

- 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<sup>-1</sup> K<sup>-1</sup> and 0.4498 J g<sup>-1</sup> K<sup>-1</sup>, respectively.

3

Answer:

**Marks**  
**4**

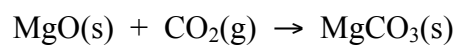
- A mass of 1.250 g of benzoic acid,  $C_7H_6O_2$ , underwent combustion in a bomb calorimeter. The heat of combustion of benzoic acid is  $-3226 \text{ kJ mol}^{-1}$ . What is the change in internal energy during this reaction?

Answer:

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

Answer:

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

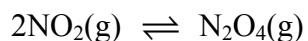


Data:	Compound	MgO(s)	CO <sub>2</sub> (g)	MgCO <sub>3</sub> (s)
	$\Delta_f H^\circ / \text{kJ mol}^{-1}$	-602	-394	-1096

Answer:

**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

- Consider the following reaction and associated thermochemical data?



Data:

Compound	$\text{NO}_2(\text{g})$	$\text{N}_2\text{O}_4(\text{g})$
$\Delta_f H^\circ / \text{kJ mol}^{-1}$	33	9
$S^\circ / \text{J K}^{-1} \text{mol}^{-1}$	240	304

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

**Marks**  
**3**

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

$\Delta H^\circ =$

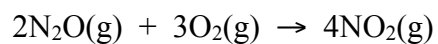
$\Delta S^\circ =$

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

$\Delta G^\circ =$

**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

- Consider the following reaction:



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

**Marks****3**

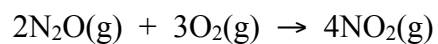
Answer:

**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

<ul style="list-style-type: none"><li>• Explain the following terms or concept.</li></ul>	<b>Marks</b> <b>3</b>
Third law of thermodynamics	
<ul style="list-style-type: none"><li>• The specific heat capacity of water at 0 °C is undefined. Explain why this is so.</li></ul>	<b>2</b>

**Marks**  
**3**

- Consider the following reaction:

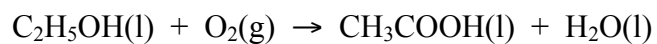


Calculate  $\Delta G^\circ$  for this reaction given the following data.



Answer:

- 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



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

Data:		$\Delta S^\circ$ ( $\text{J K}^{-1} \text{mol}^{-1}$ )
	$\text{C}_2\text{H}_5\text{OH}(\text{l})$	161
	$\text{O}_2(\text{g})$	205.0
	$\text{CH}_3\text{COOH}(\text{l})$	160
	$\text{H}_2\text{O}(\text{l})$	69.96

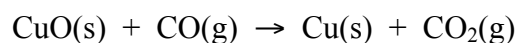
**Marks****2**

Answer:

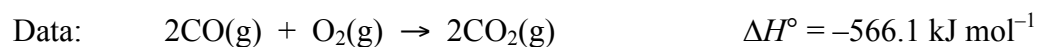


<ul style="list-style-type: none"><li>• Explain the following term or concept.</li></ul>	<b>Mark 1</b>
Second law of thermodynamics	

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



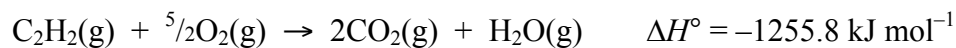
Calculate  $\Delta H^\circ$  for this reaction in  $\text{kJ mol}^{-1}$ .



**Marks**  
**2**

Answer:

- Acetylene burns in air according to the following equation:



The  $\Delta_f H^\circ$  of  $\text{CO}_2\text{(g)} = -393.5 \text{ kJ mol}^{-1}$ ,  $\Delta_f H^\circ$  of  $\text{H}_2\text{O(l)} = -285.8 \text{ kJ mol}^{-1}$  and  $\Delta_{\text{vap}} H^\circ$  of  $\text{H}_2\text{O(l)} = +44.0 \text{ kJ mol}^{-1}$ . What is  $\Delta_f H^\circ$  of  $\text{C}_2\text{H}_2\text{(g)}$ ?

**2**

Answer:

**Marks**  
**3**

- 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<sup>-1</sup>. 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?

Answer:

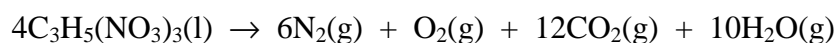
- A bar of hot iron with a mass of 1.000 kg and a temperature of 100.00 °C is plunged into an insulated tank of water. The mass of water was 2.000 kg and its initial temperature was 25.00 °C. What will the temperature of the resulting system be when it has stabilised? (The specific heat capacities of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



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,  $\Delta H^\circ$ , 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:		$\Delta_f H^\circ$ (kJ mol <sup>-1</sup> )
	H <sub>2</sub> O(g)	-242
	CO <sub>2</sub> (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  $10.134 \text{ kJ K}^{-1}$  and the heat of combustion of benzoic acid is  $-3226 \text{ kJ mol}^{-1}$ , what is the change in internal energy during this reaction?

