



INSIGHT

Year 12 Trial Exam Paper

2012

CHEMISTRY

Written examination 2

Solutions book

This book presents:

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

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SECTION A – 20 Multiple-choice questions (20 marks)**Question 1**

A chemical change will occur in the fuel tank of a car

- A. whenever an oxygen molecule collides with a hydrocarbon molecule in the fuel.
- B. only when an oxygen molecule collides with a hydrocarbon molecule in the fuel in the presence of a catalyst.
- C. **only when an oxygen molecule collides with a hydrocarbon molecule in the fuel with enough energy to overcome the activation energy barrier.**
- D. never, as only a physical change will result from the collision between oxygen and hydrocarbon molecules in the fuel.

Answer is C

Worked solution

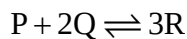
- C is correct because a collision will not be successful unless the activation energy barrier is overcome.
- A is incorrect because not every collision between reactants is a successful collision. If the energy of the particles does not reach the activation energy barrier a chemical reaction will not occur.
- B is incorrect because although a catalyst will increase the proportion of successful collisions in a mixture, it does not ensure every collision is successful. Also, other conditions can increase the number of successful collisions such as a high temperature provided by a spark.
- D is incorrect because combustion of a fuel is a chemical reaction that involves a chemical change.

**Tip**

Memorise the collision theory of chemical reactions; that is, a reaction will only occur if particles collide with enough energy to overcome the activation energy barrier.

Question 2

Consider the following equilibrium equation.



The expression for the equilibrium constant for the backward reaction is

A. $K = \frac{[\text{R}]^3}{[\text{P}][\text{Q}]^2}$

B. $K = \frac{3[\text{R}]}{[\text{P}]2[\text{Q}]}$

C. $K = \frac{[\text{P}][\text{Q}]^2}{[\text{R}]^3}$

D. $K = \frac{[\text{P}]2[\text{Q}]}{3[\text{R}]}$

Answer is C

Worked solution

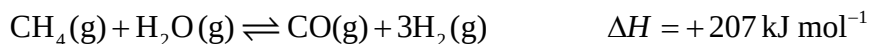
- C is correct because the backward reaction is $3\text{R} \rightleftharpoons \text{P} + 2\text{Q}$. In the equilibrium expression, the concentration of the products is divided by the concentration of the reactants.
- A is incorrect because this is the equilibrium expression for the forward reaction; the question asks for the equilibrium expression of the backward reaction.
- B is incorrect because this is the equilibrium expression for the forward reaction, not the backward reaction, and the coefficients in the reaction must be the index of each concentration in the equilibrium expression.
- D is incorrect because the coefficients in the reaction must be the index of each concentration in the equilibrium expression.

**Tip**

Use reading time effectively to look for important words such as 'backward' reaction, especially in equilibrium questions.

Questions 3 and 4 refer to the following information.

Hydrogen gas can be produced industrially by the following reaction.



Question 3

A catalyst is added to a mixture of gaseous methane and water that is at equilibrium. As a result of this change, the rate at which hydrogen gas is produced will

- A. decrease.
- B. **increase.**
- C. initially increase and then decrease over time.
- D. remain unchanged.

Answer is B

Worked solution

- B is correct because adding a catalyst increases the rate of a reaction. The forward and backward reactions will both increase. The **amount** of hydrogen gas produced will not change.
- A is incorrect because adding a catalyst always increases the rate of a reaction.
- C is incorrect because the position of equilibrium is not changed by the addition of a catalyst. The rate of the backward reaction increases at the same rate as the forward reaction. Overall, the concentration of hydrogen gas remains unchanged.
- D is incorrect because although the overall concentration of hydrogen gas remains unchanged, the rate at which it is produced will increase by the addition of a catalyst.

Question 4

0.450 mol of methane and 0.540 mol of gaseous water were placed in a sealed and insulated reaction vessel. Once equilibrium was established, the temperature change in the reaction vessel indicated 72.5 kJ of energy had been absorbed in the reaction.

The amount of gaseous water remaining in the vessel at equilibrium is

- A. 0.100 mol
- B. 0.140 mol
- C. **0.190 mol**
- D. 0.350 mol

Answer is C

Worked solution

- C is correct according to the following steps.

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

1 mol consumed absorbs 207 kJ of energy so:

$$\begin{aligned} n(\text{H}_2\text{O}) &= \frac{72.5}{207} \\ &= 0.350 \text{ mol} \end{aligned}$$

Step 2: Determine the amount of unreacted water.

$$\begin{aligned} n(\text{H}_2\text{O}) \text{ unreacted} &= n(\text{H}_2\text{O}) \text{ initially} - n(\text{H}_2\text{O}) \text{ unreacted} \\ &= 0.540 - 0.350 \\ &= 0.190 \text{ mol} \end{aligned}$$

- A is incorrect because only 0.350 mol of water is consumed in the absorption of 207 kJ of energy.
- B is incorrect because there was 0.540 mol of water present initially, not 0.450 mol.
- D is incorrect because 0.350 mol is the amount of water that reacted, not the amount of water remaining in the vessel after the reaction.

Question 5

A large equilibrium constant indicates a particular reaction

- I reacts very quickly.
- II has a large amount of products present at equilibrium.
- III is most likely to be exothermic.

Which of the following are correct statements?

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

Answer is A

Worked solution

- A is correct because II is the only true statement. The equilibrium constant is calculated using the concentration of products divided by the concentration of reactants. A very large constant indicates there is much more products than reactants present. The size of the equilibrium constant gives no indication of the rate of the reaction or whether it releases or absorbs energy.
- B is incorrect because I is not a correct statement.
- C is incorrect because III is not a correct statement.
- D is incorrect because I and III are not correct statements.

