AQA

A-level
Chemistry (7405/1)

Paper 1: Inorganic and Physical Chemistry

Specimen 2014 Session 2 hours

Materials
For this paper you must have:
- the Data Booklet, provided as an insert
- a ruler
- a calculator.

Instructions
- Answer **all** questions.
- Show **all** your working.

Information
- The maximum mark for this paper is 105.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number ☐☐☐☐☐ Candidate number ☐☐☐☐

Surname

Forename(s)

Candidate signature _____

Answer **all** questions.

0 1 . 1 State the full electron configuration of phosphorus.

[1 mark]

0 1 . 2 Draw the shape of a PF_3 molecule and predict the bond angle.

[2 marks]

Shape

Bond angle

0 1 . 3 Explain how the shape of PF_3 and the bond angle can be deduced using the electron pair repulsion theory.

[4 marks]

0 1 . 4 State the full electron configuration of a cobalt(II) ion.

[1 mark]

0 1 . 5 State the shape of the complex cobalt ion, $[CoCl_4]^{2-}$ and state the bond angle.

[2 marks]

Shape _____

Bond angle _____

0 1 . 6 Suggest **one** reason why electron pair repulsion theory **cannot** be used to predict the shape of the $[CoCl_4]^{2-}$ ion.

[1 mark]

_____

_____

Turn over for the next question

0 2 . 1 Explain why the atomic radii of the elements decrease across Period 3 from sodium to chlorine.

[2 marks]

0 2 . 2 Explain why the melting point of sulfur is greater than that of phosphorus.

[3 marks]

0 2 . 3 Explain, in terms of its bonding, why sodium oxide forms an alkaline solution when it reacts with water.

[2 marks]

0 2 . 4 Write an equation for the reaction of phosphorus(V) oxide with water.

[1 mark]

0 2 . 5 State the pH of the resulting solution formed in Question **2.4**.

[1 mark]

0 2 . 6 Draw a diagram to show the shape of one of the phosphorus-containing species that is a product of the reaction in Question **2.4**.

[1 mark]

Turn over for the next question

3 **Table 1** contains some standard electrode potential data.

Table 1

Electrode half-equation	$E^{\ominus}$ / V
$F_2 + 2e^- \longrightarrow 2F^-$	+2.87
$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36
$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23
$Br_2 + 2e^- \longrightarrow 2Br^-$	+1.07
$I_2 + 2e^- \longrightarrow 2I^-$	+0.54
$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$	+0.40
$SO_4^{2-} + 4H^+ + 2e^- \longrightarrow SO_2 + 2H_2O$	+0.17
$2H^+ + 2e^- \longrightarrow H_2$	0.00
$4H_2O + 4e^- \longrightarrow 4OH^- + 2H_2$	–0.83

0 3 . 1 Use data from **Table 1** to deduce the halide ion that is the weakest reducing agent.

[1 mark]

0 3 . 2 Use data from **Table 1** to explain why sulfate ions should **not** be capable of oxidising bromide ions.

[1 mark]

0 3 . 3 Write the conventional representation for the cell used to measure the standard electrode potential for reduction of bromine to bromide ions.

[1 mark]

0 3 . 4 Use data from **Table 1** to calculate a value for the EMF of a hydrogen–oxygen fuel cell operating under alkaline conditions.

[1 mark]

EMF = _____ V

0 3 . 5 Reduction takes place at the positive electrode of the hydrogen–oxygen fuel cell.

State and explain the change in oxidation state that occurs at this electrode.

[2 marks]

_____

_____

_____

_____

_____

0 3 . 6 There are two ways to use hydrogen as a fuel for cars. One way is in a fuel cell to power an electric motor, the other is as a fuel in an internal combustion engine.

Give the major advantage of using the fuel cell.

[1 mark]

_____

_____

Turn over for the next question

4 In the Haber process, nitrogen reacts with hydrogen in the presence of an iron catalyst. The process operates at a temperature of 500 °C and at a high pressure.

$$\tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$$

Some mean bond enthalpies are shown in **Table 2**.

Table 2

Bond	N≡N	H–H	N–H
Mean bond enthalpy / kJ mol^{-1}	944	436	388

0 4 . 1 Use data from **Table 2** to calculate a value for the enthalpy of formation of ammonia.
[3 marks]

Enthalpy of formation = _____ kJ mol^{-1}

0 4 . 2 A data book value for the enthalpy of formation of ammonia is –46.2 kJ mol^{-1}.

Suggest **one** reason why this value is different from your answer to Question **4.1**.
[1 mark]

_____

_____

_____

0 4 . 3 State Le Chatelier's principle.

[1 mark]

0 4 . 4 Use Le Chatelier's principle to justify why the Haber process is carried out at a high pressure rather than at atmospheric pressure.

[3 marks]

0 4 . 5 State why the iron catalyst in the Haber process may **not** be so effective if the nitrogen and hydrogen are impure.

[1 mark]

Question 4 continues on the next page

0 4 . 6 Use the following equation to write an expression for the equilibrium constant, K_c, for the formation of ammonia.

