Name: _____

Period: _____

Heat

Basic Definitions

Internal Energy (U)— the energy inside an object due to the kinetic energy (motion) of the molecules. More U = higher T.

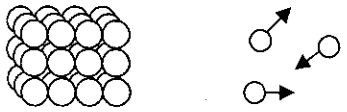
Temperature (T) —a measure of the average internal energy of the substance. As internal energy changes, temperature changes. Higher T = more U.

Because they are at the same temperature no energy is being transferred: Q = 0, but T ≠ 0

35°C	35°C

Cold atoms are moving slow.

Hot atoms are moving quickly.



The cold atoms may have more total energy because there are more atoms.

Heat (Q) — energy transferred between objects of different temperatures. +Q = heat is added, which causes a raise in temperature; –Q = heat is removed, which causes a lower temperature. T ≠ Q. **Temperature is not heat!** Temperature can change without heat—by stirring, for instance, because it increases the internal energy of the substance.

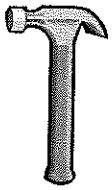
15°C	40°C
+Q ←	– Q

Q always moves from hot to cold. Q is + if gained; Q is –if energy is lost.

Temperature Scales

We are bad judges of temperatureSo we use thermometers to measure temperature for us.

The metal feels colder because it is a conductor. The wood handle feels warmer because it is an insulator. Actually, they are at the same temperature.



Celsius/Fahrenheit conversions

$$T_F = \frac{9}{5}T_C + 32.0$$

Celsius/Kelvin conversions

$$T_K = T_C + 273$$

Scale	Freezing point of H_2O	Boiling point of H_2O (at 1 atm)
Fahrenheit	32°F	212°F
Celsius	0°C	100°C
Kelvin	273K	373K

The lowest possible temperature is **absolute zero**: 0K, -273° C, -459°F. At absolute zero objects have no internal energy (U = 0 J) and atoms are still, meaning they have no kinetic energy. Matter acts very strangely at and near absolute zero.

0K

*This object has no internal energy: it is at **absolute zero.***

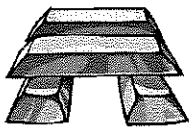
Specific Heat—C_p

The specific heat of a substance measures how hard it is to change temperature. It is like temperature inertia. Objects with high c_p resist a change of temperature.

Water has a very high c_p (4186 J/kg•°C) so it can hold a lot of heat and requires a lot of heat to change its temperature. Insulators tend to have high specific heats.

Water—high c_p

Gold (a very good conductor) has a low c_p (129 J/kg•°C), so it takes very little heat to change its temperature.



Gold—low c_p

Substance	Cp (J/kg·°C)
aluminum	899
copper	387
gold	129
iron	448
steam	2010
ice	2090
water	4186

Calculating Heat

The amount of heat absorbed or released by an object depends on the object's mass, specific heat, and the change of temperature of the object.

Heat Transferred During a Temperature Change

Mass (*in kg*), Specific Heat (*in J/kg•°C*), Heat (*in J*), Change of Temperature (in °C)

$$Q = mc_p\Delta T \quad (T_f - T_i)$$

A hot tub requires a lot of heat (Q) to raise the water's temperature. There is lot of water (big m) and water has a high c_p. If the water is cold to begin with, then the low initial temperature would mean even more Q, since there would be a large ΔT.

***Example:** How much heat is lost by a 10 kg iron skillet when it is removed from 180° C oven (350°F) and cools to room temperature 24°C (75°F)?*

$$Q = mc_p\Delta T$$
$$Q = mc_p(T_f - T_i)$$
$$Q = 10(448)(24 - 180)$$
$$Q = 4480(-156)$$
$$Q = -6.99\times10^5\ J$$

Name: _____

Period: _____

1. Heat	A. Amount of energy in an object due to the internal motion of the atoms and mass.	6. Kelvin	A. Measures how hard it is for a substance to change temperature.
2. Temperature	B. A measure of the internal energy of a substance. Not equal to heat.	7. Absolute zero	B. Temperature scale used in science that is based on absolute zero.
3. Internal Energy	C. Energy transferred between objects due to a change of temperature.	8. Specific Heat	C. The coldest possible temperature, where all atoms stop moving.
4. Q	D. Energy due to motion. More of this = more internal energy.	9. Fahrenheit	D. Temperature scale used in the United States. Water boils at 212°; freezes at 32°.
5. Kinetic energy	E. Symbol for heat.	10. Celsius	E. Temperature scale based on phases of water: boiling = 100° freezing = 0°.

