CH34 [0.3] - Calorimetry - Workshop

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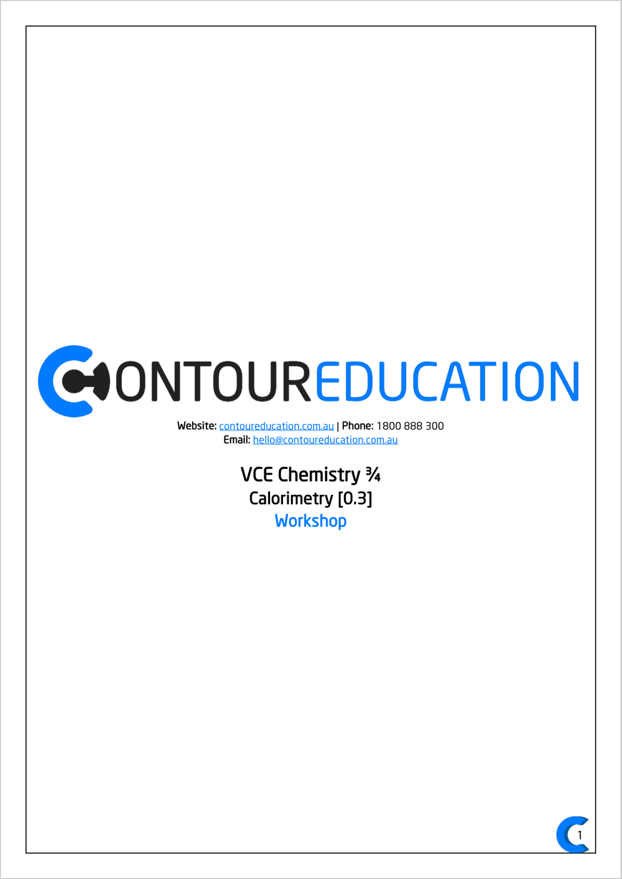
CH34 [0.3] -
Calorimetr...



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VCE Chemistry ¾
Calorimetry [0.3]
Workshop

Section A: Recap

Learning Objective: [1.4.1] - Calculate Calibration Factor via Electrical and Chemical Calibration ($CF = E/\Delta T$)

- Calorimeters are used to minimise heat loss.
- Heat is transferred directly to water.

kJ/mol kJ/g

Electrical Calibration	Chemical Calibration
$E = VIt$	$E = \Delta H \times n$ or $\Delta H \times m$

Learning Objective: [1.4.2] - Apply Calibration Factor to Find Energy Released ($E = CF \times \Delta T$)

- Calorimetry Calculation Steps:

1. Find energy (chemical/electrical) ($E = VIt$ or $E = \Delta H \times n$).
2. Find CF ($CF = \frac{E}{\Delta T}$).
3. Use CF ($E = CF \times \Delta T$).
4. Find ΔH ($\Delta H = \frac{E}{n}$).

impure

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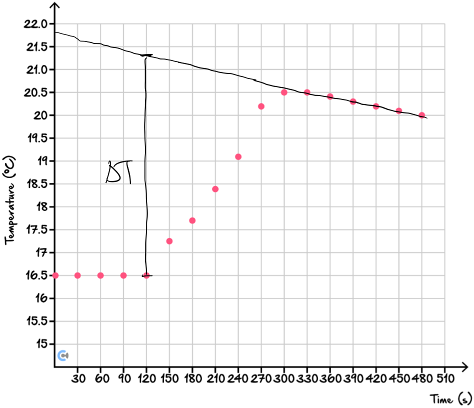
Learning Objective: [1.4.3] – Apply Temperature – Time Graphs to Calorimetry

- Find ΔT by extrapolation.
- For the following temperature-time graph, the change in temperature is as labelled:



- If the calorimeter has poor insulation, it has a [higher] / [lower] calibration factor.

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Question 1 Walkthrough.

A solution calorimeter was calibrated by reacting 0.053 mol of nitric acid (HNO_3) $\Delta H = -21.30\ kJ/g$ at 20.00°C. The temperature of the water in the calorimeter increased to 23.50°C during the calibration.

This calorimeter was then used to determine the heat content of a sample of Doritos. 25.00 g of Doritos were reacted in the calorimeter and the temperature of the water in the calorimeter rose by 4.9°C. Calculate the energy content of the Doritos in $kJ\ g^{-1}$.

