INSIGHT
Trial Exam Paper

2010
CHEMISTRY
Written examination 2

Solutions book

This book presents:

- correct solutions with full working
- explanatory notes
- mark allocations
- tips and guidelines

SECTION A – Multiple-choice questions

Question 1

Increasing the temperature of a chemical reaction

A. lowers the activation energy of the reaction.

B. increases the energy of the reactant particles only.

C. increases the value of ΔH for the reaction.

D. **increases the energy of the reactant and product particles.**

Answer is D.

Worked solution

- D is correct because increasing the temperature increases the energy of all particles present.
- A is incorrect because increasing the temperature does not affect the value of the activation energy. However, as the particles have more energy, it is easier for them to overcome the activation energy barrier.
- B is incorrect because increasing the temperature increases the energy of all particles, not just the reactant particles.
- C is incorrect because increasing the temperature does not affect the ΔH, which is the change in enthalpy value.

Question 2

Which of the following changes that can be made to a chemical reaction will result in a greater **proportion** of successful collisions between reactant particles?

I addition of a catalyst

II grinding reactant lumps into a powder

III increasing the concentration of reactants

A. **I only**

B. II and III only

C. I and II only

D. I, II and III

Answer is A.

Worked solution

- A is correct because the addition of a catalyst reduces the activation energy of a reaction, making a greater proportion of the collisions successful.
- B, C, and D are incorrect because II and III both increase the total number of collisions, thus increasing the rate of a reaction, without actually increasing the **proportion** of collisions that are successful.

Question 3

Which of the following statements regarding the energy changes for a particular exothermic chemical reaction is **not** correct?

A. The activation energy of the forward reaction is lower than the activation energy of the reverse reaction.

B. The enthalpy value of the products is lower than the enthalpy value of the reactants.

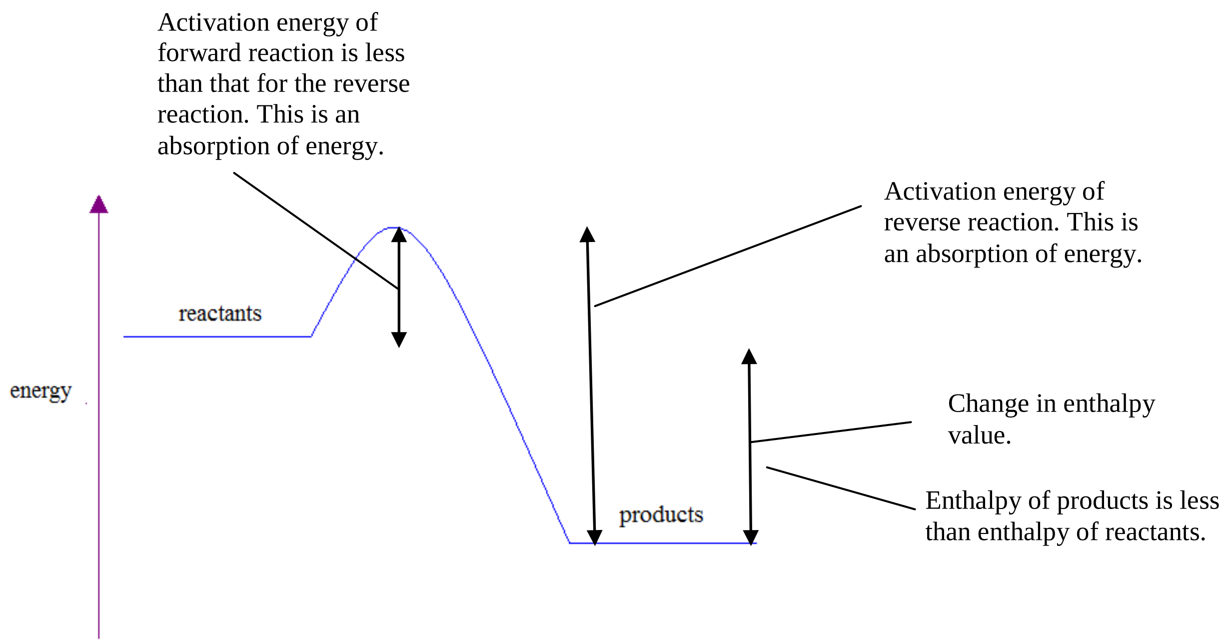
C. **The value of the activation energy of the reverse reaction is lower than the change in enthalpy value.**

D. The forward and reverse reactions both require the absorption of some energy.

Answer is C.

Worked solution

- C is not a correct statement. Consider the energy profile diagram for an exothermic reaction shown below.



- The activation energy of the reverse reaction will always be greater than the change in enthalpy value (ΔH).
- A, B and D are all correct statements, as shown on the diagram.

Question 4

Consider the reaction

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -91 \text{ kJ mol}^{-1}$ $K = 0.052 \text{ M}^{-2}$ at 400°C

The ΔH and K values for the reaction

$2N_2(g) + 6H_2(g) \rightleftharpoons 4NH_3(g)$

will be

	ΔH	**K**
A.	–91	0.0027
B.	**–182**	**0.0027**
C.	–91	0.104
D.	–182	0.104

Answer is B.

Worked solution

- B is correct because doubling the amounts of all species in a chemical reaction causes the ΔH value to be doubled and the K value to be squared.
- A is incorrect because doubling the amounts of all species in a chemical reaction causes the ΔH value to be doubled. If twice as much of reactants is involved, then twice as much energy will be released in an exothermic reaction.
- C is incorrect because doubling the amounts of all species in a chemical reaction causes the ΔH value to be doubled, as twice as much of reactants is involved, and the K value to be squared, not doubled.
- D is incorrect because doubling the amounts of all species in a chemical reaction causes the K value to be squared, not doubled.

