- A bar of hot iron with a mass of 1.000 kg and a temperature of 100.00 °C is plunged into an insulated tank of water. The mass of water was 2.000 kg and its initial temperature was 25.00 °C. What will the temperature of the resulting system be when it has reached equilibrium? The specific heat capacities of water and iron are 4.184 J g^{-1} K^{-1} and 0.4498 J g^{-1} K^{-1}, respectively. 3

Answer:

Marks 4

- A mass of 1.250 g of benzoic acid, $C_7H_6O_2$, underwent combustion in a bomb calorimeter. The heat of combustion of benzoic acid is –3226 kJ mol^{-1}. What is the change in internal energy during this reaction?

Answer:

If the heat capacity of the calorimeter is 10.134 kJ K^{-1}, calculate the temperature change that should have occurred in the apparatus.

Answer:

- What is the value of the enthalpy change for the following reaction? 1

$$MgO(s) + CO_2(g) \rightarrow MgCO_3(s)$$

Data:

Compound	$MgO(s)$	$CO_2(g)$	$MgCO_3(s)$
$\Delta_f H^\circ$ / kJ mol^{-1}	–602	–394	–1096

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks
3

- Consider the following reaction and associated thermochemical data?

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

Data:

Compound	$NO_2(g)$	$N_2O_4(g)$
$\Delta_f H°$ / kJ mol^{-1}	33	9
$S°$ / J K^{-1} mol^{-1}	240	304

What is the expression for the equilibrium constant, K_c, for this reaction?

What are the values of $\Delta H°$ and $\Delta S°$ for the reaction?

$\Delta H°$ =

$\Delta S°$ =

What is the value of $\Delta G°$ for the reaction at 298 K?

$\Delta G°$ =

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks 3

- Consider the following reaction:

$$2N_2O(g) + 3O_2(g) \rightarrow 4NO_2(g)$$

Calculate $\Delta G°$ for this reaction given the following data.

$4NO(g) \rightarrow 2N_2O(g) + O_2(g)$	$\Delta G° = –139.56$ kJ mol$^{–1}$
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$	$\Delta G° = –69.70$ kJ mol$^{–1}$

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks

- Explain the following terms or concept. **3**

Third law of thermodynamics

- The specific heat capacity of water at 0 °C is undefined. Explain why this is so. **2**

Marks
3

- Consider the following reaction:

$$2N_2O(g) + 3O_2(g) \rightarrow 4NO_2(g)$$

Calculate $\Delta G°$ for this reaction given the following data.

$4NO(g) \rightarrow 2N_2O(g) + O_2(g)$	$\Delta G° = -139.56$ kJ mol^{-1}
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$	$\Delta G° = -69.70$ kJ mol^{-1}

Answer:

Marks
2

- Good wine will turn to vinegar if it is left exposed to air because the alcohol is oxidised to acetic acid. The equation for the reaction is

$$C_2H_5OH(l) + O_2(g) \rightarrow CH_3COOH(l) + H_2O(l)$$

Calculate $\Delta S°$ for this reaction in J K^{-1} mol^{-1}.

Data:

	$\Delta S°$ (J K^{-1} mol^{-1})
$C_2H_5OH(l)$	161
$O_2(g)$	205.0
$CH_3COOH(l)$	160
$H_2O(l)$	69.96

Answer:

• Explain the following term or concept.	Mark 1
Second law of thermodynamics	

Marks

- Copper metal can be obtained by heating copper oxide , CuO, in the presence of carbon monoxide, CO, according to the following reaction. **2**

$$CuO(s) + CO(g) \rightarrow Cu(s) + CO_2(g)$$

Calculate $\Delta H°$ for this reaction in kJ mol^{-1}.

Data: $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\Delta H° = –566.1$ kJ mol^{-1}

$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$ $\Delta H° = –310.5$ kJ mol^{-1}

Answer:

- Acetylene burns in air according to the following equation: **2**

$$C_2H_2(g) + {}^5/{}_2O_2(g) \rightarrow 2CO_2(g) + H_2O(g) \quad \Delta H° = –1255.8 \text{ kJ mol}^{-1}$$

The $\Delta_f H°$ of $CO_2(g)$ = –393.5 kJ mol^{-1}, $\Delta_f H°$ of $H_2O(l)$ = –285.8 kJ mol^{-1} and $\Delta_{vap}H°$ of $H_2O(l)$ = +44.0 kJ mol^{-1}. What is $\Delta_f H°$ of $C_2H_2(g)$?

