AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname MODEL ANSWERS

Forename(s)

Candidate signature

# AS CHEMISTRY

## Paper 1 Inorganic and Physical Chemistry

Tuesday 22 May 2018 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 scientific 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 marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

**Advice**

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

| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| Section B | |
| **TOTAL** | |

## Section A

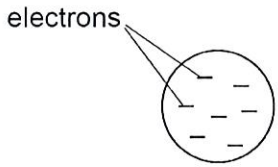
Answer **all** questions in this section.

**0 1** This question is about atomic structure.

In the nineteenth century JJ Thomson discovered the electron. He suggested that negative electrons were found throughout an atom like 'plums in a pudding of positive charge'.

**Figure 1** shows an atom of element **R** using the 'plum pudding' model.
An atom of **R** contains seven electrons.

**Figure 1**




**0 1 . 1** State **two** differences between the 'plum pudding' model and the model of atomic structure used today.

**[2 marks]**

1 Contains a nucleus with protons and neutrons M1

2 Electrons are arranged in energy levels | shells | orbits M2

**0 1 . 2** Deduce the full electron configuration of an atom of element **R**.

**[1 mark]**

$1s^2 2s^2 2p^3$

**0 1 . 3** Identify **R** and deduce the formula of the compound formed when **R** reacts with the Group 2 metal in the same period as **R**.

**[1 mark]**

N (nitrogen) $Be_3N_2$

4

**0 2** This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.
The concentration of sodium fluoride can be expressed in parts per million (ppm).
1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

**0 2 . 1** A 1.00 g sample of toothpaste was found to contain $2.88 \times 10^{-5}$ mol of sodium fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste.
Give your answer to 3 significant figures.

**[4 marks]**

M1

$M = 2.88 \times 10^{-5} \times 42.0 = 1.210 \times 10^{-3}$ g M2

$\therefore$ in 1 kg $1.210 \times 10^{-3} \times 10^{3} = 1.21$ g M3

Concentration NaF $= 1.210 \times 10^{3}$ mg

$= 1210$ ppm M4

Concentration of sodium fluoride 1210 ppm

**0 2 . 2** Sodium fluoride is toxic in high concentrations.
Major health problems can occur if concentrations of sodium fluoride are greater than $3.19 \times 10^{-2}$ g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

**[1 mark]**

$3.19 \times 10^{-2} \times 10^{3}$ mg per 1 kg

31.9 mg × 75

Mass of sodium fluoride 2393 mg

also allow 2390 mg

**0 2 . 3** The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.
2800 mg per 1 kg

Use your answer to Question **02.2** to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

**[1 mark]**

$\frac{2393}{2800} = 0.855$

Mass of toothpaste 0.855 kg
(2 sig fig)

also allow 0.854

**0 2 . 4** Identify the diagram in **Figure 2** that shows the correct relative sizes of the ions in sodium fluoride.
Justify your answer.

**[3 marks]**

**Figure 2**

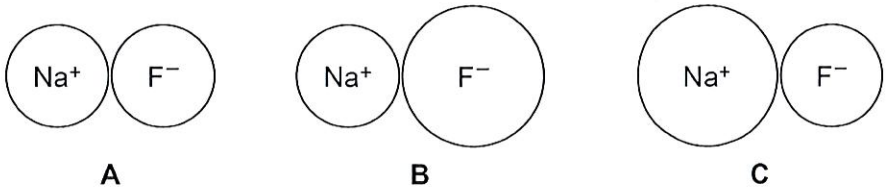



Diagram B M1

Justification

Both $Na^+$ and $F^-$ have same electron arrangement ($1s^2 2s^2 2p^6$)

$Na^+$ has more protons so attracts electrons closer M2

or stronger attraction for electrons

9

**Turn over for the next question**

**0 3** A student heated a solid sample of $Na_2CO_3 . xH_2O$ for 1 minute to remove water and determine a value for $x$
**Figure 3** shows the apparatus used. **Table 1** shows the results recorded.

**Figure 3**

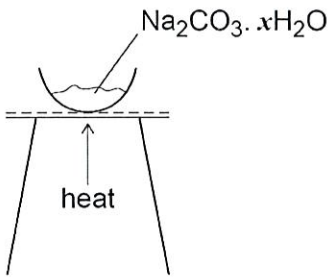



**Table 1**

| | |
|---|---|
| Mass of empty evaporating basin | 24.35 g |
| Mass of evaporating basin and solid before heating | 25.47 g |
| Mass of evaporating basin and solid after heating for 1 minute | 24.92 g |

**0 3 . 1** Use the data in **Table 1** to calculate a value for $x$ in the formula $Na_2CO_3 . xH_2O$
Give your answer to 2 decimal places.