Question 5

Consider the following exothermic reaction.

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $K = 48.1$ at 460°C.

A particular reaction mixture contains the following concentrations of gases at equilibrium.

$[H_2] = 0.0345$ M, $[I_2] = 0.0835$ M, and $[HI] = 0.456$ M

The temperature of this reaction mixture is

A. 460°C

B. greater than 460°C

C. **lower than 460°C**

D. unable to be determined.

Answer is C.

Worked solution

- C is correct according to the calculations below.

  The equilibrium law for this reaction is

  $$K = \frac{[\mathrm{HI}]^2}{[\mathrm{H_2}][\mathrm{I_2}]}$$

  So for the reaction mixture, $K = \dfrac{(0.456)^2}{(0.0345)(0.0835)}$

  $$= \frac{0.208}{0.00288} = 72.2$$

  This K value is higher than the K value at 460°C, indicating there is a greater proportion of products present in the mixture in comparison. Given this is an exothermic reaction the greater proportion of products indicates the temperature is lower than 460°C.

- A is incorrect because the K value of the mixture can be calculated and is not the same as the K value at 460°C. The second equilibrium must be at a different temperature.
- B is incorrect because the K value of the mixture is higher than the K value at 460°C. This is an exothermic reaction, so if the temperature was greater it would result in a net backward reaction and a decreased K value.
- D is incorrect because the K value of the reaction mixture can be calculated and compared to the value at 460°C, to determine a comparative temperature.

Tips

- *For an exothermic reaction, an increase in K value indicates a decrease in temperature.*

Question 6

Which of the following changes will **not** affect the value of the equilibrium constant of a particular gaseous reaction?

I addition of a catalyst

II addition of a reactant

III increasing temperature

IV moving the reactants to a larger container

A. I and III

B. **I, II and IV**

C. I and IV

D. III only

Answer is B.

Worked solution

- B is correct because a temperature change is the only change that can be made to an equilibrium mixture that will result in a change to the equilibrium constant.
- A is incorrect because addition of a catalyst will not affect the value of the equilibrium constant.
- C and D are incorrect because a temperature change is the only change that can be made to an equilibrium mixture that will result in a change to the equilibrium constant.

Question 7

In a volumetric flask, 100.0 mL of 0.50 M HNO_3 solution is diluted to 1.00 L. In a second flask, 100.0 mL of 0.50 M CH_3COOH solution is diluted to 1.00 L. Which statement best describes the pH changes in these flasks?

A. The pH will increase in one flask and decrease in the other.

B. The pH of both flasks will change equally.

C. **The pH of the HNO_3 solution will change by a greater magnitude than the pH of the CH_3COOH solution.**

D. The pH of the HNO_3 solution will change by a lesser magnitude than the pH of the CH_3COOH solution.

Answer is C.

Worked solution

- C is correct because HNO_3 is a strong acid and CH_3COOH is a weak acid. Dilution of a weak acid will cause increased ionisation of acid molecules, lessening the effect of the dilution and lessening the increase in pH. HNO_3, which is a strong acid and already completely ionised, will have a greater change of pH.
- A is incorrect because HNO_3 and CH_3COOH are both acids. Dilution of both will reduce acidity and cause an increase in pH.
- B is incorrect because HNO_3 is a strong acid and CH_3COOH is a weak acid, meaning the dilution will have slightly different effects in the pH of each.
- D is incorrect because dilution of the weak acid, CH_3COOH, will cause increased ionisation of acid molecules, lessening the effect of the dilution and lessening the increase in pH. HNO_3, which is a strong acid and already completely ionised, will have a greater change of pH.

Question 8

Which one of the following statements regarding the pH of pure water is correct?

A. Pure water at different temperatures is always neutral, however, the pH may vary slightly.

B. Pure water at different temperatures is always neutral and always has a pH of 7.00.

C. Pure water at a temperature less than 25°C has a pH less than 7.00 and is acidic.

D. Pure water at a temperature less than 25°C has a pH greater than 7.00 and is basic.

Answer is A.

Worked solution

- A is correct because the pH of pure water is 7.00 at 25°C only. Temperatures higher or lower than this will change the extent of the self-ionisation of water and vary the $[H_3O^+]$, since $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ (endothermic reaction). pH = $-\log_{10}[H_3O^+]$ so pH also varies with varying temperature. However, $[H_3O^+]$ and $[OH^-]$ are still equal so the solution is neutral.
- B is incorrect because although pure water is always neutral, its pH varies with temperature.
- C is incorrect because pure water is always neutral since $[H_3O^+]$ and $[OH^-]$ are equal.
- D is incorrect because pure water is always neutral because $[H_3O^+]$ and $[OH^-]$ are equal.

Tips

- *The definition of a neutral solution is that $[H_3O^+] = [OH^-]$.*

Question 9

Which of the following fuels will release the greatest energy when burnt in air?

A. 10 g of ethane

B. 10 g of propane

C. 10 g of methanol

D. 10 g of glucose

Answer is A.

Worked solution

- A is correct. The amount of energy released by each fuel is determined using molar enthalpy values, which are located in the VCE data booklet. The steps in the calculation are shown for ethane.

  $$n(\text{ethane}) = \frac{m}{M} = \frac{10}{2\times 12.0 + 6\times 1.0}$$

  $$= 0.33 \text{ mol}$$

  Energy released = n × molar enthalpy

  $$= 0.33 \times 1557$$

  $$= 519 \text{ kJ}$$

- B is incorrect because the energy released by 10 g of propane is 504 kJ, which is less than the energy released by 10 g of ethane.

SECTION A – Question 9 – continued

- C is incorrect because the energy released by 10 g of methanol is 227 kJ, which is less than the energy released by 10 g of ethane.
- D is incorrect because the energy released by 10 g of glucose is 156 kJ, which is less than the energy released by 10 g of ethane.