$\Delta H = \frac{E}{m}$ $E = \Delta H \times m$ $CF = \frac{E}{\Delta T}$

$$m(HNO_3) = n \times M_r = 0.053\,mol \times (1+14+3\times16) = 3.339g$$

$$E = \Delta H \times m = 21.3\,kJ/g \times 3.339g = 71.1\,kJ$$

$$CF = \frac{E}{\Delta T} = \frac{71.1\,kJ}{(23.5-20)°C} = 20.3\,kJ/°C$$

$$E(\text{Donut}) = CF \times \Delta T = 20.3\,kJ/\cancel{°C} \times 4.9\cancel{°C} = 99.5\,kJ$$

Space for Personal Notes $\Delta H = \frac{E}{m} = \frac{99.5\,kJ}{25g} = 3.98\,kJ\,g^{-1}$ $\boxed{\approx 4.0\,kJ\,g^{-1}}$

Section B: Warm Up (10 Marks)

INSTRUCTION: 10 Marks. 7 Minutes Writing.

Question 2 (1 mark) $22.1-19.5 = \boxed{2.6°C}$

A bomb calorimeter was calibrated using a constant current of 3.40 *A* for 5.00 minutes. The voltage was 3.85 *V*. The temperature increased from 19.5°C to 22.1°C.

What is the calibration factor?

$$E = VIt = 3.85 \times 3.4 \times 5 \times 60 = 3927\,J$$

$$CF = \frac{E}{\Delta T} = \frac{3927\,J}{(22.1-19.5)°C} = 1.5\times10^3\,J/°C$$

Question 3 (3 marks)

A magnesium strip which weighs 30.0 g is added to excess cadmium nitrate, which reacts according to the following reaction:

$$Cd(NO_3)_2(aq) + Mg(s) \rightarrow Mg(NO_3)_2(aq) + Cd(s) \quad \Delta H = -105\ kJ/mol$$

Given that the temperature of the system increases from 32.6°C to 39.1°C, find the calibration factor in $kJ/°C$.

$n(Mg) = \frac{m}{Mr} = \frac{30}{24.3} = 1.235\ mol$

$E = \Delta H \times n = 105\ kJ/mol \times 1.235\ mol = 129.6\ kJ$

$CF = \frac{E}{\Delta T} = \frac{129.6\ kJ}{(39.1-32.6)°C} = 19.94\ kJ/°C$

$= 20\ kJ/°C$

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Question 4 (2 marks)

Given that the calibration factor of a particular calorimeter is 369.0 $J/°C$, find the energy content of a 1.40 g biscuit in kJ/g, which happens to increase the temperature of the same calorimeter from 15.7°C to 23.2°C.

$E = CF \times \Delta T = 369\ J/°C \times (23.2-15.7)°C$

$= 2768\ J$

$\Delta H = \frac{E}{m} = \frac{2768\ J}{1.4\ g} = 1.977\ kJ/g$

$= 2.0\ kJ/g$

$\Delta H = \frac{E}{n}$

Question 5 (1 mark)

A bomb calorimeter is calibrated by burning 1.05 g of benzoic acid (molar mass of 122 $g\ mol^{-1}$) and (ΔH_c of 3227 $kJ\ mol^{-1}$). If the temperature rose by 3.45°C, the calibration factor of the calorimeter in $kJ\ °C^{-1}$ is:

A. 0.137

[✓ **B.** 8.05]

C. 27.1

D. 95.9

$n(benz) = \frac{m}{Mr} = \frac{1.05}{122} = 0.00861\ mol$

$E = \Delta H \times n = 3227 \times 0.00861 = 27.8\ kJ$

$CF = \frac{E}{\Delta T} = \frac{27.8\ kJ}{3.45°C} = 8.05\ kJ\ °C$

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Question 6 (3 marks) 25.0000000

A solution calorimeter containing 200 mL of water at SLC is calibrated by passing a 4.00 A current through the instrument for 5.20 minutes, at a potential difference of 2.25 V. The temperature of the water in the calorimeter rises to 31.80°C.

a. Calculate the calibration factor for the calorimeter and water in $J/°C$. (1 mark)

$E = VIt = 2.25V \times 4A \times 5.2 \times 60s = 2808J$

$CF = \frac{E}{\Delta T} = \frac{2808J}{31.80-25} = \boxed{413J/°C}$

b. A piece of garlic of mass 1.20 g was reacted in the calibrated solution calorimeter.

