Q1.

This question is about metals and the reactivity series.

(a) Which **two** statements are properties of most transition metals?

Tick (✓) **two** boxes.

They are soft metals.	☐
They form colourless compounds.	☐
They form ions with different charges.	☐
They have high melting points.	☐
They have low densities.	☐

(2)

(b) A student added copper metal to colourless silver nitrate solution.

The student observed:

- pale grey crystals forming
- the solution turning blue.

Explain how these observations show that silver is less reactive than copper.

_____

_____

_____

_____

_____

_____

(3)

(c) A student is given three metals, **X**, **Y** and **Z** to identify.

The metals are magnesium, iron and copper.

Plan an investigation to identify the three metals by comparing their reactions with dilute hydrochloric acid.

Your plan should give valid results.

(4)

(d) Metal **M** has two isotopes.

The table below shows the mass numbers and percentage abundances of the isotopes.

Mass number	Percentage abundance (%)
203	30
205	70

Calculate the relative atomic mass (A_r) of metal **M**.

Give your answer to 1 decimal place.

Relative atomic mass (1 decimal place) = _____

(2)

(Total 11 marks)

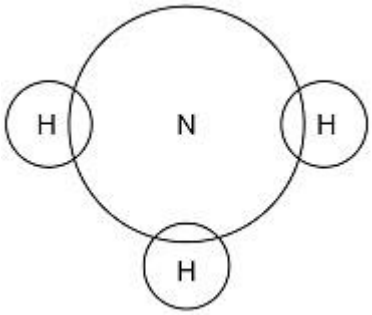
Q2.

This question is about ammonia, NH_3

(a) Complete the dot and cross diagram for the ammonia molecule shown in **Figure 1**.

Show only the electrons in the outer shell of each atom.

Figure 1



(2)

(b) Give **one** limitation of using a dot and cross diagram to represent an ammonia molecule.

_____

_____

(1)

(c) Explain why ammonia has a low boiling point.

You should refer to structure and bonding in your answer.

_____

_____

_____

_____

_____

_____

(3)

Ammonia reacts with oxygen in the presence of a metal oxide catalyst to produce nitrogen and water.

(d) Which metal oxide is most likely to be a catalyst for this reaction?

Tick (✓) **one** box.

CaO ☐

Cr_2O_3 ☐

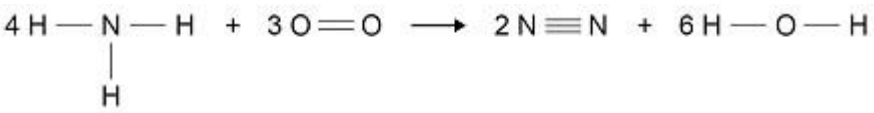
MgO ☐

Na_2O ☐

(1)

Figure 2 shows the displayed formula equation for the reaction.

Figure 2



The table shows some bond energies.

Bond	N — H	O = O	N ≡ N	O — H
Bond energy in kJ/mol	391	498	945	464

(e) Calculate the overall energy change for the reaction.

Use **Figure 2** and the table.

_____

_____

_____

_____

_____

_____

Overall energy change = _____ kJ/mol

(3)

(f) Explain why the reaction between ammonia and oxygen is exothermic.

Use values from your calculation in part (e).

_____

_____

_____

_____

_____

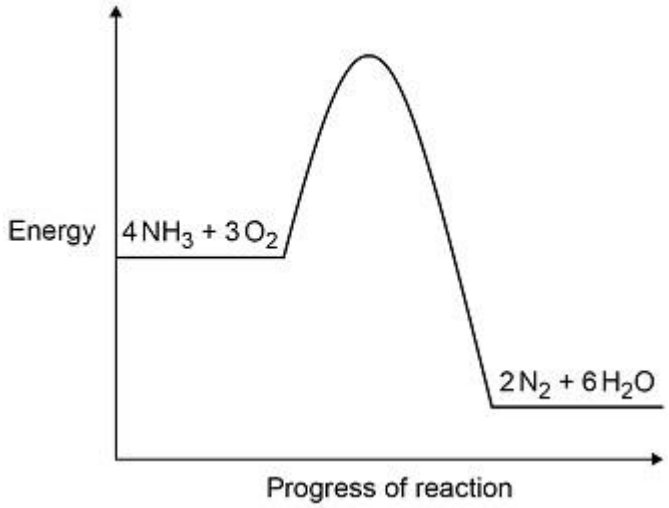
(2)

(g) **Figure 3** shows the reaction profile for the reaction between ammonia and oxygen.