Question 10

Ammonium nitrate dissolves in water according to the equation

$$NH_4NO_3(s) \xrightarrow{H_2O(l)} NH_4NO_3(aq) \qquad \Delta H = +25 \text{ kJ mol}^{-1}$$

In an insulated vessel, 2.50 g of ammonium nitrate is mixed rapidly with 150 mL of water. The temperature change of the water, in °C, is closest to

A. –0.001 24

B. –0.0997

C. **–1.25**

D. –1.51

Answer is C.

Worked solution

- C is correct according to the following steps.

Step 1: Determine the amount, in mol, of ammonium nitrate.

$$n(NH_4NO_3) = \frac{m}{M} = \frac{2.50}{14.0 + 4\times1.0 + 14.0 + 3\times16.0}$$

$$= \frac{2.50}{80} = 0.0313 \text{ mol}$$

Step 2: Determine the energy absorbed by the ammonium nitrate dissolving.

If 1 mol absorbs 25 kJ, then 0.0313 mol absorbs x kJ.

$$\frac{x}{25} = \frac{0.0313}{1}$$

$$x = 0.78 \text{ kJ}$$

$$= 781 \text{ J}$$

Step 3: Determine the temperature change, using specific heat capacity (*SHC*) from the VCE data booklet.

$$E(\text{J}) = 150 \times \Delta T \times SHC$$

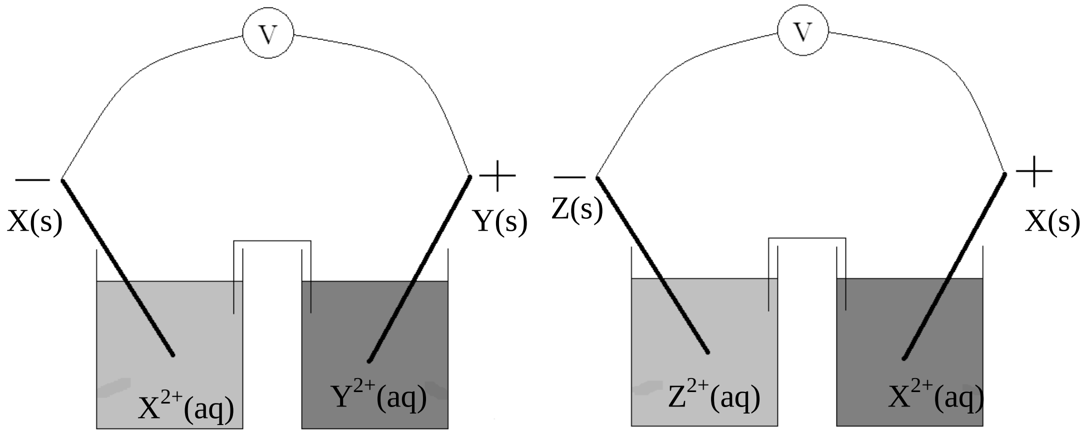
$$-781 = 150 \times \Delta T \times 4.18$$

$$\Delta T = -1.25\text{°C}$$

- A is incorrect because the unit for specific heat capacity provided in the VCE data booklet is
J g^{-1} K^{-1}, not kJ g^{-1} K^{-1}. The energy absorbed must be converted from kJ to J for use with this equation.
- B is incorrect as 2.50 g is the mass of ammonium nitrate and must be converted to the amount in moles before determining the energy absorbed.
- D is incorrect because the molar mass of ammonium nitrate is 80 g mol^{-1}, not 66 g mol^{-1}.

Question 11

Two standard galvanic cells are shown below.



The strongest reductant present in the galvanic cells is

A. Y
B. Y^{2+}
C. **Z**
D. Z^{2+}

Answer is C.

Worked solution

- C is correct. In the first galvanic cell, X is the negative electrode, making it the anode, and therefore Y is the cathode. X(s) is undergoing oxidation, indicating that X(s) is a stronger reductant than Y(s). In the second galvanic cell X is the positive electrode, making it the cathode, and therefore Z is the anode. Z(s) is undergoing oxidation, making Z(s) a stronger reductant than X(s).
- A is incorrect because the first galvanic cell shows that X is a stronger reductant than Y. Y is the cathode where reduction of Y^{2+}(aq) takes place.
- B is incorrect because Y^{2+}(aq) undergoes reduction to Y(s), making it an oxidant and not a reductant.
- D is incorrect because Z^{2+}(aq) is an oxidant, not a reductant. Also, it is the product of the oxidation reaction in the second galvanic cell, not a reactant.

Question 12

A brass ring is to be electroplated with gold. In the constructed cell, the ring is the

A. **cathode and is connected to the negative terminal of the battery.**

B. cathode and is connected to the positive terminal of the battery.

C. anode and is connected to the negative terminal of the battery.

D. anode and is connected to the positive terminal of the battery.

Answer is A.

Worked solution

- A is correct because the electroplating of a metal is always a reduction reaction, so the ring will be the cathode. Electrons are sent to the cathode to force reduction of gold ions to occur. Electrons come out of the negative terminal of a battery, so the negative terminal is always connected to the substance being electroplated.
- B is incorrect because electrons come out of the negative terminal of a battery, so the negative terminal is always connected to the substance being electroplated.
- C is incorrect because the electroplating of a metal is always a reduction reaction, so the ring will be the cathode.
- D is incorrect because the ring will be the cathode and is connected to the negative terminal of the battery.

Questions 13 and 14 refer to the following information.