If the temperature of the water increased from 20.00°C to 24.80°C, calculate the energy content of the garlic in $kJ\,g^{-1}$. (2 marks)

$E = CF \times \Delta T = 413\ J/°C \times 4.80°C = 1982J$ $= 1.982kJ$

$\Delta H = \frac{E}{m} = \frac{1.982kJ}{1.2g}$

$= \boxed{1.65kJ/g}$

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Section C: Ramping Up (6 Marks)

INSTRUCTION: 6 Marks. 5 Minutes Writing.

The following information applies to the three questions that follow.

The energy content of peanuts in a particular sample was investigated using two different methods.

- Method 1: A peanut was weighed and set alight. The burning peanut was then held close to a flask containing 25.0 *g* of water. The temperature of the water increased by 14.2°C by burning 0.113 *g* of the peanut.
- Method 2: 0.238 *g* of crushed peanuts were burnt in a bomb calorimeter to produce an increase in the temperature of 6.35°C. The energy content of the peanuts was calculated to be 23.1 *kJ g*$^{-1}$.

m

$\Delta H = \frac{E}{m}$

Question 7 (1 mark)

How many joules of energy were used to heat the water in the method 1?

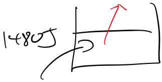
A. 8.49 kJ

B. 1.67×10^2 kJ

C. 1.06×10^3 kJ

[✓ **D.**] 1.48×10^3 kJ

$q = mc\Delta T = 25 \times 4.18 \times 14.2 = 1480\ J$



Question 8 (1 mark)

What is the calibration factor (in $J\ °C^{-1}$) of the bomb calorimeter used in the method 2?

A. 86.6

B. 616

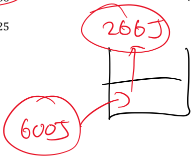
[✓ **C.**] 866

D. 925

$E = \Delta H \times m = 23.1\ kJ g^{-1} \times 0.238 g = 5497\ J$

$CF = \frac{E}{\Delta T} = \frac{5497\ J}{6.35°C} = 865.7\ J/°C$

$866\ J/°C$



Question 9 (1 mark)

Method 2 produced a much higher value for the energy content per gram of peanuts than the method 1. What is the main reason for this discrepancy?

A. The peanut used in the method 1 was not crushed.

B. Method 2 used different peanuts to method 1.

C. A greater mass of peanuts was used in method 2.

[✓ **D.**] Method 1 did not use any calibration.

1 kJ/g

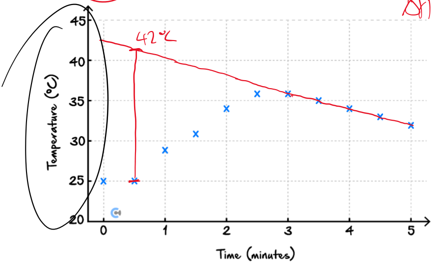
3 kJ ← 3g

$\frac{3kJ}{3g} = 1kJ/g$

Question 10 (3 marks)

To more accurately find the calibration factor of a calorimeter, Jayden plots the following temperature-time graph. He reacts with some nitrogen dioxide (NO_2), which is known to have a change in enthalpy of $-15.29\ kJ/g$. Find the calibration factor, if 2.00 mol of nitrogen dioxide is reacted.

$\Delta H = \frac{E}{m}$



$m(NO_2) = n \times Mr = 2mol \times (14 + 2 \times 16) = 92g$ $T_f = 42°C$

$E = \Delta H \times m = 15.29 kJ/g \times 92g = 1407 kJ$

$CF = \frac{E}{\Delta T} = \frac{1407kJ}{42-25} = 83 kJ/°C$

75-95

Section D: Getting Trickier I (8 Marks)

INSTRUCTION: 8 Marks. 7 Minutes Writing.

