Insight Publications

INSIGHT

Trial Exam Paper

2007
CHEMISTRY
Written examination 2

Solutions book

This book presents:

- correct solutions
- explanatory notes
- mark allocations
- tips and guidelines

SECTION A – Multiple choice questions

Question 1

The elements in Dimitri Mendeleev's periodic table were arranged in order of

A. **increasing atomic mass and those with similar chemical properties grouped in columns.**

B. increasing atomic number and those with similar chemical properties grouped in columns.

C. increasing atomic mass and those with similar chemical properties grouped in rows.

D. increasing atomic number and those with similar chemical properties grouped in rows.

Answer is A.

Explanatory notes

- A is correct because Mendeleev realised that the chemical properties of elements vary periodically with their atomic masses and he used this as the basis of his table. He placed them in order of increasing atomic mass and organised elements with similar properties into groups.
- B is incorrect because Mendeleev used atomic masses, not atomic numbers. Protons and neutrons were, as yet, undiscovered and the concept of atomic number did not exist.
- C is incorrect because elements with similar chemical properties were grouped in columns.
- D is incorrect because the concept of atomic number did not yet exist and elements with similar chemical properties were grouped in columns.

Question 2

The amount of energy required to raise the temperature of 75.0 g of lead by 14.6°C is 142 J. The specific heat capacity of lead in J g^{-1} $°C^{-1}$, is

A. 1.30×10^{-4}

B. 6.58×10^{-3}

C. **0.130**

D. 7.71

Answer is C.

Explanatory notes

- C is correct according to the following calculation.

  E = specific heat capacity × m × ΔT

  So, specific heat capacity = $\dfrac{E}{m \times \Delta T}$

  $= \dfrac{142}{75.0 \times 14.6}$

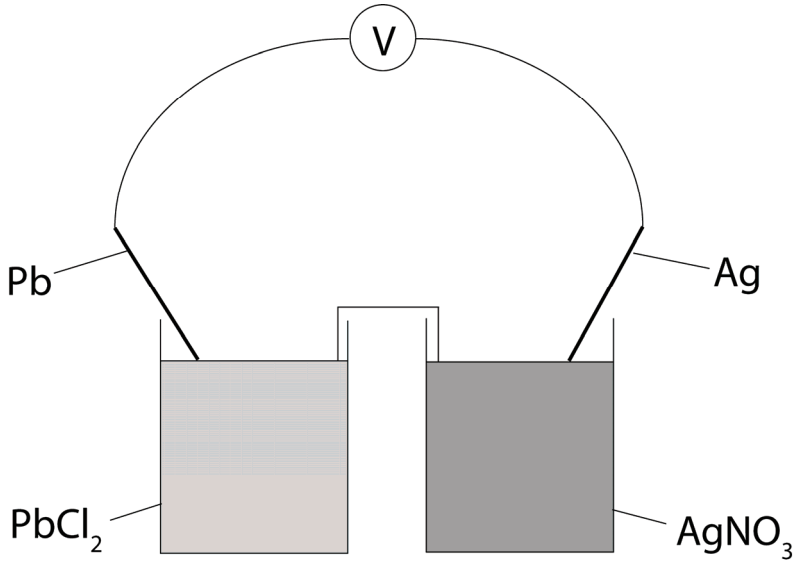
  $= 0.130 \text{ J g}^{-1} \text{ °C}^{-1}$
- B is incorrect because temperature should be expressed in °C, not K, for the calculation of the specific heat capacity in terms of the requested unit J g^{-1} $°C^{-1}$.
- A is incorrect because energy should be expressed in J, not kJ, for the calculation of the specific heat capacity in terms of the requested unit J g^{-1} $°C^{-1}$.
- D is incorrect because specific heat capacity = $\dfrac{\text{energy}}{\text{mass} \times \Delta T}$, not $\dfrac{\text{mass} \times \Delta T}{\text{energy}}$.

Tips

- *Make sure you always check in which unit you must express your answer. This will help you determine in which units the data must be for the calculations.*

Questions 3 and 4 refer to the following information.

The following diagram represents a galvanic cell.



Question 3

Which one of the following correctly describes the anode, cathode and direction of electron flow when the wires are connected at 25°C?

	Anode	Cathode	Direction of electron flow
A.	**Pb**	**Ag**	**left to right**
B.	Pb	Ag	right to left
C.	Ag	Pb	left to right
D.	Ag	Pb	right to left

Answer is A.

Explanatory notes

- A is correct. This is a galvanic cell so the reactions will be spontaneous. Pb is a stronger reductant than Ag (i.e. it is lower in the electrochemical series), so will be oxidised and will act as the anode. $Ag^{+}(aq)$ is a stronger oxidant than $Pb^{2+}(aq)$ and so will be reduced at the cathode. Electrons always flow from the anode (i.e. the site of oxidation that produces electrons) to the cathode (i.e. the site of reduction that consumes electrons), which in this case is Pb to Ag, so left to right.
- B is incorrect because electron flow is from anode to cathode, which is left to right.
- C is incorrect because Ag is the cathode and Pb is the anode.
- D is incorrect because Ag is the cathode and Pb is the anode.

Tips

- *It is helpful in multiple-choice questions to immediately disregard any answers that cannot be correct. In this case, simply knowing that electron flow is always from anode to cathode allows you to eliminate choices B and C as they both contradict this fact.*

Question 4

When the circuit is made complete, 5.00 g of one metal is consumed. The mass, in g, produced of the other metal is

A. 1.30

B. 2.60

C. 5.00

D. **5.21**

Answer is D.

Explanatory notes

- D is the mass of Ag produced calculated according to the following steps.
  Step 1: Write an overall equation for the cell reaction.
  $Pb(s) + 2Ag^{+}(aq) \rightarrow Pb^{2+}(aq) + 2Ag(s)$
  Step 2: Calculate the amount, in mol, of Pb consumed.
  $n(Pb) = \frac{m}{M}$
  $= \frac{5.00}{207.2}$
  $= 0.0241$ mol
  Step 3: Calculate the amount, in mol, of Ag produced.
  The coefficients in a balanced chemical equation provide the ratio of amounts, in mol, of reactants and products consumed or produced in the reaction.
  According to the equation provided:
  $n(Pb) : n(Ag)$
  $1 : 2$
  So, $n(Ag) = \frac{2}{1} \times n(Pb)$
  $= \frac{2}{1} \times 0.0241$
  $= 0.0482$ mol
  Step 4: Calculate the mass, in g, of Ag produced.
  $m = n \times M$
  $= 0.0482 \times 107.9$
  $= 5.21$ g
- A is incorrect because the ratio of Pb consumed to Ag produced is 1 : 2, not 2 : 1.
- B is incorrect because the ratio of Pb consumed is 1 : 2, not 1 : 1.
- C is incorrect because the coefficients in a balanced chemical equation provide the ratio of amounts, in mol, of reactants and products consumed or produced in the reaction, **not a ratio in terms of mass.**

Question 5

The products of the electrolysis of a 1.0 M solution of aluminium chloride at 25°C are

A. $Cl_2(g)$, Al(s)

B. **$O_2(g)$, $H_2(g)$**

C. $Cl_2(g)$, $H_2(g)$, $OH^-(aq)$

D. Al(s), $O_2(g)$, $H^+(aq)$

Answer is B.

Explanatory notes

- B is correct because water is the strongest reductant present as well as the strongest oxidant present. This is identified using the electrochemical series. An excerpt is shown below.