Question 6

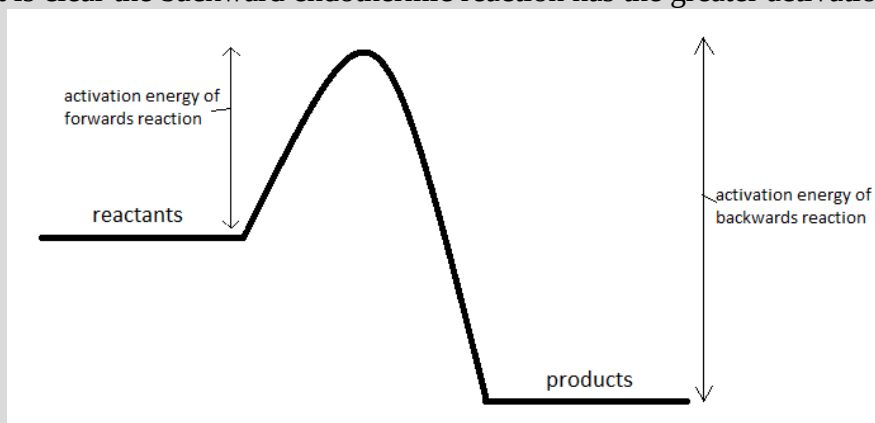
In an exothermic equilibrium reaction

- A. the enthalpy of the products is greater than the enthalpy of the reactants.
- B. increasing the temperature will decrease the rate of the reaction.
- C. the rate of the forward reaction is always greater than the rate of the backward reaction.
- D. **the activation energy of the reverse reaction is greater than the activation energy of the forward reaction.**

Answer is D

Worked solution

- D is correct because when you consider the energy profile diagram of an exothermic reaction, it is clear the backward endothermic reaction has the greater activation energy.



- A is incorrect because the enthalpy of the products is less than the enthalpy of the reactants.
- B is incorrect because the rate of a chemical reaction is always increased by increasing temperature.
- C is incorrect because the position of equilibrium and hence the relative rates of the forward and backward reactions are not determined by the reaction being exothermic or endothermic.

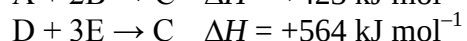


Tip

It is a good idea to sketch an energy profile diagram for these types of questions to refer to when selecting the best response.

Question 7

Consider the following reactions.



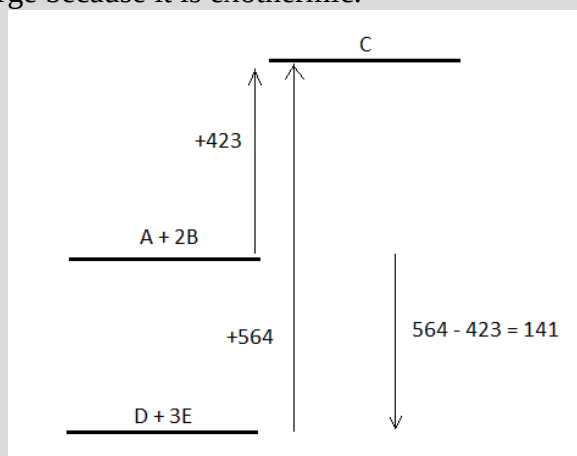
The enthalpy change for the reaction $A + 2B \rightarrow D + 3E$ is

- A. $+141 \text{ kJ mol}^{-1}$
- B. -141 kJ mol^{-1}
- C. $+987 \text{ kJ mol}^{-1}$
- D. -987 kJ mol^{-1}

Answer is B

Worked solution

- B is correct because when the reactions are sketched on an energy profile diagram, the energy difference between $A + 2B$ and $D + 3E$ becomes evident and easily determined. It carries a negative charge because it is exothermic.



- A is incorrect because the enthalpy of the products is less than the enthalpy of the reactants, making it an exothermic reaction so ΔH is negative.
- C is incorrect because $A + 2B$ and $D + 3E$ both have to absorb energy to produce C . The enthalpy of both sets of reactants is lower than that of C .
- D is incorrect because $A + 2B$ and $D + 3E$ both have to absorb energy to produce C . The enthalpy of both sets of reactants is lower than that of C .

Question 8

The complete combustion of 5.00 g of methane in a fully insulated calorimeter is used to heat 200.0 g of water with an initial temperature of 23.4°C. The temperature of the water after the combustion, in °C, will be closest to

- A. 59.0
- B. 82.0
- C. 332
- D. 355

Answer is D

Worked solution

- D is correct according to the following steps.

Step 1: Determine the amount, in mol, of methane present

The formula of methane is CH₄ and it has a molar mass of 16.0 g mol⁻¹.

$$\begin{aligned} n(\text{CH}_4) &= \frac{m}{M} \\ &= \frac{5.00}{16.0} \\ &= 0.313 \text{ mol} \end{aligned}$$

Step 2: Determine the amount of energy released by the methane.

The molar enthalpy of methane is -889 kJ mol⁻¹.

$$\begin{aligned} E &= 0.313 \text{ mol} \times 889 \\ &= 278 \text{ kJ} \end{aligned}$$

Step 3: Determine the change in temperature of the water.

$$E \text{ (in J) required to heat water} = m \text{ of water} \times \Delta T \times 4.18$$

$$\begin{aligned} \text{So } \Delta T &= \frac{278 \times 10^3}{200.0 \times 4.18} \\ &= 332^\circ\text{C} \end{aligned}$$

The temperature after the combustion is 23.4 + 332 = 355°C

- A is incorrect because the temperature is already in °C, not in K. It does not need further conversion to °C. Also the value of 332 is the change in temperature, not the final temperature.
- B is incorrect because the temperature is already in °C, not in K. It does not need further conversion to °C.
- C is incorrect because 332°C is the change in temperature and must be added to the initial temperature to find the final temperature.