11. Which of the following has more internal energy?
    A. Hot cup of water or a cold ocean?

    B. A hot frying pan or a cold frying pan?

    C. 25 kg of water or 25 kg of gold at thermal equilibrium?

    D. Fast moving or slow moving atoms?

12. Give two examples of changing temperature without adding heat.

13. Kelvin, Celsius, or Fahrenheit?
    A. ____ 0° = the freezing point of water.
    B. ____ 212° = boiling point of water.
    C. ____ Used all around the world.
    D. ____ Used only in science.
    E. ____ 373 = the boiling point of water.
    F. ____ Based on absolute zero.

14. Convert the following:
    A. 98.6° F to Celsius.

    B. 35° C to Fahrenheit.

    C. 40°C to Kelvin.

15. Is Q positive or negative?
    A. ____ If an object gains energy.
    B. ____ If an object loses energy.
    C. ____ If an object is surrounded by a colder object.
    D. ____ U increases.

16. Given 1000 J of heat, which will gain more temperature?
    A. Copper or gold?
    B. Ice or steam?
    C. Ice or water?
    D. Aluminum or iron?

17. How much energy is need to raise 50 kg of water from 45° C to 80°C?

18. 12 kg of gold at 90°C cools to 20°C. How much heat is given off?

19. A piece of aluminum requires 4,000 J of energy to change from 68°C to 110° C. How much aluminum is there?

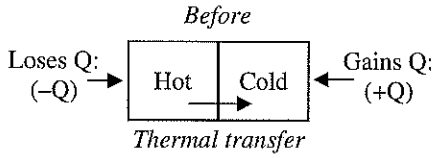
20. $5x10^4$ J of heat are added 35 kg of water initially at 12°C. What is the water's final temperature?

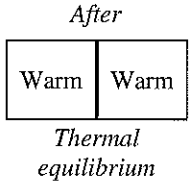
Name: _____

Period: _____

Thermal Equilibrium

Thermal Equilibrium When two objects of different temperature are put in contact, they will eventually come to thermal equilibrium. Q is transferred from object of higher temperature to the object of lower temperature.





For all thermal equilibrium problems:

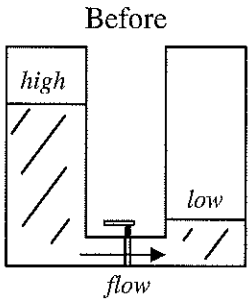
$$-Q_{hot} = Q_{cold}$$

$$-m_{hot} c_p \Delta T = m_{cold} c_p \Delta T$$

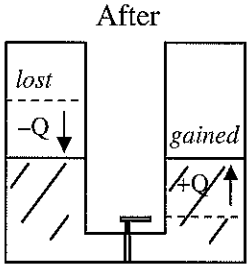
$$\text{where } T_{f\,hot} = T_{f\,cold}$$

Because at thermal equilibrium two objects have the same temperature.

A Water Analogy



Imagine a tank of water with a divider between two sides. If the divider is opened at the bottom, the water flows from high to low (just as heat flows from hot [high energy] to cold [low energy]).



Eventually the water will equalize (thermal equilibrium). The high side loses water (Q_{hot} is negative). The low side gains water (Q_{cold} is positive). The amounts are the same, but a negative ≠ a positive. This is why $-Q_{hot} = Q_{cold}$.

