GCSE · AQA · Chemistry

2 hours 18 questions

Exam Questions

Properties of Transition Metals

Typical Properties of Transition Metals / Transition Metals vs. Alkali Metals

Easy (4 questions)	/30
Medium (10 questions)	/34
Hard (4 questions)	/45
Total Marks	**/109**

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Easy Questions

1 (a) Transition elements are metals with similar properties.

Where are they found in the periodic table?

Tick (✓) **one** box.

In Group 1	
Between Group 2 and 3	
In Group 0	
Between Group 4 and 5	

Answer

Transition elements are found:

- In between Group 2 and 3; [1 mark]

[Total: 1 mark]

(1 mark)

(b) Which of the following metals are transition elements?

Tick (✓) **two** boxes.

Calcium	
Copper	
Caesium	
Chlorine	
Chromium	

Answer

The two transition elements are:

- Copper; [1 mark]
- Chromium; [1 mark]

[Total: 2 marks]

- Copper and chromium are both found within the middle section of the periodic table, between Group 2 and 3
- Caesium is a metal found in Group 1
- Calcium is a metal found in Group 2
- Chlorine is a non-metal found in Group 7

(2 marks)

(c) Iron is a transition element. An atom of iron has the symbol $^{56}_{26}\mathrm{Fe}$

Give the number of protons, electrons and neutrons in an atom of iron.

Answer

The number of protons, electrons and neutrons in an atom of irons is:

- Protons = 26; [1 mark]
- Electrons = 26; [1 mark]
- Neutrons = 30; [1 mark]

[Total: 3 marks]

- The number of protons is given by the atomic (proton) number
    - For iron, the atomic number and therefore the number of protons is 26
- In an atom, the number of protons is the same as the number of electrons. The charges cancel out and the atom will be neutral overall
    - For iron, the number of electrons = 26
- The number of neutrons = mass number – atomic number
    - For iron, the number of neutrons = 56 – 26 = 30

(3 marks)

(d) Iron reacts with oxygen to form iron(II) oxide.

Complete the balanced symbol equation for this reaction.

$$\_\_ Fe + O_2 \rightarrow \_\_ FeO$$

Answer

The correct balanced symbol equation is:

- **2** Fe + O_2 → **2** FeO; [2 marks]
    - *1 mark for each correct number*

[Total: 2 marks]

- **Remember:** When balancing equations, there needs to be the same number of atoms of each element on either side of the equation
- In this equation, there need to be 2 atoms of iron and 2 atoms of oxygen on both sides to balance

(2 marks)

2 (a) Manganese is a typical transition element

Which of the following properties would you expect manganese to have.

Tick (✓) **four** boxes.

Property	
Low melting point	
Useful as a catalyst	
Only forms a 1+ ion	
Dull	
Soft	
Good conductor of heat and electricity	
Low density	
Brittle	
Forms coloured compounds	
Strong	

Answer

The properties of manganese are:

Property	
Low melting point	
Useful as a catalyst	✓; [1 mark]
Only forms a 1+ ion	
Dull	
Soft	
Good conductor of heat and electricity	✓; [1 mark]
Low density	
Brittle	
Forms coloured compounds	✓; [1 mark]
Strong	✓; [1 mark]

[Total: 4 marks]

- These properties are typical of transition elements

(4 marks)

(b) Sodium is a Group 1 metal.

Which of the following properties would you expect sodium and manganese to both have.

Tick (✓) **one** box.

Property	
Low melting point	
Useful as a catalyst	
Only forms a 1+ ion	
Dull	
Soft	
Good conductor of heat and electricity	
Low density	
Brittle	
Forms coloured compounds	
Strong	

Answer

The property that sodium and manganese both have is:

Property	
Low melting point	
Useful as a catalyst	
Only forms a 1+ ion	
Dull	
Soft	
Good conductor of heat and electricity	✓; [1 mark]
Low density	
Brittle	
Forms coloured compounds	
Strong	

[Total: 1 mark]

(1 mark)

(c) Give two properties listed in the table in part a) that sodium would have but manganese would not.

Answer

Properties that sodium would have but manganese wouldn't have are:

Any **two** from:

- Low melting point; [1 mark]
- Only forms a 1+ ion; [1 mark]
- Soft; [1 mark]
- Low density; [1 mark]

[Total: 2 marks]

(2 marks)

3 (a) Transition elements and their compounds have many different uses.

Draw a ring around the correct words to complete the sentences.

Gold is used in jewellery because it

conducts electricity.
is dull.
does not react with air.

Copper is used in wiring because it

conducts electricity.
is dull.
does not react with air.

Cobalt oxide is added to glazes in pottery as it

is a catalyst.
is a coloured compound.
conducts electricity.

Iron is used to build bridges because it

is strong.
is brittle.
conducts electricity.

Answer

The correct words are:

- Gold is used in jewellery because it does not react with air; [1 mark]
- Copper is used in wiring because it conducts electricity; [1 mark]
- Cobalt oxide is added to glazes in pottery as it is a coloured compound; [1 mark]
- Iron is used to build bridges because it is strong; [1 mark]

[Total: 4 marks]

- **Careful**: Some of the options are correct properties for the metal/compound but the property needs to explain why it is suitable for that particular use

(4 marks)

