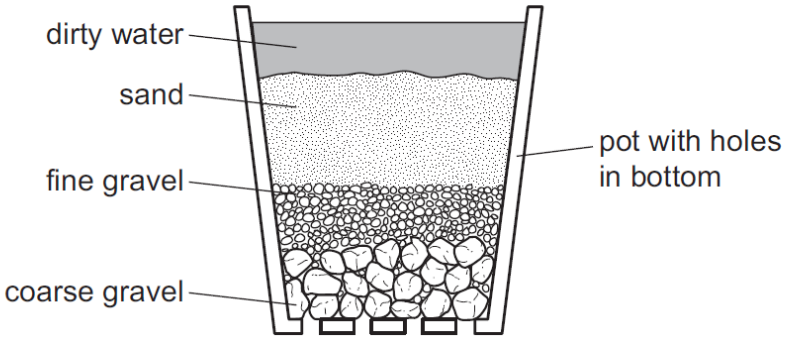
caffeine

Which formula represents caffeine?

A $C_7H_{10}N_4O_2$ **B** $C_8H_{10}N_3O_2$ **C** $C_8H_{10}N_4O_2$ **D** $C_8H_{11}N_4O_2$

Question 23

The diagram shows a stage in the purification of dirty water.



Which process does this apparatus show?

A chlorination

B condensation

C distillation

D filtration

Question 24

Which compound is a member of the alkene homologous series?

A C_2H_6 **B** C_4H_{10} **C** C_6H_{12} **D** C_8H_{18}

Question 25

Which type of covalent bond is found in both a molecule of methane and a molecule of ethane?

A a double bond between a carbon atom and a hydrogen atom

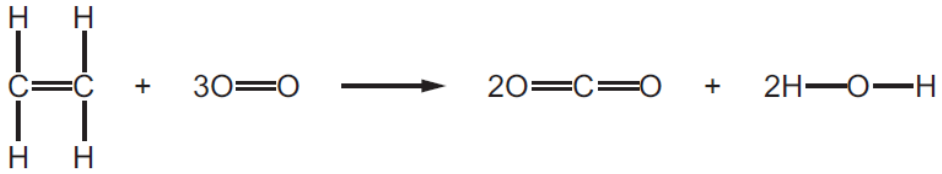
B a double bond between two carbon atoms

C a single bond between a carbon atom and a hydrogen atom

D a single bond between two carbon atoms

Question 26

Ethene can undergo complete combustion, as shown.



Some bond energies are given in the table.

bond	bond energy in kJ / mol
C=C	612
C–H	412
O–H	463
O=O	496

The energy change of the reaction is –1408 kJ / mol.

What is the bond energy of the C=O bond in CO_2?

A 454 kJ / mol **B** 673 kJ / mol **C** 826 kJ / mol **D** 1619 kJ / mol

Question 27

Which sample does **not** contain a number of atoms equal to the Avogadro constant?

A 14 g of nitrogen, N_2

B 6 g of water, H_2O

C 4 g of helium, He

D 28 g of carbon monoxide, CO

Question 28

Which particles are present in the structure of metals?

1 positive ions

2 negative ions

3 shared pairs of electrons

4 mobile electrons

A 1 and 2 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

Question 29

When magnesium is heated with zinc oxide a reaction occurs.

The equation is shown.

$$Mg + ZnO \rightarrow MgO + Zn$$

Which substance is oxidised?

A magnesium

B magnesium oxide

C zinc

D zinc oxide

Question 30

Ethanoic acid reacts with water to produce an acidic solution.

Which row describes the roles of ethanoic acid and water in this reaction?

	ethanoic acid	water
A	accepts a proton	donates a proton
B	accepts an electron	donates an electron
C	donates a proton	accepts a proton
D	donates an electron	accepts an electron

END OF SECTION A

Section B [Answer **TWO** of the **THREE** questions]

Question 1

(a) Sulfur is converted into sulfuric acid, H_2SO_4, by the Contact process.

