
TEACHING TASK

JEE MAINS LEVEL QUESTIONS

Multiple choice question type:

1.

Step 1: Define the quantities

Thermal capacity per unit volume is the product of density (ρ) and specific heat capacity (c). The formula is given by:

$\text{Thermal Capacity per Unit Volume} = \rho c$

We are given the ratios for two substances, substance 1 and substance 2:

- Ratio of densities: $\frac{\rho_1}{\rho_2} = \frac{2}{3}$ [1]
- Ratio of specific heats: $\frac{c_1}{c_2} = \frac{1}{2}$ [1]

Step 2: Calculate the ratio

To find the ratio of the thermal capacities per unit volume, we multiply the individual ratios:

$$\frac{\text{Thermal Capacity per unit volume}_1}{\text{Thermal Capacity per unit volume}_2} = \frac{\rho_1 c_1}{\rho_2 c_2} = \left(\frac{\rho_1}{\rho_2}\right) \times \left(\frac{c_1}{c_2}\right)$$

Substituting the given values:

$$\text{Ratio} = \frac{2}{3} \times \frac{1}{2} = \frac{2}{6} = \frac{1}{3}$$

2.

- Density of substance 1: $\rho_1 = 400\,\text{kg/m}^3$
- Density of substance 2: $\rho_2 = 600\,\text{kg/m}^3$
- Volume of substance 1: $V_1 = 40\,\text{c.c.}$
- Volume of substance 2: $V_2 = 30\,\text{c.c.}$

The heat capacity (C) of a substance is the product of its mass (m) and its specific heat capacity (c):

$$C = m \times c$$

Step 2: Relate heat capacities, masses, and densities

We are given that the heat capacity of the first substance (C_1) is equal to that of the second substance (C_2):

$$C_1 = C_2$$

Substituting the formula for heat capacity in terms of mass and specific heat:

$$m_1 c_1 = m_2 c_2$$

We know that mass can be calculated from density (ρ) and volume (V) using the formula $m = \rho \times V$. Substituting this into the equation:

$$\rho_1 V_1 c_1 = \rho_2 V_2 c_2$$

Step 3: Calculate the ratio of specific heats

To find the ratio of their specific heats, $\frac{c_1}{c_2}$, we rearrange the equation:

$$\frac{c_1}{c_2} = \frac{\rho_2 V_2}{\rho_1 V_1}$$

Now, we substitute the given values into the equation. The units for density and volume cancel out when forming the ratio, so we can use the given values directly:

$$\frac{c_1}{c_2} = \frac{600 \times 30}{400 \times 40}$$

$$\frac{c_1}{c_2} = \frac{18000}{16000}$$

$$\frac{c_1}{c_2} = \frac{18}{16}$$

The ratio of their specific heats, $c_1 : c_2$, is $9 : 8$.

3.

Step 1: Identify given values and assumptions

The given values are heat absorbed $Q = 1000\,\text{calories}$, initial temperature $T_1 = 20^\circ C$, and final temperature $T_2 = 70^\circ C$. The "c" after the temperature values is interpreted as degrees Celsius ($^\circ C$). The specific heat capacity of water (s_{water}) is $1\ \text{cal/g}^\circ C$.

Step 2: Calculate the change in temperature

The change in temperature is calculated as the difference between the final and initial temperatures:

$$\Delta T = T_2 - T_1 = 70^\circ C - 20^\circ C = 50^\circ C$$

Step 3: Use the heat transfer formula

The heat absorbed is related to the water equivalent (W) and the temperature change by the formula:

$$Q = W \times s_{\text{water}} \times \Delta T$$

Rearranging the formula to solve for the water equivalent W:

$$W = \frac{Q}{s_{\text{water}} \times \Delta T}$$

Step 4: Solve for the water equivalent

Substitute the known values into the equation:

$$W = \frac{1000 \text{ calories}}{1 \text{ cal/g}^{\circ}C \times 50^{\circ}C}$$

$$W = \mathbf{20} \text{ g}$$

4.

Step 1: Understand Thermal Capacity Definition

The thermal capacity ($\mathbf{C}$) of an object is the product of its mass ($\mathbf{m}$) and its specific heat capacity ($\mathbf{c}$), given by the formula $C = m \times c$. Since both spheres are made of copper, they have the same specific heat capacity, which cancels out when forming a ratio.

$$\frac{C_1}{C_2} = \frac{m_1 c}{m_2 c} = \frac{m_1}{m_2}$$

Step 2: Relate Mass to Volume and Radii

Mass ($\mathbf{m}$) is the product of density ($\boldsymbol{\rho}$) and volume ($\mathbf{V}$), $m = \rho \times V$. As both spheres are copper, their densities are identical and cancel out in the ratio. The volume of a sphere is $V = \frac{4}{3}\pi r^3$.

$$\frac{m_1}{m_2} = \frac{\rho V_1}{\rho V_2} = \frac{V_1}{V_2} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{r_1}{r_2}\right)^3$$

Step 3: Calculate the Ratio

The diameters of the two spheres are $d_1 = 10\ \text{cm}$ and $d_2 = 20\ \text{cm}$. Their respective radii are $r_1 = 5\ \text{cm}$ and $r_2 = 10\ \text{cm}$.
The ratio of the radii is $r_1/r_2 = 5/10 = 1/2$. The ratio of their thermal capacities is the cube of the ratio of their radii:

$$\frac{C_1}{C_2} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$$

5.