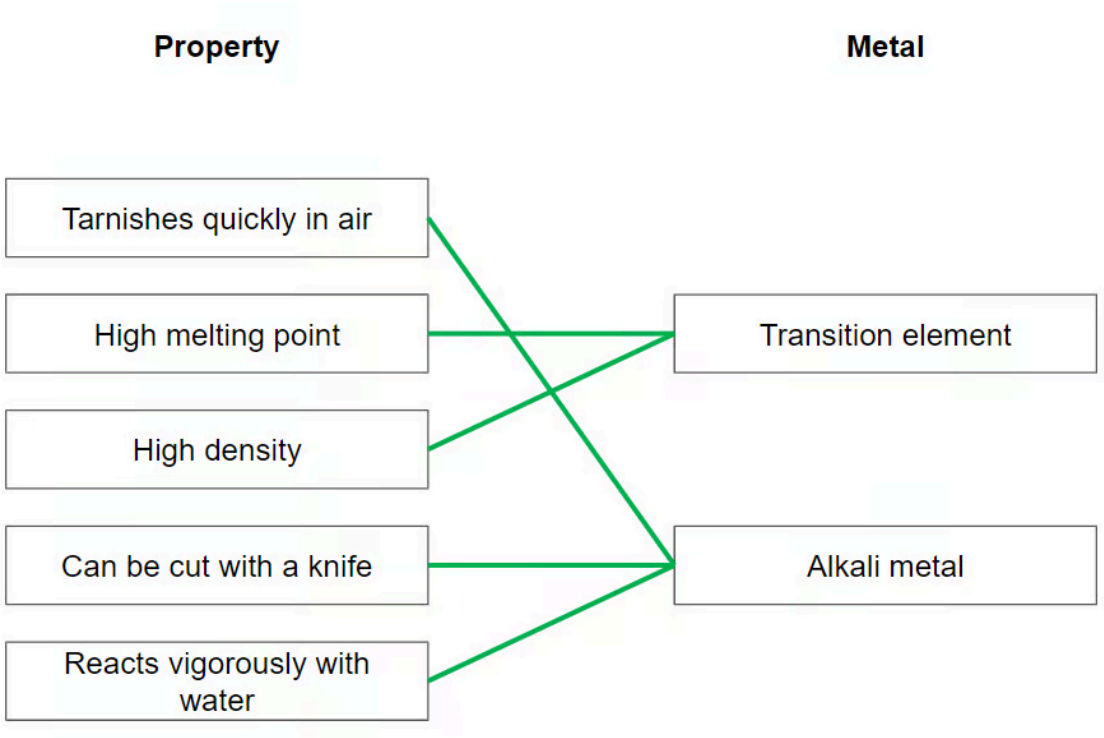
(b) Transition elements and alkali metals are all metals that have some differing properties.

Draw **one** line from each property to the metal it relates to.

Property	Metal
Tarnishes quickly in air	
High melting point	Transition element
High density	
Can be cut with a knife	Alkali metal
Reacts vigorously with water	

Answer

The properties that match the metals are:



- All correct; [3 marks]
- 3 or 4 correct; [2 marks]
- 1 or 2 correct; [1 mark]

[Total: 3 marks]

- The alkali metals are more reactive than the transition elements, so they will react quicker and more vigorously than the transition elements
- Alkali metals have a lower density and are softer than the transition elements, which is why they can be cut with a knife
- Alkali metals have much lower melting points than transition elements
    - Lithium has the highest melting point of Group 1 metals with a melting point of 181 ^{o}C
    - The melting point of caesium is just 28 ^{o}C

- Transition element melting points are often above 1000 ^{o}C, e.g. copper – 1083 ^{o}C and chromium – 1890 ^{o}C

(3 marks)

(c) Which of the following metals would be most suitable as a catalyst?

Tick (✓) **one** box.

Sodium	
Nickel	
Calcium	
Aluminium	

Answer

The most suitable metal to be used as a catalyst is:

Sodium	
Nickel	✓; [1 mark]
Calcium	
Aluminium	

[Total: 1 mark]

- Transition elements are useful as catalysts as they are able to interchange between a range of oxidation states

    - This allows them to form complexes with reagents that can easily **donate** and **accept** electrons from other chemical species within a reaction system

    - You do **not** need to be able to explain how transition elements act as catalysts
- Nickel is the only transition element

- Nickel is the catalyst used in the hydrogenation of alkenes

(1 mark)

4 (a) Copper is a useful transition element.

What properties of copper make it suitable to make pipes that carry water, for example, in central heating systems.

Tick (✓) **two** boxes.

It conducts electricity	
It can be bent and shaped	
It conducts heat	
It is reddish-brown in appearance	
It does not react with water	

Answer

Copper is used as water pipes because:

It conducts electricity	
It can be bent and shaped	✓; [1 mark]
It conducts heat	
It is reddish-brown in appearance	
It does not react with water	✓; [1 mark]

[Total: 2 marks]

- **Careful:** The other statements are all correct for copper but they are not the reason why it is used to make water pipes
- Copper is used in electrical wiring because it can conduct electricity
- It is also used to make cooking pans as it can conduct heat

(2 marks)

(b) Copper can be alloyed with zinc to make brass.

Brass is used to make musical instruments.

Explain why brass is more suitable for making musical instruments than copper?

Answer

Brass is more suitable than copper because:

- It is harder; [1 mark]
- Because the layers of atoms are distorted
  OR
  The layers can't slide over each other (as easily); [1 mark]

[Total: 2 marks]

- Brass is an alloy made from a mixture of zinc and copper atoms which are different sized atoms
- This distorts the regular arrangement of atoms found in pure copper
- The layers of atoms cannot slide over each other as easily, making the brass harder
- If copper was used to make a musical instrument, it would be bent out of shape more easily than brass

(2 marks)

(c) Copper reacts slowly with oxygen in the air to form copper oxide.

Complete the word equation for this reaction.

_____ + oxygen → _____

Answer

The correct word equation is:

- Copper (+ oxygen) → copper oxide; [1 mark]
  Both copper and copper oxide need to be correct to gain 1 mark

[Total: 1 mark]

- All the necessary information is given in the question
- You need to read the information and decide what the reactants and the products are to construct the word equation

(1 mark)

(d) Copper can form copper(I) ions, Cu^{+} and copper(II) ions, Cu^{2+}.

What would the formula be of copper(I) oxide?

Tick (✓) **one** box.