Ex. A 60 kg chunk of gold at 90°C is dropped into a bucket containing 20 kg of water at 5°C. When they come to thermal equilibrium, what will be the final temperature?

$$-Q_{hot} = Q_{cold}$$

$$-mc_{p(gold)}\Delta T_{hot} = mc_{p(water)}\Delta T_{cold}$$

$$-60(129)(T_f - 90) = 20(4186)(T_f - 5)$$

$$-7740(T_f - 90) = 83720(T_f - 5)$$

$$-7740T_f + 7740(90) = 83720T_f - 83720(5)$$

$$-7740T_f + 696600 = 83720T_f - 418600$$

$$\underline{+7740T_f} \qquad \underline{+7740T_f}$$

$$0 + 696600 = 91460T_f - 418600$$

$$\underline{+418600} \qquad \underline{+418600}$$

$$1115200 = 91460T_f$$

$$12.19°C = T_f$$

Name: _____

Period: _____

1. A 75 kg block of copper is at a temperature of 140°C. It is then dropped into a bucket containing 25 kg of water that is at 30°C.
   A. What will happen to the temperature of the copper?
   B. What will happen to the temperature of the water?
   C. Will heat go into or out of the copper?
   D. Will heat go into or out of the water?
   E. Is Q + or – for the copper?
   F. Is Q + or – for the water?
   G. Which is greater: the energy lost by the copper of the energy gained by the water?
   H. What do you know about the T_f of the copper, compared to T_f for the water?
   I. Solve for the final temperature.

2. 60 kg of aluminum at 15°C is placed into 20 kg of 90°C water. Find the final temperature of the two.

3. A 120 kg piece of iron originally at 250°C is dropped into a bucket with 85 kg of water. If they equalize at 62°C, how was the original temperature of the water?

4. A 5 kg piece of aluminum at 150°C is at thermal equilibrium with an 18 kg piece of gold. Both are dropped into a bucket of 5° water. If the final temperature of the water ends up being 8.5°C, how much water was in the bucket?

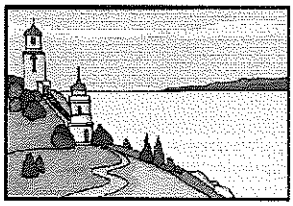
Name: _____

Period: _____

Heat and Water/ Heat Review

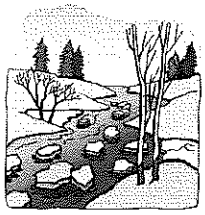
Heat and Water Most people know that water is necessary for life, but most do not know that the properties of water in regard to heat and temperature are also essential for life on our planet.

Water has a high specific heat capacity (4186 J/ kg·°C) It is hard to change water's temperature. This is why lakes and oceans do not change temperature quickly and why the temperature near large bodies of water do not fluctuate much.

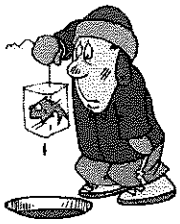


Most people live by oceans because the weather is more temperate—it doesn't change much. Very hot and cold temperatures exist farther inland.

Water expands as it freezes. As objects cool, they contract (get smaller) except water, which starts to expand again below 4°C. The expansion of freezing water causes erosion: rocks breaking. Also, ice (solid water) is less dense than liquid water, so it floats on water and is a better insulator than water.



As it freezes, ice floats to the top of water, insulating the water below it. This is why fish do not freeze in a pond or lake during the winter.



Funny, but not true.

1. What property of water helps it maintain its temperature?

2. A large swimming pool has a temperature of 60°F at 6 a.m. in morning. The air temperature climbs to 100°F during the day. That evening, will the swimming pool be at 100°F?

3. A glass bottle is filled to the top with water and then sealed tightly. What will happen when the bottle is placed in the freezer?

   Why?

4. If solid iron is dropped into liquid iron, will the solid iron float or sink?

   If solid water is dropped into liquid water, will the solid water float or sink

   Which of the above is the exception: iron or water?

5. Which is a better insulator: ice or water?

   Why?

6. Why do roads break during the winter?

7. Why don't fish freeze under a frozen pond?

8. 75°F is a comfortable temperature for humans. What temperature is that in degrees Celsius?

9. The hottest temperature ever recorded was on earth was 56.7°C. How hot is that in degrees Fahrenheit?

10. What is the boiling point of water in Celsius?

    What is the boiling point of water in Kelvin?

11. Which equation: $Q = mc_p\Delta T$ or $Q = mL$?
    - A. _____ Water changes from 20°C to 50°C.
    - B. _____ Water melts.
    - C. _____ A substance liquefies.
    - D. _____ Water going from melting point to –10°C.
    - E. _____ During a phase change.
    - F. _____ During a change of temperature?