Complete **Figure 3** by labelling the:

- activation energy
- overall energy change.

Figure 3



(2)

(Total 14 marks)

Q3.

Titanium is a transition metal.

Titanium is extracted from titanium dioxide in a two-stage industrial process.

Stage 1 $TiO_2 + 2\ C + 2\ Cl_2 \longrightarrow TiCl_4 + 2\ CO$

Stage 2 $TiCl_4 + 4\ Na \longrightarrow Ti + 4\ NaCl$

(a) Suggest **one** hazard associated with **Stage 1**.

_____

_____

(1)

(b) Water must be kept away from the reaction in **Stage 2**.

Give **one** reason why it would be hazardous if water came into contact with sodium.

_____

_____

(1)

(c) Suggest why the reaction in **Stage 2** is carried out in an atmosphere of argon and **not** in air.

_____

_____

_____

_____

(2)

(d) Titanium chloride is a liquid at room temperature.

Explain why you would **not** expect titanium chloride to be a liquid at room temperature.

_____

_____

_____

_____

_____

_____

_____

(3)

In **Stage 2**, sodium displaces titanium from titanium chloride.

(e) Sodium atoms are oxidised to sodium ions in this reaction.

Why is this an oxidation reaction?

_____

_____

(1)

(f) Complete the half equation for the oxidation reaction.

$$Na \longrightarrow \_\_\_\_\_ + \_\_\_\_\_$$

(1)

(g) In Stage 2, 40 kg of titanium chloride was added to 20 kg of sodium.

The equation for the reaction is:

$$TiCl_4 + 4\ Na \longrightarrow Ti + 4\ NaCl$$

Relative atomic masses (A_r): Na = 23 Cl = 35.5 Ti = 48

Explain why titanium chloride is the limiting reactant.

You **must** show your working.

(4)

(h) For a **Stage 2** reaction the percentage yield was 92.3%

The theoretical maximum mass of titanium produced in this batch was 13.5 kg.

Calculate the actual mass of titanium produced.

Mass of titanium = _____ kg

(2)

(Total 15 marks)

Q4.

Older cars are tested each year to measure the amount of pollutants contained in exhaust fumes.

The table below shows the maximum allowed percentages of exhaust pollutants

for petrol cars.

Age of car in years	Maximum allowed percentage (%) of exhaust pollutant	
	Carbon monoxide	**Unburned hydrocarbons**
16−24	0.30	0.02
3−16	0.20	0.02

(a) Explain how carbon monoxide is produced when petrol is burned in car engines.

_____

_____

_____

_____

(2)

(b) Suggest **two** reasons why the maximum allowed percentage of carbon monoxide has been decreased for newer cars.

1.

_____

_____

2.

_____

_____

(2)

(c) Give **one** reason for having a maximum allowed percentage of unburned hydrocarbons in exhaust fumes.

_____

_____

(1)

Oxides of nitrogen are also pollutants contained in exhaust fumes.

(d) Describe how oxides of nitrogen are produced when petrol is burned in car engines.

_____

_____

_____

_____

(2)

Catalytic converters are fitted to car exhausts to reduce the amount of pollutants released into the atmosphere.

(e) Nitrogen dioxide is an oxide of nitrogen.

Nitrogen dioxide reacts to produce nitrogen and oxygen in catalytic converters.

Complete the equation for this reaction.

The equation should be balanced.

$$\_\_\_\ NO_2\ (g) \longrightarrow \_\_\_\_\_ + \_\_\_\ O_2\ (g)$$

(2)

(f) Give **two** effects of atmospheric pollution which are reduced by using catalytic converters.

1.

_____

_____

2.

_____

_____

(2)

(g) The catalyst in catalytic converters is a mixture of three elements.

Where in the periodic table are these elements most likely to be found?

Tick **one** box.

Alkali metals ☐

Halogens ☐

Noble gases ☐

Transition metals ☐

(1)

(Total 12 marks)

Q5.

Cobalt forms coloured compounds.