Answer:

- A calorimeter, consisting of an insulated coffee cup containing 50.0 g of water at 21.0 °C, has a total heat capacity of 9.4 J K^{-1}. When a 30.4 g sample of an alloy at 92.0 °C is placed into the calorimeter, the final temperature of the system is 31.2 °C. What is the specific heat capacity of the alloy?

Marks
3

Answer:

- A bar of hot iron with a mass of 1.000 kg and a temperature of 100.00 °C is plunged into an insulated tank of water. The mass of water was 2.000 kg and its initial temperature was 25.00 °C. What will the temperature of the resulting system be when it has stabilised? (The specific heat capacities of water and iron are 4.184 J g^{-1} K^{-1} and 0.4498 J g^{-1} K^{-1}, respectively.) **3**

Answer:

Marks
4

- Nitroglycerine, $C_3H_5(NO_3)_3$, decomposes to form N_2, O_2, CO_2 and H_2O according to the following equation.

$$4C_3H_5(NO_3)_3(l) \rightarrow 6N_2(g) + O_2(g) + 12CO_2(g) + 10H_2O(g)$$

If 15.6 kJ of energy is evolved by the decomposition of 2.50 g of nitroglycerine at 1 atm and 25 °C, calculate the enthalpy change, $\Delta H°$, for the decomposition of 1.00 mol of this compound under standard conditions.

Answer:

Hence calculate the enthalpy of formation of nitroglycerine under standard conditions.

Data:

	$\Delta_f H°$ (kJ mol^{-1})
$H_2O(g)$	–242
$CO_2(g)$	–394

Answer:

- A mass of 1.250 g of benzoic acid ($C_7H_6O_2$) underwent combustion in a bomb calorimeter. If the heat capacity of the calorimeter was 10.134 kJ K^{-1} and the heat of combustion of benzoic acid is –3226 kJ mol^{-1}, what is the change in internal energy during this reaction? **4**

Answer:

Calculate the temperature change that should have occurred in the apparatus.

Answer:

Marks 5

- Carbon monoxide is commonly used in the reduction of iron ore to iron metal. Iron ore is mostly haematite, Fe_2O_3, in which case the complete reduction reaction is:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \qquad \Delta H° = –25 \text{ kJ mol}^{-1}$$

Incomplete reduction, however, results in the formation of magnetite, Fe_3O_4:

$$3Fe_2O_3(s) + CO(g) \rightarrow 2Fe_3O_4(s) + CO_2(g) \qquad \Delta H° = –47 \text{ kJ mol}^{-1}$$

Use these heats of reaction to calculate the enthalpy change when one mole of magnetite is reduced to iron metal using carbon monoxide.

Answer:

Another iron oxide that can be formed as an intermediate during reduction is FeO. Use the following table of thermochemical data to show whether the formation of FeO from Fe_3O_4 is spontaneous or not at 25 °C.

	$\Delta_f H°$ (kJ mol^{-1})	$S°$ (J K^{-1} mol^{-1})
FeO	–272	61
Fe_3O_4	–1118	146
CO	–111	198
CO_2	–394	214

Marks
4

- A 150.0 g block of iron metal is cooled by placing it in an insulated container with a 50.0 g block of ice at 0.0 °C. The ice melts, and when the system comes to equilibrium the temperature of the water is 78.0 °C. What was the original temperature (in °C) of the iron?

  Data: The specific heat capacity of liquid water is 4.184 J K^{-1} g^{-1}.
  The specific heat capacity of solid iron is 0.450 J K^{-1} g^{-1}.
  The molar enthalpy of fusion of ice (water) is 6.007 kJ mol^{-1}.

Answer:

Marks

- Anhydrous copper(II) sulfate is a white powder that reacts with water to give blue crystals of copper(II) sulfate-5-water. **2**

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4{\cdot}5H_2O(s)$$

Calculate the standard enthalpy change for this reaction from the heats of solution.

