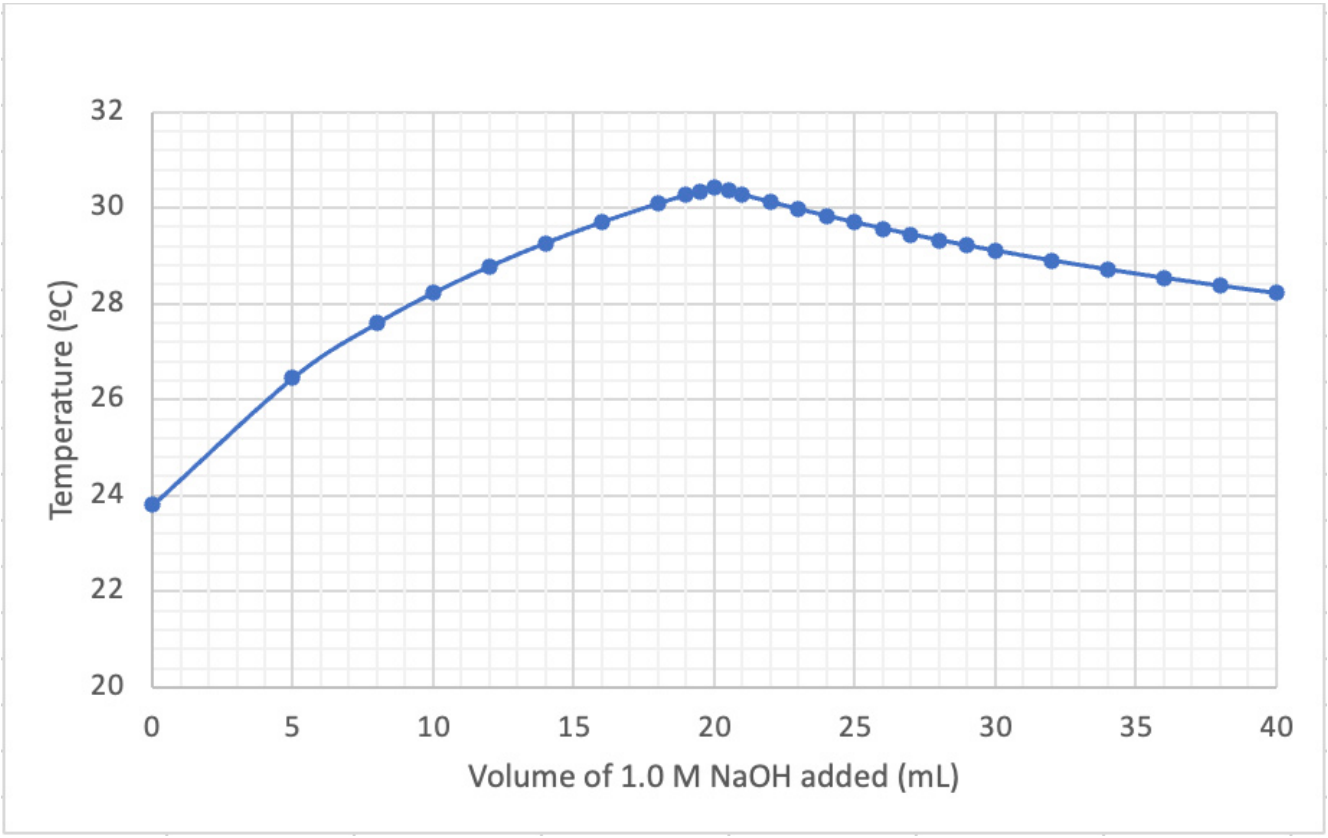
# THERMOMETRIC TITRATIONS

*UQ-STAQ PD Day & Griffith University Cutting Edge STEM PD - 27/28 November 2023*
- from Dr Richard Walding

The questions below all refer to the following information:

A titration was performed using a 20 mL sample of 1.00 M HCl transferred by pipette into a flask. To that a solution of exactly 1.00 M NaOH was gradually added from a burette. The temperature of the solution in the flask was measured with a thermometer, and values recorded as shown in the graph.




