

2.4 Nanoparticles

Name: _____ Class: _____ Date: _____

Total: 18 marks**KEY WORDS** nanoparticle • surface area to volume ratio

Objective

Use nanoparticle size ranges and the surface-area-to-volume rule. Chemistry only. Original questions for spec statement 4.2.4.

1 Key knowledge and worked examples

Size bands:

- **nanoparticles** – 1–100 nm; smallest structures are of the order of a few hundred atoms;
- **fine particles (PM2.5)** – 100–2500 nm (1×10^{-7} – 2.5×10^{-6} m);
- **coarse particles (PM10, “dust”)** – 2.5×10^{-6} – 1×10^{-5} m.

SA : V rule: for a cube, $SA = 6l^2$, $V = l^3$, so $SA:V = 6/l$. When the side **decreases** by $10\times$, the SA:V ratio **increases** by $10\times$.

Consequences: a high surface-area-to-volume ratio makes nanoparticles more effective **catalysts** than the bulk material; smaller quantities may be needed – uses in **medicine** (drug delivery), **cosmetics** (sun creams), **electronics**. Concerns: their effects on health and the environment are **not fully known**.

Worked example (3 marks). A cube has side 100 nm; another 10 nm. Compare their surface-area-to-volume ratios.

First cube: $A/V = 6/100 = 0.06 \text{ nm}^{-1}$. Second cube: $6/10 = 0.6 \text{ nm}^{-1}$. The side fell $10\times$, so the ratio rose $10\times$ – smaller particles have proportionally more surface.

2 Practice

2.1 Give the diameter range of nanoparticles in nanometres. [1]

2.2 Which is larger: a fine particle or a coarse particle? [1]

2.3 A cube's side drops from 50 nm to 5 nm. What happens to the SA:V ratio? [1]

2.4 Convert 20 nm to metres. A typical atom has diameter 0.1 nm. How many such atomic diameters span the particle? Does that make the particle one atom? [3]

3 Exam-style questions

3.1 Calculate the surface area : volume ratio of a cubic nanoparticle of side 10 nm. [2]

3.2 Explain why a nanoparticle catalyst can work in smaller quantities than the same material in bulk. [4]

3.3 Sun creams use nanoparticles. Give one benefit and one concern of this use. [2]

3.4 Equal masses of the same material remove a pollutant in 12 minutes as nanoparticles and 40 minutes in bulk. Evaluate using the nano form in a skin product. State what this result supports, one limitation, and two further kinds of evidence needed. [4]

Solutions

2.1 1–100 nm.

2.2 A coarse particle.

2.3 Increases $10\times$.

2.4

$20\text{ nm} = 20 \times 10^{-9}\text{ m} = 2.0 \times 10^{-8}\text{ m}$. Ratio = $20/0.1 = 200$ atomic diameters. The particle contains many atoms; a diameter comparison is not an atom count and does not make it one atom.

3.1 $SA = 6 \times 10^2 = 600\text{ nm}^2$; $V = 10^3 = 1000\text{ nm}^3$, so $A/V = 600/1000 = 0.6\text{ nm}^{-1}$.

3.2 Nanoparticles have a much higher surface-area-to-volume ratio than bulk material; a greater proportion of their atoms is on the surface; so more of the catalyst's surface contacts the reactants per unit mass; the reaction rate per gram is higher, so less catalyst is needed.

3.3 Benefit – a suitable formulation can block UV while being transparent rather than visibly white. Concern – the possible health or environmental effects require evidence for the particular material and exposure; safety cannot be inferred from small size alone.

3.4

Under the reported test conditions the nano form removes pollutant faster per equal mass. The result does not establish skin-product safety or effectiveness for its intended use. Seek evidence for that intended benefit and formulation, and for health/environmental effects under realistic exposure. Accept equivalent relevant evidence requests; small size alone proves neither safety nor harm.