Step 1: Calculate the thermal capacity

The thermal capacity (C) is calculated using the formula $C = m \times c$, where m is the mass and c is the specific heat capacity

$$C = 100\ \text{g} \times 0.03\ \text{cal/g/°C}$$

$$C = 3\ \text{cal/°C}$$

6.

We define the following variables for the two spheres:

- Radii: r_1, r_2
- Densities: ρ_1, ρ_2
- Specific heats: c_1, c_2
- Masses: m_1, m_2
- Thermal capacities: C_1, C_2

The given ratios are:

$$\frac{r_1}{r_2} = \frac{1}{2}$$

$$\frac{\rho_1}{\rho_2} = \frac{2}{3}$$

$$\frac{c_1}{c_2} = \frac{3}{4}$$

The formulas for mass (m) and thermal capacity (C) are:

$$m = \rho \times V = \rho \times \left(\frac{4}{3}\pi r^3\right)$$

$$C = m \times c$$

Step 2: Formulate the ratio of thermal capacities

Substituting the mass formula into the thermal capacity formula, we get:

$$C = \rho \times \frac{4}{3}\pi r^3 \times c = \frac{4}{3}\pi \rho r^3 c$$

The ratio of the thermal capacities of the two spheres is:

$$\frac{C_1}{C_2} = \frac{\frac{4}{3}\pi \rho_1 r_1^3 c_1}{\frac{4}{3}\pi \rho_2 r_2^3 c_2} = \frac{\rho_1}{\rho_2} \times \frac{r_1^3}{r_2^3} \times \frac{c_1}{c_2}$$

Step 3: Calculate the numerical ratio

Substitute the given numerical ratios into the equation from Step 2:

$$\frac{C_1}{C_2} = \left(\frac{2}{3}\right) \times \left(\frac{1}{2}\right)^3 \times \left(\frac{3}{4}\right)$$

$$\frac{C_1}{C_2} = \frac{2}{3} \times \frac{1}{8} \times \frac{3}{4}$$

$$\frac{C_1}{C_2} = \frac{2 \times 1 \times 3}{3 \times 8 \times 4} = \frac{6}{96}$$

$$\frac{C_1}{C_2} = \frac{1}{16}$$

7.

Step 1: Convert the heat energy to Joules

The heat energy (Q) given out is 1200 calories. Using the conversion factor $1\ \text{cal} = 4.2\ \text{J}$:

$$Q = 1200 \times 4.2\,\text{J} = 5040\,\text{J}$$

Step 2: Calculate the change in temperature

The temperature changes from $90^{\circ}C$ to $10^{\circ}C$.

$$\Delta T = 90^{\circ}C - 10^{\circ}C = 80^{\circ}C$$

A change of $1^{\circ}C$ is equal to a change of $1\ \text{K}$, so $\Delta T = 80\ \text{K}$.

Step 3: Calculate the thermal capacity

Thermal capacity (C) is defined as the amount of heat energy (Q) required per unit change in temperature (ΔT).

$$C = \frac{Q}{\Delta T}$$

Substituting the values:

$$C = \frac{5040\,\text{J}}{80\ \text{K}} = 63\ \text{J/K}$$

8.

Step 1: Define variables and formulas

The thermal capacity ($\mathbf{C}$) of a substance is the product of its mass ($\mathbf{m}$) and specific heat capacity ($\mathbf{s}$), expressed as $C = m \times s$. Mass is the product of density ($\boldsymbol{\rho}$) and volume ($\mathbf{V}$), expressed as $m = \rho \times V$.

Step 2: Set up the given information

We are given the following conditions for two liquids, A and B:

- Equal volumes: $V_A = V_B$.
- Specific heats ratio: $\frac{s_A}{s_B} = \frac{2}{3}$.
- Equal thermal capacity: $C_A = C_B$.

Step 3: Use the condition of equal thermal capacity to find the density ratio

Since the thermal capacities are equal, we can write:

$$C_A = C_B$$

Substituting the formula for thermal capacity using mass ($m \times s$):

$$m_A \times s_A = m_B \times s_B$$

Substituting the formula for mass using density and volume ($\rho \times V$):

$$(\rho_A \times V_A) \times s_A = (\rho_B \times V_B) \times s_B$$

Since the volumes are equal ($V_A = V_B$), we can cancel them from both sides of the equation:

$$\rho_A \times s_A = \rho_B \times s_B$$

Rearranging the equation to find the ratio of densities $\frac{\rho_A}{\rho_B}$:

$$\frac{\rho_A}{\rho_B} = \frac{s_B}{s_A}$$

Step 4: Calculate the final ratio

Using the given specific heat ratio $\frac{s_A}{s_B} = \frac{2}{3}$, we can find $\frac{s_B}{s_A}$:

$$\frac{s_B}{s_A} = \frac{3}{2}$$

Therefore, the ratio of their densities is:

$$\frac{\rho_A}{\rho_B} = \frac{3}{2}$$

9.