**QUESTION 1**
Which one of the following best describes the enthalpy of the reaction before the end point and after the end point.

| | **Before the end point** | **After the end point** |
|---|---|---|
| (A) | exothermic | exothermic |
| (B) | exothermic | endothermic |
| (C) | endothermic | no reaction |
| (D) | exothermic | no reaction |

Answer (D). *Reasoning:* as the reaction proceeds heat is generated as shown by a temperature rise. This means the reaction is exothermic. After the end point of an acid-base reaction there is no further reaction. However, the temperature does fall but this is only because cool sodium hydroxide solution is being added and not because there is an endothermic reaction occurring. There is no further reaction after the end point.

**QUESTION 2**
Calculate the pH of the solution in the flask after 15 mL of NaOH has been added.
(A) 0.48
(B) 0.60
(C) 0.85
(D) 5.3

*Reasoning:*

| | |
|---|---|
| (A) | Incorrect. Used 15 mL as total volume (see below). |
| (B) | Incorrect. Used 20 mL as total volume (see below) |
| (C)* | Correct. The concentration of HCl must be 1.00 M as the titre was 20.00 mL of 1.00 M NaOH for a 20.00 mL aliquot of the acid. $$n(HCl)xs = \frac{20 \times 1.0}{1000} - \frac{15 \times 1.0}{1000} = 0.005\ mol$$ $$C(HCl) = \frac{n(HCl)}{V(total)} = \frac{0.005}{0.035} = 0.143M$$ $$pH = -log_{10}[H^+] = -log_{10}[0.143] = 0.85$$ |
| (D) | Incorrect. Used amount of NaOH added relative to end point titre as fraction of end point pH 7. $$pH = \frac{15}{20} \times 7 = 5.3$$ |

**QUESTION 3 (UNIT 1 CONTENT. NOT APPROPRIATE FOR THE UNIT 3 IA2 OR THE EA)**
Determine the amount of heat released by the neutralisation reaction from the start to the end point.
(A) 28 J
(B) 570 J
(C) 1100 J
(D) 5100 J

*Reasoning*

| | | |
|---|---|---|
| (A) | Incorrect. | $Q = mc\Delta T = 4.18 \times (30.6 - 23.8) = 28\ J$ |
| (B) | Incorrect. | $Q = mc\Delta T = 20 \times 4.18 \times (30.6 - 23.8) = 570\ J$ |
| (C)* | Correct. | $Q = mc\Delta T = 40 \times 4.18 \times (30.6 - 23.8) = 1100\ J$ |
| (D) | Incorrect. | $Q = mc\Delta T = 40 \times 4.18 \times (30.6) = 5100\ J$ |

**QUESTION 4 (UNIT 1 CONTENT. NOT APPROPRIATE FOR THE UNIT 3 IA2 OR THE EA)**
The enthalpy change after 15 mL of NaOH has been added is *Q* joules. Which one of the following best gives the heat of neutralisation for the reaction in J mol$^{-1}$?

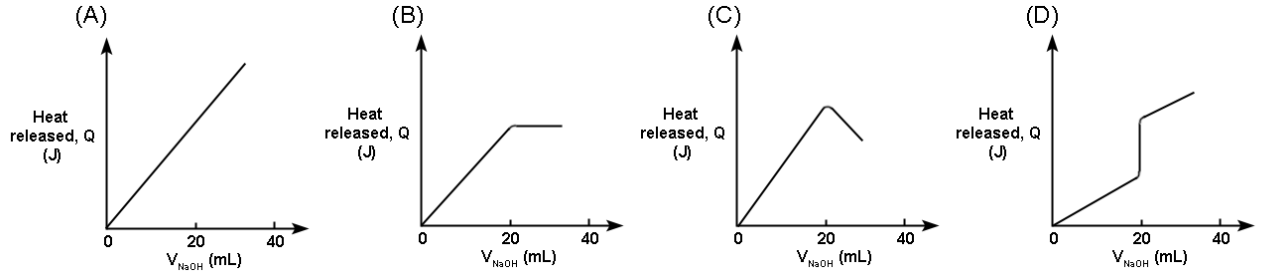
(A) 0.015 *Q*
(B) 0.035 *Q*
(C) 29 *Q*
(D) 67 *Q*