  $Cl_2(g) + 2e^- \rightarrow \mathbf{2Cl^-}$ 1.36 V
  $O_2(g) + 4H^+(aq) + 2e^- \rightarrow \mathbf{2H_2O(l)}$ 1.23 V
  $\mathbf{2H_2O(l)} + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ –0.83 V
  $\mathbf{Al^{3+}(aq)} + 3e^- \rightarrow Al(s)$ –1.71 V

  $H_2O(l)$ as an oxidant is higher on the left side of the series than $Al^{3+}(aq)$, so is a stronger oxidant and will be reduced preferentially. $H_2O(l)$ as a reductant is lower on the right side of the series than $Cl^-(aq)$, so will be oxidised preferentially. Water is both oxidised and reduced according to the equations:
  $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$
  $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
  The overall equation is
  $2H_2O(l) \rightarrow O_2(g) + 2H_2(g)$

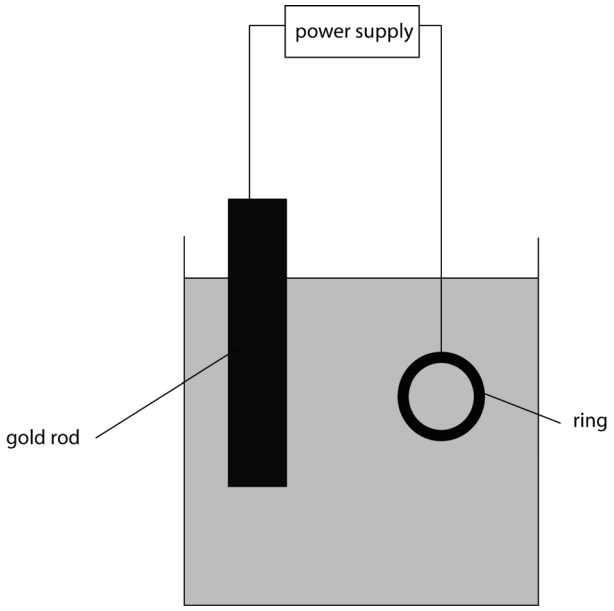
- A is incorrect because $H_2O(l)$ is a stronger reductant than $Cl^-(aq)$ and a stronger oxidant than $Al^{3+}(aq)$, so will react preferentially to both of them.
- C is incorrect because $H_2O(l)$ is a stronger reductant than $Cl^-(aq)$, so will react preferentially
- D is incorrect because $H_2O(l)$ is a stronger oxidant than $Al^{3+}(aq)$, so will react preferentially.

Tips

- *Whenever a solution is electrolysed, water must be considered as a possible reactant. The only way to remove water from consideration is to have the reactant in molten form rather than aqueous.*
- *Remember that the electrochemical series is applicable only under certain conditions, which are*
  1 atm, 25°C and 1.0 M solutions. If any of these are varied, predictions based on the series may not be valid.

Questions 6 and 7 refer to the following information.

An electrolytic cell is constructed to gold plate some jewellery.



Question 6

Which one of the following is correct when the power is switched on?

A. The gold rod acts as the cathode and the ring acts as the anode.

B. The anode is negative and the cathode is positive**.**

C. **Anions in the electrolyte are attracted to the gold rod.**

D. Reduction occurs at the gold rod.

Answer is C.

Explanatory notes

- C is correct because the gold rod is the anode. In electrochemical cells, anions move towards the anode and cations towards the cathode.
- A is incorrect. The anode is always the site of oxidation and the cathode is always the site of reduction. In electroplating, reduction of a metal atom takes place on the item being plated, so the item, in this case the ring, acts as the cathode.
- B is incorrect because in an electrolytic cell the anode is positive and the cathode is negative. This is owing to the non-spontaneous nature of the reactions.
- D is incorrect because the gold rod is the anode and the site of oxidation. Gold atoms are oxidised to gold ions. Reduction occurs at the ring where the gold ions are reduced to gold atoms in order to electroplate the ring.

Tips

- *'AN OILRIG CAT' is a useful way of remembering that the ANode is where Oxidation Is Loss (of electrons) and Reduction Is Gain at the CAThode. This is the case in both galvanic and electrolytic cells. It is the polarity of the electrodes that changes.*

Question 7

Calculate the mass, in g, of gold deposited from gold ions (Au^{3+}) on the ring when the cell is run at 6.00 V and 4.00 A for 20.0 min.

A. 0.0544

B. **3.27**

C. 29.4

D. 58.8

Answer is B.

Explanatory notes

- B is the correct mass of gold, calculated according to the following steps.
  Step 1: Calculate the charge, in coulomb, applied to the cell.
  $Q = It$
  $= 4.00 \times 20.0 \times 60$
  $= 4800$ C
  Step 2: Determine the amount, in mol, of electrons.
  $n(e^-) = \frac{Q}{F}$
  $= \frac{4800}{96\,500}$
  $= 0.0497$ mol
  Step 3: Write a half-equation for the reduction of gold ions.
  $Au^{3+}(aq) + 3e^- \rightarrow Au(s)$
  Step 4: Calculate the amount, in mol, of gold produced.
  $n(Au) : n(e^-)$
  $1 : 3$
  So, $n(Au) = \frac{1}{3} \times n(e^-)$
  $= \frac{1}{3} \times 0.0497$
  $= 0.0166$ mol
  Step 5: Calculate the mass, in g, of gold deposited.
  $m = nM$
  $= 0.0166 \times 197.0$
  $= 3.27$ g
- A is incorrect because the time must be expressed in seconds, not minutes.
- C is incorrect because the $n(Au)$ is $\frac{1}{3} \times n(e^-)$, not $\frac{3}{1} \times n(e^-)$.
- D is incorrect because $Q = It$, not $Q = VIt$. The voltage is not required for the calculation.

Tips

- *Be very clear on your formulas. $Q = It$ and $E = VIt$ are similar formulas and can be confused, especially when you are provided with the voltage in a question that does not require it.*

Question 8

Which of the following energy sources **cannot** be traced back to the Sun as the original provider of energy?

A. hydroelectricity

B. natural gas

C. **nuclear fission**

D. coal

Answer is C.

Explanatory notes

- C is correct because the energy released in a nuclear fission reaction is the result of a conversion of mass into energy consistent with $E = mc^2$.
- A is incorrect because the Sun evaporates water, which then rains on higher ground to flow down along rivers and collect in holding dams. The flow of water can be harnessed to drive a turbine connected to a generator to produce electricity.
- B is incorrect because natural gas is a fossil fuel created from the remains of dead plants and animals, including marine life, over millions of years. The energy in the plants and animals originated from the Sun through the process of photosynthesis and the food cycle.
- D is incorrect because coal is a fossil fuel created from the remains of dead plants and animals over millions of years. The energy in the plants and animals originated from the Sun through the process of photosynthesis and the food cycle.

Question 9

Which formula represents an α-amino acid in acidic solution?

A. $^{+}\mathbf{H_3NCH(CH_3)COOH}$

B. $^{+}H_3NCH_2CH_2COOH$

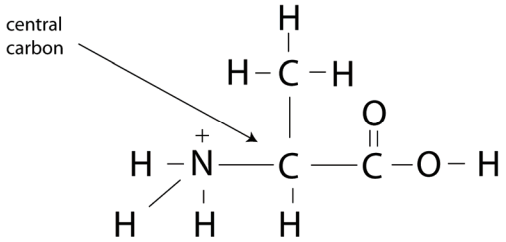
C. $H_2NCH(CH_3)COO^{-}$

D. $H_2NCH_2CH_2COO^{-}$

Answer is A.

Explanatory notes

- A is correct. It is an α-amino acid because the $–NH_3^+$ and –COOH functional groups are attached to the same carbon.



- It is the correct representation of an amino acid in acidic solution because it has accepted as many protons as it is able (on the amino and carboxyl groups).
- B is incorrect because it is not an α-amino acid. It does not have the $–NH_3^+$ and –COOH functional groups attached to the same carbon.
- C is incorrect because, although it is an α-amino acid, it represents the structure it would take in a basic solution.
- D is incorrect because it is not an α-amino acid as it does not have the $–NH_2$ and $–COO^–$ functional groups attached to the same carbon. Also, it shows the structure in a basic solution.

Question 10

Which of the following correctly describes the main type of bonding responsible for primary and secondary structure in proteins?

