From models to materials [44 marks]

1. [Maximum mark: 1]
Which statements are correct for alloys?

I. They are homogeneous mixtures of metals with other metals or non-metals.

II. The different sizes of atoms in alloys prevent layers of metallic cations sliding over each other easily.

III. Adding carbon to iron produces an alloy that is stronger than pure iron.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III [1]

2. [Maximum mark: 11]
Aluminium is useful as a metal, in alloys, and in ceramic compounds.

(a.i) Using graphite electrodes, aluminium is extracted by the electrolysis of a molten mixture containing alumina, Al_2O_3.

Explain why adding cryolite to the molten electrolyte improves the process. [2]

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(a.ii) Aluminium oxide is a hard ceramic. Outline the bonding and electrical conductivity of this ceramic. Use sections 9 and 17 of the data booklet.

Bonding: . . . . . .

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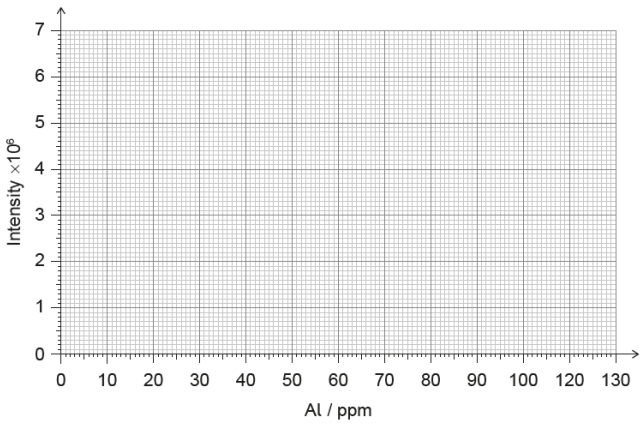
Electrical conductivity: . . . . . [3]

(b) Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) is used for quantifying trace amounts of aluminium in samples. On the axes, draw a graph of intensity against the concentration of aluminium, given that a concentration of 40 ppm of Al has an intensity of 2×10^6. Assume the only species yielding a signal is Al.



[1]

(c.i) Alloys of aluminium containing nickel are used to make engine parts. Explain, by referring to the structure of these alloys, why they are less malleable than pure aluminium. [2]

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(c.ii) Raney nickel catalysts are produced by treating a Ni–Al alloy with sodium hydroxide to remove some of the aluminium, which creates a porous material.

Deduce the coefficients to complete the balanced equation for this process.

$$\_\_\ Al(s) + \_\_\ NaOH(aq) + \_\_\ H_2O(l) \rightarrow \_\_\ Na[Al(OH)_4](aq) + \_\_\ H_2(g)$$

[1]

(c.iii) Ni is used as a catalyst for hydrogenation reactions. Suggest why Raney nickel is particularly effective for this reaction. [1]

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(c.iv) Suggest how the catalytic activity of Ni could have been discovered before the way it works was understood. [1]

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3. [Maximum mark: 3]

(a) State the electron configuration of sulfur, S. [1]

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(b) State a physical property of sulfur which supports its classification as a non-metal element. [1]

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(c) Suggest a balanced equation for the reaction of an oxide of sulfur with water. [1]

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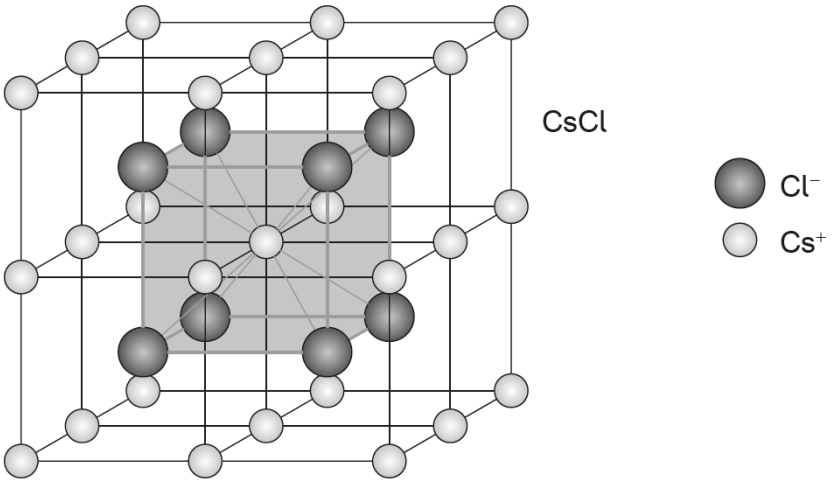
4. [Maximum mark: 20]

Caesium chloride, CsCl, has the ionic lattice structure shown.