An **alkaline** hydrogen–oxygen fuel cell has the overall equation

$$O_2(g) + 2H_2(g) \rightleftharpoons 2H_2O(l)$$

Question 13

In this fuel cell, the species reacting at the cathode would be

A. $O_2(g)$ and $H^+(aq)$

B. $H_2(g)$ only

C. **$O_2(g)$ and $H_2O(l)$**

D. $H_2(g)$ and $OH^-(aq)$

Answer is C.

Worked solution

- C is correct because reduction occurs at the cathode and the cathode half-equation in an alkaline hydrogen–oxygen fuel cell is $O_2(g) + H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$.
- A is incorrect because $O_2(g)$ and $H^+(aq)$ are the species reacting at the cathode in an **acidic** hydrogen–oxygen fuel cell.
- B is incorrect because $H_2(g)$ is the only reactant at the anode in an acidic hydrogen–oxygen fuel cell.
- D is incorrect because $H_2(g)$ and $OH^-(aq)$ are the species reacting at the anode in an alkaline hydrogen–oxygen fuel cell.

Question 14

Which one of the following statements about this fuel cell is **not** correct?

A. The generation of electricity in this cell is more efficient than the generation of electricity by the burning of coal.

B. **The products in the cell remain in contact with the electrodes, enabling the cell to be recharged once the reactants are completely consumed.**

C. The conversion of chemical energy to electrical energy is not 100% efficient.

D. The technology required to produce fuel cells is relatively expensive.

Answer is B.

Worked solution

- B isan incorrect statement because fuel cells have a continual supply of reactants and removal of products. They are not recharged like secondary cells can be.
- A, C and D are correct statements about fuel cells.

Questions 15 and 16 refer to the following information.

The methanol fuel cell uses methanol and oxygen to produce electricity. The half-equations are

$$CH_3OH(l) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$$

$$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$$

Question 15

What current, in amperes (A), is produced by the methanol fuel cell when 0.884 g of methanol is consumed in 15.0 minutes?

A. 0.494

B. 11.8

C. **17.8**

D. 1.07×10^3

Answer is C.

SECTION A – Question 15 – continued

Worked solution

- C is correct according to the calculations below.

Step 1: Determine the amount, in mol, of methanol consumed.

$$n(CH_3OH) = \frac{m}{M} = \frac{0.884}{12.0 + 4 \times 1.0 + 16.0}$$

$$= \frac{0.884}{32.0} = 0.0276 \text{ mol}$$

Step 2: Determine the amount, in mol, of electrons produced.

$n(CH_3OH) : n(e^-)$

1 : 6

So $n(e^-) = \frac{6}{1} \times 0.0276$

$= 0.166$ mol

Step 3: Determine the charge, in coulombs (C), produced by the electrons.

$Q = n(e^-) \times F$

$= 0.166 \times 96\,500$

$= 1.60 \times 10^4$ C

Step 4: Determine the current, in amperes (A).

$$I = \frac{Q}{t} = \frac{1.6 \times 10^4}{15.0 \times 60}$$

$= 17.8$ A

- A is incorrect because the ratio $n(CH_3OH) : n(e^-)$ is 1 : 6, not 6 : 1.
- B is incorrect because the ratio $n(CH_3OH) : n(e^-)$ is 1 : 6, not 1 : 4.
- D is incorrect because time must be expressed in seconds, not minutes, for use in the calculations.

Question 16

The species acting as a reductant in this fuel cell is

A. CH_3OH

B. O_2

C. CO_2

D. H_2O

Answer is A.

Worked solution

- A is correct because CH_3OH is losing electrons in this reaction, meaning it is being oxidised and is itself the reductant. The oxidation number of C increased from –2 to +4.
- B is incorrect because O_2 is being reduced in this reaction and is itself the oxidant. The oxidation number of O is decreased from 0 to –2.
- C is incorrect because CO_2 is a product of this reaction, so is neither the oxidant nor the reductant.
- D is incorrect because H_2O is a product of this reaction, so is neither the oxidant nor the reductant.

Question 17

Four different experiments are described below.

I Electrolysis of 1.0 M copper(II) chloride.

II A nickel rod is placed in a beaker of copper(II) sulfate.

III Electrolysis of molten copper(II) chloride.

IV A silver rod is placed in a beaker of copper(II) sulfate.

The experiments that would produce copper metal are

A. all of them.

B. I, II and III

C. II, III and IV

D. I, III and IV

Answer is B.

Worked solution

- B is correct. Cu^{2+} ions are a stronger oxidant than H_2O, so experiment I will produce copper. Cu^{2+} is above Ni in the electrochemical series, so experiment II will produce copper and experiment III will also produce copper because Cu^{2+} is the strongest oxidant present.
- A is incorrect because experiment IV will not produce copper. Cu^{2+} is a weaker oxidant than Ag^+, so Cu^{2+} and Ag (silver solid) will not react spontaneously. Solid copper will not be produced.
- C is incorrect because experiment I will produce copper because Cu^{2+} ions are a stronger oxidant than H_2O. Also, experiment IV will not produce copper. Cu^{2+} is a weaker oxidant than Ag^+, so Cu^{2+} and Ag (silver solid) will not react spontaneously.
- D is incorrect because experiment II will produce copper because Cu^{2+} is a stronger oxidant than Ni^{2+}. Also, experiment IV will not produce copper. Cu^{2+} is a weaker oxidant than Ag^+, so Cu^{2+} and Ag (silver solid) will not react spontaneously.

Question 18

Which of the following statements about cathodes in galvanic and electrolytic cells is correct?

A. The cathode is always the positive electrode.

B. The cathode is always the same species as the oxidant.

C. **Electrons always move towards the cathode.**

D. The cathode is the site of oxidation in one cell and the site of reduction in the other.

Answer is C.

