WESTMINSTER SCHOOL
THE CHALLENGE 2023

CHEMISTRY

Thursday 27 April 2023

Time allowed: 30 minutes

Instructions to candidates:

This paper has **three** questions.
You should answer **all** questions
There are 33 marks available.

The marks for individual questions and parts of questions are shown in square brackets []. **Calculators are allowed.** Any data needed will be given in the questions.

Please write in black or blue ink.
Write your answers in the spaces provided.
For examiner use only

Total Mark	

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C1. The following multiple-choice questions test a range of chemical principles. For each question, circle the letter corresponding to your chosen answer.

a) Which one of the following would produce an acidic solution when placed in water?

A Sodium

B Magnesium oxide

C Sulphur dioxide

D Sodium oxide

b) The equation for the effect of heat on hydrated copper (II) sulphate is as shown.

$$CuSO_4.5H_2O\ (s) \rightarrow CuSO_4\ (s) + 5H_2O\ (g)$$

Statements made by four students about the reaction are given.

P Anhydrous copper sulphate is formed.
Q Steam is formed.
R There is a colour change from white to blue.
S The reaction is reversible.

Which students' statements are correct?

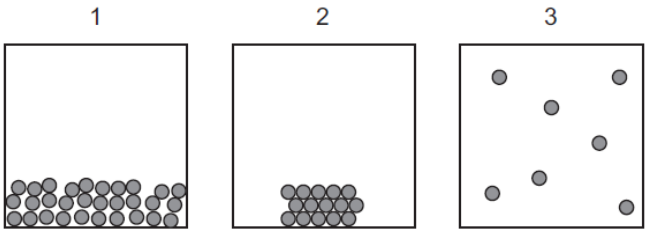
A P, Q and R only

B P, Q and S only

C Q, R and S only

D P, Q, R and S

c) The diagrams below show particles in a container.



Which two diagrams show the process of evaporation?

A 1 to 2

B 1 to 3

C 2 to 3

D 3 to 1

d) Consider the following reaction between magnesium metal and copper oxide solid.

$$Mg\ (s) + CuO\ (s) \rightarrow MgO\ (s) + Cu\ (s)$$

Which of the following terms does **not** apply to this reaction?

A Displacement

B Reduction

C Oxidation

D Neutralisation

e) Which of the following processes would be most appropriate to separate a sample of sand from liquid ethanol?

A Chromatography

B Simple distillation

C Filtration

D Crystallisation

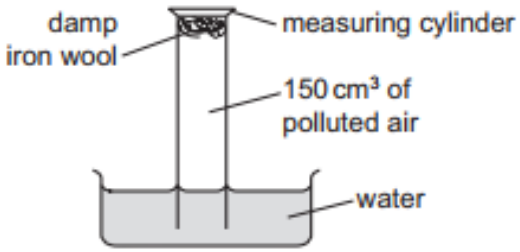
f) The diagrams show liquids in a burette and a measuring cylinder.

burette measuring cylinder

Which row shows the correct readings for the burette and the measuring cylinder?

	Burette	Measuring cylinder
A	27.8	42
B	27.8	44
C	28.2	42
D	28.2	44

g) An experiment to find the percentage of oxygen in 150cm^3 of polluted air is shown below.



The apparatus is left for one week, during which the oxygen reacts with the iron wool. After this time, the volume of gas in the measuring cylinder is 122cm^3.

What is the percentage of oxygen, to the nearest whole number, in the polluted air?

A 19%

B 21%

C 28%

D 81%

[Total: 7 marks]

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C2. This question is about rocket fuels.

NASA uses a variety of different fuels for its space rockets, such as liquid oxygen and liquid hydrogen. These are chosen since they have low mass but give out a lot of energy when they combust together.

In a rocket engine, the fuel components are first vaporised before reacting. The only reaction product from a hydrogen-oxygen rocket is water, which is expelled out of the exhaust at high velocity.

The chemical equation for the reaction between hydrogen and oxygen is given below.

$$H_2 + O_2 \rightarrow H_2O$$

a) Explain what is meant by the term **vaporised**.

……

……

[1]

b) Give a chemical test for water and state the positive result.

……

……

……

[3]

The table below gives the energy (in Joules) required to break the bonds in hydrogen, oxygen and water. When a bond is <u>formed</u>, it <u>releases</u> the same amount of energy as it would take to break that bond.

Bond	Energy required per bond / J
H – H	7.20×10^{-19}
O = O	*to be calculated*
O – H	7.67×10^{-19}

The chemical equation for the reaction between hydrogen and oxygen is given below.

$$2H_2 + O_2 \rightarrow 2H_2O$$

c)

(i) Calculate the energy required to break the bonds in two molecules of hydrogen.

