

**Chemistry**  
**Standard level**  
**Paper 2**

Wednesday 8 November 2017 (afternoon)

Candidate session number

1 hour 15 minutes

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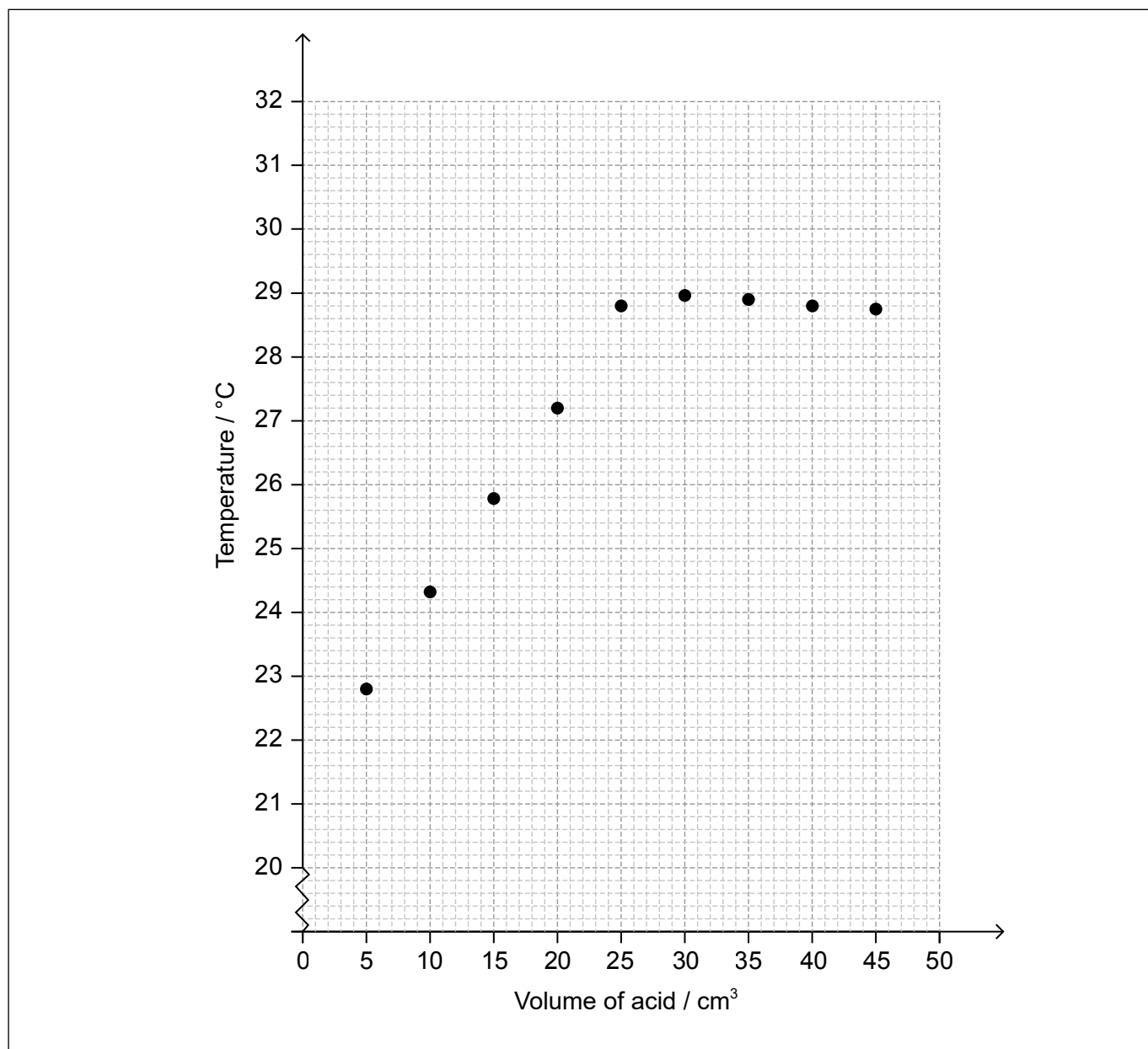
**Instructions to candidates**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.



Answer **all** questions. Write your answers in the boxes provided.

1. A student titrated an ethanoic acid solution,  $\text{CH}_3\text{COOH}(\text{aq})$ , against  $50.0 \text{ cm}^3$  of  $0.995 \text{ mol dm}^{-3}$  sodium hydroxide,  $\text{NaOH}(\text{aq})$ , to determine its concentration. The temperature of the reaction mixture was measured after each acid addition and plotted against the volume of acid.



- (a) Using the graph, estimate the initial temperature of the solution.

