



### Question 1 (6 marks)

The United Nations is marking 2019 as the International Year of the Periodic Table of Chemical Elements.

Many scientists have contributed to the classification of the elements although Mendeleev is perhaps the best known. At the time of his research, around sixty elements had been identified. Mendeleev arranged the elements according to their increasing atomic mass. He soon realized that most elements with similar chemical properties appeared at regular intervals.

The image below shows the periodic table Mendeleev published in 1871. The gaps in this table corresponded to elements that had not yet been discovered.

### Periodic table 1871

I									
H 1	II		III	IV	V	VI	VII		
Li 7	Be 9.4	B 11	C 12	N 14	O 16	F 19			
Na 23	Mg 24	Al 27.3	Si 28	P 31	S 32	Cl 35.5	VIII		
K 39	Ca 40		Ti 48	V 51	Cr 52	Mn 55	Fe 56	Co 59	Ni 59
Cu 63	Zn 65			As 75	Se 78	Br 80			
Rb 85	Sr 87	Y 88	Zr 90	Nb 94	Mo 96		Ru 104	Rh 104	Pd 106
Ag 108	Cd 112	In 113	Sn 118	Sb 122	Te 125	I 127			
Cs 133	Ba 137	La 138		Ta 182	W 184		Os 195	Ir 197	Pt 198
Au 199	Hg 200	Tl 204	Pb 207	Bi 208					
			Th 231			U 240			

## Modern day periodic table

1		2												3	4	5	6	7	0
H																			He
1																			4
Li	Be											B	C	N	O	F	Ne		
7	9											11	12	14	16	19	20		
Na	Mg											Al	Si	P	S	Cl	Ar		
23	24											27	28	31	32	35.5	40		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
39	40	45	48	51	52	55	56	59	59	63.5	65	70	73	75	79	80	84		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
85	88	89	91	93	96	98	101	103	106	108	112	115	119	122	128	127	131		
Cs	Ba	La <sup>†</sup>	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
133	137	139	178	181	184	186	190	192	195	197	201	204	207	209	209	210	222		
Fr	Ra	Ac <sup>‡</sup>	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg									



### Question 1a (1 mark)

**State** the symbol of one element present in the modern periodic table but not in Mendeleev's original version.

B I ← → U x<sub>2</sub> x<sup>2</sup> ∑ ∏ Ω Σ

Styles ↕



### Question 1b (2 marks)

There are a number of transition elements present in Mendeleev's table but they are not grouped together.

**State** another group of elements present in the modern periodic table that is missing from Mendeleev's table.

**Suggest** a reason why this group was unknown to Mendeleev.

B I ← → U x<sub>2</sub> x<sup>2</sup> ∑ ∏ Ω Σ

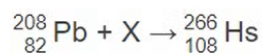
Styles ↕

**Question 1c** (2 marks)

Most of the elements with atomic numbers greater than 95 are made in a laboratory. These elements are produced by nuclear fusion. In nuclear fusion, atoms undergo collision at high speed to form a heavier atom which has the subatomic particles from both original atoms. The animation below shows an example of nuclear fusion: the formation of the element with atomic number 117. Element 117 is now officially recognised by the International Union of Pure and Applied Chemistry (IUPAC) and is named tennessine, symbol Ts.

The element hassium, atomic number 108, is made in a laboratory. Hassium was created by the nuclear fusion of  ${}_{82}^{208}\text{Pb}$  and atoms of a lighter element, element X. The isotope of hassium produced has a mass number 266.

**Calculate** the number of protons and neutrons in element X.

**Question 1d** (1 mark)

Use your answer to part (c) to **state** the name of element X.

**B** *I* ← → U  $\times_2$   $\times^2$   $\equiv$   $\equiv$   $\Omega$   $\Sigma$  Styles

Question 2 (12 marks)

The clipping below shows the headline from a British newspaper on December 8, 1952. The fog described in the headline was mixed with smoke and pollutants. When the fog finally lifted, at least 4000 people had died from different lung diseases. The pollutants were made by people burning coal to heat their homes. Coal contains sulfur. When the coal was burned, the following pollutants were formed: sulfur dioxide, ( $\text{SO}_2$ ) and nitrogen dioxide, ( $\text{NO}_2$ ).

No. 30,399 LONDON, MONDAY, DECEMBER 8, 1952

**LONDON'S 40-MILE\*  
FOG BLACK-OUT**

ALL BUSES STOPPED:  
PLANES DIVERTED

**EFFORT TO MAINTAIN  
SERVICES TO-DAY**

LITTLE HOPE OF CLEARANCE:  
DRIVERS WARNED



\*40 mile: 60 km



### Question 2a (1 mark)

Select the correct Lewis structure (dot cross diagram) for a water molecule.



### Question 2b (2 marks)

When  $\text{NO}_2$  reacts with water in the presence of oxygen, nitric acid  $\text{HNO}_3$  is produced.

Select numbers to balance the chemical equation for  $\text{NO}_2$ ,  $\text{H}_2\text{O}$  and  $\text{HNO}_3$ . Make sure you select an option for each box.



### Question 2c (1 mark)

When the fog was tested with universal indicator paper, the paper turned red.

State what this information can tell you about the chemical properties of the fog.

**B** **I**   $x_2$   $x^p$   $\frac{1}{x}$   $\frac{1}{x^p}$   $\Omega$   $\Sigma$

Styles



### Question 2d (2 marks)

The  $\text{SO}_2$  can react with the water in the fog to form sulfuric acid  $\text{H}_2\text{SO}_4$ . State the group and period of sulfur.

**B** **I**   $x_2$   $x^p$   $\frac{1}{x}$   $\frac{1}{x^p}$   $\Omega$   $\Sigma$

Styles



Question 2e (2 marks)

**Calculate** the mass of one mole of sulfuric acid,  $\text{H}_2\text{SO}_4$ .

**B** *I* ← → U  $\times_2$   $\times^2$   $\frac{1}{x}$   $\frac{1}{x^2}$   $\Omega$   $\Sigma$  Styles



Question 2f (4 marks)

The type of air pollution described above has become less common. Today, most of the air pollution in cities is *photochemical smog*. Photochemical smog contains many different pollutants including volatile organic compounds, or VOCs.

The ball-and-stick models of two VOCs are shown below.

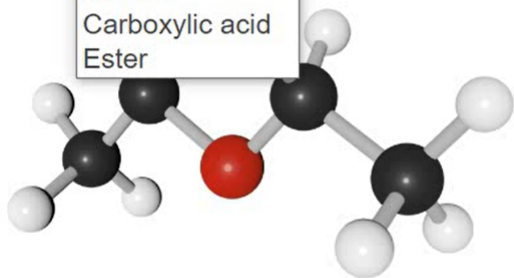
**Select** the class and name of each compound.

The black spheres represent C atoms, the white spheres represent H atoms and the red spheres represent O atoms.



