End of topic questions

Topic review

1. Using your knowledge from the *Reactivity 1.1* topic, answer the guiding question as fully as possible:

   What can be deduced from the temperature change that accompanies chemical or physical change?

Exam-style questions

Multiple-choice questions

2. Which is correct for the following reaction?

   $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$
   $\Delta H = -1049 \text{ kJ mol}^{-1}$

   A Reactants are less stable than products and the reaction is endothermic.
   B Reactants are more stable than products and the reaction is endothermic.
   C Reactants are more stable than products and the reaction is exothermic.
   D Reactants are less stable than products and the reaction is exothermic.

3. Which statement is correct?

   A In an exothermic reaction, the products have more energy than the reactants.
   B In an exothermic reversible reaction, the activation energy of the forward reaction is greater than that of the reverse reaction.
   C In an endothermic reaction, the products are more stable than the reactants.
   D In an endothermic reversible reaction, the activation energy of the forward reaction is greater than that of the reverse reaction.

4. Which statement is correct for this reaction?

   $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$
   $\Delta H = -26.6 \text{ kJ mol}^{-1}$

   A 13.3 kJ are released for every mole of Fe produced.
   B 26.6 kJ are absorbed for every mole of Fe produced.
   C 53.2 kJ are released for every mole of Fe produced.
   D 26.6 kJ are released for every mole of Fe produced.

5. In which reaction do the reactants have a lower energy than the products?

   A $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
   B $HBr(g) \rightarrow H(g) + Br(g)$
   C $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$
   D $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Extended-response questions

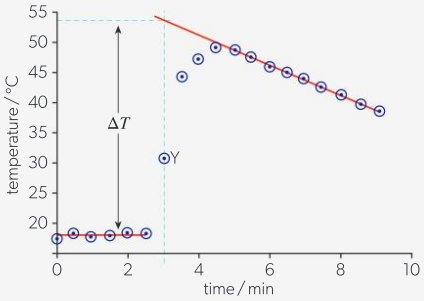
6. Nitrogen dioxide and carbon monoxide react according to the following equation:

$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$
$\Delta H = -226 \text{ kJ mol}^{-1}$

a. Calculate the enthalpy change for the reverse reaction. [1]

b. State the equation for the reaction of NO_2 in the atmosphere to produce acid deposition. [1]

7. Powdered zinc was reacted with 25.00 cm^3 of 1.000 mol dm^{-3} copper(II) sulfate solution in an insulated beaker. Temperature was plotted against time.



a. Estimate the time at which the powdered zinc was placed in the beaker. [1]

b. State what point **Y** on the graph represents. [1]

The maximum temperature used to calculate the enthalpy change of reaction was chosen at a point on the extrapolated (red) line.

c. State the maximum temperature that should be used, and outline **one** assumption made in choosing this temperature on the extrapolated line. [1]

d. To determine the enthalpy of reaction, the experiment was carried out five times. The same volume and concentration of copper(II) sulfate was used but the mass of zinc was different each time. Suggest, with a reason, if zinc or copper(II) sulfate should be in excess for each trial. [1]

The formula $q = mc\Delta T$ was used to calculate the amount of energy released.

The values used in the calculation were $m = 25.00$ g and $c = 4.18$ J g^{-1} K^{-1}.

e. State an assumption made when using these values for m and c. [1]

f. Predict, giving a reason, how the final enthalpy of reaction calculated from this experiment would compare with the theoretical value. [1]

8. A potato chip (crisp) was ignited, and the flame was used to heat a test tube containing water.

Mass of water/g	7.8
Mass of chip/g	1.2
Initial temperature/°C	21.3
Final temperature/°C	22.6

a. Calculate the heat required, in kJ, to raise the temperature of the water, using data in the table above and from section 2 of the data booklet. [1]

b. Determine the enthalpy of combustion of the potato chip, in kJ g^{-1}. [1]

End of topic questions

Topic review

1. Using your knowledge from the *Reactivity 1.2* topic, answer the guiding question as fully as possible:

   How does application of the law of conservation of energy help us to predict energy changes during reactions?