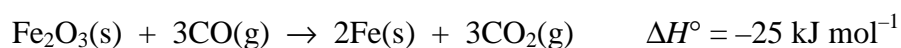
Answer:

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

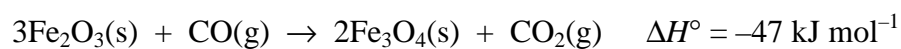
Answer:

**Marks**  
**5**

- Carbon monoxide is commonly used in the reduction of iron ore to iron metal. Iron ore is mostly haematite,  $\text{Fe}_2\text{O}_3$ , in which case the complete reduction reaction is:



Incomplete reduction, however, results in the formation of magnetite,  $\text{Fe}_3\text{O}_4$ :



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  $\text{Fe}_3\text{O}_4$  is spontaneous or not at 25 °C.

	$\Delta_f H^\circ$ (kJ mol <sup>-1</sup> )	$S^\circ$ (J K <sup>-1</sup> mol <sup>-1</sup> )
FeO	-272	61
Fe <sub>3</sub> O <sub>4</sub>	-1118	146
CO	-111	198
CO <sub>2</sub>	-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  $4.184 \text{ J K}^{-1} \text{ g}^{-1}$ .

The specific heat capacity of solid iron is  $0.450 \text{ J K}^{-1} \text{ g}^{-1}$ .

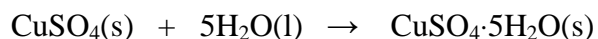
The molar enthalpy of fusion of ice (water) is  $6.007 \text{ kJ mol}^{-1}$ .

Answer:



**Marks**  
**2**

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



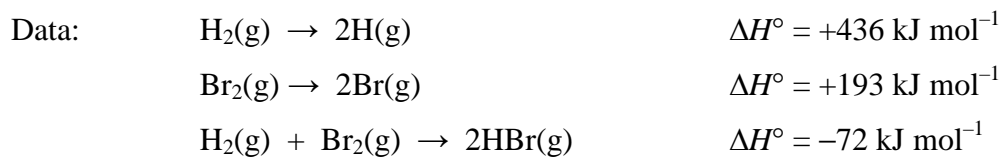
Calculate the standard enthalpy change for this reaction from the heats of solution.

Compound	$\Delta H^\circ_{\text{solution}} / \text{kJ mol}^{-1}$
$\text{CuSO}_4(\text{s})$	-66.5
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$	+11.7

Answer:

**2**

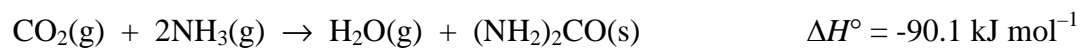
- Using the given data, calculate  $\Delta H^\circ$  for the reaction:  $\text{H}(\text{g}) + \text{Br}(\text{g}) \rightarrow \text{HBr}(\text{g})$



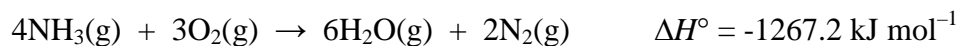
$\Delta H^\circ =$

**Marks**  
**6**

- The final step in the industrial production of urea,  $(\text{NH}_2)_2\text{CO}$ , is:



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



Answer:

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

Answer:

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

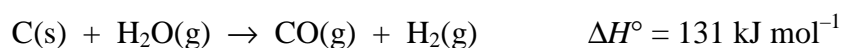
- The specific heat capacity of water is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$  and the specific heat capacity of copper is  $0.39 \text{ J g}^{-1} \text{ K}^{-1}$ . If the same amount of energy were applied to a 1.0 mol sample of each substance, both initially at  $25 \text{ }^\circ\text{C}$ , which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

**Marks**  
**2**

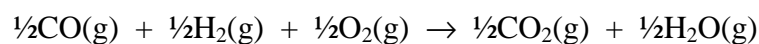
Answer:

**Marks**  
**3**

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



The equation for the complete combustion of 1 mol of water gas (*i.e.* 0.5 mol CO(g) and 0.5 mol H<sub>2</sub>(g)) can be written as:



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

$$\Delta H^\circ_{\text{vap}}(\text{H}_2\text{O}) = 44 \text{ kJ mol}^{-1}$$

$$\Delta H^\circ_{\text{f}}(\text{H}_2\text{O(l)}) = -286 \text{ kJ mol}^{-1}$$

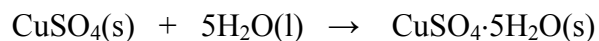
$$\Delta H^\circ_{\text{f}}(\text{CO}_2\text{(g)}) = -393 \text{ kJ mol}^{-1}$$

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.



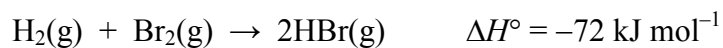
Calculate the standard enthalpy change for this reaction from the heats of solution.

Compound	$\Delta H^\circ_{\text{solution}} / \text{kJ mol}^{-1}$
$\text{CuSO}_4(\text{s})$	-66.5
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$	+11.7

Answer:

**3**

- Using the given data, calculate  $\Delta H^\circ$  for the reaction:  $\text{H}(\text{g}) + \text{Br}(\text{g}) \rightarrow \text{HBr}(\text{g})$



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:  $C_p \text{H}_2\text{O(l)} = 75 \text{ J K}^{-1} \text{ mol}^{-1}$

$\Delta H_{\text{vap}} \text{H}_2\text{O(l)} = 41 \text{ kJ mol}^{-1}$        $\Delta H_{\text{fus}} \text{H}_2\text{O(s)} = 6.0 \text{ kJ mol}^{-1}$