Question 11 (8 marks)

Methyl palmitate, $C_{17}H_{34}O_2$, is a component of one type of biochemical fuel. It is a liquid at room temperature. The molar enthalpy of combustion of methyl palmitate was determined using a bomb calorimeter. The calorimeter was calibrated by passing a current of 4.40 amperes at a potential difference of 5.61 volts through an electric heater for 240 seconds. The temperature of the calorimeter rose by 1.75°C.

a. Calculate the calibration factor of the calorimeter. Include the units of the calibration factor with your answer. (3 marks)

$$CF = \frac{E}{\Delta T} = \frac{Vt}{\Delta T} = \frac{5.61 \times 4.4 \times 240}{1.75}$$ ① energy

$$= 3385\ J/°C$$

$$= 3.39 \times 10^3\ J/°C \text{ or } 3.39\ kJ/°C$$

① ans ① units

A 0.529 g sample of methyl palmitate was then burned in excess oxygen in the calorimeter and the temperature rose by a further 6.19°C. The molar mass of methyl palmitate is 270 $g\ mol^{-1}$.

b. Calculate the amount of energy, in kJ, absorbed by the calorimeter when the sample of methyl palmitate was burned. (1 mark)

$$E = CF \times \Delta T = 3.39\ kJ/°C \times 6.19°C$$

$$= 20.95\ kJ$$

$$= 21.0\ kJ$$

1mol → 890kJ

$\Delta H =$ kJ/mol

$$x = \frac{21}{0.00196} \quad - \frac{E}{n} = \Delta H$$

$$21 = 0.00196x$$

0.00196mol → 21.0kJ

1mol → x

c. Calculate the amount of energy released, in kJ by the combustion of 1.00 mol of methyl palmitate. (2 marks)

$$n(\text{methyl palmitate}) = \frac{m}{Mr} = \frac{0.529g}{270} = 0.00196mol$$

$$\Delta H = \frac{E}{n} = \frac{21kJ}{0.00196mol} = 1.07 \times 10^4\ kJ$$

$$\Delta H = 1.07 \times 10^4\ kJ/mol$$

1.07×10⁴ kJ released when 1mol combusted

d. The balanced equation for the combustion of liquid methyl palmitate in excess oxygen is:

$$2C_{17}H_{34}O_2(l) + 49O_2(g) \rightarrow 34CO_2(g) + 34H_2O(l)$$

Write the value of ΔH for this reaction, in $kJ\ mol^{-1}$. (2 marks)

$$\Delta H = -2.14 \times 10^4\ kJ$$

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Section E: Getting Trickier II (8 Marks)

INSTRUCTION: 8 Marks. 8 Minutes Writing.

$0°C \rightarrow 1°C$ 1°C ✓

$273K \rightarrow 274K$ $\boxed{1K}$

420J ↑1K

Question 12 (1 mark)

The reaction between solutions of hydrochloric acid and sodium hydroxide can be represented by the following equation:

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) \quad \Delta H = -56\ kJ\ mol^{-1}$$

60.0 mL of 2.0 M HCl, at 21°C is mixed with 40.0 mL of 2.0 M NaOH, also at 21°C, in a well-insulated calorimeter. The calibration factor for the calorimeter and contents is 420 $J\ K^{-1}$. The final temperature, in °C, of the resultant solution in the calorimeter would be closest to:

0.08mol

$CF = \frac{E}{\Delta T}$ $\Delta T = \frac{E}{CF}$

A. 11

[✓ **B.** 32]

C. 37

D. 52

$T_f = 21 + 10.7$
$= 31.7$

$n(NaOH) = cV = 2M \times 0.04 = 0.08mol$

$E = \Delta H \times n = 56kJ/mol \times 0.08mol = 4.48kJ$

$\Delta T = \frac{E}{CF} = \frac{4.48kJ}{0.420kJ/°C} = 10.7°C$

Question 13 (7 marks)

Angela loves playing around with some chemicals, and tries dissolving sulphuric acid into water. Below is the equation which represents what occurs:

350J/°C = CF

$CF = \frac{E}{\Delta T}$

$$H_2SO_4(s) \rightarrow H_2SO_4(aq) \qquad \Delta H = +75\ kJ/mol$$

endo T↓

$\Delta T = \frac{E}{CF}$

a. When starting at 38.0°C, a sample of 8.30 g of sulphuric acid is dissolved into water. Given that the calibration factor is known to be 350 J/°C, find the expected final temperature of the water. (3 marks)

$n(H_2SO_4) = \frac{m}{Mr} = \frac{8.3}{98.1} = 0.0846mol$

$E = \Delta H \times n = 75\ kJ/mol \times 0.0846mol = 6.346kJ$

$= 6346J$

$\Delta T = \frac{E}{CF} = \frac{6346\cancel{J}}{350\cancel{J}/°C} = 18.1°C$

$T_f = T_i - \Delta T = 38 - 18.1 = \boxed{19.9°C}$

$\boxed{= 20°C}$

$\Delta H = \frac{E}{m}$

Another reaction that involves sulphuric acid has excess lead (Pb) added to it, which reacts in the following manner:

