Test bank: Focus 02

Type: multiple choice question
Title: Focus 02 - Question 01
01) Calculate the expansion work done *on* the system when exactly 1 mol of solid ammonium chloride, NH_4Cl, decomposes completely to yield gaseous ammonia, NH_3 and hydrogen chloride, HCl at a temperature of 1250 K. Treat the expansion as irreversible and the gases formed as perfect.
Feedback: The work done on a system when it expands against a constant pressure is given by eqn 2A.1a

$$w = -p_{ex}\Delta V$$

The decomposition of exactly 1 mol of solid ammonium chloride
$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$ yields 2 mol of gas. We may assume that the volume of the solid ammonium chloride is negligible in comparison with the volume of the gas produced. The change in volume on decomposition is therefore

$$\Delta V = V_f - V_i \approx V_f$$

Treating the gas as perfect, so that

$$V_f = \frac{nRT}{p_{ex}}$$

then

$$w = -p_{ex} \times \frac{nRT}{p_{ex}} = -nRT = -(2.00\ mol) \times (8.3145\ J\ K^{-1} mol^{-1}) \times (1250\ K)$$
$$= -20.8\ \times 10^3 J = -20.8\ kJ$$

Page reference: 41
a. –15.4 kJ
b. –4.96 kJ
c. –16.6 kJ
***d.** –20.8 kJ

Type: multiple choice question
Title: Focus 02 - Question 02
02) Calculate the heat transferred to the system when 1.00 mol of a perfect gas expands reversibly at a constant temperature of 25°C so that its volume doubles.
Feedback: For the isothermal expansion of a perfect gas, eqn 2B.4 shows that the heat transferred and work done are related by

$$q = -w$$

and so, using eqn 2A.2 for a reversible expansion, we obtain eqn 2B.5,

$$q = -nRTln V_f / V_i$$

For this expansion,

$$V_f / V_i = 2$$

so that

$$q = -(1.00\ mol) \times (8.3145\ J\ K^{-1} mol^{-1}) \times (273 + 25) K \times \ln 2 = -1.72 \times 10^3 J$$
$$= -1.72\ kJ\ mol^{-1}$$

Page reference: 43, 51
a. –144 J
b. –746 J
***c.** –1.72 kJ mol^{-1}
d. 2.48 kJ

Type: multiple choice question
Title: Focus 02 - Question 03
08) The constant pressure molar heat capacity of zinc is 25.40 J K^{-1} mol^{-1} at 298 K. Calculate the constant pressure specific heat capacity of zinc at this temperature.
Feedback: Specific heat capacity is defined as the heat capacity per unit mass of sample

$$C_s = C/m$$

and so,

$$C_s = C_{p,m}/M$$

For zinc, the molar mass is

$$M = 65.37\ \ g\ \ mol^{-1}$$

so that

$$C_s = C_{p,m}/M = \left(25.40\ \ J\ \ K^{-1} mol^{-1}\right)\ /\ \left(65.37 \times 10^{-3} kg\ \ mol^{-1}\right) = 388.6\ \ J\ \ K^{-1} kg^{-1}$$

Page reference: 48
a. 1.660 kJ K^{-1} kg^{-1}
***b.** 388.6 J K^{-1} kg^{-1}
c. 17.09 J K^{-1} kg^{-1}
d. 33.71 J K^{-1} kg^{-1}

Type: multiple choice question
Title: Focus 02 - Question 04
03) The molar heat capacity of solid aluminium is 24.4 J K^{-1} mol^{-1} at 25°C. Calculate the change in internal energy when 1.00 mol of solid aluminium is heated from a temperature of 20°C to 30°C.
Feedback: Heat capacity is defined by eqn 2C.4a and so we can write

$$\Delta U = C_V \Delta T$$

For a solid,

$$C_p \approx C_V$$

and so we do not need to worry about the distinction between the heat capacity at constant volume and pressure. We may also reasonably assume that the heat capacity does not vary over the range of temperature. A change in temperature from 20 °C to 30 °C means

$$\Delta T = +10\ \ K$$

Thus

$$\Delta U = n C_m \Delta T = \left(1.00\ \ mol\right)\ \times \left(24.4\ \ J\ \ K^{-1} mol^{-1}\right) \times \left(10\ \ K\right) = 244\ \ J$$