CuO	
Cu_2O	
CuO_2	
Cu_2O_2	

Answer

The correct formula of copper(I) oxide is:

CuO	
Cu_2O	✓; [1 mark]
CuO_2	
Cu_2O_2	

[Total: 1 mark]

- A copper(I) ion has a 1+ charge (this information is given in the question)
- An oxide ion has a 2– charge (because it gains 2 electrons to form a full outer shell of electrons)
- For the compound to be neutral overall, the charges must cancel out
- Therefore, copper(I) oxide must have 2 copper atoms for every one oxygen atom
- Its formula is Cu_2O

(1 mark)

(e) Copper doesn't react with most dilute acids but it can react with dilute nitric acid.

What is the name of the salt produced when copper reacts with nitric acid?

Answer

The name of the salt is:

- Copper nitrate; [1 mark]

[Total: 1 mark]

- Salts take the first part of their name from the metal used
- The second part of their name comes from the acid used
    - Nitric acid produces nitrate salts
- This reaction is not typical of metal + acid reactions as it doesn't form hydrogen gas in addition to the salt – you would **not** be expected to know the remaining products (which are water and nitrogen monoxide)

(1 mark)

Medium Questions

1 (a) Iron is a transition metal and is one of the most widely used metals.

Name two physical properties that iron shares with all metals.

Answer

Two physical properties are:

Any **two** of the following:

- Conduct electricity (in solid and molten state); [1 mark]
- Conduct heat; [1 mark]
- Shiny surface when freshly cut; [1 mark]

[Total: 2 marks]

- Remember, transition metals also have some different properties to group 1 you need to learn.

(2 marks)

(b) Complete **and** balance the equation for the reaction of iron with hydrochloric acid

$$\_\_Fe + \_\_HCl \rightarrow \_\_\_\_\_ + H_2$$

Answer

The balanced equation is: $Fe + \mathbf{2}HCl \rightarrow \mathbf{FeCl_2} + H_2$

- Correct formulae of iron chloride; [1 mark]
- Correctly balanced; [1 mark]

[Total: 2 marks]

- Fractions or multiples would also be accepted but you should always use the lowest common denominator.

(2 marks)

(c) Francium lies at the bottom of Group 1 on the Periodic Table and is the most reactive member of the alkali metals.

Explain why it is the most reactive, referring to its electronic structure.

Answer

Francium is the most reactive because:

- Francium has the largest number of shells in group 1; [1 mark]
- There is less attraction between the positive nucleus and the outer electron; [1 mark]
- The outer electron is more easily lost; [1 mark]

[Total: 3 marks]

- Remember, you need to specify that it is the outer electron being lost for all three marks.

(3 marks)

(d) The properties of the transition elements are different from the elements in Group 1.

State **three** of these different properties of transition elements.

Answer

Compared to Group 1 metals, the transition elements:

Any **three** for one mark each from:

- Have higher melting points and boiling points; [1 mark]
- Are more dense; [1 mark]
- Are stronger and harder; [1 mark]
- Less reactive; [1 mark]
- Form ions with different charges; [1 mark]
- Form coloured compounds; [1 mark]
- Used as catalysts; [1 mark]

[Total: 3 marks]

- Make sure you say they are **less** reactive and not unreactive, as that would be incorrect.

(3 marks)

2 Transition metals are located in the middle of the periodic table and have certain properties.

Which two properties do most transition metals have?

	Property 1	Property 2
A	soft	form colourless compounds
B	high melting points	low densities
C	high densities	form coloured compounds
D	form ions with multiple charges	do not conduct electricity

Answer

The correct answer is C because:

- Transition metals have the following properties:
  - Conduct electricity and heat
  - High densities
  - Strong
  - Shiny
  - Lower reactivity than Group 1 metals
  - Form ions with multiple charges (e.g. Fe^{2+} and Fe^{3+})
  - Form coloured compounds

(1 mark)

3 Nitrogen and water are produced when ammonia reacts with oxygen.

A metal oxide catalyst is used to speed up the rate of reaction.

Which of the following metal oxides would most likely be used for this reaction?

A. Na_2O

B. Li_2O

C. Al_2O_3

D. Cr_2O_3

Answer

The correct answer is D because:

- Cr_2O_3 contains chromium- a transition metal element
- Transition metals are often used as catalysts

A, **B** & **C** are incorrect as these oxides do not contain a transition metal element

(1 mark)

4 (a) An atom of titanium has the symbol, $^{48}_{22}Ti$

Write down the number of protons, neutrons and electrons in this atom.

Protons _____

Neutrons _____

Electrons _____

Answer

The number of each subatomic particle is:

- 22 protons; [1 mark]
- 26 neutrons; [1 mark]
- 22 electrons; [1 mark]

[Total: 3 marks]

- The atomic number of 22 tells you the number of protons and electrons.
- The number of neutrons is calculated by subtracting the atomic number away from the mass number.
- If you got the incorrect numbers for all three answers but had the **same number** for the protons and electrons then you would be awarded 1 mark.

(3 marks)

(b) Using the Periodic Table, state why titanium is referred to as a transition element.

Answer

It is known as a transition element because:

- It is in the transition element / central block of the Periodic Table; [1 mark]

[Total: 1 mark]

- Make sure you also learn the names of Group 1, Group 7 and Group 0.

(1 mark)

(c) Explain why titanium is a good conductor of electricity.

Answer

Titanium can conduct electricity because:

- It has delocalised electrons; [1 mark]
- Which are free to move through the structure (and carry charge); [1 mark]

[Total: 2 marks]

- This is using your knowledge about the properties of metals and applying it to a specific metal

(2 marks)

5 (a) Rhodium is a typical transition metal.

Place a tick (✔) next to each of the **four** properties in the table that you would expect for rhodium.

