RSC TOP OF THE BENCH NATIONAL FINAL 2021

Older paper

Please make sure you add in your school name in full and the year group you are currently in.

You have 30 minutes to complete the quiz. It has 2 sections and a total of 13 questions. Section A is a short answer section and is worth 10 marks in total. Section B is a longer answer section with calculations and is worth 18 marks in total

You will require a calculator and periodic table.

Check your spelling only correctly spelled answers will be marked correct.

Good luck!

Name

Name of School

School Year

SECTION A It's elemental!

The answer to each of these questions is an element found on the Periodic table.

(one mark for each correct answer)

1.	The Nobel Prize for Chemistry in 2019 was awarded for the development of batteries containing this element.	lithium
2.	This element makes up the largest proportion of the air we breathe in.	nitrogen
3.	The most reactive non-metallic element.	fluorine
4.	Before the lamps were replaced with LEDs, this element was responsible for giving street lamps their orange glow.	sodium
5.	This element glows when exposed to oxygen. Its name is derived from the Greek for '*light bearer.*'	phosphorus
6.	This metal is used to make artificial joints as it is biocompatible and resists corrosion.	titanium
7.	The surface of Mars appears red due to the oxide of this element.	iron
8.	This metal melts in your hand.	gallium or caesium
9.	Poisoning of hat makers by this element during the manufacture of hats led to the phrase '*as mad as a hatter.*'	mercury
10.	Diamond and graphite are made from this element.	carbon

SECTION B

11. This question is about the Group 1 metals – **the Alkali metals**.

(a) Group one metals react with water to produce the metal hydroxide and hydrogen gas.

(i) Write a word equation for the reaction of lithium with water. (1 mark)

lithium + water → lithium hydroxide + hydrogen

All correct for 1 mark; no mark awarded if an = sign is used instead of an arrow

(ii) Describe a test a student could carry out to prove that hydrogen gas is produced. (2 marks)

Place a lit splint into the gas (1 mark)

Burns with a pop (1 mark)

(b) The table below gives the properties of some of the other group one metals; sodium, potassium, rubidium and caesium, arranged in no particular order.

Metal	Density in g/cm^3	Melting point in °C	Relative hardness
W	1.53	39	0.03
X	0.86	64	0.04
Y	0.97	98	0.07
Z	1.87	28	0.02

Explain which metal (**W**, **X**, **Y** or **Z**) is caesium. (2 marks)

Metal **Z** (1 mark identification, 1 mark for correct explanation)

Either; it is the softest of the four/as you go down the group the metals get softer

Or; it has the lowest melting point / as you go down the group the mp decreases

Or; it has the highest density / as you go down the group the density increases

The yellow colour in fireworks is produced by addition of chemical compounds that contain the element sodium. One such compound added is sodium nitrate ($NaNO_3$).

(c) Calculate the percentage by mass of sodium in sodium nitrate. (2 marks)

A_r Na = 23; N = 14; O = 16

RFM of $NaNO_3$ = 23 + 14 + (16 × 3) = 85 *(1 mark)*

Percentage by mass of Na = (23 / 85) × 100 = **27%** (1 mark)

Correct answer with no working = both marks

Sodium nitrate also acts as an oxidising agent in the firework mixture. At high temperatures it undergoes thermal decomposition to produce sodium nitrite ($NaNO_2$) and oxygen gas.

(d) (i) What is meant by a *thermal decomposition* reaction. (1 mark)

When a substance is broken down into two or more substances using heat

(ii) Write a balanced symbol equation for the thermal decomposition described. (1 mark)

$2NaNO_3 \rightarrow 2NaNO_2 + O_2$

12. This question is about the chemistry of the Group 7 elements – **the halogens**.

(a) (i) Complete the table to describe the appearance of the group 7 elements, chlorine, bromine and iodine. (3 marks)

One/both of the colours and state needed for each mark

Element	Formula	Appearance at room temperature	Melting point in °C	Boiling point in °C
Fluorine	F_2	Pale yellow gas	–220	–188
Chlorine	Cl_2	Yellow/green gas	–102	–34
Bromine	Br_2	Orange/brown liquid	–7	59
Iodine	I_2	Grey/black solid	114	184

(iii) Use an understanding of bonding to explain why the boiling point of the halogens increases as you go down the group. (3 marks)

(1 mark) Chlorine is a simple covalent molecule

(1 mark) Molecules held together by weak intermolecular forces / forces between molecules

(1 mark) which require little energy to overcome

Bromine exists as two isotopes ^{79}Br and ^{81}Br.

(b) (i) Define what is meant by an isotope. (1 mark)

An isotope is an atom of the same element / with the same number of protons with a different mass owing to a different number of neutrons

(ii) The relative atomic mass of an atom is defined as *the average mass of atoms of that element taking into account the relative abundance of each isotope present*.

Calculate the relative atomic mass of a sample of bromine knowing that it contains 50% ^{79}Br and 50% ^{81}Br.

Give your answer to **1 decimal place**. (2 marks)

$$\frac{(50 \times 79) + (50 \times 81)}{100} = \mathbf{80.0}$$

1 mark – correct answer; 1 mark – 1 decimal place

One use for iodine is as an antiseptic to treat wounds.