Page reference: 54
***a.** 244 J
b. 24.4 J
c. 171 J
d. 327 J

Type: multiple choice question
Title: Focus 02 - Question 05
04) The constant pressure molar heat capacity of ammonia, NH_3, has been found to vary with temperature according to the relation

$$C_{p,m}\ \ /\ \ J\ \ K^{-1} mol^{-1} = a + bT + c/T^2$$

with $a = 29.73$, $b = 25.1 \times 10^{-3}$ K^{-1} and $c = -1.55 \times 10^5$ K^2. Calculate the value of the constant pressure molar heat capacity at 25.0 °C.
Feedback: The constant pressure molar heat capacity may be calculated by direct substitution. We must, however, remember to convert the temperature to units of kelvin. Thus

$$T = \left(273.15 + 25.0\right) K\ \ = 298.15\ \ K$$

so that

$$C_{p,m}/\left(\ J\ \ K^{-1} mol^{-1}\right) = a + bT + \frac{c}{T^2}$$

$$= 29.73 + \left\{\left(25.1 \times 10^{-3}\ \ K^{-1}\right) \times \left(298.15\ \ K\right)\right\} - \left\{1.55 \times 10^5\ \ K^2 / \left(298.15\ \ K\right)^2\right\}\ =\ 35.47$$

Thus

$$C_{p,m} = 35.47\ \ J\ \ K^{-1} mol^{-1}$$

Page reference: 59

a. 217.6 J K^{-1} mol^{-1}
b. 29.73 J K^{-1} mol^{-1}
***c.** 35.47 J K^{-1} mol^{-1}
d. 657.2 J K^{-1} mol^{-1}

Type: multiple choice question

Title: Focus 02 - Question 06

05) In the calibration step of a thermochemistry experiment, a current of 117 mA, from a 24.0 V source was allowed to flow through the electrical heater for 247 s and was found to result in an increase in the temperature of the calorimeter and its contents of +1.25 K. Calculate the heat capacity of the calorimeter and its contents.

Feedback: Heat capacity is defined by eqn 2B.1

$$C = q / \Delta T$$

For an electrical heater, the amount of heat transferred is given by eqn 2B.3

$$q_{cal} = I V t$$

so that, if we combine these two expressions

$$C = I V t / \ \Delta T = \left(117 \times 10^{-3} A\right) \times \left(24.0 \ \ V\right) \times \left(247 \ \ s\right) \ / \ \left(1.25 \ \ K\right) = 555 \ \ J \ \ K^{-1}$$

Page reference: 50

a. 694 J K^{-1}
b. 277 J K^{-1}
***c.** 555 J K^{-1}
d. 867 J K^{-1}

Type: multiple choice question

Title: Focus 02 - Question 07

06) The constant pressure molar heat capacity of methane, CH_4, is 35.31 J K^{-1} mol^{-1} at temperatures close to 298 K. Calculate the enthalpy change when 2.00 mol of methane is heated from a temperature of 278 K to 318 K.

Feedback: We may calculate the change in enthalpy on heating by rearranging eqn 2B.5

$$\Delta H = C \, \Delta T$$

if we know that the heat capacity is constant and does not vary with temperature. We know the constant pressure molar heat capacity, so that

$$C = n \ \ C_{p,m}$$

$$\Delta H = n \ \ C_{p,m} \ \ \Delta T = \left(2.00 \ \ mol\right) \times \left(35.31 \ \ J \ \ K^{-1} mol^{-1}\right) \times \left(318 - 278\right) \ K$$
$$= 2830 \ \ J = 2.83 \ \ kJ$$

Page reference: 59

a. 21.2 kJ
b. 353 J
c. 1.41 kJ
***d.** 2.83 kJ

Type: multiple choice question

Title: Focus 02 - Question 08

07) The constant pressure molar heat capacity of argon is 20.79 J K^{-1} mol^{-1} at 298 K. Predict the value of the constant volume molar heat capacity of argon at this temperature.