12. +Q or –Q?
    - A. ____ Endothermic
    - B. ____ Ice melting to water.
    - C. ____ Heat in.
    - D. ____ For your hand when you touch something cold.
    - E. ____ If ΔT is positive.

Name: _____

Period: _____

13. Newton's Law of Cooling	A. Relates to the kinetic energy of the atoms inside a substance.
14. Specific Heat	B. Heat necessary to change a substance's state of matter.
15. Latent Heat	C. Objects cools faster if the temperature around them is colder.
16. Internal Energy	D. How much heat is necessary to change a substance's temperature.

17. Evaporation	A. Energy transferred between objects of different temperature.
18. Absolute Zero	B. All atoms stop moving here.
19. Heat	C. A cooling process because energy comes is drawn in.
20. Exothermal	D. Energy is given off in a process.

21. Which has more internal energy (U): a full cup of hot soup or the metal spoon in the soup?

22. 10 kg of steam is dropped 5°C. 10 kg of ice is also dropped 5°C. Which gives off more heat?

23. A new substance is discovered. It is determined that it has a Cp of 3560 J/ kg·°C.
    A. Is it likely to be an insulator or conductor?

    B. Will it change temperature easily?

24. Conduction (N), Convection (V), or Radiation (R)?
    A. _____Cooks pasta in a pot of hot water.
    B._____Heats the water throughout the pot.
    C._____Heats your hand next to, but not touching the pot.

25. A heat lamp is placed near two objects, which one changes temperature faster?
    A. _____A black one or a white one?
    B._____The dull one or shiny one?
    C._____One made up of gold or aluminum?

26. A black cup and a white cup are both at 80°C. Which one will cool down faster?

27. Does water have to be at 100°C to turn to a gas?

28. A. Use arrows to show the direction of heat transfer.
    B. Draw 2 arrows for fast heat transfer.
    C. Which object has no internal energy?

0° C conductor	35° C conductor	10° C insulator

29. How much heat is necessary to raise the temperature of 8 kg of water 12 degrees?

30. How many kilograms of copper <u>give off</u> 2500 J of energy to cool from 140°C to 70°C?

31. How much of the heat is necessary to change 3 kg of water to steam?

32. 40kg of water at 110°C is cooled to water at 85°C. How much heat was given off?

+ or –?	Cp or L (give #)	Ti	Tf	Calculate Q
Q_{steam}				
Q_{vapor}				
Q_{water}				
Q_{fusion}				
Q_{ice}				

Total Q =

33. 28kg of iron at 150°C is dropped into 30kg of water at 5°C. What is the final temperature of the two?

Name: _____

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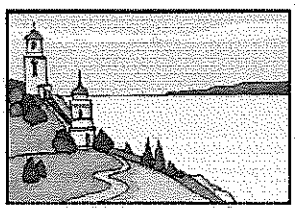

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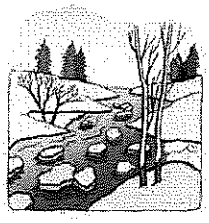


As it freezes, ice floats to the top of water, insulating the water below it. This is why fish do not freeze in a pond or lake during the winter.

Funny, but not true.

1. What property of water helps it maintain its temperature?
   high specific heat (Cp)
2. A large swimming pool has a temperature of 60°F at 6 a.m. in morning. The temperature climbs to 100°F during the day. That evening, will the swimming pool be at 100°F?
   No – takes a long time + a lot of heat to change water's T
3. A glass bottle is filled to the top with water and then sealed tightly. What will happen when the bottle is placed in the freezer?
   It will break the bottle.

   Why?
   water expands as it freezes
4. If solid iron is dropped into liquid iron, will the solid iron float or sink?

   If solid water is dropped into liquid water, will the solid water float or sink

   Which of the above is the exception: iron or water?
5. Which is a better insulator ice or water?

   Why? less dense (more space in between molecules)

   Roads break because water freezes in the cracks and expands, breaking the road.
6. Why don't fish freeze under a frozen pond?
   Ice floats and is an insulator.
7. 75°F is a comfortable temperature for humans. What temperature is that in degrees Celsius?