Property	
strong	
reactive	
low boiling point	
forms coloured compounds	
high melting point	
dull	
brittle	
conducts heat	

Answer

Typical properties of rhodium include:

- Conducts heat; [1 mark]
- Forms coloured compounds; [1 mark]
- High melting point; [1 mark]
- Strong; [1 mark]

[Total: 4 marks]

(4 marks)

(b) Rhodium is used in the production of alloys and in ornaments and jewellery although its main use is in the automotive industry.

It is used in the exhaust systems where it changes harmful unburned hydrocarbons, carbon monoxide, and nitrogen oxide emissions into less toxic gases.

Suggest **two** properties of rhodium that allows it to be used in this way.

Answer

Two properties that allow rhodium to be used in this way include:

- It can be used as a catalyst; [1 mark]
- It has a high melting point (so can withstand high temperatures); [1 mark]

[Total: 2 marks]

(2 marks)

6 A catalyst is used during the Haber Process to manufacture ammonia.

Which elements are usually used as catalysts?

A. The transition metals

B. The alkali metals

C. The noble gases

D. The halogens

Answer

The correct answer is A because:

- Transition metals are generally used as catalysts during reactions
- For example, iron is the catalyst used in the Haber Process

(1 mark)

7 Nickel is a transition metal.

Sodium is a Group 1 metal.

Which statement below is correct when comparing their properties?

A. Group 1 metals are less reactive than transition metals

B. Group 1 metals are harder than transition metals

C. Transition metals have lower melting points than Group 1 metals

D. Transition metals are more dense than Group 1 metals

Answer

The correct answer is D because:

- Transition metals are harder, stronger, more dense, less reactive and have higher melting points than Group 1 metals

(1 mark)

8 Which combination of properties makes transition metals suitable for use in cutting tools?

	Property 1	Property 2
A	malleable	hard
B	strong	ductile
C	not reactive	high melting point
D	high boiling point	conducts electricity

Answer

The correct answer is C because:

- For use in cutting tools the material needs to be able to withstand high temperatures, and not react with other substances
- It should also be hard in order to withstand high pressures and force

A is incorrect as a malleable substance can be hammered into shape

B is incorrect as a ductile material can have its shape changed

D is incorrect as these two properties are irrelevant to the metal being used as a cutting tool

(1 mark)

9 (a) What is the name used to describe the block of elements in the middle of the Periodic Table?

Answer

The block in the middle is called:

- Transition metals / elements (or d- block elements); [1 mark]

[Total: 1 mark]

(1 mark)

(b) Vanadium is a transition metal. Some of its properties are listed below:

- It has a high melting point.
- It is a good conductor of heat and electricity.
- It forms coloured compounds.
- It forms crystalline compounds.
- Its compounds can act as catalysts.

From the list, identify the **two** properties that are most characteristic of transition metals and help to distinguish them from main group metals (like those in Group 1 or 2).

Answer

Two properties typical of transition metals are:

- Forms coloured compounds; [1 mark]
- Useful as a catalyst; [1 mark]

[Total: 2 marks]

(2 marks)

10 (a) The transition elements have certain properties which make them very useful.

Why is copper used to produce electrical wiring?

Answer

Copper is used in electrical wiring because:

- It is a good conductor of electricity; [1 mark]
- It is ductile and can be drawn / pulled into wires easily; [1 mark]

[Total: 2 marks]

(2 marks)

(b) State why their compounds are used in glazing pottery.

Answer

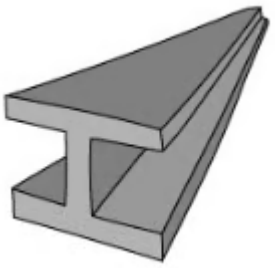
Transition metals are used for glazing pottery as

- They form coloured compounds; [1 mark]

[Total: 1 mark]

(1 mark)

(c) Why is iron used in the construction industry as girders in buildings?



Answer

They are used as girders in buildings because:

- They are strong

OR

They have high tensile strength; [1 mark]

[Total: 1 mark]

(1 mark)

Hard Questions

1 (a) Vanadium reacts with excess oxygen to form vanadium(III) oxide.

Write the balanced symbol equation for the reaction.

Answer

The balanced symbol equation for the reaction between vanadium and oxygen is:

$4V + 3O_2 \rightarrow 2V_2O_3$

- Correct formulae for reactants; [1 mark]
- Correct formula for products; [1 mark]
- Correct balancing; [1 mark]

[Total: 3 marks]

- The name vanadium(III) oxide tells you that the charge on the vanadium ion is 3+
- The charge on the oxide ion is 2−
- For the charges to cancel, there need to be 2 vanadium ions and 3 oxygen ions to give the formula V_2O_3

(3 marks)

(b) Vanadium(III) ions can be reduced to vanadium(II) ions.

In terms of electrons, what does reduction mean?

Answer

In terms of electrons, reduction means:

- The gain of electrons; [1 mark]

[Total: 1 mark]

- **Remember:** The mnemonic OIL RIG can help:
    - **O**xidation **I**s **L**oss **R**eduction **I**s **G**ain of electrons

(1 mark)

(c) Write the half equation to show the reduction of vanadium(III) ions to vanadium(II) ions.

Answer

The half equation to show the reduction of vanadium(III) ions is:

- $V^{3+} + e^- \rightarrow V^{2+}$; [2 marks]
  1 mark for V^{3+} as reactant, V^{2+} as product
  1 mark for e^- as reactant

[Total: 2 marks]

- When V^{3+} undergoes reduction, it gains an electron
- As it gains a negative charge, its overall charge is reduced from 3+ to 2+
- **Careful**: V^{3+} also undergoes reduction when it gains 3 electrons to form V (half equation shown below) but the question is specifically referring to the formation of V^{2+} ions
    - $V^{3+} + 3e^- \rightarrow V$

(2 marks)

(d) Describe the structure and bonding in vanadium.