[1 mark]

$$\tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$$

0 4 . 7 In a laboratory experiment to simulate the Haber process, 1.0 mol of nitrogen and 3.0 mol of hydrogen were sealed into a container with a volume of 0.20 dm^3.
The yield of ammonia at equilibrium was 0.36 mol.

Calculate a value for K_c

[4 marks]

K_c = _____

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

5 **Table 3** contains some entropy data.

Table 3

Substance	$N_2(g)$	$H_2(g)$	$NH_3(g)$
Entropy ($S^{\ominus}$) / J K^{-1} mol^{-1}	192	131	193

$$\tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g) \rightleftharpoons NH_3(g) \quad \Delta H = -46.2 \text{ kJ mol}^{-1}$$

0 5 . 1 Use information from **Table 3** to calculate the entropy change for the formation of ammonia from its elements.
Give units with your answer.

[2 marks]

Entropy change ΔS = _____ Units = _____

0 5 . 2 Use your answer to Question **5.1** and the enthalpy change given with the equation to calculate a value for the free-energy change of formation of ammonia at 500 °C.
Give units with your answer.

[2 marks]

Free-energy change of formation ΔG = _____ Units = _____

0 5 . 3 Calculate a value for the temperature when the formation of ammonia becomes feasible.

[2 marks]

Temperature = _____ K

0 5 . 4 Gaseous ammonia from the Haber process is liquefied before storage.

With the aid of a diagram showing the bonding between two molecules, explain why ammonia is easy to liquefy.

[4 marks]

_____

_____

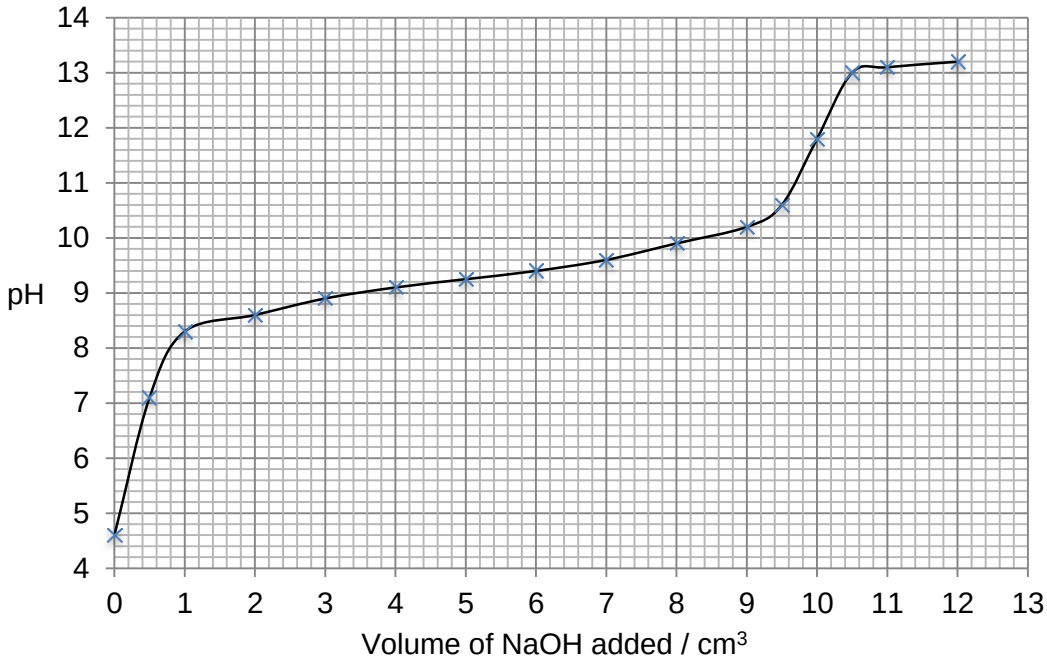
_____

6 Ammonium chloride, when dissolved in water, can act as a weak acid as shown by the following equation.

$$NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$$

Figure 1 shows a graph of data obtained by a student when a solution of sodium hydroxide was added to a solution of ammonium chloride. The pH of the reaction mixture was measured initially and after each addition of the sodium hydroxide solution.

Figure 1



0 6 . 1 Suggest a suitable piece of apparatus that could be used to measure out the sodium hydroxide solution.
Explain why this apparatus is more suitable than a pipette for this purpose.

[2 marks]

Apparatus _____

Explanation _____

_____

_____

0 6 . 2 Use information from the curve in **Figure 1** to explain why the end point of this reaction would be difficult to judge accurately using an indicator.

[2 marks]

0 6 . 3 The pH at the end point of this reaction is 11.8

Use this pH value and the ionic product of water, $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}, to calculate the concentration of hydroxide ions at the end point of the reaction.

[2 marks]

Concentration = _____ mol dm^{-3}

0 6 . 4 Write an expression for the acid dissociation constant (K_a) for aqueous ammonium ions.

