Essential Pre-Uni Chemistry F1.4

A Level

P P P

Specific heat capacity of water $= 4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$.

The enthalpy change of combustion of decane, $\mathrm{C_{10}H_{22}}$, is $-6778\,\mathrm{kJ\,mol^{-1}}$. Calculate the mass required to raise the temperature of $450\,\mathrm{g}$ of water by $80\,^{\circ}\mathrm{C}$ when burnt completely, with no heat losses from the water. Give your answer to 2 significant figures.

Essential Pre-Uni Chemistry F1.6

A Level

Specific heat capacity of water $= 4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$.

Calculate the enthalpy of combustion of propyne, $\mathrm{C_3H_4}$, given that complete combustion of $65\,\mathrm{mg}$ of propyne raises the temperature of $800\,\mathrm{g}$ of water from $20.15\,^{\circ}\mathrm{C}$ to $21.09\,^{\circ}\mathrm{C}$.

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STEM SMART Chemistry Week 17

Essential Pre-Uni Chemistry F1.8

A Level

Specific heat capacity of water $= 4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$

$30.0\,\mathrm{cm^3}$ of ethanoic acid at $1.60\,\mathrm{mol\,dm^{-3}}$ and $18.65\,^\circ\mathrm{C}$ is placed in an insulated polystyrene cup. When $40.0\,\mathrm{cm^3}$ of sodium hydroxide at $1.00\,\mathrm{mol\,dm^{-3}}$ and $18.65\,^\circ\mathrm{C}$ is added, the temperature rises to $25.80\,^\circ\mathrm{C}$.

Assuming that no heat is lost, that the specific heat capacity of water may be used, and that the solutions have a density of $1.00\,\mathrm{g\,cm^{-3}}$ at $18.65\,^\circ\mathrm{C}$, find the enthalpy change of the reaction per mole of water produced by neutralisation.

Gameboard:

STEM SMART Chemistry Week 17

Essential Pre-Uni Chemistry F1.9

A Level

P P P

Specific heat capacity of water $= 4.18\,\mathrm{J\,g^{-1}\,K^{-1}}$.

When $5.0\,\mathrm{g}$ of ammonium nitrate dissolves in $100\,\mathrm{g}$ of water, the temperature of the water drops from $18\,^{\circ}\mathrm{C}$ to $14\,^{\circ}\mathrm{C}$. Calculate the enthalpy of solution of ammonium nitrate in $\mathrm{kJ\,mol^{-1}}$ using the following scheme.

Part A Formula

Write down the formula of ammonium nitrate.

Part B Formula mass

Calculate the formula mass of ammonium nitrate. Give your answer to 3 significant figures.

Part C Number of moles

Calculate the number of moles of ammonium nitrate in $5.0\,\mathrm{g}$.

Part D Heat loss of water

Calculate the heat lost from the $100\,\mathrm{g}$ of water. Give your answer to 2 significant figures.

Part E Molar heat loss of ammonium nitrate

Calculate the heat lost per mole of ammonium nitrate.

Part F Enthalpy of ammonium nitrate

Give the enthalpy of solution of ammonium nitrate.

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Essential Pre-Uni Chemistry F2.4

A Level

Given that the bond energy of $\mathrm{H{-}H}$ is $4.53\,\mathrm{eV}$, $\mathrm{D{-}D}$ is $4.59\,\mathrm{eV}$, and the energy change on reaction $\mathrm{H_2 + D_2 \longrightarrow 2\,HD}$ is $+0.02\,\mathrm{eV}$, find the bond energy of $\mathrm{H{-}D}$. Give your answer to 3 significant figures.

Gameboard:

STEM SMART Chemistry Week 17

Essential Pre-Uni Chemistry F3.3

A Level

Data (all in $\mathrm{kJ\,mol^{-1}}$):

	$\Delta_f H^\circ$		$\Delta_c H^\circ$
$CH_4\,(g)$	-74.8	$C_6H_6\,(l)$	-3267.4
$CCl_4\,(l)$	-129.6	$H_2\,(g)$	-285.8
$HCl\,(g)$	-92.3	$C_6H_{12}\,(l)$	-3919.5
$TiCl_4\,(l)$	-804.2	$C_2H_2\,(g)$	-1300.8
$TiCl_3\,(s)$	-720.9	$C_2H_6\,(g)$	-1559.7
$PCl_3\,(l)$	-319.7	$C_2H_5OH\,(l)$	-1367.3
$PCl_5\,(s)$	-443.5	$C_2H_4\,(g)$	-1410.8
$POCl_3\,(l)$	-597.1	$CH_3COOH\,(l)$	-874.1
$GeO\,(s)$	-212.1	$C_6H_{14}\,(l)$	-4163.0
$GeO_2\,(s)$	-551.0	$CH_3COOC_2H_5\,(l)$	-2237.9
$NH_3\,(g)$	-46.1	$CO\,(g)$	-283.0
$TiO_2\,(s)$	-939.7	$Mg\,(s)$	-601.7

Use enthalpies of formation and combustion to calculate the reaction enthalpy for the reaction:
$Ge\,(s) + 2\,H_2O\,(l) \longrightarrow GeO_2\,(s) + 2\,H_2\,(g)$ Give your answer to 3 significant figures.

