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(0.25) Title: Calorimetry; Determination of Heats of Solution
(Full title. "Calorimetry" alone would not be enough.)

(0.25) Purpose: Use a simple calorimeter to determine the heats of solution of two solids.
(Paraphrase or alter Purpose in lab manual. DO NOT COPY)

(1.5) Hazards: Page 52 lists the two chemicals requiring Hazards information for this experiment.

- Sodium Acetate
  - Overview:
  - Health Effects:
  - First Aid:

  } use internet to search "sodium acetate + MSDS" to fill this in.

- Sodium Acetate Trihydrate
  - Overview:
  - Health Effects:
  - First Aid:

  } use internet to search "sodium acetate trihydrate + MSDS" to fill this in.

* even if all the MSDS parts seem the same, you must write them out each time, for every chemical in every lab. *

The above content (filled in as required) is the minimum required for NOTEBOOK-PRELAB.

Theory (optional) (some important concepts + equations)

- Systems (open, closed, isolated) vs. surroundings
- HEAT: difference between the final and initial thermal energy of a system
- Many physical process involve the absorption or release of heat
- ENTHALPY (ΔH) = change of heat of a system

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- $\Delta H_{soln} = H_{soln} - H_{components}$
  cannot measure individually, but can measure difference.
- HEAT OF SOLUTION: heat released or absorbed when a solid (solute) is dissolved in a liquid (solvent)
- when solute is an ionic salt, energy must be "put into system" in order to overcome LATTICE ENERGY (attractive forces holding ions together) before full dissolution can occur. ($\Delta H_{hydration}$ is energy released as solute is fully dissolved, or "hydrated")
- Note: 1st law of thermodynamics:
  heat of universe is zero
  $q_{universe} = 0$
- when considering smaller system, general rule becomes: any heat lost (or gained) by the system is then gained (or lost, respectively) by the surroundings (so that the difference between the two is always zero).
- Our lab system has the flaw of having some heat lost to the container (styrofoam), so we calibrate the calorimeter first:
  determine the heat capacity (C) of the calorimeter.

$$C_{calorimeter} = -\frac{[(m_{cool\,water})(P_{water})(\Delta T_{cal/cool\,water}) + (m_{warm\,water})(P_{water})(\Delta T_{warm})]}{\Delta T_{cal/cool}}$$

- m → mass of respective portions of water (in g)
- P → specific heat of water (4.184 J/g °C)
- ΔT → temperature change of respective portions of system

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- C_{cal}, once calculated, can then be used to determine the heat of solution

$$q_{soln} = -[(m_{solv/solu})(\rho_{solv/solu})(\Delta T_{solv/solu}) + (C_{cal})(\Delta T_{cal})]$$

where:
- $m_{solv/solute}$ = sum of mass of solvent and solute
- $\rho_{solv/solute}$ = specific heat of solution (same as pure water for low concentrations)
- $\Delta T_{solv/solute}$ = temperature change of solution
- C_{cal} = heat capacity of calorimeter (calculated earlier in exp.)
- ΔT_{cal} = temperature change of calorimeter

- Molar heat of solution ($\Delta H_{solution}$):

$$\Delta H_{soln} = \frac{q_{soln}}{n}$$

- q_{soln}: heat of solution
- n: # moles of solute

Procedure (optional)

- Mostly on computer for this lab, but keep written tables for important info.

- Procedure steps (heat of solution part) 1-6 to be followed TWICE (once for each type of salt).

- Calibration procedure allows for determination of Heat Capacity of calorimeter, which is slightly different for each.

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Data (table prep for easy notation in lab)

- Anhydrous $NaC_2H_3O_2$

may have different uncertainty when using digital thermometer

Mass of salt (±0.0001 g)	Volume of "cool" water (±0.2 mL)	$T_{cool\ (initial)}$ (±0.2°C)	T_{final} (±0.2°C)

You will have 4 trials to fill in here for the anhydrous $NaC_2H_3O_2$ salt.

- $NaC_2H_3O_2 \cdot 3H_2O$ (trihydrate)

may have different uncertainty value when using digital thermometer.

Mass of salt (±0.0001g)	Volume of "cool" water (±0.2 mL)	$T_{cool\ (initial)}$ (±0.2°C)	T_{final} (±0.2°C)

You will again have 4 trials for the trihydrate salt.

- Calorimeter calibration

uncertainty different if digital thermometer is used.

Volume of "cool" water (±0.2 mL)	T "cool" water (T_1) (±0.2°C)	Volume of "hot" water (±0.2mL)	T "hot water" (T_2) (±0.2°C)	T_{final} (±0.2°C)

3 trials to be averaged after calculations.