Worked solution

- C is correct because electrons always move from the anode where oxidation always occurs, to the cathode where reduction always occurs.
- A is incorrect because the cathode is the positive electrode in galvanic cells but is the negative electrode in electrolytic cells.
- B is incorrect because the cathode is an electrode that is always the site of reduction, not always the oxidant itself. If the oxidant is a gas, liquid or solution the cathode will consist of a specialised gas electrode or an inert solid.
- D is incorrect because the cathode is always the site of reduction, that is, the gain of electrons.

Question 19

A mixture of 1.0 M NaI, 1.0 M $AlCl_3$ and 1.0 M KCl was electrolysed. Which of the following reactions is most likely to occur at the cathode?

A. $Na^+(aq) + e^- \rightarrow Na(s)$

B. $\mathbf{2H_2O(l) + 2e– \rightarrow H_2(g) + 2OH–(aq)}$

C. $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

D. $2I^-(aq) \rightarrow I_2(s) + 2e^-$

Answer is B.

Worked solution

- B is correct because H_2O is a stronger oxidant than Na^+, Al^{3+} and K^+, so will be the species reduced at the cathode.
- A is incorrect because Na^+ is a weaker oxidant than H_2O, so it is the H_2O that will be preferentially reduced at the cathode.
- C is incorrect because Cl^- is a reductant and this reaction is an oxidation reaction. The cathode is always the site of reduction.
- D is incorrect because I^- is a reductant and this reaction is an oxidation reaction. The cathode is always the site of reduction.

Question 20

Which of the following factors are important considerations in the design of an electrolytic cell for the commercial production of sodium?

I using electrolytes that are cheap and readily available

II using a molten electrolyte

III keeping the products separated from each other

IV using electrodes that are unreactive

A. I, III and IV

B. I, II and IV

C. I and IV

D. **All of them.**

Answer is D.

Worked solution

- D is correct because all of these factors are important. Na^+ is a weaker oxidant than water so a molten electrolyte must be used, and the products of electrolysis must be kept separate otherwise they would spontaneously react if they came into contact with each other.
- A is incorrect because II is also an important consideration. Na^+ is a weaker oxidant than water so a molten electrolyte must be used.
- B is incorrect because III is also an important consideration. The products of electrolysis must be kept separate otherwise they would spontaneously react if they came into contact with each other.
- C is incorrect because II and III are also important considerations. Na^+ is a weaker oxidant than water so a molten electrolyte must be used, and the products of electrolysis must be kept separate otherwise they would spontaneously react if they came into contact with each other.

END OF SECTION A

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SECTION B – Short-answer questions

Question 1

a. Use information provided in the VCE data booklet to write an overall balanced equation in which $Fe^{2+}(aq)$ is a reactant and provides a voltage of 1.90 V under standard conditions.

Solution

$Fe^{2+}(aq) + Mg(s) \rightarrow Fe(s) + Mg^{2+}(aq)$

1 mark

Explanatory notes

The electrochemical series lists the half-cell potentials of redox half-equations under standard conditions. If $Fe^{2+}(aq)$ is involved it is being oxidised or reduced, so the spontaneous reaction must be one of the following:

oxidation reaction	$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$	+0.77
reduction reaction	$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44

The cell voltage is 1.90 V. If the spontaneous oxidation of $Fe^{2+}(aq)$ is occurring, the other half-cell must be above it in the series, so must have a half-cell potential of 0.77 + 1.90 = 2.67 V. There is no half-equation with this E^o value listed in the data booklet.

If the reduction of $Fe^{2+}(aq)$ is occurring, the other half-cell must be below it in the series, so must have a half-cell potential of –0.44 – 1.90 = –2.34 V. The half-reaction listed in the electrochemical series with this E^o value is $Mg^{2+}(aq)/Mg(s)$.

Tips

- *The voltage of a cell = higher half-cell E^o – lower half-cell E^o.*
- *Standard conditions are specified, so the electrochemical series is valid for this prediction. Different values for the cell voltage would be obtained under non-standard conditions.*

b. A rod of iron is added to a mixture of iron(III) nitrate and tin(II) chloride under standard conditions and a reaction is observed. Give the formula of the species acting as the oxidant in the observed reaction.

Solution

Fe^{3+}

1 mark

Explanatory notes

The oxidants are listed on the left side of the electrochemical series. $Fe^{3+}(aq)$ and $Sn^{2+}(aq)$ are both oxidants. $Fe^{3+}(aq)$ is the highest in the series and so is the strongest oxidant and will be the first to undergo reduction in a reaction with the iron rod.

Tips

- *This question asked for a formula to be given rather than a name of the species. Read questions carefully to ensure answers are always given in the required form.*

SECTION B – Question 1– continued

c. List the conditions under which the electrochemical series is valid.

Solution

1 M, 1 atm, 25°C.

1 mark

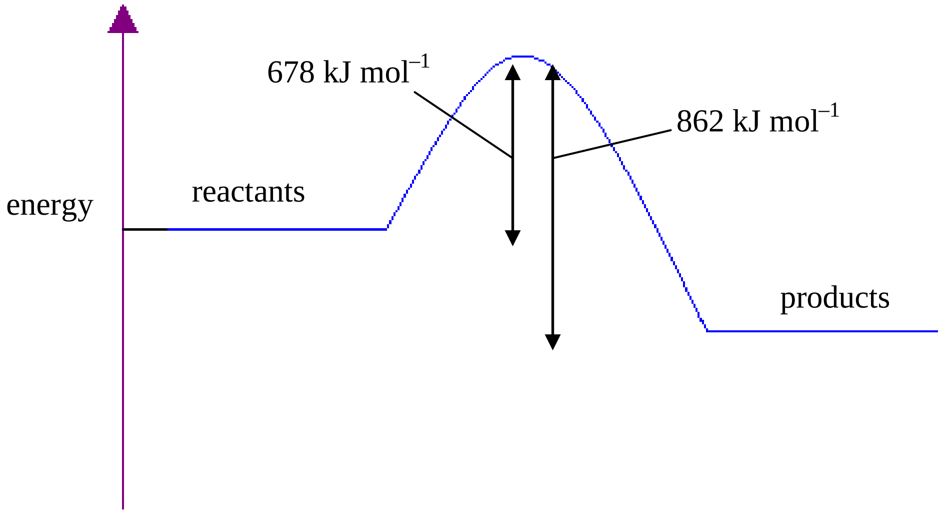
Explanatory notes

All three conditions must be included to obtain the mark.