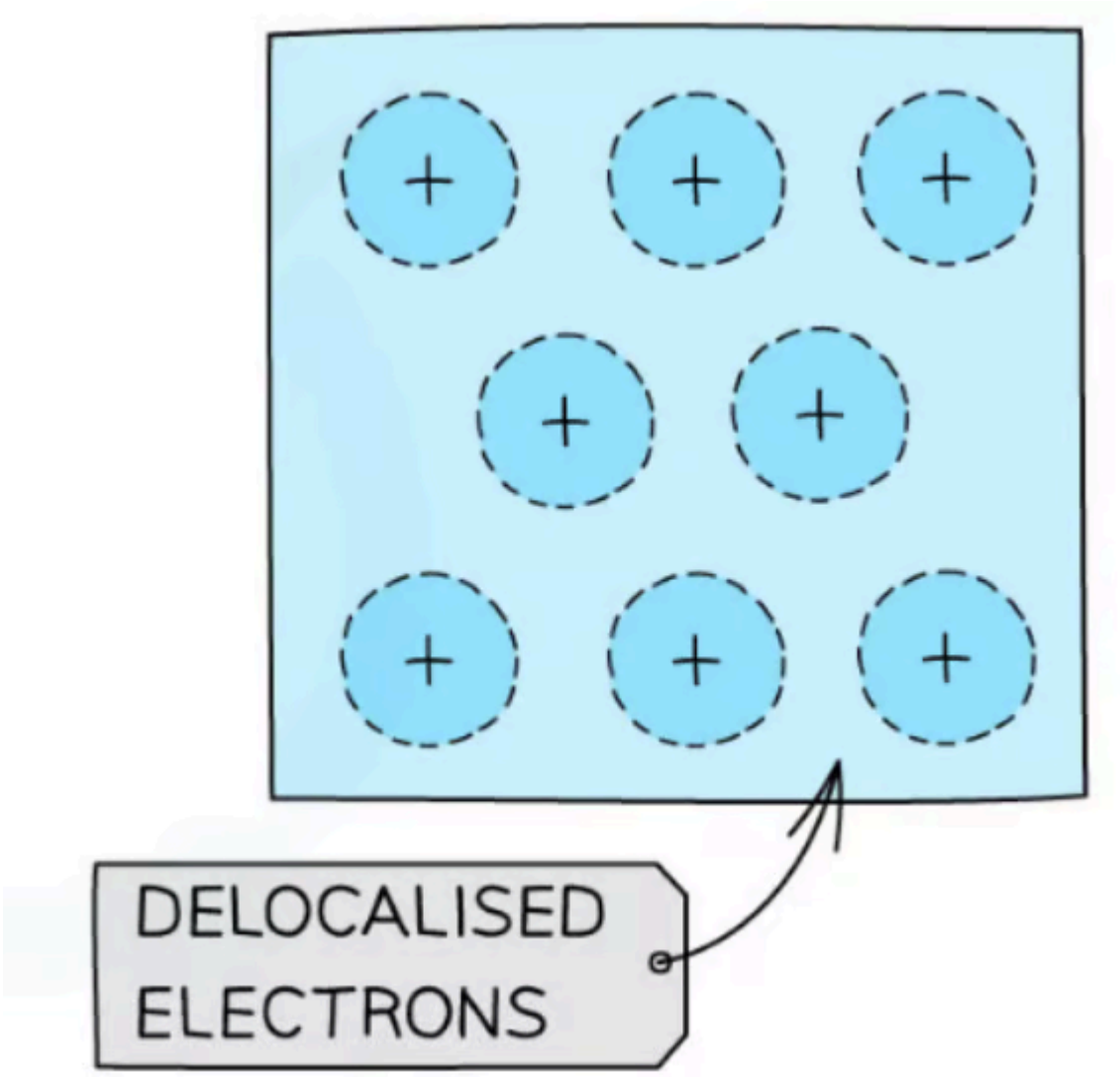
Answer

The structure and bonding in vanadium can be described as:

- A giant structure / lattice / regular arrangements; [1 mark]
- Of atoms / of ions; [1 mark]
- Delocalised / free electrons; [1 mark]

[Total: 3 marks]

- This requires the application of your knowledge of the structure and bonding of metals
- Vanadium is a transition metal and will have a structure like typical metals



(3 marks)

2 (a) Nickel has been used in making the electrodes in spark plugs in car engines for many years. Spark plugs are responsible for igniting the fuel in the combustion engine.

The material the electrodes are made of need to be able to withstand the very high temperatures and corrosive atmosphere found in the car engine and also be able to conduct electricity.

More recently, platinum has been used to make the electrode in spark plugs.

Table 1 shows some information about nickel and platinum.

Table 1

	Nickel	**Platinum**
Melting point in ^{o}C	1455	1769
Boiling point in ^{o}C	2920	4107
Cost in £ per kg	22	25,058
Approximate lifetime in km	30,000	70,000
Efficiency	Reduces rapidly, petrol is not burnt completely	More efficient, petrol is burnt completely for much longer
Relative reactivity	More reactive than gold	Less reactive than gold

Evaluate the use of nickel and platinum for making the electrodes in spark plugs.

You should refer to the information in **Table 1** and your knowledge about the properties of these metals in your answer.

Answer

This is a 6 mark Extended Response question. To gain full marks you need to show a sustained and coherent line of reasoning where you link knowledge, skills and understanding from various areas of the specification. The following level descriptors in the mark scheme are to help you to build and develop your answers for this style of question.