Feedback: For a perfect gas, eqn 2D.7, shows that

$$C_{p,m} - C_{V,m} = R$$

and hence

$$C_{V,m} = C_{p,m} - R = \left(20.79 \ \ J \ \ K^{-1} mol^{-1}\right) - \left(8.3145 \ \ J \ \ K^{-1} mol^{-1}\right) = 12.48 \ \ J \ \ K^{-1} mol^{-1}$$

This relationship holds only for perfect gases. The volume of solids and liquids varies little with temperature and the difference between the molar heat capacity at constant pressure and constant volume is much less.

Page reference: 60

a. 29.11 J K^{-1} mol^{-1}
b. 8.31 J K^{-1} mol^{-1}
c. 4.16 J K^{-1} mol^{-1}
***d.** 12.48 J K^{-1} mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 09
09) The heat capacity of a bomb calorimeter and its contents was measured to be 6.14 kJ K^{-1}. Calculate the change in temperature when a current of 245 mA from a 12.0 V source was allowed to flow through the electrical heater for a period of 254 s.
Feedback: Heat capacity is defined by eqn 2B.1

$$C = q / \Delta T$$

For an electrical heater, the amount of heat transferred is given by eqn 2B.3

$$q_{cal} = I V t$$

so that, if we combine these two expressions,

$$\Delta T = I V t / C = \left(245 \times 10^{-3} A\right) \times \left(12.0 \ V\right) \times \left(254 \ s\right) \ / \ \left(6.14 \times 10^{3} J \ K^{-1}\right)$$
$$= +0.122 \ K$$

Page reference: 50
***a.** +0.122 K
b. +4.59 K
c. +18.7 K
d. +2.45 K

Type: multiple choice question
Title: Focus 02 - Question 10
10) The constant pressure molar heat capacity of nitrogen gas, N_2, is 29.125 J K^{-1} mol^{-1} at 298.15 K. Calculate the change in the internal energy when 2.00 mol of nitrogen gas is heated so that its temperature increases by 25.0°C. Assume that the value of the heat capacity does not vary with temperature.
Feedback: The change in internal energy on heating is

$$\Delta U = q_V = C_V \Delta T$$

and therefore for an amount *n*

$$\Delta U = n \ C_{V,m} \Delta T$$

For a perfect gas, from eqn 2D.7,

$$C_{p,m} - C_{V,m} = R$$

and so

$$C_{V,m} = C_{p,m} - R$$

Thus

$$\Delta U = n \ \left(C_{p,m} - R\right) \ \Delta T = \left(2.00 \ mol\right) \times \left\{\left(29.125 - 8.3145\right) \ J \ K^{-1} mol^{-1}\right\} \times \left(25.0 \ K\right)$$
$$= 1040 \ J = 1.04 \ kJ$$

Page reference: 54, 60
***a.** 1.04 kJ
b. 1.46 kJ
c. 1.87 kJ
d. 520 J

Type: multiple choice question
Title: Focus 02 - Question 11
03) Use the following data to determine the standard enthalpy change for the reaction $K(g) + \frac{1}{2}Cl_2(g) \rightarrow K^+(g) + \frac{1}{2}Cl^-(g)$ at a temperature of 298.15 K. The values refer to standard enthalpy changes at this temperature.

Ionization enthalpy of potassium

$\Delta_{\text{ion}}H^{\ominus} = +418\ \text{kJ mol}^{-1}$

Enthalpy of formation of atomic chlorine

$\Delta_{\text{f}}H^{\ominus} = +121\ \text{kJ mol}^{-1}$

Electron gain enthalpy of atomic chlorine

$\Delta_{\text{eg}}H^{\ominus} = -349\ \text{kJ mol}^{-1}$

Feedback: We may express the reaction as a series of steps

$$K(g) + \tfrac{1}{2}Cl_2(g) \rightarrow K^+(g) + e^- + \tfrac{1}{2}Cl_2(g) \rightarrow K^+(g) + e^- + Cl(g) \rightarrow K^+(g) + \tfrac{1}{2}Cl^-(g)$$

We know the enthalpy changes for each of these individual steps, because the first step corresponds to ionization of potassium, the second step formation of atomic chlorine and the final step electron gain by atomic chlorine.