   $T_F = \frac{9}{5} T_C + 32$

   $75 = \frac{9}{5} T_C + 32$

   $-32 \quad -32$

   $43 = \frac{9}{5} T_C$

   $\frac{5}{9}(43) = T_C$

   $T_C = 24°C$
8. The hottest temperature ever recorded was on earth was 56.7°C. How hot is that in degrees Fahrenheit?

   $T_F = \frac{9}{5}(56.7) + 32$

   $= 134°F$
9. What is the boiling point of water in Celsius?
   100°C

   What is the boiling point of water in Kelvin?
   373 K
10. Which equation: $Q = mc_p\Delta T$ or $Q = mL$?
    A. ΔT Water changes from 20°C to 50°C.
    B. mL Water melts.
    C. mL A substance liquefies.
    D. ΔT Water going from melting point to –10°C.
    E. mL During a phase change.
    F. ΔT During a change of temperature?
11. +Q or –Q?
    A. + Endothermic
    B. + Ice melting to water.
    C. + Heat in.
    D. – For your hand when you touch something cold.
    E. + If ΔT is positive. (temp. went up)

Name: _____

Period: _____

13. Newton's Law of Cooling C	A. Relates to the kinetic energy of the atoms inside a substance.
14. Specific Heat D	B. Heat necessary to change a substance's state of matter. (to change phase)
15. Latent Heat B	C. Objects cools faster if the temperature around them is colder.
16. Internal Energy A	D. How much heat is necessary to change a substance's temperature.

17. Evaporation C	A. Energy transferred between objects of different temperature.
18. Absolute Zero B	B. All atoms stop moving here.
19. Heat A	C. A cooling process because energy comes is drawn in.
20. Exothermal D	D. Energy is given off in a process.

21. Which has more internal energy (U): a full cup of hot soup or the metal spoon in the soup?

Soup - made up of mostly water, which has a very high spec. heat

22. 10 kg of steam is dropped 5°C. 10 kg of ice is also dropped 5°C. Which gives off more heat?

$C_{p_{ice}} = 2090$ Ice gives off more Q.

$C_{p_{steam}} = 2010$

23. A new substance is discovered. It is determined that it has a Cp of 3560 J/ kg·°C.

A. Is it likely to be an insulator or conductor?

high Cp

B. Will it change temperature easily?

No

24. Conduction (N), Convection (V), or Radiation (R)?

A. N Cooks pasta in a pot of hot water.
B. V Heats the water throughout the pot.
C. R Heats your hand next to, but not touching the pot.

25. A heat lamp is placed near two objects, which one changes temperature faster?

A. B A black one or a white one?
B. dull The dull one or shiny one? shiny reflects Q
C. G One made up of gold or aluminum? lower Cp

26. A black cup and a white cup are both at 80°C. Which one will cool down faster?

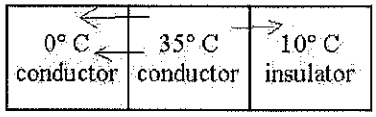
black - good absorbers are good emitters.

27. Does water have to be at 100°C to turn to a gas?

No - evaporation can happen at room temp. or lower

(evap. is a cooling process)

28. A. Use arrows to show the direction of heat transfer.
B. Draw 2 arrows for fast heat transfer.
C. Which object has no internal energy? none - all have int. energy (ΔU)



29. How much heat is necessary to raise the temperature of 8 kg of water 12 degrees?

$Q = mC_p\Delta T$

$Q = 8(4186)(12) = 401856\ J$ or $4.02 \times 10^5\ J$

30. How many kilograms of copper give off 2500 J of energy to cool from 140°C to 70°C?

$Q = mC_p\Delta T$

$-2500 = m(387)(70-140)$

$-2500 = m(387)(-70)$ $m =$

$-2500 = -27090m$ .09 kg

31. How much of the heat is necessary to change 3 kg of water to steam?

$Q = mL_v$

$Q = 3(2.26 \times 10^6) = 6.78 \times 10^6\ J$

32. 40kg of water at 110°C is cooled to water at 85°C. How much heat was given off?