Class:

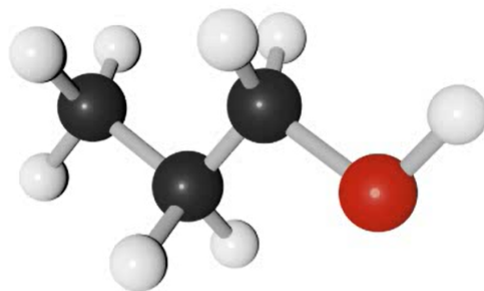
- Select
- Alcohol
- Alkane
- Carboxylic acid
- Ester



©

Name:

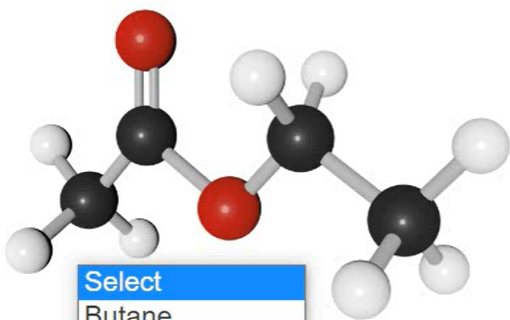
Class:



©

Name:

Class:

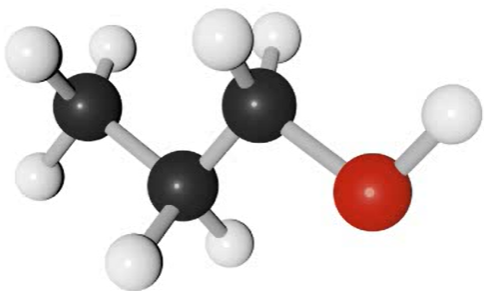


- Select
- Butane
- Pentanoic acid
- Propan-1-ol
- Ethyl ethanoate

©

Name:

Class:



©

Pause (Ctrl+P)



### Question 3 (9 marks)



One everyday task that people undertake is cooking food. A variety of materials are used to make cooking pans including different metals and heat-resistant glass. The main metals used for making cooking pans are copper, iron and aluminium.



### Question 3a (2 marks)

**State** two physical properties of metals that make them suitable to make cooking pans.

Property 1:



### Question 3b (3 marks)

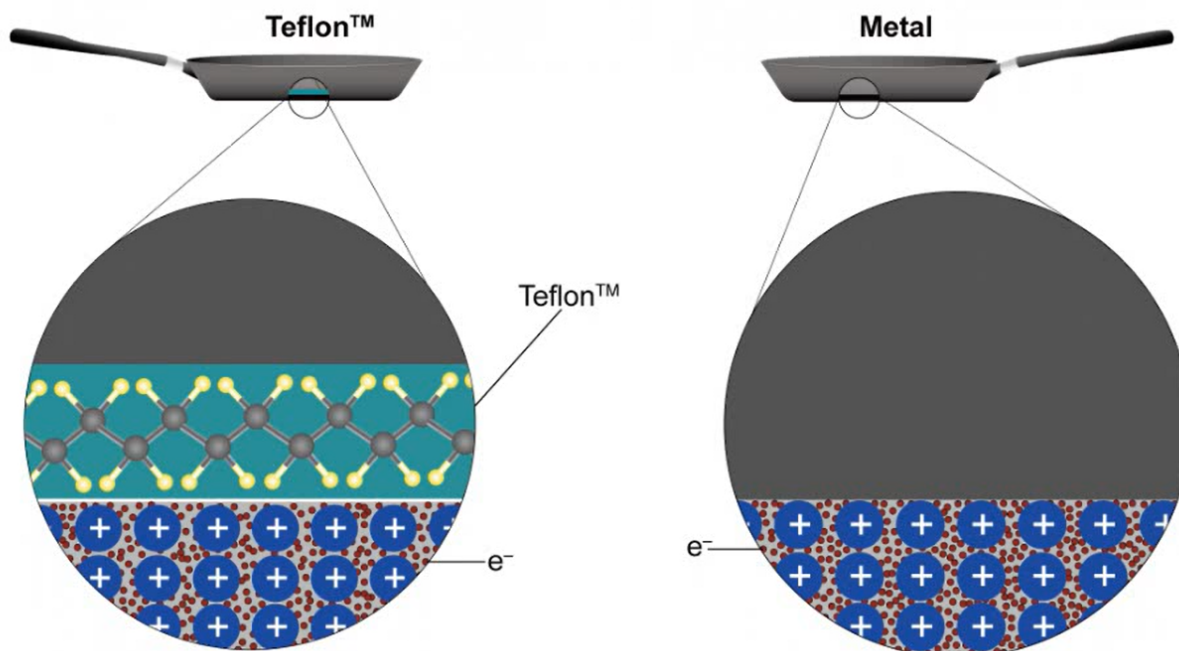
During cooking, a chemical reaction takes place in which metals are converted into metal ions. These metal ions mix with the food being cooked and it has been suggested that these could have an impact on health. Copper ions have been linked with liver damage and aluminium ions have been linked to Alzheimer's disease. In rural Africa, iron ions in cooked food have been shown to reduce anemia in children.

**Determine** the charge on an aluminium ion and **justify** if the aluminium has been reduced or oxidised.

**B** **I**   $x_2$   $x^2$    $\Omega$   $\Sigma$  Styles

Question 3c (4 marks)

Some cooking pans have protective layers added to reduce the production of ions. An example of a protective layer used on a cooking pan is Teflon™, an unreactive plastic.



**State** the type of bonding in the Teflon™ coated cooking pan and in the metal cooking pan in the diagram above. Use the diagram to **discuss** the advantages of Teflon™ coated cooking pans compared with metal cooking pans.

**B** **I** **←** **→** **U** **x<sub>e</sub>** **x<sup>e</sup>** **≡** **≡** **Ω** **Σ** Styles **↕**

A student has noticed that when making a cup of tea by placing a tea bag in boiling water, the colour of the water changes. This is due to the diffusion of the tea from the tea bag. The student wanted to know whether there is a relationship between the temperature of the water and the time for the diffusion to be complete.



©

The variables for this experiment are given below.

The variables for this experiment are given below.

Independent variable	Dependent variable	Control variable 1	Control variable 2
Temperature	Time taken for diffusion to be complete	Type of tea	Same type of tea bag used



**Question 4a** (1 mark)

**Suggest** another control variable for this investigation.

Rich text editor toolbar with buttons for Bold (B), Italic (I), Undo, Redo, Underline (U), Subscript (x<sub>2</sub>), Superscript (x<sup>2</sup>), Bulleted List, Numbered List, Link (Ω), and Unlink (Σ). Below the toolbar is a 'Styles' dropdown menu and a 'Paste' icon.