Thus

$$\Delta_r H^o = (+418 + 121 - 349)\ kJ\ mol^{-1} = +190\ kJ\ mol^{-1}$$

Note that the enthalpy change for electron gain is negative; the process is exothermic. The final value for the overall reaction is, however, positive, indicating that it is endothermic.

Page reference: 66

***a.** +190 kJ mol^{-1}
b. +888 kJ mol^{-1}
c. –52 kJ mol^{-1}
d. +646 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 12

01) A sample of liquid butan-1-ol, C_4H_7OH was brought to the boil in an open calorimeter. An electric current of 289 mA from a 12.0 V source was then passed through a resistive heater coil which was immersed in the liquid. The current was allowed to flow for a period of 245 s, during which time the temperature remained constant and 1.416 g of butan-1-ol was found to have evaporated. Calculate the molar enthalpy of vaporization of butan-1-ol.

Feedback: We can use eqn 2B.3 to calculate the energy provided when a current flows through the heater coil

$q_{cal} = I V \Delta t$This is the heat required to vaporize 5.42 g of butan-1-ol. Because the process occurs at constant pressure,

$$\Delta H = q_p = q$$

The standard enthalpy of vaporization is a molar quantity

$$\Delta_{vap} H^o = \frac{\Delta H}{n}$$

and the amount vaporized is given by

$$n = \frac{m}{M}$$

so that, because the molar mass of butan-1-ol is

$$M = \{(4 \times 12.01) + (8 \times 1.01) + 16.00\}\ g\ mol^{-1} = 72.12\ g\ mol^{-1},$$

then

$$\Delta_{vap} H^o = \frac{IV\Delta t}{m/M} = \frac{IV\Delta tM}{m} = \frac{(0.289\ A) \times (12.0\ V) \times (245\ s) \times (72.12\ g\ mol^{-1})}{(1.416\ g)}$$

$$= 43.3\ \times 10^3\ J\ mol^{-1} = 43.3\ kJ\ mol^{-1}$$

Page reference: 50, 71

a. 86.8 kJ mol^{-1}
b. 850 J mol^{-1}
c. 16.7 kJ mol^{-1}
***d.** 43.3 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 13

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07) The mean bond enthalpy of a P–Cl bond is 331 kJ mol^{-1} and of a Cl–Cl bond is 242 kJ mol^{-} at 298 K. If the mean standard enthalpy of atomization of white phosphorus is 315 kJ mol^{-1}, estimate the standard enthalpy of formation of gaseous phosphorus trichloride, PCl_3, at this temperature.
Feedback: We may write the chemical equation for the formation of phosphorus trichloride from its constituent elements

$$P(s, white) + 3/2\ Cl_2(g) \rightarrow PCl_3(g)$$

as a series of steps

$$P(s, white) + 3/2\ Cl_2(g) \rightarrow P(g) + 3/2\ Cl_2(g) \rightarrow P(g) + 3\ Cl(g) \rightarrow PCl_3(g)$$

The standard enthalpy of reaction is therefore the combination of the energy required to atomize the phosphorus and chlorine and the energy released by the formation and condensation of the phosphorus trichloride. Thus

$$\Delta_f H^o = \Delta_a H(P,\ white) + \{(3/2)\ \times\ \Delta_B H(Cl-Cl)\} - \{3\ \times\ \Delta_B H(P-Cl)\}$$
$$= [315 + \{(3/2)\ \times\ 242\} - (3\ \times\ 331)]\ kJ\ mol^{-1} = -315\ kJ\ mol^{-1}$$

Page reference: 69–71
***a.** –315 kJ mol^{-1}
b. +226 kJ mol^{-1}
c. +1671 kJ mol^{-1}
d. -1041 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 14
08) The standard enthalpy of formation of methane, CH_4, is –75 kJ mol^{-1} at 298.15 K. Calculate the mean bond enthalpy of a H–CH_3 bond, given that, at this temperature, the standard enthalpy of atomization of carbon

$$C(s, graphite) \rightarrow C(g)$$

is +717 kJ mol^{-1} and the standard bond enthalpy of hydrogen, H_2, is 436 kJ mol^{-1}.
Feedback: Writing the chemical formation for the formation of methane

$$C(s, graphite) + 2\ H_2(g) \rightarrow CH_4(g)$$

as a series of steps

$$C(s, graphite) + 2\ H_2(g) \rightarrow C(g) + 2\ H_2(g) \rightarrow C(g) + 4\ H(g) \rightarrow CH_4(g)$$

allows us to see that

$$\Delta_f H^o(CH_4) = \Delta_a H(C,\ graphite) + \{2\ \times\ \Delta_B H(H-H)\} - \{4\ \times\ \Delta_B H(CH_3-H)\}$$

Rearranging gives

$$\Delta_B H(CH_3-H) = \tfrac{1}{4}[\Delta_a H(C,\ graphite) + \{2\ \times\ \Delta_B H(H-H)\} - \Delta_f H^o(CH_4)]$$
$$= \tfrac{1}{4}[+717 + (2\ \times\ +436) - (-75)]\ kJ\ mol^{-1} = \tfrac{1}{4}\ \times\ 1664\ kJ\ mol^{-1} = +416\ kJ\ mol^{-1}$$

The result is in reasonable agreement with the accepted value for the bond enthalpy of a H–CH_3 bond, which is +435 kJ mol^{-1}.
Page reference: 69–71
a. +1664 kJ mol^{-1}
b. +1078 kJ mol^{-1}
c. +379 kJ mol^{-1}
***d.** +416 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 15
02) When 7.82 g of benzaldehyde, C_6H_5CHO, was burned in a bomb calorimeter at 298.15 K, the heat released was 259.2 kJ. Calculate the enthalpy of combustion of benzaldehyde at this temperature.
Feedback: Processes carried out in a bomb calorimeter occur at constant volume. The heat transferred is therefore

$$q = q_V$$

and is the change in the internal energy

$$\Delta U = q$$

The molar mass of benzaldehyde is

$$M = \{(7 \times 12.01) + (6 \times 1.01) + 16.00\} \ g \ mol^{-1} = 106.12 \ g \ mol^{-1}$$

and therefore because the amount of substance is

$$n = m / M$$

the molar change in internal energy on combustion

$$\Delta_c U = \Delta U / n = \Delta U \ \times \ (M / m) = (259.2 \ kJ) \ \times \ (106.12 \ g \ mol^{-1}) / \ (7.82 \ g)$$

$$= 3517 \ kJ \ mol^{-1}$$

Enthalpy and internal energy are related by eqn 2.11

$$H = U + pV$$

or, if we consider molar quantities

$$H_m = U_m + p V_m$$

Since for solids and liquids, the molar volume is small, for substances in these phases

$$H_m \approx U_m$$

However, for gases, the molar volume is more significant and we can use the perfect gas equation

$$p V_m = RT$$

to write, for a substance in the gas phase,

$$H_m = U_m + RT$$

For a reaction, such as combustion, the difference between the enthalpy change and internal energy change therefore depends only on the change in the gas-phase species. Applying eqn 2F.1,

$$\Delta_c H = \Delta_c U + \Delta \nu_{gas} RT$$

where $\Delta \nu_{\text{gas}}$ is the difference in the stoichiometric coefficients of the gas-phase products and reactants.

The chemical equation for the combustion of benzaldehyde is

$C_6H_5CHO(l) + 7\ O_2(g) \rightarrow 6\ CO_2(g) + 3\ H_2O(l)$ so that

$$\Delta \nu_{gas} = 6 - 7 = -1$$

Thus

$$\Delta_c H = \Delta_c U - (1 \ \times \ RT)$$

$$= -3517 \ \times 10^3 \ J \ mol^{-1} - \{(8.3145 \ J \ K^{-1} mol^{-1}) \ \times \ (298.15 \ K)\}$$

