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Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

AS CHEMISTRY

Paper 1: Inorganic and Physical Chemistry

Friday 27 May 2016

Morning

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The maximum mark for this paper is 80.
- The Periodic Table/Data Sheet is provided as an insert.

Advice

- You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.

Section A

Answer **all** questions in this section.

1 This question is about electron configuration.

0 1 . **1** Give the full electron configuration of an Al atom and of a Cr^{3+} ion.

[2 marks]

Al atom $1s^2 2s^2 2p^6 3s^2 3p^1$

Cr^{3+} ion $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

0 1 . **2** Deduce the formula of the ion that has a charge of 2+ with the same electron configuration as krypton.

[1 mark]

Sr^{2+}

0 1 . **3** Deduce the formula of the compound that contains 2+ ions and 3- ions that both have the same electron configuration as argon.

[1 mark]

Ca_3P_2

Turn over for the next question

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

2

This question is about Period 3 of the Periodic Table.

- 0 2** . **1** Deduce which of Na^+ and Mg^{2+} is the smaller ion.
Explain your answer.

[2 marks]

Smaller ion Mg^{2+}

Explanation Mg^{2+} has more protons (a larger nuclear charge) than
 Na^+ but the same number of electrons, same electron
arrangement and same shielding, so its electrons are attracted more
strongly and held closer to the nucleus.

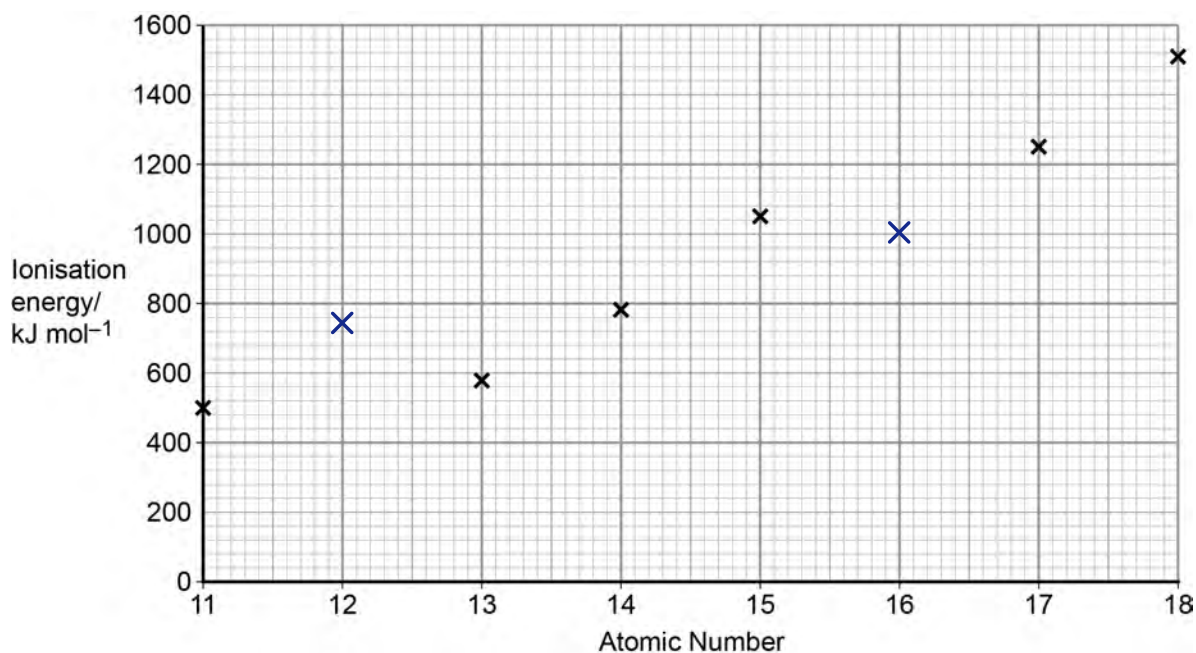
- 0 2** . **2** Write an equation to represent the process that occurs when the first ionisation energy for sodium is measured.