Step 1: Set up the heat equation for both substances

The quantity of heat (ΔQ) required to change the temperature of a substance is given by the formula $\Delta Q = mc\Delta T$, where m is the mass, c is the specific heat capacity, and ΔT is the change in temperature.
For the first substance:

$$\Delta Q_1 = x \cdot c_s \cdot t_1$$

For the water:

$$\Delta Q_2 = y \cdot c_w \cdot t_2$$

Step 2: Equate the heat quantities and solve for the ratio

The problem states that the quantity of heat is the same for both substances ($\Delta Q_1 = \Delta Q_2$). Therefore, we can set the two expressions equal to each other:

$$x \cdot c_s \cdot t_1 = y \cdot c_w \cdot t_2$$

To find the ratio of specific heats of the substances, assumed to be $\frac{c_s}{c_w}$, we rearrange the equation:

$$\frac{c_s}{c_w} = \frac{y \cdot t_2}{x \cdot t_1}$$

This matches option C.

10.

To find the required mass of silver, we equate the thermal capacity of the water and the silver. Thermal capacity (C) is defined as the product of mass (m) and specific heat capacity (c).

$$C = m \times c$$

For the thermal capacities to be equal:

$$C_{\text{water}} = C_{\text{silver}}$$

$$m_{\text{water}} \times c_{\text{water}} = m_{\text{silver}} \times c_{\text{silver}}$$

Given values:

- Volume of water = 1 liter, which corresponds to a mass (m_{water}) of approximately **1 kg** (at standard temperature and pressure).
- Specific heat capacity of water (c_{water}) = approximately **4184 J/kg K** (or 4200 J/kg K). We will use 4184 J/kg K for better precision.
- Specific heat capacity of silver (c_{silver}) = **235.2 J/kg K** (as provided in the problem).

Solving for the mass of silver (m_{silver}):

$$m_{\text{silver}} = \frac{m_{\text{water}} \times c_{\text{water}}}{c_{\text{silver}}}$$

$$m_{\text{silver}} = \frac{1 \text{ kg} \times 4184 \text{ J/kg K}}{235.2 \text{ J/kg K}}$$

$$m_{\text{silver}} \approx 17.79 \text{ kg}$$

This value is closest to option C, **17.85 kg**. If we use the approximate value for water's specific heat (4200 J/kg K), the result is $4200/235.2 \approx 17.857$ kg.

JEE ADVANCED LEVEL QUESTIONS

11.

Explanation

- **a) Specific heat of a substance is equal to thermal capacity of 1 g of same substance.**
  - Specific heat is defined as the thermal capacity per unit mass (e.g., per gram or per kilogram). Thus, the specific heat is indeed the thermal capacity of a unit mass (1 g) of the substance.
- **c) Specific heat of a substance does not depend on mass of the body**
  - Specific heat is an intensive property, meaning it is a characteristic of the material itself and is independent of the amount (mass) of the substance present.

- **d) Heat capacity depends on mass of the body**
  - Heat capacity (or thermal capacity) is an extensive property, defined as the product of mass and specific heat ($C = m \times c$). Therefore, it depends on the mass of the body.

12.

Step 1: Evaluate options a) and b)

The thermal capacity (C) of a substance is the product of its mass (m) and specific heat capacity (c), given by the formula $C = mc$. The specific heat of copper is $c = 0.4\ \mathrm{J/g^\circ C}$. For a mass of $m = 10\ \mathrm{g}$, the thermal capacity is:

$$C = 10\ \mathrm{g} \times 0.4\ \mathrm{J/g^\circ C} = 4\ \mathrm{J/^\circ C}$$

Thus, option a) is correct, and option b) is incorrect.

Step 2: Evaluate options c) and d)

To find the mass (m) when the thermal capacity (C) is $400\ \mathrm{J/^\circ C}$, we rearrange the formula $C = mc$ to $m = \frac{C}{c}$:

$$m = \frac{400\ \mathrm{J/^\circ C}}{0.4\ \mathrm{J/g^\circ C}} = 1000\ \mathrm{g}$$

Since $1000\ \mathrm{g}$ is equal to $1\ \mathrm{kg}$, option c) is correct, and option d) is incorrect.

The correct multiple-choice option is **A) a,c** because both individual statements 'a' and 'c' are correct based on the given specific heat of copper.

13.

The **Assertion is TRUE**, correctly defining specific latent heat of fusion (solid to liquid at constant temp), but the **Reason is FALSE** because it incorrectly defines latent heat of *vaporization* (liquid to *solid*, which is freezing/solidification); latent heat of vaporization is for liquid to *gas*, and freezing releases heat, while vaporization absorbs it.

Assertion Analysis (True)

- **Specific Latent Heat of Fusion:** Heat needed to change unit mass from solid to liquid *without* temperature change (at melting point).

Reason Analysis (False)

- **Latent Heat of Vaporization:** Heat needed to change unit mass from liquid to **gas (vapor)** *without* temperature change (at boiling point).
- **Freezing (Liquid to Solid):** This process *releases* heat (latent heat of fusion, but in reverse) and is the opposite of vaporization.