$\Delta H = kJ/g$

$$H_2SO_4(aq) + Pb(s) \rightarrow PbSO_4(aq) + H_2(g)$$

15°C 25°C

The reaction is known to be exothermic, which produces 22.0 *L* of hydrogen gas at SLC.

b. Given that the reaction begins at 15.0°C, find the change in enthalpy of the reaction, which indicates the energy produced for every 1.00 *g* of lead. (4 marks)

$n(H_2) = \frac{V}{V_m} = \frac{22}{24.8} = 0.887 mol$

$n(Pb) = n(H_2) = 0.887 mol$

$m(Pb) = n \times M = 0.887 \times 207.2 = 183.8 g$

$E = CF \times \Delta T = 350 J/\cancel{°C} \times 10\cancel{°C} = 3500J$

$\Delta H = \frac{E}{m} = \frac{3500J}{183.8g} = \boxed{-19.0 J/g}$

Let's take a BREAK!

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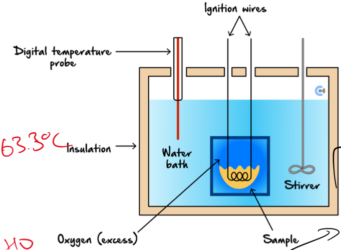
Section F: VCAA-Level Questions I (12 Marks)

INSTRUCTION: 12 Marks. 30 Seconds Reading. 11 Minutes Writing.

Question 14 (12 marks)

Inspired from VCAA Chemistry Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/2022chem-w.pdf#page=27

The energy content of food can be determined experimentally using a bomb calorimeter similar to the one shown in the diagram below.



$\Delta T = 63.3°C$

C_2H_2

CHO

$\Delta H = -1300 kJ/mol$

a. The calorimeter is first chemically calibrated by burning 8.30 *g* of ethyne which causes the temperature which is originally at 23.3°C to rise by 63.3°C. Write out the thermochemical equation for the combustion of ethyne and hence or otherwise calculate the calibration factor of this calorimeter. (3 marks)

$C_2H_{2(g)} + \frac{5}{2}O_{2(g)} \rightarrow 2CO_{2(g)} + H_2O_{(l)}$ $\Delta H = -1300 kJ/mol$

① ① ΔH & sign

$n(C_2H_2) = \frac{m}{Mr} = \frac{8.30g}{24+2} = 0.319 mol$

$E = \Delta H \times n = 1300 kJ/mol \times 0.319 mol = 415 kJ$

$CF = \frac{E}{\Delta T} = \frac{415 kJ}{63.3°C} = 6.56 kJ/°C$

① CF

A 1.50 g sample of air-popped popcorn is placed in the bomb calorimeter. The initial temperature of the water is 22.2°C and the final temperature is 25.7°C. Assume that the air-popped popcorn is fully combusted.

b. Using the calibration factor provided, calculate the energy released by the air-popped popcorn in kilojoules per gram. (2 marks)

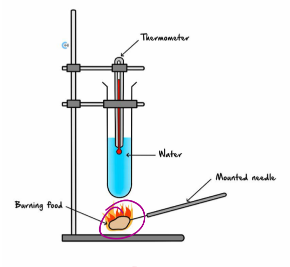
$E = CF \times \Delta T = 6.56\ kJ/°C \times (25.7-22.2)°C$

$= 22.9\ kJ$ ① E or method

$\Delta H = \frac{E}{m} = \frac{22.9\ kJ}{1.5\ g} = 15.3\ kJ/g$ ① ans

$= 15\ kJ/g$

To test the impact of using a calorimeter, a 0.89 g of popcorn is burned below a test-tube water, as shown below, till food of mass 0.12 g are left.



c. Water of mass 60.00 g is heated from 20.8°C to 46.1°C. Calculate the experimental energy content from this method. (2 marks)

① E

$q = mc\Delta T = 60 \times 4.18 \times (46.1-20.8)°C = 6345\ J$

$\Delta H = \frac{E}{m} = \frac{6.345\ kJ}{(0.89-0.12)\ g} = \boxed{8.24\ kJ/g}$ ① ans

$\boxed{= 8.2\ kJ/g}$

d. Compare the two results from **part b.** and **part c**. Provide two different reasons to explain this difference. (3 marks)

① comparison

Energy content obtained from calorimeter is larger, and almost double that of the energy content obtained in part c. (15.3 kJ/g vs 8.24 kJ/g)

Reason 1: Heat is lost to environment in part c ①

Reason 2: Popcorn has non-uniform distribution of energy ①

e. Describe 2 ways to improve the methodology used in **part c.,** apart from using a calorimeter. (2 marks)

- stir water to ensure uniform heat distribution ①
- Bring food/flame as close to test tube as possible ①
- Add lid to test tube/enclose apparatus in small box to minimise ① heat loss

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Section G: Multiple Choice Questions (7 Marks)

INSTRUCTION: 7 Marks. 7 Minutes Writing.