**Tip**

The molar enthalpy values of the combustion of many common fuels are listed in the Data Booklet.

Question 9

A packet of dried noodles is labelled as having an energy content of 2620 kJ per 100 g. A 2.85 g sample of the noodles was combusted in a bomb calorimeter that has a calibration factor of $2.94 \times 10^3 \text{ J } ^\circ\text{C}^{-1}$. The expected temperature increase, in $^\circ\text{C}$, observed over the course of the reaction is

- A. 25.4×10^{-3}
- B. 0.891
- C. 25.4
- D. 298

Answer is C

Worked solution

- C is correct according to the following.

$$\begin{aligned} E \text{ released} &= \frac{2.85}{100} \times 2620 \\ &= 74.7 \text{ kJ} \end{aligned}$$

$$\begin{aligned} \Delta T &= \frac{E}{\text{calibration factor}} \\ &= \frac{74.7 \times 10^3}{2.94 \times 10^3} \\ &= 25.4^\circ\text{C} \end{aligned}$$

- A is incorrect because the calibration factor is given in $\text{J } ^\circ\text{C}^{-1}$, so the energy released by the sample must be converted from kJ to J.
- B is incorrect because the sample burnt in the calorimeter was only 2.85 g, not 100 g.
- D is incorrect because 298 is the temperature increase in K, not $^\circ\text{C}$.

Question 10

The molar enthalpy of combustion for a particular fuel is

- A. the energy released when 1 g of the fuel completely reacts in oxygen.
- B. **the energy released when 1 mole of the fuel completely reacts in oxygen**
- C. the energy released when 1, 2 or 3 mole of the fuel completely reacts in oxygen, depending on the balanced chemical equation.
- D. always less than the energy released by the fuel in terms of kJ g^{-1} .

Answer is B

Worked solution

- B is correct because the molar enthalpy value is always kJ mol^{-1} .
- A is incorrect because the mass of 1 mole of a fuel varies. It will not be 1.0 g.
- C is incorrect because while the ΔH value of the combustion equation will vary depending on how the equation is balanced, the molar enthalpy value of the fuel is always kJ per 1 mole.
- D is incorrect because 1 mole of all fuels will weigh more than 1.0 g; hence, the molar enthalpy value will be higher than the energy released when expressed in kJ g^{-1} .

Question 11

A galvanic cell consists of one half-cell that is made up of an inert electrode in a solution containing 1.0 M of $\text{Sn}^{4+}(\text{aq})$ and 1.0 M of $\text{Sn}^{2+}(\text{aq})$.

Which one of the following could be used as the second half-cell so that a current is produced and the polarity of the electrode in the $\text{Sn}^{4+}(\text{aq})/\text{Sn}^{2+}(\text{aq})$ half-cell is positive?

- A. a sodium electrode in a solution of 1.0 M $\text{NaCl}(\text{aq})$
- B. an inert electrode in a solution containing 1.0 M $\text{Fe}^{2+}(\text{aq})$ and 1.0 M $\text{Fe}^{3+}(\text{aq})$
- C. **an iron electrode in a solution containing 1.0 M $\text{Fe}^{2+}(\text{aq})$**
- D. a silver electrode in a solution containing 1.0 M $\text{Ag}^{+}(\text{aq})$

Answer is C

Worked solution

- C is correct because if the electrode in the $\text{Sn}^{4+}(\text{aq})/\text{Sn}^{2+}(\text{aq})$ half-cell is positive it will be the cathode and so reduction will be occurring. The species in the other half-cell must contain a stronger reductant than Sn^{2+} . The only stable species listed that is a stronger reductant (lower on the right side of the electrochemical series) is solid iron.
- A is incorrect because sodium metal is too reactive to be used as an electrode in a solution. It could not possibly be used in a solution half-cell.
- B is incorrect because Fe^{2+} is not a stronger reductant than Sn^{2+} .
- D is incorrect because Ag is not a stronger reductant than Sn^{2+} .

Question 12

The predicted maximum voltage produced by a galvanic cell containing $\text{Br}_2(\text{aq})/\text{Br}^{-}(\text{aq})$ and $\text{I}_2(\text{s})/\text{I}^{-}(\text{aq})$ half-cells is

- A. 0.54 V
- B. **0.55 V**
- C. 1.09 V
- D. 1.64 V

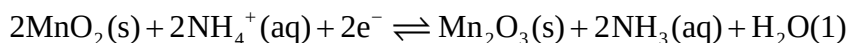
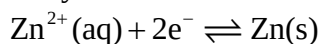
Answer is B

Worked solution

- B is correct because the potential difference of a galvanic cell is determined by values given on the electrochemical series by calculating E° value of higher half-equation – E° value of higher half-equation: $(+1.09) - (+0.54) = 0.55 \text{ V}$
- A is incorrect because 0.54 V is the E° value of the $\text{I}_2(\text{s})/\text{I}^{-}(\text{aq})$ half-equation and not the difference between the two equations.
- C is incorrect because 1.09 V is the E° value of the $\text{Br}_2(\text{s})/\text{Br}^{-}(\text{aq})$ half-equation and not the difference between the two equations.
- D is incorrect because it is the difference between the E° values of the two half-equations that determines the maximum voltage, not the two E° values being added together.

Questions 13–15 refer to the following information.

The zinc–carbon dry cell utilises the following half-equations.



When the cell is in operation, solid zinc acts as the anode.