The process involves four stages.

In **stage 1**, iron pyrites, FeS_2, can be used instead of molten sulfur.
The iron pyrites is heated strongly in air.

Balance the equation for the reaction occurring when iron pyrites reacts with oxygen in the air.

$$.....FeS_2 + ...O_2 \rightarrow .....Fe_2O_3 + ...SO_2$$ [1]

(b) Boron, B, has two isotopes.

Table 2.1 shows the relative masses and the percentage abundances of the two isotopes of boron.

Table 2.1

relative mass of isotope	percentage abundance of isotope
10	20
11	80

Calculate the relative atomic mass of boron to **one** decimal place.

relative atomic mass = ... [2]

(c) Carbon dioxide, CO_2, is a covalent compound.

Complete the dot-and-cross diagram in Fig. 3.3 to show the electronic configuration in a molecule of carbon dioxide. Show outer shell electrons only.

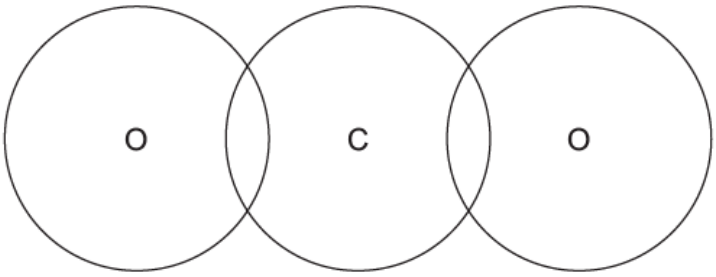


Fig. 3.3

[2]

(d) Lead(II) sulfate is an insoluble salt.

Lead(II) sulfate can be made from aqueous ammonium sulfate using a precipitation reaction.

(i) Name a solution that can be added to aqueous ammonium sulfate to produce a precipitate of lead(II) sulfate.

..... [1]

(ii) Write an ionic equation for this precipitation reaction. Include state symbols.

..... [2]

(iii) The precipitate of lead(II) sulfate forms in an aqueous solution.

Describe how pure lead(II) sulfate can be obtained from the mixture.

.....

.....

..... [2]

[Total: 10]

Question 2

(a) Ethene is an alkene which reacts with bromine as shown in the equation.

$$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$$

Write the general formula of alkenes.

..... [1]

(b) Describe the colour change seen when ethene is bubbled through aqueous bromine.

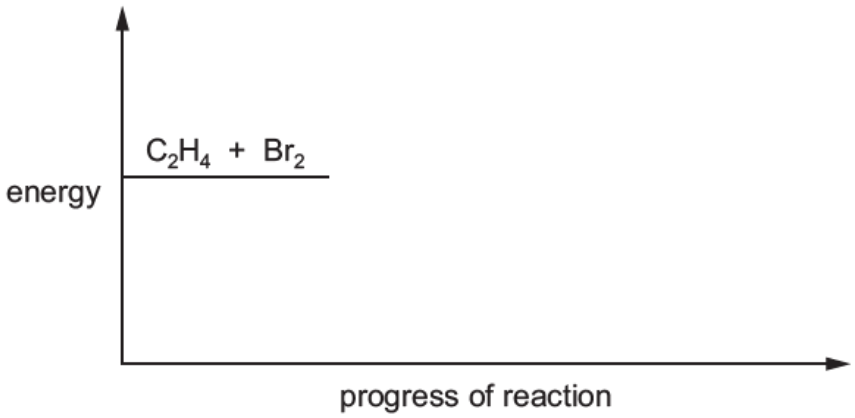
from ..... to ..... [1]

(c) In this reaction only one product is formed from two reactants.

Name this type of organic reaction.

..... [1]

(d) Part of the energy profile diagram of this reaction is shown.