**Question 4b** (3 marks)

**Formulate** a hypothesis for the student's investigation.

**If:**

the temperature of the water increases

**then:**

the time taken for diffusion to be complete

Select

**because:**



**Question 4a** (1 mark)

**Suggest** another control variable for this investigation.

Rich text editor toolbar with buttons for Bold (B), Italic (I), Undo, Redo, Underline (U), Subscript (x<sub>2</sub>), Superscript (x<sup>2</sup>), Bulleted List, Numbered List, Link (Ω), and Unlink (Σ). Below the toolbar is a 'Styles' dropdown menu and a 'Paste' icon.



**Question 4b** (3 marks)

**Formulate** a hypothesis for the student's investigation.

**If:**

the temperature of the water increases

**then:**

the time taken for diffusion to be complete

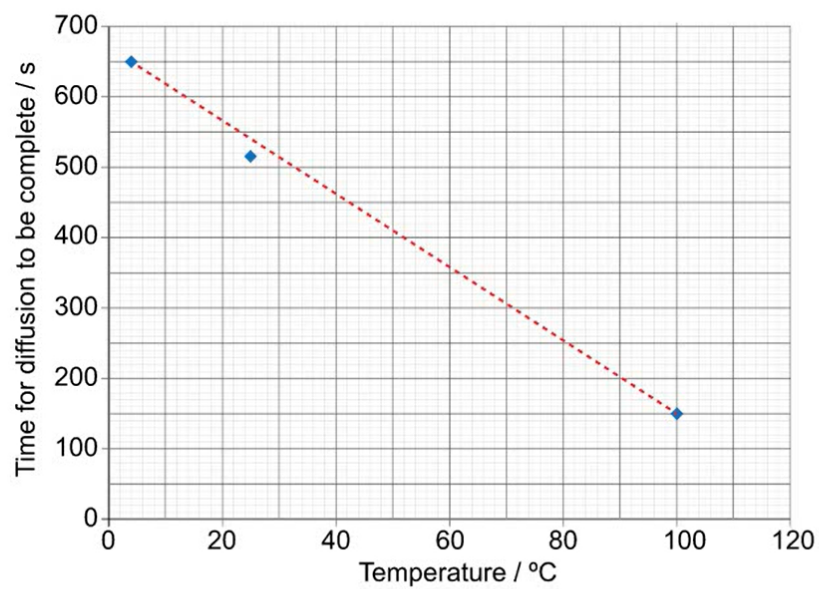
Select

- Select
- increases
- decreases
- stays the same



Question 4c (2 marks)

The student carried out one trial and collected data to test his hypothesis. He presented this data in a graph.



Use the graph to **predict** how long it would take for diffusion to be complete at a temperature of 50°C

Use the graph to **predict** how long it would take for diffusion to be complete at a temperature of 50°C.

**B** *I* ← → U  $x_2$   $x^2$   $\Omega$   $\Sigma$  Styles



#### Question 4d (3 marks)

After further research, the student determined that the relationship in the graph should have been non-linear.

**Outline** how the method could be improved to confirm that the relationship is non-linear.

**B** *I* | ← → | U  $x_e$   $x^2$  | ☰ ☷ |  $\Omega$   $\Sigma$  | Styles ▾ | 📱



#### Question 5 (19 marks)

Children enjoy blowing bubbles. The bubbles do not last a long time and burst easily if they come into contact with another object or if they are made with too much force. Bubbles used in play are made from a mixture of liquid soap and water in a fixed ratio.

The basic structure of the bubble consists of two layers of soap film with a layer of water inside. The exact ratio of water to soap will determine its lifespan.

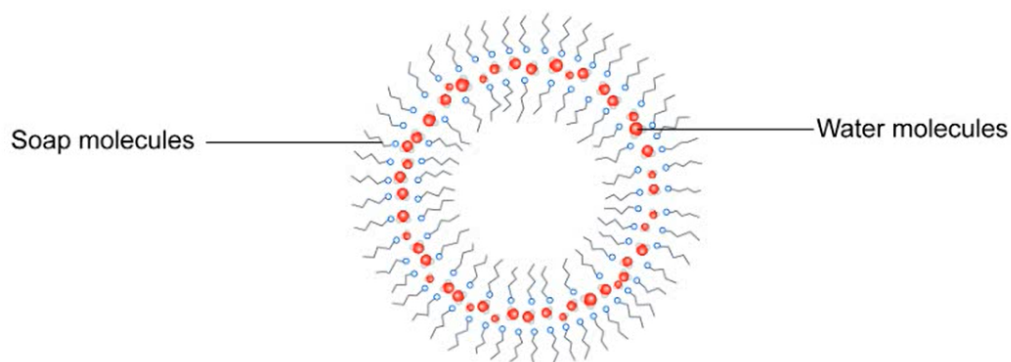


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### Question 5a (1 mark)

A student has decided to explore the ratio of water to soap to determine the mixture that will produce the bubbles with longest lifespan. The student has liquid soap, distilled water and various pieces of laboratory equipment. A volume of  $10\text{ cm}^3$  of each solution was produced in the following dilutions.

Bubble mixture	Volume of soap / $\text{cm}^3$	Volume of water / $\text{cm}^3$	Total volume / $\text{cm}^3$
1	1.0	9.0	10.0
2	2.0	8.0	10.0
3	3.0	7.0	10.0
4	4.0	6.0	10.0
5	5.0	5.0	10.0
6	6.0	4.0	10.0
7	7.0	3.0	10.0

**Select** the most appropriate piece of equipment for accurately measuring the volume of each liquid.

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6	6.0	4.0	10.0
7	7.0	3.0	10.0

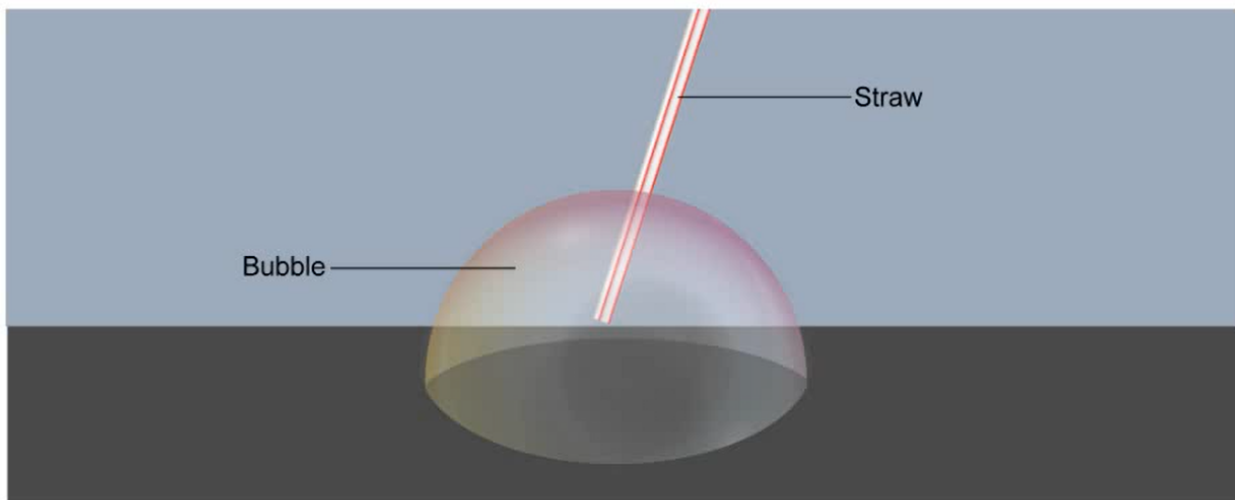
Select  
Beaker  
100  $\text{cm}^3$  measuring cylinder  
Ruler  
1  $\text{cm}^3$  pipette  
Select

