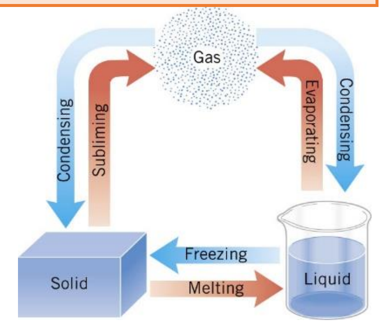
**_Physics 06-05 Phase Change and Latent Heat_** **_Name: ____________________________________**

## _Phase Change_

- ______________ is required to (or released by) changing the ______________ bonds in ______________ of matter
- Heat ______________ always ______________ the ___________________ of a material
- Phases of matter
    - Solid
    - Liquid
    - Gas
- Top arrows ______________ energy
- Bottom arrows ______________ energy




When you cook pasta (or anything that requires boiling), is it better to have a vigorous boil or to turn down the heat to produce barely boiling water?

Latent heat

- The amount of ______________ per ______________ required to change ______________

$$Q = mL$$

- $Q$ = heat required; $m$ = mass; $L$ = latent heat

Latent heat of fusion ($L_f$)

- Refers to change between ______________ and ______________

Latent heat of vaporization ($L_v$)

- Refers to change between ______________ and ______________

Latent heat of sublimation ($L_s$)

- Refers to change between ______________ and ______________

Table 14.2 Heats of Fusion and Vaporization [4]

| | | $L_f$ | | | $L_v$ | |
|---|---|---|---|---|---|---|
| **Substance** | **Melting point (°C)** | **kJ/kg** | **kcal/kg** | **Boiling point (°C)** | **kJ/kg** | **kcal/kg** |
| Helium | −269.7 | 5.23 | 1.25 | −268.9 | 20.9 | 4.99 |
| Hydrogen | −259.3 | 58.6 | 14.0 | −252.9 | 452 | 108 |
| Nitrogen | −210.0 | 25.5 | 6.09 | −195.8 | 201 | 48.0 |
| Oxygen | −218.8 | 13.8 | 3.30 | −183.0 | 213 | 50.9 |
| Ethanol | −114 | 104 | 24.9 | 78.3 | 854 | 204 |
| Ammonia | −75 | | 108 | −33.4 | 1370 | 327 |
| Mercury | −38.9 | 11.8 | 2.82 | 357 | 272 | 65.0 |
| Water | 0.00 | 334 | 79.8 | 100.0 | 2256[5] | 539[6] |
| Sulfur | 119 | 38.1 | 9.10 | 444.6 | 326 | 77.9 |
| Lead | 327 | 24.5 | 5.85 | 1750 | 871 | 208 |
| Antimony | 631 | 165 | 39.4 | 1440 | 561 | 134 |
| Aluminum | 660 | 380 | 90 | 2450 | 11400 | 2720 |
| Silver | 961 | 88.3 | 21.1 | 2193 | 2336 | 558 |
| Gold | 1063 | 64.5 | 15.4 | 2660 | 1578 | 377 |
| Copper | 1083 | 134 | 32.0 | 2595 | 5069 | 1211 |
| Uranium | 1133 | 84 | 20 | 3900 | 1900 | 454 |
| Tungsten | 3410 | 184 | 44 | 5900 | 4810 | 1150 |

You have a glass of 1-kg warm water (25°C). To make it cold you put in some ice cubes (-5°C). After an equilibrium temperature is reached, there is a little ice left. What is the minimum mass of the ice cubes? (Assume no heat is lost to the environment.)

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|---|---|
| ***Homework*** | |

1. To help lower the high temperature of a sick patient, an alcohol rub is sometimes used. Isopropyl alcohol is rubbed over the patient's back, arms, legs, etc., and allowed to evaporate. Why does the procedure work?
2. Fruit blossoms are permanently damaged when the temperature drops below about -4°C (a "hard freeze"). Orchard owners sometimes spray a film of water over the blossoms to protect the when a hard freeze is expected. From the point of view of phase changes, give a reason for the protection.
3. Heat transfer can cause temperature and phase changes. What else can cause these changes?
4. How does the latent heat of fusion of water help slow the decrease of air temperatures, perhaps preventing temperatures from falling significantly below 0°C, in the vicinity of large bodies of water?
5. What is the temperature of ice right after it is formed by freezing water?
6. If you place 0°C ice into 0°C water in an insulated container, what will happen? Will some ice melt, will more water freeze, or will neither take place?
7. In very humid climates where there are numerous bodies of water, such as in Florida, it is unusual for temperatures to rise above about 35°C (95°F). In deserts, however, temperatures can rise far above this. Explain how the evaporation of water helps limit high temperatures in humid climates.
8. How much heat transfer (in kilocalories) is required to thaw a 0.450-kg package of frozen vegetables originally at 0°C if their heat of fusion is the same as that of water? (OpenStax 14.11) **35.9 kcal**
9. A bag containing 0°C ice is much more effective in absorbing energy than one containing the same amount of 0°C water. (a) How much heat transfer is necessary to raise the temperature of 0.800 kg of water from 0°C to 30.0°C? (b) How much heat transfer is required to first melt 0.800 kg of 0°C ice and then raise its temperature? (c) Explain how your answer supports the contention that the ice is more effective. (OpenStax 14.12) $\mathbf{1.00 \times 10^5}$ **J**, $\mathbf{3.68 \times 10^5}$ **J**
10. (a) How much heat transfer is required to raise the temperature of a 0.750-kg aluminum pot containing 2.50 kg of water from 30.0°C to the boiling point and then boil away 0.750 kg of water? (b) How long does this take if the rate of heat transfer is 500 W? (OpenStax 14.13) **4940 s**
11. In 1986, a gargantuan iceberg broke away from the Ross Ice Shelf in Antarctica. It was approximately a rectangle 160 km long, 40.0 km wide, and 250 m thick. (a) What is the mass of this iceberg, given that the density of ice is 917 $kg/m^3$? (b) How much heat transfer (in joules) is needed to melt it? (c) How many years would it take sunlight alone to melt ice this thick, if the ice absorbs an average of 100 $W/m^2$, 12.00 h per day? (OpenStax 14.18) $\mathbf{1.47 \times 10^{15}}$ **kg**, $\mathbf{4.90 \times 10^{20}}$ **J, 48.5 y**
12. The energy released from condensation in thunderstorms can be very large. Calculate the energy released into the atmosphere for a small storm of radius 1 km, assuming that 1.0 cm of rain is precipitated uniformly over this area. (OpenStax 14.21) $\mathbf{7 \times 10^{13}}$ **J**
13. To help prevent frost damage, 4.00 kg of onto a fruit tree. 0°C water is sprayed. (a) How much heat transfer occurs as the water freezes? (b) How much would the temperature of the 200-kg tree decrease if this amount of heat transferred from the tree? Take the specific heat to be 3.35 kJ/kg·°C, and assume that no phase change occurs. (OpenStax 14.22) **319 kcal, 2.00 °C**
14. A woman finds the front windshield of her car covered with ice at −12 °C. The ice has a thickness of $4.50 \times 10^{-4}$ m, and the windshield has an area of 1.25 $m^2$. The density of ice is 917 $kg/m^3$. How much heat is required to melt the ice? (Cutnell 12.57) $\mathbf{1.85 \times 10^5}$ **J**