$$= -3520 \ \times 10^3 \ J \ mol^{-1} = -3520 \ kJ \ mol^{-1}$$

Page reference: 73

a. 262 kJ mol^{-1}

b. 3515 kJ mol^{-1}

c. 257 kJ mol^{-1}

***d.** –3520 kJ mol^{-1}

Type: multiple choice question

Title: Focus 02 - Question 16

04) Use the following data to determine the standard enthalpy of reaction at 298 K for the addition of hydrogen chloride, HCl, to ethene, C_2H_4

$$C_2H_4(g) + HCl(g) \rightarrow C_2H_5Cl(g)$$

	$\Delta_f H^\ominus$(298 K) / kJ mol^{-1}
C_2H_4	+52.2
HCl	–92.3
C_2H_5Cl	–109.8

Feedback: The application of Hess's law means that we can use eqn 2F.3 to calculate the standard enthalpy of reaction if we know the standard enthalpies of formation of the products and reactants. Thus

$$\Delta_r H^o = \sum \nu \Delta_f H^o(products) - \sum \nu \Delta_f H^o \ (reactants)$$
$$= \Delta_f H^o(C_2H_5Cl,\ g) - \{\Delta_f H^o(C_2H_4,\ g) + \Delta_f H^o(HCl,\ g)\}$$
$$= \{-109.8 - (52.2 - 92.3)\}\ kJ\ \ mol^{-1} = -69.7\ \ kJ\ \ mol^{-1}$$

Page reference: 73–75

a. –34.7 kJ mol^{-1}
b. 149.9 kJ mol^{-1}
***c.** –69.7 kJ mol^{-1}
d. 254.3 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 17
05) The standard enthalpy of formation of benzoic acid, C_6H_5COOH, is –385 kJ mol^{-1} at 298 K. Calculate the standard enthalpy of combustion of benzoic acid at this temperature, given that the standard enthalpy of formation of liquid water, H_2O is –285.8 kJ mol^{-1} and gaseous carbon dioxide, CO_2, is –393.51 kJ mol^{-1}.
Feedback: We can use eqn 2F.3.5 to calculate the standard enthalpy of reaction if we know the standard enthalpies of formation of the products and reactants

$$\Delta_r H^o = \sum \nu \Delta_f H^o(products) - \sum \nu \Delta_f H^o(reactants)$$

The chemical equation for combustion of benzoic acid is

$$C_6H_5COOH(s) + 7\tfrac{1}{2}\ O_2(g) \rightarrow 7\ CO_2(g) + 3\ H_2O(l)$$

so that, because the standard enthalpy of formation of gaseous oxygen, O_2, is defined as exactly 0 kJ mol^{-1}, we can write

$$\Delta_r H^o = \{7 \times \Delta_f H^o(CO_2) + 3 \times \Delta_f H^o(H_2O)\} - \Delta_f H^o(C_6H_5COOH)$$
$$= \{(7\ \times\ -393.51\ \ kJ\ \ mol^{-1}) + (3\ \times\ -285.8\ \ kJ\ \ mol^{-1})\} - (-385.0\ \ kJ\ \ mol^{-1})$$
$$= -3227.0\ \ kJ\ \ mol^{-1}$$

Page reference: 73
a. –294.3 kJ mol^{-1}
b. –3997 kJ mol^{-1}
***c.** –3227.0 kJ mol^{-1}
d. 2282.2 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 18
06) Hydrazine, N_2H_4, may be produced by the reaction

$$2\ NH_3(g) + H_2O_2(l) \rightarrow N_2H_4(l) + H_2O(l)$$

Use the following data for the standard enthalpies of formation at 298 K for the various species to calculate the standard enthalpy of reaction at this temperature.