Exam-style questions

Multiple-choice questions

2. Which equation represents the N–H bond enthalpy in NH_3?

   A $NH_3(g) \rightarrow N(g) + 3H(g)$

   B $\frac{1}{3}NH_3(g) \rightarrow \frac{1}{3}N(g) + H(g)$

   C $NH_3(g) \rightarrow \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$

   D $NH_3(g) \rightarrow \bullet NH_2(g) + \bullet H(g)$

3. Bond enthalpies can be used to calculate the enthalpy change of the following reaction, in kJ mol^{-1}.

   $$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

   Referring to section 12 of the data booklet, deduce which of the following represents the calculation of the enthalpy change of reaction from bond enthalpies.

   A $(6 \times 391) - [(3 \times 436) + 945]$

   B $(3 \times 391) - (436 + 945)$

   C $-[(3 \times 436) + 945] + (3 \times 391)$

   D $-(6 \times 391) + [(3 \times 436) + 945]$

AHL

4. Which equation represents lattice enthalpy?

   A $NaCl(g) \rightarrow Na^+(g) + Cl^-(g)$

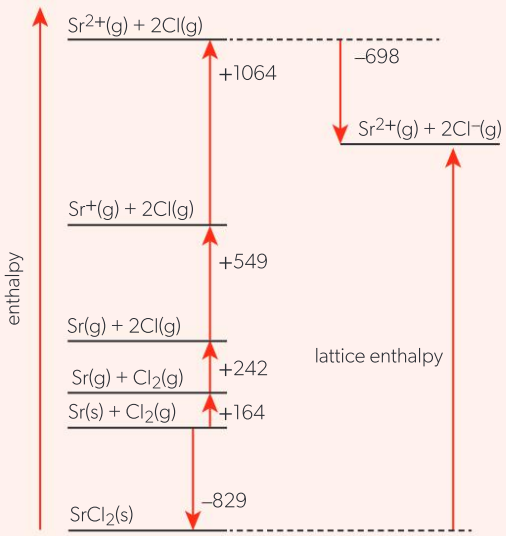
   B $NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$

   C $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

   D $NaCl(s) \rightarrow Na^+(s) + Cl^-(s)$

AHL

5. Using the Born–Haber cycle below, determine which calculation represents the lattice enthalpy of strontium chloride, $SrCl_2$, in kJ mol^{-1}.



   A $-(-829) + 164 + 242 + 549 + 1064 - (-698)$

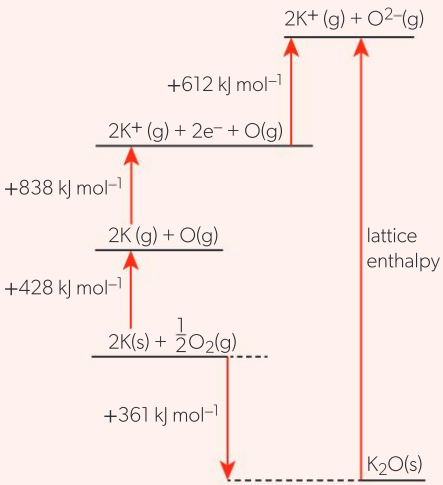
   B $-829 + 164 + 242 + 549 + 1064 - 698$

   C $-(-829) + 164 + 242 + 549 + 1064 - 698$

   D $-829 + 164 + 242 + 549 + 1064 - (-698)$

AI-HL

6. The Born–Haber cycle for potassium oxide, K_2O, is shown below:



Which calculation represents the lattice enthalpy in kJ mol^{-1}?