[1 mark]

0 6 . 5 The initial concentration of the ammonium chloride solution was 1.00 mol dm^{-3}.

Use the pH of this solution, before any sodium hydroxide had been added, to calculate a value for K_a

[3 marks]

K_a = _____ mol dm^{-3}

7 **Table 4** shows some successive ionisation energy data for atoms of three different elements **X**, **Y** and **Z**.

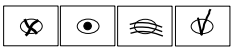
Elements **X**, **Y** and **Z** are Ca, Sc and V but not in that order.

Table 4

	First	Second	Third	Fourth	Fifth	Sixth
X	648	1370	2870	4600	6280	12 400
Y	590	1150	4940	6480	8120	10 496
Z	632	1240	2390	7110	8870	10 720

For questions 7.1 and 7.2, 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. 

0 7 . 1 Which element is calcium?

[1 mark]

X ⬭

Y ⬭

Z ⬭

0 7 . 2 Which element is vanadium?

[1 mark]

X ⬭

Y ⬭

Z ⬭

0 7 . 3 Explain how you identified vanadium from the ionisation energy data.

[1 mark]

0 7 . 4 Explain why solutions containing calcium(II) ions are colourless whereas solutions that contain vanadium(II) ions are coloured.

[4 marks]

Why calcium(II) ions are colourless

Why vanadium(II) ions are coloured

0 7 . 5 An acidified solution of NH_4VO_3 reacts with zinc.

State the role of zinc in this reaction.
Explain how observations from this reaction show that vanadium exists in at least **two** different oxidation states.

[3 marks]

8 Aqueous copper(II) ions, $[Cu(H_2O)_6]^{2+}$, react with an excess of ammonia to form the ion $[Cu(NH_3)_4(H_2O)_2]^{2+}$ in which the water molecules are opposite each other.

0 8 . 1 Describe what you would observe when dilute aqueous ammonia is added dropwise, to excess, to an aqueous solution containing copper(II) ions.

[2 marks]

0 8 . 2 Draw a diagram to illustrate the shape of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ion.

[1 mark]

0 8 . 3 State the name of the shape of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ion.

[1 mark]

0 8 . 4 Give the value of the N–Cu–N bond angle.

[1 mark]

0 8 . 5 When the complex ion $[Cu(NH_3)_4(H_2O)_2]^{2+}$ reacts with 1,2-diaminoethane, the ammonia molecules but not the water molecules are replaced.

Write an equation for this reaction.

[1 mark]

0 8 . 6 Suggest why the enthalpy change for the reaction in Question **8.5** is approximately zero.

[2 marks]

0 8 . 7 Explain why the reaction in Question **8.5** occurs despite having an enthalpy change that is approximately zero.

[2 marks]

9 A 5.00 g sample of potassium chloride was added to 50.0 g of water initially at 20.0 °C. The mixture was stirred and as the potassium chloride dissolved, the temperature of the solution decreased.

0 9 . 1 Describe the steps you would take to determine an accurate minimum temperature that is **not** influenced by heat from the surroundings.

[4 marks]

0 9 . 2 The temperature of the water decreased to 14.6 °C.

Calculate a value, in kJ mol^{-1}, for the enthalpy of solution of potassium chloride.

You should assume that only the 50.0 g of water changes in temperature and that the specific heat capacity of water is 4.18 J K^{-1} mol^{-1}.

[4 marks]

Enthalpy of solution = _____ kJ mol^{-1}

0 9 . 3 The enthalpy of solution of calcium chloride is –82.9 kJ mol^{-1}.
The enthalpies of hydration for calcium ions and chloride ions are –1650 and –364 kJ mol^{-1}, respectively.

Use these values to calculate a value for the lattice enthalpy of dissociation of calcium chloride.

[3 marks]

Lattice enthalpy of dissociation = _____ kJ mol^{-1}

0 9 . 4 Explain why your answer to Question **9.3** is different from the lattice enthalpy of dissociation for magnesium chloride.

[2 marks]

_____

_____

_____

_____

_____

10 **Table 5** shows observations of changes from some test-tube reactions of aqueous solutions of compounds **Q**, **R** and **S** with five different aqueous reagents. The initial colours of the solutions are not given.

Table 5

	$BaCl_2$ + HCl	**$AgNO_3$ + HNO_3**	**NaOH**	**Na_2CO_3**	**HCl (conc)**
Q	no change observed	pale cream precipitate	white precipitate	white precipitate	no change observed
R	no change observed	white precipitate	white precipitate, dissolves in excess of NaOH	white precipitate, bubbles of a gas	no change observed
S	white precipitate	no change observed	brown precipitate	brown precipitate, bubbles of a gas	yellow solution

1 0 . 1 Identify each of compounds **Q**, **R** and **S**.
You are **not** required to explain your answers.

[6 marks]

Identity of **Q** _____

_____

Identity of **R** _____

_____

Identity of **S** _____

_____

1 0 . 2 Write simple ionic equations, with state symbols, for each of the positive observations with **S**.

[4 marks]

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED