Science Olympiad Regional Competition ***Division C***

Thermodynamics

Multiple Choice: Choose the one answer that best answers the question or completes the statement

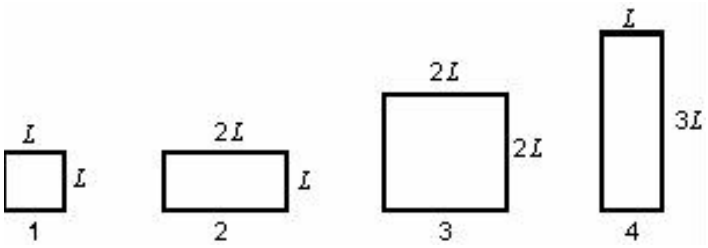
1. A balloon is filled with cold air and placed in a warm room. The balloon is NOT in thermal equilibrium with the air in the room until:
   a. It sinks to the floor
   b. It stops expanding
   c. It starts to contract
   d. It rises to the ceiling
   e. None of these

2. The zeroth law of thermodynamics allows us to define
   a. Pressure
   b. Internal energy
   c. Temperature
   d. Thermal equilibrium
   e. Work

3. When a certain constant volume gas thermometer is in thermal contact with water at its triple point (273.16 K) the pressure is $6.30\ x\ 10^4\ Pa$. For this thermometer a kelvin corresponds to a change in pressure of about:
   a. $2.31\ x\ 10^2\ Pa$
   b. $4.34\ x\ 10^2\ Pa$
   c. $1.72\ x\ 10^3\ Pa$
   d. $2.31\ x\ 10^3\ Pa$
   e. $1.72\ x\ 10^7\ Pa$

4. It is more difficult to measure the coefficient of expansion of a liquid than that of a solid because:
   a. A liquid tends to evaporate
   b. A liquid expands too little when heated
   c. A liquid expands too much when heated
   d. The containing vessel also expands
   e. No relation exists between linear and volume expansion coefficients

5. The diagram shows four rectangular plates and their dimensions. All are made of the same material. The temperature of the plates is increased.



   a. The vertical dimension of plate 2 increases the most and the area of plate 4 increases the most.
   b. The vertical dimension of plate 4 increases the most and the area of plate 4 increases the most.
   c. The vertical dimension of plate 4 increases the most and the area of plate 3 increases the most.
   d. The vertical dimension of plate 3 increase the most and the area of plate 1 increases the most.
   e. The vertical dimension of plate 1 increases the most and that area of plate 1 increases the most.

Note: This is just one example of information that may be included on an exam. Information on future exams is not limited to the scope or topics covered here.

Science Olympiad Regional Competition ***Division C***

6. Heat is:
    a. Energy content of an object
    b. A property objects have by virtue of their temperatures
    c. A temperature difference
    d. Energy transferred by virtue of a temperature difference
    e. Energy transferred by macroscopic work

7. The same energy Q enters five different substances as heat.
    - The temperature of 3g of substance A is raised by 10K
    - The temperature of 4g of substance B is raised by 4K
    - The temperature of 6g of substance C is raised by 15K
    - The temperature of 8g of substance D is raised by 5K
    - The temperature of 10g of substance E is raised by 10K

    Which of these has the greatest specific heat?
    a. Substance A
    b. Substance B
    c. Substance C
    d. Substance D
    e. Substance E

8. A cube of aluminum is 20cm on edge. Aluminum has a density 2.7 times that of water ($1\,\frac{g}{cm^3}$) and a specific heat 0.217 times that of water ($1\,\frac{cal}{g \cdot C}$). The heat in calories needed to raise the temperature of the cube from 20 C to 30 C is about:
    a. 27 cal
    b. 37 cal
    c. 47 cal
    d. 27000 cal
    e. 47000 cal

9. An air bubbles doubles in volume as it rises from the bottom of a lake $\left(\rho_{water} = 1000\,\frac{kg}{m^3}\right)$. Ignoring any temperature changes, the depth of the lake is:
    a. 10m
    b. 21m
    c. 4.9m
    d. 0.99m
    e. 0.76m

10. An ideal gas undergoes an isothermal process starting with a pressure of $2\ x\ 10^5 Pa$ and a volume of $6\ cm^3$. Which of the following might be the pressure and volume of the final state?
    a. $4\ x\ 10^5\ Pa$ and $4\ cm^3$
    b. $8\ x\ 10^5\ Pa$ and $2\ cm^3$
    c. $6\ x\ 10^5\ Pa$ and $2\ cm^3$
    d. $1\ x\ 10^5\ Pa$ and $10\ cm^3$
    e. $3\ x\ 10^5\ Pa$ and $6\ cm^3$

Note: This is just one example of information that may be included on an exam. Information on future exams is not limited to the scope or topics covered here.

Science Olympiad Regional Competition ***Division C***

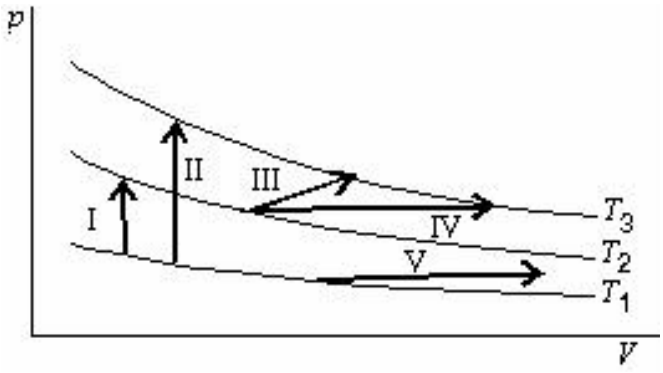
11. An adiabatic process for an ideal gas is represented on a ***p-V*** diagram by:
    a. A hyperbola
    b. A circle
    c. A horizontal line
    d. A vertical line
    e. None of these

12. A real gas is slowly changed from state #1 to state #2. During this process no work is done on or by the gas. This process must be:
    a. A closed cycle with a point #1 coinciding with point #2
    b. Isobaric
    c. Isothermal
    d. Adiabatic
    e. Isovolumetric

13. Evidence that molecules of a gas are in constant motion is:
    a. Two gases interdiffuse quickly
    b. Energy as heat is needed to vaporize a liquid
    c. Gases are easily compressed
    d. Winds exert pressure
    e. Warm air rises

14. The *Principle of Equipartition of Energy* states that internal energy of a gas is shared equally:
    a. Between translational and vibrational kinetic energy
    b. Among the relevant degrees of freedom
    c. Between temperature and pressure
    d. Among the molecules
    e. Between kinetic and potential energy

15. The diagram shows five thermodynamic processes carried out on an ideal gas. For which of these processes is the change in internal energy of the gas the greatest?



    a. I
    b. II
    c. III
    d. IV
    e. V

16. The temperature of n moles of an ideal monatomic gas is increased by ΔT at constant pressure. The energy Q absorbed as heat, change in ΔE_{int} in internal energy, and work W done by the environment are given by:
    a. $Q = \frac{5}{2}nRvT, \quad \Delta E_{int} = \frac{5}{2}nR\Delta T, \quad W = 0$
    b. $Q = \frac{3}{2}nRvT, \quad \Delta E_{int} = \frac{5}{2}nR\Delta T, \quad W = -\frac{3}{2}nR\Delta T$
    c. $Q = \frac{5}{2}nRvT, \quad \Delta E_{int} = 0, \quad W = -nR\Delta T$
    d. $Q = \frac{5}{2}nRvT, \quad \Delta E_{int} = \frac{3}{2}nR\Delta T, \quad W = -nR\Delta T$
    e. $Q = \frac{3}{2}nRvT, \quad \Delta E_{int} = 0, \quad W = -nR\Delta T$

17. The difference in entropy $\Delta S = S_B - S_A$ for two states A and B of a system can be computed by $\Delta S = \int \frac{dQ}{T}$ provided:
    a. A and B are on the same adiabat
    b. The energy absorbed as heat by the system is first computed
    c. A reversible path is used for the integral
    d. A and B have the same temperature
    e. The work done on the system is first computed

18. According to the Maxwellian speed distribution, as the temperature increases the number of molecules with speeds within a small interval near the most probable speed:
    a. Decreases at high temperatures and increases at low
    b. Increases at high temperatures and decreases at low
    c. Increases
    d. Stays the same
    e. Decreases

19. One mole of an ideal gas expands slowly and isothermally at temperature T until its volume is doubled. The change of entropy of this gas for this process is:
    a. $(\ln 2)/T$
    b. $2R$
    c. Zero
    d. $R \ln 2$
    e. $RT \ln 2$

20. Consider the following processes: The temperatures of two identical gases are increased from the same initial temperature to the same final temperature. Reversible processes are used in both cases. For gas A, the process is carried out at constant volume while for gas B it is carried out at constant pressure. The change in entropy:
    a. Is greater for B
    b. Is greater for A
    c. Is the same for A and B
    d. Is greater for A only if the initial temperature is high
    e. Is greater for A only if the initial temperature is low

21. A Carnot cycle:
    a. Is bounded by two isotherms and two adiabats on a ***p – V*** graph
    b. Consist of two isothermal and two constant volume processes
    c. Has an efficiency equal to the enclosed area on a ***p – V*** diagram
    d. Is any four sided process on a ***p – V*** graph
    e. Only exists for an ideal gas