Question 13

The species acting as the reductant when the cell is in operation is

- A. MnO_2
- B. Mn_2O_3
- C. Zn^{2+}
- D. Zn

Answer is D

Worked solution

- D is correct because in operation zinc is the anode meaning it is the site of oxidation. Zn metal is oxidised to Zn^{2+} , making Zn metal the reductant.
- A is incorrect because when the cell is operating, MnO_2 is undergoing reduction so acting as the oxidant.
- B is incorrect because when the cell is in operation, Mn_2O_3 is a product, not a reactant.
- C is incorrect because when the cell is in operation, Zn^{2+} is a product not a reactant.

Question 14

When the dry cell is in operation the energy transformation occurring is

- A. **chemical → electrical + heat**
- B. chemical + heat → electrical
- C. kinetic → electrical + heat
- D. kinetic + heat → electrical

Answer is A

Worked solution

- A is correct because the dry cell is a type of galvanic cell, meaning energy is transformed from chemical to electrical.
- B is incorrect because heat is a by-product of the reaction, not another reactant.
- C and D are incorrect because there is no kinetic energy involved in the energy transformations in a galvanic cell.

Question 15

Which of the following best describes why the zinc–carbon dry cell is a primary cell and not a secondary cell?

- A. The cell can be connected to an external power source and be recharged.
- B. When the cell is in operation, the reaction is exothermic.
- C. **When the cell is in operation, the products of the reaction migrate away from the electrodes.**
- D. Over a period of time, the cell will eventually become ‘flat’ and can no longer be used to produce a voltage.

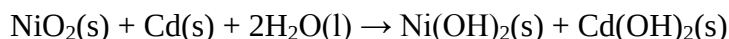
Answer is C

Worked solution

- C is correct: a primary cell is unable to be recharged because of the products migrating away from the electrodes.
- A is incorrect because only a secondary cell can be recharged, not a primary cell.
- B is incorrect because both primary and secondary cells release energy.
- D is incorrect because both primary and secondary cells can become flat over a period of time.

Question 16

The overall reaction in the rechargeable nickel–cadmium cell while it is powering a computer tablet is



The reaction that occurs at the positive electrode when the cell is recharging is

- A. **$\text{Ni}(\text{OH})_2(\text{s}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{NiO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^-$**
- B. $\text{Cd}(\text{OH})_2(\text{s}) + 2\text{e}^- \rightarrow \text{Cd}(\text{s}) + 2\text{OH}^-(\text{aq})$
- C. $\text{NiO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightarrow \text{Ni}(\text{OH})_2(\text{s}) + 2\text{OH}^-(\text{aq})$
- D. $\text{Cd}(\text{s}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Cd}(\text{OH})_2(\text{s}) + 2\text{e}^-$

Answer is A

Worked solution

- A is correct because when it is recharging, the cell is an electrolytic cell; hence, the positive electrode is the anode where oxidation is occurring. The oxidation number of Ni increases from +2 in $\text{Ni}(\text{OH})_2$ to +4 in NiO_2 , indicating that it is undergoing oxidation.
- B is incorrect because this is a reduction reaction so would occur at the negative cathode when the cell is recharging.
- C and D are incorrect because recharging will be the reverse of the discharging equation so $\text{Ni}(\text{OH})_2(\text{s})$ and $\text{Cd}(\text{OH})_2(\text{s})$ are the reactants.

Question 17

If a primary cell is compared to a recharging secondary cell, it is true to state that

- A. in the primary cell, reduction occurs at the negative electrode.
- B. in the primary cell, oxidation occurs at the positive anode.
- C. in the recharging secondary cell, products are continuously removed.
- D. **the reaction in the recharging secondary cell is endothermic.**

Answer is D

Worked solution

- D is correct because the recharging of a secondary cell requires the input of electrical energy to reverse the discharging cell reaction.
- A is incorrect because a primary cell is a galvanic cell so reduction occurs at the positive cathode.
- B is incorrect because a primary cell is a galvanic cell so oxidation occurs at the negative anode.
- C is incorrect because it is a fuel cell, not a secondary cell, in which products are continuously removed.

Question 18

An electrolytic cell was used to deposit 0.060 mol of chromium on a carbon electrode. If the amount of electricity passed through the cell is X , how much electricity, in terms of X , would be required to deposit 0.060 mol of silver on a carbon electrode using the same cell?

- A. X
- B. $3X$
- C. X^3
- D. $\frac{X}{3}$

Answer is D

Worked solution

- D is correct. A chromium ion is Cr^{3+} whereas a silver ion is Ag^+ so 3 mole of electrons are required to deposit 1 mole of chromium whereas 1 mole of electrons is required to deposit 1 mole of silver metal. One-third of the electrons required to deposit 1 mol of Cr are required to deposit 1 mol of Ag.
- A is incorrect because the chromium and silver ions have different electrovalencies so require different amounts of electricity to deposit 1 mole of metal.
- B and C are incorrect because silver requires less electricity than chromium to deposit an equivalent amount of metal.

Question 19

When electroplating an object, the object to be plated will be the

- A. **negative electrode, which is the cathode.**
- B. negative electrode, which is the anode.
- C. positive electrode, which is the cathode.
- D. positive electrode, which is the anode.

Answer is A

Worked solution

- A is correct because electroplating requires metal ions to be reduced to metal atoms, so the object to be plated must be the cathode. An electroplating cell is an electrolytic cell so the cathode is negative.
- B is incorrect because an electroplating cell is an electrolytic cell so the negative electrode is the cathode.
- C is incorrect because an electroplating cell is an electrolytic cell so the cathode is the negative electrode.
- D is incorrect because electroplating requires metal ions to be reduced to metal atoms so the object to be plated must be the cathode.