	Primary structure	**Secondary structure**
A.	covalent	dispersion
B.	hydrogen	covalent
C.	**covalent**	**hydrogen**
D.	hydrogen	peptide

Answer is C.

Explanatory notes

- C is correct. The primary structure of a protein is the order of amino acids linked together by peptide bonds, which involve covalent bonding. Secondary structure is the localised areas of pleating and folding caused by hydrogen bonding between different parts of the chain.
- A is incorrect because hydrogen bonds, not dispersion forces, are responsible for secondary structure.
- B is incorrect because covalent bonds, not hydrogen bonds, are responsible for primary structure. Also, hydrogen bonds, not covalent bonds, are responsible for secondary structure.
- D is incorrect because covalent bonds, not hydrogen bonds, are responsible for primary structure. Also, hydrogen bonds, not peptide bonds, are responsible for secondary structure. Peptide bonds are the linkages between the neighbouring amino acids in the protein chain (i.e. covalent bonds between C and N).

Question 11

The functional groups involved in a condensation reaction between a glucose molecule and a fructose molecule are

A. **hydroxyl and hydroxyl**

B. carboxyl and carboxyl

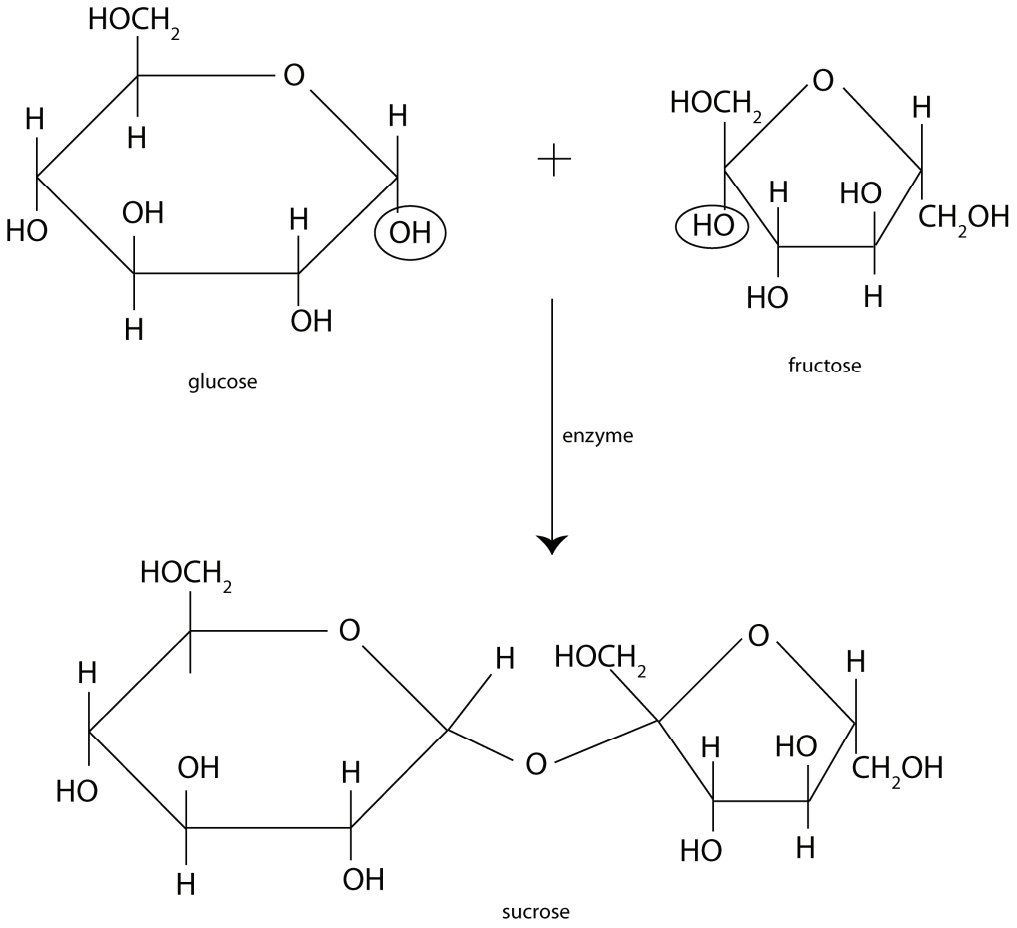
C. hydroxyl and carboxyl

D. carboxyl and amino

Answer is A.

Explanatory notes

- A is correct because glucose and fructose are both simple carbohydrates. Carbohydrates link together by a reaction between two hydroxyl functional groups.



- B is incorrect because carbohydrates do not contain carboxyl functional groups.
- C is incorrect because glucose and fructose are both simple carbohydrates that link together by a reaction between two hydroxyl functional groups. Reactions between hydroxyl and carboxyl functional groups produce ester groups.
- D is incorrect because glucose and fructose are both simple carbohydrates that link together by a reaction between two hydroxyl functional groups. A reaction between a carboxyl and an amino functional group takes place to produce a peptide group.

Question 12

The main energy reserves in the body are

A. glucose and fats

B. glycerol and fats

C. **glycogen and fats**

D. proteins and fats

Answer is C.

Explanatory notes

- C is correct because glycogen, a complex carbohydrate, is an energy reserve and fats are a long-term energy reserve in the body.
- A is incorrect because, although glucose reacts with oxygen to produce energy in the body via respiration, it is not an energy reserve.
- B is incorrect because glycerol is used in the production of triglycerides. It is not, by itself, an energy reserve.
- D is incorrect because proteins have many other uses, including as enzymes, structure, hormones and antibodies, in the body. They can be used for energy but only as an extreme last resort.

Question 13

A mass spectrometer is used to identify the existence of isotopes. Which of the following are all parts of a mass spectrometer?

A. ionisation chamber, prism, magnetic field

B. flame, magnetic field, detector

C. prism, magnetic field, ion collector

D. **magnetic field, ion collector, detector**

Answer is D.

Explanatory notes

- D is correct. The magnetic field deflects ions in the mass spectrometer according to their mass : charge ratio, allowing isotopes to be separated. The ion collector collects ions travelling on a particular path and the detector measures ion current.
- A is incorrect because a mass spectrometer does not contain a prism. It does have an ionisation chamber in which a sample is bombarded with electrons to turn atoms into positive ions.
- B is incorrect because a mass spectrometer does not use a flame.
- C is incorrect because a mass spectrometer does not contain a prism.

Question 14

Element X has a relative atomic mass of 63.5. It has two naturally occurring isotopes of masses 62.9 and 64.9. The percentage abundance of the lighter isotope is

A. 30.0%

B. 50.0%

C. **70.0%**

D. 90.0%

Answer is C.

Explanatory notes

- C is correct according to the following calculation.
  Let the abundance of the lighter isotope be x. Therefore, the abundance of the heavier isotope will be $100 - x$.

$$A_r(\text{Cu}) = \frac{(\%\text{ abundance} \times \text{relative mass}) + (\%\text{ abundance} \times \text{relative mass})}{100}$$

$$63.5 = \frac{(62.9 \times x) + (64.9 \times (100 - x))}{100}$$

$$63.5 = \frac{62.9x + 6490 - 64.9x}{100}$$

$$6350 = 62.9x + 6490 - 64.9x$$

$$-140 = -2.0x$$

$$x = 70$$

- A is incorrect because 30.0% is the relative abundance of the heavier isotope.
- B is incorrect because the relative atomic mass is a **weighted average of** the masses of the isotopes. They exist in nature in different proportions.
- D is incorrect and could be selected only as a guess.

Question 15

Beryllium is produced by a nuclear fusion reaction between two helium nuclei. The mass of the beryllium nucleus, relative to the combined mass of the helium nuclei, is

A. **lower**

B. higher

C. equal

D. sometimes higher and sometimes lower

Answer is A.