Gameboard:
STEM SMART Chemistry Week 17

Essential Pre-Uni Chemistry F3.4

A Level

Data (all in $\mathrm{kJ\,mol^{-1}}$):

	$\Delta_f H^\circ$		$\Delta_c H^\circ$
$CH_4\,(g)$	-74.8	$C_6H_6\,(l)$	-3267.4
$CCl_4\,(l)$	-129.6	$H_2\,(g)$	-285.8
$HCl\,(g)$	-92.3	$C_6H_{12}\,(l)$	-3919.5
$TiCl_4\,(l)$	-804.2	$C_2H_2\,(g)$	-1300.8
$TiCl_3\,(s)$	-720.9	$C_2H_6\,(g)$	-1559.7
$PCl_3\,(l)$	-319.7	$C_2H_5OH\,(l)$	-1367.3
$PCl_5\,(s)$	-443.5	$C_2H_4\,(g)$	-1410.8
$POCl_3\,(l)$	-597.1	$CH_3COOH\,(l)$	-874.1
$GeO\,(s)$	-212.1	$C_6H_{14}\,(l)$	-4163.0
$GeO_2\,(s)$	-551.0	$CH_3COOC_2H_5\,(l)$	-2237.9
$NH_3\,(g)$	-46.1	$CO\,(g)$	-283.0
$TiO_2\,(s)$	-939.7	$Mg\,(s)$	-601.7

Use the reaction enthalpies given, and the combustion or formation enthalpies above to find the requested enthalpy change in each case:

Part A $NH_4Cl\,(s)$

$NH_3\,(g) + HCl\,(g) \longrightarrow NH_4Cl\,(s)$, $\Delta_r H^\circ = -176\,\mathrm{kJ\,mol^{-1}}$ find $\Delta_f H^\circ$ of $NH_4Cl\,(s)$

Part B $MgCl_2\,(s)$

$TiCl_4\,(l) + 2\,Mg\,(s) \longrightarrow 2\,MgCl_2\,(s) + Ti\,(s)$ $\Delta_r H^\circ = -478.4\,kJ\,mol^{-1}$, find $\Delta_f H^\circ$ of $MgCl_2\,(s)$

Part C $CH_3COOCOH_3\,(l)$

$CH_3COOCOCH_3\,(l) + H_2O\,(l) \longrightarrow 2\,CH_3COOH\,(l)$ $\Delta_r H^\circ = -46\,kJ\,mol^{-1}$, find $\Delta_c H^\circ$ of $CH_3COOCOCH_3\,(l)$ Give your answer to 4 significant figures.

Part D $C_6H_5CHCH_2$

$4\,C_2H_2\,(g) \longrightarrow C_6H_5CHCH_2\,(l),\ \Delta_r H^\circ = -808.2\,kJ\,mol^{-1}$, find $\Delta_c H^\circ$ of $C_6H_5CHCH_2$ Give your answer to 4 significant figures.

Part E $Al_2O_3\,(s)$

$4\,Al\,(s) + 3\,GeO_2\,(s) \longrightarrow 2\,Al_2O_3\,(s) + 3\,Ge\,(s)$ $\Delta_r H^\circ = -1698.4\,kJ\,mol^{-1}$, find $\Delta_f H^\circ$ of $Al_2O_3\,(s)$ Give your answer to 4 significant figures.

Part F Fe_2O_3

$Fe_2O_3\,(s) + 3\,CO\,(g) \longrightarrow 2\,Fe\,(s) + 3\,CO_2\,(g),\ \Delta_r H^\circ = -24.8\,kJ\,mol^{-1}$, find $\Delta_f H^\circ$ of Fe_2O_3

Part G $\mathrm{CuO\,(s)}$

$\mathrm{3\,CuO\,(s) + 2\,NH_3\,(g) \longrightarrow 3\,Cu\,(s) + N_2\,(g) + 3\,H_2O\,(l)}$, $\Delta_r H^\circ = -293.3\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{CuO\,(s)}$ Give your answer to 3 significant figures.

Part H $\mathrm{H_3PO_4\,(s)}$

$\mathrm{2\,PCl_5\,(s) + 8\,H_2O\,(l) \longrightarrow 2\,H_3PO_4\,(s) + 10\,HCl\,(g)}$, $\Delta_r H^\circ = -307.6\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{H_3PO_4\,(s)}$ Give your answer to 3 significant figures.

Part I Ga

$\mathrm{Ga_2O_3\,(s) + 3\,Mg\,(s) \longrightarrow 2\,Ga\,(s) + 3\,MgO\,(s)}$, $\Delta_r H^\circ = -716.1\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_c H^\circ$ of Ga.

Part J $\mathrm{HCl\,(g)}$

$\mathrm{TiCl_4\,(l) + 2\,H_2O\,(l) \longrightarrow TiO_2\,(s) + 4\,HCl\,(aq)}$, $\Delta_r H^\circ = -232.3\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_{sol} H^\circ$ of $\mathrm{HCl\,(g)}$ Give your answer to 3 significant figures.