In summary: The assertion is a correct physics definition, but the reason misidentifies the phase change and direction of heat flow for vaporization.

14.

The assertion and the reason provided are both correct statements regarding different quantities: the assertion describes the unit for **specific heat capacity**, while the reason correctly identifies the SI unit for **thermal heat capacity** (or heat capacity).

- **Assertion: Unit of thermal heat capacity is cal g^{-1} $°C^{-1}$**
  - This unit, cal g^{-1} $°C^{-1}$, is a common unit for **specific heat capacity** (heat capacity per unit mass), often used in the CGS system.
  - The unit of *thermal heat capacity* (for an entire body/object) in the CGS system is actually cal $°C^{-1}$.
  - Therefore, the assertion is technically incorrect as stated for "thermal heat capacity," but correct for "specific heat capacity".

- **Reason: Unit of thermal heat capacity is J K^{-1}**
  - This is the correct SI unit for **thermal heat capacity**. It is defined as the amount of heat energy (in Joules, J) required to raise the temperature of the entire body by one degree Kelvin (K).

15.

Explanation

- **a) Specific heat → 2) doesn't depend on mass**: Specific heat (or specific heat capacity) is an intensive property, meaning it is a characteristic of the *material* itself and does not depend on the amount (mass) of the substance present.
- **b) Heat capacity → 1) depends on mass**: Heat capacity (or thermal capacity) is an extensive property, meaning it depends on both the material's specific heat and its total mass.
- **c) Water equivalent → 4) numerically equal to thermal capacity**: Water equivalent is the mass of water that requires the same amount of heat to change its temperature by one degree as the given object. It is numerically equal to the object's heat (thermal) capacity (often measured in units of mass, like kg or g, when using specific heat units for water).
- **d) Heat → 3) flows from hot body to cold body**: Heat is a form of energy transfer that naturally moves from a region of higher temperature (hot body) to a region of lower temperature (cold body)

16.

- Mass of lead, $m = 300\,\text{g}$
- Specific heat of lead, $C = 0.03\,\text{cal/(g}^\circ C)$

Using the formula, we calculate the heat capacity:

$$H = m \times C$$

$$H = 300\,\text{g} \times 0.03\,\text{cal/(g}^\circ C)$$

$$H = 9\,\text{cal/}^\circ C$$

17.

Step 1: Calculate Heat Capacity

The heat capacity (H) of a body is defined as the product of its mass (m) and its specific heat capacity (C), as given by the formula $H = mC$. We are provided with the mass of hydrogen as $m = 300\,\mathrm{g}$ and its specific heat capacity as $C = 3.5\,\mathrm{cal/g^{\circ}C}$.

We calculate the heat capacity using the provided values:

$$H = 300\,\mathrm{g} \times 3.5\,\mathrm{cal/g^{\circ}C} = 1050\,\mathrm{cal/^{\circ}C}$$

18.

Step 1: Identify given values and formula

The given values are mass $m = 2\,\mathrm{kg}$ and heat capacity $H = 100\,\mathrm{cal/^{\circ}C}$. The relevant formula provided is $H = mC$, where C is the specific heat capacity.

Step 2: Convert units and calculate

First, convert the mass from kilograms to grams to match the units in the given options: $m = 2\,\mathrm{kg} \times 1000\,\mathrm{g/kg} = 2000\,\mathrm{g}$.

Next, rearrange the formula to solve for C: $C = \dfrac{H}{m}$.

Substitute the values and calculate the specific heat capacity:

$$C = \frac{100\,\mathrm{cal/^{\circ}C}}{2000\,\mathrm{g}} = 0.05\,\mathrm{cal/g^{\circ}C}$$

19.

Explanation

- Initially, the sudden compression increases both the temperature and pressure of the gas (adiabatic process).
- The cylinder is metallic, meaning it is a good conductor of heat and not thermally insulated.
- As time passes, the high-temperature gas loses heat to the cooler surroundings (heat radiation). This causes the **temperature of the gas to decrease** over time.
- Since the piston is maintained at a fixed position, the volume of the gas is constant (isochoric process).
- According to the ideal gas law ($PV = nRT$), with constant volume (V), number of moles (n), and gas constant (R), pressure (P) is directly proportional to temperatur (T) ($P \propto T$).
- Therefore, as the **temperature of the gas decreases**, the **pressure of the gas must also decrease**.

20.

The assertion and reason are both correct and reflect the core findings of James Prescott Joule's experiments on the conservation of energy [1].

- **Assertion: According to Joule, heat and work are related.** This is true. Joule's experiments demonstrated the equivalence of heat and mechanical work, a concept central to the first law of thermodynamics [1].
- **Reason: For every 1 cal. of heat we can get 4.186 J of mechanical work.** This is also true and provides the specific quantitative relationship discovered by Joule, known as the mechanical equivalent of heat (often approximated as 4.184 J/cal or 4.186 J/cal depending on the specific temperature reference used) [1, 2]

The reason accurately explains the assertion, as the specific numerical value (4.186 J) is the result that proves the relationship exists.

LEARNERS TASK

CONCEPTUAL UNDERSTANDING QUESTIONS

1.