22. Twenty-five identical molecules are in a box. Identifying the molecules in the left and right halves of the box designates microstates. The Boltzmann constant is $1.38\ x\ 10^{-23}\ \frac{J}{K}$. The entropy associated with the configuration for which 15 molecules are in the left half and 10 molecules are in the right half is:
    a. $4.44\ x10^{-23}\ \frac{J}{K}$
    b. $6.91\ x10^{-23}\ \frac{J}{K}$
    c. $2.07\ x10^{-22}\ \frac{J}{K}$
    d. $7.31\ x10^{-22}\ \frac{J}{K}$
    e. $2.22\ x10^{-23}\ \frac{J}{K}$

Short Answer: Answer each question in the space provided on your answer sheet. Your answer will be the only part of the question scored. There is room for your work on the answer sheet.

23. Lemonade has been sitting on the picnic table all day at 33°C. You pour 0.24 kg into a Styrofoam cup and add 2 ice cubes (each 0.025 kg at 0°C). Assuming no heat lost to the surroundings, what is the final temperature of the lemonade?

    The specific heat of Lemonade is $4.18\ \frac{kJ}{kg\ ℃}$, and the latent heat of fusion is $333.5\ \frac{kJ}{kg}$

24. 1 kg of water at temperature $T_1 = 30℃$ is mixed with 2 kg of water at $T_1 = 90℃$ in a calorimeter of negligible heat capacity at constant pressure of 1 atm. Find the change in entropy of the system.

25. Propane, C_3H_8, is a common fuel gas. Use the following to calculate the kJ of heat produced when 99.00 grams of propane react with 288.0 grams of oxygen gas.

$$C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4H_2O\ (g) \qquad \Delta H = -2043\ kJ$$

Science Olympiad Regional Competition ***Division C***

ANSWER SHEET

School Name: _____ Team Number: _____

1. ____	9. ____	17. ____
2. ____	10. ____	18. ____
3. ____	11. ____	19. ____
4. ____	12. ____	20. ____
5. ____	13. ____	21. ____
6. ____	14. ____	22. ____
7. ____	15. ____	
8. ____	16. ____	

Short Answer Questions

23.

ANSWER

24.

ANSWER

25.

ANSWER

Note: This is just one example of information that may be included on an exam. Information on future exams is not limited to the scope or topics covered here.

Science Olympiad Regional Competition ***Division C***

SOLUTIONS

1. __B__	9. __A__	17. __C__
2. __C__	10. __C__	18. __E__
3. __A__	11. __E__	19. __D__
4. __D__	12. __E__	20. __A__
5. __C__	13. __A__	21. __A__
6. __D__	14. __B__	22. __C__
7. __B__	15. __B__	
8. __E__	16. __D__	

Short Answer Questions

23.

$$Q_{out} = m_L c \Delta T$$
$$Q_{out} = 33kJ - \left(1.00 \frac{kJ}{°C}\right) t_f$$

$$Q_{in} = L_f m_{ice} + m_{ice} c \Delta T$$
$$Q_{in} = 16.7kJ + \left(\frac{0.209kJ}{°C}\right) t_f$$

$$Q_{out} = Q_{in}$$
$$33kJ - \left(1.00 \frac{kJ}{°C}\right) t_f = 16.7kJ + \left(\frac{0.209kJ}{°C}\right) t_f$$

ANSWER $t_f = 13.5\ °C$

Note: This is just one example of information that may be included on an exam. Information on future exams is not limited to the scope or topics covered here.

Science Olympiad Regional Competition ***Division C***

24.

$$\Delta S_1 = m_1\, c_p \ln \frac{T_f}{T_1}$$
$$\Delta S_2 = m_2\, c_p \ln \frac{T_f}{T_2}$$

$$Q_{out} = Q_{in}$$
$$m_1 c_p (T_f - 30.0℃) = m_2 c_p (90.0℃ - T_f)$$
$$T_f = 343\ K$$

$$\Delta S_1 = 0.518 \frac{kJ}{K}$$
$$\Delta S_1 = -0.474\ \frac{kJ}{K}$$

ANSWER $\Delta S = +0.044 \frac{kJ}{K}$

25.

If C_3H_8 is limiting reactant:

$$\frac{99.0\ g\ x\ 1\ mol\ C_3H_8}{44\ g\ x\ 2043 \frac{kJ}{mol\ C_3H_8}} = 4597\ kJ\ released$$

If O_2 is the limiting reactant:

$$\frac{288.0\ g\ x\ 1\ mol\ O_2}{32\ g\ x\ 2043 \frac{kJ}{5\ mol\ C_3H_8}} = 3677\ kJ\ released$$

ANSWER $\Delta H = -3677\ kJ$