	$\Delta_f H^⦵$ / (kJ mol^{-1}
$NH_3(g)$	–46
$H_2O_2(l)$	–188
$N_2H_4(l)$	+51
$H_2O(l)$	–286

Feedback: We know the standard enthalpies of formation of the products and reactants and can therefore use eqn 2F.3 to calculate the standard enthalpy of reaction. Thus

$$\Delta_r H^o = \sum \nu \Delta_f H^o(products) - \sum \nu \Delta_f H^o(reactants)$$
$$= \{\Delta_f H^o(N_2H_4) + \Delta_f H^o(H_2O)\} - [\{2\ \times\ \Delta_f H^o(NH_3)\} + \Delta_f H^o(H_2O_2)]$$
$$= [\{51 - 286\} - \{(2 \times 46) - 188\}]\ \ kJ\ \ mol^{-1} = +45\ \ kJ\ \ mol^{-1}$$

Page reference: 73

***a.** +45 kJ mol^{-1}
b. –139 kJ mol^{-1}
c. –1 kJ mol^{-1}
d. –469 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 19
09) The enthalpy of vaporization of tetrachloromethane, CCl_4, is 30.5 kJ mol^{-1} at its normal boiling temperature of 350 K. Estimate the enthalpy of vaporization at 298 K, given that the molar constant pressure heat capacities of liquid and gaseous tetrachloromethane are 83.5 and 135 J K^{-1} mol^{-1}.
Feedback: We can use Kirchhoff's law, eqn 2F.4,

$$\Delta_r H^o(T') = \Delta_r H^o(T) \ + \ \Delta_r C_p^o \times (T' - T)$$

to calculate the change in a standard enthalpy of reaction because we know the heat capacities at constant pressure of the products and reactants. The quantity $\Delta_r C_p°$ is the difference between the standard molar heat capacities of the vapour and the liquid, so that

$$\Delta_{vap} H^o(298 \ \ K) = (30.5 \ \ \times 10^3 \ \ J \ \ mol^{-1}) + \{(135 - 83.5) \ \ J \ \ K^{-1} mol^{-1} \ \ \times \ \ (298 - 350) \ \ K\}$$

$$= 27.8 \ \ \times \ \ 10^3 \ \ J \ \ mol^{-1} = 27.8 \ \ kJ \ \ mol^{-1}$$

Page reference: 77
***a.** 27.8 kJ mol^{-1}
b. 33.2 kJ mol^{-1}
c. 30.5 kJ mol^{-1}
d. 2.7 kJ mol^{-1}

Type: multiple choice question
Title: Focus 02 - Question 20
10) The standard enthalpy of formation of gaseous diborane, B_2H_6, is +31 kJ mol^{-1} at 298 K. Use the following data for the molar heat capacities at constant pressure to determine the standard enthalpy of reaction at 450 K.

	$C_{p,m}^{\ominus}$ / kJ mol^{-1}
B(s)	12.0
H_2(g)	28.8
B_2H_6(g)	56.4

Feedback: The enthalpy of formation of diborane is the enthalpy change for the reaction

$$2 \text{ B(s)} + 3 \text{ H}_2 \rightarrow \text{B}_2\text{H}_6\text{(g)}$$

Applying Kirchhoff's law, eqn 2F.4,

$$\Delta_r H^o(T') = \Delta_r H^o(T) \ + \ \Delta_r C_p^o \times (T' - T)$$

requires us to calculate the difference between the weighted sums of the standard molar heat capacities of the products and the reactants

$$\Delta_r C_p^o = \sum v C_{p,m}^o(products) - \sum v C_{p,m}^o(reactants)$$

$$= C_{p,m}^o(B_2 H_6) - \{(2 \ \ \times \ \ C_{p,m}^o(B)) + (3 \ \ \times \ \ C_{p,m}^o(H_2))\}$$

$$= [56.4 - \{(2 \ \ \times \ \ 12.0) + (3 \ \ \times \ \ 28.8)\}] \ \ J \ \ K^{-1} mol^{-1} = -54.0 \ \ J \ \ K^{-1} mol^{-1}$$ Thus

$$\Delta_f H^o(450 \ \ K) = (31 \times 10^3 \ \ J \ \ mol^{-1}) - \{(54.0 \ \ J \ \ K^{-1} mol^{-1}) \ \ \times \ \ (450 - 298) \ \ K\}$$

$$= +23 \ \ \times \ \ 10^3 J \ \ mol^{-1} = +23 \ \ kJ \ \ mol^{-1}$$

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a. +39 kJ mol^{-1}
***b.** +23 kJ mol^{-1}
c. +33 kJ mol^{-1}
d. +29 kJ mol^{-1}