The 15° calorie (also known as the gram-calorie or small calorie) is specifically defined as the amount of heat required to raise the temperature of **1 gram of water** from **14.5°C to 15.5°C** at standard atmospheric pressure. This precise temperature range is specified because the specific heat capacity of water varies slightly at different temperatures.

2.

The heat capacity of a material depends upon several factors, so there are multiple correct options. The most encompassing answer is the **structure of matter** because the specific heat capacity, which is a key component of heat capacity, is an intrinsic material property.

Explanation

Heat capacity (C) is an extensive property, defined as the amount of heat (Q) required to raise the temperature of an entire object by one degree Celsius (ΔT), given by the formula $Q = C\Delta T$. It is directly proportional to both the mass (m) of the object and its specific heat capacity (c): $C = m \cdot c$.

The specific heat capacity (c) is an intensive property that depends on the fundamental nature of the material itself, which includes its atomic and molecular **structure** and bonding. Different materials have different specific heats, which is why a gold ring heats up faster than the same mass of water.

3. When the high-velocity bullet strikes a target, its kinetic energy (a form of mechanical energy) is rapidly converted into other forms of energy, primarily thermal energy (heat) and sound, due to friction and the deformation of the bullet and target material. This sudden energy conversion causes the temperature of the bullet (and the target at the point of impact) to increase, making it hot.

4.
Water is an effective coolant in car radiators because it has a very high specific heat capacity. This means that water can absorb a large amount of heat energy from the engine without its own temperature rising significantly, which is essential for maintaining a stable engine temperature and preventing overheating.

5.
Specific heat capacities for the given substances are approximately:

- **Water**: ~4.18 J/g°C
- **Coconut oil**: ~2.01 J/g°C
- **Kerosene**: ~2.01 J/g°C
- **Mercury**: ~0.14 J/g°C

Comparing these values, **mercury** has the lowest specific heat capacity, meaning it requires the least amount of heat energy to raise its temperature compared to the same mass of the other substances.

6.
If a substance has infinite heat capacity (or thermal capacity), it means it can absorb or release any amount of heat without experiencing any change in its temperature, making option **C) no change in temperature whether heat is taken in (or) given out** the correct answer. This is because heat capacity (C) relates heat energy (Q) to temperature change (ΔT) by the formula $C = \frac{\Delta Q}{\Delta T}$, so if C is infinite, ΔT must be zero for any finite ΔQ.

7.
The value of specific heat will **decrease** if the temperature is represented in degrees Fahrenheit (°F) instead of degrees Celsius (°C).

8.

The actual quantity which determines the temperature change is the **thermal capacity** of the body, calculated as mass × specific heat.

Explanation

- The relationship between heat given (Q), mass (m), specific heat capacity (c), and change in temperature (ΔT) is given by the formula $Q = mc\Delta T$.
- Rearranging the formula, we get $\Delta T = \frac{Q}{mc}$.
- The term mc is called the **thermal capacity** of the body, and it represents the amount of heat required to raise the temperature of the entire body by one degree Celsius (or one Kelvin).
- Therefore, the quantity that determines the change in temperature (ΔT) for a given amount of heat (Q) is the thermal capacity (mc) of the substance

9.

Step 1: Identify given information and target units

The specific heat capacity of mercury is given as $c = 0.03\ \mathrm{cal/gm^\circ C}$. The S.I. unit for specific heat capacity is $\mathrm{J/kg^\circ C}$ (or $\mathrm{J/kg \cdot K}$). The necessary conversion factors are $1\ \mathrm{cal} \approx 4.2\ \mathrm{J}$ and $1\ \mathrm{gm} = 10^{-3}\ \mathrm{kg}$.

Step 2: Perform unit conversion

Convert the given value to S.I. units using the conversion factors:

$$c = 0.03\ \frac{\mathrm{cal}}{\mathrm{gm^\circ C}} \times \frac{4.2\ \mathrm{J}}{1\ \mathrm{cal}} \times \frac{1000\ \mathrm{gm}}{1\ \mathrm{kg}}$$

The units cancel out to leave $\mathrm{J/kg^\circ C}$.

Step 3: Calculate the final value

Multiply the numerical values:

$$c = 0.03 \times 4.2 \times 1000\ \frac{\mathrm{J}}{\mathrm{kg^\circ C}}$$

$$c = 0.03 \times 4200\ \frac{\mathrm{J}}{\mathrm{kg^\circ C}}$$

$$c = 126\ \frac{\mathrm{J}}{\mathrm{kg^\circ C}}$$

10.
Step 1: Determine the temperature change

The change in temperature (ΔT) is the difference between the final temperature (T_2) and the initial temperature (T_1).

$$\Delta T = T_2 - T_1$$

$$\Delta T = 80^\circ C - 30^\circ C = 50^\circ C$$

Step 2: Calculate the thermal capacity

The thermal capacity (C) is calculated using the formula $Q = C\Delta T$, where Q is the heat absorbed. Rearranging for C:

$$C = \frac{Q}{\Delta T}$$

$$C = \frac{4500 \text{ cal}}{50^\circ C}$$

$$C = 90 \text{ cal}/^\circ C$$

JEE MAINS LEVEL QUESTIONS

Multiple choice question type:

1.