Question 15 (1 mark)

Inspired from VCAA Chemistry Exam 2021
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2021/2021chem-w.pdf#page=10

A food chemist conducted an experiment in a bomb calorimeter to determine the energy content, in joules per gram, of a muesli bar. A 3.95 g sample of the muesli bar was combusted in the calorimeter, and the temperature of the water rose by 16.7°C. The calibration factor of the calorimeter was previously determined to be $4780\ J\ °C^{-1}$.

The energy content of the muesli bar is:

$E = CF \times \Delta T = 4780\ J/°C \times 16.7°C = 7.98 \times 10^4\ J$

$E_c = \frac{E}{m} = \frac{7.98 \times 10^4\ J}{3.95\ g} = 2.02 \times 10^4\ J\ g^{-1}$

A. $3.51 \times 10^2\ kJ\ g^{-1}$

[✓ **B.** $2.02 \times 10^4\ J\ g^{-1}$]

C. $3.51 \times 10^0\ kJ\ g^{-1}$

D. $2.02 \times 10\ J\ g^{-1}$

Question 16 (1 mark)

A foam cup calorimeter containing 100 mL of water is calibrated by passing an electric current through a small heater placed in the solution.

Assuming that all measurements are accurate, which one of the following is the most likely calibration factor (in $J\,^{\circ}C^{-1}$) for the calorimeter and contents?

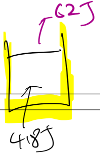
$q = mc\Delta T = 100 \times 4.18 \times 1^{\circ}C = 418\ J$

A. 120

B. 240

[✓ **C.** 480]

D. 960



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Question 17 (1 mark)

$\downarrow m = \frac{q}{c\Delta T\uparrow}$

Inspired from VCAA Chemistry Exam 2021
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2021/NHT/2021chem-nht-w.pdf#page=3

Ammonium nitrate, NH_4NO_3, can be used in chemical cold packs that are often found in first-aid kits.

A calorimeter was electrically calibrated using 100 mL of pure water and was then used to determine the molar heat of the solution of NH_4NO_3.

$q = mc\Delta T$

If the water was replaced prior to the determination of the molar heat of the solution and, instead of 100 mL, only 90 mL was added to the calorimeter, the molar heat of the solution determined would be:

A. Lower due to the temperature change being smaller.

B. Lower due to the temperature change being greater.

$\uparrow E = CF \times \boxed{\Delta T \uparrow}$

C. Higher due to the temperature change being smaller.

[✓ **D.** Higher due to the temperature change being greater.]

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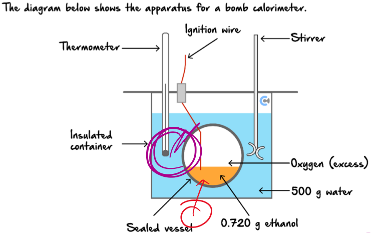
Question 18 (1 mark)

Inspired from VCAA Chemistry Exam 2021
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2021/NHT/2021chem-nht-w.pdf#page=9

The diagram below shows the apparatus for a bomb calorimeter.



The bomb calorimeter containing 500 *g* of water was chemically calibrated by combusting 0.720 *g* of ethanol with an excess of oxygen. The increase in temperature was found to be 22.0°C.

1370 kJ/mol

Which one of the following best explains these results?

[✓ **A.**] The stirrer was not working.