[1 mark]



0 2 . 3 The first ionisation energies of some Period 3 elements are shown in **Figure 1**.

Figure 1



Complete **Figure 1** by plotting the approximate first ionisation energy values for magnesium and sulfur.

Explain why the first ionisation energy of sulfur is different from that of phosphorus.

[4 marks]

Mg plotted at about 740 kJ mol⁻¹ and S at about 1000 kJ mol⁻¹, so S is lower than P.

The first ionisation energy of sulfur is lower than that of phosphorus.

In sulfur (3p⁴) the electron is removed from a 3p orbital that contains a pair of electrons, whereas in phosphorus (3p³) each 3p orbital holds a single unpaired electron.

The two paired electrons in the same 3p orbital repel each other, so less energy is needed to remove one of them from sulfur.

3

This question is about a white solid, MHCO_3 , that dissolves in water and reacts with hydrochloric acid to give a salt.



A student was asked to design an experiment to determine a value for the M_r of MHCO_3 . The student dissolved 1464 mg of MHCO_3 in water and made the solution up to 250 cm^3 .

25.0 cm^3 samples of the solution were titrated with $0.102 \text{ mol dm}^{-3}$ hydrochloric acid. The results are shown in **Table 1**.

Table 1

	Rough	1	2	3
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

- 0 3** . **1** Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the MHCO_3 solution.

[3 marks]

Concordant titres: 9.75 and 9.65 cm^3 (the rough and 9.50 are not used)

Mean titre = $(9.75 + 9.65) \div 2 = 9.70 \text{ cm}^3$

Moles of HCl = $0.102 \times 9.70 \div 1000 = 9.89 \times 10^{-4} \text{ mol}$

- 0 3** . **2** Calculate the amount, in moles, of MHCO_3 in 250 cm^3 of the solution. Then calculate the experimental value for the M_r of MHCO_3 . Give your answer to the appropriate number of significant figures.

[3 marks]

Moles of MHCO_3 in 25.0 cm^3 = 9.89×10^{-4} (1 : 1 ratio)

Moles in 250 cm^3 = $9.89 \times 10^{-4} \times 10 = 9.89 \times 10^{-3} \text{ mol}$

M_r = mass $\div$ moles = $1.464 \div 9.89 \times 10^{-3} = 148$ (3 s.f.)

- 0 3** . **3** The student identified use of the burette as the largest source of uncertainty in the experiment.

Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.

Justify your suggested improvement.

[2 marks]

Suggestion Use a larger mass of MHCO_3 in the 250 cm^3 (a more concentrated MHCO_3 solution).

Justification So a larger titre (larger volume of HCl) is needed. The burette uncertainty per reading stays the same, so the percentage uncertainty is smaller.

- 0 3** . **4** Another student is required to make up 250 cm^3 of an aqueous solution that contains a known mass of MHCO_3 . The student is provided with a sample bottle containing the MHCO_3 .

Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

[6 marks]

Weigh the sample bottle containing the MHCO_3 on a balance (reading to 2 decimal places) and record the mass. Tip the solid into a clean beaker, then reweigh the empty sample bottle and record the mass.

The difference in mass is the known mass of solid transferred.

Add about 100 cm^3 of distilled (deionised) water to the beaker and stir with a glass rod until all of the solid has dissolved.

Pour the solution through a funnel into a 250 cm^3 volumetric flask.

Rinse the beaker, glass rod and funnel with distilled water and add all the washings to the flask.

Add distilled water until the bottom of the meniscus is on the 250 cm^3 mark, adding the last few drops with a dropping pipette, with the mark at eye level.

More answer space is available on page 8

Stopper the flask and invert it / shake it several times so that the solution is thoroughly mixed.

4

Table 2 shows some data about the elements bromine and magnesium.

Table 2

Element	Melting point / K	Boiling point / K
Bromine	266	332
Magnesium	923	1383

0 4

1

In terms of structure and bonding explain why the boiling point of bromine is different from that of magnesium. Suggest why magnesium is a liquid over a much greater temperature range compared to bromine.

[5 marks]

Bromine is simple molecular: it is made of Br₂ molecules held together by weak van der Waals forces between the molecules.

Magnesium is metallic: a lattice of positive Mg²⁺ ions in a sea of delocalised electrons, held together by strong metallic bonding (attraction between the ions and the delocalised electrons).

Boiling bromine only needs the weak intermolecular forces to be overcome, but much more energy is needed to overcome the strong metallic bonds in magnesium, so magnesium has a much higher boiling point.

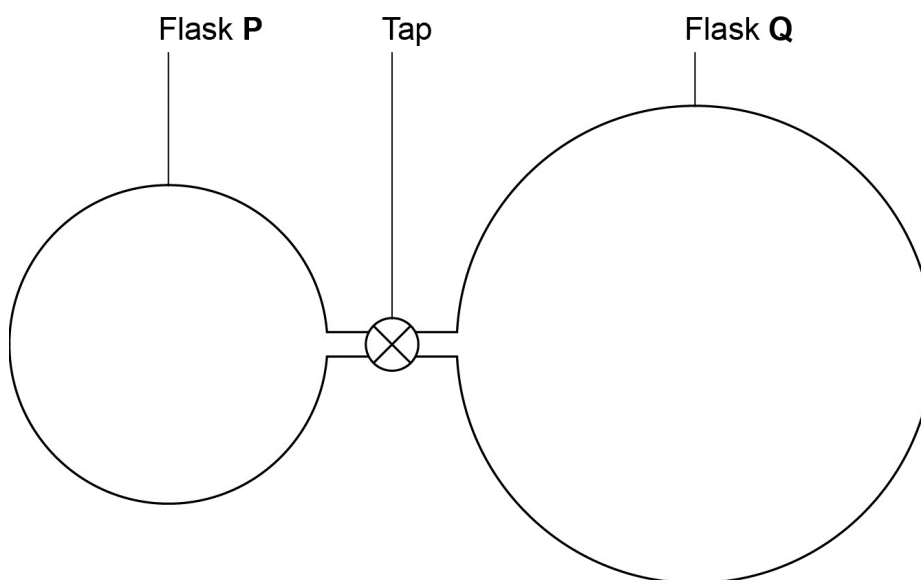
Magnesium has a much greater liquid range because the forces of attraction in the liquid (molten) metal are still strong, so a lot more energy is needed before the atoms can separate into a gas, whereas the weak forces in liquid bromine are easily overcome.

5

Figure 2 represents two glass flasks, **P** and **Q**, connected via a tap.

Flask **Q** (volume = $1.00 \times 10^3 \text{ cm}^3$) is filled with ammonia (NH_3) at 102 kPa and 300 K. The tap is closed and there is a vacuum in flask **P**.
(Gas constant $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$)

Figure 2



0 5 . **1** Calculate the mass of ammonia in flask **Q**.

Give your answer to the appropriate number of significant figures.

[3 marks]

$$n = pV \div RT$$

$$n = (102\,000 \times 1.00 \times 10^{-3}) \div (8.31 \times 300) = 4.09 \times 10^{-2} \text{ mol}$$

$$\text{Mass} = 4.09 \times 10^{-2} \times 17.0 = 0.696 \text{ g}$$

- 0 5** . **2** When the tap is opened, ammonia passes into flask **P**. The temperature decreases by 5 °C. The final pressure in both flasks is 75.0 kPa. Calculate the volume, in cm³, of flask **P**.

[3 marks]

$$T = 300 - 5 = 295 \text{ K and } p = 75\,000 \text{ Pa}$$

$$\text{Total } V = nRT \div p = (4.091 \times 10^{-2} \times 8.31 \times 295) \div 75\,000$$

$$= 1.337 \times 10^{-3} \text{ m}^3$$

$$\text{Volume of P} = 1.337 \times 10^{-3} - 1.00 \times 10^{-3} = 3.37 \times 10^{-4} \text{ m}^3$$

$$\text{Volume of flask P} = 337 \text{ cm}^3$$

Turn over for the next question

6

- 0 6** . **1** Explain how ions are accelerated, detected and have their abundance determined in a time of flight (TOF) mass spectrometer.