piece of equipment for accurately measuring the volume of each



**Question 5b** (2 marks)

Bubbles were produced by dipping a straw into the bubble solution and blowing a bubble.



The time of the bubble's lifespan for each solution is recorded in the table below.

Bubble mixture	Trial 1 / s	Trial 2 / s	Trial 3 / s	Mean lifespan / s
1	7.2	6.6	6.2	6.7
2	11.4	10.1	10.5	
3	13.7	14.1	12.3	13.4
4	5.3	5.9	5.1	5.4
5	4.0	4.2	3.8	4.0
6	3.2	2.9	2.9	3.0
7	2.9	2.8	3.3	3.0

For bubble mixture 2, **calculate** the mean lifespan to 1 decimal place. Show your working in the box below and add your final value to the table.

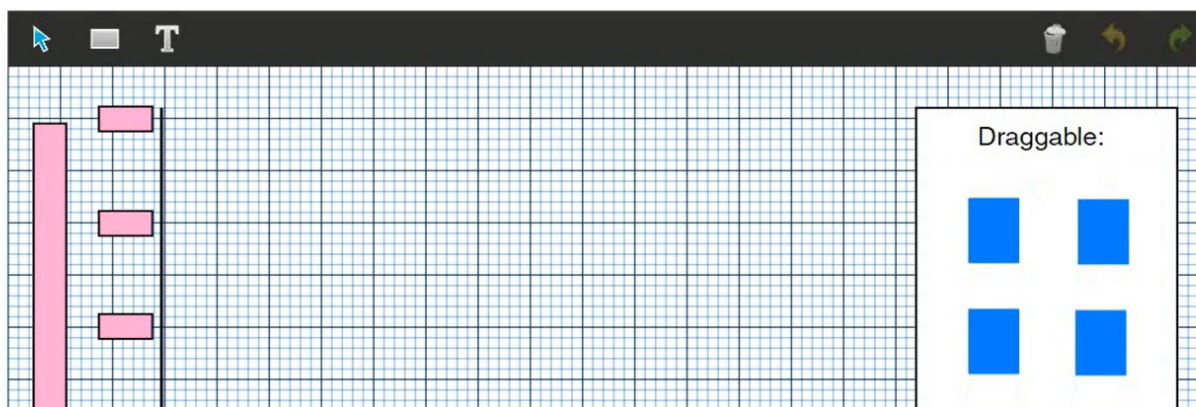
**B** *I* ← → U  $x_2$   $x^2$  ☰ ☷ Ω Σ Styles ▼ 📄



### Question 5c (6 marks)

**Present** the bubble lifespan data in a graph. You should give your graph an appropriate title, add the scale and label the axes.

Title:



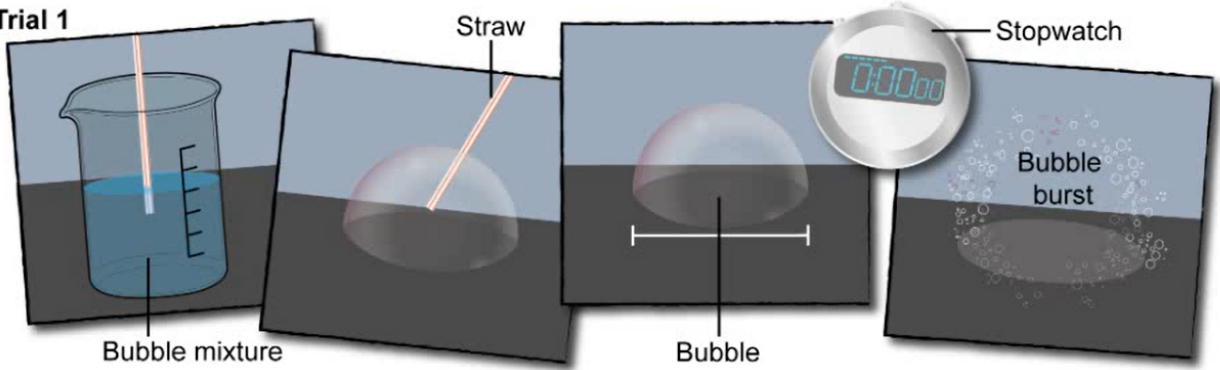
### Question 5d (2 marks)

A student suggested the following research question:

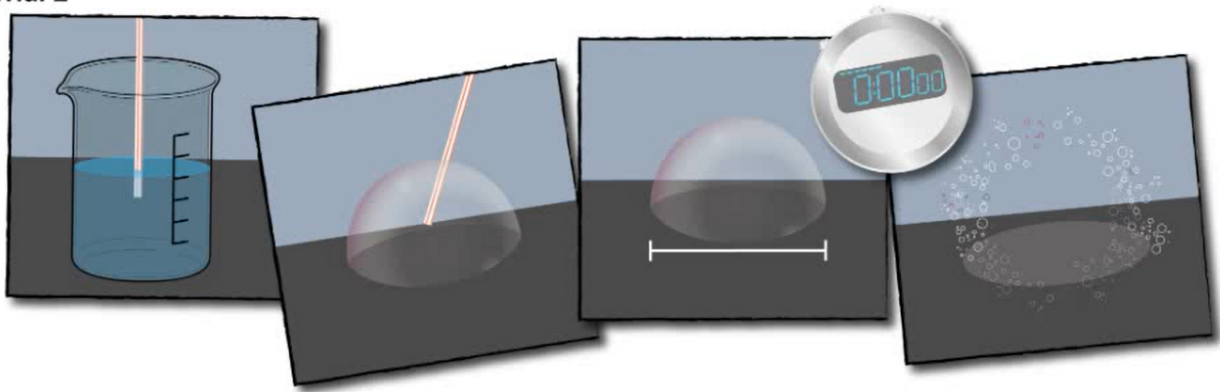
The lifespan of a bubble will increase if an additive is added to the soap solution because there is increased bonding between the additive and the soap solution.