**[5 marks]**

| | $Na_2CO_3$ | $H_2O$ | |
|---|---|---|---|
| m | 0.57 g | 0.55 g | M1 |
| n | $0.57/106 = 0.0054$ | $0.55/18 = 0.30\dot{5}$ | M2 |
| | 1 | 5.68 | M3 (at least 2sf) |
| | | (If keep all numbers in calculator) | M4 |

Value for $x$ 5.68 (2 d.p.) M5

allow 5.67 - 5.74

**0 3 . 2** The correct value for $x$ is 10

Suggest a reason for the difference between the experimental value for $x$ and the correct value.
(If you were unable to calculate an experimental value for $x$ assume it was 8.05.
This is **not** the correct experimental value.)

**[1 mark]**

Did not heat for long enough
or not heated to constant mass

**0 3 . 3** Suggest how the procedure could be improved, using the same apparatus, to give a more accurate value for $x$
Justify your answer.

**[2 marks]**

Suggestion Heat to constant mass
or Heat for longer M1

Justification Make sure all the water has been driven off / evaporated M2

8

**Turn over for the next question**

**0 4 . 1** Separate unlabelled solid samples of three anhydrous sodium compounds are provided for a student to identify.

LEVELLED

These compounds are known to be sodium carbonate, sodium fluoride and sodium chloride but it is not known which sample is which.

Outline a logical sequence of test-tube reactions that the student could carry out to identify each of these compounds.
Include the observations the student would expect to make.
Give equations, including **state symbols**, for any reactions that would take place.

**[6 marks]**

- Add $HNO_3$ to all 3 test tubes
  - $Na_2CO_3$ will effervesce

$Na_2CO_3(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$

  - other 2 test tubes will show no change

- Add water to the 2 test tubes
- Add $AgNO_3$
  - NaCl will produce a white precipitate
  - NaF will show no visible change

$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

Additional incorrect observations loses mark

6

**Turn over for the next question**

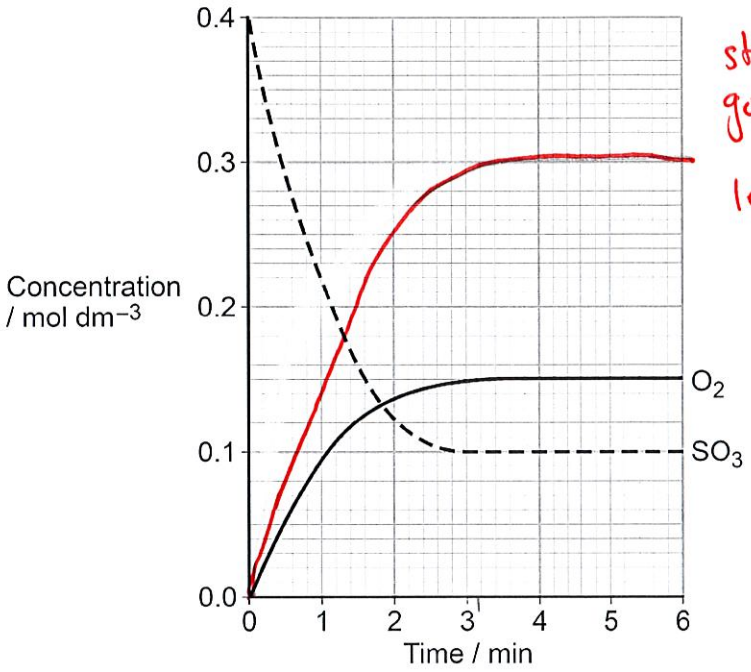
**0 5** This question is about equilibrium.

Sulfur trioxide decomposes to form sulfur dioxide and oxygen at temperature $T_1$ according to the equilibrium shown.

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g) \qquad \Delta H = +196 \text{ kJ mol}^{-1}$$

The graph in **Figure 4** shows the concentrations of sulfur trioxide and of oxygen over a period of 6 minutes at temperature $T_1$

**Figure 4**




starts at origin goes up to 3 mins M1

level at 0.3 mol dm$^{-3}$ M2

**0 5 . 1** State the time, to the nearest minute, when equilibrium is first established. Explain your answer.

**[2 marks]**

Time 3 minutes M1

Explanation concentrations $O_2$ and $SO_2$ remain constant M2

**0 5 . 2** Sketch on the graph in **Figure 4** how the concentration of sulfur dioxide changes over these 6 minutes at temperature $T_1$

**[2 marks]**

See graph

**0 5 . 3** The temperature of the mixture was changed to $T_2$ and the mixture left to establish a new equilibrium.
In the new equilibrium mixture the concentration of sulfur trioxide was found to be 0.07 mol $dm^{-3}$

Deduce which of $T_1$ and $T_2$ is the higher temperature.
Explain your deduction.