A $-361 + 428 + 838 + 612$
B $-(-361) + 428 + 838 + 612$
C $-361 + 428 + 838 - 612$
D $-(-361) + 428 + 838 - 612$

Extended-response questions

7. The following equation describes the industrial production of ammonia using the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

a. Calculate the enthalpy change of reaction for this process using bond enthalpy data. [3]

b. State and explain whether the reaction is exothermic or endothermic. [2]

8. Ammonia reacts with oxygen to form nitrogen and steam.

a. Write a balanced chemical equation for this reaction, showing the states of all species. [1]

b. Draw full structural formulas for all reactants and products to determine the nature of the covalent bonds present. [4]

c. Using bond enthalpy values from section 12 of the data booklet, determine the enthalpy change for this reaction. [3]

9. Octane, C_8H_{18}, is a component of liquid gasoline. When gasoline is burned as fuel, octane is combusted in oxygen via the following reaction:

$$C_8H_{18}(l) + \frac{25}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$$

a. Using bond enthalpy data, calculate the enthalpy change for this reaction. [3]

b. The enthalpy change for this reaction was determined experimentally to be -5470 kJ mol^{-1}. Give **two** reasons why the enthalpy change value you obtained from bond enthalpy data differs from the experimental value. [2]

End of topic questions

Topic review

1. Using your knowledge from the *Reactivity 1.3* topic, answer the guiding question as fully as possible:

   What are the challenges of using chemical energy to address our energy needs?

Exam-style questions

Multiple-choice questions

2. Which of the following statements is false?

   A. The complete combustion of a hydrocarbon forms carbon dioxide and water.

   B. All combustion reactions are endothermic reactions.

   C. The incomplete combustion of hydrocarbons and alcohols form the same products.

   D. Complete combustion reactions require an excess of oxygen gas as a reactant.

3. Which equation(s) represent the incomplete combustion of methane?

   I. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

   II. $CH_4(g) + 1\frac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(g)$

   III. $CH_4(g) + O_2(g) \rightarrow C(s) + 2H_2O(g)$

   A. I, II and III C. III only

   B. II and III only D. II only

Extended-response questions

4. a. Write the chemical equation for the incomplete combustion of methane. [1]

   b. Explain how one of the products of incomplete combustion can lead to increased health risks. [2]

   c. Calculate the enthalpy change for the incomplete combustion of methane, in kJ mol^{-1}, using the bond enthalpy data given below. [2]

Bond	Average bond enthalpy / kJ mol^{-1}
C—H	414
O—H	463
O═O	498
C≡O	1077

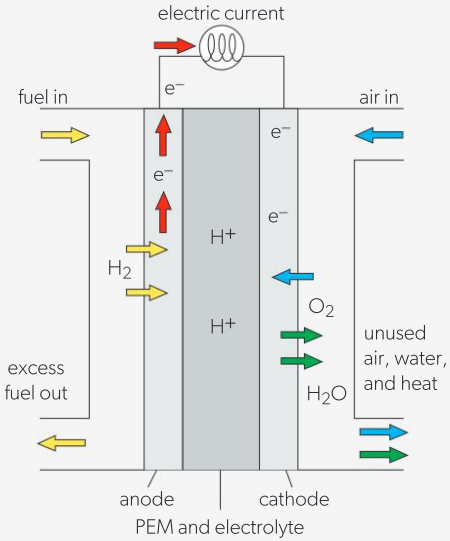
5. Ethanol is a biofuel that can be mixed with gasoline.

   a. Write the equation for the complete combustion of ethanol. [1]

   b. Outline the evidence that relates global warming to increasing concentrations of greenhouse gases in the atmosphere. [3]

   c. Explain, including a suitable equation, why biofuels are considered to be carbon neutral. [2]

6. A hydrogen fuel cell uses pure hydrogen gas as the fuel and a proton exchange membrane as the electrolyte. A diagram of the hydrogen fuel cell is shown below.



   a. Suggest an advantage of the hydrogen fuel cell over the lead–acid battery for use in cars. [1]

   b. Outline **one** advantage and **one** disadvantage of the methanol cell (DMFC) compared with a hydrogen fuel cell. [2]

7. Even though fuel cells, primary cells and rechargeable cells have similar fundamental characteristics, there are important differences between them.

   a. Suggest one common feature that fuel cells, primary cells and rechargeable cells share. [1]

   b. Outline the difference between primary and rechargeable cells. [1]

   c. Identify **one** factor that affects the voltage of a cell and **a different factor** that affects the current it can deliver. [2]

End of topic questions

AHL

Topic review

1. Using your knowledge from the *Reactivity 1.4* topic, answer the guiding question as fully as possible:

   What determines the direction of chemical change?