Two students examined the lifespan of bubbles made using a mixture of soap solution and different volumes of glycerine additive. One student produced bubbles using a straw and blew the bubbles onto the laboratory bench while the other student blew bubbles using a bubble wand.

**Trial 1**

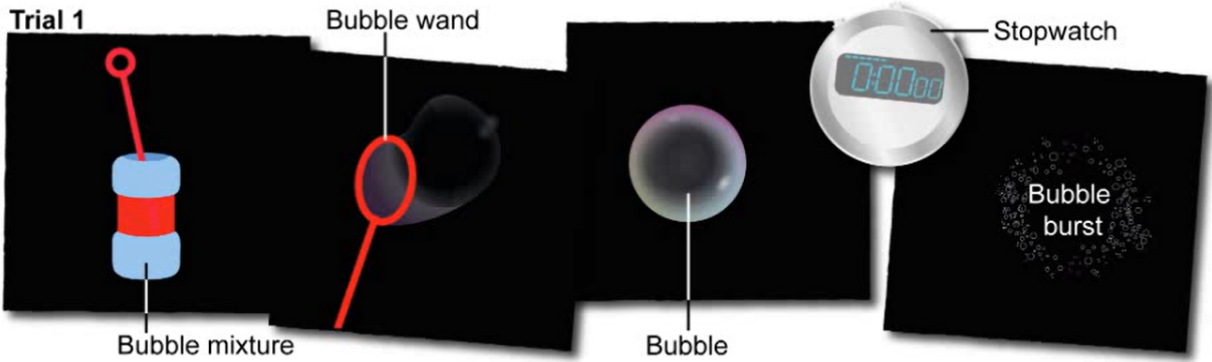


**Trial 2**

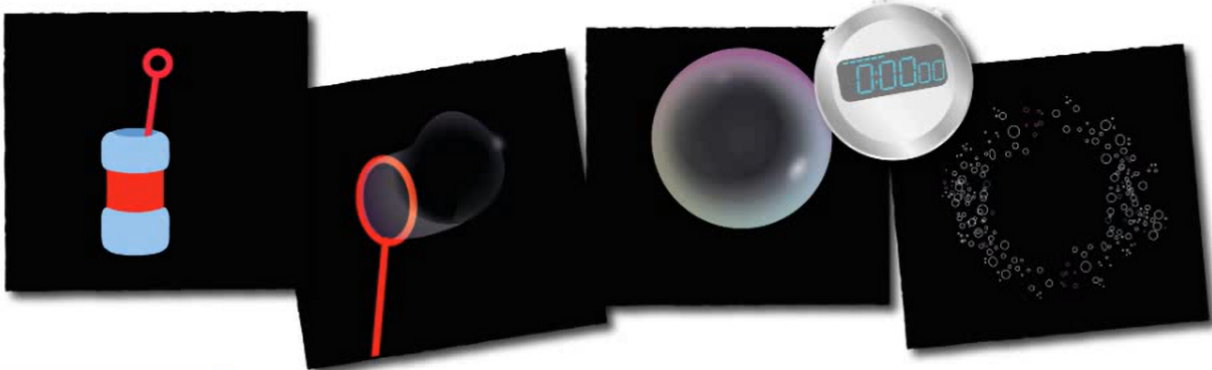


**Blowing bubbles with a bubble wand**

**Trial 1**



**Trial 2**



Identify the independent and dependent variables.

Independent variable	Dependent variable
Select	Select

Select

Lifespan of bubble

Volume of bubble solution

Volume of glycerine

Colour of bubble

Reset

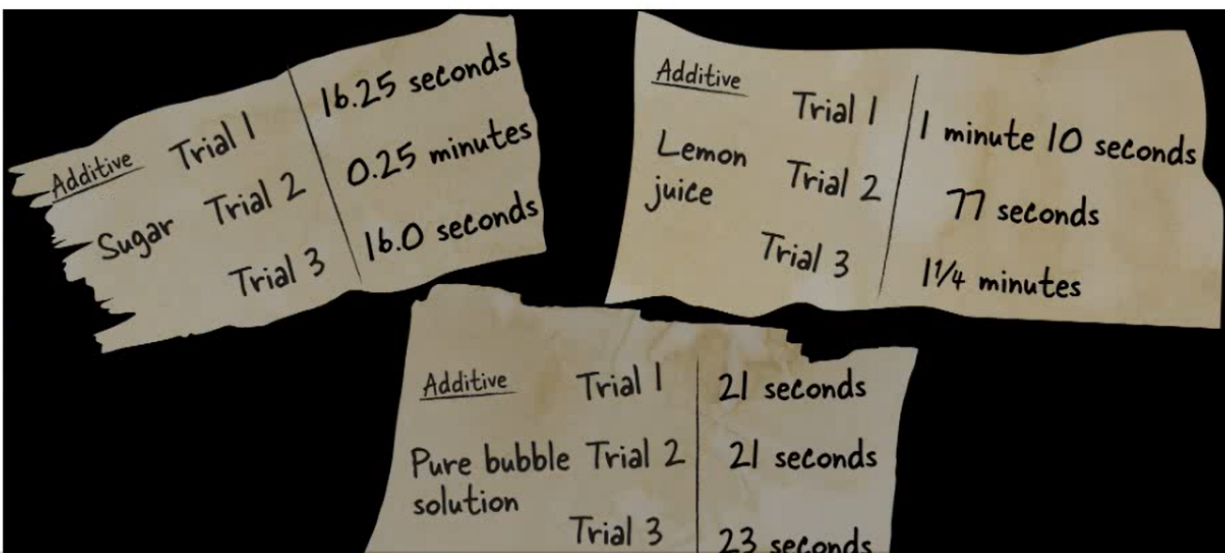
**Question 5e** (3 marks)

**Suggest** which of the two methods for producing bubbles shown in the image above will produce the most reliable data. **Justify** your answer.

**B I** ← → U x<sub>2</sub> x<sup>2</sup> ≡ ≡ Ω Σ Styles - 📄

**Question 5f** (3 marks)

A student recorded lifespan values for bubbles with lemon juice or sugar added to the mixture. Their results are shown below.



A student recorded lifespan values for bubbles with lemon juice or sugar added to the mixture. Their results are shown below.

The image shows three pieces of handwritten paper with experimental data. The first piece is for 'Sugar' with three trials: 16.25 seconds, 0.25 minutes, and 16.0 seconds. The second piece is for 'Lemon juice' with three trials: 1 minute 10 seconds, 77 seconds, and 1 1/4 minutes. The third piece is for 'Pure bubble solution' with three trials: 21 seconds, 21 seconds, and 23 seconds.

Additive	Trial 1	Trial 2	Trial 3
Sugar	16.25 seconds	0.25 minutes	16.0 seconds
Lemon juice	1 minute 10 seconds	77 seconds	1 1/4 minutes
Pure bubble solution	21 seconds	21 seconds	23 seconds

©

Calculate the mean lifespan for the bubble with lemon juice added.