*Reasoning*

| | |
|---|---|
| (A) | Incorrect. $n(reacted) = CV = \frac{1 \times 15}{1000} = 0.015\ mol.\ \ \Delta H = 0.015\ Q$ |
| (B) | Incorrect. $n(reacted) = CV = \frac{1 \times 35}{1000} = 0.035\ mol.\ \ \Delta H = 0.035\ Q$ |
| (C) | Incorrect. $n(reacted) = CV = \frac{1 \times 35}{1000} = 0.035\ mol.\ \ \Delta H = \frac{Q}{0.015} = 29\ Q$ |
| (D) | Correct. $n(reacted) = CV = \frac{1 \times 15}{1000} = 0.015\ mol.\ \ \Delta H = \frac{Q}{0.015} = 67\ Q$ |

**QUESTION 5**

Which one of the following best shows the relationship between the amount of heat released by the reaction and the volume of NaOH solution added to the flask?

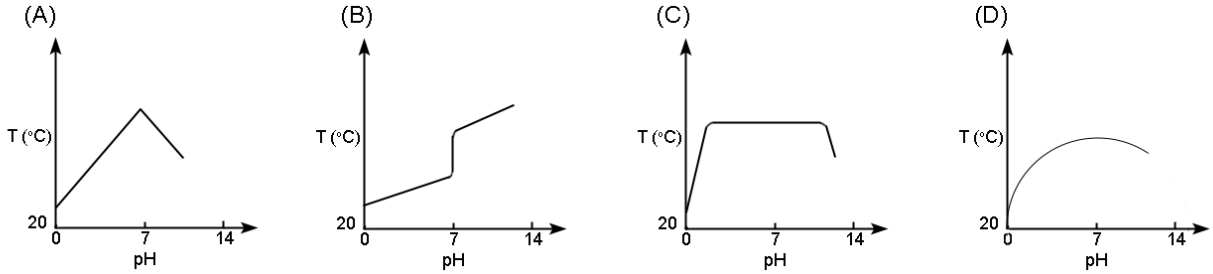



Answer (B).

*Reasoning.* As NaOH is added a reaction occurs with the HCl in the flask so heat is released in proportion to the amount of NaOH added (and thus reacted). At the end point of 20 mL, no further reaction occurs so no more heat is released.

**QUESTION 6**

Which one of the following best shows the relationship between temperature of the solution in the flask and its pH?