Total 1 + 1 + 1 = 3 marks

Question 2

Hydrogen gas reacts with chlorine gas to produce gaseous hydrogen chloride. The diagram below shows the energy profile diagram of the changes that occur in chemical energy as the reaction proceeds.



a. Write a thermochemical equation for the reaction between hydrogen and chlorine.

Solution

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) \qquad \Delta H = -184 \text{ kJ mol}^{-1}$

3 marks

Mark allocation

- 1 mark for correct species and correctly balanced chemical equation with states.
- 1 mark for ΔH value of 184.
- 1 mark for correct negative sign on ΔH value.

Explanatory notes

The ΔH value is the difference in enthalpy between products and reactants and can be calculated using the values 862 – 678 = 184 kJ mol^{-1}. The ΔH is negative because this is an exothermic reaction.

b. What would be the effect on the two energy values shown on the diagram by the addition of a catalyst?

Solution

Both values will be decreased by the same amount.

2 marks

Mark allocation

- 1 mark for an indication that both values are affected by the same amount.
- 1 mark for an indication that the effect is a decrease.

Explanatory notes

Catalysts provide an alternative pathway with a lower activation energy. Less energy is required to break the bonds in the reactants and less energy is released in the formation of the bonds in the products.

Total 3 + 2 = 5 marks

Question 3

Consider the expression for K below for a reaction in which all species are gases.

$$K = \frac{[\mathrm{NO}]^2[\mathrm{Cl_2}]}{[\mathrm{NOCl}]^2} = 1.6 \times 10^{-5} \text{ at } 35°\mathrm{C}$$

a. Write a balanced chemical equation for this reaction.

Solution

$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$

2 marks

Mark allocation

- 1 mark for balanced equation. Must show the equilibrium arrow in equation.
- 1 mark for states.

b. Calculate the value of K for the reverse reaction.

Solution

$$K(\text{reverse}) = \frac{1}{K(\text{forward})}$$

$$= \frac{1}{1.6 \times 10^{-5}} = 6.3 \times 10^4$$

1 mark

Explanatory notes

When the reaction is reversed, the products become reactants and the reactants become products, meaning the K value is inversed.

c. An amount of NOCl is added to an empty 1.50 L container. The reaction is allowed to come to equilibrium, at which point 0.0156 mol of Cl_2 is present at 35°C.

i. Determine the concentration, in M, of Cl_2 at equilibrium.

Solution

$$[\mathrm{Cl}] = \frac{n}{V}$$

$$= \frac{0.0156}{1.5} = 0.0104 \text{ M}$$

1 mark

ii. Determine the concentration, in M, of NO at equilibrium.

Solution

n(NO) : n(Cl_2)

2 : 1

So n(NO) produced = $\frac{2}{1} \times 0.0156$

= 0.0312 mol

[NO] = $\frac{n}{V}$

$= \frac{0.0312}{1.5} = 0.0208$ M

2 marks

Mark allocation

- 1 mark for using the ratio n(NO) : n(Cl_2) correctly.
- 1 mark for correctly determining [NO].

iii. Determine the concentration, in M, of NOCl at equilibrium.

Solution

$$K = \frac{[\text{NO}]^2[\text{Cl}_2]}{[\text{NOCl}]^2}$$

$$1.6 \times 10^{-5} = \frac{[0.0208]^2[0.0104]}{[\text{NOCl}]^2}$$

$$[\text{NOCl}]^2 = \frac{4.5 \times 10^{-6}}{1.6 \times 10^{-5}}$$

$[\text{NOCl}]^2 = 0.281$

[NOCl] = 0.530 M

2 marks

Mark allocation

- 1 mark for $1.6 \times 10^{-5} = \frac{[0.0208]^2[0.0104]}{[\text{NOCl}]^2}$
- 1 mark for [NOCl] = 0.530 M

iv. Determine, in mol, the amount of NOCl initially added to the container.

Solution

$n(\text{NOCl})_{\text{equilibrium}} = cV$

$= 0.530 \times 1.5$

$= 0.795$ mol

$n(\text{NOCl})_{\text{reacted}} = 2 \times n(\text{Cl}_2)$

$= 2 \times 0.156$

$= 0.0312$ mol

$n(\text{NOCl})_{\text{initially}} = n(\text{NOCl})_{\text{equilibrium}} + n(\text{NOCl})_{\text{reacted}}$

$= 0.795 + 0.0312$

$= 0.826$ mol

3 marks

Mark allocation

- 1 mark for $n(\text{NOCl})_{\text{equilibrium}} = 0.795$ mol
- 1 mark for $n(\text{NOCl})_{\text{reacted}}$
- 1 mark for $n(\text{NOCl})_{\text{initially}}$

Total 2 + 1 + 8 = 11 marks

Question 4

The energy content of fuels and food can be determined using calorimetry. The energy content of a new brand of a wheat cereal was determined by a series of experiments using a bomb calorimeter. The calorimeter was first calibrated by combusting 0.125 g of propane in the calorimeter and measuring the resultant temperature rise. The following data was collected.