[1]

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**(Question 1 continued)**

- (b) Determine the maximum temperature reached in the experiment by analysing the graph. [1]

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- (c) Calculate the concentration of ethanoic acid,  $\text{CH}_3\text{COOH}$ , in  $\text{mol dm}^{-3}$ . [2]

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- (d) (i) Determine the heat change,  $q$ , in kJ, for the neutralization reaction between ethanoic acid and sodium hydroxide. Assume the specific heat capacities of the solutions and their densities are those of water. [2]

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- (ii) Calculate the enthalpy change,  $\Delta H$ , in  $\text{kJ mol}^{-1}$ , for the reaction between ethanoic acid and sodium hydroxide. [2]

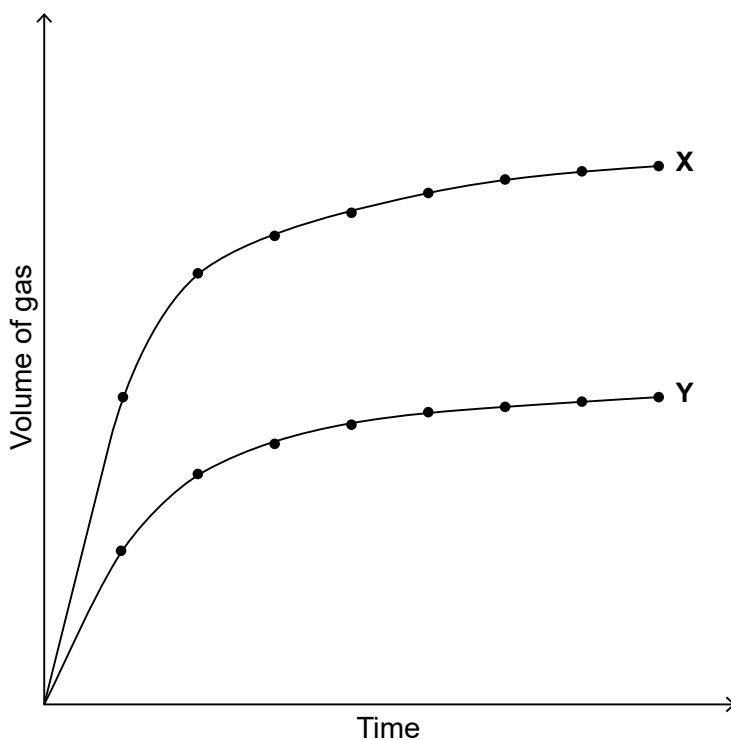
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(Question 1 continued)

- (e) Curves **X** and **Y** were obtained when a metal carbonate reacted with the same volume of ethanoic acid under two different conditions.



- (i) Explain the shape of curve **X** in terms of the collision theory.

[2]

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- (ii) Suggest **one** possible reason for the differences between curves **X** and **Y**.

[1]

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2. Trends in physical and chemical properties are useful to chemists.

(a) Explain the general increasing trend in the first ionization energies of the period 3 elements, Na to Ar. [2]

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(b) Explain why the melting points of the group 1 metals (Li → Cs) decrease down the group. [2]

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(c) State an equation for the reaction of phosphorus(V) oxide, P<sub>4</sub>O<sub>10</sub> (s), with water. [1]

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(d) Describe the emission spectrum of hydrogen. [2]

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**(Question 2 continued)**

(e) The Activity series lists the metal in order of reactivity.

Mn ↑ Most reactive  
Ni |  
Ag | Least reactive

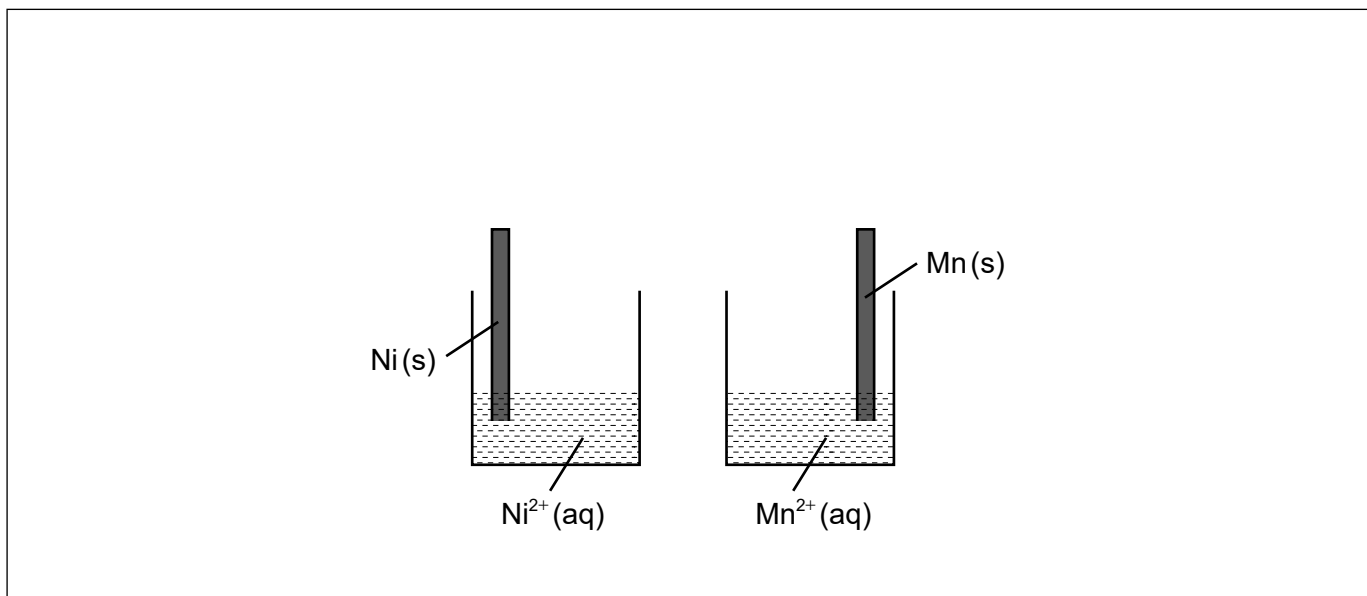
(i) Identify the strongest reducing agent in the given list. [1]