[3 marks]

Positive ions are accelerated by attraction to a negatively charged plate (electric field), so all have the same kinetic energy.

At the detector the ions are detected by gaining an electron.

This produces a current, and the size of the current is proportional to the abundance.

- 0 6** . **2** Calculate the mass, in kg, of a single $^{52}\text{Cr}^+$ ion.
Assume that the mass of a $^{52}\text{Cr}^+$ ion is the same as that of a ^{52}Cr atom.

(The Avogadro constant $L = 6.022 \times 10^{23} \text{ mol}^{-1}$)

[1 mark]

$$m = (52 \div 1000) \div 6.022 \times 10^{23}$$
$$= 8.64 \times 10^{-26} \text{ kg}$$

- 0 6** . **3** In a TOF mass spectrometer the kinetic energy (KE) of a $^{52}\text{Cr}^+$ ion was $1.269 \times 10^{-13} \text{ J}$

Calculate the velocity of the ion using the equation.

$$\text{KE} = \frac{1}{2}mv^2$$

(m = mass/kg and v = velocity/ ms^{-1})

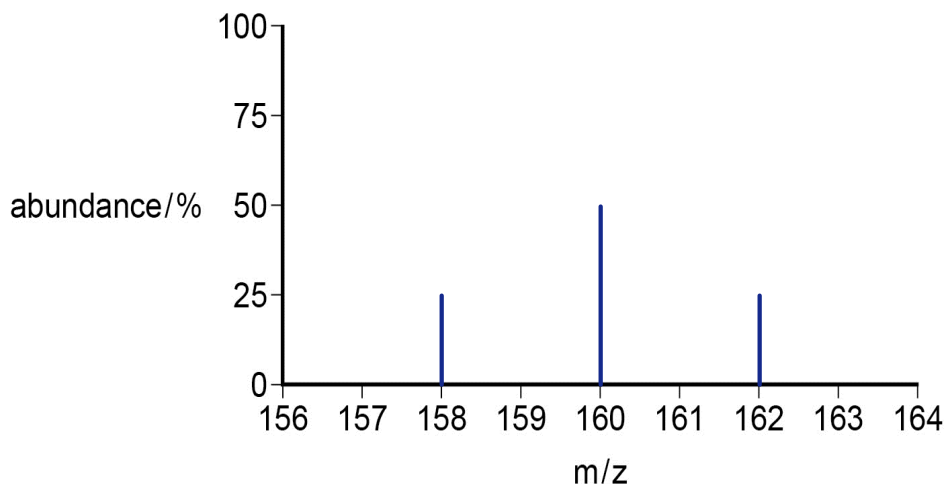
[2 marks]

$$v^2 = 2\text{KE} \div m = (2 \times 1.269 \times 10^{-13}) \div 8.64 \times 10^{-26} = 2.94 \times 10^{12}$$
$$v = \sqrt{2.94 \times 10^{12}} = 1.71 \times 10^6 \text{ m s}^{-1}$$

- 0 6 . 4** Bromine has two isotopes, ^{79}Br and ^{81}Br , in approximately equal abundance. In a TOF mass spectrometer bromine forms ions with formula $[\text{Br}_2]^+$

Sketch the pattern of peaks you would expect to see in the mass spectrum of a sample of bromine.

[2 marks]



- 0 6 . 5** A sample of xenon has $A_r = 131.31$. The sample consists of four isotopes. The abundances of three of the isotopes are shown in **Table 3**. The data for one of the isotopes, ^mXe , is missing.

Table 3

Isotope	^{129}Xe	^{131}Xe	^{132}Xe	^mXe
% abundance	28.0	25.0	27.0	To be calculated

Use the data to calculate the abundance of isotope ^mXe and calculate m , the mass number of ^mXe . Show your working.