Mass of propane = 0.125 g

Temperature rise = 2.35°C

a. Use the data above to calculate the calibration factor, in kJ $°C^{-1}$, for this calorimeter.

Solution

$$n(\text{propane}) = \frac{m}{M}$$

$$= \frac{0.125}{3\times 12.0 + 8\times 1.0}$$

$$= \frac{0.125}{44} = 2.84 \times 10^{-3} \text{ mol}$$

From the VCE data booklet, the molar enthalpy of propane is –2217 kJ mol^{-1}.

So E released by propane = $2.84 \times 10^{-3} \times 2217$

$= 6.30$ kJ

$$\text{Calibration factor} = \frac{E}{\Delta T}$$

$$= \frac{6.30}{2.35} = 2.68 \text{ kJ °C}^{-1}$$

3 marks

Mark allocation

- 1 mark for calculating n(propane).
- 1 mark for determining energy (E) released.
- 1 mark for calculating calibration factor.

b. A mass of 0.286 g of the dried wheat cereal was then burnt in the calorimeter and a temperature change of 1.24°C was recorded. Calculate the energy content of the cereal, in kJ g^{-1}.

Solution

E released by 0.286 g cereal = calibration factor × ΔT

$= 0.286 \times 1.24$

$= 3.32$ kJ

$$\text{Energy content in kJ g}^{-1} = \frac{3.32}{0.286} = 11.6 \text{ kJ g}^{-1}$$

2 marks

Mark allocation

- 1 mark for *E* released by cereal.
- 1 mark for energy content in kJ g^{-1}.

c. Why is the energy content of the cereal given in kJ g^{-1} rather than in kJ mol^{-1}?

Solution

Wheat cereal is a mixture, not a pure substance with a known molar mass.

1 mark

d. Give two possible experimental errors that that would result in the calculated value for energy content being lower than it actually is.

Solution

Any two of

- poor insulation
- poorly fitting lid
- not stirring the water
- incomplete combustion of the cereal.

2 marks

Mark allocation

- 1 mark for each experimental error.

Brown coal is an important fuel source in Victoria.

e. i. Name the main use of brown coal in Victoria.

Solution

Production of electricity

1 mark

ii. State two advantages of using brown coal for this purpose.

Solution

Examples include: is cheap and readily available.

2 marks

iii. State two disadvantages of using brown coal for this purpose.

Solution

Examples include: produces carbon dioxide and is a non-renewable resource.

2 marks

Total 3 + 2 + 1 + 2 + 5 =13 marks

Question 5

The nickel–cadmium cell is a rechargeable cell used in mobile phones, laptop computers and many other portable electronic devices.

The two relevant half-equations for the discharge reaction are

$$Cd(s) + 2OH^{-}(aq) \rightarrow Cd(OH)_2(s) + 2e^{-}$$

$$NiOOH(s) + H_2O(l) + e^{-} \rightarrow Ni(OH)_2(s) + OH^{-}(aq)$$

a. Will the pH in the region immediately surrounding the anode increase or decrease as the cell discharges? Give a reason for your answer.

Solution

Decrease because hydroxide ions are being consumed, meaning that the $[OH^{-}]$ is decreasing.

1 mark

Explanatory notes

A valid reason must be given to receive the mark.

The anode is the site of oxidation. The half-equation is
$Cd(s) + 2OH^{-}(aq) \rightarrow Cd(OH)_2(s) + 2e^{-}$

Hydroxide ions are being consumed, so the immediate region is becoming less alkaline and so the pH will decrease.

b. **i.** Write a balanced overall equation for the reaction that occurs when the cell is being recharged.

Solution

$Cd(OH)_2(s) + 2Ni(OH)_2(s) + \rightarrow Cd(s) + 2NiOOH(s) + 2H_2O(l)$

1 mark

Explanatory notes

The half-reactions when the cell is being recharged are the reverse of the half-reactions when the cell is being discharged. The electrons lost in oxidation must be balanced by the electrons gained in reduction. The hydroxide ions cancel each other out.

ii. What is the polarity of the anode when the cell is being recharged?

Solution

Positive

1 mark

Explanatory notes

The recharging reaction is an electrolysis reaction. It is not spontaneous, so the anode carries a positive charge.

c. A particular secondary cell delivers 1.96×10^5 J of energy per mole of cadmium.
At what voltage is this cell operating?

Solution

$n(\text{Cd}) = 1.0$ mol

$n(\text{e}^-) = 2 \times n(\text{Cd})$

$= 2.0$ mol

$Q = n(\text{e}^-) \times F$

$= 2.0 \times 96\,500$

$= 193\,000$ C

$\text{E} = \text{VQ}$

$1.96 \times 10^5 = V \times 193\,000$

$\text{V} = 1.02$ V

2 marks

Mark allocation

- 1 mark for determining $Q = 193\,000$ C.
- 1 mark for determining $V = 1.02$ V.

Total 1 + 2 + 2 = 5 marks

Question 6

A beaker containing 250 mL of 1.00 M $CuSO_4(aq)$ is electrolysed using carbon rods.

a. Write half-equations for the oxidation and reduction reactions.

i. oxidation reaction

ii. reduction reaction

Solution

i. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

ii. $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

2 marks

Explanatory notes

The strongest reductant present is H_2O, so it undergoes oxidation. The possible oxidants present are Cu^{2+} and H_2O. Cu^{2+} is the stronger oxidant and so is the species that undergoes reduction.

Mark allocation

- 1 mark for each correct half-equation.

b. As electrolysis proceeds, the blue colour of the solution fades. How long, in seconds, would it take the Cu^{2+} to reach a concentration of 0.347 M if the rods are connected to a power source with a current of 4.50 A and an approximate voltage of 5 V?