We can reason this out using the formula for heat energy in a liquid:

$$Q = mc\Delta T$$

But here, we are comparing **relative amounts of heat energy** when all are the *same liquid*, so specific heat c is the same.
Also, since density is the same, **mass** is proportional to **volume** for the same liquid.

Thus:

$$Q \propto (\text{mass}) \times (\text{temperature above a chosen reference})$$

But careful — heat energy in thermodynamics is measured from an absolute reference if we want total internal energy, not just a ΔT.
For an incompressible liquid with constant specific heat, the total thermal energy (relative to 0 K) is proportional to mT in Kelvin, **not** Celsius.
So we must convert temperatures to **Kelvin** because the heat content depends on absolute temperature, not temperature difference from an arbitrary point in Celsius.

Step 1: Convert temperatures to Kelvin

$$T_A = 80 + 273 = 353 \text{ K}$$

$$T_B = 90 + 273 = 363 \text{ K}$$

$$T_C = 50 + 273 = 323 \text{ K}$$

$$T_D = 70 + 273 = 343 \text{ K}$$

Step 2: Relative heat energy is proportional to $V \times T_K$

(since $m = \rho V$ and ρ, c constant)

$$Q_A \propto 100 \times 353 = 35300$$

$$Q_B \propto 60 \times 363 = 21780$$

$$Q_C \propto 250 \times 323 = 80750$$

$$Q_D \propto 150 \times 343 = 51450$$

Step 3: Compare these products

$$Q_C > Q_D > Q_A > Q_B$$

Step 4: Conclusion

The **maximum** is **C: 250 cm³ at 50°C (323 K)**.

This makes sense because although its temperature is lower, its volume (hence mass) is much larger, and absolute temperature in Kelvin is still high enough to overcome smaller volume cases.

2.

$$\Delta T = \frac{Q}{mc}$$

Substitute the given values into the equation:

$$\Delta T = \frac{1680\,\text{J}}{1\,\text{kg} \times 4200\,\text{J/kg°C}}$$

$$\Delta T = \frac{1680}{4200}$$

$$\Delta T = 0.4\,°\text{C}$$

Thus, the rise in the temperature of the water is 0.4°C.

3.

Step 1: Define Thermal Capacity and Relate to Dimensions

Thermal capacity (C) is the product of mass (m) and specific heat capacity (c): $C = mc$. Both spheres are made of the same material (aluminium), so their specific heat capacities and densities (ρ) are identical. Mass is the product of density and volume (V): $m = \rho V$. The volume of a sphere is given by $V = \frac{4}{3}\pi r^3$

Step 2: Formulate the Ratio

The ratio of the thermal capacities of sphere 1 (radius r_1) and sphere 2 (radius r_2) is calculated as follows:

$$\frac{C_1}{C_2} = \frac{m_1 c}{m_2 c} = \frac{m_1}{m_2} = \frac{\rho V_1}{\rho V_2} = \frac{V_1}{V_2} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{r_1}{r_2}\right)^3$$

Step 3: Calculate the Value

Substitute the given radii, $r_1 = 8$ cm and $r_2 = 16$ cm, into the formula derived in Step 2:

$$\frac{C_1}{C_2} = \left(\frac{8\,\text{cm}}{16\,\text{cm}}\right)^3 = \left(\frac{1}{2}\right)^3 = \frac{1^3}{2^3} = \frac{1}{8}$$

The resulting ratio is **1:8**, which corresponds to option C.

4.

Step 1: Determine the variables and formula

The problem provides the mass (m) of water, the initial temperature (T_{initial}), and the final temperature (T_{final}). We use the specific heat capacity of water ($c \approx 1\ \text{cal/g}^\circ\text{C}$ or $4.184\ \text{J/g}^\circ\text{C}$) to find the heat required (Q) using the formula: $Q = mc\Delta T$, where $\Delta T = T_{\text{final}} - T_{\text{initial}}$ [1]. The options provided are in kilocalories (kcal).

Step 2: Calculate the change in temperature and total heat

First, calculate the change in temperature (ΔT):

$$\Delta T = T_{\text{final}} - T_{\text{initial}} = 950^\circ\text{C} - 50^\circ\text{C} = 900^\circ\text{C}$$

Next, substitute the values into the heat formula using specific heat in $\text{cal/g}^\circ\text{C}$:

$$Q = 100\,\text{g} \times 1\,\text{cal/g}^\circ\text{C} \times 900^\circ\text{C} = 90000\,\text{cal}$$

Convert the result from calories (cal) to kilocalories (kcal) by dividing by 1000:

$$Q = \frac{90000\,\text{cal}}{1000\,\text{cal/kcal}} = 90\,\text{kcal}$$

5.