Question 20

In a 100 mL solution of 0.10 M of nitrous acid

- A. the molar concentration of NO_2^- (aq) is greater than the molar concentration of hydronium ions.
- B. the molar concentration of hydronium ions is less than the molar concentration of hydroxide ions.
- C. apart from H_2O , the species present in the highest concentration is HNO_3 .
- D. **the pH is higher than a 10 mL solution of 0.10 M nitric acid.**

Answer is D

Worked solution

- D is correct because nitrous acid is a weak acid so has a higher pH than the same concentration of nitric acid, which is a strong acid and completely ionises in water.
- A is incorrect because NO_2^- and H_3O^+ ions will be present in equal concentration as they are produced at the same rate when nitrous acid partially ionises in water.
- B is incorrect because although nitrous acid is a weak acid it is still an acid. It is a proton donor and creates H_3O^+ ions when it partially ionises in water. In an acid, the concentration of hydronium ions is higher than the concentration of hydroxide ions.
- C is incorrect because nitrous acid has the formula HNO_2 , not HNO_3 .

END OF SECTION A

**END OF SECTION A
TURN OVER**

SECTION B – Short-answer questions**Question 1**

During this semester you studied the production of one of the following chemicals as part of your study of the industrial production of an important chemical. Place a tick in the box next to the chemical you studied.

	ammonia
	ethene
	nitric acid
	sulfuric acid

a. The chemical you studied is produced by a series of chemical reactions from raw materials.

- i.** Give the name and formula of a raw material that can be used in the production of your chosen chemical.

1 mark

Solution

Ammonia: N_2 , H_2 or CH_4

Ethene: e.g. C_3H_8 or C_2H_6

Nitric acid: NH_3 or O_2

Sulfuric acid: S , SO_2 or O_2

- ii.** Write a balanced equation for a chemical reaction in which the raw material given in part **i.** is used. State symbols are not necessary.

1 mark

Solution

Ammonia: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$, $\text{CH}_4 + \text{H}_2\text{O} \rightleftharpoons \text{CO} + \text{H}_2$

Ethene: $\text{C}_3\text{H}_8 \rightarrow \text{C}_2\text{H}_4 + \text{CH}_4$

Nitric acid: $4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$

Sulfuric acid: $\text{S} + \text{O}_2 \rightarrow \text{SO}_2$ or $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$

b. Excess heat results from the production of your chemical. Describe one way in which waste heat from the production of your chosen chemical is reused to reduce energy costs.

1 mark

Solution

Ammonia: Waste heat is used to heat up the incoming gas mixture.

Ethene: Waste heat is used to generate more high-pressure steam for the cracking process.

Nitric acid: Waste heat is used to heat incoming gases or generate electricity.

Sulfuric acid: Waste heat is used to generate electricity or to liquefy the sulfur (Frasch process).

- c. Identify two risks to humans of exposure to your selected chemical.

2 marks

Solution

Ammonia: Two of: extreme irritant to eyes, respiratory system or other parts of the body, frost bite, severe burning.

Ethene: Two of: dizziness, headaches, nausea, explosions

Nitric acid: Two of: severe burns to skin or to eyes, harmful if inhaled.

Sulfuric acid: Two of: severe burns to skin or to eyes, build-up of fluid in the lungs

Mark allocation

- 1 mark for each risk

Total 1 + 1 + 1 + 2 = 5 marks

Question 2

The energy sources currently available to society include a range of renewable and non-renewable sources. Governments need to make choices about future energy needs and the best energy sources available.

- a. i. Describe one renewable energy source and give one reason why you would recommend this energy source, in addition to it being renewable.

1 mark

Solution

For example:

Wind, hydro, solar, bioethanol, biodiesel – no net greenhouse gas emissions.

- ii. Give one disadvantage of using this energy source.

1 mark

Solution

For example: too expensive, unreliable due to dependence on the weather, excessive land-clearing to grow crops for biofuels.

- b. i. Describe one non-renewable energy source and give one reason why you would recommend this energy source.

1 mark

Solution

For example:

- coal – cheap
- natural gas – environmentally friendly as no sulfur emissions
- nuclear – no greenhouse gas emissions.

- ii. Give one disadvantage, besides it being non-renewable, of using this energy source.
1 mark

Solution

For example:

- coal – burning of sulfur in coal contributes to acid rain
- natural gas – carbon dioxide emissions contribute to the enhanced greenhouse effect
- nuclear – risk of nuclear explosions, need to dispose of radioactive waste materials.

- c. Fuel cells offer a clean and efficient way of producing electricity directly from chemicals.
i. What main feature makes a fuel cell different to a primary or secondary cell?
1 mark

Solution

The supply of reactants (and removal of products) is continuous.

- ii. Give the names of two reactants used in a fuel cell you are familiar with.
1 mark

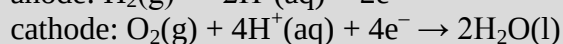
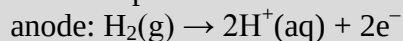
Solution

For example: hydrogen and oxygen.

- iii. Give possible anode and cathode reaction half-equations in this fuel cell.
2 marks

Solution

For example:

**Explanatory notes**

This is only one example of correct reactions for an acidic hydrogen–oxygen fuel cell. There are other possibilities with which you may be familiar.

Mark allocation

- 1 mark for each reaction.

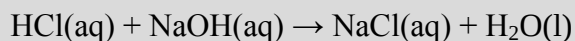
Total 1 + 1 + 1 + 1 + 1 + 1 + 2 = 8 marks

Question 3

70.0 mL of 1.3 M HCl and 30.0 mL of 2.0 M NaOH, both at 21.3°C, are mixed in a calorimeter. After the reaction is complete the temperature inside the calorimeter has reached 29.2°C. The calibration factor for the calorimeter and contents is 423 J K⁻¹.