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(ii) A voltaic cell is made up of a  $Mn^{2+}/Mn$  half-cell and a  $Ni^{2+}/Ni$  half-cell. Deduce the equation for the cell reaction. [1]

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(iii) The voltaic cell stated in part (ii) is partially shown below. Draw and label the connections needed to show the direction of electron movement and ion flow between the two half-cells. [2]



3. Lewis (electron dot) structures are useful models.

(a) Draw the Lewis (electron dot) structures of  $\text{PF}_3$  and  $\text{PF}_4^+$  and use the VSEPR theory to deduce the molecular geometry of each species. [4]

	$\text{PF}_3$	$\text{PF}_4^+$
<b>Lewis (electron dot) structure</b>		
<b>Molecular geometry</b>	.....	.....

(b) Predict with a reason, whether the molecule  $\text{PF}_3$  is polar or non-polar. [1]

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4. Menthol is an organic compound containing carbon, hydrogen and oxygen.

(a) Complete combustion of 0.1595 g of menthol produces 0.4490 g of carbon dioxide and 0.1840 g of water. Determine the empirical formula of the compound showing your working. [3]

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**(Question 4 continued)**

- (b) 0.150 g sample of menthol, when vaporized, had a volume of 0.0337 dm<sup>3</sup> at 150 °C and 100.2 kPa. Calculate its molar mass showing your working. [2]

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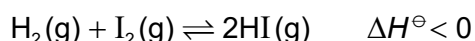
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**5. Many reactions are in a state of equilibrium.**

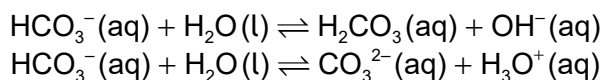
- (a) The following reaction was allowed to reach equilibrium at 761 K.



Outline the effect, if any, of each of the following changes on the position of equilibrium, giving a reason in each case. [2]

	Effect	Reason
Increasing the volume, at constant temperature	..... .....	..... .....
Increasing the temperature, at constant pressure	..... .....	..... .....

- (b) The equations for two acid-base reactions are given below.



- (i) Identify two different amphiprotic species in the above reactions. [1]

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**(Question 5 continued)**

(ii) State what is meant by the term conjugate base. [1]

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(iii) State the conjugate base of the hydroxide ion, OH<sup>-</sup>. [1]

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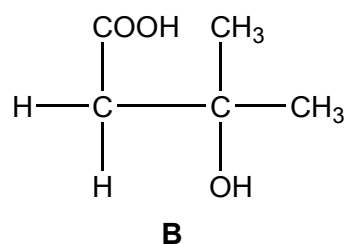
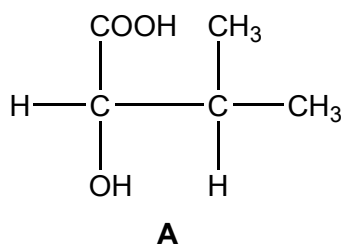
(c) A student working in the laboratory classified HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>PO<sub>4</sub> and HClO<sub>4</sub> as acids based on their pH. He hypothesized that "all acids contain oxygen and hydrogen". Evaluate his hypothesis. [2]

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6. The reactivity of organic compounds depends on the nature and positions of their functional groups.

(a) The structural formulas of two organic compounds are shown below.



(i) Deduce the type of chemical reaction and the reagents used to distinguish between these compounds. [1]

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(ii) State the observation expected for each reaction giving your reasons. [2]

Compound **A**:  
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Compound **B**:  
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**(Question 6 continued)**

- (iii) Deduce the number of signals and the ratio of areas under the signals in the <sup>1</sup>H NMR spectra of the two compounds. [4]

Compound	Number of signals	Ratio of areas
<b>A</b>	.....	.....
<b>B</b>	.....	.....

- (b) Explain, with the help of equations, the mechanism of the free-radical substitution reaction of ethane with bromine in presence of sunlight. [4]

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