Question 5g (2 marks)

The hypothesis for this experiment was:

The lifespan of a bubble will increase if an additive is added to the soap solution because there is increased bonding between the additive and the soap solution.

Use the data in part (f) to **comment** on the validity of the hypothesis.

**B** *I* ← → U  $\times_2$   $\times^2$   $\equiv$   $\equiv$   $\Omega$   $\Sigma$  Styles -

Question 6 (18 marks)

Question 6a (17 marks)

Bubbles can burst when the soap film is pulled towards the ground by gravity. The soap film gets thinner and eventually pulls apart. A dry finger will also cause a bubble to burst as it breaks the bonding in the bubble. Water evaporating from the bubble is another cause of bubbles bursting.



You have seen that the lifespan of a bubble will change if additives are added to the bubble mixture.

**Design** a method to investigate whether corn syrup, glycerine, sugar or lemon juice produce the bubbles with the longest lifespan. In your answer, you should include:

- the independent, dependent and control variables
- a list of equipment you will use
- the method you will follow
- details of the measurements you will take to collect sufficient data.

**B** **I** **U**  $x_2$   $x^2$   $\Omega$   $\Sigma$  Styles



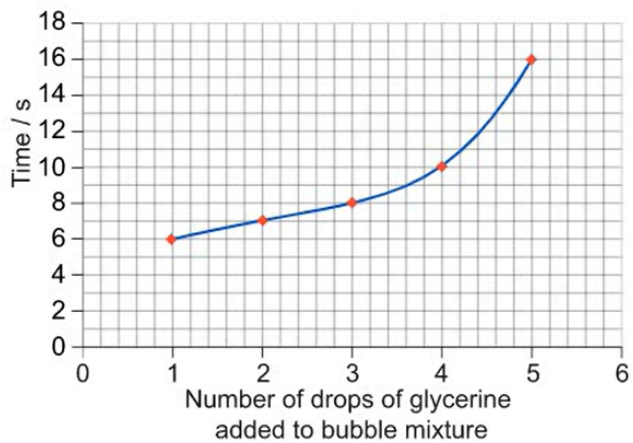
**Question 6b** (1 mark)

The student found that the best additive for increasing the lifespan of a bubble was glycerine. The results that were obtained for adding drops of glycerine into bubble mixture 1 were as follows.

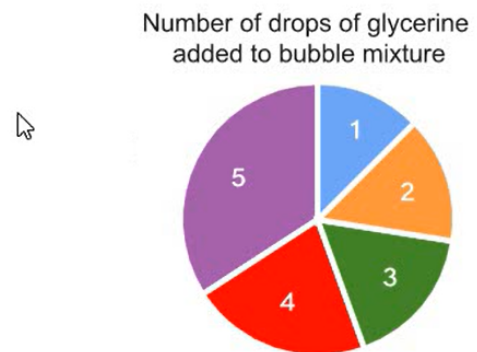
Drops of glycerine added	Lifespan / s
1	6.4
2	7.3
3	8.7
4	10.2
5	15.5

Select the correct graph to present the data.

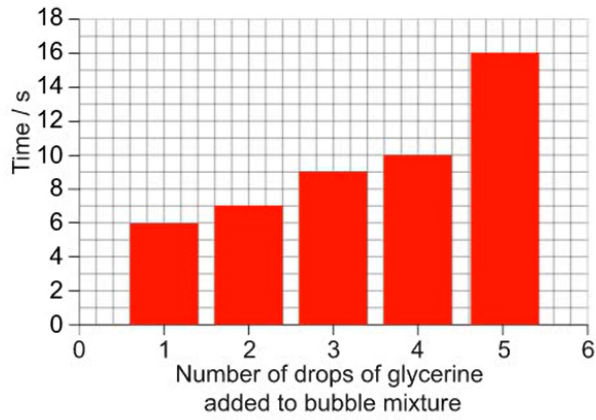
**Graph A**



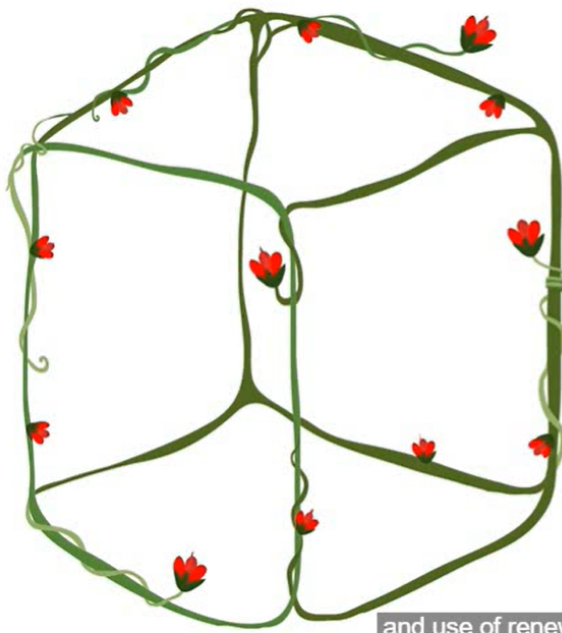
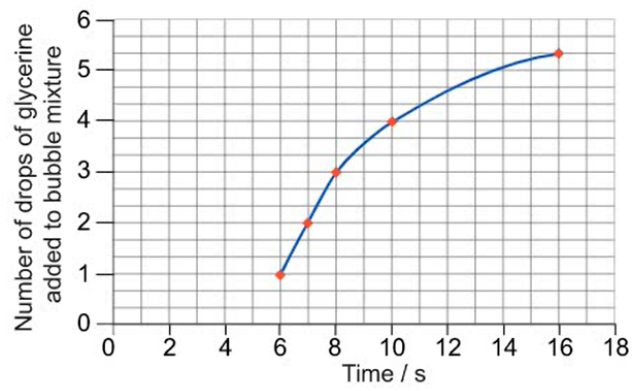
**Graph B**



**Graph C**



**Graph D**



constant monitoring of processes for hazardous chemicals



prevention of waste



energy efficiency



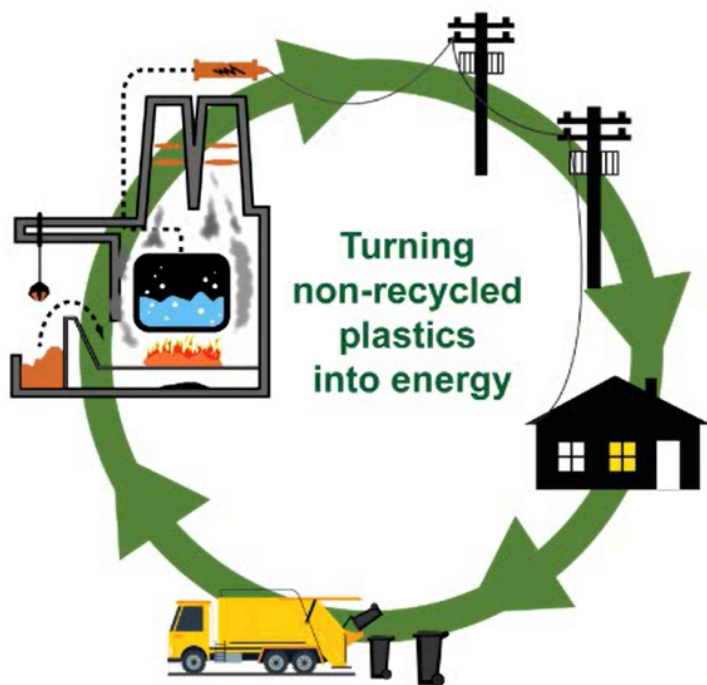
use of renewable raw materials

and use of renewable raw materials.