Level 3 (5–6 marks):

- A detailed and coherent comparison is given which mentions most of the advantages and disadvantages of both metals
- A justified conclusion is made

Level 2 (3–4 marks):

- Some advantages and disadvantages are given
- Comparisons are made but may not be fully articulated and / or precise
- A simple conclusion is made

Level 1 (1–2 marks):

- Simple statements about some advantages and disadvantages are given
- Little or no attempt to compare the metals
- No conclusion is given

Indicative content

Advantages of nickel:

- Cheaper to produce as lower in cost
- Able to conduct electricity to produce a spark
- Able to withstand high temperatures of the engine as the melting point is quite high

Disadvantages of nickel:

- Higher in reactivity than platinum so will corrode more in the engine, so don't last as long
- Reduced efficiency causes unburnt petrol which causes air pollution

Advantages of platinum:

- Less reactive so will withstand the corrosive atmosphere in the engine for much longer
- Improves efficiency so not as much unburnt petrol is released, reduces air pollution
- Lasts longer than nickel due to lower reactivity
- Spark plugs doesn't need to be replaced as frequently
- Higher melting point so can withstand high temperatures in the engine
- Good conductor of electricity

Disadvantages of platinum:

- Cost/price per kg is much greater so spark plug will be more expensive

Conclusion

- A justified conclusion may justify the use of platinum because the greater cost is offset against a longer life, better fuel consumption and less pollution
- A justified conclusion may justify the use of nickel because the cost is so much less than platinum, they can be replaced a lot more frequently

[Total: 6 marks]

(6 marks)

(b) Spark plugs with iridium electrodes are also available. They can last 25% longer than platinum spark plugs.

Iridium is six times harder than platinum with a melting point 700 ^{o}C higher.

Suggest **one** other property of iridium.

Answer

One other property of iridium is:

Any **one** from:

- Strong; [1 mark]
- High density; [1 mark]
- Good conductor of heat/electricity; [1 mark]
- Ductile / malleable; [1 mark]
- Low reactivity; [1 mark]

[Total: 1 mark]

- Iridium is a transition metal as it can be found in the central block in the periodic table
- You can apply your knowledge of the properties of transition metals to iridium and suggest any of the typical transition metal properties

(1 mark)

(c) Platinum, palladium and rhodium are all used within a catalytic convertor to remove harmful gases from the car's exhaust.

The catalytic convertor consists of a honeycomb structure which is coated with the metals. The exhaust gases travel through the catalytic convertor before leaving the vehicle.

Suggest why the convertor has a honeycomb structure.

Explain your answer.

Answer

A catalytic convertor has a honeycomb structure because:

- It has a large surface area; [1 mark]

- To increase/maximise contact between the metal/catalyst and the (exhaust) gases
  OR
  To minimise the amount of metal used
  OR
  To increase the rate of reaction; [1 mark]

[Total: 2 marks]

- As the surface area increases, the rate of reaction increases as more frequent collisions can occur

- Platinum, palladium and rubidium act as catalysts so the harmful exhaust gases molecules adhere onto the surface (this is known as adsorption) which lowers the activation energy for a reaction to occur

- A honeycomb structure provides the maximum surface area for the reaction to occur whilst using the minimum amount of catalyst

(2 marks)

(d) **Table 2** shows the amount of metals used in a catalytic convertor and the cost of each metal.

Table 2

Metal	Platinum	Palladium	Rhodium
Mass of metal used in catalytic convertor in grams	5.8	4.5	2.1
Cost of metal in £ per gram	25.06	48.32	363.27

What is the total cost of the three metals used in the catalytic convertor?

Give your answer to the nearest pound.

Answer

The total cost of the three metals used in the catalytic convertor is:

- (5.8 x 25.06) + (4.5 x 48.32) + (2.1 x 363.27); [1 mark]
- = 1125.655; [1 mark]
- = (£)1126; [1 mark]
  An answer of (£)1126 without working scores 3 marks

[Total: 3 marks]

- This question is a mathematical based question with no chemistry knowledge required
- It requires you to find the cost of each metal by multiplying the cost per gram by the mass in grams of the metal used and adding them together – the workings are shown in the first marking point
- Don't forget to quote your answer to the nearest pound, as specified in the question – an easy mark to gain (or lose if you forget!)

(3 marks)

3 (a) The transition elements are metals which are found in the central section of the periodic table.

Group 1 elements are also metals.

Table 1 shows the melting point and oxide formulae of two elements from Group 1 and two transition elements

Table 1

	Lithium	**Rubidium**	**Chromium**	**Cobalt**
Melting point in °C	180	39	1857	1535
Formula of oxides	Li_2O	Rb_2O	CrO Cr_2O_3 CrO_2 CrO_3	CoO Co_2O_3 Co_3O_4

Use the data from **Table 1** and your knowledge of Group 1 metals and transition metals to compare their chemical and physical properties.

Answer

This is a 6 mark Extended Response question. To gain full marks you need to show a sustained and coherent line of reasoning where you link knowledge, skills and understanding from various areas of the specification. The following level descriptors in the mark scheme are to help you to build and develop your answers for this style of question.

Level 3 (5–6 marks):

- A detailed and coherent comparison is given, which demonstrates a broad knowledge and understanding of the key scientific ideas.

- The response makes logical links between the points raised and uses sufficient examples to support these links.

Level 2 (3–4 marks):

- A description is given which demonstrates a reasonable knowledge and understanding of the key scientific ideas.
- Comparisons are made but may not be fully articulated and/or precise.

Level 1 (1–2 marks):

- Simple statements are made which demonstrate a basic knowledge of some of the relevant ideas.
- The response may fail to make comparisons between the points raised.

Indicative content

Chemical

Transition elements

- Low reactivity, react slowly with water and/or oxygen e.g. rusting
- Used as catalysts e.g. iron in the Haber process
- Ions with different charges as they can have variable oxidation states
- Coloured compounds

Group 1

- Very reactive e.g. they react violently with water
- Not used as catalysts as they are too reactive
- White or colourless compounds
- Only forms a 1+ ion and no other ion is formed

Physical

Transition elements

- High melting points
- High densities
- Strong
- Hard

Group 1

- Low melting points
- Low densities
- Soft and can be cut with a knife

[Total: 6 marks]

(6 marks)

(b) Iron is another transition metal. When it reacts with oxygen, it can form different compounds which contain the Fe^{2+} ion or the Fe^{3+} ion.