A pink cobalt compound reacts with hydrochloric acid.

The reaction can be represented as:

pink cobalt compound + hydrochloric acid ⇌ blue cobalt compound + water

The forward reaction is endothermic.

When both cobalt compounds are present in a solution at equilibrium, the equilibrium mixture is purple.

(a) What is meant by equilibrium?

(2)

(b) The equilibrium mixture is cooled.

Explain what happens to the concentration of the pink cobalt compound.

(3)

(c) More hydrochloric acid is added.

Explain what happens to the colour of the equilibrium mixture

_____

_____

(3)

(d) Why does cobalt form different coloured compounds?

_____

(1)

(e) An oxide of cobalt has the formula Co_2O_3

Which cobalt ion is present in this oxide?

Tick (✓) **one** box.

Co^+ ☐

Co^{2+} ☐

Co^{3+} ☐

Co^{4+} ☐

(1)

(f) Cobalt compounds can act as catalysts.

Which two statements about cobalt compounds are correct?

Tick (✓) **two** boxes.

They allow reactions to reach equilibrium more quickly. ☐

They are reactants in reactions catalysed by cobalt compounds. ☐

They are used up when acting as catalysts. ☐

They increase the equilibrium yield of reactions. ☐

They provide a different reaction pathway. ☐

(2)

(g) The reaction of hydrogen with carbon monoxide is catalysed by cobalt

metal.

Balance the equation for the reaction.

$$H_2 \quad + \quad CO \quad \longrightarrow \quad C_6H_{14} \quad + \quad H_2O$$

(1)

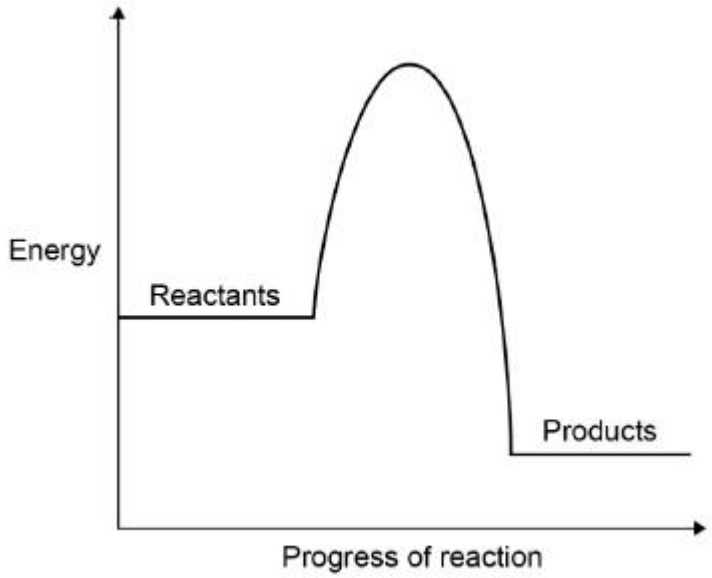
(h) C_6H_{14} is an alkane.

What is the formula of an alkane containing 18 hydrogen atoms?

_____

(1)

(i) The graph shows a reaction profile diagram for a reaction **without** a catalyst.



On the graph:

- draw the reaction profile diagram for a catalysed reaction
- draw and label an arrow to show the activation energy for the reaction **without** a catalyst.

(2)

(Total 16 marks)

Q6.

An atom of aluminium has the symbol $^{27}_{13}Al$

(a) Give the number of protons, neutrons and electrons in this atom of aluminium.

Number of protons _____

Number of neutrons _____

Number of electrons _____

(3)

(b) Why is aluminium positioned in Group 3 of the periodic table?

_____

_____

(1)

(c) In the periodic table, the transition elements and Group 1 elements are metals.

Some of the properties of two transition elements and two Group 1 elements are shown in the table below.

	Transition elements		**Group 1 elements**	
	Chromium	Iron	Sodium	Caesium
Melting point in °C	1857	1535	98	29
Formula of oxides	CrO Cr_2O_3 CrO_2 CrO_3	FeO Fe_2O_3 Fe_3O_4	Na_2O	Cs_2O

Use your own knowledge **and** the data in the table above to compare the chemical and physical properties of transition elements and Group 1 elements.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 10 marks)