Oxyzyme™ is a sterile wound dressing that uses iodine. The iodine is generated by the oxidation of iodide ions present within a gel matrix. The oxidising agent is hydrogen peroxide produced by the oxidation of beta D-glucose when exposed to the air by the enzyme glucose oxidase.

(c) (i) Write a **half equation** for the oxidation of iodide ions to iodine. (1 mark)

$2I^- \rightarrow I_2 + 2e^-$ (allow $2I^- - 2e^- \rightarrow I_2$)

(ii) Each dressing contains iodide ions present within the gel matrix at a concentration of 0.04% w/w. This means 100 g of the hydrogel contains 0.04 g of iodide ions.

If the mass of hydrogel within one dressing is 8.4 g, calculate the mass of iodine in milligrams that will be released by the oxidation of the iodide ions within a single dressing.

1000 mg = 1 g (2 marks)

0.04% of 8.4 g = (8.4 / 100) × 0.04 = 3.36×10^{-3} g or 0.00336 g (1 mark)

All the iodide is converted into iodine so the mass of iodine released is 0.00336 g.

0.00336 g = **3.36 mg** (1 mark for the correct conversion of their mass to milligrams)

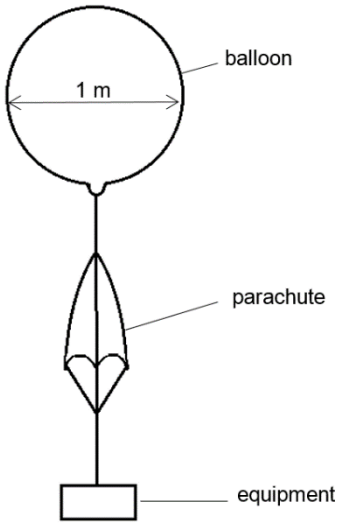
13. This question is about the chemistry of Group 0 – **the Noble gases**.

(a) Helium is commonly used to fill weather balloons. This is because it is less dense than air.

A scientist wishes to investigate the weather at high altitude.

He fills a weather balloon with a diameter of 1 m with helium gas.

For the weather balloon to rise, the mass of the air displaced must be larger than the mass of the balloon, helium and any attached equipment.



(i) Assuming that the weather balloon is a perfect sphere, calculate the mass of helium needed to fill the balloon. (2 marks)

Volume of a sphere = 4/3 πr^3

Density of helium = 0.18 kg/m^3

Volume of balloon = 4/3 × π × (0.5 m)^3 = 0.524 m^3 (1 mark)

Mass of helium = density × volume

= 0.164 kg/m^3 × 0.524 m^3

= **0.0859 kg** (1 mark; *allow 0.085 - 0.087 kg*)

(ii) As the balloon fills an equal volume of air is displaced.

Calculate the mass of air displaced when the balloon is full. (1 mark)

Density of air = 1.28 kg/m^3

Mass of air = density × volume

= 1.28 kg/m^3 × 0.524 m^3

= **0.670 kg** (1 mark; *allow 0.671 kg)*
(allow error carried forward in volume)

(iii) Use your answers to parts (i) and (ii) to calculate the maximum mass of equipment that can be added to the balloon if the weather balloon is to rise. (1 mark)

You can assume that the balloon material, parachute and rope have no mass.

= Answer part (ii) – answer to part (i)

= 0.670 kg – 0.0859 kg = **0.584 kg** (allow errors carried forward)

Elements normally bond so that each atom has a full outer shell. For elements in periods 1 and 2 this is when they have 8 electrons in their outer shell. This is known as 'the octet rule.'

However some elements in period 3 onwards can '**expand the octet.**' This means they can hold more than 8 electrons in their outer shell.

(b) Noble gases are unreactive because they have a full outer shell of electrons containing 8 electrons.

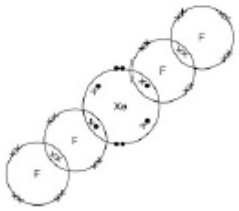
However argon, krypton, xenon and radon can form compounds if they expand the octet.

For example, xenon reacts with fluorine to form xenon tetrafluoride, XeF_4.

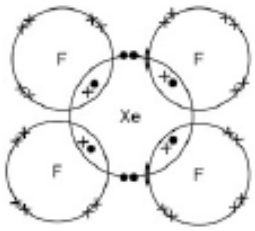
$$Xe + 2F_2 \rightarrow XeF_4$$

(i) Which dot and cross diagram below represents the bonding in xenon tetrafluoride.

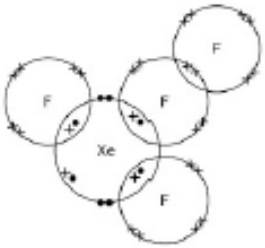
Tick **one** option.



Option 1 ☐



Option 2 ☑



Option 3 ☐

(ii) Use your diagram to predict the most likely shape for xenon tetrafluoride from the options below.

A bond to two dots (—:) on the diagrams shows the space occupied by a non-bonding pair of electrons.

Tick **one** option. (1 mark)

Tetrahedral ☐

Sawhorse ☐

Square planar ☑

Images taken from Compound Chemistry Infographic on VSEPR Shapes of Molecules