Gameboard:

STEM SMART Chemistry Week 17

C_3H_6 Combustion

A Level

P P P

A and **B** are two isomers with the molecular formula C_3H_6. The standard enthalpies of formation, $\Delta_f H^{\circ}$, of both **A** and **B** have been found by first measuring the standard enthalpies of combustion, $\Delta_c H^{\circ}$, of each. These values are given in the table below, together with the standard enthalpies of combustion of carbon and hydrogen.

	A	**B**	**carbon**	**hydrogen**
$\Delta_c H^{\circ} / \mathrm{kJ\,mol^{-1}}$	-2058	-2091	-393.5	-241.8

Part A Combustion equation

Give the equation for the complete combustion of C_3H_6. (Balance it for one mole of the hydrocarbon.)

Part B $\Delta_f H^{\circ}$ of A

Calculate the standard enthalpy of formation of **A**.

Part C $\Delta_f H^{\circ}$ of B

Calculate the standard enthalpy of formation of **B**.

Part D Isomerisation

Gaseous **B** needs to be stored carefully since it can convert explosively to the elements, to isomer **A**, or to other hydrocarbons. Calculate the standard enthalpy change for the reaction **B** $\longrightarrow$ **A**.

Adapted with permission from the Cambridge Chemistry Challenge 2011, Question 1

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Homologous Series: Combustion

A Level

A student was studying the enthalpies of combustion of different alkanes, and thinking about the pattern seen when descending the homologous series.

Part A General equation

The student started by writing a balanced chemical equation for the combustion of a general alkane C_nH_{2n+2}, by balancing for one mole of the alkane:

$$C_nH_{2n+2} + x\,O_2 \longrightarrow y\,CO_2 + z\,H_2O$$

Find the correct expressions for x, y and z as a function of n.

x:

The following symbols may be useful: n

y:

The following symbols may be useful: n

z:

The following symbols may be useful: n

Part B Bonds broken

Next, the student was thinking about all the bonds present on the left-hand side of the equation previously balanced, which need to be broken in order to form the products. How many of the different types of bond are present, per molecule of C_nH_{2n+2}, assuming a correctly balanced equation?

Number of $C{-}C$ bonds:

The following symbols may be useful: n

Number of $C{-}H$ bonds:

The following symbols may be useful: n

Number of $O{=}O$ bonds:

Part C Bonds formed

The following consideration concerned all the bonds present on the right-hand side of the equation previously balanced, i.e. the bonds formed during the reaction. How many of the different types of bond are present, per molecule of C_nH_{2n+2}, assuming a correctly balanced equation?

Number of $C{=}O$ bonds present:

The following symbols may be useful: n

Number of $O{-}H$ bonds present:

Part D Bond enthalpy assumption

When using average bond enthalpies to estimate enthalpies of reaction, we must assume that the average values used are representative of the bonding present (we can use different average values, e.g. specific to hydrocarbons to improve estimates). What other assumption about the chemicals present must be met for a calculation using bond enthalpies alone to give a good estimate of the enthalpy of reaction?

Part E Bond enthalpy calculation

Using the following bond enthalpies, find an expression for the enthalpy change (in $\mathrm{kJ\,mol^{-1}}$) of the reaction previously written out (corresponding to the complete combustion of C_nH_{2n+2}) assuming it is carried out under conditions so that the assumption from the previous part is met. Do not include the units in the expression, and quote numerical values in the expression to 3 s.f.

Bond	**Bond enthalpy** $/\mathrm{kJ\,mol^{-1}}$
$C-C$	348
$C-H$	412
$O=O$	498
$C=O$ in CO_2	805
$O-H$	463

The following symbols may be useful: n

Part F Deviation at RTP

If the combustion is instead carried out at RTP (room temperature and pressure), how would you expect the empirically obtained enthalpy change of combustion of ethane to compare to that calculated using the formula derived above?

The RTP enthalpy change will be ______ exothermic. This is because ______ is now present as a ______ and energy is ______ during the ______ as ______ bonds are formed.

Items:

more | less | O_2 | H_2O | CO_2 | solid | liquid | gas | steam | absorbed | released | vaporisation | freezing | sublimation | condensation | covalent | ionic | hydrogen

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STEM SMART Chemistry Week 17

Dinitrogen Pentoxide Formation

A Level

In the gas phase, N_2O_5 decomposes to oxygen and nitrogen dioxide. Use the data below (determined at $298\,K$) to calculate the standard enthalpy change at $298\,K$ for the reaction:

$2\,N_2O_5\,(g) \longrightarrow 4\,NO_2\,(g) + O_2\,(g)$

	value$/\mathrm{kJ\,mol^{-1}}$
$\Delta_f H^\circ$ of $N_2O_5\,(g)$	11.3
$\Delta_r H^\circ$ for $NO\,(g) + \frac{1}{2}\,O_2\,(g) \longrightarrow NO_2\,(g)$	-58.1
bond strength in $N_2\,(g)$	945
bond strength in $O_2\,(g)$	498
bond strength in $NO\,(g)$	631

Adapted with permission from the Cambridge Chemistry Challenge, Question 1, 2019