Compound	$\Delta H°_{solution}$ / kJ mol^{-1}
$CuSO_4(s)$	–66.5
$CuSO_4{\cdot}5H_2O(s)$	+11.7

Answer:

- Using the given data, calculate $\Delta H°$ for the reaction: $H(g) + Br(g) \rightarrow HBr(g)$ **2**

Data:

$H_2(g) \rightarrow 2H(g)$ $\Delta H° = +436$ kJ mol^{-1}

$Br_2(g) \rightarrow 2Br(g)$ $\Delta H° = +193$ kJ mol^{-1}

$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$ $\Delta H° = -72$ kJ mol^{-1}

$\Delta H°$ =

Marks 6

- The final step in the industrial production of urea, $(NH_2)_2CO$, is:

$CO_2(g) + 2NH_3(g) \rightarrow H_2O(g) + (NH_2)_2CO(s)$ $\Delta H° = -90.1 \text{ kJ mol}^{-1}$

Using the following data, calculate the standard enthalpy of formation of solid urea.

$4NH_3(g) + 3O_2(g) \rightarrow 6H_2O(g) + 2N_2(g)$ $\Delta H° = -1267.2 \text{ kJ mol}^{-1}$

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H° = -393.5 \text{ kJ mol}^{-1}$

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta H° = -483.6 \text{ kJ mol}^{-1}$

Answer:

The formation of urea in the industrial process is only spontaneous below 821 °C. What is the value of the entropy change $\Delta S°$ (in J K^{-1} mol^{-1}) for the reaction?

Answer:

Rationalise the sign of $\Delta S°$ in terms of the physical states of the reactants and products.

Marks
2

- The specific heat capacity of water is 4.18 J g^{-1} K^{-1} and the specific heat capacity of copper is 0.39 J g^{-1} K^{-1}. If the same amount of energy were applied to a 1.0 mol sample of each substance, both initially at 25 °C, which substance would get hotter? Show all working.

Answer:

Marks
3

- "Water gas" is a mixture of combustible gases produced from steam and coal according to the following reaction:

$$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g) \qquad \Delta H^\circ = 131 \text{ kJ mol}^{-1}$$

The equation for the complete combustion of 1 mol of water gas (*i.e.* 0.5 mol CO(g) and 0.5 mol $H_2(g)$) can be written as:

$$\tfrac{1}{2}CO(g) + \tfrac{1}{2}H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow \tfrac{1}{2}CO_2(g) + \tfrac{1}{2}H_2O(g)$$

Calculate the standard enthalpy of combustion of water gas, given the following thermochemical data.

ΔH°_{vap} (H_2O) = 44 kJ mol^{-1}
ΔH°_f ($H_2O(l)$) = –286 kJ mol^{-1}
ΔH°_f ($CO_2(g)$) = –393 kJ mol^{-1}

Answer:

THIS QUESTION CONTINUES ON THE NEXT PAGE.

Marks

2

- Anhydrous copper(II) sulfate is a white powder that reacts with water to give the familiar light blue crystals of copper(II) sulfate-5-water.

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4{\cdot}5H_2O(s)$$

Calculate the standard enthalpy change for this reaction from the heats of solution.

Compound	$\Delta H^\circ_{solution}$ / kJ mol^{-1}
$CuSO_4(s)$	-66.5
$CuSO_4{\cdot}5H_2O(s)$	+11.7

Answer:

3

- Using the given data, calculate ΔH° for the reaction: $H(g) + Br(g) \rightarrow HBr(g)$

Data:

$H_2(g) \rightarrow 2H(g)$ $\Delta H^\circ = +436$ kJ mol^{-1}

$Br_2(g) \rightarrow 2Br(g)$ $\Delta H^\circ = +193$ kJ mol^{-1}

$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$ $\Delta H^\circ = -72$ kJ mol^{-1}

Answer:

- Calculate the heat input required (in J) for the conversion of 9.0 g of water from ice at 273 K to steam at 373 K. **2**

  Data: C_p $H_2O(l)$ = 75 J K^{-1} mol^{-1}

  ΔH_{vap} $H_2O(l)$ = 41 kJ mol^{-1} ΔH_{fus} $H_2O(s)$ = 6.0 kJ mol^{-1}