Exam-style questions

Multiple-choice questions

2. Which system has the most negative entropy change, ΔS, for the forward reaction?

   A. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
   B. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
   C. $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$
   D. $H_2O(l) \rightarrow H_2O(g)$

3. Which combinations of values will result in a spontaneous reaction?

	$\Delta H^\ominus$ / kJ mol^{-1}	$\Delta S^\ominus$ / J K^{-1} mol^{-1}	T / K
I	−100	−100	300
II	+100	−100	300
III	+100	+100	1500

   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II and III

4. Which statement is correct?

   A. If $\Delta H < 0$, the reaction is always spontaneous.
   B. If $\Delta H > 0$, the reaction is never spontaneous.
   C. If $\Delta S < 0$, the reaction can be spontaneous if the temperature is low enough.
   D. If $\Delta S < 0$, the reaction can be spontaneous if the temperature is high enough.

Extended-response questions

5. The hydrogenation of propene produces propane.

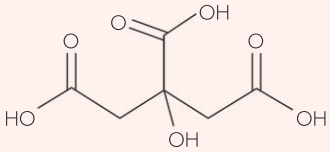
   $$C_3H_6(g) + H_2(g) \rightarrow C_3H_8(g)$$

   a. Calculate the standard entropy change, $\Delta S^\ominus$, for the hydrogenation of propene. [2]

Substance	$\Delta S^\ominus$ / J K^{-1} mol^{-1}
$H_2(g)$	+131
$C_3H_6(g)$	+267
$C_3H_8(g)$	+270

   b. The standard enthalpy change, $\Delta H^\ominus$, for the hydrogenation of propene is −124.4 kJ mol^{-1}. Predict the temperature above which the hydrogenation reaction is non-spontaneous. [2]

6. A molecule of citric acid, $C_6H_8O_7$, is shown.



   The equation for the first dissociation of citric acid in water is

   $$C_6H_8O_7(aq) + H_2O(l) \rightleftharpoons C_6H_7O_7^-(aq) + H_3O^+(aq)$$

   The value of K for this reversible reaction at 298 K is 5.01×10^{-4}.

   a. Calculate the standard Gibbs energy change, $\Delta G^\ominus$, in kJ mol^{-1}, for this reaction at 298 K, using section 1 of the data booklet. [1]
   b. Comment on the spontaneity of the reaction at 298 K. [1]

7. The reaction for the formation of liquid tetracarbonylnickel is shown below:

   $$Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(l)$$

   a. Calculate the standard entropy change, $\Delta S^\ominus$, of the forward reaction, in J K^{-1} mol^{-1}, using the values given. [2]

Substance	$S^\ominus$ / J K^{-1} mol^{-1}
Ni(s)	3
CO(g)	198
$Ni(CO)_4(l)$	313

   b. Calculate the standard enthalpy change, $\Delta H^\ominus$, of the forward reaction in kJ mol^{-1}. [1]

Substance	$\Delta H_f^\ominus$ / kJ mol^{-1}
CO(g)	−110.5
$Ni(CO)_4(l)$	−633.0

   c. Use your answers to (a) and (b) to determine the temperature, in °C, below which the reaction becomes favourable. [3]
   d. At a given point in the forward reaction pathway, the reaction quotient, Q, is equal to 0.5. Calculate the Gibbs energy change, ΔG, at this point and determine whether the reaction is spontaneous at this point. [2]