ANSWER KEY

Thermodynamics Exam Division C

Summer Science Olympiad Exchange

Made By: A Brookwood High School Student

TIE BREAKERS (in order)

Question 34

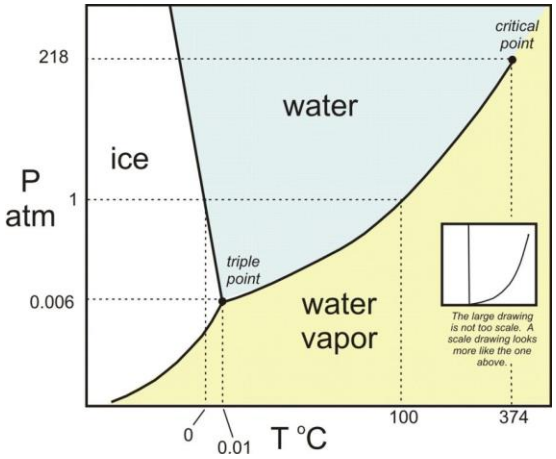
Question 14

Question 23

1. D
2. C
3. A
4. B
5. Fahrenheit
6. Celsius
7. Kelvin
8. Rankine
9. Delisle
10. 2 points: An acceptable answer would be “Work is done by the condenser to expel heat from within in. Because no real thermodynamics process is a hundred percent efficient due to friction, and the heat created must equal the heat expelled (work) plus other things energy goes into, such as friction, the heat created is more than the heat expelled, increasing the temperature of the room.
    a. (1 pt) Condenser expels heat (Reverse Carnot Cycle)
    b. (1 pt) Some mention of the 1st Law of Thermodynamics
11. 2 points:
    a. (1 pt) Explicitly stating marble has a higher thermal conductivity than carpet
    b. (1 pt) Heat transfer between feet and marble will occur very quickly, meaning more heat transfers from the feet on marble in the same period of time.
12. 9 points:
    a. 3 points:
        i. Correct work shown. 1/3 point for mc(deltaT)=mc(deltaT) or m(deltaT)=m(deltaT). 1/3 point for correct substitution, where one mass is 74, other mass is 68, deltaT on side with 74 is T(final)-10.556 Celsius (or equivalent in Kelvin) and other deltaT is 69.44 Celsius (or equivalent in Kelvin) – T(final). 1/3 point for heat transferred = mc(deltaT) AND proper m and deltaT pairing AND c = 4.184 (similar work is allowed, such as multiplying masses by their respective temperatures, adding those values, divide by total mass, convert to Celsius, and using mc(deltaT))
        ii. 3 sig figs AND units in kJ
        iii. Answer: 8.70 - 8.75
    b. 3 points:
        i. Correct work shown. 1/2 point for mc(deltaT)=mc(deltaT) or m(deltaT)=m(deltaT). 1/2 point for correct substitution, where one mass is 74, other mass is 68, deltaT on side with 74 is T(final)-10.556 Celsius (or equivalent in Kelvin) and other deltaT is 69.44 Celsius (or equivalent in Kelvin) – T(final). (similar work is allowed, such as multiplying masses by their respective temperatures, adding those values, divide by total mass)
        ii. 3 sig figs AND units in Celsius
        iii. Answer: 38.8 degrees Celsius

13. 2 points:
    a. Correct understanding of what these vocab words mean, explicitly stating that the heat of vaporization is what turns water/liquid into steam/gas and heat of fusion is what turns ice/solid into water/liquid
    b. Heat of fusion is only partially separating molecules, vaporization is complete separation

14. 10 points max:



    a. (1 pt) Ice region labeled
    b. (1 pt) Water region labeled
    c. (1 pt) Water vapor region labeled
    d. (1 pt) Supercritical region labeled
    e. (1 pt) Lines create roughly a “y” shape
    f. (1 pt) Slope of solid-liquid phase boundary is negative
    g. (0.5 pt) X-axis labeled with units Celsius
    h. (0.5 pt) Y-axis labeled with units atm
    i. (0.5 pt) Triple point labeled
    j. (0.5 pt) Triple point given (0.01 Celsius, 0.006 atm)
    k. (0.5 pt) Normal freezing/melting point labeled
    l. (0.5 pt) Normal freezing/melting point given (0 Celsius, 1 atm)
    m. (0.5 pt) Normal condensation/boiling point labeled
    n. (0.5 pt) Normal condensation/boiling point given (100 Celsius, 1 atm)
    o. (0.5 pt) Critical point labeled
    p. (0.5 pt) Critical point given (~374 Celsius, ~218 atm)

15. 2 points:
    a. Correctly identifying the slope on THEIR graph
    b. Their slope is negative AND they say that it is because ice has a lower density than water
16. D

17. 3 points:
    a. Correct work shown: ½ point for entropy = Boltzmann's constant * ln(# of microstates), ½ point for substitute in numbers given AND isolate # of microstates
    b. 3 sig figs AND units in quantity per mol (or quantity per molecule)
    c. Answer: e^(75.3/(Boltzmann's Constant)) [or some logical derivative of that]

18. 2 points:
    a. Delta S is positive
    b. Goes from solid to solid + gas (gases are more disorderly)

19. 2 points:
    a. Delta S is negative
    b. Goes from 4 mol to 2 mol of gas (less disorderly)
20. 2 points:
    a. Delta S is negative
    b. Goes from liquid to solid (solids are less disorderly)
21. 2 points:
    a. Delta S is positive
    b. Several reasons: more mols in products; reaction occurs spontaneously (and heat released)
22. 4 points
    a. Correct work shown
    b. Cooling constant (k) is calculated
    c. 3 sig figs AND answer in unit of time
    d. 6.61×10^3 s OR 1.10×10^2 min OR 1.84 hr. Use Newton's law of cooling, where ln ((T(initial) - T(reservoir)) / (T(final) - T(reservoir))) = k (constant) * t (time). The constant k ends up being .000148368 where time is in seconds, then replugging everything back in, time equals 6610 seconds. T(initial) is always 225 and T(reservoir) is always 25. When solving for the constant, T(final) is 200 and time is 900. When solving for the answer, T(final) is 100.