Explanatory notes

- A is correct because nuclear fusion reactions release energy when producing nuclei up to the size of a ^{26}Fe nucleus. This energy is produced by a small amount of mass being converted to energy according to the equation $E = mc^2$. The nuclear reaction is

  $$2\,{}^{4}_{2}\mathrm{He} \rightarrow {}^{8}_{4}\mathrm{Be}$$

- B is incorrect because the mass of the product in an energy-releasing nuclear reaction is lower than the reactant nuclei. The mass is converted to energy according to the equation $E = mc^2$.
- C is incorrect because the reaction produces a large amount of energy resulting from a small amount of mass being converted to energy according to the equation $E = mc^2$.
- D is incorrect. The same nuclear fusion reaction will always have the same outcome.

Tips

- *Nuclear fusion reactions can result in a product that is higher or lower in mass than the reactant nuclei. It is dependent on whether the nucleus produced is more or less stable than the reactants. Remember that the most stable nucleus is ^{26}Fe. Fusion of nuclei towards ^{26}Fe releases energy converted from mass, whereas fusion of nuclei away from ^{26}Fe requires energy that is converted to mass.*

Question 16

The element that has a +2 ion with the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ is

A. Ca

B. Fe

C. Ni

D. **Zn**

Answer is D.

Explanatory notes

- D is correct because the electronic configuration of this ion contains 2 + 2 + 6 + 2 + 6 + 10 = 28 electrons. The atom has two additional electrons, making a total of 30. In a neutral atom the number of protons and electrons are the same, so the element has 30 protons and an atomic number of 30. According to the periodic table the element is zinc.
- A is incorrect because Ca has only 20 electrons.
- B is incorrect because the Fe atom has 26 electrons.
- C is incorrect because the Ni atom has 28 electrons. Its +2 ion has 26 electrons.

Question 17

Consider the nuclear reaction represented by the equation

$$^{238}_{92}\text{U} + ^{14}_{7}\text{N} \rightarrow ^{248}_{99}\text{Es} + 4X$$

Species X is

A. **a neutron**
B. an electron
C. a proton
D. a helium nucleus

Answer is A.

Explanatory notes

- A is correct because particle X is $^{1}_{0}n$. In a nuclear equation the mass and atomic numbers must be balanced. The mass number of X is $\frac{(238+14)-248}{4} = 1$.
  The atomic number is (92 + 7) – 99 = 0.
- B is incorrect because an electron does not have the required mass and atomic numbers. It is represented by the symbol $^{0}_{-1}\text{e}$.
- C is incorrect because a proton does not have the required mass and atomic numbers. It is represented by the symbol $^{1}_{1}\text{p}$.
- D is incorrect because a helium nucleus does not have the required mass and atomic numbers. It is represented by the symbol $^{4}_{2}\text{He}$.

Question 18

The fatty acid with the greatest amount of unsaturation is

A. $C_{17}H_{35}COOH$
B. $C_{17}H_{33}COOH$
C. **$C_{19}H_{35}COOH$**
D. $C_{19}H_{37}COOH$

Answer is C.

Explanatory notes

- C is correct because $C_{19}H_{35}COOH$ contains two double bonds. The formula of a saturated fatty acid can be represented by $C_nH_{2n+1}COOH$. Each loss of two H atoms represents one double bond.
- A is incorrect because $C_{17}H_{35}COOH$ is a saturated fatty acid.
- B is incorrect because $C_{17}H_{33}COOH$ contains one double bond.
- D is incorrect because $C_{19}H_{37}COOH$ contains one double bond.

Question 19

The formula of an acidic oxide formed from a period 3 element is

A. Na_2O

B. MgO

C. Al_2O_3

D. **SO_3**

Answer is D.

Explanatory notes

- D is correct because SO_3 reacts with water to produce sulfuric acid according to the equation
  $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$.
- A is incorrect because Na_2O is a basic oxide.
- B is incorrect because MgO is a basic oxide.
- C is incorrect because Al_2O_3 is an amphoteric oxide. It acts as an acid when reacting with a base and as a base when reacting with an acid, but cannot itself be dissolved in water.

Question 20

A polysaccharide is formed by condensation reactions between 100 glucose ($C_6H_{12}O_6$) molecules. The molar mass of the polysaccharide, in g mol^{-1}, is

A. 16 200

B. 16 218

C. 18 000

D. 19 782

Answer is B.

Explanatory notes

- B is correct because the linking of 100 glucose molecules requires 99 condensation reactions in which 99 water molecules will be eliminated. The mass of the polysaccharide can be calculated:
  $M(\text{polysaccharide}) = 100 \times M(C_6H_{12}O_6) - 99 \times M(H_2O)$
  $= 100 \times 180 - 99 \times 18$
  $= 18\,000 - 1782$
  $= 16\,218$
- A is incorrect because the linking of 100 glucose molecules eliminates only 99 water molecules, not 100.
- C is incorrect because the linking of 100 glucose molecules eliminates 99 water molecules, not just 1.
- D is incorrect because the linking of the glucose molecules requires condensation reactions in which water molecules are eliminated. They are not hydrolysis reactions in which 99 water molecules are required to be added.

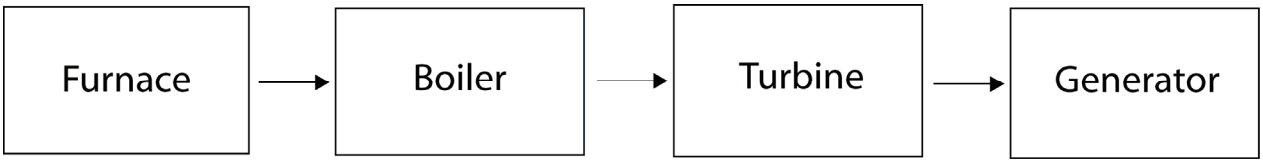
END OF SECTION A

SECTION B – Short-answer questions

Question 1

Maintaining an adequate energy supply into the future while being mindful of environmental issues presents a challenge for Australia.

1a. Most of Australia's electricity is currently produced from coal via a series of energy transformations in a coal-fired power station, which is represented by the flow chart below.



1a. i. The main reaction in the furnace is

$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393.5 \text{ kJ mol}^{-1}$

Calculate the amount of heat energy produced by the complete combustion of 1.00 tonne of carbon. (*Note:* 1 tonne = 10^6 g)

Solution

Step 1: Convert the mass of carbon to g.

1 tonne = 10^6 g
1.00 tonne = 1.00×10^6 g

Step 2: Calculate the amount, in mol, of carbon.

$$n(\text{C}) = \frac{m}{M}$$
$$= \frac{1.00 \times 10^6}{12.0}$$
$$= 8.33 \times 10^4 \text{ mol}$$

Step 3: Calculate the amount of energy produced.

n(C) : ΔH
1 : 393.5

So, energy released $= \frac{393.5}{1} \times n(\text{C})$
$= 393.5 \times 8.33 \times 10^4$
$= 3.28 \times 10^7$ kJ

3 marks

Mark allocation

- 1 mark for the correct conversion of mass of 1.00×10^6 g.
- 1 mark for the calculation of 8.33×10^4 mol.
- 1 mark for the calculation of 3.28×10^7 kJ.

Explanatory notes

- The coefficients in a balanced thermochemical equation give a ratio by which reactants are consumed and energy is produced, i.e. the ΔH value is consistent with the numbers of moles of reactants/products shown in the equation.

Tips

- *Students may lose a mark for not converting the mass from tonnes to grams, but still earn consequential marks for the next two steps.*

1a. ii. What is the main energy conversion occurring in the turbine?

Solution

thermal energy → mechanical energy

1 mark

Explanatory notes

- The steam produced in the boiler is used to drive the turbine.

1a. iii. What is the main energy conversion occurring in the generator?

Solution

mechanical energy → electrical energy

1 mark

1b. Wind power is being considered as an alternative to coal as an energy source. Give **one** advantage and **one** disadvantage of wind power as a source of electricity.

Solution

Advantages include it is renewable, no pollution.