[4 marks]

$$\% \text{ abundance of } ^m\text{Xe} = 100 - (28.0 + 25.0 + 27.0) = 20.0\%$$

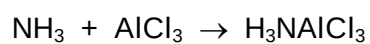
$$131.31 = (0.280 \times 129) + (0.250 \times 131) + (0.270 \times 132) + 0.200m$$

$$131.31 = 104.51 + 0.200m, \text{ so } 0.200m = 26.80$$

$$m = 26.80 \div 0.200 = 134$$

7

Ammonia reacts with aluminium chloride as shown by the equation:

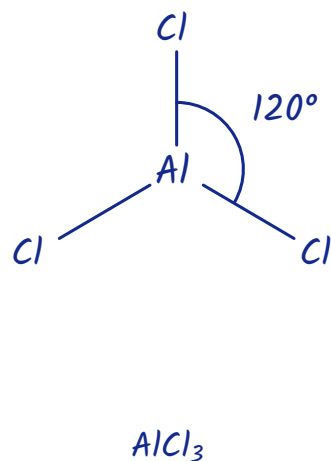
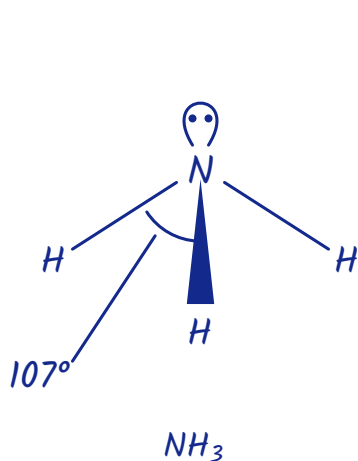


0 7 . 1 Draw diagrams to illustrate the shapes of NH_3 molecules and of AlCl_3 molecules.

Include in your diagrams any lone pairs of electrons that influence the shape.

Indicate the values of the bond angles.

[3 marks]



- 0 7** . **2** Name the type of bond formed between N and Al in H_3NAlCl_3 and explain how this bond is formed.

[2 marks]

Type of bond Dative covalent (co-ordinate) bond

Explanation The lone pair of electrons on the N atom of NH_3 is
donated into an empty orbital on the Al atom, so both
electrons in the shared pair come from the nitrogen.

- 0 7** . **3** Explain how the value of the Cl-Al-Cl bond angle in AlCl_3 changes, if at all, on formation of the compound H_3NAlCl_3

[2 marks]

In H_3NAlCl_3 the aluminium is surrounded by 4 bonding pairs of
electrons (tetrahedral) instead of 3.

The 4 pairs repel equally to be as far apart as possible, so the
Cl-Al-Cl bond angle decreases from 120° to about 109.5° .

Turn over for the next question

8

A student oxidised a solution of hydrochloric acid with a few drops of sodium chlorate(I) solution. The reaction mixture effervesced and turned pale green. The gas formed bleached universal indicator paper.

0 8 . 1 Write a half-equation for the oxidation of chloride ions.

[1 mark]



0 8 . 2 Write a half-equation for the reduction of chlorate(I) ions to chlorine in acidic conditions.

[1 mark]



0 8 . 3 Write an overall equation for the redox reaction of chlorate(I) ions with hydrochloric acid.

[1 mark]



0 8 . 4 A solution of sodium chlorate(I) was added to a colourless solution of potassium iodide.
Suggest what is observed.

Explain the reaction that leads to this observation.

[3 marks]

The colourless solution turns brown.

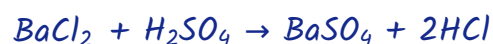
This is because iodine (I_2) is formed: the iodide ions are oxidised by the chlorate(I) ions, $2\text{I}^- \rightarrow \text{I}_2 + 2\text{e}^-$, and the chlorate(I) is reduced to chloride ions.

- 0 9 . 1** A student was given a powder made from a mixture of anhydrous barium chloride and anhydrous magnesium chloride. The student dissolved 1.056 g of the powder in water in a conical flask and added an excess of sulfuric acid. A white precipitate formed and was filtered off, washed and dried. The mass of this solid was 0.764 g.