Solution

$n(Cu^{2+})_{initially} = cV$

$= 1.00 \times 0.250$

$= 0.250$ mol

$n(Cu^{2+})_{at\ end} = cV$

$= 0.347 \times 0.250$

$= 0.0868$ mol

$n(Cu^{2+})_{reacted} = 0.250 - 0.0868$

$= 0.163$ mol

$n(e^-) = 2 \times n(Cu^{2+})_{reacted}$

$= 2 \times 0.163$

$= 0.326$ mol

$Q = n(e^-) \times F$

$= 0.326 \times 96\ 500$

$= 3.15 \times 10^4$ C

$$t = \frac{Q}{I}$$

$$= \frac{3.15 \times 10^4}{4.50}$$

$= 7.00 \times 10^3$ s

4 marks

SECTION B – Question 6 – continued

Mark allocation

- 1 mark for calculating $n(Cu^{2+})_{reacted}$.
- 1 mark for calculating $n(e^-)$.
- 1 mark for calculating Q.
- 1 mark for calculating t (to 3 significant figures).

Total 2 + 4 = 6 marks

Question 7

A student investigating equilibrium uses mixtures of NO_2 and N_2O_4, which react according to the equation given below.

$2NO_2(g) \rightleftharpoons N_2O_4(g)$ ΔH is negative

Three samples of the mixture at equilibrium undergo a change.

a. State Le Chatelier's Principle.

Solution

If an equilibrium system is subject to a change it will adjust itself to partially oppose the effects of the change.

2 marks

Mark allocation

- 1 mark for indicating that a system subject to change adjusts itself to oppose the change.
- 1 mark for indicating that the response is only partial.

b. Complete the table below to indicate the effect of each change made by the student to the mixture on the rate of the reaction and the amount, in mol, of N_2O_4.

$2NO_2(g) \rightleftharpoons N_2O_4(g)$ ΔH is negative

Solution

	Is the rate of the reaction increased, decreased or unchanged?	Is the amount, in mol, of N_2O_4 when equilibrium is re-established increased, decreased or unchanged?
Sample 1: The reaction mixture is heated.	increased	decreased
Sample 2: The mixture is moved to a container double the size of the first.	decreased	decreased
Sample 3: More N_2O_4 gas is added without changing the volume.	increased	increased

6 marks

Mark allocation

- 1 mark for each correct box.

Explanatory notes

All three changes affect the reaction rate. In sample 1 the temperature is increased and in sample 3 the concentration is increased, both leading to an increase in reaction rate. In sample 2 the concentration is decreased, leading to a decrease in reaction rate.

The effect on the amount, in mol, of N_2O_4 is explained by Le Chatelier's Principle, which states that if an equilibrium system is subject to change then it will adjust itself to partially oppose the effects of the change.

- Sample 1: Heating the container adds energy to the reaction mixture. It responds by a shift in the endothermic direction, which in this case is backwards. The amount of N_2O_4 is decreased.
- Sample 2: Moving the mixture to a larger container decreases the pressure. The ratio of particles in this equation is 2 on reactant side : 1 on product side; hence, a net backward reaction results and the amount of N_2O_4 is decreased.
- Sample 3: Addition of a product causes a net backward reaction in order to remove some of the added N_2O_4. However, the response is only partial and, once equilibrium is re-established, the amount of N_2O_4 will remain higher than at the initial equilibrium.

c. In VCE Chemistry this year you have studied in detail the industrial production of a chemical.

i. Give the name and a major use for the chemical you studied.

Solution

Ammonia – manufacture of fertilisers

Ethene – manufacture of polyethene OR plastics

Nitric acid – manufacture of the fertiliser ammonium nitrate

Sulfuric acid – manufacture of fertilisers

1 mark

Tips

- *Simply writing 'fertilisers' for ammonia, nitric acid and sulfuric acid does not earn the mark. It must be specified that they are used in the manufacture of fertilisers. Answers referring to the properties of the chemical do not earn the mark; e.g. a major **use** of sulfuric acid is **not** as a dehydrating agent or as an oxidant.*

ii. Fill in the table below about the conditions used for a selected equation in the production of your chemical. **Fill in the part of the table relevant to your chosen chemical only.**

SECTION B – Question 7 – continued

Solution

Chemical & selected equation	Would a **high or low** pressure be expected to maximise yield?	Would a **high or low** temperature be expected to maximise yield?
Ammonia $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$	high	low
Ethene $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$	low	high
Nitric acid $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$	high	low
Sulfuric acid $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$	high	low

2 marks

Mark allocation

- 1 mark for pressure.
- 1 mark for temperature.

iii. Give a safety precaution that is followed by workers in the factories where your chosen chemical is produced, as well as the reason for this precaution being taken.

Safety precaution
Reason

Solution

One of the following:

Ammonia – Areas are well ventilated and workers wear protective clothing, including gloves, face masks, rubber boots and rubber aprons, because ammonia is a toxic gas OR the plant design and operation is planned carefully because the hydrogen used as a reactant is explosive and can cause fires.

Ethene – Fire-fighting prevention and fire-fighting strategies are used by industry because ethene can form explosive mixtures with air OR protective clothing is used because high and low temperatures used during its manufacture can cause burns.

Nitric acid – Stainless steel pipes and reaction vessels are sometimes used because nitric acid is corrosive OR workers wear protective clothing because nitric acid can cause severe burns to the skin and eyes OR breathing apparatus is used because the fumes are harmful if inhaled.

Sulfuric acid – Protective clothing is worn because sulfuric acid is highly corrosive and can burn skin and eyes severely OR areas are well ventilated and breathing apparatus is used because inhaled sulfuric acid mist is harmful.

2 marks

Mark allocation

- 1 mark for the precaution.
- 1 mark for a logical reason.

Total 2 + 6 + 5 = 13 marks

END OF SOLUTIONS BOOK