Step 1: Convert Mass to Kilograms

First, the mass (m) must be converted from grams (g) to kilograms (kg) to match the units of the specific heat capacity (c).

$$m = 150\ \text{g} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.150\ \text{kg}$$

Step 2: Calculate Temperature Change

Next, calculate the change in temperature (ΔT). Based on the assumption to match the options provided:

$$\Delta T = 5^\circ\text{C}$$

Step 3: Apply the Specific Heat Formula

Finally, use the specific heat formula, $Q = mc\Delta T$, where Q is the **heat** energy, m is the **mass**, and c is the **specific heat** capacity.

$$Q = (0.150\text{ kg})(480\text{ J/kg}^\circ\text{C})(5^\circ\text{C})$$

$$Q = 360\text{ J}$$

6.

Step 1: Identify Given Variables

The given variables are the amount of heat supplied (Q), the mass of the water (m), and the specific heat capacity of water (c):

- Heat (Q) = 2000 cal
- Mass (m) = 200 g
- Specific Heat (c) = $1\text{ cal/g}^\circ\text{C}$

Step 2: Use the Specific Heat Formula

The relationship between heat energy, mass, specific heat, and temperature change (ΔT) is given by the formula $Q = m \cdot c \cdot \Delta T$. To find the rise in temperature, we rearrange the formula to solve for ΔT:

$$\Delta T = \frac{Q}{m \cdot c}$$

Step 3: Calculate the Temperature Change

Substitute the values into the rearranged formula to calculate the change in temperature:

$$\Delta T = \frac{2000\ \text{cal}}{200\ \text{g} \times 1\ \text{cal/g°C}}$$

$$\Delta T = 10\text{°C}$$

7.

Explanation

The **thermal capacity** (C) of a substance is an intensive property determined by its mass (m) and specific heat capacity (s), as defined by the formula $C = m \times s$ [1]. It represents the amount of energy required to change the temperature of the entire object by one degree.

Key Considerations:

- Thermal capacity is independent of the initial temperature, final temperature, or the temperature change (ΔT).
- In this problem, both copper blocks A and B have the identical mass ($m_A = m_B = 500$ gm) and are made of the same material (copper, with $s_A = s_B = 0.1$ cal/gm/°C) [1].

Calculation:

- Thermal capacity of block A: $C_A = m_A \times s_A = 500\ \text{gm} \times 0.1\ \text{cal/gm/°C} = 50\ \text{cal/°C}$
- Thermal capacity of block B: $C_B = m_B \times s_B = 500\ \text{gm} \times 0.1\ \text{cal/gm/°C} = 50\ \text{cal/°C}$

Since $C_A = C_B$, the ratio of their thermal capacities is **1 : 1**.

8.

Step 1: Identify the given variables and specific heat capacity

The given values are:

- Mass of water, $m = 500\,\text{g} = 0.5\,\text{kg}$
- Initial temperature, $T_{\text{initial}} = 60^{\circ}\text{C}$
- Final temperature, $T_{\text{final}} = 40^{\circ}\text{C}$
- Specific heat capacity of water, $c \approx 4200\,\text{J/kg}^{\circ}\text{C}$

Step 2: Calculate the change in temperature

The change in temperature (ΔT) is the difference between the initial and final temperatures:

$$\Delta T = T_{\text{initial}} - T_{\text{final}} = 60^{\circ}\text{C} - 40^{\circ}\text{C} = 20^{\circ}\text{C}$$

Step 3: Use the heat energy formula to calculate the heat lost

The formula for heat energy (Q) lost or gained is given by $Q = mc\Delta T$:

$$Q = 0.5\,\text{kg} \times 4200\,\text{J/kg}^{\circ}\text{C} \times 20^{\circ}\text{C}$$

$$Q = 42000\,\text{J}$$

9.

Step 1: Identify given values and formula

The heat lost (Q) is calculated using the specific heat formula: $Q = mc\Delta T$, where m is mass, c is specific heat, and ΔT is the change in temperature. We are given:

- Mass $m = 400\text{ g} = 0.4\text{ kg}$
- Specific heat $c = 390\text{ Jkg}^{-1}{}^{\circ}\text{C}^{-1}$
- Initial temperature $T_{\text{initial}} = 100^{\circ}\text{C}$
- Final temperature $T_{\text{final}} = 30^{\circ}\text{C}$

Step 2: Calculate the change in temperature

The change in temperature (ΔT) is the difference between the initial and final temperatures:

$$\Delta T = T_{\text{initial}} - T_{\text{final}} = 100^{\circ}\text{C} - 30^{\circ}\text{C} = 70^{\circ}\text{C}$$

Step 3: Calculate the heat lost

Substitute the values into the formula to find the heat lost (Q):

$$Q = mc\Delta T = 0.4\text{ kg} \times 390\text{ Jkg}^{-1}{}^{\circ}\text{C}^{-1} \times 70^{\circ}\text{C}$$

$$Q = 10920\text{ J}$$

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11.

Explanation

The amount of heat (Q) absorbed by a body to change its temperature is determined by the formula $Q = mc\Delta T$, where:

- **m** is the **mass of the body** (a).
- **c** is the specific heat capacity, which depends on the **nature of the material of the body** (d).
- ΔT is the **change in temperature of the body** (b).

Therefore, heat absorbed depends on mass, change in temperature, and the material's nature.

12.