Disadvantages include low efficiency, visual pollution and wind levels can be variable.

2 marks

Mark allocation

- 1 mark for giving an advantage.
- 1 mark for giving a disadvantage.

1c. Fuel cell technology also promises to be a potential alternative source of energy.

1c. i. Give **one** reason why using a fuel cell produces more electricity per mass unit of fuel than if the same amount of fuel was burnt in a power station.

Solution

A fuel cell involves a direct conversion of chemical energy → electrical energy whereas a power station requires several steps for the same overall conversion.

1 mark

Explanatory notes

- All energy conversions involve the loss of some energy in the form of heat, therefore minimising the number of steps increases efficiency. Also, the step in the turbine of a power station that involves a conversion of thermal energy to mechanical energy is highly inefficient. The general energy conversions in a power station are chemical energy → thermal energy → thermal energy (steam) → mechanical energy → electrical energy.

1c. ii. Give **one** reason why the use of fuel cells to produce electricity is not more widespread.

Solution

Fuel cells are still too expensive.

1 mark

Total 9 marks

Question 2

A calibrated bomb calorimeter can be used in the laboratory to determine the energy content of food.

2a. A student calibrated a bomb calorimeter by passing an electric current of 1.56 A and 8.50 V through the calorimeter for 10.00 min. The student found that the temperature of the water inside the calorimeter rose from 16.0°C to 18.7°C.
Calculate the calibration factor, in J °C^{-1}, for this bomb calorimeter.

Solution

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

$$= \frac{8.50 \times 1.56 \times 10.00 \times 60}{(18.7 - 16.0)}$$

$$= \frac{7.96 \times 10^3}{2.70}$$

$$= 2.95 \times 10^3 \text{ J °C}^{-1}$$

2 marks

Mark allocation

- 1 mark for calculating 7.96×10^3, i.e. correct conversion and use of time in seconds.
- 1 mark for the calculation of 2.95×10^3 J °C^{-1}.

Explanatory notes

- Time must be expressed in seconds for this calculation.

Tips

- *Students may gain a consequential mark if the wrong time is used but the calculation is carried out correctly.*

2b. To find the energy content of a sample of dried pasta, 3.60 g of the dried pasta was burnt in the calorimeter that was calibrated above. The temperature of the water rose by 23.5°C. Calculate, in kJ g^{-1}, the energy content of the pasta.

Solution

Step 1: Calculate the energy, in kJ, produced by the sample.

E = calibration factor × ΔT

= $2.95 \times 10^3 \times 23.5$

= 6.92×10^4 J

= 69.2 kJ

Step 2: Calculate the heat energy of the pasta.

$$\text{Heat energy} = \frac{\text{energy}}{\text{mass (g)}}$$

$$= \frac{69.2}{3.60}$$

= 19.2 kJ g^{-1}

2 marks

Mark allocation

- 1 mark for the calculation of 6.92×10^4 J or 69.2 kJ.
- 1 mark for the calculation of 19.2 kJ g^{-1}.

Tips

- *Some common errors made by students are forgetting to convert energy from J to kJ and forgetting the second step of calculating the heat energy in kJ g^{-1}. Always make sure your answer is expressed in the units specified.*

2c. A possible source of error in this experiment is that the pasta was not completely dried before being weighed and burned in the calorimeter. Explain the effect that this will have on the student's results.

Solution

The student's calculated result for energy content in kJ g^{-1} will be lower than it should be. 3.60 g of wet pasta will not release as much energy as 3.60 g of wet pasta because the wet pasta sample contains less combustible material. Also, some of the heat released by the combustible material in the pasta will be used to vaporise the water in the sample. The student still assumes a 3.60 g sample, however, the lower ΔT leads to a lower calculated energy released, thus a lower calculated energy content.

2 marks

Mark allocation

- 1 mark for stating that student's result is decreased.
- 1 mark for explaining this is owing to the increased mass of the pasta.

Tips

- *When asked to comment on the effect that an error will have on results, students should be sure to describe clearly whether the results will be higher or lower.*

2d. Give a reason why the energy provided to the body by the pasta is less than the amount of energy determined correctly using a bomb calorimeter.

Solution

Incomplete digestion in the body occurs because the body lacks the enzyme required to digest cellulose, a component of the pasta.

1 mark

Total 7 marks

Question 3

The diaphragm cell is used for the industrial production of chlorine.

3a. Give the chemical formula and state of the substance used as the electrolyte.

Solution

NaCl(aq)

1 mark

Explanatory notes

- Concentrated sodium chloride solution is used. It is also known as brine.

3b. Write a half-equation for the reaction that occurs at the

3b. i. anode

Solution

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

1 mark

Explanatory notes

- Chloride ions are oxidised at the anode. Although the electrochemical series indicates water is a stronger reductant and will be preferentially oxidised, their reducing strengths are very similar and the highly concentrated NaCl solution makes the electrochemical series less accurate. Remember that the electrochemical series is most accurate at conditions of 1 atm, 25°C and 1 M solutions.

3b. ii. cathode

Solution

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

1 mark

Explanatory notes

- H_2O is a much stronger oxidant than $Na^+(aq)$ ions, so even in the concentrated solution it is reduced at the cathode.

3c. A membrane cell has also been developed for the production of chlorine. Give **two** advantages the membrane cell has over the diaphragm cell.

Solution

The membrane cell uses a plastic barrier rather than an asbestos barrier, which can be a health risk. The membrane cell uses a semi-permeable barrier that restricts the movement of $Cl^-(aq)$ ions, allowing pure NaOH to be produced in addition to the chlorine gas.

2 marks

Mark allocation

- 1 mark for stating plastic barrier is safer than asbestos.
- 1 mark for stating that cell allows the production of pure NaOH.

Total 5 marks

Question 4

A student eats a hamburger in a bun with lettuce, tomato and cheese.

4a. Chemical digestion of starch, a polysaccharide present in the bun, begins in the mouth.

4a. i. What type of reaction is involved in chemical digestion?

Solution

hydrolysis

1 mark

Explanatory notes

- A hydrolysis reaction is one in which water is a reactant.

4a. ii. Give the molecular formula of the other reactant required for this reaction.

Solution

H_2O

1 mark

4a. iii. Lettuce, a plant material, contains a different type of polysaccharide that cannot provide energy for the student. Give the name of this polysaccharide and explain why it cannot provide any energy.

Solution

cellulose

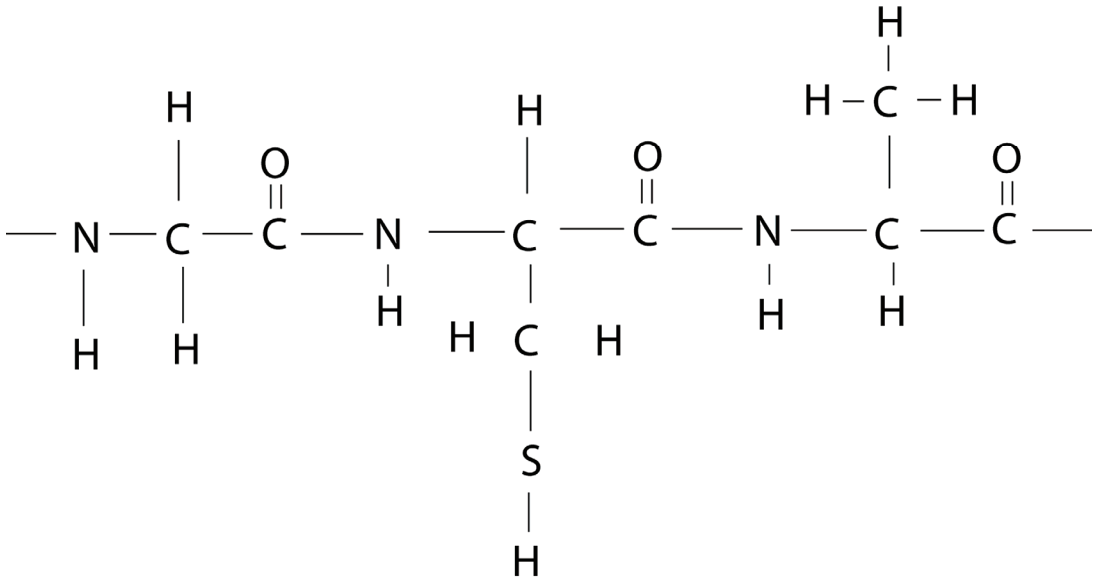
Humans lack the enzyme required for its digestion.