**[2 marks]**

Higher temperature $T_2$

Explanation

Equilibrium has moved to RHS in endothermic direction H1

Equilibrium opposes increase in temperature moving to decrease temperature H2

6

**Turn over for the next question**

**0 6** A student determined the relative molecular mass, $M_r$, of an unknown volatile liquid **Y** in an experiment as shown in **Figure 5**.
The student used a hypodermic syringe to inject a sample of liquid **Y** into a gas syringe in an oven.
At the temperature of the oven, liquid **Y** vaporised.

The student's results are shown in **Table 2**.

**Figure 5**

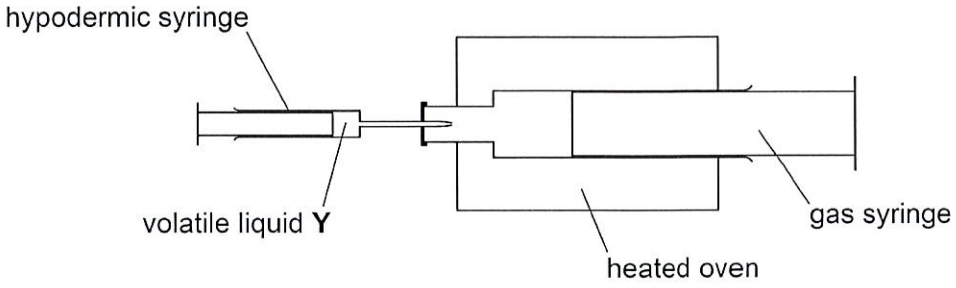



**Table 2**

| | |
|---|---|
| Mass of hypodermic syringe and liquid **Y** before injection | 10.91 g |
| Mass of hypodermic syringe and liquid **Y** after injection | 10.70 g |
| Oven temperature | 98.1 °C 371.1 K |
| Atmospheric pressure | 102 kPa $\times 10^3$ Pa |
| Increase in volume in gas syringe after injection of **Y** | 85.0 $cm^3$ $\times 10^{-6}$ $m^3$ |

**0 6 . 1** Define the term relative molecular mass ($M_r$).

Use the experimental results in **Table 2** to determine the relative molecular mass of **Y**.
The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$

**[5 marks]**

$PV = nRT \Rightarrow n = \frac{PV}{RT}$ M1

$n = \frac{102 \times 10^3 \times 85 \times 10^{-6}}{8.31 \times 371.1} = 2.81 \times 10^{-3}$ M2

$M_r = \frac{m}{n}$ $m = 10.91 - 10.70 = 0.21g$ M3

$M_r = 74.7$ M4

$M_r = \frac{\text{sum of average mass of one molecule}}{1/12 \text{ mass of an atom } ^{12}C}$ M5

**0 6 . 2** Some of the liquid injected did not evaporate because it dripped into the gas syringe nozzle outside the oven.

Explain how this would affect the value of the $M_r$ of **Y** calculated from the experimental results.

**[2 marks]**

lower volume of gas recorded M1

$M_r$ would be greater M2

7

**0 7** Chlorine is used to decrease the numbers of microorganisms in water.

When chlorine is added to water, there is a redox reaction, as shown by the equation

$$Cl_2 + H_2O \rightleftharpoons HClO + HCl$$

**0 7 . 1** Deduce the oxidation state of chlorine in HClO and the oxidation state of chlorine in HCl

**[1 mark]**

Oxidation state of chlorine in $\overset{+1}{H}\overset{}{Cl}\overset{-2}{O}$ +1

Oxidation state of chlorine in $\overset{+1}{H}Cl$ −1

**0 7 . 2** Give two half-equations to show the oxidation and reduction processes that occur in this redox reaction.

**[2 marks]**

Oxidation half-equation $Cl_2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2e^-$

Reduction half-equation $Cl_2 + 2e^- + 2H^+ \rightarrow 2HCl$

**0 7 . 3** Chlorine is reacted with cold, aqueous sodium hydroxide in the manufacture of bleach.

Give an equation for this reaction between chlorine and sodium hydroxide.