- a. Write a balanced equation for the chemical reaction between HCl and NaOH.

1 mark

Solution

- b. Calculate the ΔH value of this reaction equation in kJ mol⁻¹.

4 marks

Solution

$$\begin{aligned} \text{energy released} &= \Delta T \times \text{calibration factor} \\ &= (29.2 - 21.3) \times 423 \\ &= 3341.7 \text{ J} \\ &= 3.34 \text{ kJ} \end{aligned}$$

$$\begin{aligned} n(\text{HCl}) &= cV \\ &= 1.3 \times 0.0700 \\ &= 0.091 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(\text{NaOH}) &= cV \\ &= 2.0 \times 0.0300 \\ &= 0.060 \text{ mol} \end{aligned}$$

NaOH and HCl react in a 1:1 ratio so NaOH is the limiting reagent.
The limiting sample of 0.060 mol NaOH released 3.34 kJ.

$$\text{So 1 mol of NaOH will release } \frac{3.34}{0.060} = 55.7 \text{ kJ}$$

The ΔH value is -55.7 kJ mol⁻¹.

Mark allocation

- 1 mark for determining the energy released by the sample as 3.34 kJ.
- 1 mark for determining that NaOH is the limiting reagent.
- 1 mark for correctly determining the energy change for the equation.
- 1 mark for showing the ΔH value is negative.

- c. The value determined in part **b.** is found to be slightly less than the actual value. Suggest two likely errors that could contribute to this result.

2 marks

Solution

Two of:

- Some heat was lost due to poor insulation or a poorly fitting lid etc.
- The volume of NaOH was slightly greater than 30.0 mL.
- The volume of HCl was slightly greater than 70.0 mL.
- Stirring was not adequate during the reaction.

Mark allocation

- 1 mark for each error

Total 1 + 4 + 2 = 7 marks

Question 4

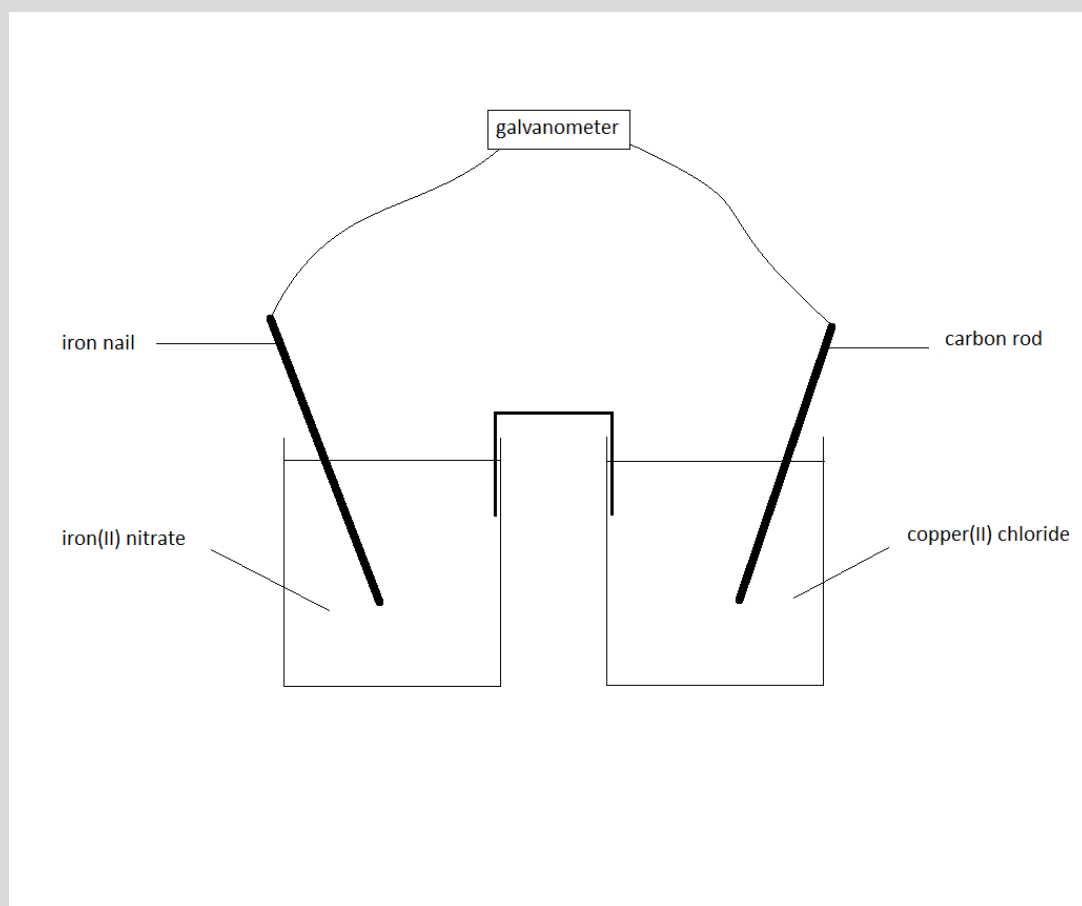
A student is provided with the following materials:

- iron nails
- carbon rods
- copper rods
- copper(II) chloride
- iron(II) nitrate
- sodium nitrate
- potassium hydroxide
- beakers
- filter paper
- wires
- galvanometer

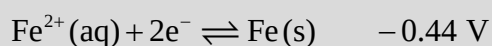
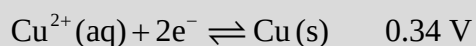
The student is then asked to set up a galvanic cell that will produce a voltage as close to 0.75 V as possible.