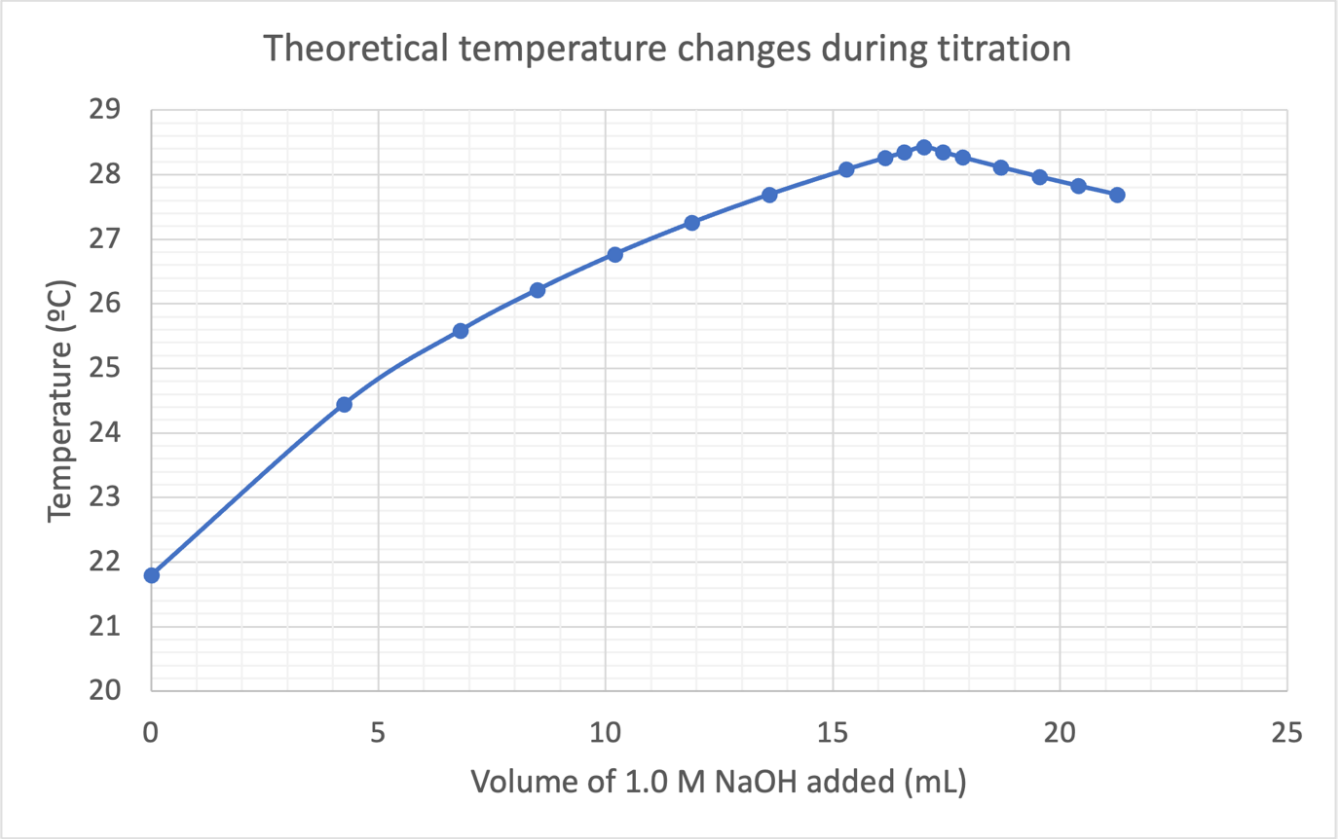



Answer (C).

*Reasoning.* As the NaOH is added the temperature rises until the end point at a pH of 7 when no more reaction occurs so the temperature stops rising and begins to fall. However, the change in pH near the end point is very sudden and goes quickly from pH 2 to pH 12 over just a few drops (may be 0.5 mL) so there is little change in temperature for this big change in pH. After the end point (about pH12) the temperature starts to drop.

**Further questions overleaf**

**QUESTION 7**
Another titration was performed using a 20 mL sample of HCl in a flask against 1.00 M NaOH in the burette. The following graph shows the results.




Calculate the initial concentration of the HCl solution in the flask.
(A) 0.70 M
(B) 0.85 M
(C) 1.18 M
(D) 1.42 M

Reasoning:

| | |
|---|---|
| (A) | Incorrect. Used $T_f$ (28.4) as $V_A$ and had $V_B$ as 20.0 mL. |
| (B)* | Correct. The end point is at 17.0 mL of 1.00 M NaOH. $$C_A V_A = C_B V_B$$ $$C_A = \frac{C_B V_B}{V_A} = \frac{1.00 \times 17.0}{20.0} = 0.85\ M$$ |
| (C) | Incorrect. Had volumes upside down: $$C_A = \frac{C_B V_B}{V_A} = \frac{1.00 \times 20.0}{17.0} = 1.18\ M$$ |
| (D) | Incorrect. Used final temperature value $T_f$ (28.4) as $V_B$ titre. |

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