B. The calorimeter actually contained 450 *g* of water. 250g

$q = mc\Delta T$

C. The temperature in the calorimeter was still rising after the final temperature was noted.

×2

D. Some of the ethanol evaporated after it was weighed but before it was added to the calorimeter.

0°C → 22°C → 30°C

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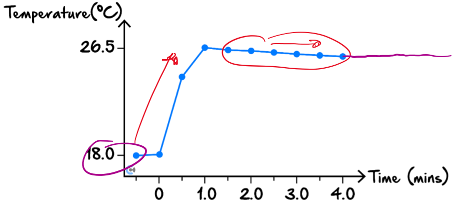
$n(C_2H_5OH) = \frac{m}{M} = \frac{0.72}{46} = 0.0157\,mol$

$q = \Delta H \times n = 1370 \times 0.0157 = 21.4\,kJ$

$q = mc\Delta T \quad \Delta T = \frac{q}{mc} = \frac{21.4\,kJ \times 10^3}{500 \times 4.18} = 10.2°C$

Question 19 (1 mark)

A temperature-time graph from a solution calorimetry experiment is shown below.



Which one of the following statements related to the graph is incorrect?

A. The calorimeter is poorly insulated and lost heat to the surroundings.

B. The graph depicts a reaction which has a negative enthalpy change.

[✓ **C.**] After 4.0 minutes the graph will plateau at a constant value.

D. Before mixing, the temperature of the reactant solutions was 18.0°C.

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The following information applies to the two questions that follow

Inspired from VCAA Chemistry Exam 2 2007
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2007chem2.pdf#page=8

A chemist used bomb calorimetry to measure the enthalpy change (ΔH) for the combustion of butane.

Question 20 (1 mark)

$$\boxed{Q = It}$$

The calibration factor (CF) of the calorimeter was determined by measuring the temperature rise (ΔT_1) that occurred when a known amount of charge (Q) was passed through the heating element in the calorimeter at a measured voltage (V).

The CF, in $J\ °C^{-1}$, is:

$$CF = \frac{VIt}{\Delta T} = \frac{VQ}{\Delta T}$$

A. Q

B. $\frac{\Delta T_1}{Q \times V}$

C. $V \times Q \times \Delta T_1$

[✓ **D.** $\frac{V \times Q}{\Delta T_1}$]

Question 21 (1 mark)

In the calorimeter (calibration factor, CF), n mol of butane was then burnt, and the resulting temperature rise (ΔT_2) was measured.

The ΔH, in J ~~mol^{-1}~~, for the reaction,

$$E = CF \times \Delta T$$

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$$

is:

$$\Delta H = \frac{E}{n} = \frac{CF \times \Delta T \times 2}{n}$$

A. $2 \times CF \times \Delta T_2 \times n$

[✓ **B.** $\frac{2 \times CF \times \Delta T_2}{n}$]

C. $\frac{CF \times \Delta T_2}{2 \times n}$

D. $\frac{CF \times \Delta T_2}{n}$

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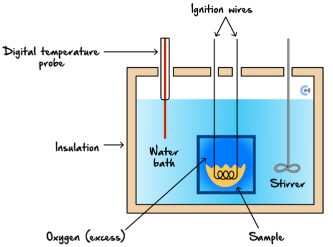
Section H: VCAA-Level Questions II (12 Marks)

INSTRUCTION: 12 Marks. 30 Seconds Reading. 11 Minutes Writing.

Question 22 (12 marks)

Inspired from VCAA Chemistry NHT Exam 2018
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2018/nht/2018chem-nht-w.pdf#page=26

The energy content of foods can be determined using a bomb calorimeter similar to the one shown in the diagram below.



The calibration factor for the bomb calorimeter is initially determined by burning a known amount of naphthalene, $C_{10}H_8$.

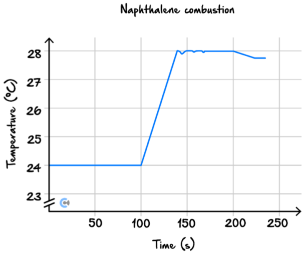
The combustion reaction for $C_{10}H_8$ is shown below:

$$C_{10}H_8\ (s) + 12O_2\ (g) \rightarrow 10CO_2\ (g) + 4H_2O\ (l) \qquad \Delta H = -5133\ kJ\ mol^{-1}$$

Data for the calibration of the bomb calorimeter

mass of $C_{10}H_8$	0.212 *g*
mass of water	300 *g*

The graph produced by the digital temperature probe in the bomb calorimeter is shown below.