+ or −?	Cp or L (give #)	Ti	Tf	Calculate Q
$-Q_{steam}$	2010	110°	100°	$40(2010)(100-110) = -8.04 \times 10^5$
$-Q_{vapor}$	2.26×10^6	100	100	$40(2.26 \times 10^6) = -9.04 \times 10^7$
$-Q_{water}$	4186	100	85	$40(4186)(85-100) = -2.5 \times 10^6$
Q_{fusion}				
Q_{ice}				

Total Q = -9.37×10^7 J

neg. because it is cooling

33. 28kg of iron at 150°C is dropped into 30kg of water at 5°C. What is the final temperature of the two?

$-Q_{hot} = Q_{cold}$

$-mC_p\Delta T_h = mC_p\Delta T_c$

$-28(448)(T_f - 150) = 30(4186)(T_f - 5)$

$-12544(T_f - 150) = 125580(T_f - 5)$

$-12544T_f + 1881600 = 125580T_f - 627900$

$+12544T_f \quad +627900 \quad +12544T_f \quad +627900$

$2509500 = 138124T_f$

div.

$T_f = 18.17°C$

Name: _____

Period: _____

1. Heat C	A. Amount of energy in an object due to the internal motion of the atoms and mass.	6. Kelvin B	A. Measures how hard it is for a substance to change temperature.
2. Temperature B	B. A measure of the internal energy of a substance. Not equal to heat.	7. Absolute zero C	B. Temperature scale used in science that is based on absolute zero.
3. Internal Energy A	C. Energy transferred between objects due to a change of temperature.	8. Specific Heat A	C. The coldest possible temperature, where all atoms stop moving.
4. Q E	D. Energy due to motion. More of this = more internal energy.	9. Fahrenheit D	D. Temperature scale used in the United States. Water boils at 212°; freezes at 32°.
5. Kinetic energy D	E. Symbol for heat.	10. Celsius E	E. Temperature scale based on phases of water: boiling = 100° freezing = 0°.

11. Which of the following has more internal energy?
    A. Hot cup of water or a cold ocean?

    more mass

    B. A hot frying pan or a cold frying pan?

    C. 25 kg of water or 25 kg of gold at thermal equilibrium?

    higher c_p

    D. Fast moving or slow moving atoms?

12. Give two examples of changing temperature without adding heat. stirring, shaking, (super hero death ray)

13. Kelvin, Celsius, or Fahrenheit?
    A. C 0° = the freezing point of water.
    B. F 212° = boiling point of water.
    C. C Used all around the world.
    D. K Used only in science.
    E. K 373 = the boiling point of water.
    F. K Based on absolute zero.

14. Convert the following:
    A. 98.6° F to Celsius.

    $98.6 = \frac{9}{5}T_C + 32$

    $66.6 = \frac{9}{5}T_C$

    $\frac{5}{9}(66.6) = 37°C$

    B. 35° C to Fahrenheit.

    $T_F = \frac{9}{5}(35) + 32$

    $T_F = 63 + 32 = 95°F$

    C. 40°C to Kelvin.

    $T_K = 40 + 273 = 313\ K$

15. Is Q positive or negative?
    A. + If an object gains energy.
    B. − If an object loses energy.
    C. − If an object is surrounded by a colder object.
    D. + U increases.

16. Given 1000 J of heat, which will gain more temperature?
    A. Copper or gold?
    B. Ice or steam? but not by much
    C. Ice or water?
    D. Aluminum or iron?

17. How much energy is need to raise 50 kg of water from 45° C to 80°C?

    $Q = m c_p \Delta T$

    $= 50(4186)(80-45)$

    $= 50(4186)(35) = 7.3 \times 10^6\ J$

18. 12 kg of gold at 90°C cools to 20°C. How much heat is given off?

    $Q = 12(129)(20-90) =$

    $-1.108 \times 10^5\ J$

19. A piece of aluminum requires 4,000 J of energy to change from 68°C to 110° C. How much aluminum is there?

    $Q = m c_p (T_F - T_i)$

    $4000 = m(899)(110-68)$

    $4000 = 37758m$

    $m = .10\ kg$

20. 5×10^4 J of heat are added 35 kg of water initially at 12°C. What is the water's final temperature?

    $Q = m c_p (T_F - T_i)$

    $5 \times 10^4 = 35(4186)(T_F - 12)$

    $5 \times 10^4 = 146510(T_F - 12)$

    $.3413 = T_F - 12$

    $T_F = 12.34°C$