Identify the white precipitate and calculate the percentage, by mass, of magnesium chloride in the powder.

[4 marks]

The white precipitate is barium sulfate, BaSO_4 .



Moles of $\text{BaSO}_4 = 0.764 \div 233.4 = 3.273 \times 10^{-3} \text{ mol} = \text{moles of}$
 BaCl_2

$$\text{Mass of } \text{BaCl}_2 = 3.273 \times 10^{-3} \times 208.3 = 0.6818 \text{ g}$$

$$\text{Mass of } \text{MgCl}_2 = 1.056 - 0.6818 = 0.3742 \text{ g}$$

$$\% \text{ MgCl}_2 = (0.3742 \div 1.056) \times 100 = 35.4\%$$

Turn over for the next question

Section B

Answer **all** questions in the spaces provided

Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD 

WRONG METHODS    

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working out in the blank spaces around the questions but this will not be marked.
Do **not** use additional sheets for this working.

1 0

Which element is in the d-block of the Periodic Table?

[1 mark]

A Selenium

☐

B Antimony

☐

C Tantalum

☒

D Lead

☐

1 1

Which species contains an element with an oxidation state of +4?

[1 mark]

A NO_2^+

☐

B ClO_3^-

☐

C H_2SO_3

☒

D PCl_5

☐

1 2

There are 392 mol of pure gold in a bar measuring 10 cm by 10 cm by 40 cm.
What is the density of gold in kg dm^{-3} ?

[1 mark]

A 193

☐

B 19.3

☒

C 1.93

☐

D 0.193

☐

1 3

Ions of two isotopes of iron are



Which statement is correct?

[1 mark]

A The ions of both the isotopes have the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

☐

B The ions of both the isotopes contains 26 neutrons

☐

C $^{53}\text{Fe}^{2+}$ has fewer protons than $^{56}\text{Fe}^{2+}$

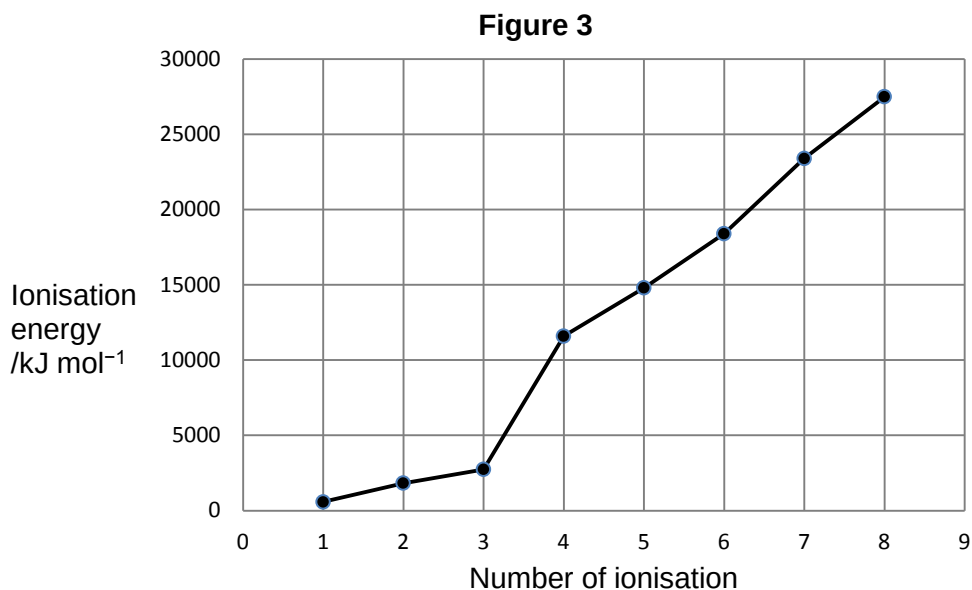
☐

D After acceleration to the same kinetic energy $^{56}\text{Fe}^{2+}$ will move more slowly than $^{53}\text{Fe}^{2+}$

☒

1 4

The successive ionisation energies for element X are shown in **Figure 3**.