- a.** Draw and fully label how the student should use these materials to construct the cell. Not all of the materials necessarily need to be used.

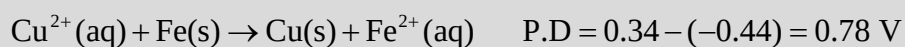
5 marks

Solution**Explanatory notes**

The only two possible reactions with E° values that will produce a potential difference close to 0.75 V are:



This makes an overall equation of



Copper or carbon rods will work equally well as the cathode to produce a voltage close to 0.75 V.

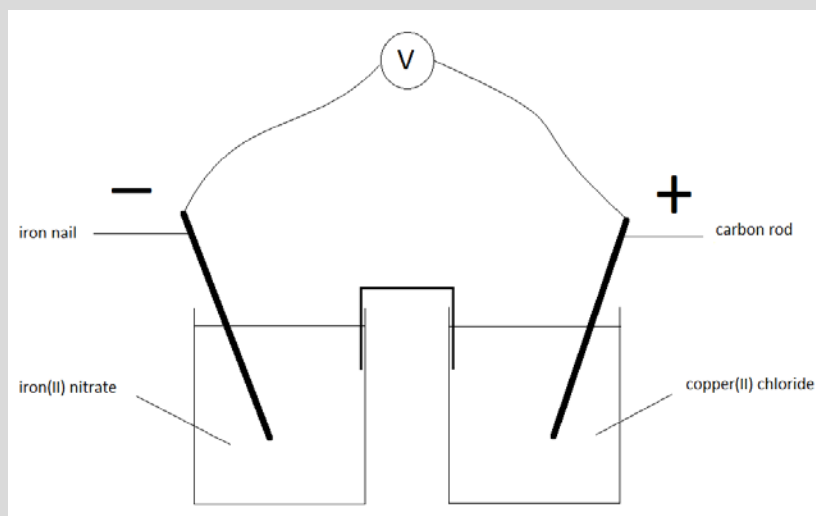
Mark allocation

- 1 mark for correctly drawn cell.
- 1 mark for iron nail as one electrode.
- 1 mark for iron(II) nitrate as one electrolyte.
- 1 mark for carbon or copper rod as one electrode.
- 1 mark for copper(II) chloride as one electrolyte.

- b. Label the positive and negative electrodes on the cell you drew in part a.

1 mark

Solution



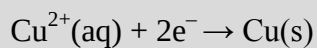
Explanatory notes

The positive electrode is the cathode, which is where the reduction of copper ions occurs.

- c. Write the reduction half-equation that occurs in the cell.

1 mark

Solution



- d. State which solution would be best used to soak the filter paper when making the salt bridge.

1 mark

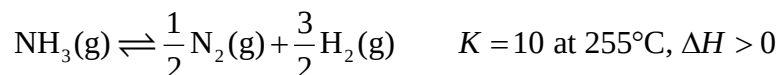
Solution

Sodium nitrate

Total 5 + 1 + 1 + 1 = 8 marks

Question 5

Consider the following equation



- a. A mixture of these gases in a 2.0 L container, at 255°C, was found to contain 2.0 mol of NH_3 , 3.0 mol of N_2 and 1.4 mol of H_2 .
- i. Determine whether this mixture is at equilibrium. Show your working in your answer.

3 marks

Solution

$$[\text{NH}_3] = \frac{2.0}{2.0} = 1.0 \text{ M}$$

$$[\text{N}_2] = \frac{3.0}{2.0} = 1.5 \text{ M}$$

$$[\text{H}_2] = \frac{1.4}{2.0} = 0.70 \text{ M}$$

$$\begin{aligned} \text{Concentration fraction} &= \frac{[\text{N}_2]^{\frac{1}{2}} [\text{H}_2]^{\frac{3}{2}}}{[\text{NH}_3]} \\ &= \frac{(1.5)^{\frac{1}{2}} (0.70)^{\frac{3}{2}}}{(1.0)} \\ &= \frac{(1.22)(0.59)}{1.0} \\ &= 0.72 \end{aligned}$$

The mixture is not at equilibrium.

Mark allocation

- 1 mark for correct expression of equilibrium constant.
- 1 mark for correct calculation of concentrations.
- 1 mark for correct calculation of the concentration fraction and statement that mixture is not at equilibrium.

- ii. In order to reach equilibrium, will the forward or backward reaction need to be favoured? Give a reason for your answer.

1 mark

Solution

Net forward reaction. The concentration fraction is less than the K value, so more products need to be present in the mixture to reach equilibrium.

- b. Describe two changes you could make to this set-up in order to increase the proportion of products in the equilibrium mixture.

2 marks

Solution

Two of :

- decrease the pressure
- increase the volume of the container
- increase the temperature.

Explanatory notes

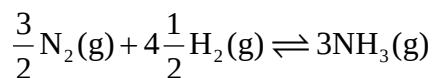
The reaction is endothermic so products are favoured by high temperatures, which will increase the K value.

The reaction has a greater number of particles on the product side of the equation so products are favoured by lower pressures and/or larger volumes.

Mark allocation

- 1 mark each for up to two correct changes

- c. Calculate the equilibrium constant for the following reaction at 255°C. The unit is not necessary.



2 marks

Solution

$$K = \frac{1}{(0.72)^3}$$

$$= 2.7$$

Explanatory notes

This equation is the reverse of the earlier equation, meaning the K value will be the inverse of the forward reaction. Also, the coefficients in the second equation are 3 times the coefficients in the first equation so the K value must also be cubed.