Complete the two balanced symbol equations for the reaction between iron and oxygen to show how the different compounds are formed.

Formation of compound containing Fe^{2+} ions:

$$\_\_ Fe + \_\_ O_2 \rightarrow \_\_\_\_\_$$

Formation of compound containing Fe^{3+} ions:

$$\_\_ Fe + \_\_ O_2 \rightarrow \_\_\_\_\_$$

Answer

The correct balanced symbol equations are:

- Formation of compound containing Fe^{2+} ions:
  2Fe + O_2 → **2FeO**; [2 marks]
  Correct formula of FeO gains 1 mark
  Correct balancing gains 1 mark

- Formation of compound containing Fe^{3+} ions:
  4Fe + **3**O_2 → **2**Fe_2O_3; [2 marks]
  Correct formula of Fe_2O_3 gains 1 mark
  Correct balancing gains 1 mark

[Total: 4 marks]

- Oxygen forms the oxide ion which has a 2– charge
- When working out the formula of the product, the charges need to cancel out
- When Fe^{2+} is formed, one ion of Fe^{2+} will cancel the charge on the O^{2-} ion so the formula is FeO
- When Fe^{3+} is formed, two ions of Fe^{3+} will cancel out the charge of 3 O^{2-} ions, so the formula is Fe_2O_3

(4 marks)

(c) Sodium hydroxide was added to one solution containing Fe^{2+} ions and another solution containing Fe^{3+}.

What observations would be made?

Observations with sodium hydroxide and solution containing Fe^{2+} ions:

_____

Observations with sodium hydroxide and solution containing Fe^{3+} ions:

_____

Answer

The names of these compounds and the colours that they would form are:

- With Fe^{2+} ions: a green precipitate / solid; [1 mark]
- With Fe^{3+} ions: a brown precipitate / solid; [1 mark]

[Total: 2 marks]

- These are colours that you are expected to know
- You are also expected to know the colours of the precipitates formed when sodium hydroxide is added to solutions containing copper(II), aluminium, magnesium and calcium ions
- It is important that you say that a precipitate is produced too, just stating the colours is not sufficient to award you any marks

(2 marks)

(d) Iron can be used to displace copper from a solution of copper(II) sulfate.

Iron(II) sulfate is also formed. The equation for this reaction is:

$$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$$

Identify which species has been oxidised and which has been reduced.

You should include the ionic equation for the reaction and the two half equations in your answer.

Answer

The species that have been oxidised and reduced, together with the required equations are:

- $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$; [1 mark]
- Iron has been oxidised (as it has lost electrons);[1 mark]
- $Fe \rightarrow Fe^{2+} + 2e^-$; [1 mark]
- Copper has been reduced (as it has gained electrons); [1 mark]
- $Cu^{2+} + 2e^- \rightarrow Cu$; [1 mark]

[Total: 5 marks]

- The ionic equation shows the species which change during the reaction
    - In this equation, the sulfate ions are unchanged (they are known as spectator ions) and they do not appear in the ionic equation
- Half equations show what happens to the electrons in a reaction to help show what loses and what gains electrons
- When constructing half equations, remember that they must include electrons and the charges must balance either side of the equation
- To work out what has been oxidised or reduced, remember OIL RIG
    - **O**xidation **I**s **L**oss, **R**eduction **I**s **G**ain (of electrons)

(5 marks)

4 (a) Manganese can form compounds which are black, brown, pink, red, green, blue, and purple.

Why does manganese form different coloured compounds?

Answer

Manganese forms different coloured compounds because:

- (Manganese has) ions with different charges; [1 mark]
  Allow (manganese is a) transition metal

[Total: 1 mark]

- Manganese can form ions that have a 2+, 3+, 4+, 5+, 6+ and 7+ charge
- Each of these form compounds which have different colours
- This is characteristic of transition metals; other metals tend to form white compounds

(1 mark)

(b) A compound of manganese, manganese dioxide, has the formula, MnO_2.

What is the charge on the manganese ion is manganese dioxide?

Answer

The charge on the manganese ion is:

- 4+ / Mn^{4+}; [1 mark]

[Total: 1 mark]

- Oxygen forms the oxide ion which has a 2– charge
    - It is in Group 6 so will gain 2 electrons to achieve a full outer shell of electrons
- There are 2 oxide ions so contribute 4– charge to the compound
- The compound will be neutral overall so the charge on the manganese ion must balance this charge out
- The charge on the manganese ion is therefore 4+

(1 mark)

(c) Manganese dioxide acts as a catalyst in the decomposition of hydrogen peroxide.

A student made the following statements about the role of manganese dioxide in this reaction:

"Manganese dioxide increases the rate of reaction by providing an alternative reaction pathway which has a lower activation energy.

The yield of oxygen produced increases as more oxygen can be produced in a given amount of time".

Is the student correct?

Explain your answer.

Answer

The student's comments

- The first statement is correct **AND** the second statement is incorrect; [1 mark]
- The amount of oxygen produced in a given time will increase initially; [1 mark]
- (But) the total yield / amount of oxygen produced will remain the same; [1 mark]