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Calculations

1. Heat capacity of calorimeter (C_{cal})

$$C_{cal} = -\frac{[(m_{cool\ water})(\rho_{water})(\Delta T_{cool}) + (m_{warm})(\rho_{water})(\Delta T_{warm})]}{\Delta T_{cool}}$$

Units: $\frac{(g)(J/g\,°C)(°C) + (g)(J/g\,°C)(°C)}{(°C)} = J/°C$

Uncertainty of C_{cal} = $\%\sigma_{m_{cool\ water}} + \%\sigma_{\Delta T_{cool}} + \%\sigma_{m_{warm}} + \%\Delta T_{warm} + \%\Delta T_{cool}$
(resulting units = %)

2. Molar heat of solution (each trial)
Sodium acetate (anhydrous)

$$\frac{\Delta H_{soln}}{(units = J/mol)} \quad \frac{q_{soln}}{n} = -\frac{[(m_{soln})(\rho_{soln})(\Delta T_{soln}) + (C_{cal})(\Delta T_{cal})]}{n_{solute}}$$

	Trial 1 (~1.5g)	Trial 2 (~2.0g)	Trial 3 (~2.5g)	Trial 4 (~3.0g)
ΔH_{soln}				
% uncertainty				

SHOW ALL CALCULATIONS (at least one sample calc for each salt), then tabulate results

Sodium acetate trihydrate

(same calc as above, with other values)

(same table as above, with other results)

Uncertainty to be calculated for EACH trial, for each salt (8 times)

$\%\sigma\Delta H_{soln} = \%\sigma m_{soln} + \%\sigma\Delta T_{soln} + \%\sigma C_{cal} + \%\sigma\Delta T_{cal} + \%\sigma n_{solute}$ (units = %)

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3. Average Molar heat of solution:

Sodium Acetate (Anhydrous)

$$\Delta H_{sol^n\ avg} = \frac{\Delta H_{sol^n}(\text{trial 1}) + \Delta H_{sol^n}(\text{trial 2}) + \Delta H_{sol^n}(\text{trial 3}) + \Delta H_{sol^n}(\text{trial 4})}{4}$$

(units = J/mol) (# of trials)

$$\%\sigma_{avg\ \Delta H_{sol^n}} = \frac{(\%\sigma_{\Delta H_{sol^n}\text{-trial 1}} + \%\sigma_{\Delta H_{sol^n}\text{-trial 2}} + \%\sigma_{\Delta H_{sol^n}\text{-trial 3}} + \%\sigma_{\Delta H_{sol^n}\text{-trial 4}})}{4}$$

(= avg % uncertainty) (resulting units = %)

Accepted value: Molar heat of solution of sodium acetate = −17.3 kJ/mol

Compare result to accepted value:

$$\text{Relative spread} = \frac{\text{difference between extreme results}}{\text{average result}} \times 1000$$

(units = ppt) (= "parts per thousand")

$$= \frac{(\text{highest } \Delta H_{sol^n}) - (\text{lowest } \Delta H_{sol^n})}{\text{avg. } \Delta H_{sol^n}} \times 1000$$

$$\text{Relative Error} = \frac{\text{Experimental Result} - \text{Accepted value}}{\text{Accepted value}} \times 100\%$$

(units = %)

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(3-cont'd)

Average molar heat of solution:

Sodium Acetate trihydrate

$\Delta H_{sol^n\text{-}avg}$ = (same as previous page, but use results from trihydrate trials)
(units = J/mol)

$\%\sigma_{\Delta H_{sol^n\text{-}avg}}$ = (average of %uncertainties from the 4 trihydrate trials)

Accepted value: Molar heat of solution of sodium acetate trihydrate = 19.7 kJ/mol

Compare results to accepted value:

$$\text{Relative Spread} = \frac{\text{(difference between extreme results)}}{\text{(average result)}} \times 1000$$
(units = ppt)

$$= \frac{(\text{highest } \Delta H_{sol^n}) - (\text{lowest } \Delta H_{sol^n})}{\text{avg } \Delta H_{sol^n}} \times 1000$$

$$\text{Relative Error} = \frac{\text{Experimental Result} - \text{Accepted value}}{\text{Accepted value}} \times 100$$
(units = %)

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Discussion

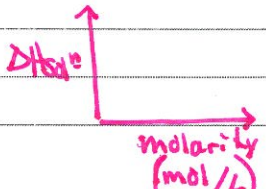
Lab manual Q.4

① The sign (positive or negative) of the heat of solution describes the energy change of the system. The theory section of this lab described ENDOTHERMIC (heat/energy absorbed) versus EXOTHERMIC (heat/energy released) reactions. Use the signs (+ or -) of your results for each salt to describe what type of reaction (endo- or exothermic) each salt used.

② "Explain why a substance with an endothermic heat of solution actually dissolves".
When considering most chemical systems, one that needs an energy input to proceed is seen as "unfavourable" and not spontaneous. Some salts though, when dissolving, gain this energy input with the association of water molecules around its ions, so the reaction may proceed without external influence. Is this what happened for one of the salts you used in this lab?

Lab manual Q.5

Plot (either by hand or on a computer (recommended)) the molar heat of solution versus the molarity of the salt solution for each trial (and for each salt). Do you notice any trend(s)? (Attach the printed plot to your short report submission.)



You will have to calculate the molarity of each trial (moles per litre, mol/L).

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(Discussion - cont'd)

Discuss why your results for each salt might be higher or lower than the accepted values (higher = +ve relative error; lower = -ve relative error). (need two valid reasons for Full marks) "Human error" is NOT acceptable error.

Consider things about the instruments or methods that might have flaws / loss points. Like:

- is the calorimeter a perfectly closed system?
- is the mass transfered to the solution always exact, or is there a point where some could be lost/left behind?
- were the salts always fully dissolved at the final temperature reading?

...

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Conclusion

Statement summary of results. Must include:
- Ccal
- ΔH_{sol} of both salts (avg)
- Relative spread of both salts
- Relative error of both salts

write this in full sentences; not point form.

END OF SHORT REPORT WRITE-UP!

Hand in pages for Calculations, Discussion, Conclusion, + created graph at BEGINNING of next lab.

(write up will be marked out of 4 for each short report).

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