**[1 mark]**

$Cl_2 + 2NaOH \rightarrow NaCl + NaClO + H_2O$

**0 7 . 4** The concentration of $ClO^-$ ions in bleach solution can be found by reaction with iodide ions.

The overall equation for this reaction is shown.

$$ClO^- + 2I^- + 2H^+ \rightarrow I_2 + Cl^- + H_2O$$

A sample of bleach solution was found to contain $ClO^-$ ions with a concentration of 0.0109 mol $dm^{-3}$
Potassium iodide is added to a 20.0 $cm^3$ portion of this bleach solution.

Calculate the mass, in mg, of potassium iodide needed to react with all of the $ClO^-$ ions in the sample of bleach.
Give your answer to the appropriate number of significant figures.
Give **one** observation during this reaction.

**[4 marks]**

n=cv $n\ ClO^- = 0.0109 \times 20 \times 10^{-3} = 2.18 \times 10^{-4}$ mol M1

$n\ I^- = 2 \times 2.18 \times 10^{-4} = 4.36 \times 10^{-4}$ M2

$m\ KI = 4.36 \times 10^{-4} \times 166 = 0.0723\ g \times 10^3$ M3

Mass of potassium iodide 72.4 (3 s.f.) mg

Observation

black solid | ppt M4

or turns brown solution

**Question 7 continues on the next page**

**0 7 . 5** Potassium chlorate(VII), $KClO_4$, is used in fireworks. When potassium chlorate(VII) decomposes, it produces potassium chloride and oxygen.

Give an equation for the decomposition of potassium chlorate(VII).
Use the data in **Table 3** to calculate the enthalpy change for this reaction.

**[2 marks]**

**Table 3**

| Substance | $\Delta_f H$ / kJ mol$^{-1}$ |
|---|---|
| $KClO_4(s)$ | −434 |
| KCl(s) | −436 |

Equation $KClO_4 \rightarrow KCl + 2O_2$ M1

$\Delta H = \Sigma \Delta H_f(P) - \Sigma \Delta H_f(R)$

$= -436 - (-434)$

M2

Enthalpy change $-2$ kJ mol$^{-1}$

10

**0 8** A sample of bromine was analysed in a time of flight (TOF) mass spectrometer and found to contain two isotopes, $^{79}Br$ and $^{81}Br$

After electron impact ionisation, all of the ions were accelerated to the same kinetic energy (*KE*) and then travelled through a flight tube that was 0.950 m long.

**0 8 . 1** The $^{79}Br^+$ ions took $6.69 \times 10^{-4}$ s to travel through the flight tube.

DIFFICULT

Calculate the mass, in kg, of one ion of $^{79}Br^+$

Calculate the time taken for the $^{81}Br^+$ ions to travel through the same flight tube.

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

$KE = \frac{1}{2} mv^2$ where $m$ = mass (kg) and $v$ = speed ($m\ s^{-1}$)

$v = \frac{d}{t}$ where $d$ = distance (m) and $t$ = time (s)

**[5 marks]**

$m\ ^{79}Br^+ = \frac{79}{6.022 \times 10^{23}} = 1.31186 \times 10^{-22}\ g \times 10^{-3}$

$= 1.31186 \times 10^{-25}\ kg$

$v = \frac{d}{t}$ $v_{79} = \frac{0.950}{6.69 \times 10^{-4}} = 1420\ ms^{-1}$

$KE = \frac{1}{2} mv^2$ $KE_{79} = \frac{1}{2} \times 1.31186 \times 10^{-25} \times (1420)^2$

$= 1.3226 \times 10^{-19}\ J$

$KE_{79} = KE_{81}$

If $KE = \frac{1}{2} mv^2$ $v = \sqrt{\frac{2KE}{m}}$ (in kg)

$v_{81} = \sqrt{\frac{2 \times 1.3226 \times 10^{-19}}{\left(\frac{81 \times 10^{-3}}{6.022 \times 10^{23}}\right)}} = \sqrt{\frac{2.645 \times 10^{-19}}{1.345 \times 10^{-25}}}$

$= \sqrt{1.967 \times 10^6} = 1.40 \times 10^3\ ms^{-1}$

$v = \frac{d}{t}$ $t_{81} = \frac{d}{v} = \frac{0.950}{1.40 \times 10^3} = 6.80 \times 10^{-4}$

Mass of one ion of $^{79}Br^+$ 1.31 × 10⁻²⁵ kg

Time taken by $^{81}Br^+$ ions 6.80 × 10⁻⁴ s

**Turn over ▶**

**0 8 . 2** Explain how ions are detected and relative abundance is measured in a TOF mass spectrometer.

**[2 marks]**

- positive ion hits the detector and gains an electron M1
- abundance is proportional to the size of the current M2

7

**0 9** This question is about compounds containing fluorine.

**0 9 . 1** Draw the shape of a molecule of krypton difluoride ($KrF_2$).
Include in your answer any lone pairs of electrons that influence the shape.
Name the shape produced by the atoms in a $KrF_2$ molecule and suggest a bond angle.