(a.i) Demonstrate, using sections 9 and 17 of the data booklet, how this type of bonding could be predicted. [2]

(a.ii) Outline the nature of the forces holding this structure together. [1]

(a.iii) Outline why caesium chloride crystals are very brittle. [1]

(b) Justify why caesium chloride is diamagnetic. [1]

(c) Caesium metal is produced by electrolysis of molten caesium chloride.

(c.i) Outline why caesium can only be produced by electrolysis. [1]

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(c.ii) State the half-equation for the formation of caesium by electrolysis. [1]

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(c.iii) Determine the charge, in C, required to produce 1.00 g of caesium.

Use sections 2 and 6 of the data booklet. [2]

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(d) Caesium metal and Cu–Ni nanoparticles are combined as the heterogeneous catalyst in the synthesis of long-chain alcohols.

(d.i) Compare and contrast homogeneous and heterogeneous catalysts.

One similarity:

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One difference:

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[2]

(d.ii) State why many heterogeneous catalysts involve nanoparticles. [1]

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(d.iii) Nanoparticles are often produced by chemical vapour deposition (CVD).

Suggest why this is carried out in an inert atmosphere. [1]

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(d.iv) Suggest **one** ethical concern about the use of nanoparticles. [1]

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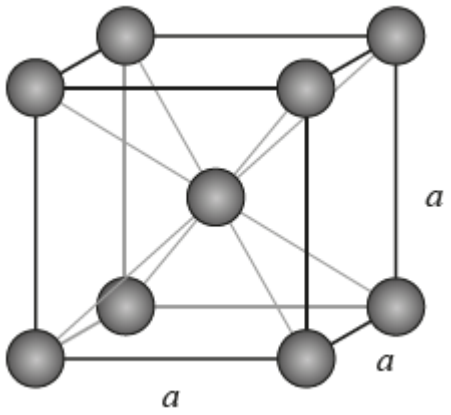
(e) Caesium metal has a body centred cubic, BCC, structure.



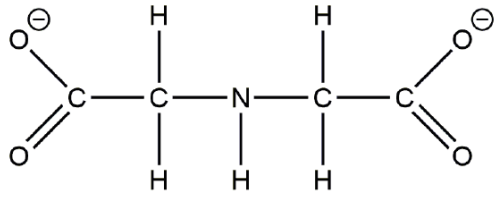
(e.i) Deduce the number of metal atoms in the unit cell. [1]

(e.ii) The side of the unit cell, a, is 614 pm (6.14×10^{-8} cm). Calculate the volume of the unit cell. [1]

(e.iii) Determine the density of caesium metal, in g cm^{-3}. Use your answers to (e)(i), (e)(ii) and sections 2 and 6 of the data booklet. [2]

(f) Caesium-137, a dangerous radioisotope, can be removed from radioactive waste by forming a complex ion with a polydentate ligand.
Outline why this complex ion is more stable than one in which caesium forms bonds to many monodentate ligands. [1]

(g) The iminodiacetate ion, shown below, is an example of a polydentate ligand. Circle the atoms that bond to a metal ion.



[1]

5. [Maximum mark: 4]

Sodium hydride forms a crystalline lattice.

(a) Estimate the percent ionic character of this compound using sections 8 and 29 of the data booklet. [1]

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(b) Deduce, giving a reason, whether sodium hydride could be classified as a Brønsted–Lowry acid or a Brønsted–Lowry base. [1]

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(c) Materials with high ion-exchange capacity, such as zeolites, can be used to soften water by replacing calcium ions with sodium ions. Outline **two** reasons for using zeolites for ion exchange. [2]

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6. [Maximum mark: 4]

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7. [Maximum mark: 1]

Alloying a metal with a metal of smaller atomic radius can disrupt the lattice and make it more difficult for atoms to slide over each other.

Which property will increase as a result?

A. Electrical conductivity

B. Ductility

C. Malleability

D. Strength [1]