……

[1]

(ii) State how many O – H bonds are formed when two molecules of water are formed in the reaction.

……

[1]

(iii) Calculate how much energy would be released when two molecules of water are formed.

……

[1]

(iv) When two molecules of hydrogen react with one molecule of oxygen 8.00×10^{-19} J of energy is released.

Using this value, and your answers to the previous parts, calculate the energy required to break the bond in an oxygen molecule.

Energy required to break O=O bond = …… J

[2]

d) You should refer to the information below to answer the following question:

- 1 molecule of hydrogen has a mass of 3.3×10^{-24} g
- 8.00×10^{-19} J of energy is released when two hydrogen molecules react with one oxygen molecule (as in the equation above).
- It takes 4.2 J to heat 1 g of water by 1°C

Calculate the mass of hydrogen that would need to be combusted (in the equation above) in order to heat 10g of water by 10°C.

[4]

[Total: 13 marks]

Question C3 starts on the next page.

C3. This question is about aluminium.

Aluminium is chemically very interesting, and its compounds have been detected throughout the known universe. As a metal, it has been used extensively in components of the international space station (ISS) shown on the right.

a) Aluminium is a metal. State **three** characteristic properties of a metallic element.

1. ……

2. ……

3. ……

[3]

Aluminium chloride, $AlCl_3$, is a solid at room temperature and reacts with water to produce an acidic solution. Like any other substance, its physical state depends on the surrounding temperature and pressure.

b) Explain how you would show **by chemical reaction** that the solution formed when $AlCl_3$ reacts with water is acidic.

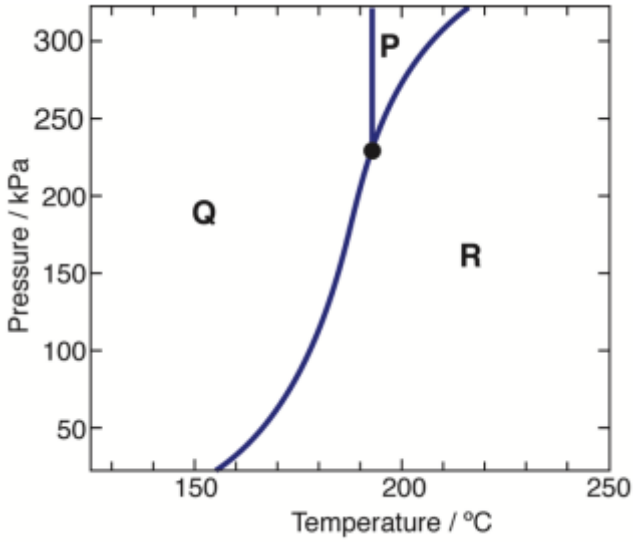
……

……

……

[2]

c) The figure below shows a **phase diagram** for aluminium chloride. This shows the conditions of temperature and pressure at which the different phases (solid, liquid and gas) are stable – these define the regions **P**, **Q** and **R** (labelled randomly).



(i) Deduce which of the regions **P**, **Q** and **R** correspond to which of the three phases: solid, liquid and gas.

Solid: ……

Liquid: ……

Gas: ……

[2]

(ii) Deduce the minimum temperature and pressure for liquid $AlCl_3$ to be stable.

……

[2]

(iii) State what is unique about the point indicated by the black circle on the graph.

……

……

[1]

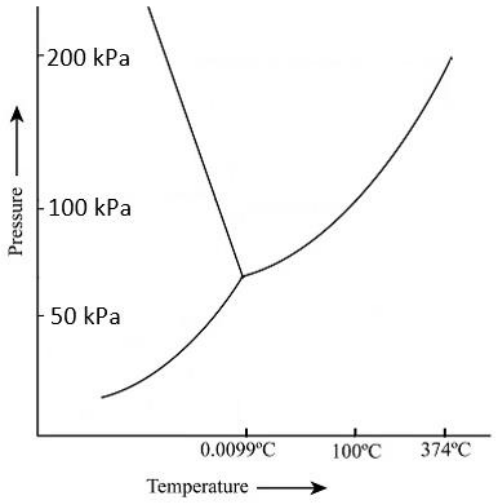
(iv) A sample of aluminium chloride is held at a temperature of 180°C and a pressure of 200kPa. Other than by heating, how might you convert this sample from physical state **Q** to state **R**? You should refer to data given in the phase diagram.

……

……

[2]

(v) The phase diagram below is for water. Estimate the value for atmospheric pressure (i.e. the approximate pressure in this room) in units of kPa.



Atmospheric pressure

= …… kPa

[1]

[Total: 13 marks]

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