In 1998, some scientists proposed a framework called green chemistry. Green chemistry promotes products, processes and systems which focus on sustainability and a safe environment.

There are 12 principles of green chemistry. This task will reflect on four of these principles: constant monitoring of processes for hazardous chemicals, prevention of waste, energy efficiency and use of renewable raw materials.

In 2008, the State of California in the United States approved two laws aiming to encourage green chemistry. Many European governments have also introduced legislation for chemical manufacturers to ensure that their products and processes are safe.



Non-recycled plastics	Plastics recycled to generate electricity
100 % of waste goes to landfill	Waste product could be used in construction industry
Increased use of landfill	10 % waste to landfill
Loss of raw materials	Loss of raw materials
Increase in waste	Removal of CO <sub>2</sub> emissions and toxic gases using filters
Process requires energy	Produces electricity which can be distributed



**Question 7a** (8 marks)

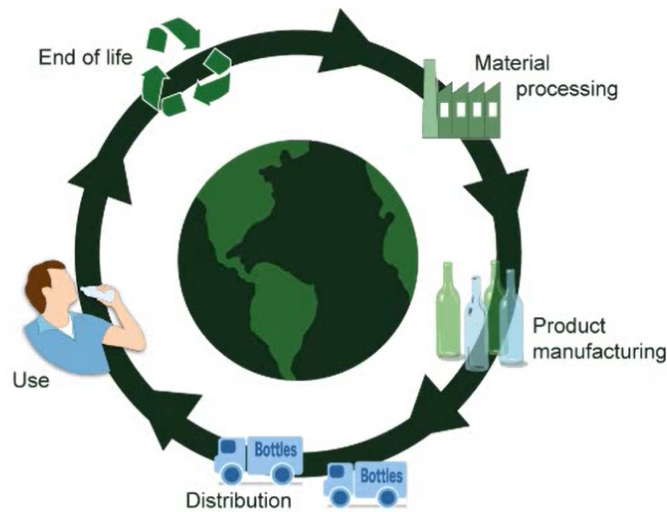
Using the table above, **discuss** why using plastics to generate energy fits with the green chemistry principles of constant monitoring of processes for pollution prevention and prevention of waste. In your answer, you should consider:

- the impact on landfills
- the effects of pollution
- the use of by-products
- reuse of raw materials.

Rich text editor toolbar with icons for Bold (B), Italic (I), Undo, Redo, Underline (U), Subscript (x<sub>2</sub>), Superscript (x<sup>2</sup>), Bulleted List, Numbered List, Link (Ω), Unlink (Σ), Styles dropdown, and a document icon.

Question 7b (2 marks)

The diagram shows the life cycle assessment of green product design. As the population rises, there is an increased awareness of the products that we use. Fifty years ago, most drinks companies used glass bottles. More recently, these companies used plastic bottles as they were lighter to transport. In the last few years, however, a number of drinks companies are using glass bottles again as they recognise that glass has a lower impact on the environment and is more economical in use.



Use the image above to **suggest** two reasons why companies are now reusing glass bottles.

Reason 1:

Reason 2:



### Question 8 (17 marks)

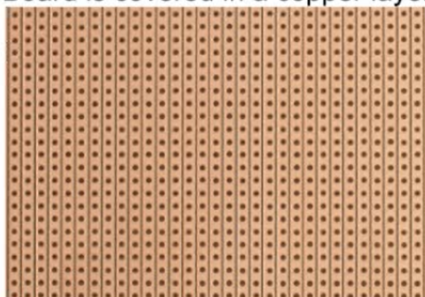
Global population increases have caused an increased demand for safe drinking water. Many governments are passing laws to make sure that factories and processing plants remove waste products from any water that leaves their sites before it enters rivers or other water sources. Heavy metal ions such as copper, arsenic, mercury and lead need to be removed as they have been linked to a variety of health problems.

Modern chemical industries try to adopt the principles of green chemistry. This involves several aspects such as preventing waste, being energy efficient and using renewable raw materials.

Printed circuit boards (PCBs) are made using a copper layer. Any copper not required for electrical connections is removed using a chemical reaction. This reaction produces a waste copper ion solution. It is important that the dissolved copper ions are removed before the water is returned to the water supply as they may cause liver damage and insomnia.

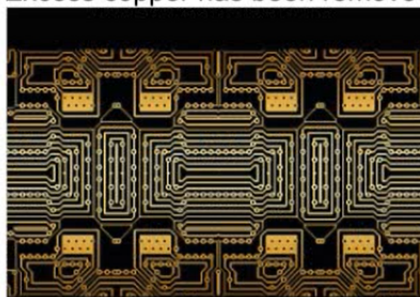
#### Before manufacture

Board is covered in a copper layer



#### After manufacture

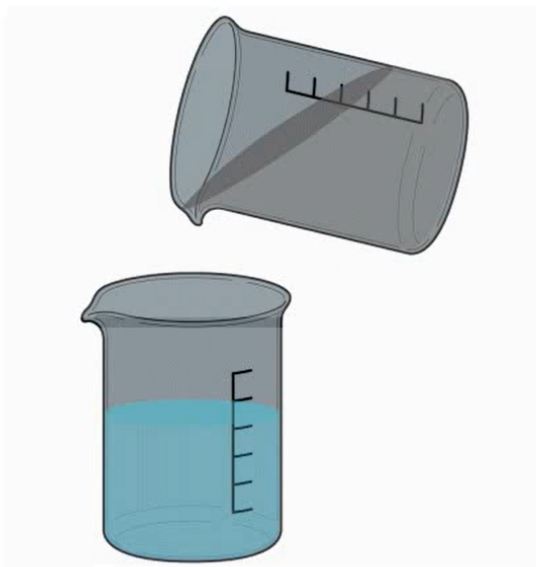
Excess copper has been removed



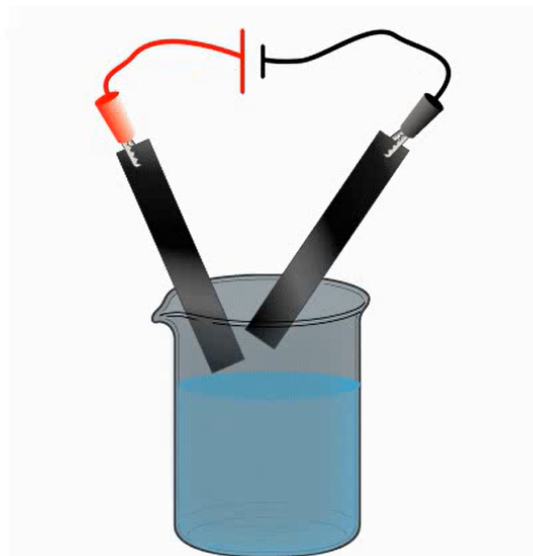
©

There are several processes for removing copper ions in industry.