2 marks

Mark allocation

- 1 mark for naming cellulose.
- 1 mark for explaining humans lack enzyme.

4b. When the food enters the stomach, chemical digestion of the protein in the meat and cheese begins. The following diagram represents part of a protein.



4b. i. What is the name of the link between different amino acids in the protein?

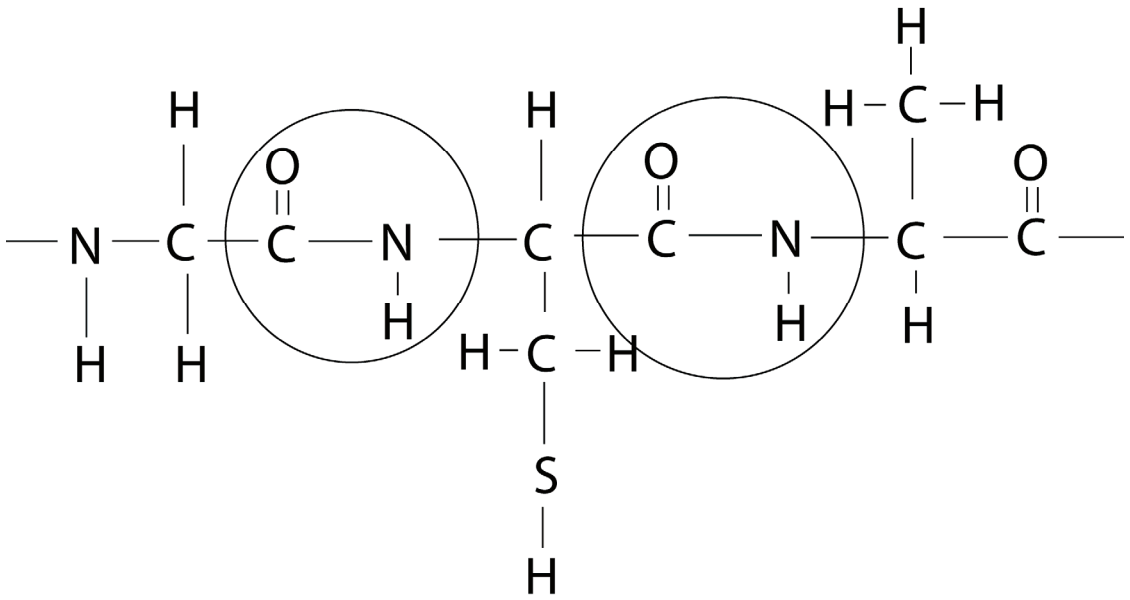
Solution

peptide

1 mark

4b. ii. Circle **one** of these links on the diagram above.

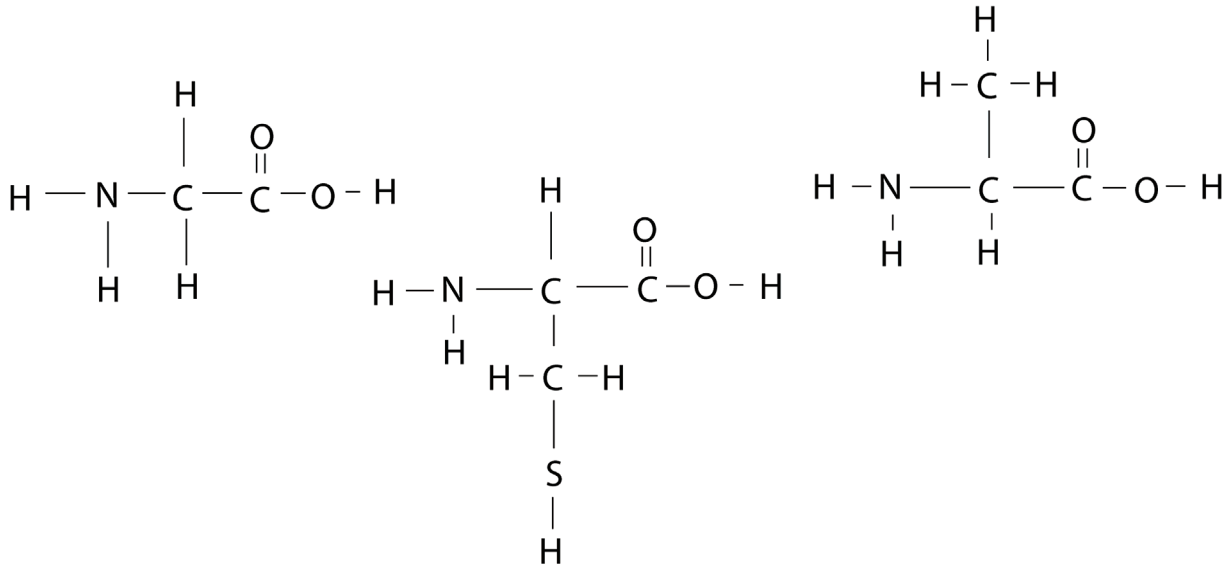
Solution



1 mark

4b. iii. Draw the structural formula for the compounds produced when this section of protein is broken down in the body.

Solution



2 marks

Mark allocation

- 2 marks if all three structures are correct.
- 1 mark if two structures are correct.
- 0 marks if only one structure is correct.

4c. In the small intestine, the fats present in the hamburger are also broken down to produce fatty acids and one other product. Give the name and molecular formula of the other compound that is a product of the digestion of all triglycerides.

Solution

glycerol, $C_3H_8O_3$

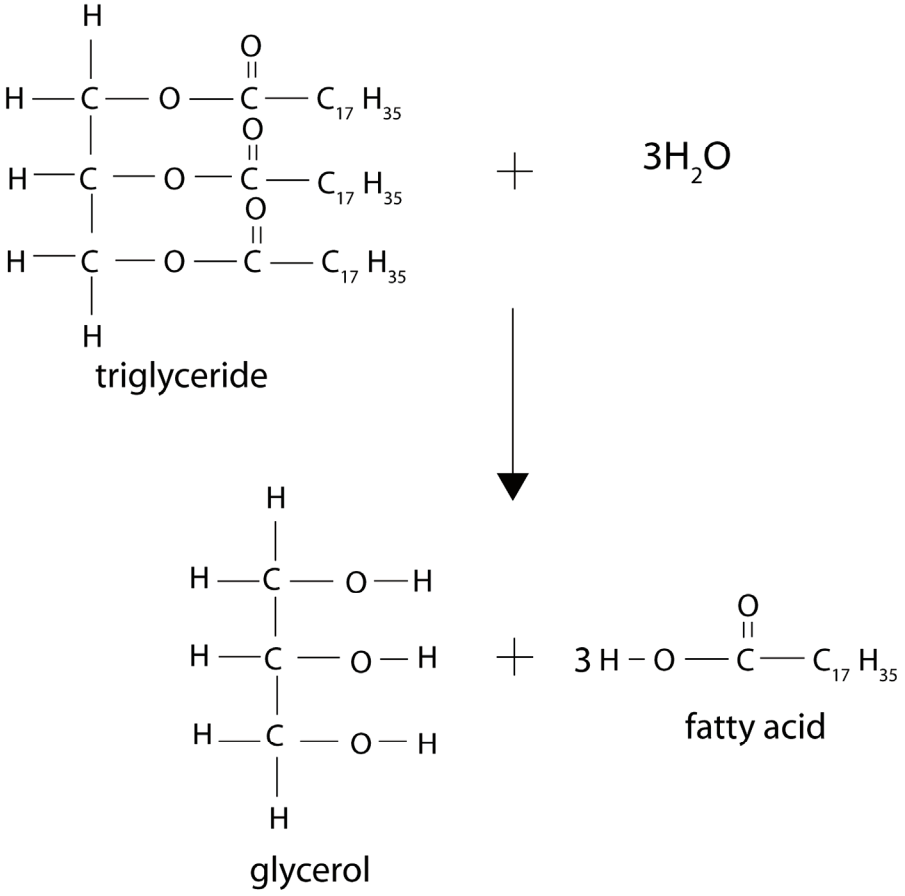
2 marks

Mark allocation

- 1 mark for naming glycerol.
- 1 mark for giving correct molecular formula $C_3H_8O_3$.