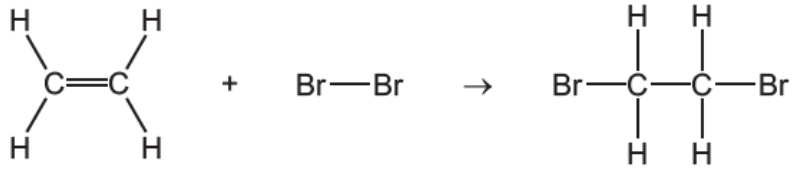
(i) The reaction is exothermic.

Complete the energy profile diagram for this reaction.
Include:

- the position of the products
- an arrow to show the activation energy, labelled as A
- an arrow to show the energy change for the reaction.

[2]

(ii) The chemical equation for the reaction can be represented as shown.



Some bond energies are given.

bond	bond energy / kJ mol
C–H	410
C=C	610
Br–Br	190
C–C	350
C–Br	290

Use the bond energies in the table to calculate the energy change in this reaction.

energy change in this reaction = ... kJ / mol
[3]

(e) Fig. 6.1 shows the displayed formula of a molecule of crotyl alcohol.

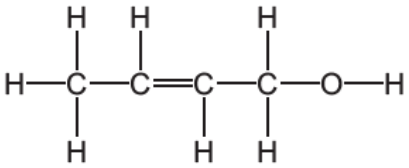


Fig. 6.1

(i) On Fig. 6.1 draw a circle around the alcohol functional group. [1]

(ii) Deduce the molecular formula of crotyl alcohol.

..... [1]

[Total: 10]

Question 3

Ethanol can be made by fermentation of sugars found in plants. A by-product of fermentation is carbon dioxide gas.

A student made some ethanol using the following method.

step 1 Cut up some sugar cane and crush it.
step 2 Add hot water to the sugar cane and stir to dissolve the sugar in the sugar cane.
step 3 Remove the solids from the mixture to obtain sugar solution.
step 4 Let the sugar solution cool and then add yeast.
step 5 Place the mixture obtained in the apparatus shown in Fig. 1.1.
step 6 Leave the apparatus until fermentation is complete.

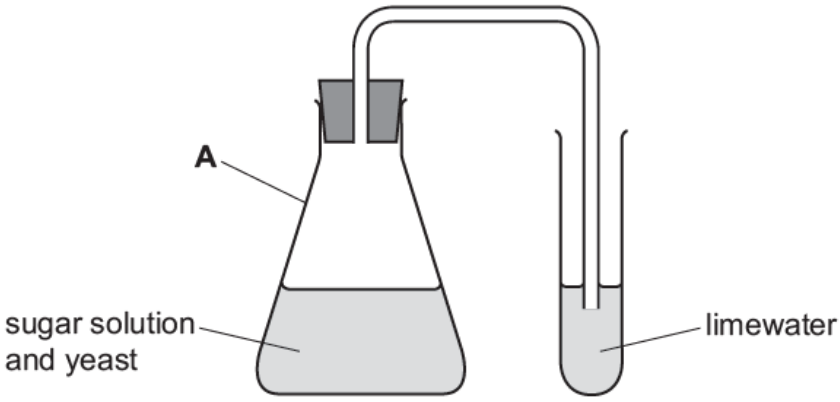


Fig. 1.1

(a) Name the item of apparatus labelled **A** in Fig. 1.1.

..... [1]

(b) Explain why hot water rather than cold water is used in **step 2**.

..... [1]

(c) Name the method used to remove the solids from the mixture in **step 3** and draw a diagram to show how this is done.

name of process .....

diagram

[2]

(d) Cadmium, cobalt and vanadium are all metals. They react with dilute hydrochloric acid to form hydrogen gas. These reactions are exothermic.

Plan an investigation to find the order of reactivity of the three metals.

Your plan must make it clear how your investigation will be a fair test and how you will use your results to place the metals in order of reactivity.

You are provided with powdered samples of each metal, dilute hydrochloric acid and common laboratory apparatus.

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..... [6]

[Total: 10]