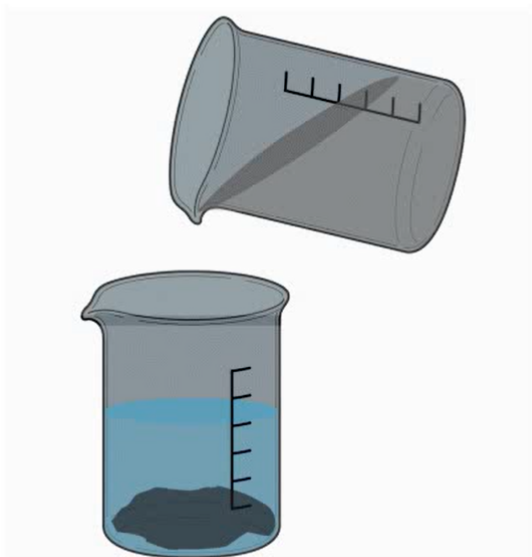
**Precipitation**



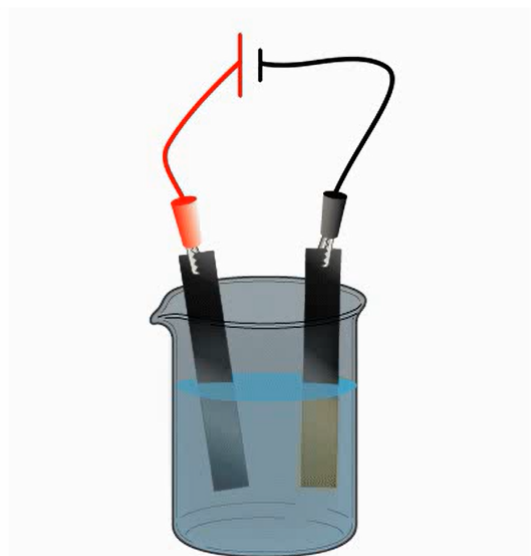
**Recovery using electrochemical methods**



**Precipitation**



**Recovery using electrochemical methods**

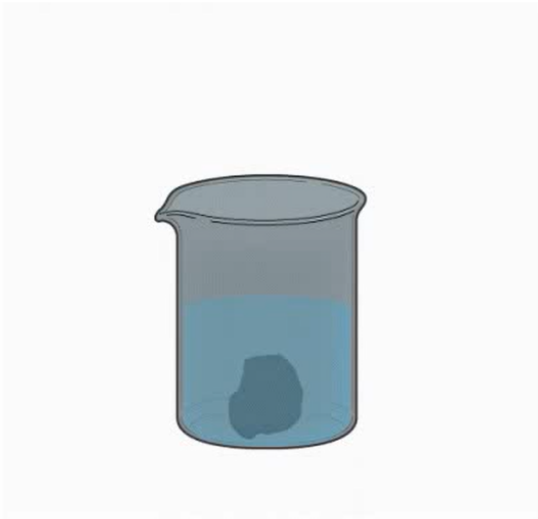


- Simple and safe process
- Inexpensive
- Majority of the metal removed even for high concentrations of copper
- Large amount of waste sludge produced
- Problems with disposal of sludge
- Large of volume of additional chemicals used in the process

©

- Particular metals can be removed
- Pure metals can be obtained
- High set-up costs
- Costs due to replacement of electrodes
- High energy consumption
- No additional chemicals are needed
- No consumption of chemicals
- No waste products

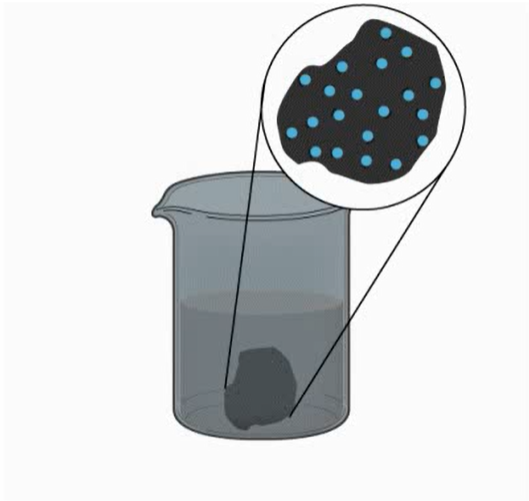
### Chemisorption



### Photocatalysis

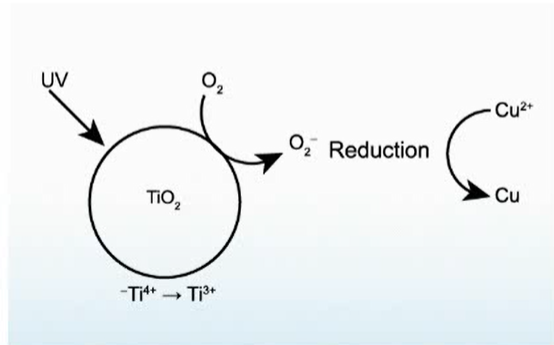


## Chemisorption



- Highly efficient at low concentrations, removes >99 % of metal ions
- Not efficient at high copper concentrations
- Some types of adsorbent can be reused
- High initial costs to set up the system
- For some types of adsorbent, copper can be recovered using further chemical processing
- Minimal waste products formed

## Photocatalysis



- New, experimental technology undergoing further development
- Uses solar energy
- 100 % copper ions removed from waste water
- Needs more than one week to remove all of the copper
- Large area needed as UV light is needed for activation
- Catalyst is cheap

You are about to set up a company in an area with a population with high levels of liver disease and insomnia which have been caused by high amounts of copper in the water supply from an old factory. Your new factory will produce PCBs. **Discuss** and **evaluate** two processes for treating waste water from the information given. In your answer, you should consider:

- the efficiency of each process
- the environmental impact of each process
- the economic impact of each process
- how each process matches the principles of green chemistry
- the complexity of each process
- your final choice of process with justification.