23. 6 points:
    a. 4 points max:
        i. Heat is a fluid that flows from hot to cold
        ii. Heat is attracted to matter, which holds heat
        iii. Heat is conserved
        iv. Sensible heat causes an increase in the temperature of the system
        v. Latent heat combines with particles in matter, which causes melting/boiling
        vi. Heat is weightless
    b. Count Rumford
    c. Cannon-drilling experiment: spun a bore in a cannon underwater to break the above rules, showed heat is not a part of matter as the size of the bore never changed.

24. 5 points:

a. PV=nRT

b. Johannes Diderik van der Waals

c. $\left(p + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$ (there are several forms of this)

d. a = correction for molecular attraction

e. b = correction for volume of molecules

26. James Prescott Joule
27. Rudolf Clausius
28. Josiah Willard Gibbs
29. Lord Kelvin
30. Otto von Guericke
31. William John Macquorn Rankine

32. 4 major components:

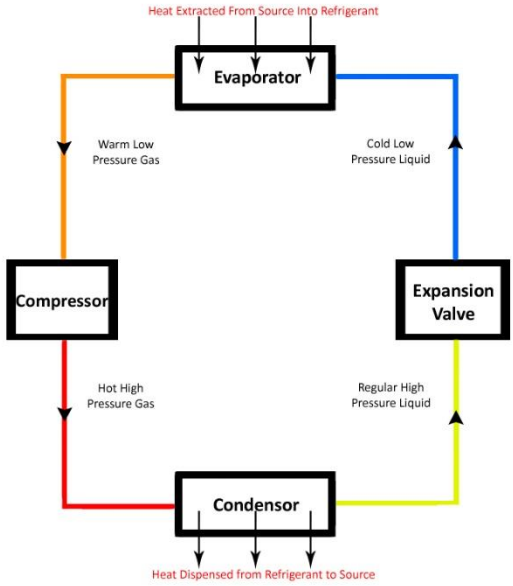
    (1 pt)Evaporator

    (1 pt)Expansion valve

    (1 pt)Condensor

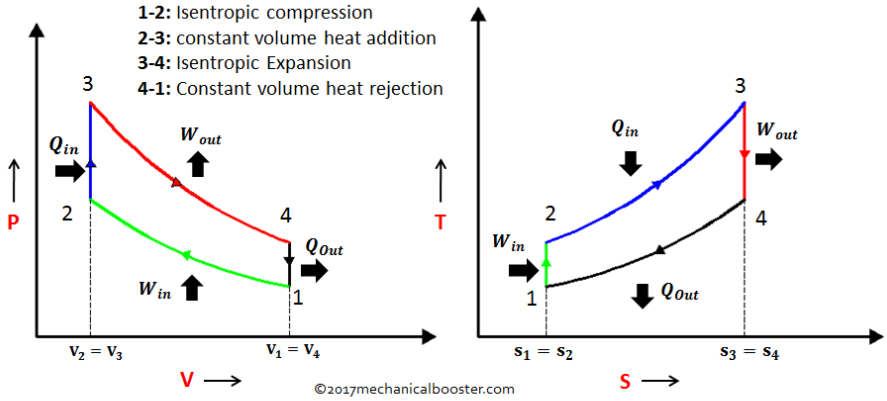
    (1 pt)Compressor

    (4 points) For every component, 1/2 point is awarded if a correct description is given for what goes into the thing. ½ point is awarder if a correct description is given for what leaves the thing



33. (1 point) There is a barrier separating two rooms with a “gate” that can be opened by the Demon
    (2 points) The rooms have similar gas, but one room’s gas is warmer than the other’s
    (2 points) The Demon opens and closes the gate in such a way that of ALL of the gas of both rooms, the top 50% fastest molecules end up in the warm room and the slower molecules end up in the other room, causing the heat to flow to the warmer room.
    (2 points) This Demon supposedly breaks Newton’s Second Law by allowing heat to flow to the warmer object, making the total change of entropy of the universe to decrease.
    (1 point) The computing power needed by Maxwell’s Demon to calculate the velocity of every particle and open the gate accordingly produces a bunch of heat, so the entropy there is positive (something like that idk look it up)

34.



P-V and T-S Diagram of Otto Cycle

(4 points) The processes of the PV diagram are labeled correctly. 1 point for every correctly labeled process. -1/2 point for every process named over the total of 4 processes (for example, if there are 7 processes named, 3/2 points should be deducted, but points can still be earned for correctly labeled processes)

(4 points) The processes of the TS diagram are labeled correctly. 1 point for every correctly labeled process. -1/2 point for every process named over the total of 4 processes

(2 points) Shape of PV diagram is correct. 1/2 point for every correct line. -1/2 for every line over 4 lines.

(2 points) Shape of TS diagram is correct. 1/2 point for every correct line. -1/2 for every line over 4 lines.

(4 points) Macrostates are labeled properly. 1 point for every correct corresponding state label (if the macrostate label on the PV diagram matched with the macrostate label on the TS diagram as per the picture provided above, 1 point is received)

35. Equal
36. Thermal Contraction
37. Conduction
38. Thermodynamics
39. Waste Heat
40. Internal Energy
41. deltaU = deltaQ + (or -) deltaW
42. Isobaric
43. Latent Heat
44. Exothermic
45. Intensive
46. Sadi Carnot
47. Isochoric