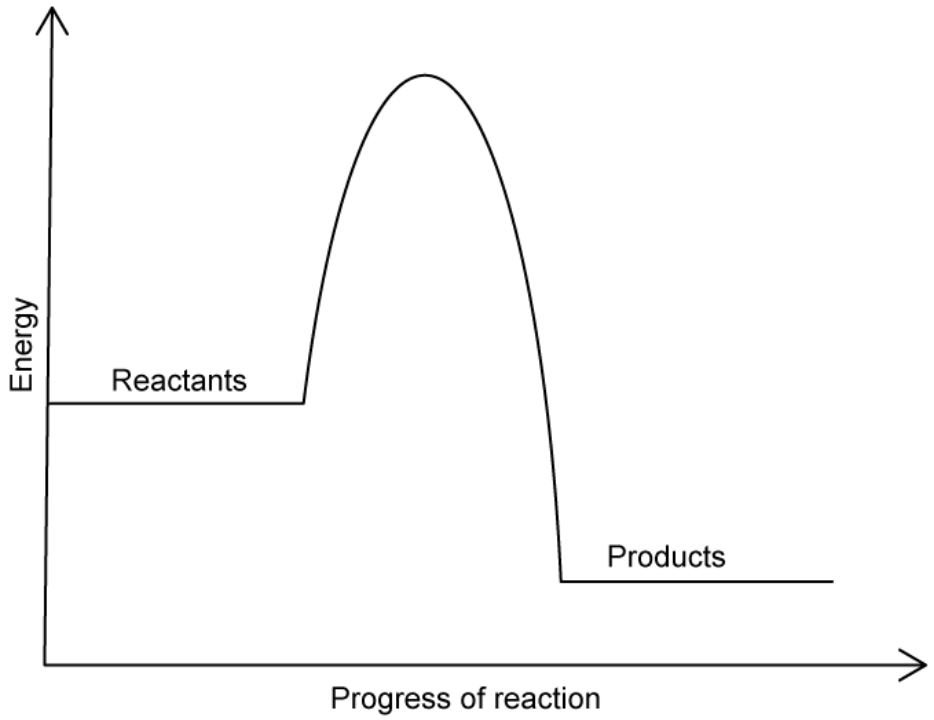
[Total: 3 marks]

- For question like this, you must comment on every statement to say whether they are correct or not
- If they are not correct, state what is wrong about them and/or how they should be changed
- Catalysts do not increase the amount of product formed, they just speed up how quickly they form – the yield of oxygen does not change

(3 marks)

(d) The diagram shows the reaction profile for the decomposition of hydrogen peroxide with a catalyst.

Figure 1

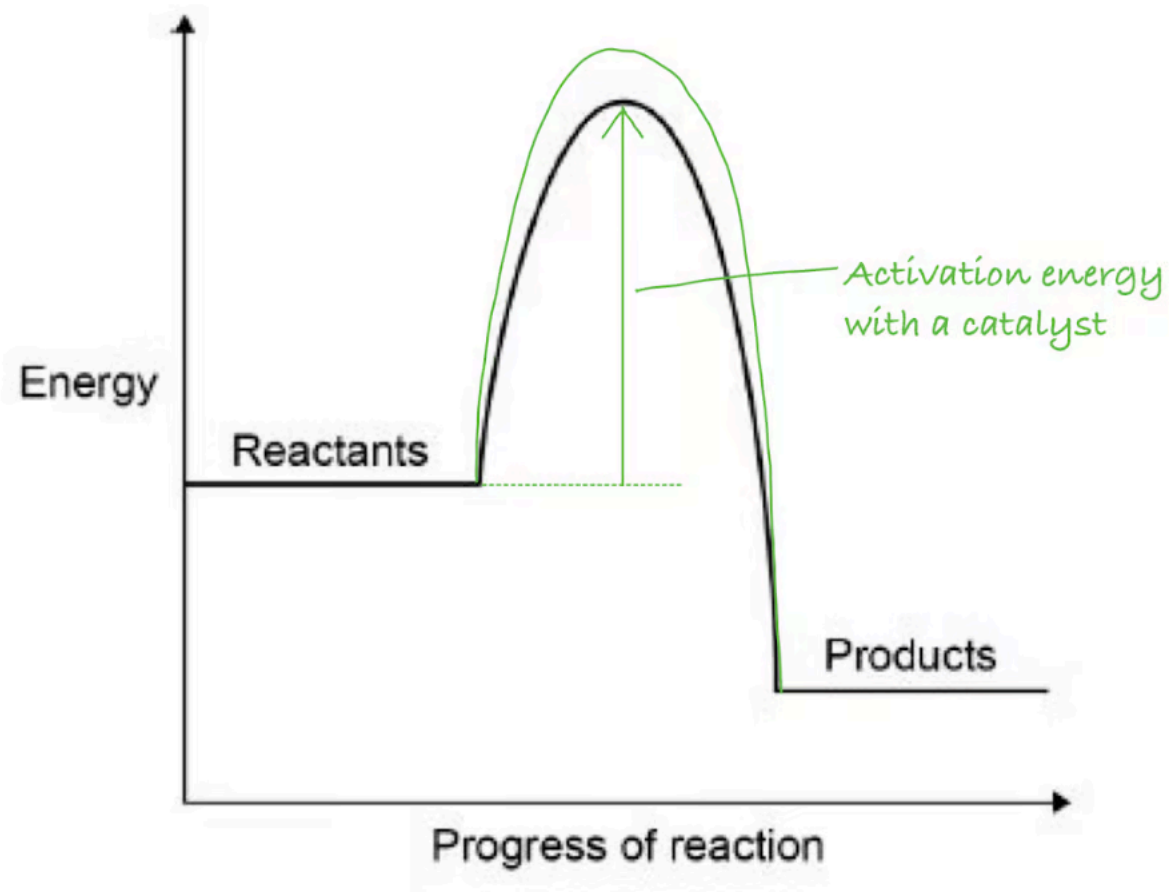


On **Figure 1**:

- Draw the reaction profile for the reaction without a catalyst
- Draw and label an arrow to show the activation energy for the reaction with a catalyst

Answer

The reaction profile should been drawn as follows:



- Curve above the printed curve; [1 mark] *Do not accept different reactant or product levels*
- Vertical arrow from reactant level to peak of printed curve; [1 mark]

[Total: 2 marks]

- **Careful**: Most questions like this ask you to draw the reaction profile of the reaction **with** a catalyst but this question is asking the opposite
- Make sure you are accurate with how you draw the arrow, it must start at a line level with the reactants and touch the peak of the curve

(2 marks)