**[3 marks]**

$KrF_2$
8
2
10 ⇒ 5 pairs trigonal bipyramidal
2 B : 3 NB

M1

Name of shape linear M2

Bond angle 180° M3

**0 9 . 2** There are two lone pairs of electrons on the oxygen atom in a molecule of oxygen difluoride ($OF_2$).

Explain how the lone pairs of electrons on the oxygen atom influence the bond angle in oxygen difluoride.

**[2 marks]**

lone pairs repel more than bonding pairs M1

bond angle will be lower/reduced M2

**0 9 . 3** Silicon tetrafluoride ($SiF_4$) is a tetrahedral molecule.

Deduce the type of intermolecular forces in $SiF_4$
Explain how this type of intermolecular force arises and why no other type of intermolecular force exists in a sample of $SiF_4$

**[3 marks]**

Intermolecular forces in $SiF_4$ van der Waals forces M1

Explanation electrons unevenly distributed so M2
induce (temporary) dipole in neighbouring molecule

molecule is symmetrical M3
or no hydrogens bonded to F so no hydrogen bonding

8

*Do not write outside the box*

**Turn over for Section B**

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

## Section B

Answer **all** questions in this section.

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 in the blank space around each question but this will not be marked. Do **not** use additional sheets for this working.

**1 0** Which row shows the bonding in ammonium chloride? $\left[ H-\underset{H}{\overset{H}{N}}\rightarrow H \right]^{+}$ **[1 mark]**

| | Covalent | Dative covalent | Ionic | |
|---|---|---|---|---|
| A | ✓ | × | × | ○ |
| B | ✓ | ✓ | × | ○ |
| C | ✓ | ✓ | ✓ | ⬬ |
| D | × | × | ✓ | ○ |

**1 1** How many protons are there in 6.0 g of nitrogen gas?

Avogadro constant, $L = 6.022 \times 10^{23}\ mol^{-1}$ **[1 mark]**

molecules = n L

$n\ N_2 = 6/14 = 0.43$

molecules $N_2 = 0.43 \times 6.022 \times 10^{23}$

$= 2.58 \times 10^{23}$

protons N = 7

total protons = $2.58 \times 10^{23} \times 7$

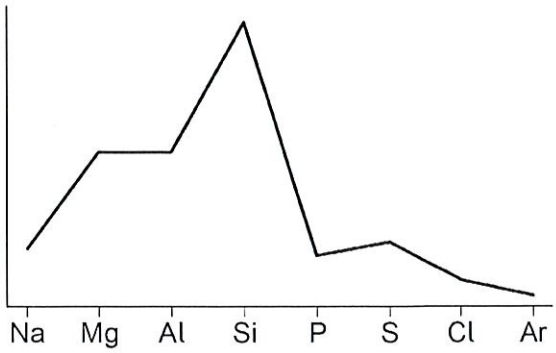
**A** $1.3 \times 10^{23}$ ○

**B** $9.0 \times 10^{23}$ ○

**C** $1.8 \times 10^{24}$ ⬬

**D** $3.6 \times 10^{24}$ ○

**1 2** The diagram shows how a property of Period 3 elements varies across the period.




What is the property?

**[1 mark]**

**A** Atomic radius ⬭

**B** Electronegativity ⬭

**C** First ionisation energy ⬭

**D** Melting point ⬬

**1 3** A 30 $cm^3$ sample of nitrogen was reacted with a 60 $cm^3$ sample of fluorine according to the equation

volumes used: 30 60

mole ratio: 1 3 2

$$\frac{1}{2}N_2(g) + \frac{3}{2}F_2(g) \rightarrow NF_3(g)$$

volumes by ratio: 20 60 40

What is the volume of the gas mixture after the reaction, at constant temperature and pressure?