Which element is X?

[1 mark]

- A Nitrogen
- B Phosphorus
- C Aluminium
- D Boron

☐☐☒☐

1 5

Which of these decreases down Group 2?

[1 mark]

- A First ionisation energy
- B Atomic radius
- C Number of protons
- D Reactivity with water

☒☐☐☐

Refer to the unbalanced equation below when answering questions **16** and **17**.



1 **6**

In the balanced equation the mole ratio for sulfuric acid to water is

[1 mark]

A 1 : 4

☐

B 1 : 2

☐

C 4 : 7

☒

D 4 : 9

☐

1 **7**

What is the reducing agent in this reaction?

[1 mark]

A H^+

☐

B $\text{C}_2\text{O}_4^{2-}$

☒

C K^+

☐

D $\text{Cr}_2\text{O}_7^{2-}$

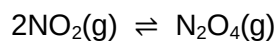
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1 8

Which substance exists as a macromolecule?

[1 mark]**A** Cu☐**B** SiO₂☒**C** P₄O₁₀☐**D** MgO☐**1 9**

A pale brown mixture of NO₂ and N₂O₄ is allowed to reach equilibrium in a sealed gas syringe according to the following equation.



When the plunger is pushed further into the syringe the pressure increases and the mixture becomes paler in colour.

When the syringe is placed in a hot oven the mixture becomes darker in colour.

Which of the following statements is correct?

[1 mark]**A** NO₂ is brown and the forward reaction is exothermic.☒**B** NO₂ is brown and the forward reaction is endothermic.☐**C** NO₂ is colourless and the forward reaction is exothermic.☐**D** NO₂ is colourless and the forward reaction is endothermic.☐

2	0
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Which molecule has the largest dipole?

[1 mark]

A ClF_3

☒

B BF_3

☐

C SF_6

☐

D CF_4

☐

2	1
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In a molecule of a hydrocarbon, the fraction by mass of carbon is $\frac{9}{11}$

What is the empirical formula of the hydrocarbon?

[1 mark]

A CH

☐

B CH_3

☐

C C_3H_8

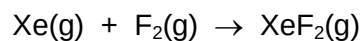
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D C_5H_{12}

☐

2	2
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30 cm³ of xenon are mixed with 20 cm³ of fluorine. The gases react according to the following equation. Assume that the temperature and pressure remain constant.



What is the final volume of gas after the reaction is complete?

[1 mark]

A 50 cm³

☐

B 40 cm³

☐

C 30 cm³

☒

D 20 cm³

☐

2	3
---	---

Which of the following solutions would react exactly with a solution containing 0.0500 mol sulfuric acid?

[1 mark]

A 50.0 cm³ of 1.00 mol dm⁻³ KOH

☐

B 100.0 cm³ of 2.00 mol dm⁻³ KOH

☐

C 100.0 cm³ of 2.00 mol dm⁻³ Ba(OH)₂

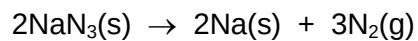
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D 50.0 cm³ of 1.00 mol dm⁻³ Ba(OH)₂

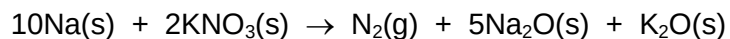
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2	4
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In a car airbag, sodium azide (NaN_3) decomposes to form sodium metal and nitrogen gas.



The sodium metal then reacts with potassium nitrate to produce more nitrogen gas.



If 2.00 mol of sodium azide react in this way, how many molecules of N_2 will be formed?

(The Avogadro constant $L = 6.022 \times 10^{23} \text{ mol}^{-1}$)

[1 mark]

A 2.41×10^{24}

☐

B 1.93×10^{24}

☒

C 1.81×10^{24}

☐

D 9.63×10^{23}

☐

END OF QUESTIONS

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