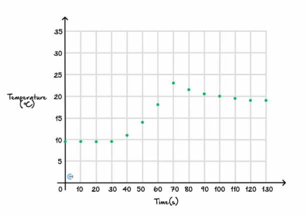
a.

i. Use the data in the graph above to calculate the calibration factor for the bomb calorimeter. (3 marks)

ii. If the calorimeter was to be electrically calibrated instead, calculate the current that would need to be run through if a voltage of 5.00 V was provided for 5.21 s leading to a temperature difference of 23.1°C. (1 mark)

b. Electrical calibration is now taken place in a different calorimeter with a voltage of 83.1 V and a current of 59.3 A running through the electric heater.

i. Draw the line of the best fit across the appropriate interval on the below temperature vs time graph. (1 mark)



ii. What is the change in temperature used in the calibration factor calculations for this calorimeter? (1 mark)

iii. Is this ΔT measured the same way as for **part a.**? Explain why there's a difference and explain how the method for measuring ΔT in **part a.** and **b.** works. (3 marks)

iv. Calculate the calibration factor for this calorimeter. (1 mark)

c. Explain the difference between the calibration factors of the two calorimeters in **parts a.** and **b.**, Calorimeter *A* and Calorimeter *B* respectively and thus how they are made. (2 marks)

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Section I: Summary

What have we learnt today?

TIPS

Pitfalls

Section J: Extension Questions (19 Marks)

Question 23 (19 marks)

Students in a VCE ¾ Chemistry class have been studying the energy released by different foods that can be used by the body. One of their practicals involves various methods of determining the energy content of a jellybean in kJ/g, which is almost entirely comprised of pure glucose.

a. The first method explored is by using a calorimeter. It is calibrated chemically in which 200 g of ammonium nitrate, NH_4NO_3, is dissolved in the water according to the following thermochemical equation:

$$NH_4NO_3(s) \rightarrow NH_4NO_3(aq) \qquad \Delta H = +25.69\ kJ/mol$$

Given that the water's temperature decreased by 7.10°C, calculate the calibration factor for this calorimeter in $kJ/°C$. (2 marks)

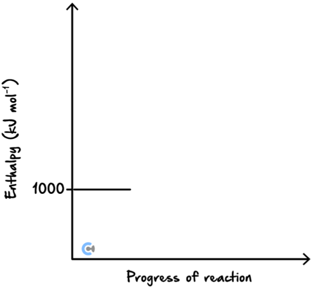
b. A jellybean is then combusted in the calorimeter, and it is found that a 5.00 g jellybean raised the water's temperature by 1.8°C. Calculate its energy content in kJ/g. (2 marks)

c.

i. Briefly explain why the above experiment would technically not be feasible in a solution calorimeter. (1 mark)

ii. In a **different experiment in the same solution calorimeter**, a jellybean is placed and begins to dissolve, and the energy changes from this process are analysed. Assuming all of the jellybeans is glucose, $C_6H_{12}O_6$, if a 4.00 g jellybean changed the water's temperature from 28.0°C to 23.0°C, write the thermochemical equation for this dissolution. (3 marks)

iii. Hence, draw the energy profile diagram for the dissolution of glucose in water on the axes below, based on the information in **part c. ii.** Ensure to label your reactants, products and change in enthalpy value. (2 marks)



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d. The second method explored is by combusting melted (liquid) jellybean in a spirit burner to heat up a sample of water to determine its energy content. Explain an expected difference in the values obtained for the jellybean's energy content and suggest a modification aimed at minimising this discrepancy. (2 marks)

e.

i. A sprinter typically consumes foods high in glucose ($C_6H_{12}O_6$), such as jellybeans, before a race for a burst of energy. Given that glucose's molar heat of combustion is $-2880\ kJ/mol$ at SLC, and a runner would like $50.0\ kJ$ of energy, how big of a jellybean, in g, which is 80% glucose, would they wish to consume? (3 marks)

ii. Which of the following is true regarding the size of jellybean that would be consumed by a runner in the subcontinent where temperatures are greater than 25°C, assuming they would also need $50.0\ kJ$ of energy before a race? (1 mark)

A. A smaller jellybean would be consumed if the molar heat of combustion of glucose were lower in the subcontinent.

B. An identical jellybean would be consumed, as the molar heat of combustion of glucose is constant.

C. If the molar heat of combustion were greater in the subcontinent, a larger jellybean would be consumed.

D. None of the above.

iii. In a typical running season, a sprinter would need $450\ g$ of jellybeans. Using this information, and relevant information in **part e. i.,** write the thermochemical equation of the complete combustion of glucose in jellybeans **with stoichiometric ratios which match those of a sprinter's seasonal needs**. (3 marks)

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