**[1 mark]**

**A** 20 $cm^3$ ⬭

**B** 30 $cm^3$ ⬭

**C** 40 $cm^3$ ⬭

**D** 50 $cm^3$ ⬬

60 $cm^3$ $F_2$ is limiting mole ratio shows only 20 $cm^3$ $N_2$ will react leaving 10 $cm^3$ unreacted only 40 $cm^3$ $NF_3$ can be produced so total volume after reaction is 10 + 40 = 50

**1 4** Which substance is used to reduce titanium(IV) chloride in the extraction of titanium metal?

**[1 mark]**

**A** Magnesium ●

**B** Manganese ○

**C** Vanadium ○

**D** Zinc ○

**1 5** Which statement about barium sulfate is correct?

**[1 mark]**

**A** It is soluble in water at a temperature of 100 °C. ○

**B** It is used in medicine because it does not dissolve in body fluids. ●

**C** It is a pale yellow solid. ○

**D** It reacts with acidified barium chloride solution. ○

**1 6** Which statement is correct about the reaction between concentrated sulfuric acid and solid sodium bromide?

**[1 mark]**

**A** Bromide ions are reduced. oxidised ○

**B** Hydrogen bromide and sulfur are formed. no sulphur ○

**C** Sulfuric acid acts as an oxidising agent. ●

**D** Bromine and hydrogen sulfide are formed. ○

**1 7** Which compound is used to treat the symptoms of indigestion?

**[1 mark]**

**A** MgO ○

**B** $Mg(OH)_2$ ●

**C** CaO ○

**D** $Ca(OH)_2$ ○

**1 8** Which element has the highest first ionisation energy?

**[1 mark]**

**A** Aluminium ○

**B** Phosphorus ●

**C** Silicon ○

**D** Sulfur ○ paired e⁻ so lower than P

**1 9** A solution of volume 500 $cm^3$ contains 150 g of ammonia.

What is the concentration, in mol $dm^{-3}$, of ammonia in this solution?

**[1 mark]**

$n NH_3 = \frac{150}{17} = 8.824 \text{ mol}$

**A** 0.51 ○

**B** 8.82 ○

$c = \frac{8.824}{500 \times 10^{-3}}$

**C** 16.7 ○

**D** 17.6 ●

Refer to the following information when answering Questions **20**, **21**, **22**, **23** and **24**.

A student devised an experiment to find the concentration of sulfuric acid in a sample of battery acid.

- A measuring cylinder was used to transfer 10 $cm^3$ of battery acid to a volumetric flask.
- Distilled water was added to the volumetric flask until the volume reached 250 $cm^3$
- A 25.0 $cm^3$ sample of diluted acid was transferred from the volumetric flask to a conical flask using a pipette.
- A few drops of methyl orange indicator were added to the acid in the conical flask before titrating the acid with sodium hydroxide.
- The titration was repeated five times but concordant results were **not** obtained. (Note: Methyl orange is red in acid and yellow in alkali.)

**2 0** Which suggestion would improve the chances of obtaining concordant titres?

**[1 mark]**

**A** Invert the volumetric flask several times after adding the distilled water. ⬬

**B** Wash the pipette with distilled water between each titration. ⬭

**C** Add extra drops of indicator to the sample when nearing the end point in each titration. ⬭

**D** Use a more concentrated solution of sodium hydroxide in the burette. ⬭

**2 1** Which suggestion about rinsing the conical flask between each titration would improve the accuracy of the titrations?

**[1 mark]**

**A** Rinsing with acid. ⬭

**B** Rinsing with alkali. ⬭

**C** Rinsing with water. ⬬

**D** No rinsing with any liquid. ⬭

**2 2** Which suggestion would reduce the overall measurement uncertainty in the titration?

**[1 mark]**

**A** Use less concentrated alkali in the burette. ⬭

**B** Use phenolphthalein indicator instead of methyl orange. ⬭ no change

**C** Use smaller samples of the diluted acid in each titration. ⬭ increase uncertainty

**D** Begin each titration with the burette filled to the 0.00 $cm^3$ mark. ⬭ no change

**2 3** Which of these is important in ensuring that the student's experiment is safe?

**[1 mark]**

**A** Do the titration in a fume cupboard. ⬭

**B** Wear gloves when measuring out the battery acid. ⬬

**C** Wash hands before doing the titration. ⬭

**D** Carry the burette horizontally when collecting the apparatus. ⬭

**2 4** Which colour change is observed at the end point in each titration?

**[1 mark]**

**A** Yellow to red ⬭

**B** Red to orange ⬬

**C** Yellow to orange ⬭

**D** Red to yellow ⬭

15

**END OF QUESTIONS**