Explanatory notes

- Triglycerides are digested in a hydrolysis reaction, as represented by the following equation.



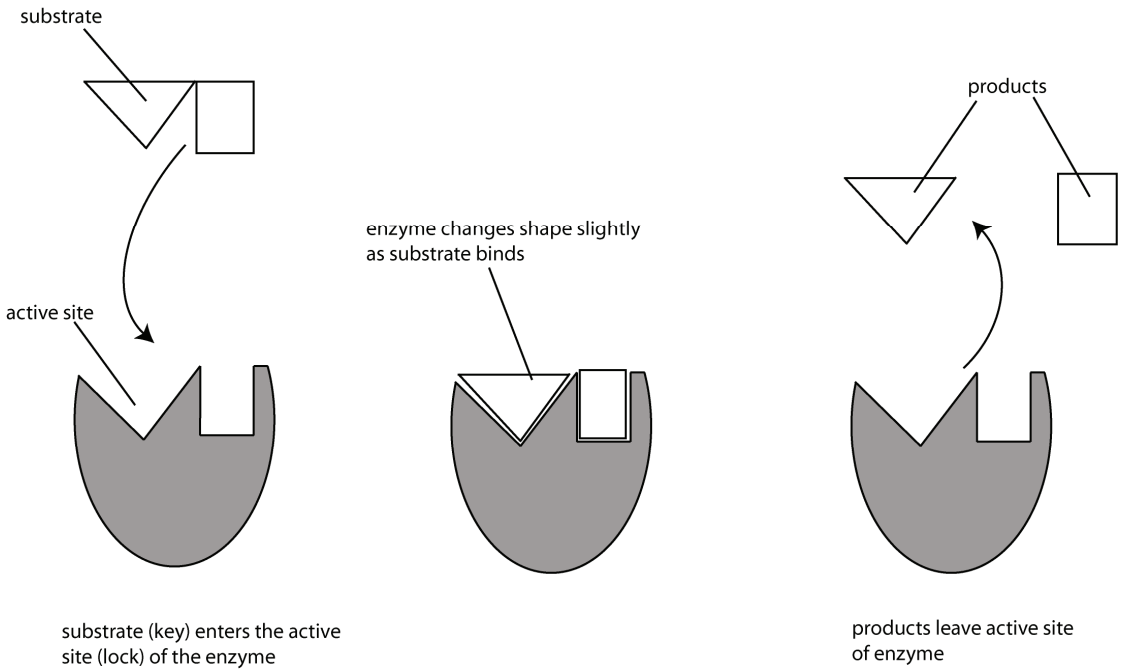
Tips

- *Students should receive full marks if the structural formula of glycerol is drawn instead of the molecular formula. However, students should endeavour to provide the formula specified.*

4d. Each digestion reaction carried out in the body is catalysed by an enzyme. The catalytic process is very specific with most enzymes catalysing just one reaction. Describe how enzymes catalyse reactions in the human body. You may use a diagram in your answer.

Solution

Enzymes catalyse chemical reactions according to a lock-and-key mechanism whereby the enzyme active site is the lock and the reactant molecules are the key. Enzymes that catalyse different reactions have different active sites. The reactant(s) enter(s) the active site and form temporary bonds with the enzyme. Bonds in the reactant(s) are broken and the products leave the active site. A possible diagram is shown below.



3 marks

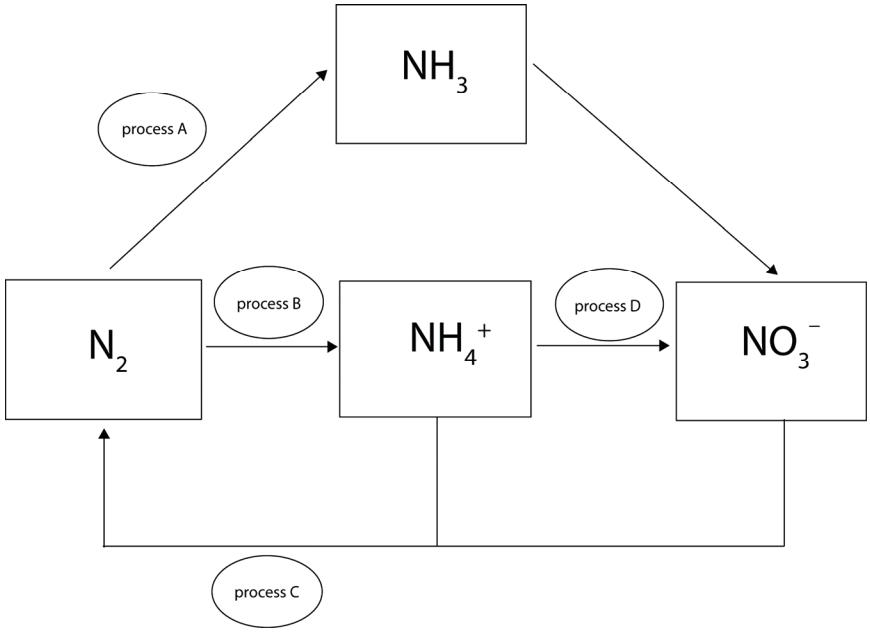
Mark allocation

- 1 mark for giving a description of the active site.
- 1 mark for stating that temporary bonds are formed.
- 1 mark for the description of reactants entering and products leaving the active site.

Total 13 marks

Question 5

The cycling of nitrogen plays an important role in food production. A simplistic nitrogen cycle is represented below.



5a. List the letter(s) of the process(es) that involve the action of nitrogen-fixing bacteria.

Solution

B

1 mark

Explanatory notes

- Nitrogen fixation is the process whereby atmospheric nitrogen, N_2, is converted to nitrogen-containing compounds.

5b. List the letter(s) of the process(es) that involve the reduction of nitrogen atoms.

Solution

A, B, C

1 mark

Explanatory notes

- In process A the oxidation number of N changes from 0 to –3. In process B it changes from 0 to –3 and in process C it changes from +5 to 0. A decrease in oxidation number indicates the species has been reduced.

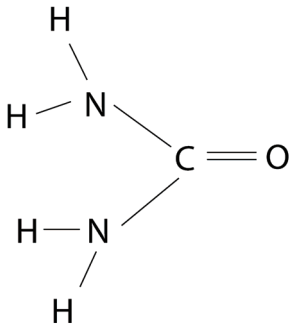
Tips

- *Use the oxidation rules, primarily that H is nearly always +1 and O is nearly always –2, to determine the oxidation number of N in each compound. Remember that* ***in a neutral compound the sum of the oxidation numbers of individual elements is zero****, and in a* ***polyatomic ion the sum of the oxidation numbers equals the charge on the ion.***

5c. Nitrogen is an important element in proteins. Give the name and structural formula of the nitrogen-containing compound that is the end product of the body's use of proteins.

