

# Chemistry 2740 Spring 2020 Test 2

**Time:** 50 minutes

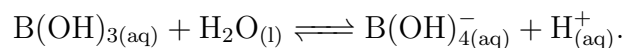
**Marks:** 34

**Aids allowed:** calculator,  $8.5 \times 11$ -inch formula sheet

**Useful data** is found on page 2.

**Instructions:** You can answer the questions in any order, but make sure that you clearly label each of your answers with the question number in your exam booklet(s).

1. You may recall that boric acid  $\text{B(OH)}_3$  is a Lewis acid. Like many Lewis acids, boric acid reacts with water: **17 marks**



The equilibrium constant for this reaction has been measured as a function of temperature. The results were as follows:<sup>1</sup>

$T/^\circ\text{C}$	15	25	35	45
$K/10^{-10}$	4.70	5.80	6.89	7.89

Note:  $K/10^{-10}$  means that the entry in the table is the result of dividing  $K$  by  $10^{-10}$ . For example, the equilibrium constant at  $15^\circ\text{C}$  is  $4.70 \times 10^{-10}$ .

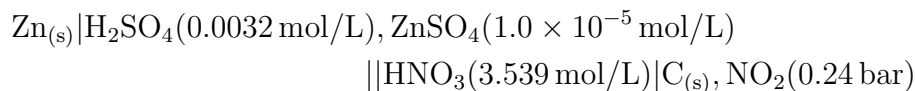
- (a) What is the standard free energy of reaction? [2 marks]  
(b) Determine the standard enthalpy of reaction. [9 marks]  
(c) What is the pH of a  $0.013 \text{ mol L}^{-1}$  solution of boric acid in water at  $45^\circ\text{C}$  assuming that boric acid and water both behave ideally? Give your answer to two decimal places. [6 marks]

Hint: The calculation is easier than it may first look. Start by thinking about what you need to calculate to get a pH.

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<sup>1</sup>Selected data from B. B. Owen, *J. Am. Chem. Soc.* **56**, 1695 (1934)

2. Robert Bunsen (of Bunsen burner fame) was a versatile chemist who, **17 marks**  
among other things, invented the Bunsen voltaic cell, which has the  
following cell diagram:



- (a) At the anode, zinc metal is oxidized to zinc ions. At the cathode, nitrate ions react to form  $\text{NO}_2$ . (The latter is why this cell was not widely used,  $\text{NO}_2$  being unpleasantly toxic.) Balance the reaction. [5 marks]
- (b) Calculate the EMF of this cell at  $25^\circ\text{C}$ . Assuming that water behaves ideally. At the concentration of nitric acid in this cell,  $\gamma_{\text{H}^+} = \gamma_{\text{NO}_3^-} = 0.968$ . Use Debye-Hückel theory to calculate the activity coefficients of any remaining ions in your balanced reaction. The permittivity of water at this temperature is  $6.939 \times 10^{-10} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$ . [12 marks]

## Useful data

### Constants and conversion factors

$$0 \text{ K} = -273.15^\circ\text{C}$$

$$F = 96\,485.342 \text{ C mol}^{-1}$$

$$R = 8.314\,472 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$\left. \begin{aligned} \ln \gamma_i &= -Az_i^2(\varepsilon T)^{-3/2} \sqrt{I_c} \\ \ln \gamma_{\pm} &= -A|z_+z_-|(\varepsilon T)^{-3/2} \sqrt{I_c} \end{aligned} \right\} \text{ with } A = 1.107 \times 10^{-10}$$

#### Standard thermodynamic data at 298.15 K

Species	$\Delta_f H^\circ$ kJ mol <sup>-1</sup>	$\Delta_f G^\circ$ kJ mol <sup>-1</sup>
$\text{H}_2\text{O}_{(\text{l})}$	-285.830	-237.140
$\text{NO}_{2(\text{g})}$	33.2	51.32
$\text{NO}_{3(\text{aq})}^-$	-205.0	-108.74
$\text{Zn}_{(\text{aq})}^{2+}$	-153.39	-111.62