Unit 11 · Bioinorganic Chemistry

ANSWER KEY · FOR TEACHERS

Full marks 34

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Match the columns

1. bioinorganic molecule → **c.** a biological molecule with a metal ion as an essential part
2. metalloenzyme → **f.** an enzyme with a metal bound tightly at its active site
3. cofactor → **g.** a metal ion or other small helper an enzyme needs to work
4. active transport → **e.** movement against a concentration gradient, using energy
5. symport → **d.** two substances carried across a membrane in the same direction
6. biomagnification → **b.** a poison building up more at each step of a food chain

K · 3

Each carries 0.5 mark.

2 Label the diagram

1. GLUT2
2. facilitated diffusion
3. SGLT (symport: secondary active transport)
4. Na^+/K^+ pump

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **c.** cobalt — K · 1

Vitamin B12, cobalamin, holds cobalt in a corrin ring; this is cobalt's only known job in the body.

ii. **c.** carbonic anhydrase — U · 1

Carbonic anhydrase, a zinc enzyme: $CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$. Catalase is an iron enzyme, urease a nickel one and tyrosinase a copper one.

iii. **b.** it carries three positive charges out for every two it brings in — U · 1

Each cycle sends 3 Na^+ out and brings 2 K^+ in, so one more positive charge leaves than enters, helping make the resting potential of about −70 mV.

iv. **c.** arsenicosis — K · 1

Arsenicosis: dark spots and thick keratosis on the palms and soles, and later cancers. Minamata disease is methylmercury poisoning, itai-itai cadmium poisoning, hemochromatosis a genetic iron overload.

v. **b.** lead — A · 1

Old paint is a source of lead; lead harms children's brains and nerves, and causes anemia by blocking two enzymes that build heme.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ Passive transport moves a substance down its concentration gradient (high to low); active transport moves it against it (low to high).
- ✓ Passive transport needs no energy; active transport uses energy, usually from ATP.

b. MARKING SCHEME — U · 2

- ✓ Both have a large flat ring whose four nitrogen atoms each give a lone pair to the metal (coordinate bonds).
- ✓ Heme holds Fe^{2+} and carries oxygen; chlorophyll holds Mg^{2+} and catches light in photosynthesis.

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c. MARKING SCHEME K · 2

- ✓ Any one, e.g. with phosphate (hydroxyapatite) it makes bones and teeth hard.
- ✓ Any second, e.g. a rush of Ca^{2+} starts muscle contraction; it is needed for blood clotting; it starts the release of nerve chemicals and hormones.

d. MARKING SCHEME U · 3

- ✓ Binding –SH groups of enzymes, with an example.
- ✓ Pushing out an essential metal, with an example.
- ✓ Making free radicals (Fenton reaction, iron), with an example.

5 Long answer

ANSWER U · 4

SGLT, in the membrane facing the gut or kidney tubule, carries Na^+ and glucose together, in the same direction, into the cell (a symport). Na^+ flows in down its gradient, because the inside of the cell is low in Na^+, and this downhill flow drags glucose in uphill, against its gradient.

SGLT splits no ATP itself: its energy comes from the Na^+ gradient, so it is secondary active transport. The gradient is made by the Na^+/K^+ pump on the blood side of the cell, which uses ATP to put the Na^+ back out (primary active transport). The glucose then leaves the cell into the blood down its own gradient through GLUT2, by facilitated diffusion.

MARKING SCHEME

- ✓ Na^+ and glucose carried in together, in the same direction (symport).
- ✓ Na^+ flows down its gradient and drags glucose up its gradient.
- ✓ Secondary: the energy comes from the Na^+ gradient, not from ATP split by SGLT.
- ✓ The Na^+/K^+ pump keeps Na^+ low inside (and GLUT2 lets glucose out into the blood).

6 Numerical problems

a. ANSWER A · 4

i. Carbohydrate $70 \times 17 = 1190$ kJ; protein $25 \times 17 = 425$ kJ; fat $20 \times 37 = 740$ kJ. Total = **2355 kJ**.
ii. Carbohydrate $1190 \div 2355 =$ **50.5%**; protein $425 \div 2355 =$ **18.0%**; fat $740 \div 2355 =$ **31.4%**.
iii. All three are within their ranges.

MARKING SCHEME

- ✓ The energy from each nutrient.
- ✓ Total 2355 kJ.
- ✓ Shares 50.5%, 18.0%, 31.4%.
- ✓ All within the ranges.

b. ANSWER A · 4

i. Glucose filtered = 180 L × 5.5 mmol/L = 990 mmol = 0.99 mol; mass = $0.99 \times 180 =$ **178 g**.
ii. Glucose taken back by SGLT2 = $0.90 \times 0.99 = 0.891$ mol, so Na^+ = **0.891 mol** (one Na^+ for each glucose).
iii. **Yes**: 14 mmol/L is above the 10–12 mmol/L the transporters can keep up with, so some filtered glucose is not taken back and appears in the urine (glycosuria).

MARKING SCHEME

- ✓ 0.99 mol filtered.
- ✓ 178 g of glucose.
- ✓ 0.891 mol of Na^+.
- ✓ Yes: above the 10–12 mmol/L limit.

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7 Think

ANSWER HA · 3

A metal is essential only if the body needs it for a job (iron in hemoglobin, zinc in enzymes) and falls ill without it. Lead and cadmium are taken in from food, water, air and smoke and stay in the body, but have no job there: they are pure poisons. Iron is needed, but free iron, not held safely in proteins, makes hydroxyl radicals by the Fenton reaction, and the body has no regulated way to excrete extra iron, so an overdose or overload damages the gut, liver, heart and DNA.

MARKING SCHEME

- ✓ Essential means needed for a job, with illness when it is missing; being present is not enough.
- ✓ Lead and cadmium are taken in from the surroundings and have no job: poisons.
- ✓ Free iron makes free radicals (Fenton reaction), and extra iron can't be excreted.

8 Activity: Bubbles from a potato

(not marked)

WHAT STUDENTS SHOULD FIND

The raw potato fizzes steadily: its enzyme catalase breaks hydrogen peroxide into water and oxygen, the bubbles. The boiled potato gives few or no bubbles, because boiling destroys the enzyme's shape, so it stops working. Catalase is an iron enzyme.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	9	13	9	3	**34**

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