Solution

urea



2 marks

Mark allocation

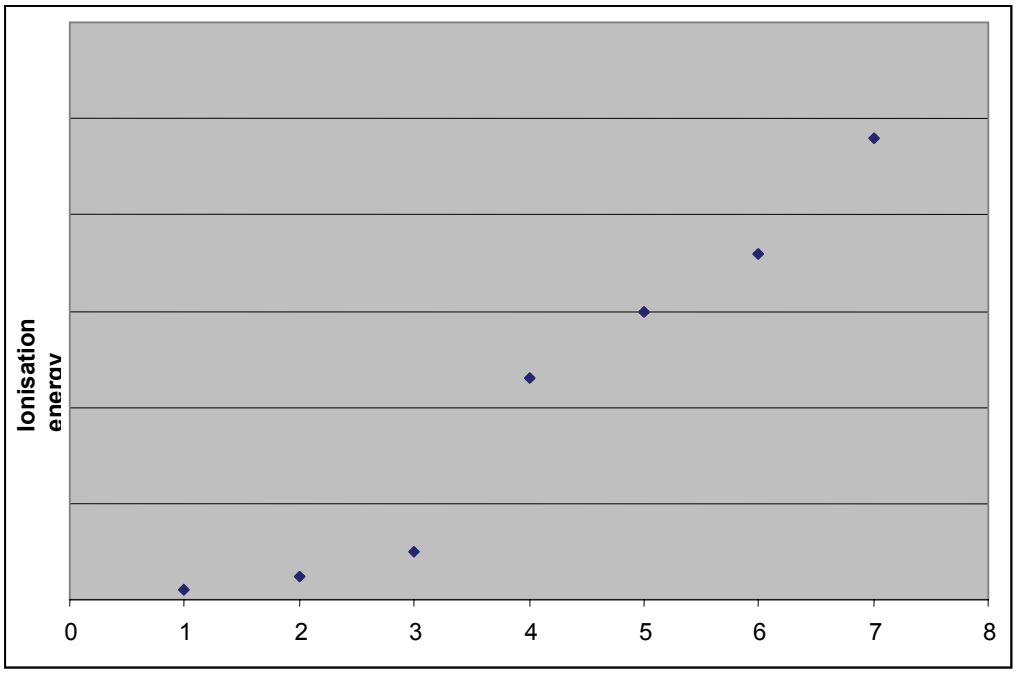
- 1 mark for correctly naming urea.
- 1 mark for giving correct structural formula.

Total 4 marks

Question 6

The current model of the atom has evolved over 100 years as new experimental observations came to light.

6a. Neils Bohr used emission spectra and ionisation energies to develop the shell model in which electrons were placed in orbits of fixed energies, called shells. A graph showing the first to sixth ionisation energies of a particular element is given below.



6a. i. Which of the following is most likely to be this element? Use a circle to select your answer.

Solution

boron nitrogen oxygen (aluminium)

1 mark

6a. ii. Explain how you determined your answer to part **i**.

Solution

The element contains at least 7 electrons, so can't be boron. The ionisation energy of the first 3 electrons is similar, after which there is a jump, indicating that there are 3 electrons in the outer shell. Aluminium has 3 electrons in its outer shell. Nitrogen has 5 and oxygen has 6.

2 marks

Mark allocation

- 1 mark for explaining that there are at least 7 electrons.
- 1 mark for explaining that there are 3 electrons in the outer shell.

6b. i. Name one other scientist who made a contribution to the development of atomic theory.

Solution

Could be, for example, Dalton, Ramsay, Curie, Seaborg, Soddy, Meitner, Rutherford or Chadwick

1 mark

6b. ii. Describe the contribution made by this scientist.

Solution

As appropriate to the scientist named. For example:

Dalton – proposed that matter was composed of indivisible particles, which he called atoms.

Ramsay – discovered the noble gases.

Curie – discovered the elements radium and polonium and studied their radioactivity.

Seaborg – discovered many of the transuranic elements using a particle accelerator to bombard uranium with hydrogen nuclei.

Soddy – confirmed the existence of isotopes.

Meitner – demonstrated that barium is a product of neutron-bombarded uranium and proposed the term 'fission' for the process.

Rutherford – used the gold-foil (alpha particle experiment) to propose the nuclear model of the atom in which electrons orbit a dense nucleus.

Chadwick – identified the neutron as a particle that was neutral and contributed to the mass of the nucleus.

1 mark

Total 5 marks

Question 7

Vanadium is used in tool making and its compounds are used for dyeing and painting fabrics.

7a. Write the electronic configuration of the following species.

7a. i. V

Solution

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$

1 mark

7a. ii. V^{2+}

Solution

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

1 mark

Explanatory notes

- Although the 4s subshell is filled before the 3d, the relative order of energies is reversed when the subshells are filled. This means electrons are first lost from the 4s subshell when ions are formed.

7a. iii. V^{3+}

Solution

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$

1 mark

7b. Explain why vanadium is able to exist in more than one oxidation state.

Solution

The 4s and 3d subshells have very similar energy levels, which means vanadium can lose electrons from both the 4s and 3d subshells and retain very similar stability.

2 marks

Mark allocation

- 1 mark for explaining that electrons can be lost from both the 3d and 4s subshells.
- 1 mark for stating that the 3d and 4s subshells have very similar energy levels.

7c. Explain why compounds of vanadium can be coloured.

Solution

The orbitals in a partially filled 3d subshell have slightly different energy levels. Electrons in one orbital in the 3d subshell can absorb the energy in white light and move to a higher energy orbital within the 3d subshell. The energy absorbed is missing from the white light, resulting in light of a distinctive colour.

2 marks

Mark allocation

- 1 mark for stating that electrons absorb the energy in white light.
- 1 mark for explaining electrons move to a high energy orbital within the 3d subshell.

Total 7 marks

Question 8

Elements X and Y are located in the same period of the periodic table in the relative positions shown below.

X																Y

8a. Place a tick in the appropriate box to describe which element you would expect to have the **higher** value.

Solution

Characteristic	**Element X**	**Element Y**
i. atomic radius	✓	
ii. electronegativity		✓
iii. oxidising strength		✓

3 marks

Mark allocation

- 1 mark for each tick.

Explanatory notes

- Atomic radius decreases across a period because the increasing core charge pulls the outer-shell electrons more tightly to the nucleus, causing the volume of the atom to decrease.
- Oxidising strength is the ability of en element to oxidise another element by attracting one of the other element's electrons. It increases across the period as the increasing core charge attracts outer-shell electrons more strongly.

8b. Explain your choice for electronegativity.

Solution

Electronegativity (i.e. the electron-attracting ability of an atom) increases from left to right across the period as core charge increases. The higher core charge on the right means electrons are attracted more strongly to the nucleus.

2 marks

Mark allocation

- 1 mark for explaining that core charge increases from left to right.
- 1 mark for explaining that electrons on the right are more strongly attracted to the nucleus.

Explanatory notes

- Core charge is calculated as the number of protons – the number of inner-shell electrons.

Total 5 marks

Question 9

Give concise explanations for each of the following.

9a. Molten sodium chloride, rather than aqueous sodium chloride, is used in the Downs cell for the production of sodium metal.

Solution

H_2O is a stronger oxidant than Na^+ ions and so would react preferentially if a solution of sodium chloride was used.

1 mark

9b. Reducing the temperature of an enzyme-catalysed reaction solution reduces the rate of the chemical reaction significantly.

Solution

Reducing the temperature reduces the reaction rate because there are fewer successful collisions between reactants.

1 mark

Tips

- *A common error would be for students to explain the reduced rate at lower temperatures being due to the enzyme being denatured. The enzyme is denatured only at **high** temperatures.*

9c. Explain why the addition of an antioxidant, in the form of vitamin C in lemon juice, prevents cut apples from going brown.

Solution

The antioxidant reduces atmospheric oxygen before it can oxidise the cut apple, preventing it from going brown.

2 marks

Mark allocation

- 1 mark for stating that antioxidant reduces atmospheric oxygen.
- 1 mark for explaining that oxidation of the cut apple is prevented.

Total 4 marks

END OF SOLUTIONS BOOK