Past-paper walk-through

Buffer Capacity ▪ 8.10

eXercise

Questions in this set

- 2017 Q3

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 3

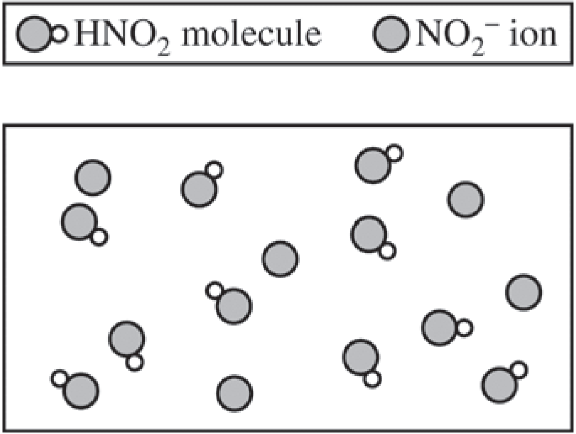
2017 ▪ Q3

$$N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$$

At high temperatures, $N_2(g)$ and $O_2(g)$ can react to produce nitrogen monoxide, $NO(g)$, as represented by the equation above.

(a) Write the expression for the equilibrium constant, K_p, for the forward reaction.

Question 3



Question 3

2017 ▪ Q3

$$N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$$

At high temperatures, $N_2(g)$ and $O_2(g)$ can react to produce nitrogen monoxide, $NO(g)$, as represented by the equation above.

(b) A student injects $N_2(g)$ and $O_2(g)$ into a previously evacuated, rigid vessel and raises the temperature of the vessel to $2000°C$. At this temperature the initial partial pressures of $N_2(g)$ and $O_2(g)$ are 6.01 atm and 1.61 atm, respectively. The system is allowed to reach equilibrium. The partial pressure of $NO(g)$ at equilibrium is 0.122 atm. Calculate the value of K_p.

Question 3

2017 ▪ Q3

$$N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$$

At high temperatures, $N_2(g)$ and $O_2(g)$ can react to produce nitrogen monoxide, $NO(g)$, as represented by the equation above.

(c)(i) Nitrogen monoxide, $NO(g)$, can undergo further reactions to produce acids such as HNO_2, a weak acid with a K_a of 4.0×10^{-4} and a pK_a of 3.40.

A student is asked to make a buffer solution with a pH of 3.40 by using 0.100 *M* $HNO_2(aq)$ and 0.100 *M* $NaOH(aq)$.

Explain why the addition of 0.100 *M* $NaOH(aq)$ to 0.100 *M* $HNO_2(aq)$ can result in the formation of a buffer solution. Include the net ionic equation for the reaction that occurs when the student adds the $NaOH(aq)$ to the $HNO_2(aq)$.

Question 3

(c)(ii) Determine the volume, in mL, of 0.100 M NaOH(aq) the student should add to 100. mL of 0.100 M $HNO_2(aq)$ to make a buffer solution with a pH of 3.40. Justify your answer.

Question 3

2017 ▪ Q3

$$N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$$

At high temperatures, $N_2(g)$ and $O_2(g)$ can react to produce nitrogen monoxide, $NO(g)$, as represented by the equation above.

(d) A second student makes a buffer by dissolving 0.100 mol of $NaNO_2(s)$ in 100. mL of 1.00 M $HNO_2(aq)$. Which is more resistant to changes in pH when a strong acid or a strong base is added, the buffer made by the second student or the buffer made by the first student in part (c) ? Justify your answer.

Question 3

2017 ▪ Q3

$$N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$$

At high temperatures, $N_2(g)$ and $O_2(g)$ can react to produce nitrogen monoxide, $NO(g)$, as represented by the equation above.

(e) A new buffer is made using $HNO_2(aq)$ as one of the ingredients. A particulate representation of a small representative portion of the buffer solution is shown below. (Cations and water molecules are not shown.) Is the pH of the buffer represented in the diagram greater than, less than, or equal to 3.40 ? Justify your answer. [Diagram: a rectangular box containing a scattered arrangement of small circles representing particles, with a legend above showing two symbol types: "HNO_2 molecule" (drawn as two overlapping circles) and "NO_2^- ion" (drawn as a single circle).

Question 3

The box shows a mixture of both symbol types scattered throughout, with noticeably more HNO_2-molecule symbols (two-circle pairs) than NO_2^--ion symbols (single circles) — approximately 8 paired (HNO_2) symbols and 4 single (NO_2^-) symbols visible.]

Solution 3

(a)

Mark scheme

- Kp = (P_NO)^2 / [(P_N2)(P_O2)]. 1 point earned for a correct Kp expression.

Solution 3

(b)

Mark scheme

- ICE table (atm): Initial N2 = 6.01, O2 = 1.61, NO = 0; Change -x, -x, +2x; Equilibrium 6.01-x, 1.61-x, 0.122. Since 2x = 0.122 atm, x = 0.0610 atm, so at equilibrium P_N2 = 5.95 atm and P_O2 = 1.55 atm. Kp = (0.122)^2 / [(5.95)(1.55)] = 0.00161. 1 point earned for the correct equilibrium partial pressures of reactants and products (may be implicit); 1 point earned for the correct calculation of Kp.

Solution 3

(c)(i)

Mark scheme

- NaOH will neutralize some of the HNO2 to produce NO2-. The resulting solution contains a mixture of a weak acid (HNO2) and its conjugate base (NO2-), which is a buffer solution. Net ionic equation: HNO2 + OH- -> NO2- + H2O. 1 point earned for the recognition that the solution produced is a mixture of a weak acid and its conjugate base; 1 point earned for the correct net ionic equation.

Solution 3

(c)(ii)

Mark scheme

- The student should add 50.0 mL of 0.100 M NaOH(aq). Using the Henderson-Hasselbalch equation, pH = pKa + log([NO2-]/[HNO2]), so pH = pKa exactly when [HNO2] = [NO2-]; since the target pH (3.40) equals pKa, a 1-to-1 ratio of HNO2 to NO2- is required, i.e. half of the 10.0 mmol HNO2 (100. mL x 0.100 M) must be converted, which needs 5.00 mmol NaOH = 50.0 mL of 0.100 M NaOH. 1 point earned for the correct volume; 1 point earned for clearly indicating a 1-to-1 ratio of HNO2 and NO2- is required (calculation not required for this point).

Solution 3

(d)

Mark scheme

- The buffer made by the second student (0.100 mol NaNO2 dissolved in 100. mL of 1.00 M HNO2) is more resistant to changes in pH, because it contains a higher concentration of HNO2 and NO2- available to react with added H+ or OH- ions (greater buffer capacity) than the buffer from part (c). 1 point earned for the correct choice and a valid justification.

Solution 3

(e)

Mark scheme

- The pH of the solution is less than 3.40. If [HNO2] $=$ [NO2-], pH $=$ pKa and the pH of the solution would be 3.40; since the particulate diagram shows more HNO2 molecules than NO2- ions (i.e. [HNO2] $>$ [NO2-]), the solution has a pH less than 3.40 (equivalently, with the diagram's ratio of about 5 NO2- to 10 HNO2, pH $= 3.40 + \log(5/10) = 3.10$). 1 point earned for the correct choice; 1 point earned for a valid justification.