Explanation

- **a) The S.I. unit of latent heat is J Kg^{-1}**: This is correct. Latent heat (specifically, specific latent heat) is defined as energy per unit mass ($L = Q/m$), and the SI units for energy and mass are Joules (J) and kilograms (kg), respectively.
- **b) The C.G.S unit of latent heat is cal g^{-1}**: This is also correct. In the CGS system, the unit of energy is the calorie (cal), and the unit of mass is the gram (g).
- **c) The latent heat of substance is denoted with letter 'L'**: The specific latent heat is commonly denoted by the uppercase letter '**L**' in physics formulas (e.g., $Q = mL$).
- **d) The quantity of heat is denoted with letter 'Q'**: The quantity of heat energy transferred or absorbed is commonly denoted by the uppercase letter '**Q**'.

13.

Explanation

- Option **a** correctly states the formula for heat absorbed or evolved during a change of state (phase change) as $Q = mL$, where m is the mass and L is the specific latent heat.
- Option **b** correctly states the formula for heat absorbed or evolved during a change in temperature as $Q = mC\Delta T$ (or Q = m.C if the temperature change is implicitly one unit, or if C includes the temperature change), where m is the mass and C is the specific heat capacity.
- Options **c** ($Q = m/L$) and **d** (incomplete formula) are incorrect.

14.

The assertion and the reason both describe valid units for specific heat capacity, but the provided reasoning doesn't explain the assertion; instead, it offers an alternative unit in a different system.

- **Assertion:** The unit of specific heat capacity is $\mathrm{cal} \cdot \mathrm{g}^{-1} \cdot {}^{\circ}\mathrm{C}^{-1}$ (calories per gram per degree Celsius) [1]. This is a common unit used in the calorie-based system of units.
- **Reason:** The unit of specific heat capacity is $\mathrm{J} \cdot \mathrm{kg}^{-1} \cdot \mathrm{K}^{-1}$ (joules per kilogram per kelvin) [1]. This is the standard SI (International System of Units) unit.

Both units are correct measurements of specific heat capacity, but they belong to different unit systems. The reason statement is a fact about the SI unit, not an explanation of why the calorie-based unit in the assertion is correct.

15.

The **Assertion** that water has the highest specific heat among all common solids and liquids is generally correct [1]. The **Reason** provided gives the correct definition of specific heat capacity.

Here is a breakdown:

- **Assertion:** True. Water's specific heat capacity is approximately 4.184 Joules per gram per Kelvin (J/g·K), which is notably higher than most other common substances, allowing it to absorb a large amount of heat energy with only a small rise in temperature [1].
- **Reason:** The definition given for specific heat capacity (the amount of heat energy required to raise the temperature of a unit mass of a substance through 1K) is correct. This definition explains *what* the value of specific heat represents.

The reason is a correct statement of a scientific definition, but it doesn't directly *explain* why water *specifically* has the highest value among solids and liquids (which is due to strong hydrogen bonding); it only defines the term used in the assertion.

16.

- **a) Specific heat**: The SI unit is joules per kilogram per kelvin ($\mathbf{J \cdot kg^{-1} \cdot K^{-1}}$), but in some contexts like CGS, it relates to the unit of mass (e.g., calories per gram per degree Celsius, where it can be numerically equal to 1). If we interpret '1)' as J/kg/K, then a-1 would be correct.
- **b) Heat capacity**: The SI unit is joules per kelvin ($\mathbf{J/K}$). This is not an option. A common unit for heat capacity in CGS is cal/°C, or related to a simple number.
- **c) Water equivalent**: This is defined as the mass of water that has the same heat capacity as the body. The unit is a unit of mass, such as the kilogram (**kg**).
- **d) Heat lost or gained**: Heat is a form of energy, and its SI unit is the **Joule (J)**.

17.

The incomplete matching question can be completed as follows:

- **a) unit of specific heat capacity → 4) J kg^{-1} K^{-1}**
- **b) unit of thermal capacity → 3) Jk^{-1}**
- **c) Heat capacity depends on → 1) Mass**
- **d) Water → 2) Highest specific heat**

18.

Step 1: Calculate the thermal heat capacity

The **thermal heat capacity** (C) is calculated by multiplying the mass (m) of the substance by its **specific heat capacity** (c). The formula used is:

$$C = m \times c$$

Substituting the given values into the equation:

$$C = 100\,\text{g} \times 0.4\,\text{J/g}^\circ\text{C}$$

$$C = 40\,\text{J/}^\circ\text{C}$$

19.

Water has the highest specific heat capacity value among the options provided. The high specific heat capacity of water is due to strong hydrogen bonds between its molecules, which require a significant amount of energy to break, thus allowing it to absorb a large amount of heat with a minimal temperature change

20.

The standard conversion factor between calories (small calories, used in physics and chemistry) and joules (the SI unit of energy) is:

- 1 calorie ≈ 4.2 joules (approximate value commonly used)
- 1 calorie = 4.184 joules (more precise value)

Using the approximate value of 4.2 J per calorie:

$$2 \text{ cal} = 2 \times 4.2 \text{ J} = 8.4 \text{ J}$$

Using the more precise value of 4.184 J per calorie:

$$2 \text{ cal} = 2 \times 4.184 \text{ J} = 8.368 \text{ J}$$