Mark allocation

- 1 mark for cubing the K value of the first equation.
- 1 mark for taking the inverse of the first equation.

Total 3 + 1 + 2 + 2 = 8 marks

Question 6

- a. i. Calculate the pH of a 0.20 M solution of hydrofluoric acid at 25°C.

2 marks

Solution

$$K_a = \frac{[\text{H}_3\text{O}^+]^2}{[\text{HA}]}$$

$$7.6 \times 10^{-4} = \frac{[\text{H}_3\text{O}^+]^2}{0.20}$$

$$[\text{H}_3\text{O}^+]^2 = 1.52 \times 10^{-4}$$

$$[\text{H}_3\text{O}^+] = 0.012$$

$$\text{pH} = -\log_{10}[\text{H}_3\text{O}^+]$$

$$= -\log_{10}(0.012)$$

$$= 1.9$$

Mark allocation

- 1 mark for correctly determining $[\text{H}_3\text{O}^+]$.
- 1 mark for correct calculation of pH.

- ii. Would you expect the pH of a 0.20 M solution of hydrofluoric acid to be the same or different at a temperature of 50°C? Give a reason for your answer.

1 mark

Solution

Different. The ionisation of a weak acid is not complete. The position of equilibrium will be affected by temperature change, changing the extent of ionisation and the amount of H_3O^+ formed.

**Tip**

Hydrofluoric acid is a weak acid. Its acidity constant is included in the Data Booklet.

b. The following two solutions are prepared.

- Solution A: a 500 mL solution containing 0.200 mole of hypochlorous acid
- Solution B: a 500 mL solution containing 0.200 mole of hypobromous acid

Which solution is the most acidic? Justify your answer in terms of the hydronium ion concentrations present.

2 marks

Solution

The K_a value of hypochlorous acid is higher than the K_a value of hypobromous acid, meaning hypochlorous acid ionises to a greater extent and produces a higher concentration of hydronium ions. Therefore solution A is a more acidic solution.

Mark allocation

- 1 mark for identifying Solution A as more acidic.
- 1 mark for a reasonable justification.

Total 2 + 1 + 2 = 5 marks

Question 7

Le Chatelier's principle can be used to explain what occurs when changes are made to an equilibrium system.

- a. Briefly outline Le Chatelier's principle.

2 marks

Solution

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

Mark allocation

- 1 mark for indicating that Le Chatelier's principle is about how an equilibrium system responds to a change.
- 1 mark for indicating that the response only partially opposes the change.

- b. A particular chemical is produced industrially by an exothermic reaction.

- i. Explain why production of this chemical is favoured by low temperatures.

2 marks

Solution

When subject to low temperatures, an equilibrium system will move to increase the temperature. An exothermic reaction releases heat to the environment so will shift right when temperature is lowered.

Mark allocation

- 1 mark for indicating that the system will oppose a decrease in temperature by attempting to increase the temperature.
- 1 mark for indicating that this will require the reaction to move in the exothermic (forward) direction.

- ii. Explain why low temperatures are rarely used industrially, even when the production reaction is exothermic.

1 mark

Solution

The rate of the reaction would be too slow.

Total 2 + 2 + 1 = 5 marks

Question 8

Determine each of the following.

- a. The mass of silver deposited on a kettle dipped in a solution of silver nitrate in an electroplating cell that is operated with a current of 1.35 A for 30 minutes.

3 marks

Solution

$$\begin{aligned} Q &= It \\ &= 1.35 \times 30.0 \times 60 \\ &= 2430 \text{ C} \end{aligned}$$

$$\begin{aligned} n(\text{e}^-) &= \frac{Q}{F} \\ &= \frac{2430}{96500} \\ &= 0.0252 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(\text{Ag}^+) : n(\text{e}^-) &\text{ is } 1 : 1 \\ \text{so } n(\text{Ag}^+) &= 0.0252 \text{ mol} \\ m(\text{Ag}) &= nM \\ &= 0.0252 \times 107.9 \\ &= 2.72 \text{ g} \end{aligned}$$

Mark allocation

- 1 mark for correctly calculating Q .
- 1 mark for correctly calculating $n(\text{e}^-)$.
- 1 mark for correctly calculating $m(\text{Ag})$.

- b. The amount of electric charge, in coulombs (C), required to reduce 0.789 mol of Al^{3+} ions to aluminium metal.

2 marks

Solution

$$\begin{aligned}
 n(\text{Al}^{3+}) : n(\text{e}^-) &\text{ is } 1 : 3 \\
 \text{so } n(\text{e}^-) &= 3 \times n(\text{Al}^{3+}) \\
 &= 3 \times 0.789 \\
 &= 2.37 \text{ mol} \\
 Q &= n(\text{e}^-) \times F \\
 &= 2.37 \times 96500 \\
 &= 2.28 \times 10^5 \text{ C}
 \end{aligned}$$

Mark allocation

- 1 mark for correct calculation of $n(\text{e}^-)$.
- 1 mark for correct calculation of Q from $n(\text{e}^-)$.

- c. The amount of electrical energy, in joules (J), provided by a fuel cell that delivers a current of 0.80 A for 15.0 minutes at a voltage of 0.78 V.

2 marks

Solution

$$\begin{aligned}
 E &= VIt \\
 &= 0.78 \times 0.80 \times 15.0 \times 60 \\
 &= 5.6 \times 10^2 \text{ J}
 \end{aligned}$$

Mark allocation

- 1 mark for correct calculation using $E = VIt$.
- 1 mark for expression of answer in J.

Total 3 + 2 + 2 = 7 marks

END OF SECTION B
END OF SOLUTIONS BOOK